**Network of European Research Infrastructures for Earthquake Risk Assessment and Mitigation**

# Report

## D7.2 State of the Knowledge of Building Inventory Data in Europe

| | |
|---|---|
| Activity: | *Classification and Inventory of European Building Stock* |
| Activity number: | *NA7* |
| Deliverable: | *State of the knowledge of building inventory data in Europe* |
| Deliverable number: | *7.2 v3.0* |
| Responsible activity leader: | *EUCENTRE* |
| Responsible participant: | *EUCENTRE* |
| Authors: | *Helen Crowley, Sevgi Ozcebe, Hannah Baker, Roxane Foulser-Piggott, Robin Spence* |

**Seventh Framework Programme**
**EC project number: 262330**

## 1. Introduction

This deliverable arises from the outcomes of the NERA/GEM European Building Workshop, held in Pavia in May 2011. This workshop had the main objective of allowing the wider European community that have experience related to building inventory data to participate and contribute to the activities of Work Package 7 of the NERA project (Classification and inventory of European Building Stock).

The aim of this workshop was to understand the existing state-of-the-knowledge of buildings in Europe, in particular for what concerns their location and structural characteristics, with a focus on the information needed for seismic risk assessment. This was achieved by bringing together experts that have used country-wide building inventories in public and private seismic risk applications, as well as representatives from national mapping and cadastre agencies, and partners that are directly involved in the Global Earthquake Model (GEM) [1], of which NERA is a regional programme. The database produced within the NERA project will be shared with GEM's Global Exposure Model (GED4GEM).

This deliverable is based on the outcomes of the workshop as well as additional research undertaken by the core partners of WP7. The main objective has been to summarise the national public data available on buildings and dwellings (noting that information on the former can often be inferred from information on the latter). Other sources of existing information which can be used to infer the characteristics of buildings in each country, such as the expert solicitations of the World Housing Encyclopaedia [2] and the PAGER initiative [3], detailed building surveys, and post-earthquake damage surveys, are also described herein. The outcome of this deliverable should be the identification of the level of heterogeneity of building data across Europe, and the areas where the NERA project will need to put more focus in order to obtain data necessary for inference of building characteristics and proposed mechanisms for carrying out such a task.

## 2. NERA/GEM European Building Inventory Workshop

Deliverable 7.1 describes the process behind the identification of experts to invite to the European Building Inventory Workshop. The final list of invitees, the agenda and the minutes of four breakout sessions are presented in Appendix A.

The countries that were represented at the workshop only covered a portion of Europe (see Figure 1 in Deliverable D7.1), but they focused on those countries with a history of seismic action and thus a higher level of sensitivity to the needs of a database of buildings for seismic risk assessment. Appendix B summarises the presentations given on each country at the workshop following a common template:

- Summary of national building information
- List of data sources
- Summary of local data sources.

## 3. Building Inventory State-of-the-Knowledge

### *3.1. Extent of Interest*

In order to obtain a more complete overview of Europe than the countries represented at the workshop, the countries listed below have been considered herein as providing a complete overview of Europe, and for which additional information has been sought and will continue to be sought over the life of the project for the purposes of developing a European Building Inventory database:

| | |
|---|---|
| Albania | Liechtenstein |
| Andorra | Lithuania |
| Austria | Luxembourg |
| Belarus | Macedonia |
| Belgium | Malta |
| Bosnia | Moldova |
| Bulgaria | Monaco |
| Croatia | Montenegro |
| Cyprus | Norway |
| Czech Republic | Poland |
| Denmark | Portugal |
| Estonia | Romania |
| Finland | Serbia |
| France | Slovakia |
| Germany | Slovenia |
| Greece | Spain |
| Greenland | Sweden |
| Hungary | Switzerland |
| Iceland | The Netherlands |
| Ireland | Turkey |
| Italy | Ukraine |
| Kosovo | United Kingdom |
| Latvia | |

In addition to the presentations provided by the participants at the workshops (see Appendix B), an extensive online research activity has been undertaken to identify public sources of data on buildings and dwellings. Appendix C provides the list of online sources from which building information has been obtained, scrutinised and summarised herein.

### *3.2. Building Taxonomy*

The building attributes that are available in different data sources have been reported following the proposed GEM Basic Taxonomy. This building classification scheme has been proposed as part of the Global Earthquake Model development. A first version taxonomy was presented to the workshop participants in May, and significant feedback was received (see Appendix A). The main outcome of the workshop was the call for a simpler, basic taxonomy to be first developed, which was then produced, further reviewed and tested. The GEM Building Taxonomy v2.0 is currently being used in the NERA project (Brzev et al. 2013).

The main attribute groups and attributes of this taxonomy are:

- Structural System: Direction, Material of the Lateral Load-Resisting System and Lateral Load-Resisting System
- Building Information: Height, Date of Construction or Retrofit, Occupancy
- Exterior Attributes: Building Position within a Block, Shape of the Building Plan, Structural Irregularity, Exterior Walls
- Roof/Floor/Foundation: Roof, Floor, Foundation information

### *3.3. Summary of National Building/Dwelling Data Sources*

The data available from national datasets in each country in Europe have been summarised in terms of the attributes in GEM taxonomy for different levels of resolution (in terms of administrative boundaries) in the following tables. The different administrative boundaries in the tables below have been classified using the local nomenclature as well as the NUTS (Nomenclature of Territorial Units for Statistics) system. The NUTS classification[1] is a hierarchical system for dividing up the economic territory of the EU with three levels (NUTS1, NUTS2, NUTS3) plus two levels of local administrative units (LAU1 and LAU2)[2] and correspondence tables for the administrative boundaries of those countries outside of the EU, which are described with Level 1, Level 2 and Level 3 rather than NUTS1, NUTS2 and NUTS3[3]. In the following tables, the black crosses represent data that is available in the publically available national databases.

As reported in the United Nations Economic Commission for Europe's report on measuring population and housing (UN, 2008), censuses are often the only source of information on the number and characteristics of dwellings and on housing facilities, both at the national and local level. All of the data summarized in the tables below has been obtained from national census databases, and also the graphical presentation of the available data is provided in the following figures.

Table 8 attempts to summarise the attributes used to describe the buildings within each country, and notes when attributes are correlated at a given resolution. For example, when the number of buildings with a given construction material from a given construction period is available at the municipality level, the following is reported in the final column: Material of construction + Date of construction (municipality). Where the final column is empty, this means that the number of buildings of given material type are known, and the number of buildings of a given date of construction are known, but information on the buildings with these combined attributes is not available.

The one parameter that is systematically obtained in the census data presented above is the date (or era) of construction. In fact, Dol and Haffner (2010) have been able to produce the following table with the distribution of buildings by age in different European countries, shown in Table 9.

[1] http://epp.eurostat.ec.europa.eu/portal/page/portal/nuts_nomenclature/introduction

[2] http://epp.eurostat.ec.europa.eu/portal/page/portal/nuts_nomenclature/local_administrative_units

[3] http://epp.eurostat.ec.europa.eu/portal/page/portal/nuts_nomenclature/correspondence_tables/national_structures_non_eu

Table 1. Summary of attributes in national building/dwelling databases

| | Structural System | | Building Information | | | Exterior Attributes | | | | Roof /Floor System | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | **Material of Lateral Load Resisting System** | **Lateral Load Resisting System** | **Number of Stories** | **Date of Construction** | **Occupancy** | **Building Position within a block** | **Shape of building plan** | **Structural Irregularity** | **Exterior Walls** | **Roof** | **Floor** | **Foundation System** |
| Albania | | | X | X | X | | | | X | | | |
| Andorra | | | | X | X | | | | | | | |
| Austria | | | X | X | X | | | | X | | | |
| Belarus | | | | X | X | | | | X | | | |
| Belgium | | | X | X | X | | | | | | | |
| Bosnia | | | | X | X | | | | | | | |
| Bulgaria | X | X | X | X | X | | | | X | | | |
| Croatia | | | | X | X | | | | | | | |
| Cyprus | | | | X | X | | | | | | | |
| Czech Republic | | | X | X | X | | | | X | | | |
| Denmark | | | | X | X | | | | | | | |
| Estonia | | | | X | X | | | | | | | |
| Finland | | | X | X | X | | | | X | | | |
| France | | | | X | X | | | | | | | |
| Germany | | | | X | X | | | | | | | |
| Greece | X | X | X | X | X | | | | | | | |
| Greenland | | | | | X | | | | | | | |
| Hungary | | | X | X | X | | | | X | | | |
| Iceland | | | | X | X | | | | | | | |
| Ireland | | | | X | X | | | | | | | |
| Italy | X | X | X | X | X | | | | X | | | |
| Kosovo | X | X | X | X | X | | | | X | | | |
| Latvia | | | | X | X | | | | X | | | |
| Liechtenstein | | | | X | X | | | | | | | |

| | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Lithuania | | | | X | X | | | | X | | | |
| Luxembourg | | | | X | X | | | | | | | |
| Macedonia | X | X | X | X | X | | | | X | | | |
| Malta | | | | X | X | | | | | | | |
| Moldova | | | X | | X | | | | X | | | |
| Monaco | | | | X | X | | | | | | | |
| Montenegro | | | | X | X | | | | | | | |
| Norway | | | X | X | X | | | | | | | |
| Poland | | | | X | X | | | | | | | |
| Portugal | X | X | X | X | X | | | | X | | | |
| Romania | X | X | X | X | X | | | | X | | | |
| Serbia | | | X | X | X | | | | | | | |
| Slovakia | | | X | X | X | | | | X | | | |
| Slovenia | X | X | X | X | X | | | | X | | | |
| Spain | | | X | X | X | | | | | | | |
| Sweden | | | | X | X | | | | | | | |
| Switzerland | | | X | X | X | | | | | | | |
| The Netherlands | | | | X | X | | | | | | | |
| Turkey | X | X | X | X | X | | | | X | | | |
| Ukraine | | | | | | | | | | | | |
| United Kingdom | | | | | X | | | | | | | |

Table 2. Summary of geographical resolution of “material” attribute in country databases

| | **Material** | **Type** | **Resolution** | **Year** | |
|---|---|---|---|---|---|
| Albania | X | Buildings | Country, prefectures | 2001 | Construction material |
| Austria | X | Buildings | Country, provinces | 1991 | Material of external walls |
| Belarus | X | Dwellings | Country, regions, districts | 2009 | Material of external walls |
| Belgium | | | | | |
| Bosnia | | | | | |
| Bulgaria | X | Buildings | Country, provinces, municipalities | 2011 | Material of LLRS |
| Croatia | | | | | |
| Cyprus | | | | | |
| Czech Republic | X | Houses | Country, districts | 2001/2011 | Material of bearing wall |
| Denmark | | | | | |
| Estonia | | | | | |
| Finland | X | Buildings | Country | 2010 | Construction material |
| France | | | | | |
| Germany | | | | | |
| Greece | X | Buildings | Country, regions, prefectures, municipalities | 2000 | Material of LLRS |
| Greenland | | | | | |
| Hungary | X | Dwellings | Country, regions, counties | 2005 | Material of external walls |
| Iceland | | | | | |
| Ireland | | | | | |
| Italy | X | Buildings | Country, regions, provinces | 2001 | Material of LLRS |
| Kosovo | X | Dwellings | Country, municipalities | 2011 | Material of external walls |
| Latvia | X | Population | Country | 2000 | Material of external walls |
| Lithuania | X | Buildings | Country, counties, municipalities | 2001 | Material of external walls |
| Luxembourg | | | | | |
| Macedonia | X | Buildings | Country, municipalities | 2002 | Material of LLRS |
| Malta | | | | | |
| Moldova | X | Dwellings | Country | 2010 | Material of external walls |
| Montenegro | | | | | |

| | | | | | |
|---|---|---|---|---|---|
| Netherlands | | | | | |
| Norway | | | | | |
| Poland | | | | | |
| Portugal | **X** | Buildings | Country, districts, municipalities, parishes | 2001 | Material of LLRS |
| Romania | **X** | Buildings | Country, regions, counties | 2002 | Material of LLRS |
| Serbia | | | | | |
| Slovakia | **X** | Dwellings | Country, groups of regions, regions, districts, municipalities | 2001 | Material of bearing wall |
| Slovenia | **X** | Buildings | Country, regions, administrative units, municipalities | 2002 | Material of LLRS |
| Spain | | | | | |
| Sweden | | | | | |
| Switzerland | | | | | |
| Turkey | **X** | Buildings | Country, provinces | 2000 | Material of LLRS |
| Ukraine | | | | | |
| United Kingdom | | | | | |

Table 3. Summary of geographical resolution of “lateral load resisting system” attribute in country databases

| | Lateral Load Resisting System | Type | Resolution | Year |
|---|---|---|---|---|
| Albania | | | | |
| Austria | | | | |
| Belarus | | | | |
| Belgium | | | | |
| Bosnia | | | | |
| Bulgaria | **X** | Buildings | Country, provinces, municipalities | 2011 |
| Croatia | | | | |
| Cyprus | | | | |
| Czech Republic | | | | |
| Denmark | | | | |
| Estonia | | | | |
| Finland | | | | |
| France | | | | |
| Germany | | | | |
| Greece | **X** | Buildings | Country, regions, prefectures, municipalities | 2000 |
| Greenland | | | | |
| Hungary | | | | |
| Iceland | | | | |
| Ireland | | | | |
| Italy | **X** | Buildings | Country, regions, provinces | 2001 |
| Latvia | | | | |
| Lithuania | | | | |
| Luxembourg | | | | |
| Macedonia | | | | |
| Malta | | | | |
| Moldova | | | | |
| Montenegro | | | | |
| Netherlands | | | | |
| Norway | | | | |

| | | | | |
|---|---|---|---|---|
| Poland | | | | |
| Portugal | **X** | Buildings | Country, districts, municipalities, parishes | 2001 |
| Romania | **X** | Buildings | Country, regions, counties | 2002 |
| Serbia | | | | |
| Slovakia | | | | |
| Slovenia | | | | |
| Spain | | | | |
| Sweden | | | | |
| Switzerland | | | | |
| Turkey | **X** | Buildings | Country, provinces | 2000 |
| Ukraine | | | | |
| United Kingdom | | | | |

Table 4. Summary of geographical resolution of “number of stories” attribute in country databases

| | Number of Stories | Type | Resolution | Year |
|---|---|---|---|---|
| Albania | X | Buildings | Country | 2001 |
| Austria | X | Dwellings (Main Residences) | Country, provinces, districts, statutory cities | 2001 |
| Belarus | | | | |
| Belgium | X | Buildings | Country, regions, provinces, arrondissements | 2011 |
| Bosnia | | | | |
| Bulgaria | X | Buildings | Country, provinces, municipalities | 2011 |
| Croatia | | | | |
| Cyprus | | | | |
| Czech Republic | X | Houses | Country, districts | 2001 |
| Denmark | | | | |
| Estonia | | | | |
| Finland | X | Buildings | Country | 2010 |
| France | | | | |
| Germany | | | | |
| Greece | X | Buildings | Country, regions, prefectures, municipalities | 2000 |
| Greenland | | | | |
| Hungary | X | Buildings | Country, regions, counties | 2001/2005 |
| Iceland | | | | |
| Ireland | | | | |
| Italy | X | Buildings | Country, regions, provinces | 2001 |
| Kosovo | X | Dwellings | Country, municipalities | 2011 |
| Latvia | | | | |
| Lithuania | | | | |
| Luxembourg | X | Buildings | Country | 2009 |
| Macedonia | X | Buildings | Country, regions | 2002 |
| Malta | | | | |
| Moldova | X | Dwellings | Country | 2010 |
| Montenegro | | | | |
| Netherlands | | | | |

| | | | | |
|---|---|---|---|---|
| Norway | **X** | Dwellings | Country, counties, municipalities | 2011 |
| Poland | | | | |
| Portugal | **X** | Buildings | Country, districts, municipalities, parishes | 2001 |
| Romania | **X** | Buildings | Country, regions, counties | 2002 |
| Serbia | **X** | Dwellings | Country,  regions, municipalities | 2002 |
| Slovakia | **X** | Houses | Country, groups of regions, regions, districts, municipalities | 2001 |
| Slovenia | **X** | Buildings | Country, regions | 2002 |
| Spain | **X** | Buildings | Country, autonomous communities, provinces, municipalities | 2001 |
| Sweden | | | | |
| Switzerland | **X** | Buildings | Country, cantons | 2010 |
| Turkey | **X** | Buildings | Country, provinces | 2000 |
| Ukraine | | | | |
| United Kingdom | | | | |

Table 5. Summary of geographical resolution of “date of construction” attribute in country databases

| | Date of Construction | Type | Resolution | Year |
|---|---|---|---|---|
| Albania | X | Buildings | Country, prefectures, districts | 2001 |
| Austria | X | Dwellings (Main Residences) | Country, provinces | 2010 |
| Belarus | X | Dwellings | Country, regions, districts, cities and towns, urban-rural settlements | 2009 |
| Belgium | X | Buildings | Country, regions, provinces, arrondissements, communes | 2011 |
| Bosnia | X | Dwellings | Country | 2007 |
| Bulgaria | X | Buildings | Country, provinces, municipalities | 2009 |
| Croatia | X | Dwellings | Country | 2001 |
| Cyprus | X | Dwellings | Country, districts | 2011 |
| Czech Republic | X | Houses | Country, districts | 2001 |
| Denmark | X | Buildings | Country, regions, provinces, municipalities | 2011 |
| Estonia | X | Buildings | Country, counties, cities, rural municipalities | 2000 |
| Finland | X | Buildings | Country, provinces, regions, sub-regions, municipalities | 2010 |
| France | X | Dwellings (Principal Residences) | Country, districts, communes | 2008 |
| Germany | X | Dwellings | Country, regions, districts | 2010 |
| Greece | X | Buildings | Country, regions, prefectures, municipalities | 2000 |
| Greenland | | | | |
| Hungary | X | Dwellings | Country, regions, counties | 2005 |
| Iceland | | | | |
| Ireland | X | Dwellings | Country, regions, counties, cities, towns | 2006 |
| Italy | X | Buildings | Country, regions, provinces | 2001 |
| Kosovo | X | Dwellings | Country, municipalities | 2011 |
| Latvia | X | Dwellings | Country, regions | 2011 |
| Lithuania | X | Buildings | Country, counties, municipalities | 2001 |
| Luxembourg | X | Buildings | Country | 2001 |
| Macedonia | X | Dwellings | Country, regions | 2002 |
| Malta | X | Dwellings | Country, districts | 2005 |
| Moldova | | | | |
| Montenegro | | | | |

| | | | | |
|---|---|---|---|---|
| Netherlands | **X** | Dwellings | Country | 2001 |
| Norway | **X** | Dwellings | Country, counties, municipalities | 2011 |
| Poland | **X** | Buildings | Country, provinces, counties | 2002 |
| Portugal | **X** | Buildings | Country, districts, municipalities, parishes | 2011 |
| Romania | **X** | Buildings | Country, regions, counties | 2002 |
| Serbia | **X** | Dwellings | Country, regions, municipalities | 2002 |
| Slovakia | **X** | Dwellings | Country, regions | 2001 |
| Slovenia | **X** | Buildings | Country, statistical regions, municipalities, settlements | 2002 |
| Spain | **X** | Buildings | Country, autonomous communities, provinces | 2001 |
| Sweden | **X** | Dwellings | Country, counties | 2011 |
| Switzerland | **X** | Buildings | Country, cantons, communes | 2010 |
| Turkey | **X** | Buildings | Country, provinces | 2000 |
| Ukraine | | | | |
| United Kingdom | **X** | Dwellings | Country | 2009 |

Table 6. Summary of geographical resolution of "structural irregularity" attribute in country databases

| | Structural Irregularity | Type | Resolution | Year |
|---|---|---|---|---|
| Albania | | | | |
| Austria | | | | |
| Belarus | | | | |
| Belgium | | | | |
| Bosnia | | | | |
| Bulgaria | | | | |
| Croatia | | | | |
| Cyprus | | | | |
| Czech Republic | | | | |
| Denmark | | | | |
| Estonia | | | | |
| Finland | | | | |
| France | | | | |
| Germany | | | | |
| Greece | | | | |
| Greenland | | | | |
| Hungary | | | | |
| Iceland | | | | |
| Ireland | | | | |
| Italy | **X** | Buildings | Country, regions, provinces | 2001 |
| Latvia | | | | |
| Lithuania | | | | |
| Luxembourg | | | | |
| Macedonia | | | | |
| Malta | | | | |
| Moldova | | | | |
| Montenegro | | | | |
| Netherlands | | | | |

| | | | | |
|---|---|---|---|---|
| Norway | | | | |
| Poland | | | | |
| Portugal | **X** | Buildings | Country, districts, municipalities, parishes | 2001 |
| Romania | | | | |
| Serbia | | | | |
| Slovakia | | | | |
| Slovenia | | | | |
| Spain | | | | |
| Sweden | | | | |
| Switzerland | | | | |
| Turkey | | | | |
| Ukraine | | | | |
| United Kingdom | | | | |

Table 7. Summary of geographical resolution of occupancy class in country databases

| | Occupancy | Type | Resolution | Year |
|---|---|---|---|---|
| Albania | X | Buildings | Country, prefectures, districts | 2001 |
| Austria | X | Buildings | Country, provinces, districts, statutory cities | 2006 |
| Belarus | X | Dwellings | Country, regions, districts | 2009 |
| Belgium | X | Buildings | Country, regions, provinces, arrondissements, communes | 2011 |
| Bosnia | X | Dwellings | Country, geographical area | 2007 |
| Bulgaria | X | Buildings | Country, provinces, municipalities | 2011 |
| Croatia | X | Dwellings | Country, counties, municipalities, towns | 2001 |
| Cyprus | X | Dwellings | Country, districts | 2011 |
| Czech Republic | X | Buildings | Country, regions, districts, municipalities | 2001 |
| Denmark | X | Buildings | Country, regions, provinces, municipalities | 2011 |
| Estonia | X | Buildings | Country, counties, cities, rural municipalities | 2000 |
| Finland | X | Buildings, Dwellings | Country, provinces, regions, sub-regions, municipalities | 2010 |
| France | X | Dwellings (Principal Residences) | Country, regions, departments, districts, cantons, communes | 2008 |
| Germany | X | Buildings | Country | 2010 |
| Greece | X | Buildings | Country, regions, prefectures, municipalities | 2000 |
| Greenland | X | Dwellings | Country, municipalities | 2010 |
| Hungary | X | Dwellings | Country, regions, counties | 2005 |
| Iceland | X | Dwellings | Country | 2009 |
| Ireland | X | Dwellings | Country, regions, counties, cities, towns | 2006 |
| Italy | X | Buildings | Country, regions, provinces | 2001 |
| Kosovo | X | Dwellings | Country | 2011 |
| Latvia | X | Dwellings | Country, regions | 2011 |
| Lithuania | X | Buildings | Country, counties, municipalities | 2001 |
| Luxembourg | X | Buildings | Country, districts | 2009 |
| Macedonia | X | Dwellings | Country, regions | 2002 |
| Malta | X | Dwellings | Country, districts, localities | 2005 |
| Moldova | X | Dwellings | Country, districts | 2010 |
| Montenegro | X | Dwellings | Country, municipalities, settlements | 2011 |

| | | | | |
|---|---|---|---|---|
| Netherlands | **X** | Dwellings | Country, regions, municipalities | 2001 |
| Norway | **X** | Buildings | Country, counties | 2012 |
| Poland | **X** | Buildings | Country, provinces, counties | 2002 |
| Portugal | **X** | Buildings | Country, districts, municipalities, parishes | 2011 |
| Romania | **X** | Buildings | Country, regions, counties | 2002 |
| Serbia | | | | |
| Slovakia | **X** | Dwellings | Country, groups of regions, regions, districts, municipalities | 2001 |
| Slovenia | **X** | Dwellings | Country, statistical regions, municipalities | 2002 |
| Spain | **X** | Buildings | Country, autonomous communities, provinces, municipalities | 2001 |
| Sweden | **X** | Dwellings | Country, counties, municipalities | 2011 |
| Switzerland | **X** | Buildings | Country, cantons, communes | 2010 |
| Turkey | **X** | Buildings | Country, provinces | 2000 |
| Ukraine | | | | |
| United Kingdom | | | | |

The information from these tables is presented in the following maps (Figures 1 to 7).

Table 8. Summary of available information per country, with notes on the “correlated” attributes, where present, and associated geographical resolution

| | **Correlation between attributes** |
|---|---|
| Albania | 1) Main construction material vs. Date of construction by prefectures<br>2) Number of stories by Date of Construction by country<br>3) Occupancy by Date of Construction by country |
| Austria | 1) Number of dwellings vs. Date of construction by provinces<br>2) Occupancy vs.number of stories by district<br>3) Construction of external walls vs. construction year by provinces |
| Belarus | 1) Material of walls vs. Date of construction by country, regions, districts<br>2) Date of construction vs. occupancy by country, regions, districts |
| Belgium | 1) Number of stories vs. Date of construction by country, regions, provinces, arrondissements, communes<br>2) Number of stories vs. Occupancy by country, regions, provinces, arrondissements, communes<br>3) Date of construction vs. occupancy class by country, regions, provinces, arrondissements, communes |
| Bosnia | |
| Bulgaria | |
| Croatia | |
| Cyprus | 1) Year if construction vs. occupancy by country, districts |
| Czech Republic | 1) Material of walls vs. Occupancy by country, regions, districts, municipalities |
| Denmark | 1) Construction year vs occupancy by country, regions, provinces, municipalities |
| Estonia | |
| Finland | 1) Date of construction vs. occupancy by country, provinces, regions, sub-regions, municipalities<br>2) Construction material vs. Date of construction by country |
| France | 1)Date of construction vs. occupancy by country, regions, departments, districts, cantons, communes |
| Germany | |
| Greece | 1)Material of construction vs. Date of construction by country, regions, prefectures, municipalities<br>2)Date of construction vs. number of floors by country, regions, prefectures, municipalities<br>3)Date of construction vs. occupancy by country, regions, prefectures, municipalities<br>4)Number of stories vs. occupancy by Country, regions, prefectures, municipalities |
| Greenland | |
| Hungary | 1) Material of walls vs. Date of construction by country, regions |
| Iceland | |
| Ireland | 1) Date of construction vs. occupancy by country, counties |
| Italy | 1) Material of construction vs. Date of construction by country, regions, provinces |
| Latvia | |
| Lithuania | 1) Material of outer walls vs. Date of construction by country, counties, municipalities |

| | |
|---|---|
| Luxembourg | |
| Macedonia | |
| Malta | |
| Moldova | |
| Montenegro | |
| Netherlands | |
| Norway | |
| Poland | |
| Portugal | 1) Material of construction vs. Number of stories<br>2) Material of construction vs. Date of construction<br>3) Number of stories vs. Date of construction<br>4) Date of construction vs. Structural irregularity<br>5) Number of Stories vs. Structural irregularity<br>All by country, regions |
| Romania | 1) Material of LLRS vs. Date of construction<br>2) LLRS vs. Date of construction<br>3) Material of LLRS vs. Number of stories vs. Date of construction<br>All by country, regions, counties |
| Serbia | |
| Slovakia | 1) Materials of carrying walls vs.occupancy<br>2) Date of construction vs.occupancy<br>3) Number of stories vs.occupancy<br>All by Country, groups of regions, regions, districts, municipalities |
| Slovenia | 1) Material of LLRS vs. Number of stories by country, regions<br>2) Number of stories vs. Date of construction by country |
| Spain | 1) Number of stories vs. Date of construction by country, regions |
| Sweden | |
| Switzerland | 1) Number of stories vs. Date of construction by country, cantons |
| Turkey | 1) Material of LLRS vs. Lateral load resisting system<br>2) Material of LLRS vs. Lateral load resisting system vs. Date of construction<br>3) Number of stories vs. Date of construction<br>4) Material of LLRS vs. Lateral load resisting system vs. Number of stories<br>All by country, provinces |
| Ukraine | |
| United Kingdom | |

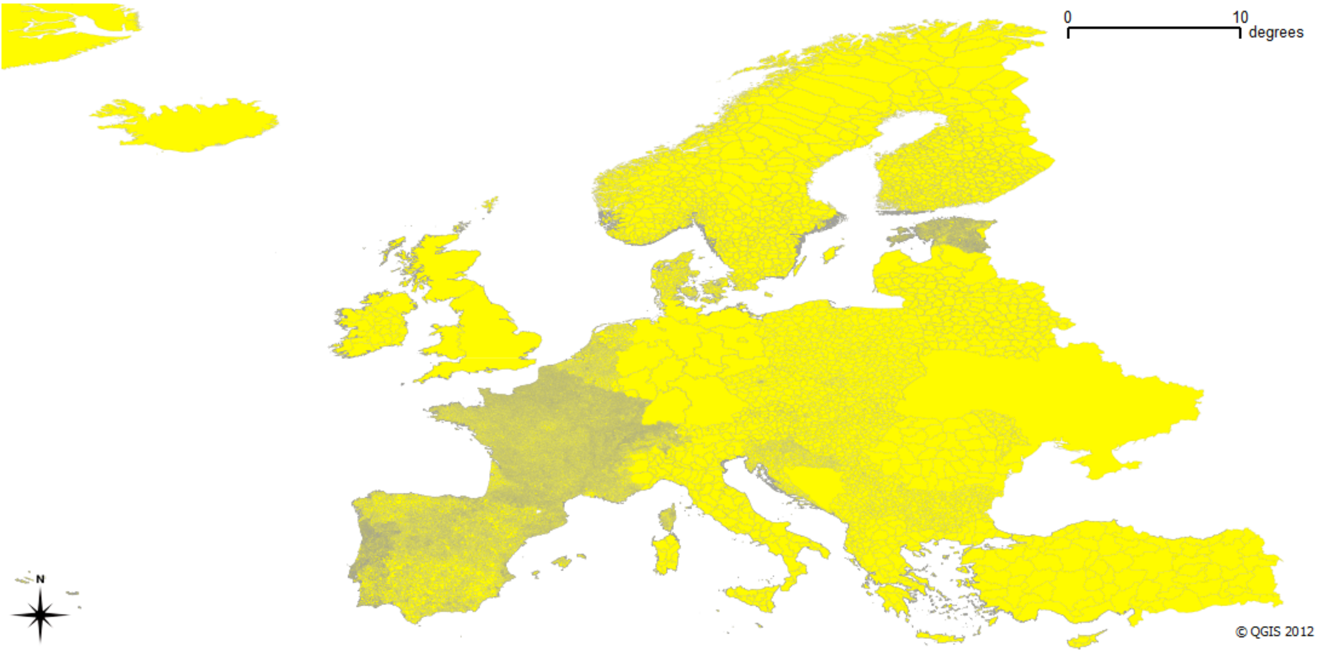
Table 9. Percentage of dwellings in each construction era

| | Year | <1919 | 1919-1945 | 1946-1970 | 1971-1980 | 1981-1990 | 1990-2000 | > 2000 |
|---|---|---|---|---|---|---|---|---|
| Austria [1 2] | 2009 | 15.2 | 8.2 | 28.0 | 15.2 | 11.5 | 13.6 | 8.3 |
| Belgium [3 4] | 2009 | 17.1 | 24.2 | 24.2 | 13.7 | 20.8 | | |
| Bulgaria | | | | | | | | |
| Cyprus [5 6] | 2001 | na | 7.4 | 16.9 | 20.7 | 27.4 | 27.1 | - |
| Czech Republic [1 5] | 2005 | 10.5 | 14.2 | 25.4 | 21.8 | 15.8 | 7.9 | 3.4 |
| Denmark [7] | 2009 | 19.7 | 16.1 | 26.4 | 16.6 | 9.1 | 5.4 | 6.7 |
| Estonia | 2009 | 9.4 | 14.2 | 30.0 | 21.5 | 19.6 | 2.0 | 3.3 |
| Finland [4] | 2009 | 1.5 | 8.1 | 27.6 | 21.5 | 18.5 | 11.5 | 9.8 |
| France [1 8] | 2006 | 17.0 | 13.2 | 17.4 | 25.2 | 10.2 | 8.5 | 8.4 |
| Germany [9] | 2006 | 14.4 | 13.6 | 46.3 | | 13.2 | 9.2 | 3.3 |
| Greece | 2001 | 3.1 | 7.2 | 31.8 | 24.5 | 19.1 | 14.4 | na |
| Hungary [10] | 2005 | - | 20.8 | 27.2 | 23.1 | 17.8 | 7.9 | 3.2 |
| Ireland | 2002 | 9.4 | 8.0 | 15.9 | 14.2 | 13.2 | 19.5 | 19.8 |
| Italy [11] | 2001 | 14.2 | 9.9 | 36.8 | 18.8 | 12.2 | 7.9 | - |
| Latvia | 2008 | 13.8 | 13.1 | 22.1 | 19.4 | 20.2 | 7.0 | 4.4 |
| Lithuania | 2002 | 6.2 | 23.3 | 33.1 | 17.6 | 13.5 | 6.3 | - |
| Luxembourg [3] | 2008 | 21.8 | 25.6 | 29.2 | 11.6 | 5.1 | 4.5 | 2.2 |
| Malta [12] | 2005 | 12.2 | 10.0 | 22.1 | 16.2 | 19.1 | 17.0 | 3.4 |
| Netherlands [13] | 2009 | 6.9 | 13.9 | 27.0 | 17.0 | 15.4 | 12.0 | 7.9 |
| Poland [14] | 2002 | 10.1 | 13.1 | 26.9 | 18.3 | 18.7 | 12.9 | - |
| Portugal [3] | 2008 | 7.4 | 10.0 | 21.9 | 16.1 | 18.8 | 17.7 | 8.1 |
| Romania [15] | 2002 | 3.9 | 11.5 | 37.3 | 23.8 | 14.8 | 7.3 | 1.4 |
| Slovak Republic [1 5] | 2001 | 3.4 | 6.6 | 35.1 | 25.6 | 21.0 | 6.2 | 0.6 |
| Slovenia [16] | 2004 | 15.1 | 7.8 | 27.7 | 23.2 | 16.0 | 6.9 | 3.4 |
| Spain [17] | 2001 | 8.9 | 4.2 | 33.5 | 24.1 | 13.6 | 15.7 | - |
| Sweden | 2008 | 12.1 | 14.7 | 37.0 | 16.8 | 9.4 | 5.5 | 4.6 |
| United Kingdom [18] | 2004/5 | 17.0 | 17.0 | 21.0 | 21.8 | 20.0 | na | na |

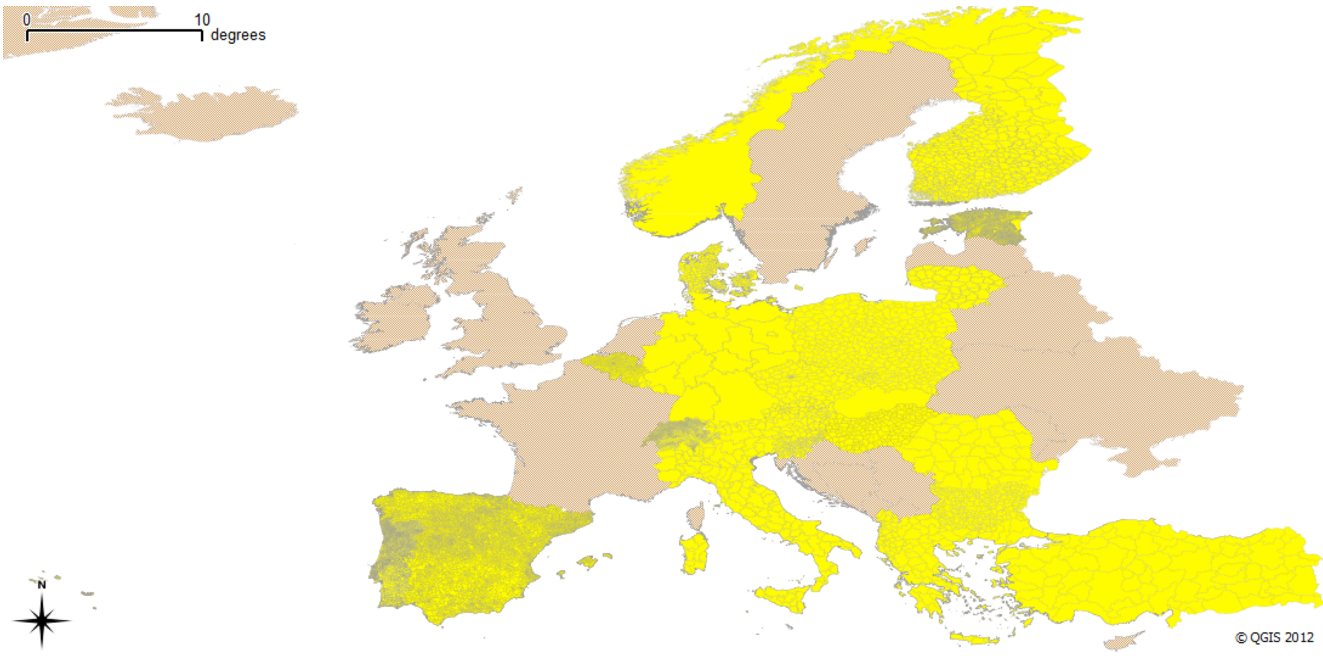
Dwellings classified by the period in which the construction of the building containing them was completed.

1 (Permanently) occupied dwellings
2 1919-1944, 1945-1970, 1991-2000
3 Estimate
4 From 1981 and onwards
5 Difference of percentage totals 100% due to unknown age of stock
6 < 1945 covers convential dwellings
7 < 1919, 1920-1945, 1945-1969, 1970-1979, 1980-1990, 1991-2000 > 2000
8 <1915, 1915-1948, 1949-1967, 1968-1981, 1982-1989, 1990-1998, >1999
9 <1919, 1919-1948, 1949-1978, 1979-1986, 1987-1990, 1991-2000, >2000
10 <1944, 1945-1969, 1970-1979, 1980-1989, 1990-1999, >2000
11 <1919, 1919-45, 1946-71, 1972-81, 1982-91, >1991
12 <1920, 1921-1950, 1951-1976, 1977-1985, 1986-1990, >1990
13 <1906, 1906-1944, 1945-1970, 1971-1980, 1981-1990, 1991-2000, >2000
14 <1918, 1918-1944, 1945-1970, 1971-1978, 1979-1988, >1988
15 <1910, 1910-1944, 1945-1970,1971-1980, 1981-1989, 1990-1999, >1999
16 Data include holiday dwellings
17 Main residences only: <1920, 1921-1940, 1941-1970, 1971-1980, 1981-1990, 1991-2001
18 <1919, 1919-1944, 1945-1964, 1965-1984, >1984

*Source: National statistical institutes*
*CZ Population and Housing Census 2001*
*DK Housing Census 2009*
*FR Enquête logement 2006*
*GR Housing Census 2001*
*MT Census of Population and Housing 2005*
*ES Censo de poblacion y viviendas 2001*




(a)




(b)

**Figure 1.** (a) Number of buildings or dwellings (b) Number of buildings

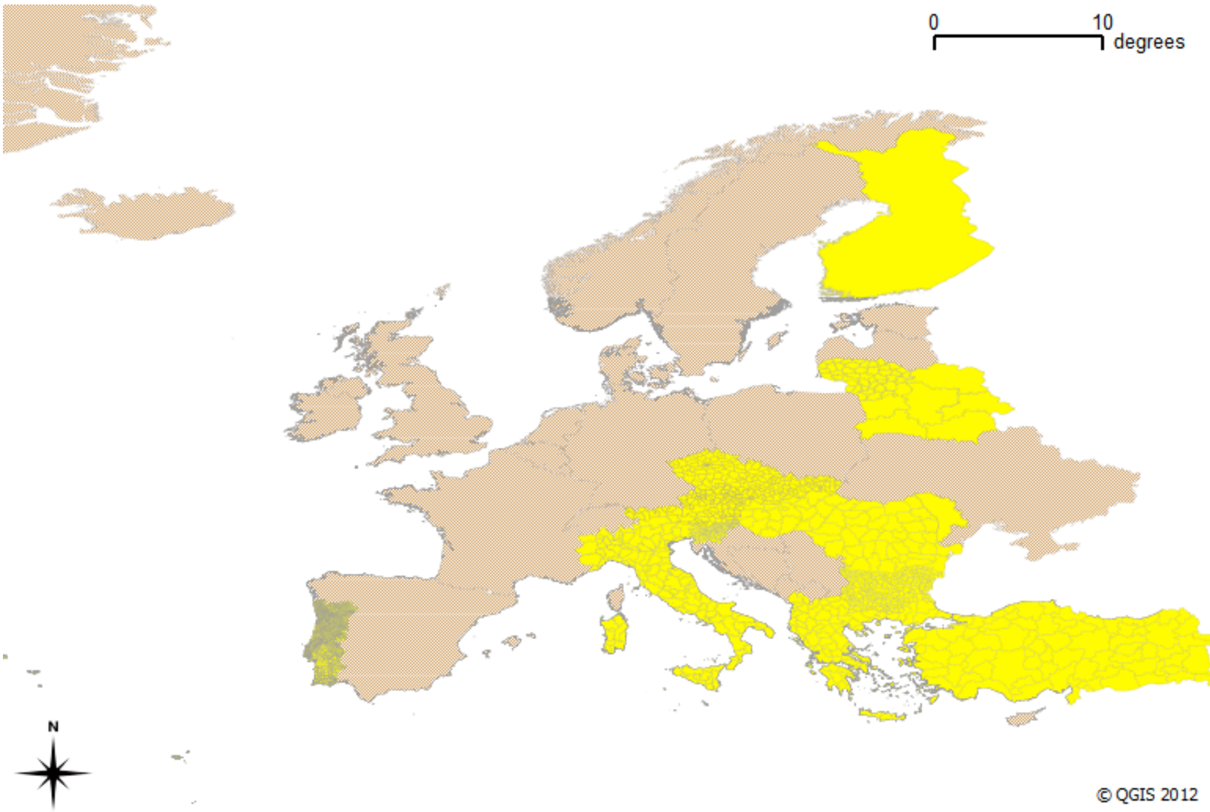
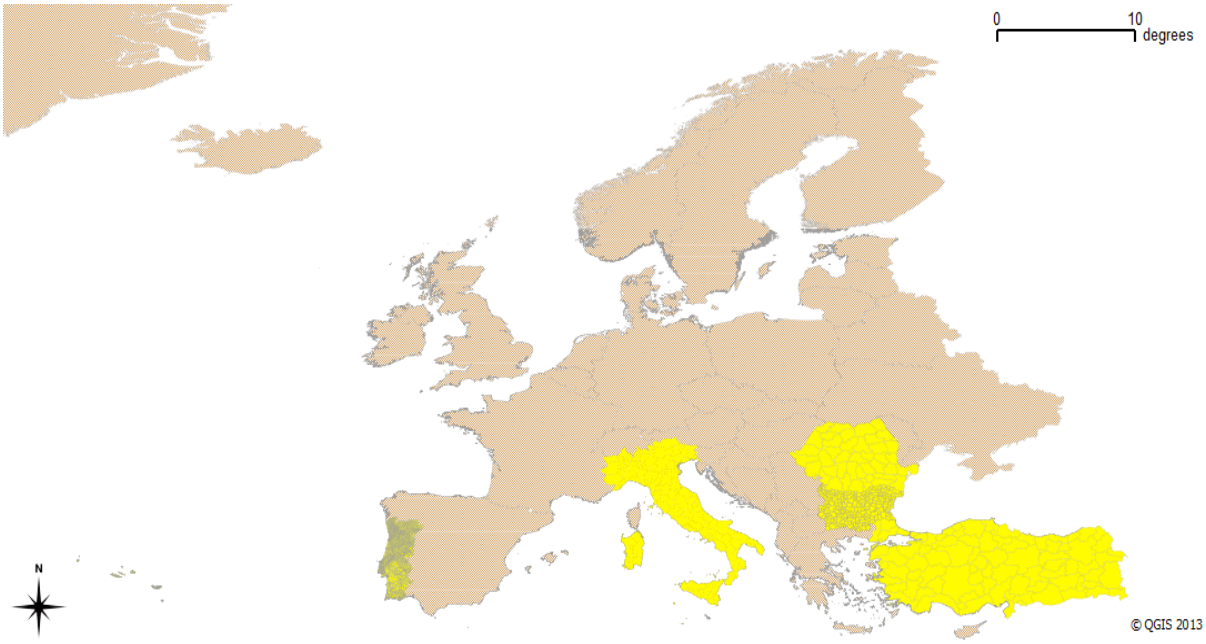



**Figure 2.** Material of Lateral Load Resisting System or Walls




(b)

**Figure 3.** Lateral Load Resisting System

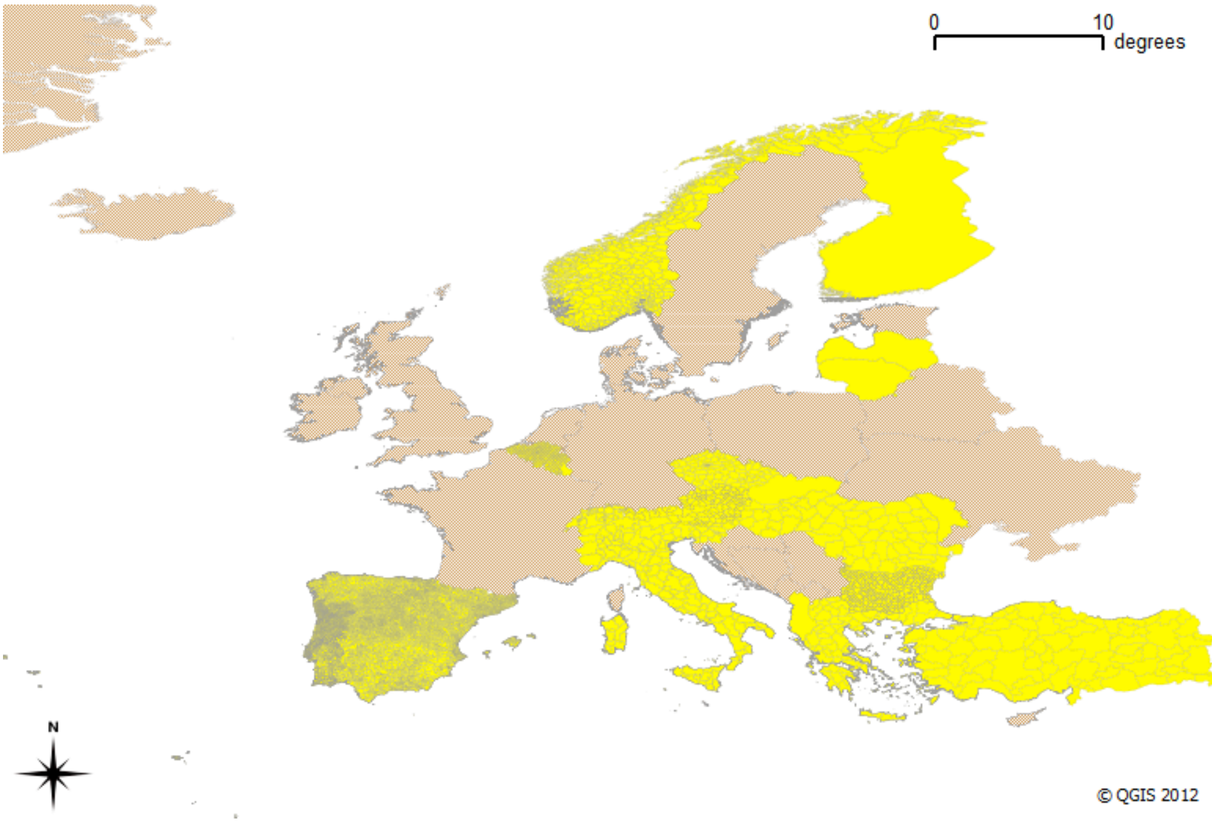



**Figure 4.** Number of Stories

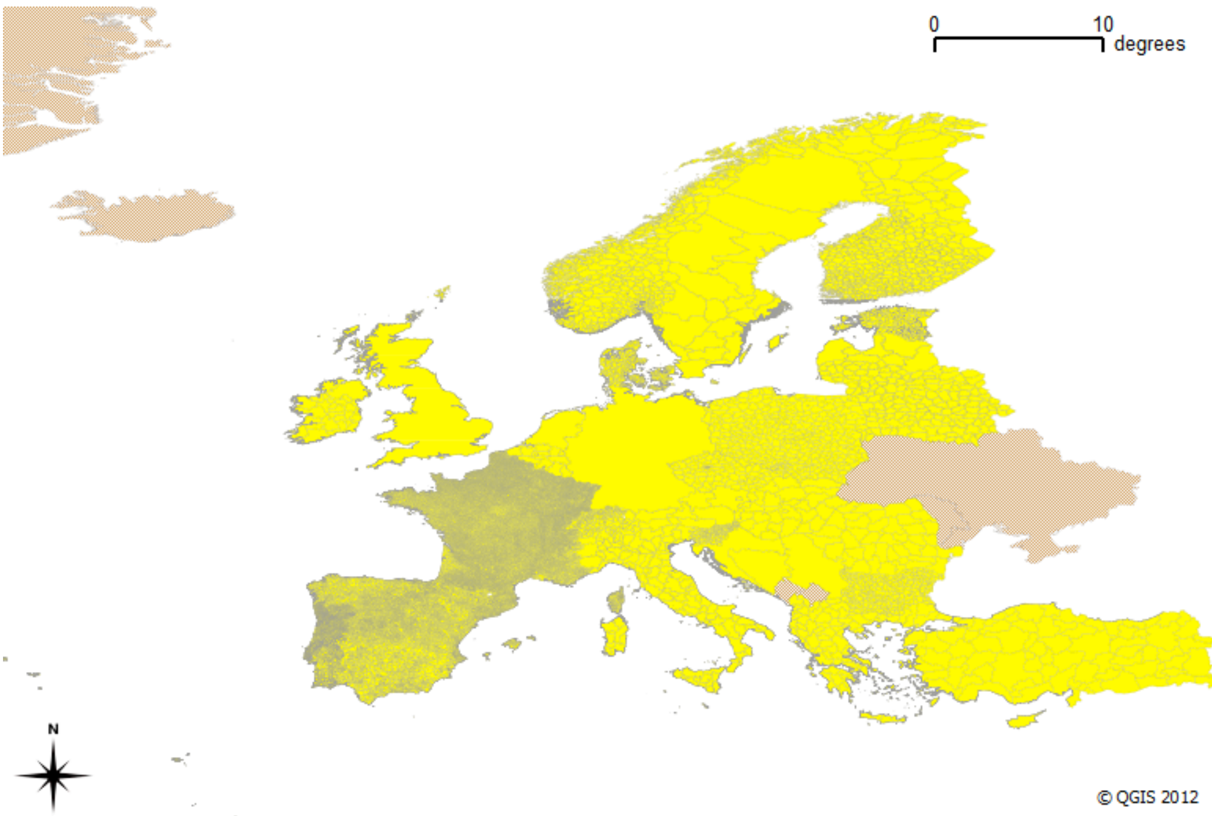



**Figure 5.** Date of Construction

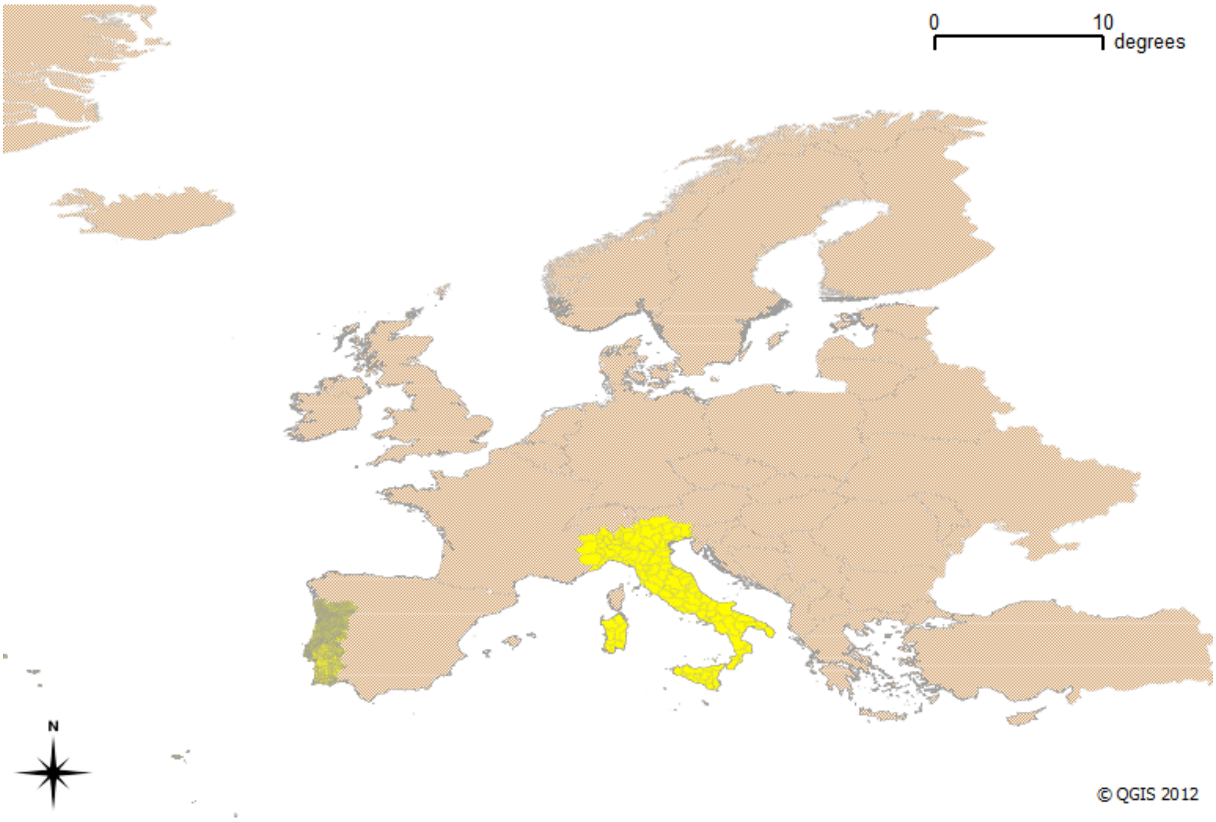



**Figure 6.** Structural Irregularity

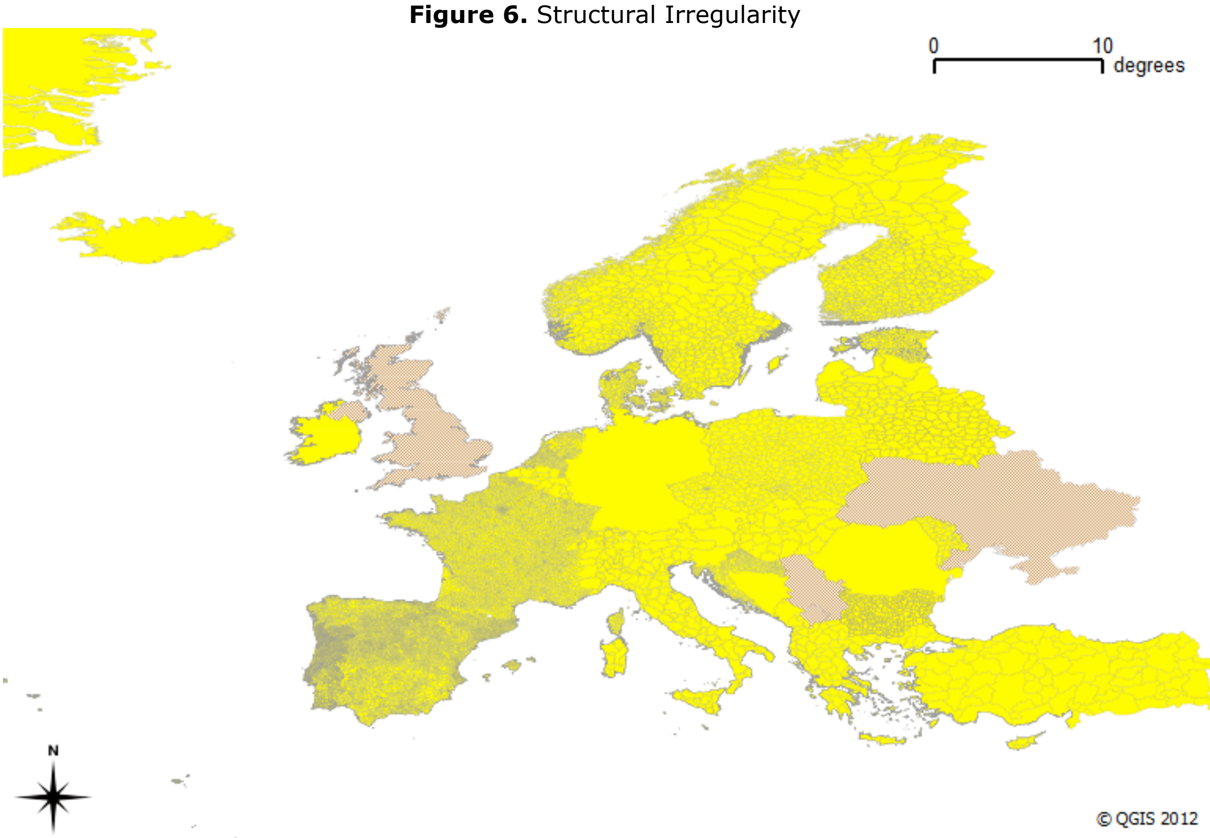



**Figure 7.** Occupancy Class

## 4. Gaps in Building Inventory Data

The tables presented in the previous section highlight the heterogeneity of building inventory data in Europe, from the fact that not all countries collect building data, to the variability in resolution and building attributes in those countries that do. Furthermore, even when a number of attributes are available to describe the buildings, they are often not correlated (see Table 8).

Given that none of the data sources discussed in the previous section can be simply used directly to develop a European building inventory database, assumptions are required to assemble a homogeneous product. The attributes from the GEM taxonomy that are missing will need to be inferred from available attributes, and it is believed that this will be done mainly through expert elicitation.

Appendix D presents the outputs of expert elicitation for European countries within the World Housing Encyclopaedia (WHE) [2] initiative and the PAGER-WHE project [3]. Also, the presentations of the countries at the workshops included a number of local, detailed building surveys which can be used for filling the gaps in building attributes in these countries (see Appendix B).

Furthermore, a study is completed by the project participant, Cambridge Architectural Research Ltd. (CAR), to define dwelling fractions in urban and rural areas for six European countries; Iceland, Switzerland, Serbia, Croatia, Bosnia and Herzegovina and Montenegro. They have been analysed through the use of various data collection methods: literature reviews, an interpretation of available data e.g. building stock age classifications; and expert questionnaires. A field trip took place to Montenegro in August 2014 and in Croatia, results were validated through a remote survey using Google Street View. The methodology and the findings of CAR's report can be found in Appendix E.

## 5. Next steps

The main follow-up steps that were carried out in the development of a European Building Inventory database following the production of this deliverable were the following:

- Collate and process all sources of data identified in this deliverable;
- Identify additional sources of data in all identified countries in Europe (e.g. cadastral data, local building survey data);
- Produce a common list of building typologies in Europe - see Deliverable 7.4 (Crowley et al., 2014);
- Produce inference algorithms to obtain building counts for those countries without building data (using population, land use, dwelling data etc. following the recommendations of GEM's Global Exposure Database consortium [5]) – see Deliverable 7.4 (Crowley and Ozcebe, 2014);
- Produce preliminary building typology inference algorithms following the GEM taxonomy using the data described herein - see Deliverable 7.5 (Ozcebe et al., 2014).

## References

Andeweg M. T., Brunoro S., Verhoef L. G. W., (2007) "COST C16: Improving the Quality of Existing Urban Building Envelopes: State of the Art"

Brzev S., C. Scawthorn, A.W. Charleson, L. Allen, M. Greene, K. Jaiswal, and V. Silva (2013), GEM Building Taxonomy Version 2.0, GEM Technical Report 2013-02 V1.0.0, 182 pp., GEM Foundation, Pavia, Italy, doi: 10.13117/GEM.EXP-MOD.TR2013.02.

Crowley, H., Colombi, M., Ozcebe S. (2014) "D7.3 European Building Classification" NERA Deliverable 7.3 v3.0.

Crowley, H., Ozcebe, S. (2014) "D7.4 European Building Inventory Database", NERA Deliverable 7.4 v2.0.

Doi, K. and Haffner, M. (2010) "Housing Statistics in the European Union 2010," OTB Research Institute for the Built Environment, Delft University of Technology

Ozcebe, S., Crowley, H., Baker, H., Spence, R., Foulser-Piggott, R. (2014) "Census data collection and harmonisation for Europe," NERA Deliverable 7.5 v2.0.

## Web References

[1] Global Earthquake Model: www.globalquakemodel.org
[2] World Housing Encyclopaedia: http://www.world-housing.net/
[3] PAGER: http://earthquake.usgs.gov/eqcenter/pager/
[4] WHE-PAGER project: http://pager.world-housing.net/
[5] GEM's Global Exposure Database: http://www.globalquakemodel.org/risk-global-components/exposure-database

## Appendix A: Documents from the European Building Inventory Workshop

### - Final list of invitees

| | | | |
|---|---|---|---|
| 1 | Alten Karoline | Austrian Institute of Technology | Austria |
| 2 | Barbat Alex | University of Catalonia | Spain |
| 3 | Bazzurro Paolo | AIR Worldwide | USA |
| 4 | Bevington John | ImageCat Inc | UK |
| 5 | Brzev Svetlana | British Columbia Institute of Technology | Canada |
| 6 | Campos Costa | Alfredo LNEC | Portugal |
| 7 | Cavalca Davide | University of Pavia | Italy |
| 8 | Chiauzzi Leonardo | University of Basilicata | Italy |
| 9 | Colombi Miriam | EUCENTRE/GEM Foundation | Italy |
| 10 | Crowley Helen | EUCENTRE/GEM Foundation | Italy |
| 11 | D'Ayala Dina | University of Bath | UK |
| 12 | Dazio Alessandro | ROSE School/IUSS | Switzerland |
| 13 | Ehrlich Daniele | Joint Research Centre, Ispra | Europe |
| 14 | Erdik Mustafa | KOERI | Turkey |
| 15 | Ernst Julius | Cadastral Agency of Austria (BEV) | Austria |
| 16 | Foulser-Piggot Roxane | CAR Ltd | UK |
| 17 | Gamba Paolo | University of Pavia | Italy |
| 18 | Gueguen Philippe | University of Grenoble Joseph Fourier | France |
| 19 | Hancilar Ufuk | Joint Research Centre, Ispra | Europe |
| 20 | Hausmann Peter | Swiss Re | Switzerland |
| 21 | Hollnack Dirk | Munich Re | Germany |
| 22 | Jaiswal Kishor | USGS/PAGER | US |
| 23 | Kappos Andreas | Aristotle University of Thessaloniki | Greece |
| 24 | Kyriakides Nicholas | Cyprus University of Technology | Cyprus |
| 25 | Lang Dominik | NORSAR | Norway |
| 26 | Langenbach Randolph | Conservationtech Consulting | USA |
| 27 | Lungu Dan | Technical University of Civil Engineering, Bucharest | Romania |
| 28 | Lutman Marjana | National Buildings And Civil Engineering Institute of Ljubljana | Slovenia |
| 29 | Magistrale Harold | FM Global | USA |
| 30 | Masi Angelo | University of Basilicata | Italy |
| 31 | Monteiro Ricardo | EUCENTRE | Italy |
| 32 | Parsons Ed | Google Earth | UK |
| 33 | Pinho Rui | GEM Foundation | Italy |
| 34 | Pomonis Antonios | CAR Ltd | Greece |
| 35 | Porter Keith | University of Colorado | USA |
| 36 | Ralbovsky Marian | Austrian Institute of Technology | Austria |
| 37 | Saito Keiko | CAR Ltd | UK |
| 38 | Scawthorn Charles | AGORA | USA |
| 39 | Schmieder Jutta | Munich Re | Germany |
| 40 | Sendova Veronika | IZIIS | Macedonia |
| 41 | Silva Vitor | GEM Foundation | Italy |

| | | | |
|---|---|---|---|
| 42 | Sokol Milan | University of Bratislava | Slovakia |
| 43 | Spence Robin | CAR Ltd | UK |
| 44 | Tashkov Ljubomir | IZIIS | Macedonia |
| 45 | Taucer Fabio | Joint Research Centre, Ispra | Europe |
| 46 | Tuzun Cuneyt | KOERI | Turkey |
| 47 | Vacareanu Radu | Technical University of Civil Engineering, Bucharest | Romania |
| 48 | Vona Marco | University of Basilicata | Italy |
| 49 | Wyss Max | WAPMERR | Switzerland |
| 50 | Zuccaro Giulio | University of Naples Federico II | Italy |

**- Final agenda**

**NERA/GEM EUROPEAN BUILDING INVENTORY WORKSHOP**

**EUCENTRE, Pavia, 23rd – 24th May 2011**

Monday 23rd May

09.00 – 10.30 Workshop Introduction and NERA Building-Related Activities
09:00 – 09:05 Welcome (Rui Pinho)
09:05 – 09:30 Introduction to NERA, GEM and Workshop Goals (Helen Crowley)
09.30 – 09:50 NERA Work Package 7 Test Bed Studies (Robin Spence & Keiko Saito)
09.50 – 10.10 Previous efforts to develop a European Building Inventory in NERIES (Mustafa Erdik)
10.10 – 10.30 Activities in field data collection of buildings in NERA (Marian Ralbovsky)

10.30 – 11.00 Coffee Break

11.00 – 12.10 GEM Building-Related Activities
11.00 – 11.15 GEM Building Taxonomy (Svetlana Brzev)
11.15 – 11.40 GED4GEM – a Global Exposure Database (Paolo Gamba and Kishor Jaiswal)
11.40 – 11.55 GEM Analytical Vulnerability Activities (Dina D'Ayala)
11.55 – 12.10 GEM Inventory Data Capture Tools (John Bevington)

12.10 – 12:30 Google Earth: building-related activities (Ed Parsons)

12.30 – 13.00 Discussion

13.00 – 14.00 Lunch

14.00 – 16.00 Status of European Building Inventory Data used in Seismic Risk Studies
14.00 – 14.15 Austria (Karoline Alten)
14.15 – 14.30 Cyprus (Nicholas Kyriakides)
14.30 – 14.45 France (Philippe Gueguen)
14.45 – 15.05 Greece (Antonios Pomonis, Andreas Kappos)
15.05 – 15.25 Italy (Giulio Zuccaro, Angelo Masi)
15.25 – 15.45 Macedonia (Veronika Shendova)
15.45 – 16.00 Norway (Dominik Lang)

16.00 – 16.15 Coffee Break

16.15 – 18.00 Status of European Building Inventory Data used in Seismic Risk Studies (cont.)
16.15 – 16.30 Portugal (Alfredo Campos Costa)
16.30 – 16.45 Romania (Dan Lungu)

16.45 – 17.00 Slovenia (Marjana Lutman)
17.00 – 17.15 Slovakia (Milan Sokol)
17.15 – 17.30 Spain (Alex Barbat)
17.30 – 17.45 Switzerland (Alessandro Dazio)
17.45 – 18.00 Turkey (Cuneyt Tuzun)

18.00 – 18.30 Discussion

20.00 – 22.30 Dinner, Osteria Del Collegio

Tuesday 24th May

09:00 – 10:30 European Building Inventory - Related Initiatives
Exposure Databases for Cat Risk Modelling (Paolo Bazzurro)
INSPIRE: Buildings Working Group (Fabio Taucer)
European Cadastral Building Information (Julius Ernst)
ACORD Standards (Peter Hausmann)
Discussion

10.30 – 11.00 Coffee Break

11.00 – 13.00 Parallel Sessions (Part 1)
Group 1: Resolution of a European building database (Chair: Mustafa Erdik)
Group 2: Building taxonomy and minimum characteristics (Chair: Charles Scawthorn)
Group 3: Methods for data collection, testing and uncertainty (Chair: Robin Spence)
Group 4: Collection of data on non-residential buildings (Chair: Paolo Bazzurro)

13.00 – 14.00 Lunch

14.00 – 14.45 Parallel Sessions (Part 2)
Group 1: Resolution of a European building database (Chair: Mustafa Erdik)
Group 2: Building taxonomy and minimum characteristics (Chair: Charles Scawthorn)
Group 3: Methods for data collection, testing and uncertainty (Chair: Robin Spence)
Group 4: Collection of data on non-residential buildings (Chair: Paolo Bazzurro)

14.45 – 15.30 Feedback from Chairs of Parallel Sessions

15.30 – 16.30 Closing Discussion and Next Steps

16.30 – 17.00 Coffee Break

**- Minutes of the 4 breakout sessions**

**Discussion Group 1: Resolution of a European Building Inventory**

It was concluded that it is premature to decide which spatial resolution the European component of a global building inventory should have. However, several factors that will greatly influence this choice where identified:

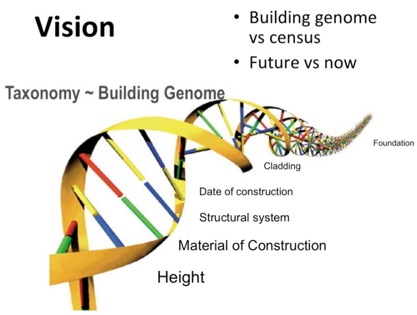
- Seismic Hazard: when performing a deterministic or probabilistic event-based assessment to a certain region, it is important to use a spatial resolution that will allow the consideration of the variability of the ground motion from cell to cell, but at the same time, that will not be too small increasing the calculation time and decreasing the computational performance.
- Spatial correlation of the ground motion models: If a spatial resolution whose grid cells will be much bigger than 5 – 50 km will be adopted, it will not be possible to properly consider the spatial correlation of the intra event variability of the ground motion. However, it should also be noted that when modeling the buildings within a grid cell as co-located at a single coordinate, the ground

motions to all buildings within the grid are considered to be equal, thus increasing the spatial correlation in the model. Sensitivity studies on the influence of these factors are needed.
- Site effects: The spatial resolution of the building inventory might be affected by the resolution of the soil conditions dataset.
- Topography: The adopted spatial resolution should take into account datasets capable of providing altitude (and therefore slope) to decrease the likelihood of allocating assets in regions, where due to the topography, the existence of buildings will be unlikely.
- Methodology: the spatial resolution that will be followed might be directly related to how the dataset will be built (if census data will be used, or remote sensing, LandScan or GRUMP, local surveys, algorithms based on regional parameters, amongst others).
- Final use of the dataset: Different spatial resolutions might be required depending on the end user. For someone who is developing a post-disaster emergency plan or computing losses for the insurance industry, a building-by-building resolution might be required. However, for someone who is only interested in identifying the zones within a country where seismic risk is higher in order to attribute funds, a bigger resolution might be satisfactory.

The available data set in Europe as portrayed by the presentations appear to have highly variable objectives, attributes and resolution. What is needed is to find the highest possible spatial resolution with authenticity, uniformity and completeness.

**Discussion Group 2: Building Taxonomy and Minimum Characteristics**

The session began with a summary of the GEM taxonomy and of the vision, which is to produce a "building genome".




The session followed with a roundtable, with each participant providing their opinions on the proposed GEM Taxonomy. The following comments were made:
- A hierarchy is needed in the taxonomy.
- The telescope effect should come across in the document, so that the different building typologies for which we can define vulnerability are clearly evident.
- We need a set of minimum parameters needed for the different vulnerability models. For example, the loss data from past events only have a limited number of attributes, and so a standard is needed for this minimum number of attributes. Indeed the taxonomy should be related to type of vulnerability assessment - mechanical (need many facets) vs. empirical. Taxonomy cannot be seen independently from type of vulnerability analysis that we are using.
- A parameter to correlate similar buildings in different cultures/countries could be included.
- The idea of the taxonomy is to allow single buildings to be assessed in the future.
- The tables in the proposed taxonomy certainly bring together all the key facets of buildings (thought of course there may be some slight modifications will be needed for local issues).
- Prioritization of the assets might depend on the building typology (e.g. storey height might be more important for RC buildings than masonry).

- This detailed, facetted approach is certainly the right way to begin – one can begin with a very detailed taxonomy and then reduce/telescope.
- It might be worth defining three different levels of detail where the "highest" defines 1/2 key facets and the "lowest" is down to the level of detail of structural drawings.
- A division of "vulnerability-related" and "general" attributes might be useful for users.
- Could users create "Frankenstein" structures? It was felt that mechanisms can be put into place to restrict the use of the taxonomy by different types of users.
- It was agreed that even if some data within the taxonomy cannot be easily collected now, it is not a problem to have it there as a placeholder for the future.
- After the 1999 Athens earthquake there was a proposal to make a building genome database, to keep all the data and history of a building in a green box, but unfortunately nothing has happened since.
- There have been presentations from 14 countries at the workshop, about half (or more) had building censuses, which all started in 1970. The group asked themselves, "what happened in the late 60's to begin this?" We, as a group, should try and find out what was the reason for this.
- In existing taxonomies nothing has dramatically changed in the last 30 years, and the GEM taxonomy is certainly a new approach to building taxonomies.
- There are three types of facets: one is "globally applicable" (e.g. height), others are "regionally constricted". Can this be touched upon in the taxonomy?
- Only things that can be measured are included. Building code compliance is difficult to measure. What do we mean by compliance? This issue needs further consideration.
- It was stated that it is what is in the building that it is important, not the code that was applied. However, in many cases you need to guess what is in the building from the code.
- It was suggested that the attributes needed for wind and flood should be added (and indeed some already have been).

The group then spent 20 minutes prioritizing a list of attributes, once considering the availability and ease of collection of the attributes and the second time ignoring such constraints. The results below summarise the outcome of this exercise:

| Main Attributes (Facets) | Secondary Attributes | IMP |
|---|---|---|
| Height | Height above grade | 30 |
| Material | Material type | 28 |
| Structural Irregularity | Vertical irregularity | 27 |
| Lateral Load Resisting System | Principal lateral structural element | 26 |
| Floors and Roof | Diaphragm | 25 |
| Exterior Walls | | 24 |
| Material | Material properties | 24 |
| Building Codes | Code compliance | 24 |
| Construction Date | Construction completed | 23 |
| Structural Irregularity | Horizontal irregularity | 23 |
| Seismic Retrofit | | 23 |
| Building condition | | 22 |
| Lateral Load Resisting System | Connections/reinforcement/detailing | 22 |
| Ductility | | 22 |
| Floors and Roof | Diaphragm structural system | 22 |
| Foundations and Site Soil Conditions | Soil conditions | 22 |
| Building Codes | Code information | 22 |
| Floors and Roof | Type | 21 |
| Occupancy | | 20 |
| Structure: Direction | | 20 |
| Foundations and Site Soil Conditions | Number of basements | 20 |
| Roof | Roof shape | 19 |
| Plan | Footprint | 19 |
| Building Hazards | Falling | 19 |
| Floor Level | | 19 |
| Foundations and Site Soil Conditions | Foundation system | 19 |
| Nonstructural Components | | 15 |

| Main Attributes (Facets) | Secondary Attributes | ACHIEV |
|---|---|---|
| Height | Height above grade | 30 |
| Exterior Walls | | 29 |
| Roof | Roof shape | 27 |
| Structural Irregularity | Horizontal irregularity | 25 |
| Plan | Footprint | 24 |
| Material | Material type | 24 |
| Structural Irregularity | Vertical irregularity | 24 |
| Floor Level | | 21 |
| Occupancy | | 21 |
| Lateral Load Resisting System | Principal lateral structural element | 21 |
| Construction Date | Construction completed | 19 |
| Floors and Roof | Type | 19 |
| Floors and Roof | Diaphragm | 19 |
| Structure: Direction | | 18 |
| Material | Material properties | 18 |
| Floors and Roof | Diaphragm structural system | 18 |
| Building Hazards | Falling | 16 |
| Lateral Load Resisting System | Connections/reinforcement/detailing | 16 |
| Nonstructural Components | | 16 |
| Building Codes | Code compliance | 16 |
| Building Codes | Code information | 16 |
| Building condition | | 14 |
| Foundations and Site Soil Conditions | Number of basements | 13 |
| Seismic Retrofit | | 13 |
| Foundations and Site Soil Conditions | Soil conditions | 12 |
| Foundations and Site Soil Conditions | Foundation system | 11 |
| Ductility | | 10 |

IMP = Importance, that is, the relative contribution of the attribute to loss estimation results and accuracy
ACHIEV = Achievability, that is, the relative likelihood of obtaining or capturing the attribute data.

**Discussion Group 3: Methods for data collection, testing, and uncertainty**

After considering and ranking a list of 9 alternatives, the following 4 discussion questions were considered, most of the time being spent on the first question.

- What methods can be used for direct/ proxy inventory data collection?
- How can remote sensing techniques be adapted for large-scale inventory collection?
- Is there a role for crowd-sourced data collection techniques?
- Should NERA data include asset values (e.g. reconstruction costs)?

A view was expressed that different levels of inventory should be aimed for across Europe, with a greater level of focus and detail on those countries (e.g. Greece, Italy, Romania) with the highest level of seismic risk.

There was general agreement that some information on individual buildings and their population was available in most European countries, either from population and building census data, or from cadastral data, and that this would probably be available to NERA at some level of aggregation (census tract or larger) as a basis for determining numbers and locations of buildings and their number of inhabitants. However, the information about the characteristics of the buildings in these data sources was likely to be limited, and not suitable on its own to estimate the distribution of building typologies needed for a vulnerability inventory.

There was discussion about how to supplement this data with more on construction typologies. It was suggested that in some cases, building age could be used to estimate vulnerability typologies. Other important information correlating with vulnerability would be height and irregularity.

There was discussion about whether the expertise of local experts could be used to map from the information available in census data to the structural typologies needed for vulnerability assessment. Several members of the group thought this would be possible for their country, if different zones were identified, and recognising that a level of uncertainty would be involved, and would need to be estimated. It was also suggested that this process could be helped by the use of local survey data available, including post-earthquake damage surveys. This general data structure would need to be overlaid by better national data (e.g. Italy) or city data (Barcelona, Bucharest, Grenoble, Ljubljana) in areas of particularly high risk where this was available from local surveys.

The suitability of crowd-sourcing methods for collecting building inventory data was discussed. These methods are under development in the GEM ICDT project, and may need further development before being applicable for wide application. A crowd-sourcing approach had been successfully used for Grenoble, where the responses of building occupants to simple questions about the form of construction of their building were shown to be close to the estimates of experts.

The potential for remote sensing techniques was considered. At a local scale some building characteristics can be determined from high resolution satellite imagery, but not direct construction typology. Pictometry (or the currently lower-resolution Bing) can give more detailed information (e.g. use in Haiti), but is unlikely to be widely available. The most valuable use for remote sensing techniques was thought likely to be for identifying more detailed land-use in urban areas. The use of the European Corine land-cover database for the NERIES-ELER project was a successful existing model of this type of application.

It was agreed that it would be important that the European database should also contain information on construction costs to enable damage data to be converted into direct loss information.

**Discussion Group 4: Collection of data on non-residential buildings**

Some challenges of non-residential data were discussed:
- Availability of commercial data
- Quality/resolution of datasets
- Vintage of datasets
- Taxonomy
- Validation of databases

Availability
The members of the meeting discussed the data from their institutions/companies:

- FM Global: they have good quality data, but they are not available.
- PAGER: non-residential data for some country are available and detailed, but they are aggregated data.
- AIR WORLDWIDE: Most data are proprietary, but there are some projects which are externally funded and the data are available (for instance for the South Pacific area). Details of these data: some are digital footprints, some are pictures, some attributes.

Furthermore it was discussed that:

- The availability of the data depends on the country, though it is certainly less than residential buildings (though some presentations at the workshop did show non-residential building data is available). Reports and papers can be of some help in collecting data.
- Economic (building replacement cost): might be obtained from the Economic Census, but this is not always available. Business surveys and business registers often offer limited and incomplete data.

Quality
The quality of available data are generally low, non homogenous and depend on the country.
One should pay attention to the use of the same proxy in a country. For instance, if we talk about China we have to be aware that it is a very big country and probably we cannot use the same proxy for all the cities of China. Maybe we can assume the same distribution if we are talking about a small country such as the Netherlands.
Vintage
The vintage of datasets of non-residential buildings is an important issue. Generally one tries to draw a trend of the losses taking data from various reports, and working with economists to draw the trend to follow (using GDP, etc.).
Taxonomy
The main categories could be commercial, industrial, public buildings and infrastructures, but the level of detail required will depend on the end user.
The attributes necessary for economic loss estimation are contents/equipment value, economic "output" of a building (productivity), which may depend on the number of people in the building.
Validation
To validate an inventory you need to have a benchmark, but what is the "truth"?
More than for residential buildings, to create an inventory of non-residential buildings different people with different backgrounds have to be involved (economists, expert people on industrial buildings, etc.)
It was suggested that an attempt to convince private/industry sponsors to process their data to render them anonymous should be made so that they can be used in GEM/NERA.

## Appendix B: Summary of Workshop Country Presentations

### 1. AUSTRIA-KAROLINE ALTEN, AIT:

**Provided Information:**

*On building inventory:*

- There are not any tables or figures presented on building inventory.

**(1)Data Sources:**

1. Address-Buildings-Flats Register (AGWR)- *www.statistik.at*
   - Data:
     - old building register with population register,
     - digital cadastral maps,
     - land plot database,
     - statistics of construction measures (updated regularly by the communities/municipalities)
   - Accessibility:
     - Public access only to address level (geographically oriented data)
     - Provincial governments, ministries, communities/municipalities (only local objects) all three data levels (address, building, unit/flat)
   - Building level:
     - Number of flats,
     - Use of building (residence, hotels etc.),
     - Construction period, geometric features as height, size, no. of floors etc.
     - Main function of the building (essential for crisis management)
   - Sub-unit level:
     - Type of unit,
     - Installations, facilities (size, energy, water etc.)

**(2)Special Studies:**

1. Vienna: GIS Infrasturcture- www.wien.gv.at/viennagis

   (All in form of interactive online maps- available but in German):

   - city zoning;
     - colour coding representing zones as residential, traffic infrastructure, industry etc.,
   - cultural environmental assets;
     - construction periods-safety standards of those periods,
     - construction type-potential vulnerability shows hospitals, schools etc.,
   - subsoil cadastre;
     - boreholes, SPTs,
   - bridge info;
     - bridges, sound barriers, walls and sign posts,
   - Orthophotos DTM, Airbore Laser Scanning.

2. Vienna: SEISMID Project- http://www.seismid.com/en/main_project.html
   - Research project in Vienna to assess the site effects and 'real' seismic vulnerability of the buildings/ PhD Thesis by Günther Achs,
   - Special focus on historic buildings,

3. Geodata/Geoland for other provinces- www.geoland.at
    - Basic GIS data for provinces but not exact detail about the buildings

## 2. CYPRUS-PROF. CHRISTIS CHRYSOSTOMOU, DR. NICHOLAS KYRIAKIDES, CYPRUS UNIVERSITY OF TECHNOLOGY:

**Provided Information:**

*On building inventory:*

- 250.000 low rise RC (≤ 2 floors), ≈60% w/ no seismic design
- 15.000 RC (> 2 floors)
- Nearly 50% of the building stock with no seismic design, before 90's, concrete strengths as low as 6 MPa and low ductility steel
- RC buildings, 3-5 floors, ≈30% w/ no seismic design
- High rise buildings, > 6 floors, ≈10-15% of >2 floors RC buildings
- The building inventory of Cyprus is formed through a combination of procedures and studies.

| Description | Period | Construction and Design Practise (CDP) |
|---|---|---|
| Pre-seismic | early 70's to mid 80's | Rapid and in general uncontrolled CDP with no seismic design provisions. The most widely used design guidelines had the sophistication level of CP110 (BSI, 1972). |
| Basic seismic | mid 80's to mid 90's | Minimum requirements for earthquake resistant structures (1985) are introduced in Cyprus and are used in addition to BS8110 (1985) for RC design. Thus, design is enhanced with the inclusion of the seismic demand in a rather simplistic manner. Minor improvement in construction practise. |
| Modern seismic | mid 90's- | The introduction of the Seismic Code for RC structures in Cyprus (Cyprus Civil Engineers and Architects Association, 1991) raised the design practise to a higher level. The seismic hazard is identified in more detail and capacity design has been introduced. Construction practise has also been improved considerably due to compulsory quality assurance checks. |

Data for building stock from Statistical Service-2009

| | Total dwelling units (2009) | 70% is ≤ 2 floors (houses) | 30% > 2 floors (apartments) | 3 flats/floor & 3 floors/block | % of blocks | % of blocks (2001 census) |
|---|---|---|---|---|---|---|
| **Nicosia** | 132632 | 92842 | 39790 | 4421 | 34% | 35% |
| **Famagusta** | 28805 | 20164 | 8642 | 960 | 7% | 8% |
| **Larnaca** | 66269 | 46388 | 19881 | 2209 | 17% | 15% |
| **Limassol** | 104187 | 72931 | 31256 | 3473 | 27% | 30% |
| **Pafos** | 60346 | 42242 | 18104 | 2012 | 15% | 12% |
| **Cyprus** | 392239 | 274567 | 117672 | 13075 | 100% | 100% |

| City | Adobe/Stone |
|---|---|
| Nicosia | 15300 |
| Larnaca | 6800 |
| Limassol | 14000 |
| Paphos | 7500 |
| Famagusta | 1800 |

**(1)Data Sources:**

1. Statistical Service of Cyprus- http://www.mof.gov.cy
    - Census of population, 2001- Volume for households and housing units
    - Annual reports on construction

2. Local municipalities
    - Building permits for mid and high rise buildings

3. Cyprus Geological Survey Department- http://www.moa.gov.cy
    - GIS satellite images

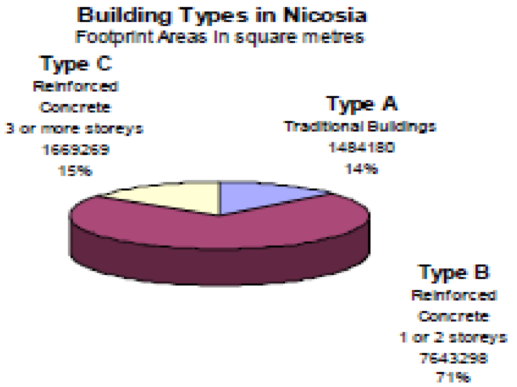
4. Micro zonation study of Nicosia

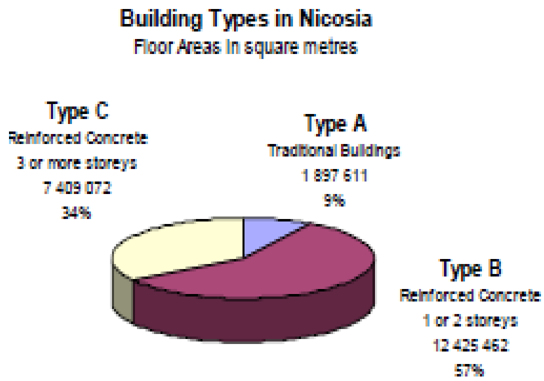
5. Department of Lands and Surveys
    - GIS satellite images
    - Digital town planning zones
    - Height of buildings with final permit

**(2)Special Studies:**

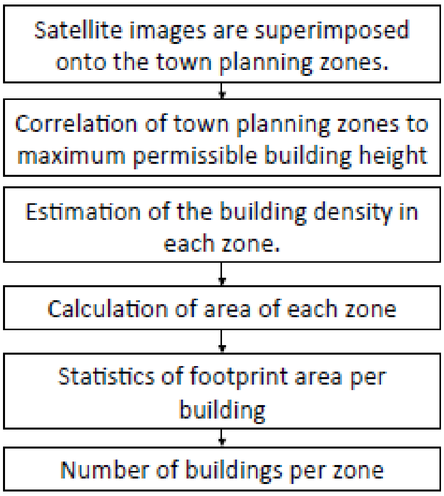
1. GIS mapping of Nicosia and Paphos:

- Satellite images were used to determine plan area
- Mean height of buildings is determined subjectively
- Total percentage of buildings per class per km$^2$ is determined:
    - Class A: traditional masonry or adobe
    - Class B: RC≤ 2 storeys
    - Class C: RC> 2 storeys



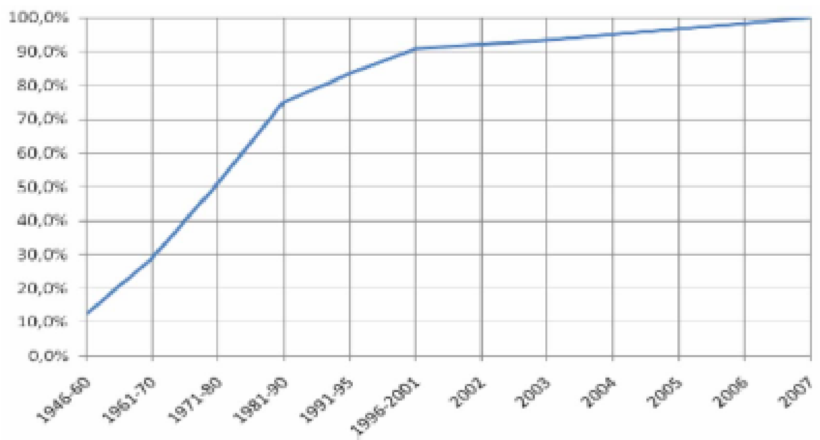




2. Methodology for cities without GIS mapping




3. <u>Using data from Statistical Service for a case study in Limossol Municipality</u>

| | 1946-60 | 61-70 | 71-80 | 81-90 | 91-95 | 96-2001 |
|---|---|---|---|---|---|---|
| Houses | 4221 | 5725 | 9973 | 12345 | 5550 | 4583 |
| Apartments | 341 | 1057 | 4267 | 7135 | 2912 | 1683 |
| | 2002 | 2003 | 2004 | 2005 | 2006 | 2007 |
| Houses | 784 | 653 | 1002 | 1039 | 1128 | 991 |
| Apartments | 186 | 177 | 312 | 669 | 989 | 1119 |




| No. of buildings | 2000 | 2001 | 2002 | 2003 | 2004 | 2005 | 2006 | 2007 | 2008 |
|---|---|---|---|---|---|---|---|---|---|
| >2 | 12 | 16 | 16 | 42 | 72 | 100 | 99 | 215 | 455 |

Houses refer to ≤ 2 floors; Buildings refer to > 2 floors

## 3. FRANCE-PROF. PHILIPPE GUEGUEN, EARTH SCIENCES INSTITUTE ISTERRE-GRENOBLE RESEARCH AND TECHOLOGICAL INSTITUTE FOR TRANSPORTATION, ENVIRONMENT AND NETWORKS IFSTTAR:

**Provided Information:**

*On building inventory:*

- Building taxonomy is same as for EMS98,
- Strong regional variabilities of historical buildings such that:
    - Wooden buildings for Normandie an Alsace Region
    - Adobe in the Alps
    - Not Rubble Stones in Bertagne and Centre
- Few steel buildings for housing,
- Few RC-Frame buildings more RC-SW,
- Urbanization in RC using tunnel techniques in years 1950-1970,
- Masonry with low level of quality in historical center,
- French cities have a scheme:
    - Old down-town with old regional material (wooden, rubble stones, adobe)
    - First ring with mixed buildings,
    - Second/third with individual masonry building (manufactured cement units) and RC-SW buildings

| IRIS2 | Nb bat | <4etages | <1915 | 1915-1948 | 1949-1967 | 1968-1974 | 1975-1982 | 1982-1989 | >1990 |
|---|---|---|---|---|---|---|---|---|---|
| 380010000 | 45 | 43 | 9 | 6 | 12 | 5 | 9 | 0 | 2 |
| 380020000 | 58 | 30 | 9 | 0 | 2 | 5 | 11 | 1 | 2 |
| 380030000 | 4 | 4 | 3 | 0 | 1 | 0 | 0 | 0 | 0 |
| 380040000 | 16 | 16 | 7 | 1 | 1 | 0 | 1 | 3 | 3 |
| 380050000 | 41 | 12 | 3 | 1 | 0 | 1 | 0 | 4 | 3 |
| 380060000 | 281 | 274 | 114 | 31 | 39 | 42 | 17 | 21 | 10 |
| 380080000 | 1 | 1 | 1 | 0 | 0 | 0 | 0 | 0 | 0 |
| 380090000 | 23 | 23 | 19 | 1 | 1 | 0 | 1 | 1 | 0 |
| 380100000 | 1 | 1 | 1 | 0 | 0 | 0 | 0 | 0 | 0 |
| 380110000 | 2 | 2 | 2 | 0 | 0 | 0 | 0 | 0 | 0 |

**(1)Data Sources:**

1. INSEE: National Institute for Statistical Studies- http://www.recensement.insee.fr **(open for research, paying for private companies)**
    - Census results available at different scales (regional, local, city etc.)
    - Building information such as:
        - Date of construction
        - Number of floors (< 4, 4 to 8, >9 floors)
        - Additional information on equipment, inhabitants etc.

2. MAJIC II Database: Updating of the Cadastral Information- http://www.cadastre.gouv.fr **(open for research after agreement)**
    - Database for Ministry of Finance
    - Information on Cadastral Unit for each parcel describing all the construction:
        - Date of construction (exact),
        - Number of floors (exact),
        - Surface of the building,
        - Material of construction,
        - Category of construction (house, hangar etc.)

*3.* BCSF: National Seismological Office- http://www.franceseisme.fr/SMC/SMCinfo/SMCinfo-en.html **(open for research)**
    - Macro seismic intensity assessment and inventory of damage after strong and moderate earthquakes,
    - Building classification following a light EMS98 classification

**(2)Special Studies:**

Seismic Vulnerability Assessment in France:

- Nice Test Bed:
  - RiskUE and GEMGEP Projects **(open for research)**
  - Inventory done by expert (BRGM)
  - Sampling within homogeneous urban area
  - RiskUE typology using RiskUE methodology

- Grenoble Test Bed:
  - Vulneralp method using GNDT method (scores and weights) **(open for research)**
  - Citizen assessment through questionnaire with parameters such as
    - Material type (masonry, RC, wood, steel, adobe or mixed)
    - Building location,
    - Foundation (slope or flat site, rock or sediments)
    - Date of construction
    - Roof shape,
    - Plan regularity (yes or no),
    - Elevation regularity (yes or no),

  - Validation by expert assessment within homogenous area (based on history of urbanization and VHR images) and citizen parameter plus EMS98 typology
  - Fragility curves for slight damage based on ambient vibrations

- Grenoble Test Bed:
  - ANR Project: URBASIS: 3D VHR images+ Cadastral units
  - WP1: Using remote sensing for seismic vulnerability assessment

## 4. GREECE-ANTONIOS POMONIS, CAR LTD. AND KAPPOS, A.J., PANAGOPOULOS, G., ARISTOTLE UNIVERSITY OF THESSALONIKI:

**Provided Information:**

*On building inventory:*

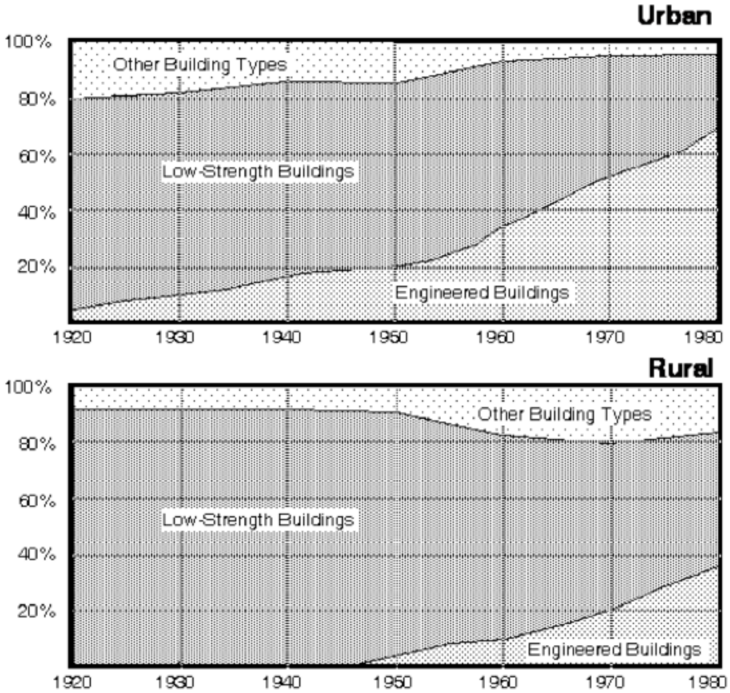
- 4.315.000 buildings (2009 estimates)
- 6.630.000 dwelling units (2009 estimates): 77%Residential, 23%Non-Residential, 10.5% mixed-occupancy
  - 31%, pre-1959,
  - 45%, 1959-1983,
  - 13%, 1984-1995,
  - 11%, post-1995,
- In large cities, mid-rise RC
- In rural areas, around 35% of the buildings are old load-bearing masonry (adobe, rubble stone, hewn stone masonry)
- Earthquake code benchmarks
  - Pre-1959 (no-code)
  - 1959-1984
  - 1984-1994
  - 1995-2003
  - 2004-present

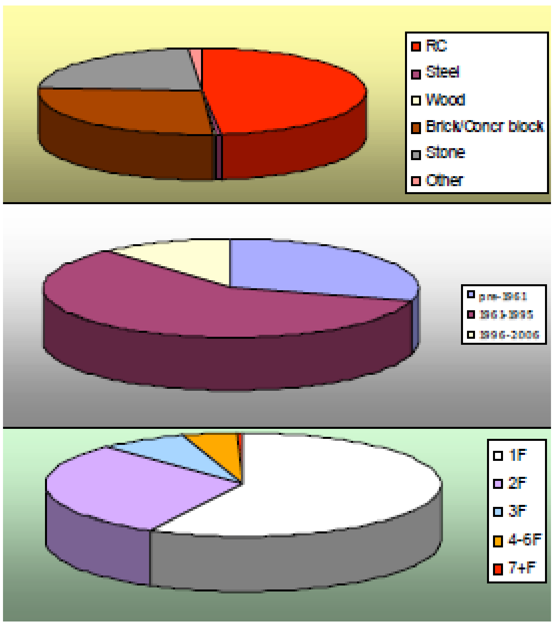
*Other information (in 2000):*

- Residential population distribution by vulnerability class (in RC buildings 96.5% of urban residents and 58.5% of rural residents-87%

of total and in URM buildings 3.4% of urban residents and 41.2% of rural residents-12% of total)

- Working population distribution by vulnerability class (in RC buildings 84.5% of urban residents and 46.7% of rural residents and in URM buildings 14.8% of urban residents and 52.4% of rural residents)
- Residential building occupancy by vulnerability class; peak average occupancy in RC residences (URBAN) 24.2 people (mid-rise), 1.9 (low-rise) and peak average occupancy in RC residence (RURAL) 17 people (mid-rise), 1.8 (low-rise). Peak average occupancy in URM residences (URBAN) 1.1 people and peak average occupancy in URM residence (RURAL) 0.6 people.



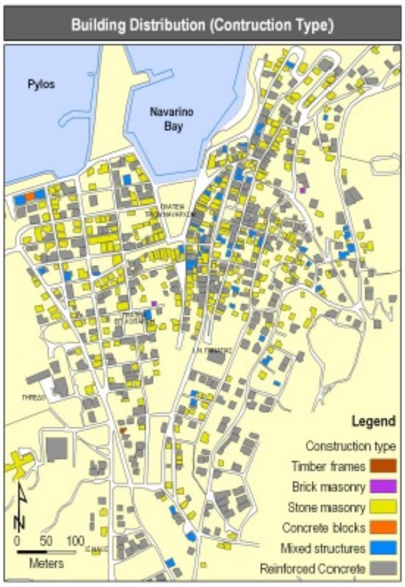



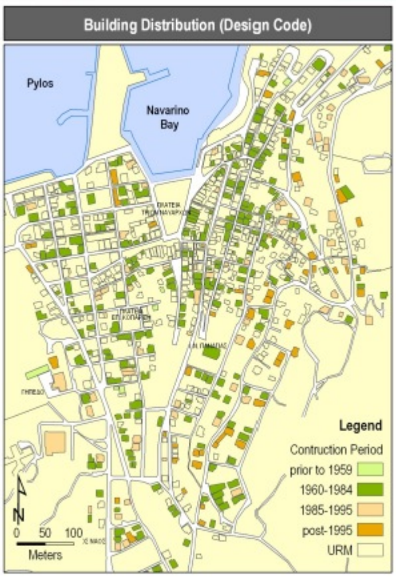

**(1)Data Sources:**

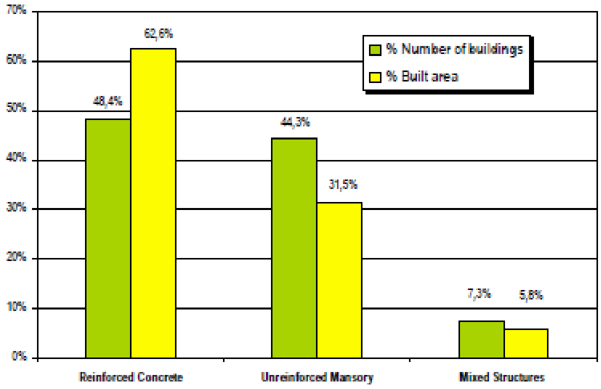
1. El.STAT: National Institute for Statistical Studies- http://www.statistics.gr **(available)**

- Attributes recorded in the building census:
  - all buildings, residential or non-residential,
  - address,
  - type of load-bearing structure (RC, timber, steel, stone, brick or concrete block, other masonry),
  - no. of floors,
  - existence of soft-story, basement,
  - construction year,
  - building in contact with other buildings or not,
  - type of roof and roof cover (2 and 3 types, respectively),
  - type of occupancy (9 types), exclusive and mixed,
  - number of dwelling units in the building
- Census data is available at census sector level; a sector consists of one or more town blocks
- For municipalities of population over 2000, the data can be combined with basis GIS map (showing individual building footprints, streets, other details)

2. EPANTYK:Technical Chamber of Greece- http://portal.tee.gr/portal/page/portal/TEE_HOME **(could not be accessed)**
   - 10-year project where building census date from 2000 for towns with population>2000 has been analyzed and connected to GIS map layers with analysis at census tract. (high proportion of seismically vulnerable buildings are highlighted, e.g. stone masonry, pre-1985 RC)
   - Pylos Town Case Study:
     - Building distribution: 48.4% RC, 44.3% URM, 7.3% Mixed Structure
     - Map of 'Building distribution in relation to the type of vertical load bearing system' is provided.
     - RC Building distribution by period of construction: 1.5% prior to 1960, 64.9% 1960-1984, 18.1% 1985-1995, 15.5% post 1995 (NEAK)
     - Building classes for Pylos town is presented by structural type, type of vertical bearing system, period of construction and no. of storey






Building classes in Pylos town.

| Structural type | Type of vertical bearing system | Period of construction | No storeys | % |
|---|---|---|---|---|
| RC1 | RC (non-pilotis) | Prior to 1959 | 1-3 | 0.6 |
| RC2 | | 1960-1984 | 1-3 | 29.6 |
| RC3 | | 1985-1995 | 1-3 | 8.2 |
| RC4 | | Post 1996 | 1-3 | 6.8 |
| LBSM | Load bearing Stone Masonry | | 1-2 | 41.5 |
| MS | Mixed Structures | | 1-2 | 6.6 |
| Other | | | | 6.7 |

3. <u>Matching with remote sensing (QuickBird):</u> Investigation of the relationship between roof shape and the structure type/vulnerability class of the buildings and the physical parameters. A simple sobel filter to identify roof shape. (**Source: Saito et al., 2009, EGU09, Vienna)**

**(2)Special Studies:**

- Damage data is limited for reliable statistical analysis; (1) not available for all intensity levels, (2) not covering properly building typologies in modern building stock, (3) not fully representative of the entire building stock in the areas from where they originate
- Evaluation on available databases is also explained in detail.

1. **Thessaloniki 1978 EQ database (Penelis et al. 1986, 1989)**
   - Density of coverage is ≈50%,
   - Recorded 5470 buildings (65% RC, 31% URM, 4% mixed):
     - Structural characteristics of the buildings
     - Description of the type of the damage
     - Post seismic tagging (green, yellow, red)
     - Repair cost data (for structural elements and infills)

2. **Kalamata 1986 EQ database**
   - Basic data for 7100 buildings in 26 neighborhoods of the city **(OASP-Andrikopoulou, 1989)**:
     - Construction material
     - Number of storeys
   - Full data for ≈700 buildings **(ITSAK- Lekidis et al., 1987)**
     - Construction material
     - Dimensions
     - Location in the block
     - Soft storey
     - Post seismic tagging
     - Behaviour of non-structural elements

3. **Aegion 1995 EQ database (Fardis et al., Karantoni&Fardis, 2004)**
   - All buildings in the city center of Aegion
   - Recorded 2014 buildings (57.5% RC, 42.5% URM):
     - Structural material
     - Age of building
     - Number of storeys
     - Location in the block
     - Post seismic tagging (green, yellow, red)

  - Emphasis on URM buildings
  - Repair methods and costs

4. **Ano Liosia- Athens 1999 EQ database (Kappos et al., 2007)**
   - Density of coverage is ≈10%,
   - Recorded 150 building blocks in the municipality
   - Data for ≈1000 buildings (62.2% RC, 37.1% URM, ≈0.7% precast):
     - Structural material
     - Age of building
     - Number of storeys
     - Post seismic tagging (green, yellow, red)
     - Type of post-earthquake intervention in repaired buildings

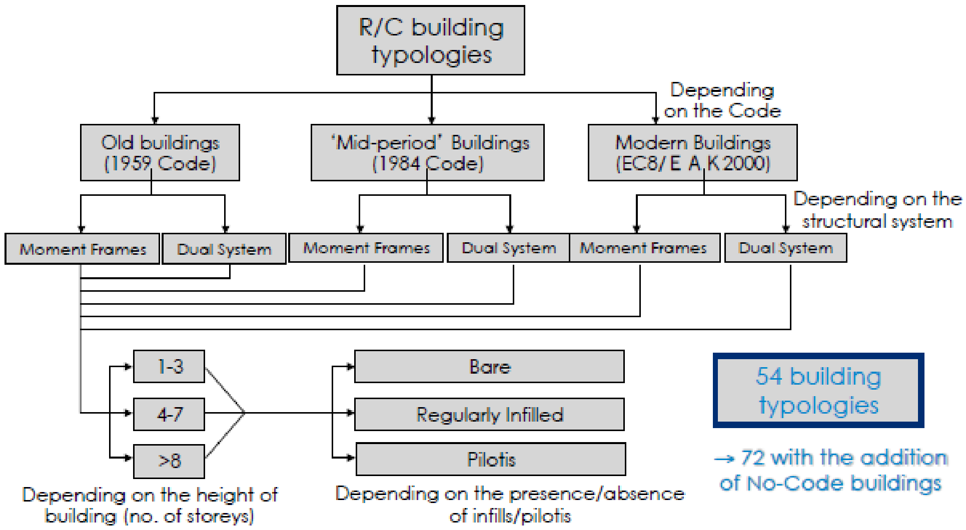
5. **Ariston research programme database- Athens 1999 EQ and small percentage from Lefkada 2003 EQ**

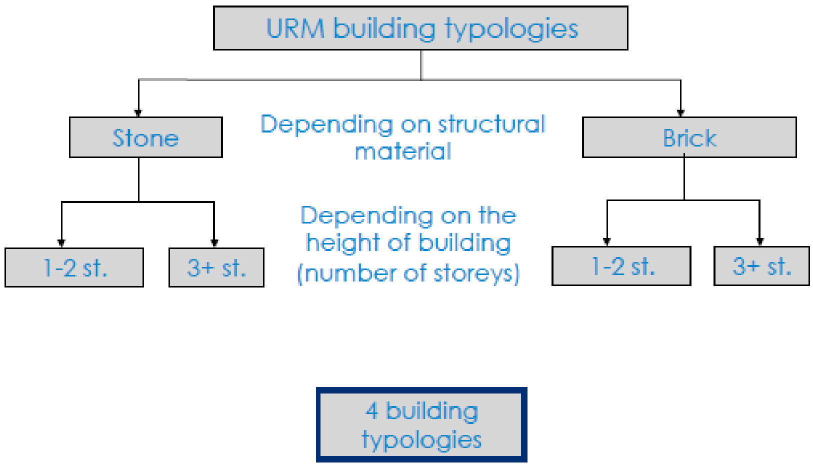
   Ethiniki Asfalistiki database **( Vlahos&Vlahos, 2006)**
   - Recorded 2150 entire buildings or parts of them (individual apartments or commercial stores) including most of the typologies that appear in Greek building stock:
     - Post seismic tagging (green, yellow, red)
     - Monetary losses in structural and non- structural elements
     - Estimated value of the buildings or their parts
     - Macro seismic intensity values in the municipality

   EPPO database **(Katsikas et al., 2006)**
   - Main objective is to assess the current practices in the field of repairs.
   - Recorded a sample of 660 RC coming from different parts of Attica, mainly the municipalities of Aharnes and Tharakomacedones.
     - Complete inventories of structural characteristics of buildings
     - Assignment to EPPO building typologies
     - Post-earthquake interventions (when applicable)

6. **Athens 1999 EQ (EPPO- Ministry of Environment and Public Works)**
   - Record over 100,000 buildings:
     - Structural material
     - Construction year
     - Number of storeys
     - Post seismic tagging (green, yellow, red)
     - Limited information on structural characteristics of buildings

7. **AUTh-LRCMS Unified Database**




| Category | Field |
|---|---|
| Building identification | ID, municipality, address, building block |
| Building Description | Construction year/age, number of storeys, material, structural system, soft storey, area/ volume, AUTh classification |
| Damage data | Post earthquake tagging, monetary loss in structural and non-structural elements, total losses |
| Seismic action data | Earthquake ID, intensity |
| Data from the original database | Original database and building ID in it |

## 5. ITALY- GIULIO ZUCCARO- PLINIVS CENTRE, ANGELO MASI, DISGG, CRIS, RELUIS:

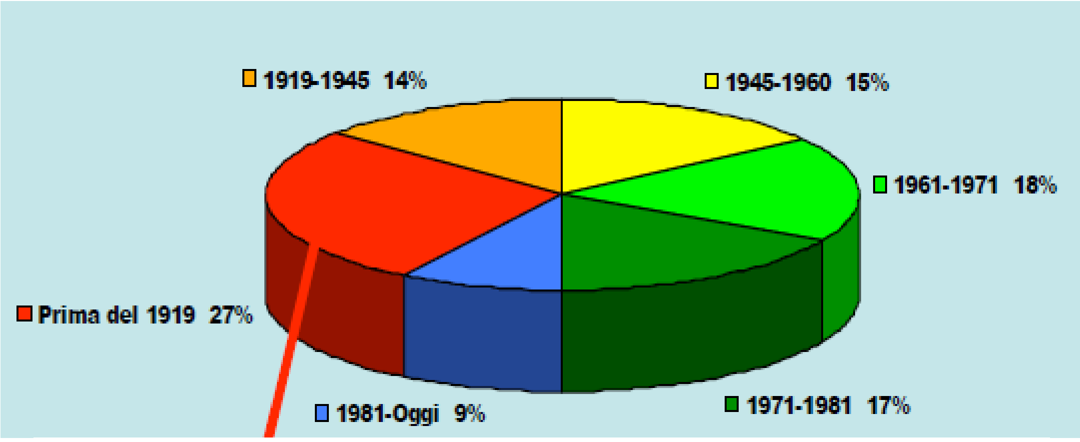
**Provided Information:**

*On building inventory:*

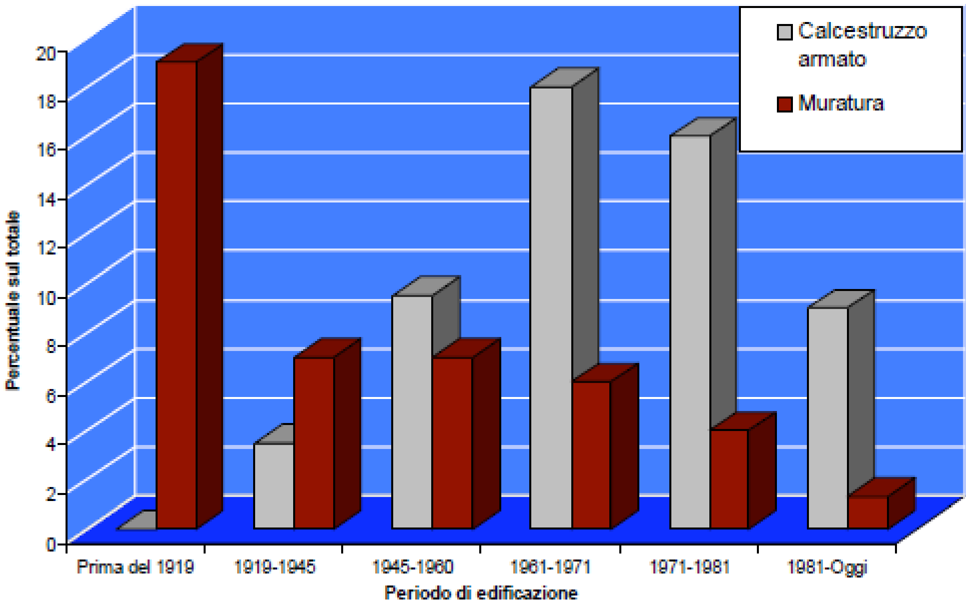
- 40% of the existing residential buildings built before 1945 and 25% of them built before 1919
    - 27% before 1919,
    - 14% 1919-1945,
    - 15% 1945-1960,

- 18% 1961-1971,
- 17% 1971-1981,
- 9% after 1981

- From 1981 aseismic design is introduced
- RC and masonry building distribution is available by construction year from the census 1991




Edificato (dati censimento ISTAT 1991)




**(1)Data Sources:**

1. ISTAT: Database for Italian Census at National Scale- http://dawinci.istat.it/MD/index.html **(available)**
   Data aggregated for census section at national scale, disaggregated for information type at regional scale and for census section (which are not commonly disseminated)

   *On building inventory:*

   - General information on buildings
     - Vertical/horizontal structure
     - Material
     - Age
     - Conditions
     - No. of storey

2. PLINIVS: Study Centre for Hydrogeological, Volcanic and Seismic Engineering, University of Naples "Federico II"- http://www.lupt.unina.it/centro_studi_plinius.html **(not available)**

Post seismic damage database:

- About 170.000 building, in about 500 towns
- Typological characteristics:
  - Building location,
  - Geometrical data,
  - Use of building,
  - Construction and interventions age
  - Finishes and system conditions
  - Structural characteristics/typology:
    - Vertical structure: masonry type, RC, mixed structure.
    - Horizontal structure: vault, timber floor, steel floor, RC floor.
    - Roof: timber and tiles, RC, other.
    - Age of building
- Damage description:
  - Damage size to structural and non-structural elements (vertical and horizontal structure, roofs, outer and inner walls, stairs) and made emergency measures
  - Induced hazard
  - Soil and foundation
  - Safe judgement

Vulnerability database:

- About 95.000 buildings, in about 250 towns
- Typological characteristics
  - Building location
  - Number of floors
  - Max. height
  - Plaster (efficient, not efficient, absent)
  - Age of the building
  - Structural typology (masonry, RC, mixed)
  - Vertical structure
  - Mortar type
  - Condition of the mortar (high, medium and poor resistance)
  - Roof typology, structure
  - Horizontal & vertical structure connections
  - Non-structural elements
  - Condition of the building

A comparative analysis between ISTAT database and survey data is conducted to prepare vulnerability and risk maps at national scale.

**(2) Special Studies:**

Seismic Vulnerability Assessment of Dwelling Buildings in Italy: The case study of Basilicata region

- Potenza Town (9000 buildings, 70.000 habitants):
  - Typological data for masonry and reinforced concrete buildings
  - GIS is available (census tracts)
  - Building stock of Potenza is representative for whole Italy

- Val D'Agri Area (18.000 buildings, 40.000 habitants):
  - In 2001-2002, typological data for masonry (detailed) and RC (very poor)

- In 2005-2006, typological data for masonry (detailed) and RC (detailed)
- GIS is available (building-by-building location)

## 6. MACEDONIA- PROF.DR. VERONIKA SHENDOVA, INSTITUTE OF EE AND ES:

**Provided Information:**

*On building inventory:*

- National building census is not carried out but dwellings information exists with:
  - Period of construction
  - Floor area etc.
- Categorization according to the main structural system:
  - Non-earthquake resistant masonry buildings (MB):
    - Unreinforced, plain masonry dominant in urban and rural areas up to 1964.
      - Masonry unit (stone, adobe, typical bond ruck, brick)
      - Type of mortar (adobe mud, lime, lime and cement, cement mortar)
      - Building height (dominantly 1-2 stories, rare 3-5 stories)
      - Floor structure (wooden floors (dominantly), RC stories)
      - Roof structure (dominantly wooden)
      - Roofing (heavy clay, stone tiles)
      - Foundation (dominantly stone)
      - Construction quality (poor, average)
  - Moderate earthquake resistant confined masonry buildings (SBM):
    - Plain masonry structure strengthened by vertical and horizontal RC belts in both orthogonal directions:
      - Vertical and horizontal RC belts in both orthogonal directions
      - Jacketing of the bearing walls
      - Replacing wooden floor w/ RC slab on RC beam
      - Strengthening of foundation
  - Earthquake resistant RC buildings (RC):
    - Low, mid, high-rise RC well designed and constructed, dominant after 1965 for mid and high-rise public and residential buildings in urban areas, extensive after 1970.
      - RC moment resisting frames
      - Combined RC frames with shear walls
      - RC shear wall structures in both orthogonal directions
      - Flat floor structures

- Categorization according to the year of construction:
  - Buildings constructed before 1960 (MB):
    - Low quality fired brick combined stone masonry of the foundation and ground floor level with dominantly wooden floor and roof structures, 1-2 stories
    - Good quality brick masonry with RC belt courses and floor structures, up to 2 stories.
  - Buildings constructed in the period 1960-1971 (CMB):
    - Dominantly moderate earthquake-resistant confined brick masonry buildings with RC monolithic or

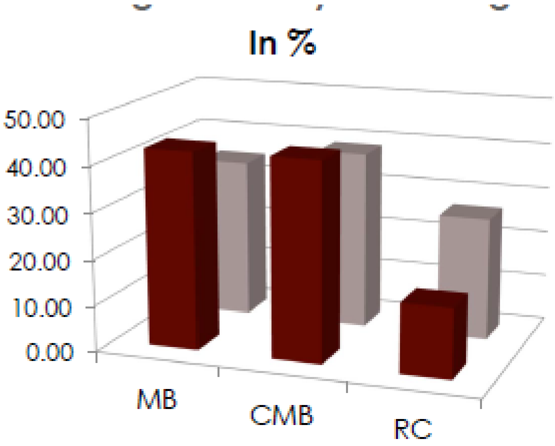
prefabricated floor structures or RC frame buildings, 1-3 stories

- Buildings constructed after 1971 (RC):
    - Dominantly well designed and constructed earthquake resistant RC frame/RC shear wall structures, hallow blocks infill walls, monolithic or prefabricated floor structure, 3 and more stories

| Total population | No. of households | Housing area | Total units | Total % |
|---|---|---|---|---|
| **According to detailed data form 1991 census** | | | | |
| 2 033 964 | 505 852 | Dwellings (No) | 586 231 | 100 |
| | | urban<br>rural | 336 842<br>249 389 | 57.46<br>42.54 |
| 19.8m²/inh | 4.02 inh/hh | Floor area (m²) | 40 275 730 | 100 |
| | | urban<br>rural | 23 564 283<br>16 711 447 | 58.50<br>41.50 |
| **According to available summary data form 2002 census** | | | | |
| 2 022 547 | 564 296 | Dwellings (No) | (+111 912)<br>698 143 | |
| 24m²/inh | 3.58 inh/hh | Floor area (m²) | (+9 395 979)<br>49 671 709 | |

| Structural type | Total Floor area m² | Total % of total | Urban Floor area m² | Urban % of total | Rural Floor area m² | Rural % of total |
|---|---|---|---|---|---|---|
| **According to detailed data form 1991 census** | | | | | | |
| **MB**<br>Non-earthquake resistant up to 1970 | 17256163 | 42.8 | 9100670 | 22.6 | 8155493 | 20.2 |
| •Low strength masonry (adobe and bondruck) | 4826257 | 11.9 | 1694115 | 4.2 | 3132142 | 7.7 |
| •Stone and brick masonry | 12429906 | 30.9 | 7406555 | 18.4 | 5023351 | 12.5 |
| earthquake resistant after 1970 | 23019567 | 57.2 | 14463613 | 35.9 | 8555954 | 21.3 |
| **SBM**<br>•Confined or strengthened masonry | 17333164 | 43.1 | 9182833 | 22.8 | 8150331 | 20.3 |
| **RC**<br>•RC frames | 3589647 | 8.9 | 3184024 | 7.9 | 405623 | 1.0 |
| •RC shear walls | 2096756 | 5.2 | 2096756 | 5.2 | - | - |
| TOTAL - 1991 | 40.275730 | 100 | 23564283 | 58.5 | 16711447 | 41.5 |

| | | |
|---|---|---|
| **According to detailed data form 1991 census** | | |
| **TOTAL - 1991** | 40.275730 | 100% |
| **According to summary data form 2002 census** | | |
| earthquake resistant structures after 1991 | 9395979 | 100% |
| •SBM<br>•RC | 1879196<br>7516783 | 20*<br>80*<br>*assumed |
| **Estimated total in 2002** | | |
| Non-earthquake resistant up to 1970<br>•MB | 17.256163 | 34.7% |
| Earthquake resistant after 1970 | 32.415546 | 65.3% |
| •SBM | 19 212 360 | 38.7% |
| •RC | 13 203 186 | 26.6% |
| **TOTAL - 2002** | 49.671709 | 100% |




| | MB | CMB | RC |
|---|---|---|---|
| up tp 1991 | 42.80 | 43.10 | 15.10 |
| up to 2002 | 34.70 | 38.70 | 26.60 |

**(1)Data Sources:**

1. Statistical Yearbook of RM for 2010, Census of Population, Households and Dwelling in 2002: State Statistical Office**-** http://www.stat.gov.mk/Default_en.aspx
2. Public Buildings:
   **a.** Schools- Census of Space in the Elementary and High Schools in RM in 1990, Republic Bureau of Statistics of RM: http://www.stat.gov.mk/Default_en.aspx
   **b.** Hotels and other tourist facilities- Data for Hotels and Restaurants Management, Statistical Review, Ministry of Economy: http://www.economy.gov.mk/Home?lang=2
   **c.** Hospitals and other medical facilities- Data for Hospitals and Clinics, Statistical Review, Ministry of Health: http://moh.gov.mk/eng/
3. IZIIS reports on post-earthquake activities in RM

**School buildings:**

| region | Total area m² | Period of construction | | | | | |
|---|---|---|---|---|---|---|---|
| | | Before 1960 | | 1960-1971 | | After 1971 | |
| | | m² | % | m² | % | m² | % |
| Skopje | 108458 | 23110 | 21.3 | 57988 | 53.5 | 27360 | 25.2 |
| Rest of RM | 290340 | 179028 | 61.7 | 66913 | 23.0 | 44399 | 15.3 |
| Total | 398798 | 202138 | 50.7 | 124901 | 31.3 | 71759 | 18.0 |

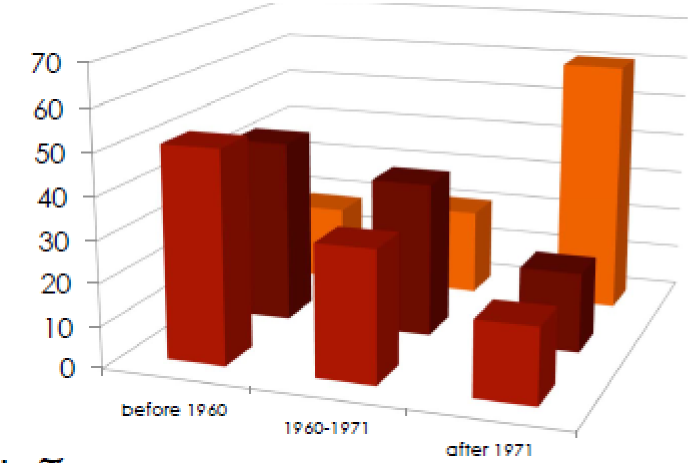
**HOTELS AND MOTELS**

| region | Total area | | Period of construction | | |
|---|---|---|---|---|---|
| | | | Before 1960 | 1960-1971 | After 1971 |
| | m² | % | m² | m² | m² |
| Skopje | 60375 | 15.1 | 26565 | 22339 | 11471 |
| Ohrid lake | 163905 | 41.1 | 72118 | 60645 | 31142 |
| Dojran lake | 28420 | 7.1 | 12505 | 10515 | 5400 |
| Tetovo | 29435 | 7.3 | 12951 | 10891 | 5593 |
| Rest of RM | 116968 | 29.4 | 51468 | 43277 | 22223 |
| Total | 399100 | 100 | 175604 | 147667 | 75829 |

### CHILDREN AND WORKERS RESORT BUILDINGS

| region | Total area | | Period of construction | | |
|---|---|---|---|---|---|
| | | | Before 1960 | 1960-1971 | After 1971 |
| | m² | % | m² | m² | m² |
| Skopje | 34130 | 5.6 | 15017 | 12628 | 6485 |
| Ohrid lake | 241540 | 39.5 | 107598 | 904080 | 46462 |
| Dojran lake | 51480 | 8.4 | 22651 | 19048 | 9781 |
| Prespa lake | 162930 | 26.7 | 71689 | 60284 | 30957 |
| Berovo | 34395 | 5.6 | 15134 | 12726 | 6535 |
| Rest of RM | 86570 | 14.2 | 38089 | 32026 | 16450 |
| Total | 611045 | 100 | 268868 | 226076 | 116101 |
| ALL TOURIST FACILITIES | | | | | |
| TOTAL tourist facilities | 1 010145 | 100 | 444 472 (44%) | 373 743 (37%) | 191930 (19%) |

| region | Total area m² | Period of construction | | | | | |
|---|---|---|---|---|---|---|---|
| | | Before 1960 | | 1960-1971 | | After 1971 | |
| | | m² | % | m² | % | m² | % |
| Hospitals& clinics | 453642 | 75210 | 16.5 | 106157 | 23.4 | 272275 | 60.1 |
| Medical centers | 190037 | 47232 | 24.8 | 36322 | 19.1 | 106483 | 56.1 |
| Medical units | 97409 | 13646 | 14.0 | 13901 | 14.3 | 69862 | 71.7 |
| ALL MEDICAL BUILDINGS | | | | | | | |
| TOTAL | 739088 | 136088 | 18.4 | 154380 | 20.9 | 448620 | 60.7 |




In %

| | before 1960 | 1960-1971 | after 1971 |
|---|---|---|---|
| SCHOOL | 50.7 | 31.3 | 18 |
| TOURISM | 44 | 37 | 19 |
| MEDICAL | 18.4 | 20.9 | 60.7 |

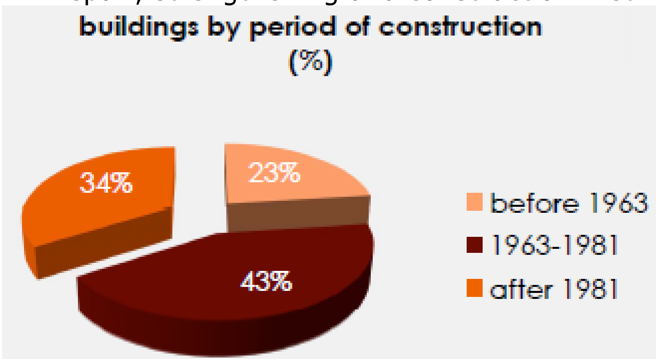
**(2)Special Studies:**

1. Skopje Earthquake, 1963
   - Building inventory for 40.000
     - Old adobe structures w/ and w/o timber bracing,
     - Load bearing brick wall structures in combination with the central RC columns supporting the woos or RC floors,
     - RC skeleton buildings w/ and w/o concrete shear walls.
   - Damage profile:
     - Brick wall structures- the most damaged
     - Mixed construction- considerably damaged
     - Old adobe structures (timber bracing)- some damage

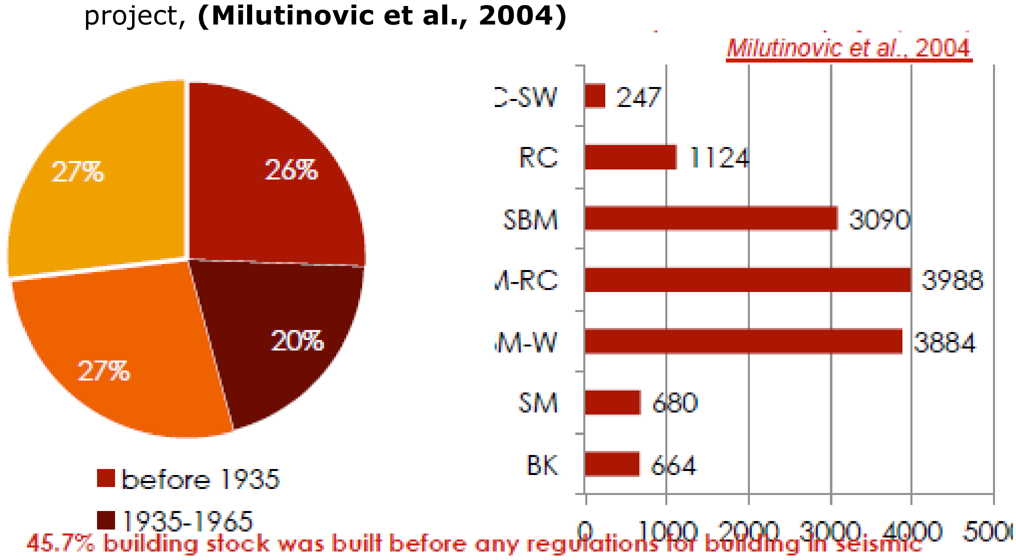
- RC skeleton- slightly damaged

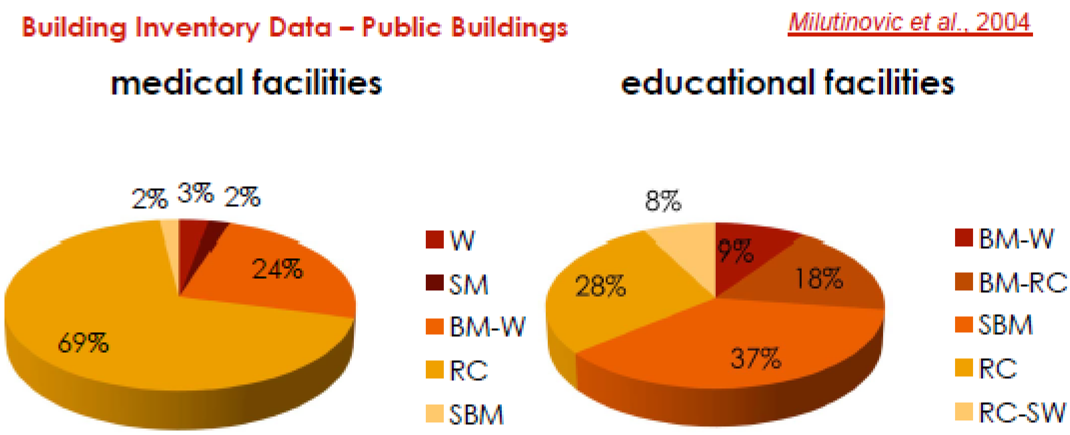
| Damage degree | Residential buildings | Other buildings | Housing area | Percent of population |
|---|---|---|---|---|
| Destroyed | 11.3 | 9.2 | 7.0 | 8.5 |
| Heavily damaged | 44.1 | 33.0 | 29.9 | 36.4 |
| Damaged | 22.0 | 32.9 | 39.9 | 30.6 |
| Slightly damaged | 16.5 | 20.1 | 19.8 | 20.3 |
| Undamaged | 6.1 | 4.8 | 3.4 | 4.2 |

- Repair, strengthening and construction method is provided.




2. Bitola Earthquake, 1994- Synthesis Report for Bitola, European RISK_UE project, **(Milutinovic et al., 2004)**



## 7. NORWAY- DOMINIK H. LANG, NORSAR:

**Provided Information:**

*On building inventory:*

- Country wide building statistics(2008); Total # of buildings and housing units by type

**(1)Data Sources**:

1. Statistics Norway- www.ssb.no/fob

**(2)Special Studies:**

Oslo building by building database, 2001:

- 87.499 individual buildings distributed over 27 geounits
- Information on the type and use of building:
  - Year of construction (not complete)
  - Type of building (single family house, residential etc.)
  - Foundation type
  - Vertical carrying construction
  - Horizontal carrying construction
  - Building materials
  - Total area of each building
  - Number of storeys
  - Base area of the building
- Building typologies:
  - Rural areas: Light timber frames, timber frame row house, timber log house, precast RC shear wall structure
  - Urban areas: Historical areas show highly vulnerable typologies; last percentage of URM buildings, story range 3-6and wooden flooring system

| Description | Height range | *N* | HAZUS MBT |
|---|---|---|---|
| Wood light frame | Low-rise | 1–2 | W1 |
| Wood framed by beams | Low-rise | 2 (>2) | W2 |
| Steel moment frame | Low-rise | 1–3 | S1L |
| | Mid-rise | 4–7 | S1M |
| Steel braced frame | Low-rise | 1–3 | S2L |
| | Mid-rise | 4–7 | S2M |
| Steel light frame | Low-rise | 1–3 | S3 |
| Steel frame with concrete shear walls | Mid-rise | 4–7 | S4M |
| Steel frame with unreinforced masonry infill walls | Low-rise | 1–3 | S5L |
| | Mid-rise | 4–7 | S5M |
| Concrete moment frame | Mid-rise | 4–7 | C1M |
| Concrete shear walls | Mid-rise | 4–7 | C2M |
| Concrete frame with unreinforced masonry infill walls | Mid-rise | 4–7 | C3M |
| Unreinforced masonry bearing walls | Low-rise | 1–2 | URML |
| | Mid-rise | 3–4 | URMM |

| | District | Wood (W) | Steel (S) | Concrete (C) | Masonry (URM) | None |
|---|---|---|---|---|---|---|
| 1 | Bygdøy, Frogner | 9.45 | 0 | 71.18 | 11.27 | 8.1 |
| 2 | Uranienborg/Majorstuen | 1.45 | 2.35 | 74.32 | 11.49 | 10.38 |
| 3 | St. Hanshaugen/Ullevål | 6.02 | 7.06 | 58.21 | 16.45 | 12.26 |
| 5 | Grünerløkka/Sofienberg | 3.75 | 1.63 | 59.34 | 17.78 | 17.49 |
| 7 | Ekeberg, Bekkelaget | 55.12 | 1.24 | 22.94 | 7.73 | 12.96 |
| 8 | Nordstrand | 59.76 | 0.52 | 21.5 | 10.81 | 7.4 |
| 9 | Søndre Nordstrand | 55.56 | 4.78 | 26.65 | 6.58 | 6.44 |
| 10 | Lamberseter | 14.44 | 0.03 | 54.55 | 25.17 | 5.82 |
| 12 | Manglerud | 35.59 | 0.9 | 38.85 | 2.73 | 21.94 |
| 14 | Helsfyr, Sinsen | 8.26 | 10.63 | 56.46 | 4.45 | 20.19 |
| 15 | Hellerud | 29.93 | 5.29 | 37.54 | 8.11 | 19.12 |
| 10 | Furuset | 21.92 | 5.67 | 54.58 | 3.22 | 14.6 |
| 12 | Romsås | 4.35 | 0.37 | 66.87 | 0.06 | 28.35 |
| 20 | Bjerke | 22.21 | 2.51 | 48.48 | 6.81 | 19.99 |
| 21 | Grefsen, Kjelsås | 43.81 | 4.85 | 26.47 | 7.98 | 16.89 |
| 22 | Sogn | 48.41 | 0.8 | 30.07 | 4.94 | 15.79 |
| 24 | Røa | 38.79 | 0.11 | 48.27 | 5.27 | 7.57 |
| 25 | Ullern | 27.61 | 11.14 | 39.99 | 10.56 | 10.71 |
| 26 | Sentrum | 1.78 | 10.53 | 67.88 | 7.18 | 12.63 |
| 27 | Marka | 45.43 | 0.15 | 0 | 0 | 54.42 |
| Total | ALL DISTRICTS | 21.4 | 4.5 | 51.1 | 9.5 | 13.5 |

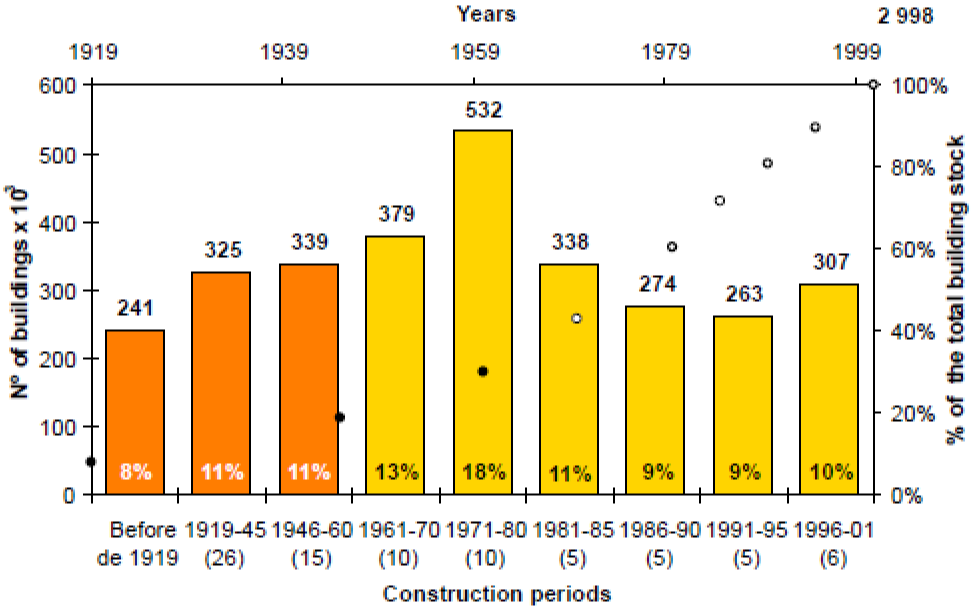
| | District | Wood (W) | Steel (S) | Concrete (C) | Masonry (URM) | None |
|---|---|---|---|---|---|---|
| HI-U | Bygdøy, Frogner | 9.45 | 0 | 71.18 | 11.27 | 8.1 |
| | Uranienborg/Majorstuen | 1.45 | 2.35 | 74.32 | 11.49 | 10.38 |
| MI-U | St. Hanshaugen/Ullevål | 6.02 | 7.06 | 58.21 | 16.45 | 12.26 |
| | Grünerløkka/Sofienberg | 3.75 | 1.63 | 59.34 | 17.78 | 17.49 |
| HI-R | Ekeberg, Bekkelaget | 55.12 | 1.24 | 22.94 | 7.73 | 12.96 |
| | Nordstrand | 59.76 | 0.52 | 21.5 | 10.81 | 7.4 |
| | Søndre Nordstrand | 55.56 | 4.78 | 26.65 | 6.58 | 6.44 |
| MI-U | Lamberseter | 14.44 | 0.03 | 54.55 | 25.17 | 5.82 |
| LI-U | Manglerud | 35.59 | 0.9 | 38.85 | 2.73 | 21.94 |
| | Helsfyr, Sinsen | 8.26 | 10.63 | 56.46 | 4.45 | 20.19 |
| LI-U | Hellerud | 29.93 | 5.29 | 37.54 | 8.11 | 19.12 |
| | Furuset | 21.92 | 5.67 | 54.58 | 3.22 | 14.6 |
| | Romsås | 4.35 | 0.37 | 66.87 | 0.06 | 28.35 |
| | Bjerke | 22.21 | 2.51 | 48.48 | 6.81 | 19.99 |
| MI-R | Grefsen, Kjelsås | 43.81 | 4.85 | 26.47 | 7.98 | 16.89 |
| | Sogn | 48.41 | 0.8 | 30.07 | 4.94 | 15.79 |
| | Røa | 38.79 | 0.11 | 48.27 | 5.27 | 7.57 |
| | Ullern | 27.61 | 11.14 | 39.99 | 10.56 | 10.71 |
| | Sentrum | 1.78 | 10.53 | 67.88 | 7.18 | 12.63 |
| All-R | Marka | 45.43 | 0.15 | 0 | 0 | 54.42 |
| Total | ALL DISTRICTS | 21.4 | 4.5 | 51.1 | 9.5 | 13.5 |

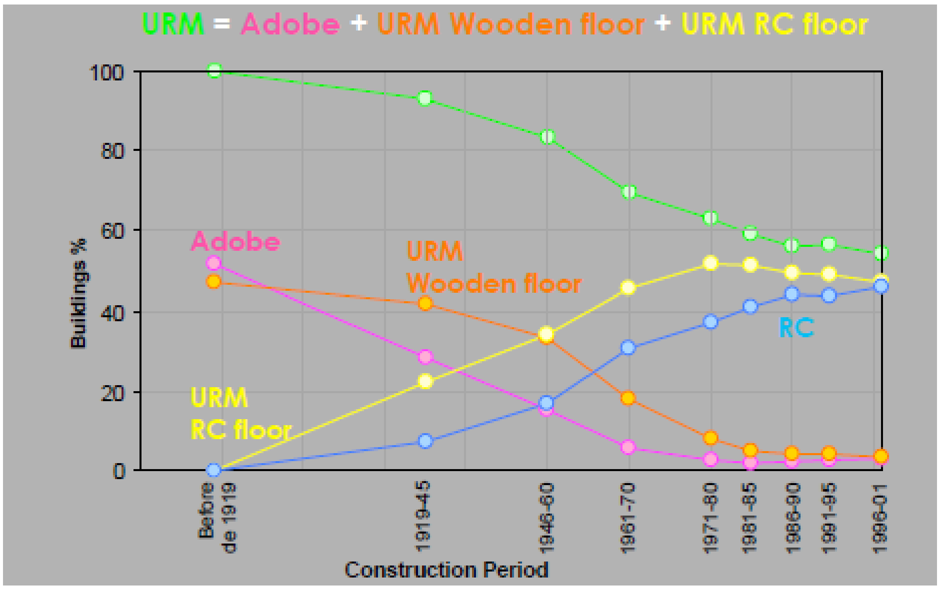
## 8. PORTUGAL- ALFREDO CAMPOS COSTA, MARIA LUISA SOUSA, LNEC:

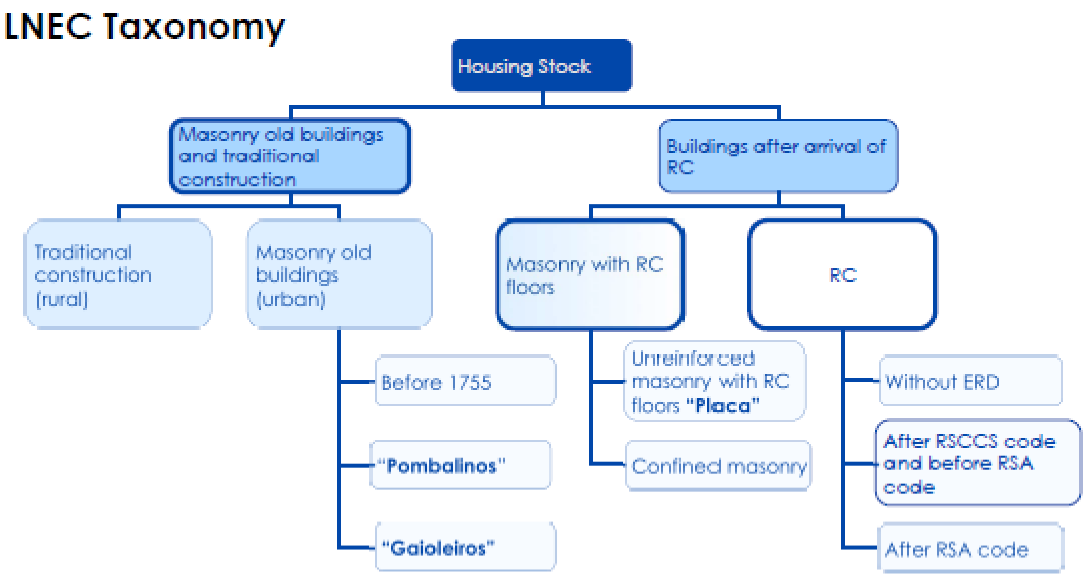
**Provided Information:**

*On building inventory:*

- Portuguese building census at every 10 year since 1970.
- Since 2001, LNEC (National Laboratory for Civil Engineering) intervention with specific question to survey building regarding seismic vulnerability and building conservation status.
- Data is disaggregated at Parish level (from 1 to 10 statistical sections) but only LNEC has access.
- IV Housing Census, 2001:
  - Number of floors (1 or more)
  - Ground floor configuration (with the same configuration of the above floors, with an open space configuration, with isolated regularly distributed columns)
  - Whether the building is isolated or higher than adjacent buildings (yes or no)
  - Whether it is a corner building or the first or the last unit of an aggregate row of the buildings (tenement) (yes or no)
  - Whether the building higher (more than 2 floors) of adjacent building (yes/no)
  - Construction period
  - Building structural types (RC frame, wall or frame- wall, unreinforced stone or brick masonry walls structure etc.)
  - Need for retrofitting (in the structure, roof, the façade or other exterior walls)
- LNEC Taxonomy from census classes to vulnerability typologies


Years
1919
1939
1959
1979
1999
2 998
Nº of buildings x 10³
% of the total building stock
241
325
339
379
532
338
274
263
307
8%
11%
11%
13%
18%
11%
9%
9%
10%
Before de 1919
1919-45 (26)
1946-60 (15)
1961-70 (10)
1971-80 (10)
1981-85 (5)
1986-90 (5)
1991-95 (5)
1996-01 (6)
Construction periods


URM = Adobe + URM Wooden floor + URM RC floor
Buildings %
Adobe
URM
Wooden floor
RC
URM
RC floor
Before de 1919
1919-45
1946-60
1961-70
1971-80
1981-85
1986-90
1991-95
1996-01
Construction Period


LNEC Taxonomy
Housing Stock
Masonry old buildings and traditional construction
Buildings after arrival of RC
Traditional construction (rural)
Masonry old buildings (urban)
Masonry with RC floors
RC
Before 1755
"Pombalinos"
"Gaioleiros"
Unreinforced masonry with RC floors "Placa"
Confined masonry
Without ERD
After RSCCS code and before RSA code
After RSA code

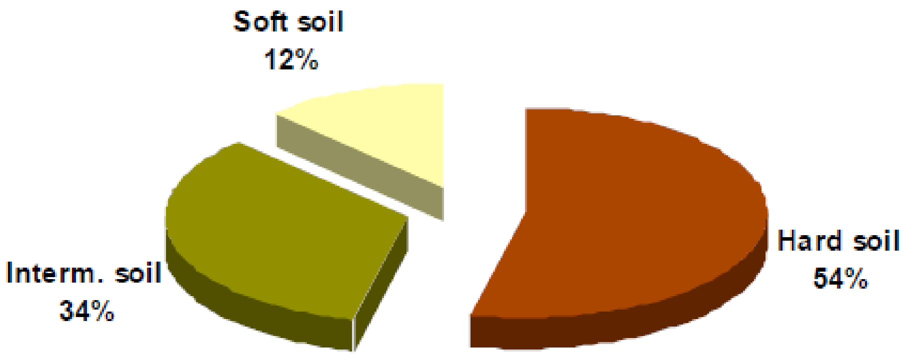
**(1)Special Studies:**

Probabilistic risk analysis case study of metropolitan area of Lisbon, MAL:

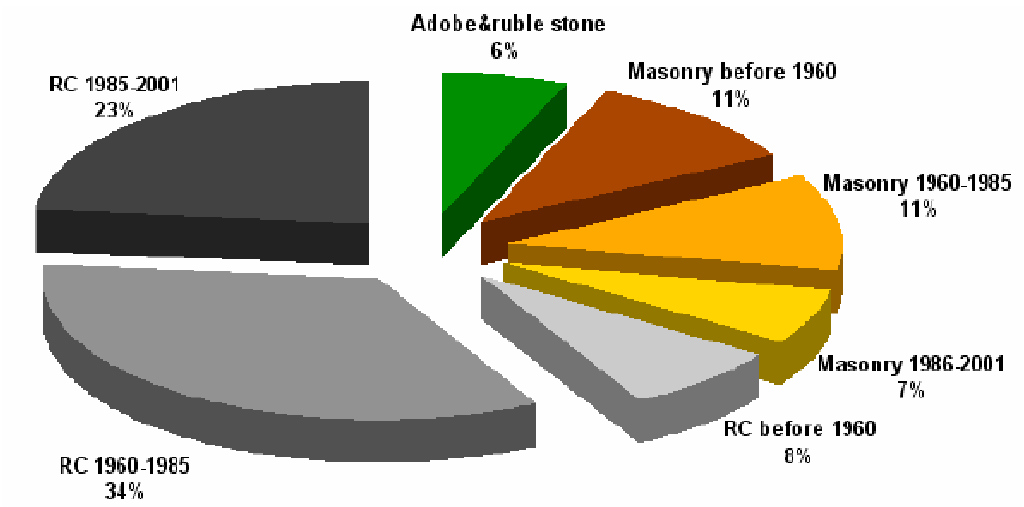
- Global statistics, 2001

| *Global Statistics 2001* | |
|---|---|
| Parishes | 277 (7%) |
| Geotechnical profiles | 37 |
| Number of smallest geographic divisions: parishes+ geotechnical profiles | 405 |
| Building classes | 49 |
| Residential buildings | 477 170 (16%) |
| Dwellings | 1 389 236 (29%) |
| Population | 2 841 067 (29%) |
| 2001 GDP | ≅ $55 \times 10^6$ € (≅ 47%) |

- Vulnerability and inventory definition;
  - Soil classification: 37 soil profiles




  - Exposure analysis




Other building surveys-Lisbon:

- The survey of Alameda-Anjos, 1983
- LNEC survey, 1989 and 1992
- In Algarve the cities of Faro and Lagos
- In Azores the city of Angra Heroismo in Terceira Island.

## 9. ROMANIA- D.LUNGU, R. VACARENAU, C.ARION, A.ALDEA, TECHNICAL UNIVERSITY OF CIVIL ENGINNERING:

**Provided Information:**

*On building inventory:*

- Classification of Bucharest buildings with the years of construction (1992&2002 Census data)

| No. of storeys | Number of buildings | Years of construction | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|
| | | until 1900 | 1901-1929 | 1930-1945 | 1946-1963 | 1963-1970 | 1970-1977 | 1978-1990 | 1990-2002 |
| | | - | - | P.I. - 1941 | I. - 1945 | P13 - 63 | P13 - 70 | P100 - 81 | P100 - 92 |
| GF&GF+1 | 98979 | 5562 | 16205 | 27275 | 30524 | 8413 | 4391 | 2893 | 3495 |
| GF+2÷GF+6 | 8178 | 315 | 1255 | 2146 | 979 | 804 | 782 | 1214 | 664 |
| >GF+7 | 6719 | 41 | 95 | 164 | 378 | 645 | 1072 | 2854 | 1436 |
| Total | 113876 | 5918 | 17555 | 29585 | 31881 | 9862 | 6245 | 6961 | 5595 |

- Distribution of Bucharest buildings with the type of the structure and the years in which seismic design practice in Romania changed (1992 Census)

| Buildings | | Approximate Bucharest population living in: | | | |
|---|---|---|---|---|---|
| Type of structure | Approximate number | Pre-code bldgs. Pre 1945 & Pre 1963 | Low code bldgs. 1963-1977 | Moderate code bldgs. 1977-1992 | All the buildings |
| High & Mid rise RC struct | 9000 | 5% | 27% | 37% | 69% 1.38 million persons |
| Low-rise Masonry structures | 94000 | 16% | 5% | 2% | 23% 460,000 persons |
| Others (GF bldgs) | 41000 | 6% | 2% | - | 8% 160,000 persons |
| Total | 114000 | 27% 540,000 persons | 34% 680,000 persons | 39% 780,000 persons | 100% 2 millions persons |

- During 1990-2011, 2644 buildings in Bucharest (22213 housing units, for 69269 persons) with total area of 2.540.641m$^2$ were investigated for the seismic safety requirements of the building code of Romania:
    - 1.5% of them strengthened
    - 24% of them represent seismic risk classes 1 and 2
- In 2011, in 8 million housing units, only 5.9% (497.000) were insured according to the existing legalization; 76% of them are urban and 24% of them are rural housing unit.

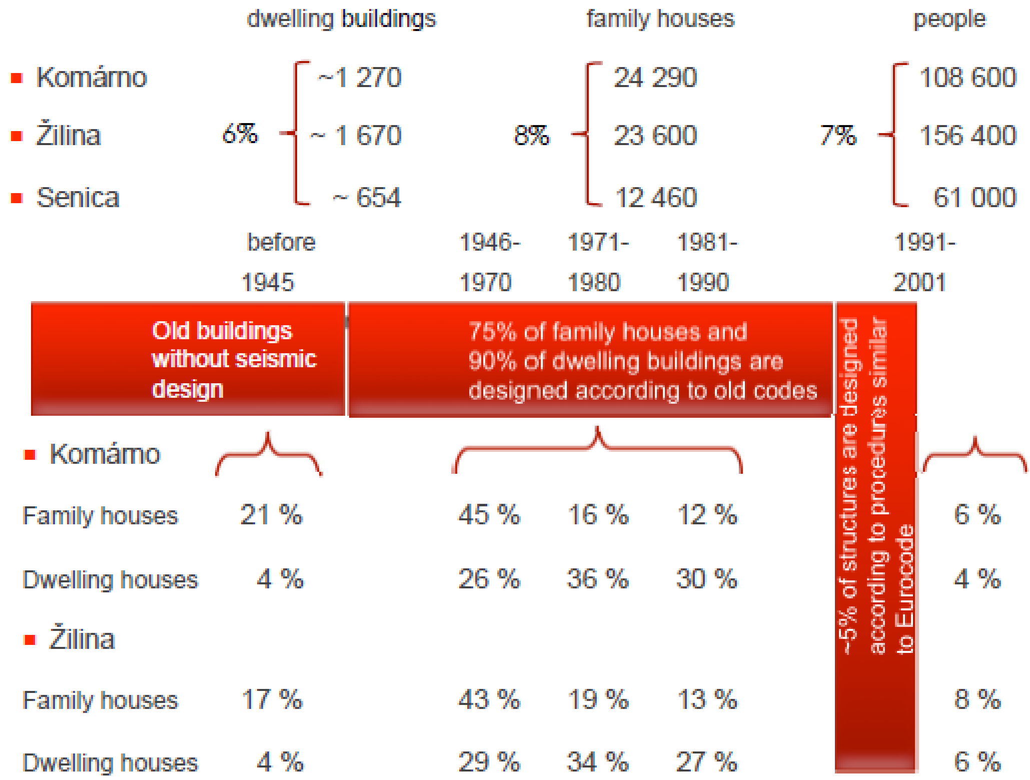
## 10. SLOVAKIA MILAN SOKOL, SLOVAK UNIVERSITY OF TECHNOLOGY:

**Provided Information:**

*On building inventory:*

- no special building census is carried out in national level

- general census held in every 10 years collects some structural data such as number of stories, structural material
- number of houses in most seismic vulnerable regions




- common building typologies in Slovakia:
  - For many decades dwelling houses were constructed using precast panel structures
  - Dwelling houses before 1990: precast panel structures, 4 to 13 stories, pure? quality, architectonic boring, designed according to old Slovak national standards
  - Dwelling houses after 1990: RC structures, cast-in-place concrete, frame structure with masonry infill, up to 24 stories, better quality, new interesting architectural design, designed according to Slovak national standards and also Eurocodes
  - Family houses before 1990: solid masonry structures, timber deck, quality of construction is questionable
  - Family houses after 1990: air- brick masonry, RC deck or ceramic deck, better quality of construction
  - 

<u>*Other data:*</u>

- Structural deficiencies are presented with seismic effect parametric study

**(1)Data Sources:**

1. 'Retrofitting of Precast Buildings I. large scale dwelling house construction up to year 1970', Jaga Group 2001, ISBN 80-88905-53-2,294, Sternova Z. et al. (in Slovak)
2. 'Retrofitting of Precast Buildings II. large scale dwelling house construction up to year 1970', Jaga Group 2001, ISBN 80-88905-68-0,237, Sternova Z. et al. (in Slovak)

Buildings information is included such as:

- Construction technology
- Structural systems (not much info)

- Energy consumption building characteristics
- Structural deficiencies
- Examples of retrofitting
- Different structural system in particular regions
- Construction period and number of houses with different structural system for almost every city

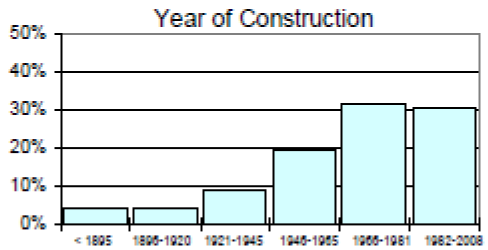
3. 'Mounted Building Systems', ALFA, Bratislava, 1981, 232 pp,, Kianichova, M (in Slovak)
    - Source for building structural system
    - Precast panel buildings with details of dimensions, structural details, construction technology etc.

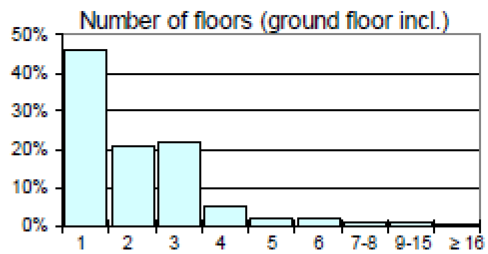
## 11. SLOVENIA MARJANA LUTMAN, SLOVENIAN NATIONAL BUILDING AND CIVIL ENGINEERING INSTITUTE, ZAG:

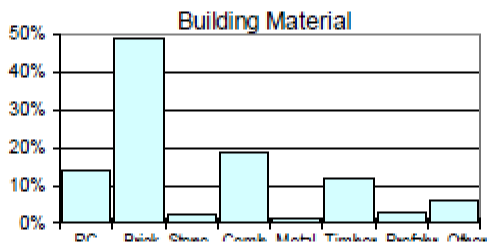
**Provided Information:**

*On building inventory:*

- Data available in the National Register of Buildings:
    - Building material ( stone masonry, brick masonry, concrete and RC, combination of materials, other)
    - Number of floors (1.2…)
    - Period of construction (before 1895,…, 1982-2005)
    - 




**(1)Special studies:**

Analysis of buildings in Municipality of Ljubljana (MOL**)**

- Seismic vulnerability and seismic resistance assessment methodologies developed at ZAG
    - Seismic vulnerability of masonry buildings RAN-Z (1995) w/ parameters: amount of walls, masonry type, confinement, distribution of walls in layout, height of building.
    - Seismic resistance of masonry buildings PO-ZID (2001); based on data and results of analytic push-over method
- Seismic vulnerability map of MOL is prepared for masonry buildings w/ up to 4-storeys but not for masonry building w/ more than 4-storeys and RC buildings
- Seismic vulnerability maps for other regions of Slovenia according to
    - Typology of buildings,
    - Classes of seismic vulnerability
    - Seismic vulnerability assessment

- Seismic vulnerability of masonry buildings in MOL:

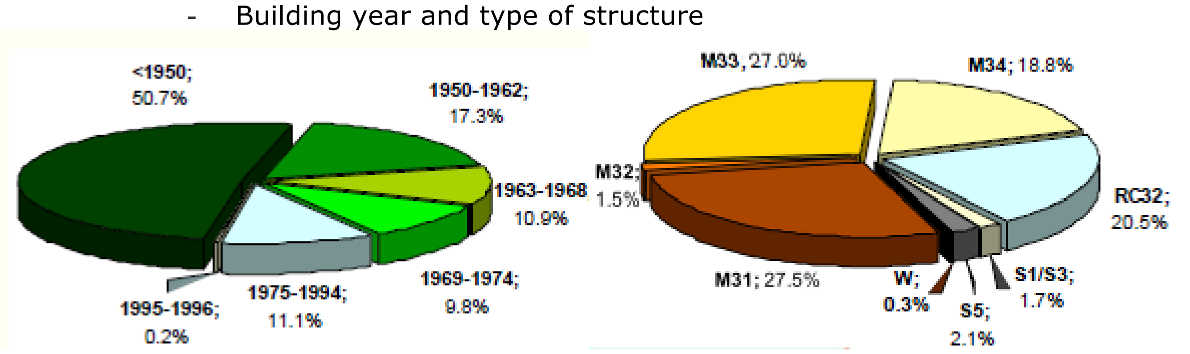
| | Buildings | | | Inhabitants |
|---|---|---|---|---|
| Vulnerability | Stone masonry | Brick masonry | Total | |
| red I | 0.5 % | | < 0.1 % | 0.1 % |
| yellow III | 45 % | 3 % | 4 % | 13 % |
| yellow II | 55 % | 39 % | 40 % | 40 % |
| yellow I | | 10 % | 9 % | 14 % |
| green III | | 28 % | 27% | 18 % |
| green II | | 20 % | 20 % | 15 % |
| Total | 100 % | 100 % | 100 % | 100 % |

## 12. SPAIN ALEX H. BARBAT, UNIVERSIDAD POLITECNICA DE CATALUNA, BARCELONA:

**Provided Information:**

*On building inventory:*

- 69982 parcels w/ information on structural typology and building age (98%) (From cadastre)
- Building year and type of structure




- Type of floors
- State of preservation

**(1)Data sources:**

1. Direccion General del Catastro
   - 5317 blocks, 71298 built parcels, 58481 residential buildings (≥1 inhabitant), 577904 dwellings
2. Department of Civil Protection, City Council of Barcelona
3. Instituto Municipal de Informatica (IMI), Barcelona
4. Statistics Department, City Council of Barcelona
5. Sistema de Informacion Territorial de Barcelona(SITEB), City Council of Barcelona
6. Instituto Nacional de Estadistica (INE), Madrid

**(2)Special studies:**

CAPRA: Comprehensive Approach for Probabilistic Risk Assessment

- Vulnerability curves for Barcelona

- Average annual loss for Barcelona

## 13. SWITZERLAND, ALESSANDRO DAZIO:

**Provided Information:**

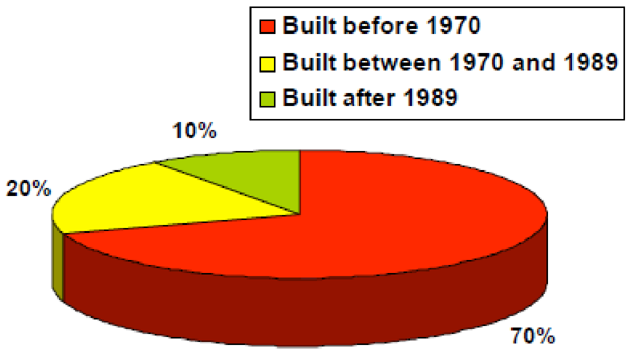
*On building inventory:*

- Currently 1.7 millions of buildings and 3.8 millions of housing, 17.000 of new buildings and 38.000 of new housing added every year
- Updated quarterly with building development
- Information included in the National Building and Housing Census:

| Characteristics | Category of building | | | | |
|---|---|---|---|---|---|
| | Temporary building | Residential building | Other building w resid. use | Other building w/o resid. use | Special building |
| Identification number | A | A | A | A | A |
| Municipality | A | A | A | A | A |
| Geographical coord. | A | A | A | A | A |
| Building status | A | A | A | A | A |
| Building category | B | B | B | B | B |
| Building class (EUROSTAT classification) | - | X | C | C | C |
| Year of construction | - | C | C | C | C |
| Construction period (5y) | - | B | B | B | B |
| Renovation year | - | C | C | C | C |
| Renovation period (5y) | - | C | C | C | C |
| Year of demolition | - | B | B | C | C |
| Building surface (base) | - | C | C | C | C |
| Number of storeys | - | B | B | C | - |
| No. of living quarters | - | C | C | - | - |
| Number of habitations | - | X | X | - | - |
| ... | | | | | |

**Legend: A=Always present, B=Mandatory, C=facultative, X=Computed automatically**

- Age of Swiss building stock




*Other data:*

- 90% of the building stock has an unknown seismic safety
- Key deficiencies of older masonry buildings:
    - Rubble masonry
    - Flexible floors
    - Local failure mechanisms
    - Insufficient in-plane strength

- Key deficiencies of newer masonry buildings
  - Thin bricks, slender walls, out-of-plane failures
  - Insufficient in-plane strength
  - Significant monetary damage expected at low level of shaking
- Key deficiencies of RC buildings
  - Soft storey
  - Short columns
  - Shear strength (RC wall buildings)
- Key deficiencies of precast structures
  - Connections
- Key deficiencies of bridges
  - Seating length
  - Shear strength of squat piers

**(1)Data sources:**

1. Swiss federal Statistical Office- www.housing-stat.admin.ch
2. Cantons and municipalities have their own databases w/ more detailed information
3. FEDRO KUBA database for seismic assessment of Federal Bridges

**(2)Special Studies:**

<u>Local Building Census- Canton Ticino, Office for Estimation of Building Values (ufficio stime):</u>

- Land data (class, value etc.)
- Detailed volumetric data of the building
- Building data (construction year, structural system, conservation, renovations, use of the building etc.)
- Estimated building value

## 14. TURKEY, PROF. MUSTAFA ERDIK, DR. MINE DEMIRCIOGLU, DR. KARIN SESTYAN, DR. UFUK HANCILAR, DR. CUNEYT TUZUN, KANDILLI OBSERVATORY AND EARTHQUAKE RESEARCH INSTITUTE:

**Provided Information:**

*On building inventory:*

- Year 2000, Building census of Turkish Statistical Institute provides information for 3212 administrative units (province, districts, villages)
- Year 1997, Building inventory census at villages based on the number of building and construction type for residential and non-residential and number of stories for residential buildings.
- TUIK building census provides information on per city/district/quarter (on separate sheets):
  - Construction type
  - Number of stories
  - Construction date
  - Use of building
- Main building types in Turkish building stock:
  - RC frame system
  - RC frame + shear wall system
  - Masonry
- Main building group in terms of code compliance:
  - Pre 1980 (low code)
  - 1980-2000 (moderate code)
  - 2000- (high code)
- Building taxonomy:

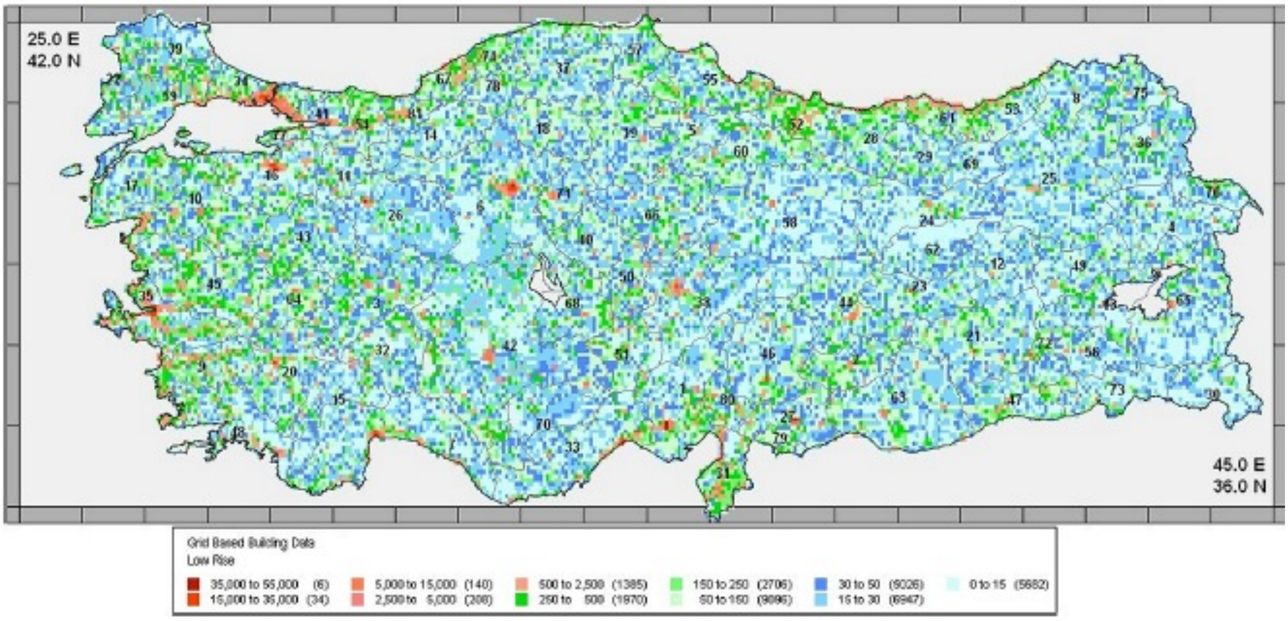
| | Building typology |
|---|---|
| | **Unreinforced Masonry** |
| M1 | Rubble stone |
| M2 | Adobe (earth bricks) |
| M3 | Simple stone |
| M4 | Massive stone |
| M5 | U Masonry (old bricks) |
| M6 | U Masonry - r.c. floors |
| | **Reinforced /confined masonry** |
| M7 | Reinforced /confined masonry |
| | **Reinforced Concrete** |
| RC1 | Concrete Moment Frame |
| RC2 | Concrete Shear Walls |
| RC3 | Dual System |
| S | **Steel Typologies** |
| W | **Timber Typologies** |

**Buildings Classification**

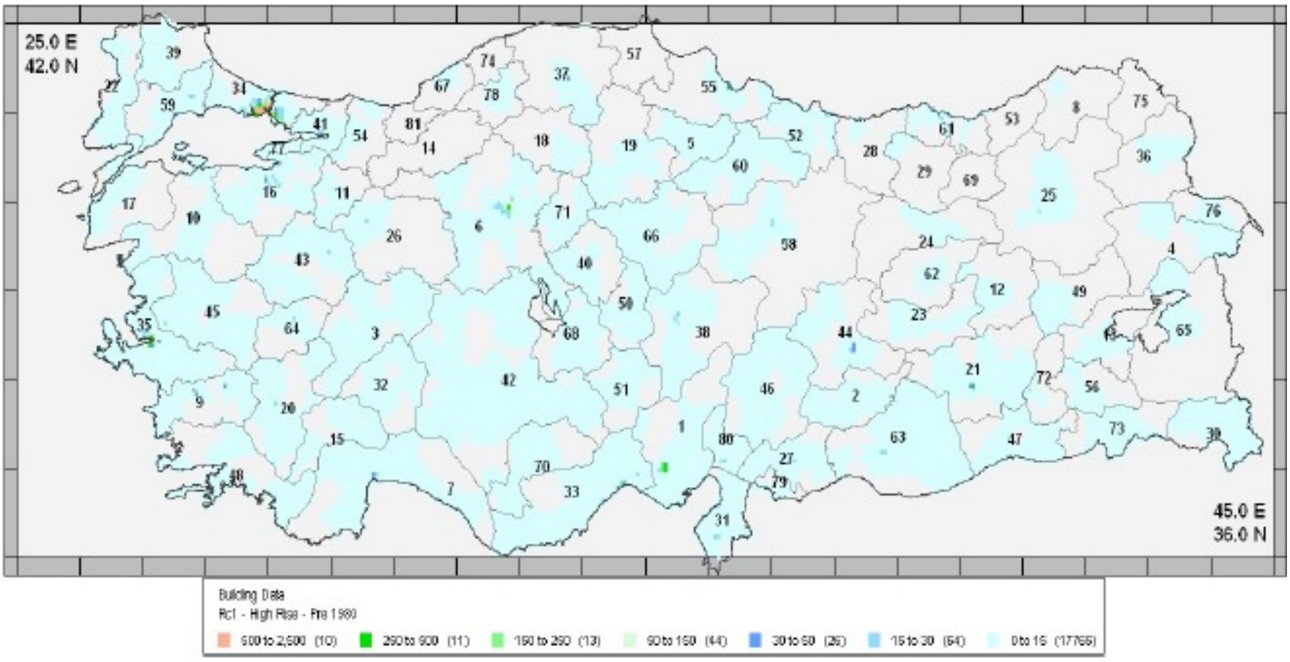
| Construction Type | | Number of Stories | | Construction Date | |
|---|---|---|---|---|---|
| RC1-Moderate | 3,837,576 | Low Rise | 6,647,014 | Pre-1979 | 3,167,482 |
| M5 | 2,977,263 | Mid Rise | 763,143 | Post -1979 | 4,345,890 |
| M2 | 472,562 | High Rise | 103,223 | - | |
| M1 | 225,976 | - | | - | |
| TOTAL | 7,513,377 | | 7,513,380 | - | 7,513,371 |

| Construction Type | The story Number of Buildings | Construction Year |
|---|---|---|
| RC1 | Low Rise | Pre – 1980 |
| M1- Rubble | Mid Rise | Post - 1980 |
| M2- Adobe | High Rise | |
| M5 – Unreinforced Masonry | | |

- Considering the grid based building inventory, the logic tree approach is utilized to determine the percentage of the construction type, the story number of buildings and construction year for each cell and then, according to that ratio, the building inventory is determined for each building type, the story number of building and construction date for each cell.
- Distribution of RC low rise type buildings:




- Distribution of RC high rise type buildings:




*Other data:*

- Basic deficiencies of Turkish building stock:
  - Low material strength: especially RC buildings before 1980
  - Lack of seismic design considerations: no proper structural system and irregularity both in plan and elevation
  - Non-engineered building construction: especially in masonry structures in rural areas.

**(1)Data sources:**

1. Turkish Statistical Institute- http://www.turkstat.gov.tr/Start.do
2. GIS based administrative boundaries dataset
3. Grid based Landscan population database

**(2)Special Studies:**

Building inventory for Istanbul:

- 4 main inventory groups:
  - Building/Structure inventory:
    - Ordinary buildings
    - Official buildings
    - Historical buildings
    - Industrial buildings
    - Buildings having flammable and explosive materials
  - Transportation inventory
  - Infrastructure inventory
  - Socio-Economic data inventory
- Building taxonomy for Istanbul building inventory:

| CODE | BUILDING TYPE | NUMBER OF FLOORS | CONSTRUCTION YEAR | NUMBER OF BUILDINGS |
|---|---|---|---|---|
| B111 | OTHER - UNKNOWN | 1-4 | -1979 | 588 |
| B121 | OTHER - UNKNOWN | 5-8 | -1979 | 162 |
| B131 | OTHER - UNKNOWN | 9- | -1979 | 3 |
| B112 | OTHER - UNKNOWN | 1-4 | 1980-2000 | 4,637 |
| B122 | OTHER - UNKNOWN | 5-8 | 1980-2000 | 536 |
| B132 | OTHER - UNKNOWN | 9- | 1980-2000 | 30 |
| B113 | OTHER - UNKNOWN | 1-4 | 2000- | 458 |
| B123 | OTHER - UNKNOWN | 5-8 | 2000- | 10 |
| B133 | OTHER - UNKNOWN | 9- | 2000- | 1 |
| B211 | Masonry | 1-4 | -1979 | 96,560 |
| B221 | Masonry | 5-8 | -1979 | 6,116 |
| B231 | Masonry | 9- | -1979 | 0 |
| B212 | Masonry | 1-4 | 1980-2000 | 123,341 |
| B222 | Masonry | 5-8 | 1980-2000 | 333 |
| B232 | Masonry | 9- | 1980-2000 | 1 |
| B213 | Masonry | 1-4 | 2000- | 1,141 |
| B223 | Masonry | 5-8 | 2000- | 1 |
| B233 | Masonry | 9- | 2000- | 0 |

| CODE | BUILDING TYPE | NUMBER OF FLOORS | CONSTRUCTION YEAR | NUMBER OF BUILDINGS |
|---|---|---|---|---|
| B311 | Precast | 1-4 | -1979 | 50 |
| B321 | Precast | 5-8 | -1979 | 0 |
| B331 | Precast | 9- | -1979 | 0 |
| B312 | Precast | 1-4 | 1980-2000 | 1,072 |
| B322 | Precast | 5-8 | 1980-2000 | 0 |
| B332 | Precast | 9- | 1980-2000 | 0 |
| B313 | Precast | 1-4 | 2000- | 3 |
| B323 | Precast | 5-8 | 2000- | 0 |
| B333 | Precast | 9- | 2000- | 0 |
| B411 | Steel | 1-4 | -1979 | 157 |
| B421 | Steel | 5-8 | -1979 | 28 |
| B431 | Steel | 9- | -1979 | 2 |
| B412 | Steel | 1-4 | 1980-2000 | 1,364 |
| B422 | Steel | 5-8 | 1980-2000 | 62 |
| B432 | Steel | 9- | 1980-2000 | 9 |
| B413 | Steel | 1-4 | 2000- | 137 |
| B423 | Steel | 5-8 | 2000- | 0 |
| B433 | Steel | 9- | 2000- | 0 |

| CODE | BUILDING TYPE | NUMBER OF FLOORS | CONSTRUCTION YEAR | NUMBER OF BUILDINGS |
|---|---|---|---|---|
| B511 | RC frame | 1-4 | -1979 | 84,006 |
| B521 | RC frame | 5-8 | -1979 | 53,900 |
| B531 | RC frame | 9- | -1979 | 1,556 |
| B512 | RC frame | 1-4 | 1980-2000 | 410,737 |
| B522 | RC frame | 5-8 | 1980-2000 | 171,093 |
| B532 | RC frame | 9- | 1980-2000 | 8,783 |
| B513 | RC frame | 1-4 | 2000- | 15,012 |
| B523 | RC frame | 5-8 | 2000- | 120,226 |
| B533 | RC frame | 9- | 2000- | 60,271 |
| B611 | RC wall | 1-4 | -1979 | 0 |
| B621 | RC wall | 5-8 | -1979 | 0 |
| B631 | RC wall | 9-19 | -1979 | 0 |
| B641 | RC wall | 20- | -1979 | 11 |
| B612 | RC wall | 1-4 | 1980-2000 | 69 |
| B622 | RC wall | 5-8 | 1980-2000 | 128 |
| B632 | RC wall | 9-19 | 1980-2000 | 327 |
| B642 | RC wall | 20- | 1980-2000 | 146 |
| B613 | RC wall | 1-4 | 2000- | 0 |
| B623 | RC wall | 5-8 | 2000- | 35 |
| B633 | RC wall | 9-19 | 2000- | 242 |
| B643 | RC wall | 20- | 2000- | 39 |

**Appendix C: Websites and collection of various sources building/dwelling data**

| Country | Websites |
|---|---|
| Albania | http://www.instat.gov.al/ |
| Austria | http://www.statistik.at/web_de/statistiken/wohnen_und_gebaeude/bestand_an_gebaeuden_und_wohnungen/hauptwohnsitz-wohnungen/index.html?ssSourceSiteId=null<br>http://www.statistik.at/web_de/services/adress_gwr_online/index.html<br>https://www.statistik.at/isis/current/jar/isis_gui_plugin_guest_en.shtml<br>regional statistics: http://www.statistik.at/blickgem/index.jsp<br>http://www.statistik.at/web_de/statistiken/wohnen_und_gebaeude/index.html |
| Belarus | http://belstat.gov.by/homep/en/main.html<br>http://belstat.gov.by/homep/en/census/2009/pc_publications.php<br>http://belstat.gov.by/homep/en/indicators/construction.php |
| Belgium | http://statbel.fgov.be/nl/statistieken/cijfers/bevolking/volkstelling/<br>http://statbel.fgov.be/fr/statistiques/chiffres/economie/construction_industrie/parc/<br>http://www.ibsa.irisnet.be/themes/amenagement-du-territoire-et-immobilier/amenagement-du-territoire-et-immobilier<br>http://www.statistics.irisnet.be/links<br>http://www.gembloux.ulg.ac.be/eg/capru/ |
| Bosnia | http://www.fzs.ba/Eng/index.htm<br>http://www.bhas.ba/index.php?lang=en<br>http://www.rzs.rs.ba/English.htm |
| Bulgaria | http://www.nsi.bg/index_en.htm<br>http://www.nsi.bg/Census_e/Census_e.htm<br>http://www.nsi.bg/otrasal-publikaciien.php?otr=45<br>Regional statistics: http://www.nsi.bg/regstatmapen.php |
| Croatia | http://www.dzs.hr/default_e.htm<br>http://www.dzs.hr/Eng/censuses/Census2001/Popis/Edefault.html |
| Cyprus | http://www.mof.gov.cy/mof/cystat/statistics.nsf/AdvancedSearch_en?OpenForm&q=&p=1&w=&t=&s=building%20census&L=E&e=&i=1 |
| Czech Republic | http://www.czso.cz/eng/redakce.nsf/i/home<br>http://www.czso.cz/sldb/sldb2001.nsf/index_en<br>http://www.czso.cz/csu/2005edicniplan.nsf/engp/4131-05<br>http://www.czso.cz/sldb2011/eng/redakce.nsf/i/census_results |
| Denmark | http://www.dst.dk/HomeUK.aspx<br>http://www.statistikbanken.dk/statbank5a/default.asp?w=1366<br>http://www.statbank.dk/statbank5a/SelectTable/omrade0.asp?SubjectCode=10&PLanguage=1&ShowNews=OFF |
| Estonia | http://www.stat.ee/statistics<br>http://www.stat.ee/population-census-2000 |
| Finland | http://www.stat.fi/til/aiheet_en.html#asu<br>http://pxweb2.stat.fi/database/StatFin/databasetree_en.asp |
| France | http://www.recensement.insee.fr/home.action<br>http://www.recensement.insee.fr/searchResults.action?codeMessage=5&plusieursReponses=true&zoneSearchField=FRANCE&codeZone=1-FE&idTheme=6&rechercher=Rechercher |
| Germany | http://www.destatis.de/jetspeed/portal/cms/<br>http://www.statistik-portal.de/Statistik-Portal/en/ |
| Greece | http://www.statistics.gr/portal/page/portal/ESYE<br>http://www.statistics.gr/portal/page/portal/ESYE/PAGE-database |

| | |
|---|---|
| Greenland | http://bank.stat.gl/database/Greenland/Housing/Housing.asp |
| Hungary | http://portal.ksh.hu/portal/page?_pageid=38,119919&_dad=portal&_schema=PORTAL<br>http://www.nepszamlalas.hu/index.php?langcode=en<br>http://www.mikrocenzus.hu/mc2005_eng/volumes/07/tartalom.html |
| Iceland | http://www.statice.is/Statistics/Manufacturing-and-energy/Constructions |
| Ireland | http://www.statcentral.ie/viewStat.asp?id=132<br>http://census.cso.ie/census/ReportFolders/ReportFolders.aspx<br>http://www.cso.ie/en/census/interactivetables/ |
| Italy | http://dawinci.istat.it/daWinci/jsp/prDownload.jsp?tav=home<br>http://dawinci.istat.it/MD/dawinciMD.jsp?a1=n0GG0c0I0&a2=mG0Y8048f8&n=1UH22P09OG0 |
| Latvia | http://www.csb.gov.lv/<br>http://data.csb.gov.lv/DATABASEEN/tautassk/Results%20of%20Population%20Census%202000/Results%20of%20Population%20Census%202000.asp |
| Liechtenstein | http://www.llv.li/amtsstellen/llv-as-volkszaehlung.htm |
| Lithuania | http://www.stat.gov.lt/en/<br>http://db.stat.gov.lt/sips/Database/cen_en/p71en/dwellings/dwellings.asp<br>Construction database:<br>http://db1.stat.gov.lt/statbank/SelectTable/omrade0.asp?SubjectCode=S4&PLanguage=1&ShowNews=OFF |
| Luxembourg | http://www.statistiques.public.lu/en/index.html<br>http://www.statistiques.public.lu/stat/ReportFolders/ReportFolder.aspx?IF_Language=eng&MainTheme=2&FldrName=1&RFPath=70 |
| Macedonia | http://www.stat.gov.mk/PrikaziPoslednaPublikacija_en.aspx?id=54<br>http://makstat.stat.gov.mk/pxweb2007bazi/dialog/statfile1.asp<br>http://makstat.stat.gov.mk/english/glavna_eng.asp?br=18 |
| Malta | http://www.nso.gov.mt/site/page.aspx<br>http://www.um.edu.mt/science/physics/smru/generalinformation/siteeffects |
| Moldova | http://www.statistica.md/index.php?l=en<br>http://statbank.statistica.md/pxweb/Database/EN/databasetree.asp |
| Montenegro | http://www.monstat.org/eng/index.php |
| Netherlands | http://www.cbs.nl/en-GB/menu/home/default.htm |
| Norway | http://www.ssb.no/english/subjects/10/09/bygningsmasse_en/<br>http://www.ssb.no/cgi-bin/tabfig.cgi?kortnavn=bygganlprod_en,bygganlord_en,byggeareal_en,bkibol_en,bkianl_en,stbygganl_en,bygganloms_en,bygningsmasse_en,fobbolig_en,bpi_en,enebolig_en,kvadenebol_en,eiendomsoms_en,boligstat_en&lang=en<br>http://statbank.ssb.no/statistikkbanken/Default_FR.asp?PXSid=0&nvl=true&PLanguage=1&tilside=selecttable/hovedtabellHjem.asp&KortnavnWeb=boligstat<br><br>Gridded statistics: http://www.ssb.no/emner/01/01/20/tettstedkart/<br>http://www.efgs.info/data/european-datasets/norway<br><br>Cost: http://www.ssb.no/en/priser-og-prisindekser/statistikker/bkibol |
| Poland | http://www.stat.gov.pl/gus/index_ENG_HTML.htm<br>http://www.stat.gov.pl/bdlen/app/strona.html?p_name=indeks |
| Portugal | http://www.ine.pt/xportal/xmain?xpid=INE&xpgid=ine_base_dados |
| Romania | http://www.insse.ro/cms/files/RPL2002INS/index_eng.htm<br>http://www.insse.ro/cms/files/RPL2002INS/vol5/tablesdwellings.htm |

| | |
|---|---|
| | http://colectaredate.insse.ro/phc/secure/public.do<br>http://www.insse.ro/cms/files/RPL2002INS/vol3/titluriv3.htm<br>http://www.insse.ro/cms/files/rpl2002rezgen1/rg2002.htm<br>Regional statistics: http://www.insse.ro/cms/rw/pages/legaturiDJS.en.do |
| Serbia | http://webrzs.stat.gov.rs/WebSite/public/ReportView.aspx |
| Slovakia | http://portal.statistics.sk/showdoc.do?docid=3214<br>http://www.infostat.sk/new_web/en/<br>http://sodb.infostat.sk/scitanie/index.htm |
| Slovenia | http://www.stat.si/popis2002/en/rezultati_obcine_stavbe.htm |
| Spain | http://www.ine.es/censo91/en/inicio.jsp<br>(http://www.ine.es/en/inebmenu/mnu_construc_en.htm#1)<br>http://www.ine.es/jaxi/menu.do?type=pcaxis&path=/t20/e242/e01/a1991/&file=pcaxis<br>http://www.ine.es/en/inebmenu/mnu_cifraspob_en.htm<br>http://www.ine.es/censo/en/estructura.jsp?k=MDDB.COLECTIVO_E2<br>http://www.fomento.gob.es/MFOM/LANG_CASTELLANO/ESTADISTICAS_Y_PUBLICACIONES/INFORMACION_ESTADISTICA/Construccion/ |
| Sweden | http://www.statistikdatabasen.scb.se/pxweb/en/ssd/ |
| Switzerland | http://www.bfs.admin.ch/bfs/portal/en/index.html<br>http://www.pxweb.bfs.admin.ch/Dialog/statfile.asp?lang=2&prod=09 |
| Turkey | http://www.turkstat.gov.tr/Start.do<br>http://tuikapp.tuik.gov.tr/Bolgesel/anaSayfa.do |
| Ukraine | http://www.ukrstat.gov.ua/ |
| United Kingdom | https://www.nomisweb.co.uk/<br>http://www.ons.gov.uk/ons/index.html<br>http://www.communities.gov.uk/corporate/<br>http://www.gro-scotland.gov.uk/files2/stats/household-estimates/he-11/j22968203.htm |
| GENERAL | UN: http://unstats.un.org/unsd/demographic/sconcerns/housing/default.htm<br>Nordic Database: http://www.norden.org/en<br>UNECE: http://w3.unece.org/stat/HumanSettlements.asp<br>Eurostat: http://epp.eurostat.ec.europa.eu/portal/page/portal/statistics/search_database<br>TABULA Project: http://episcope.eu/iee-project/tabula/<br>IMPRO-Building Project:<br>http://publications.jrc.ec.europa.eu/repository/bitstream/111111111/7070/1/reqno_jrc46667_jrc46667%5B1%5D%5B1%5D.pdf.pdf |

## Collection of various sources:

### 1) ALBANIA:

1. Census, 2001:

| Number of Floors | |
|---|---|
| 1 floor | 0.80 |
| 2 floors | 0.17 |
| 3-5 floors | 0.03 |
| 6-10 floors | 0.00 |
| 11+ floors | 0.00 |

| Main construction material | |
|---|---|
| Pre-fabricated | 0.05 |
| Bricks, stones | 0.88 |
| Wood | 0.01 |
| Other | 0.06 |

| Type of Building | |
|---|---|
| Single dwelling | 0.97 |
| Multiple dwelling | 0.03 |

| | Before 1945 | 1945-1960 | 1961-1980 | 1981-1990 | 1991-1995 | 1996 - 2001 |
|---|---|---|---|---|---|---|
| 1 floor | 0.05 | 0.10 | 0.25 | 0.20 | 0.08 | 0.11 |
| 2 floors | 0.03 | 0.03 | 0.04 | 0.02 | 0.02 | 0.03 |
| 3-5 floors | 0.00 | 0.00 | 0.01 | 0.01 | 0.00 | 0.01 |
| 6-10 floors | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 |
| 11+ floors | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 |

| | Before 1945 | 1945-1960 | 1961-1980 | 1981-1990 | 1991-1995 | 1996 - 2001 |
|---|---|---|---|---|---|---|
| Pre-fabricated | 0.00 | 0.00 | 0.01 | 0.01 | 0.01 | 0.02 |
| Bricks, stones | 0.07 | 0.13 | 0.28 | 0.20 | 0.09 | 0.12 |
| Wood | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 |
| Other | 0.01 | 0.01 | 0.01 | 0.01 | 0.01 | 0.01 |

| | Before 1945 | 1945-1960 | 1961-1980 | 1981-1990 | 1991-1995 | 1996 - 2001 |
|---|---|---|---|---|---|---|
| Single dwelling | 0.08 | 0.13 | 0.29 | 0.22 | 0.10 | 0.15 |
| Multiple dwelling | 0.00 | 0.00 | 0.01 | 0.01 | 0.00 | 0.00 |

| | |
|---|---|
| Before 1945-Brick, Stone Masonry-(1-2 Floors)-SFH | 0.07 |
| Before 1945-Other-(1-2 Floors)-SFH | 0.01 |
| 1945-1960-Brick, Stone Masonry-(1-2 Floors)-SFH | 0.13 |
| 1945-1960-Other-(1-2 Floors)-SFH | 0.01 |
| 1961-1980-Brick, Stone Masonry-(1-2 Floors)-SFH | 0.28 |
| 1961-1980-Other-(1-2 Floors)-SFH | 0.01 |
| 1961-1980-Pre-fabricated-(3-5 Floors)-MFH | 0.01 |
| 1981-1990-Brick, Stone Masonry-(1-2 Floors)-SFH | 0.20 |
| 1981-1990-Other-(1-2 Floors)-SFH | 0.01 |
| 1981-1990-Pre-fabricated-(3-5 Floors)-MFH | 0.01 |
| 1991-1995-Brick, Stone Masonry-(1-2 Floors)-SFH | 0.09 |
| 1991-1995-Other-(1-2 Floors)-SFH | 0.01 |
| 1991-1995-Pre-fabricated-(1-2 Floors)-SFH | 0.01 |
| 1995-2001-Brick, Stone Masonry-(1-2 Floors)-SFH | 0.12 |
| 1995-2001-Other-(1-2 Floors)-SFH | 0.01 |
| 1995-2001-Pre-fabricated-(3-5 Floors)-SFH | 0.02 |

2. UNDP:

A basis for vulnerability and risk assessment of the residential building stock are INSTAT 2001 building census data, grouped by: (1) material of construction (adobe, brick, stone, and reinforced concrete [RC]) and structural systems (masonry, prefabricated, RC – frame); (2) age, i.e., period of construction (pre-1960: non-earthquake resistant; 1960-90: low seismic protection; post-1990: insufficiently protected); and (3) building height, i.e. number of stories (1-2 floors, 3-5, and >5).

| | Before 1945 | 1945-1960 | 1961-1980 | 1981-1990 | 1991-1995 | 1996 -2001 |
|---|---|---|---|---|---|---|
| Pre-fabricated | 0.00 | 0.00 | 0.03 | 0.05 | 0.09 | 0.10 |
| Bricks, stones | 0.93 | 0.93 | 0.91 | 0.88 | 0.82 | 0.80 |
| Wood+Other | 0.07 | 0.07 | 0.06 | 0.07 | 0.09 | 0.10 |

3. PAGER:

| Albania | C3 | C3L | DS4 | UFB3 |
|---|---|---|---|---|
| Urban/Rural | 0.36 | 0.31 | 0.29 | 0.04 |

4. Besnik Aliaj, “Housing Models in Albania between 1945-1999”

A. Detached dwellings, are mainly distinguished as:
- Rural or urban detached dwellings
- Pre- or post-war detached dwellings

Rural 1-2 storey dwellings, depended on types and local and regional tradition. They include:
- kulla, a semi-nomadic fortified pastoral dwelling in northern upland tradition, made by **stone** and small windows;
- zadruga, large dwellings bordering Kosova region;
- 1-storey dwelling in lowland tradition, made in simple agricultural style by **mud, wattle and thatch**;
- Greek two storey village dwelling, **limestone** built on the hillsides, overlooking to the valley
- early post-war houses, **brick-built** with particular local architectural motifs in newly reclaimed agricultural areas as Maliq region in Korca;
- houses built in emergency cases or natural disasters by rapid voluntary means, such as in the cases of Dibra and Shkodra earthquakes.

Regarding old urban 1-2 storey dwellings, they were mostly demolished because of new developments in main urban centres. However, some survived due to the particular conditions, such as:

- cases under study because of their special traditional values;
- dwellings surrounded by historically old protective city walls;
- dwellings included within the traditional bazaars and urban complexes;
- dwellings involved in the former important areas of mixed residential, retailing, wholesaling, manufacturing activities and land uses;
- well-built pre-war dwellings in favourable locations for recreational purposes, such as Himara, Durresi, Pogradeci, etc.;
- dwellings protected by the legislation of the monuments of culture and environment, produced in early post-war period, such as Gjirokastra, Berati, Durresi, Kruja, etc.;
- dwellings supported by indirect state investments on housing for touristic purposes;
- dwellings that were object of work by the Institute for Restoration of the Monuments of Culture;
- dwellings maintained and enhanced for ideological purposes or the past glorious national history.

B. Low rise flats, **built in bricks by mechanised** methods. Usually they go up to **three or four storeys**. This type is mainly built in Durresi, Elbasani, Peqin, Levan, Lukova, etc.

C. Apartment blocks, constructed by some degree of mechanization and prefabrication, up to **five or six storeys** in cities of Tirana, Durresi, Fier, Ballsh, Kamza, etc. Usually they are:
- *brick-built by local stone foundations, with or without concrete*, and with similar types of facings.

**Suggested typologies:**

(by buildings, Census 2011)

| | |
|---|---|
| M99+MUN99+MO99/LWAL/RES/EWMA | 0.88 |
| W+W99/L99/RES /EWW | 0.01 |
| MAT99/L99/RES | 0.11 |

## 2) AUSTRIA:

1. Statistical Institute (Registerzählung 2011):

| By Residential Buildings | Before 1919 | 1919 - 1944 | 1945 - 1970 | 1971 - 1990 | 1991 and after | **Total** |
|---|---|---|---|---|---|---|
| SFH (1 to 2 dwellings) | 0.12 | 0.06 | 0.21 | 0.26 | 0.22 | **0.87** |
| MFH (3 and more dwellings) | 0.03 | 0.01 | 0.03 | 0.03 | 0.03 | **0.13** |
| | **0.15** | **0.07** | **0.24** | **0.29** | **0.25** | |

2. PAGER:

| **Austria** | **C1L** | **C1M** | **C3L** | **C3M** | **UFB1** | **UFB3** | **UFB4** | **UNK** |
|---|---|---|---|---|---|---|---|---|
| Urban-Rural | 0.05 | 0.05 | 0.12 | 0.20 | 0.14 | 0.14 | 0.22 | 0.09 |

3. TABULA Project:

| By Buildings | Before 1918 | 1919-1944 | 1945-1960 | 1961-1980 | 1981-1990 | 1991-2000 | 2001-2010 |
|---|---|---|---|---|---|---|---|
| SFH | 0.12 | 0.06 | 0.10 | 0.26 | 0.12 | 0.12 | 0.14 |
| TH+MFH | 0.02 | 0.01 | 0.01 | 0.02 | 0.01 | 0.01 | 0.00 |

<table>
<tr><th></th><th>Until 1944</th><th>1945 bis 1960</th><th>1961 bis 1970</th><th>1971 bis 1980</th><th>1981 bis 1990</th><th>1991 bis 2000</th><th>2001 und später</th></tr>
<tr><td>SFH (1 to 2 dwellings)</td><td>Solid Brick Masonry</td><td>Masonry with cemented stones, Solid Brick Masonry</td><td colspan="5">porous vertically perforated brick, lightweight concrete, concrete-precast walls, prestressed concrete wood blocks, multi-layer masonry, timber rail walls, wooden prefabricated walls</td></tr>
<tr><td>MFH1 (3-9 dwellings)</td><td>Solid Brick Masonry</td><td>Masonry with cemented stones, Solid Brick Masonry</td><td colspan="2">often masonry, sometimes sandwich-structured, reinforced concrete walls, later lightweight concrete walls, first use of prefabricated</td><td colspan="3">porous vertically perforated brick, lightweight concrete, concrete-precast walls, prestressed concrete wood blocks, multi-layer masonry, timber rail walls, wooden prefabricated walls</td></tr>
</table>

| | | | | | | |
|---|---|---|---|---|---|---|
| | | | components | | | |
| MFH2 (9+ dwellings) | Solid Brick Masonry | Masonry with cemented stones, Solid Brick Masonry | often masonry, sometimes sandwich-structured, reinforced concrete walls, later lightweight concrete walls, first use of prefabricated components | porous vertically perforated brick, lightweight concrete, concrete-precast walls, prestressed concrete wood blocks, multi-layer masonry, timber rail walls, wooden prefabricated walls | Hollow concrete blocks, prefabricated concrete walls. | porous vertically perforated brick, lightweight concrete, concrete-precast walls, prestressed concrete wood blocks, multi-layer masonry, timber rail walls, wooden prefabricated walls |

**Single Family Houses:**

In the first construction period, about 1918, in larger cities often spacious mansions with impressive reception areas and for that time **typical masonry** and stucco ornamentation were built. In rural areas the single-family houses were much more moderate, their appearance and construction depended on architectonical influences of the regions.
The years after World War I were, because of a lack of materials and bad quality of the construction materials, characterized by inadequate building construction. **Predominantly simple plastered brick works** without any façade decoration of stucco were built. **Single-family homes were constructed mainly in housing developments in peripheral areas of towns and villages**.

**Terraced Houses:**

Terraced houses are architecturally and energetically different from multi-family houses, but they are not listed separately in the national statistics.
In the course of industrialization in the late 19th and in the early 20th century, working class homes were built in the form of terraced one-family or two-family houses. The economic and social changes after World War I led to the construction of many settlements with functional, small floor plans and **plastered brick walls.**
Not until the beginning of the 1960s, this trend changed and generous floor plans were built again. In these years **industrially prefabricated sandwich constructions and composite construction methods** were used for reduction of construction costs and for building physical improvements.

**Multi FamilyHouses:**

According to Statistics Austria this type is defined **by two- to four-level residential buildings with about three to ten residential units**. In the Wilhelminian era, they used to build city mansions for multigenerational living. Mostly the very prestigious facades were organized by an impressive entrance and bay zones, facades were decorated by stuck ornamentation.

**Apartment Blocks:**

This part describes large multi-family houses and multi-storey residential buildings with **more than eleven living units**, which are mostly **located in larger towns**. In the urban areas residential buildings from the Wilhelminian era are **typical, with masonry** and stucco decorations on the front side and with simple masonries and due to later extensions partly very angled on the back side. From 1919 to the mid 1930s especially in the so called "Rotes Wien" (labour policy oriented Vienna) standardized dwellings with standard floor plans (38 or 48 m²) were built. In the big apartment blocks until 1944, 1- and 2- bedroom apartments with breakfast kitchen, kitchenette and bathroom/WC predominate. **The economic growth of the 1960s lead to a significant increase in new residential buildings, for the first time in skeletal construction and new materials (lightweight concrete, boards).**

**The roof typology**

In Austria there are mainly three roof types used:

- the tilted roof, double pitched, 30° roof pitch
- the tilted roof, kerb roof 45° roof pitched
- the flat roof, 7% down-grade

**The ceiling typology**

In general there are four types of ceilings:

- wooden construction
- steel-beam construction
- precast elements
- reinforced concrete

**The wall typology**

In Austria, the **main material used to build the external walls of SFH and TH is brick or reinforced concrete**. For **MFH and AB often reinforced concrete** has been and is still being used.

- brickwork
- reinforced concrete (with thermal composite systems)

**The floor typology**

- wooden construction
- steel-beam construction
- precast elements
- reinforced concrete

| EFH Detached Single-Family House | Building age class | Dwellings Storey | External Walls | Roof |
|---|---|---|---|---|
| I | Before 1919 | 1<br>1-2 | Solid brick masonry 29 – 60 cm or mixed masonry | predominately gabled (pitched), often covered in clay tiles |
| II | 1919<br>1944 | 1<br>1-2 | Solid brick masonry 29 – 45 cm (slightly reduced thickness of walls | Predominately gabled, often covered in clay tiles. |
| III | 1945<br>1960 | 1<br>1-2 | Solid brick masonry 25 – 38 cm | pitched roofs, flat roofs of reinforced concrete |
| IV | 1961<br>1980 | 1<br>1-2 | porous vertically perforated brick, lightweight concrete blocks with insulating aggregates, concrete-precast walls | rafter roof, non-ventilated flat roof or inverted roof |
| V | 1981<br>1990 | 1<br>1-2 | porous vertically perforated brick, lightweight concrete blocks with insulating aggregates, precast reinforced concrete walls, multi-layer masonry, timber rail wall, wooden prefabricated walls | rafter roof, non-ventilated flat roof or inverted roof |
| VI | 1991<br>2000 | 1<br>1-2 | porous vertically perforated brick, lightweight concrete blocks with insulating aggregates, precast reinforced concrete walls, prestressed concrete wood blocks, multi-layer masonry, timber rail walls, wooden prefabricated walls | rafter roof, non-ventilated flat roof or inverted roof |
| VII | 2001<br>2010 | 1<br>1-2 | porous vertically perforated brick, lightweight concrete blocks with insulating aggregates, precast reinforced concrete walls, prestressed concrete wood blocks, multi-layer masonry, timber rail walls, wooden prefabricated walls | rafter roof, non-ventilated flat roof or inverted roof |
| RH Terraced Houses (Town House) | Building age class | Dwellings Storey | External Walls | Roof |
| RHI | Before 1919 | 1<br>1-2 | solid brick masonry 29 – 60 cm thick, or mixed masonry | predominately gabled/pitched. Often covered with clay tiles. |
| RHII | 1919<br>1944 | 2<br>1-2 | solid brick masonry 29 – 45 cm | predominately gabled/pitched, often covered with clay tiles |
| RHIII | 1945<br>1960 | 1<br>1-2 | masonry with cemented stones (brick chips etc.) also solid brick masonry 25 – 38 cm, plaster façade | gabled/pitched, flat roof of reinforced concrete |
| RHIV | 1961<br>1980 | 1<br>1-2 | solid masonry 25 – 38 cm, plaster façade. | gabled/pitched, flat roofs of reinforced concrete |
| RHV | 1981<br>1990 | 1<br>1-2 | porous vertically perforated brick, lightweight concrete blocks with insulating | rafter roof, non-ventilated roof as flat roof or inverted roof |

| | | | | |
|---|---|---|---|---|
| | | | aggregates, precast reinforced concrete walls, prestressed concrete wood blocks, multi-layer masonry, timber rail walls, wooden prefabricated walls | |
| RHVI | 1991<br>2000 | 1<br>1-2 | porous vertically perforated brick, lightweight concrete blocks with insulating aggregates, precast reinforced concrete walls, prestressed concrete wood blocks, multi-layer masonry, timber rail walls, wooden prefabricated walls | rafter roof, non-ventilated roof as flat roof or inverted roof |
| RHVII | 2001<br>2010 | 1<br>1-2 | porous vertically perforated brick, lightweight concrete blocks with insulating aggregates, precast reinforced concrete walls, prestressed concrete wood blocks, multi-layer masonry, timber rail walls, wooden prefabricated walls | rafter roof, non-ventilated roof as flat roof or inverted roof |
| MFH<br>Multi-family House | Building age class | Dwellings<br>Storey | External Walls | Roof |
| I | Before 1919 | 4<br>3-4 | solid brick masonry 29 – 60 cm or mixed masonry | predominately gabled/pitched, often covered in clay tiles |
| II | 1919<br>1944 | 4<br>3-4 | solid brick masonry 29 – 45 cm | predominately gabled/pitched, often covered in clay tiles |
| III | 1945<br>1960 | 3<br>3-4 | masonry with cement-bound stones (brick chips etc.), also solid masonry walls 25 – 38 cm | gabled/pitched, flat roofs of reinforced concrete |
| IV | 1961<br>1980 | 6<br>3-4 | often masonry, sometimes sandwich-structured, reinforced concrete walls, later lightweight concrete walls, first use of prefabricated components | sometimes flat tin roofs |
| V | 1981<br>1990 | 5<br>3-4 | porous vertically perforated bricks, lightweight concrete blocks with insulating aggregates, precast reinforced concrete walls | rafter roof, non-ventilated flat roof or inverted roof |
| VI | 1991<br>2000 | 8<br>3-4 | porous vertically perforated bricks, lightweight concrete blocks with insulating aggregates, precast reinforced concrete walls, prestressed concrete wooden blocks, multi-layered masonry, timber rail walls, prefabricated wooden walls | rafter roof, non-ventilated flat roof or inverted roof |
| VII | 2001<br>2010 | 2<br>3-4 | porous vertically perforated bricks, lightweight concrete blocks with insulating aggregates, precast reinforced concrete walls, prestressed concrete wooden blocks, multi-layered masonry, timber rail walls, prefabricated wooden walls | rafter roof, non-ventilated flat roof or inverted roof |

| MWH Multi-storey residential building | Building age class | Dwellings Storey | External Walls | Roof |
|---|---|---|---|---|
| I | Before 1919 | 12<br>4-6 | solid brick masonry, 29 – 60 cm or mixed masonry | predominately gabled/pitched, often covered on clay tiles |
| II | 1919<br>1944 | 14<br>4-6 | solid brick masonry, 29 – 45 cm or mixed masonry | predominately gabled/pitched, often covered on clay tiles |
| III | 1945<br>1960 | 12<br>4-6 | masonry with cement-bound stones (brick chips etc.), also solid masonry 25 – 38 cm, plaster façade. | gabled/pitched, flat roof made of reinforced concrete |
| IV | 1961<br>1980 | 12<br>4-6 | often masonry, sometimes using sandwich constructions, reinforced concrete walls, later lightweight concrete walls; start of using prefabricated components | |
| V | 1981<br>1990 | 14<br>4-6 | porous vertically perforated bricks, lightweight concrete blocks with insulating aggregates, reinforced concrete, prefabricated walls | rafter roof, non-ventilated flat roof or inverted roof. |
| VI | 1991<br>2000 | 14<br>4-6 | Hollow concrete blocks, prefabricated concrete walls. | Flat roof or insulated gabled/pitched roof |
| VII | 2001<br>2010 | 25<br>4-6 | porous vertically perforated brick, lightweight concrete blocks with insulating aggregates, precast reinforced concrete walls, prestressed concrete wood blocks, multi-layer masonry, timber rail walls, wooden prefabricated walls | Brick hollow block floor, solid concrete ceiling, prefabricated ceiling, wooden beams, rafter roof, non-ventilated roof as flat roof or inverted roof. |

### 3) **BELARUS:**

1. Census,2009 (occupied dwellings)

| | | |
|---|---|---|
| bricks, stone, Masonry | 0.35 | natural or artificial stone |
| Panels, PC1 | 0.32 | concrete or reinforced concrete panels |
| Blocks, UCB | 0.05 | concrete, reinforced concrete and expanded clay blocks, cinder block |
| Monolith, RC frame | 0.00 | reinforced, cellular concrete, reinforced concrete |
| wood | 0.24 | of a house made of wood (or cobbled chopped) or polnosbornyh panel of wood |
| mixed materials | 0.03 | If the first floor (or half of the house) was built from the same material (such as brick or stone), and the second floor (or half of the house) from another (eg wood) |
| other material | 0.01 | prefabricated panel, frame-Sediment (including bricked) or any other materials that are not listed above |
| not stated | 0.00 | |

| | | Before 1946 | 1946–1960 | 1961-1970 | 1971-1980 | 1981-1990 | 1991-2000 | 2001-2005 | 2006-2009 | Not stated |
|---|---|---|---|---|---|---|---|---|---|---|
| SFH | bricks, | 0.00 | 0.01 | 0.01 | 0.01 | 0.02 | 0.01 | 0.01 | 0.00 | 0.00 |

| | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|
| | stone | | | | | | | | | |
| | panels | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 |
| | blocks | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 |
| | monolith | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 |
| | wood | 0.03 | 0.10 | 0.05 | 0.02 | 0.01 | 0.00 | 0.00 | 0.00 | 0.00 |
| | mixed materials | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 |
| | other material | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 |
| | not stated | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 |
| | | | | | | | | | | |
| MFH | bricks, stone | 0.01 | 0.03 | 0.05 | 0.06 | 0.06 | 0.05 | 0.01 | 0.01 | 0.00 |
| | panels | 0.00 | 0.00 | 0.04 | 0.08 | 0.11 | 0.06 | 0.01 | 0.02 | 0.00 |
| | blocks | 0.00 | 0.00 | 0.01 | 0.00 | 0.01 | 0.01 | 0.00 | 0.00 | 0.00 |
| | monolith | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 |
| | wood | 0.01 | 0.01 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 |
| | mixed materials | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 |
| | other material | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 |
| | not stated | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 |

2. PAGER:

| Belarus | W1 | W4 | S2 | S5 | PC1 | A | UCB |
|---|---|---|---|---|---|---|---|
| Urban/Rural | 0.02 | 0.02 | 0.09 | 0.44 | 0.17 | 0.05 | 0.22 |

**Suggested typologies:**

(by occupied dwellings, Census 2009)

| | |
|---|---|
| M99+MUN99+MO99/LWAL /EWMA | 0.35 |
| CR+CT99/LWAL/RES/EWC | 0.32 |
| M99+CB99+MO99/LWAL/RES/EWMA | 0.05 |
| W+W99/L99/RES/EWW | 0.24 |
| MAT99/L99/RES | 0.04 |

## 4) BELGIUM:

1. Statistical Institute, 2013:

Type of Buildings/Dwellings:

All buildings:

| Houses, closed type | Houses, semi-closed type | Houses open type, farms, castles | Apartment buildings | Commercial buildings | All other buildings |
|---|---|---|---|---|---|
| 0.26 | 0.21 | 0.31 | 0.04 | 0.03 | 0.14 |

Residential Buildings:

| Houses, closed type | Houses, semi-closed type | Houses open type, farms, castles | Apartment buildings |
|---|---|---|---|
| 0.32 | 0.26 | 0.38 | 0.05 |

| SFH | MFH |
|---|---|
| 0.95 | 0.05 |

All Dwellings:

| Houses, closed type | Houses, semi-closed type | Houses open type, farms, castles | Apartment buildings | Commercial buildings | All other buildings |
|---|---|---|---|---|---|
| 0.26 | 0.18 | 0.27 | 0.24 | 0.04 | 0.02 |

Dwellings in residential buildings:

| Houses, closed type | Houses, semi-closed type | Houses open type, farms, castles | Apartment buildings |
|---|---|---|---|
| 0.27 | 0.19 | 0.28 | 0.25 |

| SFH | MFH |
|---|---|
| 0.75 | 0.25 |

Number of Floors (in terms of buildings):

| | Houses, closed type | Houses, semi-closed type | Houses open type, farms, castles | Apartment buildings | Commercial buildings |
|---|---|---|---|---|---|
| 1 Floor | 0.11 | 0.30 | 0.76 | 0.01 | 0.14 |
| 2-3 Floors | 0.87 | 0.70 | 0.24 | 0.57 | 0.79 |
| 4-5 floors | 0.01 | 0.00 | 0.00 | 0.29 | 0.07 |
| 5+ floors | 0.00 | 0.00 | 0.00 | 0.13 | 0.00 |

Date of Construction (in terms of buildings):

| | SFH | MFH |
|---|---|---|
| Before 1900 | 0.17 | 0.08 |
| 1900-1918 | 0.08 | 0.05 |
| 1919-1945 | 0.15 | 0.10 |
| 1946-1961 | 0.14 | 0.15 |
| 1962-1970 | 0.10 | 0.15 |
| 1971-1981 | 0.13 | 0.14 |
| After 1981 | 0.23 | 0.33 |

| **Dwellings** | Before 1900 | 1900-1918 | 1919-1945 | 1946-1961 | 1962-1970 | 1971-1981 | After 1981 |
|---|---|---|---|---|---|---|---|
| Houses, closed type | 0.07 | 0.04 | 0.07 | 0.04 | 0.02 | 0.02 | 0.02 |
| Houses, semi-closed type | 0.03 | 0.01 | 0.03 | 0.04 | 0.02 | 0.02 | 0.04 |
| Houses open type, farms, castles | 0.03 | 0.01 | 0.02 | 0.03 | 0.03 | 0.06 | 0.11 |
| Apartment buildings | 0.02 | 0.01 | 0.02 | 0.04 | 0.04 | 0.04 | 0.08 |

In terms of dwelling number (based on 2001 census):

| | SFH | MFH |
|---|---|---|
| Urban | 0.73 | 0.88 |
| Rural | 0.27 | 0.12 |

2. PAGER:

| **Belgium** | **C3** | **UFB3** | **UFB4** |
|---|---|---|---|
| Urban | 0.02 | 0.35 | 0.63 |
| Rural | 0.00 | 0.50 | 0.50 |

3. COSTC16:

- The main part of housing market consists of houses for one family occupancy and only a very small percentage (20% of total housing stock , public and private together) of the market involves multi-storey buildings.
- Multi storey buildings are from three- to over eleven-storey high and mostly traditional brickwork was applied, concrete pre cast or on-site and very little steel constructions
- Main technologies of roofs/floors: Mostly traditional woods (rafters and boards), concrete on site, prefabricated floor slabs or concrete beams and concrete or brick floor tiles are used. Roofs are flat (bitumen) or inclined (tiles or slates) with limited use of zinc and copper plate.

4. TABULA:

| | | **Building period** | **Number of housing units** | |
|---|---|---|---|---|
| **Single Family Houses (74%)** | SFH I | until 1970 | 2126913 | 47.0% |
| | SFH II | 1970-1990 | 810024 | 17.9% |
| | SFH III | 1991-2006 | 392813 | 8.7% |
| **Multi Family Houses (26%)** | MFH I | until 1970 | 656743 | 14.5% |
| | MFH II | 1970-1990 | 319895 | 7.1% |
| | MFH III | 1991-2006 | 216397 | 4.8% |
| **TOTAL** | | | **4522784** | |

**Suggested typologies:**

(by dwellings, Statistical Institute , 2013 and IMPRO Project)

| | |
|---|---|
| M99+CL99+MO99/LWAL/RES/EWMA | 0.76 |
| M99+ST99+MO99/LWAL/RES/EWMA | 0.08 |
| W+W99/LFM/RES/EW99 | 0.04 |
| CR+CT99/L99/RES/EW99 | 0.12 |

## 5) <u>BULGARIA:</u>

1. Census 2011:

Definitions:

- Reinforced concrete structures are those in which the carrier and the floor structures are constructed of reinforced concrete and the walls are made of panels, brickwork or other material.
- Massive buildings are the ones bearing walls which are of brick or stone masonry the belts, the beams and the floor structure are constructed of reinforced concrete, but no concrete columns.
- To the "other" includes buildings, built of adobe (raw bricks), wood other materials.

| TOTAL | PC Pre-Code | LC-Low-Code | MC-Mid-Code | HC-High-Code | |
|---|---|---|---|---|---|
| RC-Panels | 0.00 | 0.00 | 0.01 | 0.00 | **0.01** |
| RC | 0.00 | 0.00 | 0.01 | 0.01 | **0.02** |
| Brick w/concrete slab | 0.01 | 0.02 | 0.23 | 0.08 | **0.34** |

| | | | | | |
|---|---|---|---|---|---|
| Brick w/wooden beams | 0.12 | 0.13 | 0.19 | 0.02 | **0.46** |
| Stone | 0.01 | 0.01 | 0.01 | 0.00 | **0.04** |
| Adobe | 0.07 | 0.02 | 0.02 | 0.00 | **0.11** |
| Wood | 0.00 | 0.00 | 0.01 | 0.00 | **0.01** |
| | **0.22** | **0.18** | **0.49** | **0.12** | |

| URBAN | PC | LC | MC | HC | |
|---|---|---|---|---|---|
| RC-Panels | 0.00 | 0.00 | 0.02 | 0.00 | **0.02** |
| RC | 0.00 | 0.00 | 0.02 | 0.02 | **0.04** |
| Brick w/concrete slab | 0.02 | 0.03 | 0.31 | 0.11 | **0.47** |
| Brick w/wooden beams | 0.09 | 0.09 | 0.19 | 0.02 | **0.39** |
| Stone | 0.00 | 0.00 | 0.00 | 0.00 | **0.01** |
| Adobe | 0.03 | 0.01 | 0.01 | 0.00 | **0.05** |
| Wood | 0.00 | 0.00 | 0.01 | 0.00 | **0.01** |
| | **0.14** | **0.14** | **0.55** | **0.16** | **1.00** |

| RURAL | PC | LC | MC | HC | |
|---|---|---|---|---|---|
| RC-Panels | 0.00 | 0.00 | 0.00 | 0.00 | **0.0** |
| RC | 0.00 | 0.00 | 0.01 | 0.01 | **0.0** |
| Brick w/concrete slab | 0.01 | 0.01 | 0.19 | 0.06 | **0.2** |
| Brick w/wooden beams | 0.14 | 0.14 | 0.20 | 0.01 | **0.5** |
| Stone | 0.02 | 0.01 | 0.02 | 0.00 | **0.0** |
| Adobe | 0.09 | 0.03 | 0.03 | 0.00 | **0.1** |
| Wood | 0.00 | 0.00 | 0.01 | 0.00 | **0.0** |
| | **0.27** | **0.20** | **0.45** | **0.09** | **1.0** |

| TOTAL | LR | MR | HR |
|---|---|---|---|
| RC-Panels | 0.51 | 0.12 | 0.37 |
| RC | 0.73 | 0.16 | 0.11 |
| Brick w/concrete slab | 0.96 | 0.03 | 0.01 |
| Brick w/wooden beams | 1 | | |
| Stone | 1 | | |
| Adobe | 1 | | |
| Wood | 1 | | |

| URBAN | LR | MR | HR |
|---|---|---|---|
| RC-Panels | 0.29 | 0.17 | 0.54 |
| RC | 0.61 | 0.23 | 0.16 |
| Bricks (w/concrete slab) | 0.92 | 0.06 | 0.02 |
| Bricks (w/ beams) | 1.00 | | |
| Stone | 1.00 | | |
| Adobe (raw bricks) | 1.00 | | |
| Wood | 1.00 | | |
| Other | 1.00 | | |

| RURAL | LR | MR | HR |
|---|---|---|---|
| RC-Panels | 0.97 | 0.02 | 0.01 |
| RC | 0.97 | 0.02 | 0.00 |
| Bricks (w/concrete slab) | 1.00 | 0.00 | 0.00 |
| Bricks (w/ beams) | 1.00 | | |
| Stone | 1.00 | | |
| Adobe (raw bricks) | 1.00 | | |
| Wood | 1.00 | | |
| Other | 1.00 | | |

Total:

- %37 Urban %63 Rural
- 86% House, 3% Apartment, 3% Country house, 7% Villa
- 97% (1-3 stories, LR), 2% (4-5 stories, MR), 1% (6+ stories, HR)
- 1% RC-Panels, 2% RC, 34% Brick w/conc.slab, 46% Brick w/o conc.slab, 4% Stone, 11% Adobe, 1% Wood
- 22% PC, 18% LC, 49% MC, 12% HC
- Houses:
  - 2% RC, 32% Brick w/conc.slab, 48% Brick w/o conc.slab, 4% Stone, 12% Adobe, 1% Wood
  - 24% PC, 20% LC, 46% MC, 10% HC
  - 100% LR
    - 2% RC (1% MC, 1%HC),
    - 32% Brick w/conc.slab (1% PC, 2% LC, 22% MC, 7% HC),
    - 48% Brick w/o conc.slab (14% PC, 14% LC, 19% MC, 2% HC),
    - 4% Stone (2% PC, 1% LC, 2% MC),
    - 12% Adobe (7% PC, 2% LC, 2% MC),
    - 1% Wood (1% HC)

Urban:

- 78% House, 9% Apartment, 2% Country house, 10% Villa
- 93% (1-3 stories), 4% (4-5 stories), 3% (6+ stories)
- 2% RC-Panels, 4% RC, 47% Brick w/conc.slab, 39% Brick w/o conc.slab, 1% Stone, 5% Adobe, 1% Wood
- 14% PC, 14% LC, 55% MC, 16% HC
- Houses:
  - 3% RC, 45% Brick w/conc.slab, 44% Brick w/o conc.slab, 1% Stone, 6% Adobe
  - 17% PC, 17% LC, 54% MC, 13% HC
  - 100% LR
    - 3% RC (1.5% MC, 1.5%HC),
    - 45% Brick w/conc.slab (2% PC, 4% LC, 31% MC, 9% HC),
    - 44% Brick w/o conc.slab (11% PC, 11% LC, 19% MC, 2% HC),
    - 1% Stone (1% PC),
    - 6% Adobe (3% PC, 1% LC, 1% MC),

Rural:

- 91% House, 4% Country House, 5% Villa
- 100% (1-3 stories)
- 1% RC-Panels, 1% RC, 27% Brick w/conc.slab, 50% Brick w/o conc.slab, 5% Stone, 15% Adobe, 1% Wood, 1% Other
- 27% PC, 20% LC, 45% MC, 9% HC
- Houses:
  - 1% RC, 25% Brick w/conc.slab, 51% Brick w/o conc.slab, 6% Stone, 15% Adobe, 1% Wood, 1% Other
  - 28% PC, 21% LC, 43% MC, 9% HC
  - 100% LR
    - 1% RC (1% MC),
    - 25% Brick w/conc.slab (1% PC, 1% LC, 18% MC, 6% HC),
    - 51% Brick w/o conc.slab (15% PC, 15% LC, 19% MC, 1% HC),
    - 6% Stone (2% PC, 1% LC, 2% MC),
    - 15% Adobe (10% PC, 3% LC, 3% MC),
    - 1% Wood (1% HC)
    - 1% Other (1% HC)

2. PAGER:

| Bulgaria | C1 | C3 | DS | UFB | UNK |
|---|---|---|---|---|---|

| | | | | | |
|---|---|---|---|---|---|
| Urban | 0.16 | 0.54 | 0.18 | 0.09 | 0.04 |
| Rural | 0.06 | 0.56 | 0.19 | 0.09 | 0.11 |

**Suggested typologies:**

(by buildings, Census 2011)

| | Urban | Rural |
|---|---|---|
| CR+CT99/LWAL/HBET:1,3/RES/EWC/FC | 0.01 | 0.01 |
| CR+CT99/LWAL/HBET:4,5/RES/EWC/FC | 0.00 | 0.00 |
| CR+CT99/LWAL/HBET:6+/RES/EWC/FC | 0.01 | 0.00 |
| CR+CT99/LFINF/HBET:1,3/RES/EWMA/FC | 0.03 | 0.01 |
| CR+CT99/LFINF/HBET: 4,5/RES/EWMA/FC | 0.01 | 0.00 |
| CR+CT99/LFINF/HBET:6+/RES/EWMA/FC | 0.01 | 0.00 |
| M99+CL99+MO99/LWAL/HBET:1,3/RES/EWMA/FC | 0.43 | 0.27 |
| M99+CL99+MO99/LWAL/HBET:4,5/RES/EWMA/FC | 0.03 | 0.00 |
| M99+CL99+MO99/LWAL/HBET:6+/RES/EWMA/FC | 0.01 | 0.00 |
| M99+CL99+MO99/LWAL/HBET:1,3/RES/EWMA/FW | 0.39 | 0.50 |
| M99+CL99+MO99/LWAL/HBET:4,5/RES/EWMA/FW | 0.00 | 0.00 |
| M99+ST99+MO99/LWAL/HBET:1,3/RES/EWMA | 0.01 | 0.05 |
| M99+ADO+MO99/LWAL/HBET:1,3/RES/EWMA | 0.05 | 0.15 |
| W+W99/L99/HBET:1,3/RES | 0.01 | 0.01 |
| MAT99/L99/RES | 0.00 | 0.01 |

**6) <u>CYPRUS:</u>**

1. Census 2011:

From Census 2011, the percentage distribution of dwellings by date of construction and type of building (in which the dwelling is located) in Cyprus is indicated below.
Examining construction practices stated in the country through various sources[1workshop,2costc16], the prevalent building typologies depending on date of construction and type of building have been decided as follows:

- According to the seismic codes enforced in Cyprus, the buildings built before 1971 are with no seismic code (NC), built between 1971 to 1991 are with moderate seismic code(MC) and built after 1991 are with high seismic code (HC).
- The single, semi-detached or duplex, row and back-yard houses are low rise (LR) buildings whereas apartment blocks and partly residential building may be from low to high rise buildings.
- Before 1971, dwellings located in single, semi-detached or duplex, row and back-yard houses are considered as masonry (mostly stone masonry [3,impro]), low rise pre-seismic code .
- All dwellings located in apartment blocks and conventional dwellings in partly residential buildings are considered as reinforced concrete (RC) infill frame.
- From 1971 to 1991, dwellings located in single, row and back-yard houses are considered as both masonry and RC infill frame (which will be equally distributed) while dwellings located in semi-detached or duplex buildings are considered as only RC infill frame.
- Since 1991, the common construction practice is considered to be RC infill frame and all dwellings built in this period are assumed to be RC infill frame.

According to the assumptions above, the dwelling fractions in different building types are obtained and given in the tables below.

| TOTAL | **Single house** | **Semi-detached or duplex** | **Row houses** | **Back-yard house** | **Apartment blocks** | **Conventional dwellings in partly residential buildings** | **Other type of building** |
|---|---|---|---|---|---|---|---|
| **Before 1960** | 0.05 | 0.01 | 0.01 | 0.00 | 0.00 | 0.00 | 0.00 |
| **1961-1971** | 0.03 | 0.01 | 0.00 | 0.00 | 0.01 | 0.00 | 0.00 |

| | | | | | | | |
|---|---|---|---|---|---|---|---|
| **1971-1991** | 0.12 | 0.06 | 0.03 | 0.01 | 0.09 | 0.04 | 0.00 |
| **After 1991** | 0.20 | 0.05 | 0.03 | 0.01 | 0.18 | 0.03 | 0.00 |
| Total | **0.39** | **0.13** | **0.08** | **0.02** | **0.28** | **0.07** | **0.00** |

| TOTAL | Masonry- LR–NC | Masonry-LR-MC | RC infill-NC | RC infill-MC | RC infill-HC | Unknown |
|---|---|---|---|---|---|---|
| | 0.12 | 0.08 | 0.01 | 0.26 | 0.50 | 0.02 |

| URBAN | **Single house** | **Semi-detached or duplex** | **Row houses** | **Back-yard house** | **Apartment blocks** | **Conventional dwellings in partly residential buildings** | **Other type of building** |
|---|---|---|---|---|---|---|---|
| **Before 1960** | 0.03 | 0.01 | 0.01 | 0.00 | 0.00 | 0.00 | 0.00 |
| **1961-1971** | 0.02 | 0.02 | 0.00 | 0.00 | 0.01 | 0.01 | 0.00 |
| **1971-1991** | 0.09 | 0.08 | 0.03 | 0.01 | 0.12 | 0.06 | 0.00 |
| **After 1991** | 0.13 | 0.06 | 0.02 | 0.01 | 0.22 | 0.04 | 0.00 |
| | **0.26** | **0.16** | **0.06** | **0.02** | **0.36** | **0.11** | **0.00** |

| URBAN | Masonry- LR–NC | Masonry-LR-MC | RC infill-NC | RC infill-MC | RC infill-HC | Unknown |
|---|---|---|---|---|---|---|
| | 0.09 | 0.06 | 0.02 | 0.32 | 0.48 | 0.02 |

| RURAL | **Single house** | **Semi-detached or duplex** | **Row houses** | **Back-yard house** | **Apartment blocks** | **Conventional dwellings in partly residential buildings** | **Other type of building** |
|---|---|---|---|---|---|---|---|
| **Before 1960** | 0.07 | 0.01 | 0.02 | 0.00 | 0.00 | 0.00 | 0.00 |
| **1961-1971** | 0.04 | 0.01 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 |
| **1971-1991** | 0.17 | 0.03 | 0.02 | 0.00 | 0.04 | 0.01 | 0.00 |
| **After 1991** | 0.31 | 0.04 | 0.05 | 0.01 | 0.12 | 0.01 | 0.00 |
| | **0.60** | **0.09** | **0.10** | **0.01** | **0.16** | **0.02** | **0.00** |

| RURAL | Masonry- LR–NC | Masonry-LR-MC | RC infill-NC | RC infill-MC | RC infill-HC | Unknown |
|---|---|---|---|---|---|---|
| | 0.10 | 0.00 | 0.17 | 0.54 | 0.03 | 0.00 |

2. COST C16:

- Until mid 20th century, the construction methods have varied only slightly. The building material such as wooden beams, straw, clay mixtures and stones were used.
- The conventional construction system comprises of reinforced concrete for the loads bearing part of the building which is completed by masonry walls (typically brick infill).
- Prefabrication systems are rarely used in the past, mainly by the Government in the construction of some low cost refugee estates in the late 70s.
- RC from foundation to the roof applies the vast majority of housing construction.
- The preliminary regulations considering seismic loads were issued in the late 80s and detailed construction regulations were adopted in the beginning of 90s.
- The most popular foundation type is separate foundations with connecting beams and whole foundation.
- The roofs are usually flat concrete slabs which are covered with light concrete.

**Suggested typologies:**

| | Urban | Rural |
|---|---|---|
| M99+MUN99+MO99/LWAL/HBET:1,3/YPRE:1971/RES+RES1//EWMA | 0.09 | 0.16 |
| M99+MUN99+MO99/LWAL/HBET:1,3/YBET:1971,1991/RES+RES1//EWMA | 0.06 | 0.10 |
| CR+CT99/LFINF/YBET:1961,1971/RES+RES2/EWMA | 0.02 | |
| CR+CT99/LFINF/YBET:1971,1991/RES+RES2/EWMA | 0.32 | 0.17 |

| | | |
|---|---|---|
| CR+CT99/LFINF/YBET:1991,2011/RES+RES2/EWMA | 0.48 | 0.54 |
| MAT99/L99/RES | 0.02 | 0.03 |

## 7) CZECH REPUBLIC:

1. Census 2011:

**A family house** is a residential structure whose structural lay-out corresponds to requirements for family living; a family house may have at most three independent dwellings, two above the ground at most and one underground floor and attic. Family house - **stand-alone** does not adjoin any peripheral wall or part thereof of a house on a neighbouring section. Family house - **semi-detached** has a part of a peripheral wall in common with a family house on the neighbouring section. Family house - **terraced** is indicated as such when at least three family houses adjoin parts of a peripheral wall to each other. **A multi-dwelling house** is a residential structure in which living is the predominant function, but does not meet the parameters of a family house. The number of floors is not determined. The majority of dwellings in a multi-dwelling house are accessible from a common hallway or stairwell. For **other**, state in words, e.g. pension for retirees, retirement home, social welfare institution, monastery, convent, home for youth, boarding house, student hostel, hotel, hospital, administrative building, school, service building, asylum facility, prison etc. In the case where a building serves more purposes, state the type of building according to its primary function.

Type of buildings (by occupied buildings)

| Family houses | Apartment buildings | Other Buildings |
|---|---|---|
| 0.86 | 0.12 | 0.02 |

Material of bearing walls (by occupied buildings):

| All occupied buildings | Stone, bricks, blocks | Wall panels | Unburnt bricks | Wood | Other | Unknown |
|---|---|---|---|---|---|---|
| 1919 and before | 0.11 | 0.00 | 0.01 | 0.00 | 0.01 | 0.00 |
| 1920 - 1945 | 0.16 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 |
| 1946 - 1960 | 0.07 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 |
| 1961 - 1970 | 0.08 | 0.01 | 0.00 | 0.00 | 0.00 | 0.00 |
| 1971 - 1980 | 0.13 | 0.02 | 0.00 | 0.00 | 0.01 | 0.00 |
| 1981 - 1990 | 0.10 | 0.01 | 0.00 | 0.00 | 0.00 | 0.00 |
| 1991 - 2000 | 0.10 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 |
| 2001 - 2011 | 0.11 | 0.00 | 0.00 | 0.01 | 0.01 | 0.00 |
| Unknown | 0.01 | 0.00 | 0.00 | 0.00 | 0.00 | 0.02 |
| | **0.87** | **0.05** | **0.02** | **0.01** | **0.03** | **0.02** |

| Family Houses | Stone, bricks, blocks | Wall panels | Unburnt bricks | Wood | Other | Unknown |
|---|---|---|---|---|---|---|
| 1919 and before | 0.11 | 0.00 | 0.01 | 0.00 | 0.01 | 0.00 |
| 1920 - 1945 | 0.16 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 |
| 1946 - 1960 | 0.07 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 |
| 1961 - 1970 | 0.08 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 |
| 1971 - 1980 | 0.14 | 0.00 | 0.00 | 0.00 | 0.01 | 0.00 |
| 1981 - 1990 | 0.11 | 0.00 | 0.00 | 0.00 | 0.01 | 0.00 |
| 1991 - 2000 | 0.11 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 |
| 2001 - 2011 | 0.12 | 0.00 | 0.00 | 0.01 | 0.01 | 0.00 |

| | | | | | | |
|---|---|---|---|---|---|---|
| Unknown | 0.01 | 0.00 | 0.00 | 0.00 | 0.00 | 0.01 |
| | **0.91** | **0.01** | **0.02** | **0.02** | **0.04** | **0.01** |

| Apartment Buildings | Stone, bricks, blocks | Wall panels | Unburnt bricks | Wood | Other | Unknown |
|---|---|---|---|---|---|---|
| 1919 and before | 0.12 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 |
| 1920 - 1945 | 0.13 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 |
| 1946 - 1960 | 0.13 | 0.01 | 0.00 | 0.00 | 0.00 | 0.00 |
| 1961 - 1970 | 0.08 | 0.08 | 0.00 | 0.00 | 0.00 | 0.00 |
| 1971 - 1980 | 0.06 | 0.11 | 0.00 | 0.00 | 0.00 | 0.00 |
| 1981 - 1990 | 0.03 | 0.09 | 0.00 | 0.00 | 0.00 | 0.00 |
| 1991 - 2000 | 0.04 | 0.02 | 0.00 | 0.00 | 0.00 | 0.00 |
| 2001 - 2011 | 0.05 | 0.01 | 0.00 | 0.00 | 0.01 | 0.00 |
| Unknown | 0.01 | 0.00 | 0.00 | 0.00 | 0.00 | 0.01 |
| | **0.65** | **0.31** | **0.00** | **0.00** | **0.02** | **0.02** |

Number of floors above ground (by occupied buildings):

| All Occupied Buildings | 1 to 3 | 4 to 7 | 7+ | Unknown |
|---|---|---|---|---|
| 1919 and before | 0.12 | 0.01 | 0.00 | 0.00 |
| 1920 - 1945 | 0.16 | 0.01 | 0.00 | 0.00 |
| 1946 - 1960 | 0.07 | 0.01 | 0.00 | 0.00 |
| 1961 - 1970 | 0.08 | 0.01 | 0.00 | 0.00 |
| 1971 - 1980 | 0.13 | 0.01 | 0.00 | 0.00 |
| 1981 - 1990 | 0.11 | 0.01 | 0.00 | 0.00 |
| 1991 - 2000 | 0.10 | 0.00 | 0.00 | 0.00 |
| 2001 - 2011 | 0.11 | 0.00 | 0.00 | 0.00 |
| Unknown | 0.00 | 0.00 | 0.00 | 0.02 |
| | **0.89** | **0.05** | **0.01** | **0.05** |

| Family Houses | 1 to 3 | Unknown |
|---|---|---|
| 1919 and before | 0.12 | 0.00 |
| 1920 - 1945 | 0.17 | 0.00 |
| 1946 - 1960 | 0.07 | 0.00 |
| 1961 - 1970 | 0.09 | 0.00 |
| 1971 - 1980 | 0.14 | 0.00 |
| 1981 - 1990 | 0.12 | 0.00 |
| 1991 - 2000 | 0.11 | 0.00 |
| 2001 - 2011 | 0.13 | 0.00 |
| Unknown | 0.00 | 0.02 |
| | **0.96** | **0.04** |

| Apartment Buildings | 1 to 3 | 4 to 7 | 7+ | Unknown |
|---|---|---|---|---|
| 1919 and before | 0.08 | 0.04 | 0.00 | 0.00 |
| 1920 - 1945 | 0.07 | 0.05 | 0.00 | 0.00 |
| 1946 - 1960 | 0.09 | 0.05 | 0.00 | 0.00 |
| 1961 - 1970 | 0.05 | 0.08 | 0.02 | 0.00 |

| | | | | |
|---|---|---|---|---|
| 1971 - 1980 | 0.05 | 0.08 | 0.04 | 0.01 |
| 1981 - 1990 | 0.03 | 0.05 | 0.04 | 0.00 |
| 1991 - 2000 | 0.03 | 0.03 | 0.01 | 0.00 |
| 2001 - 2011 | 0.03 | 0.03 | 0.00 | 0.00 |
| Unknown | 0.00 | 0.00 | 0.00 | 0.02 |
| | **0.43** | **0.41** | **0.11** | **0.05** |

Material of bearing walls (by occupied dwellings):

| | Stone, bricks, blocks | Wall panels | Unburnt bricks | Wood | Other | Unknown |
|---|---|---|---|---|---|---|
| 1919 and before | 0.08 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 |
| 1920 - 1945 | 0.12 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 |
| 1946 - 1960 | 0.08 | 0.01 | 0.00 | 0.00 | 0.00 | 0.00 |
| 1961 - 1970 | 0.07 | 0.07 | 0.00 | 0.00 | 0.00 | 0.00 |
| 1971 - 1980 | 0.08 | 0.11 | 0.00 | 0.00 | 0.00 | 0.00 |
| 1981 - 1990 | 0.06 | 0.09 | 0.00 | 0.00 | 0.00 | 0.00 |
| 1991 - 2000 | 0.06 | 0.02 | 0.00 | 0.00 | 0.00 | 0.00 |
| 2001 - 2011 | 0.07 | 0.01 | 0.00 | 0.00 | 0.01 | 0.00 |
| Unknown | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.02 |
| | **0.64** | **0.30** | **0.01** | **0.01** | **0.03** | **0.02** |

| By dwellings | |
|---|---|
| In family houses | In apartment buildings |
| 0.47 | 0.51 |

2. TABULA Project:

By dwellings:

| Large Panel Buildings (Precast concrete) | | Masonry Buildings | |
|---|---|---|---|
| SFH-TH | MFH+AB | SFH-TH | MFH+AB |
| | 0.32 | 0.43 | 0.25 |

3. PAGER:

| **Czech Republic** | 2007 |
|---|---|
| **W** | 0.01 |
| **S3** | 0.05 |
| **S4** | 0.02 |
| **C1** | 0.46 |
| **RM1** | 0.15 |
| **RM2** | 0.31 |

**Suggested typologies:**

(by dwellings, Census 2011)

| | |
|---|---|
| M99+MUN99+MO99/LWAL/RES/EWMA | 0.64 |
| CR+PC/LWAL/RES/EWC | 0.30 |
| M99+ADO+MO99/LWAL/RES/EWMA | 0.01 |
| W+W99/L99/RES/EWW | 0.01 |
| MAT99/L99/RES | 0.04 |

**8) <u>DENMARK:</u>**

1. Statistical Institute:

Buildings, by type, 2012:

| | |
|---|---|
| Detaches one-family house and farm houses | 0.48 |
| Terraced, linked or semi-detached houses | 0.09 |
| Multi-dwelling houses | 0.04 |
| Other residential building | 0.00 |
| Non-residential farm buildings | 0.18 |
| Factories, workshops, etc. | 0.03 |
| Office, trade, inventory, incl. public administration | 0.03 |
| Building for education and research (schools, laboratory etc.) | 0.01 |
| Weekend cottages | 0.09 |
| Non-distributed, unknown | 0.06 |

Dwellings by type and date of construction, 2012:

| | Before 1919 | 1920-1949 | 1950-1969 | 1970-1989 | 1990-1999 | 2000-2011 | Not stated |
|---|---|---|---|---|---|---|---|
| Detached houses/farmhouses | 0.09 | 0.08 | 0.11 | 0.12 | 0.01 | 0.03 | 0.00 |
| Terraced, linked or semi-detached houses | 0.01 | 0.01 | 0.02 | 0.06 | 0.02 | 0.02 | 0.00 |
| Multi-dwelling houses | 0.09 | 0.10 | 0.09 | 0.07 | 0.02 | 0.03 | 0.00 |
| Student hostels | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 |
| Residential buildings for communities | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 |
| Cottages | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 |
| Other | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 |

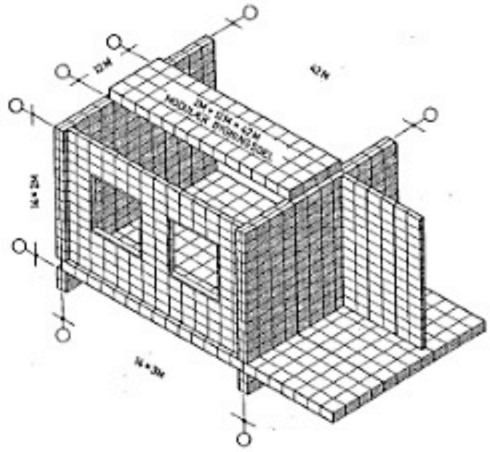
2. Pager:

| Denmark | C3 | UFB3 | UFB4 |
|---|---|---|---|
| Urban | 0.02 | 0.35 | 0.63 |
| Rural | 0.00 | 0.50 | 0.50 |

3. COSTC16:

- Housing is described as 'traditional' up to the middle of the 20th century with two structural elements/materials which are wood and brickwork, on site work.
- The attempts to use new methods didn't start until 1950s.
- The part of housing built in 1950s and not being traditional is using new techniques and materials which can be described as semi-industrialized.

- Buildings from decades after 1960s followed the standard set of 1960s. However, now, the ‘prefabricated’ look is not preferred, instead half-bricked facades as finishing layer rather than concrete or cement based siding.



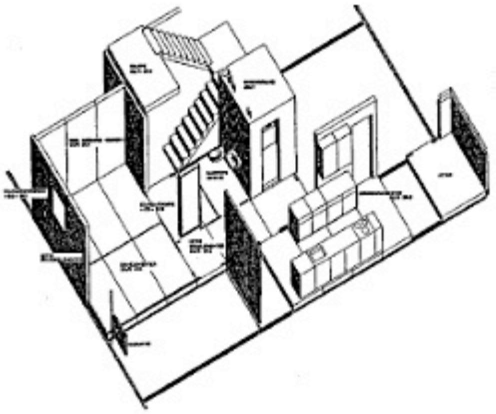


Figure 10 (left). Since the start of the 1960's government supported housing should be designed according to a modular grid of 3M (300 mm) horizontal and 2M (200 mm) vertical, to enable the upcoming of an industry of building elements independent of the single project.
Figure 11 (right). Almost all components in the industrialized housing in Denmark build since the 1960's are modular standardized (Both figures ref. Nissen, 1972).

- Two dominant construction types: One system with load bearing transverse walls and non bearing light weight façade elements and other with load bearing facades of sandwich type and spine wall. The first is far most common and the other based on the use of columns, beams, frames etc. are very seldom.
- Whatever load-bearing system is used, the top floor is always concrete slabs. The roof is either flat (covered with asphalt felt on boards) or hipped (covered with panes of tiles or cement) and in general wooden construction.

4. TABULA Project:

| Building Period | Single Family Houses | Terraced Houses | Block of flats |
|---|---|---|---|
| Before 1850 | 0.02 | 0.00 | 0.00 |
| 1851-1930 | 0.20 | 0.02 | 0.03 |
| 1931-1950 | 0.09 | 0.01 | 0.01 |
| 1951-1960 | 0.07 | 0.01 | 0.00 |
| 1961-1972 | 0.18 | 0.02 | 0.00 |
| 1973-1978 | 0.10 | 0.02 | 0.00 |
| 1979-1998 | 0.08 | 0.05 | 0.01 |
| 1999-2006 | 0.03 | 0.02 | 0.00 |
| After 2007 | 0.02 | 0.01 | 0.00 |
| | **0.79** | **0.15** | **0.06** |

| Building Period | Single Family Houses | Terraced Houses | Block of flats |
|---|---|---|---|
| Before 1850 | Brick | Brick<br>Cavity Wall | Timber framed by a half stone and<br>15% wood |
| 1851-1930 | Brick<br>Cavity Wall | Massive Brick | Brick |
| 1931-1950 | Brick<br>Cavity Wall | Brick<br>Cavity Wall | Massive brick |
| 1951-1960 | Brick<br>Cavity Wall | Brick<br>Cavity Wall | Brick<br>Cavity Wall |
| 1961-1972 | Brick | Brick | Lightweight construction |

| | | | |
|---|---|---|---|
| | Cavity Wall | Cavity Wall | |
| 1973-1978 | Brick<br>+Tiled concrete | Lightweight construction | Brick<br>Cavity Wall |
| 1979-1998 | Brick | Brick<br>+Tiled concrete | Brick |
| 1999-2006 | Lightweight construction | Brick<br>+Tiled concrete | Brick<br>+Tiled concrete |
| After 2007 | Brick | Brick | Brick |

**Suggested typologies:**

(by occupied dwellings, Statistical Institute, 2010 and TABULA Project)

| | |
|---|---|
| M99+CL99+MO99/LWAL/RES/EWMA | 0.23 |
| M99+CL99+MO99/LWAL/RES/EWMA/FC | 0.35 |
| W+W99/LFM/RES | 0.19 |
| CR+CT99/LWAL/RES/EWC | 0.20 |
| MAT99/L99/RES | 0.03 |

**9) <u>ESTONIA:</u>**

1. Census,2011:

Buildings by type and year of construction, 2011:

| BUILDINGS | Before 1946 | 1946-1990 | After 1991 | Unknown |
|---|---|---|---|---|
| Apartment building | 0.04 | 0.06 | 0.01 | 0.00 |
| One-family dwelling | 0.31 | 0.32 | 0.13 | 0.07 |
| Other small residential building | 0.02 | 0.03 | 0.02 | 0.00 |
| Non-residential building with dwelling(s) | 0.00 | 0.00 | 0.00 | 0.00 |
| URBAN | | | | |
| Apartment building | 0.08 | 0.10 | 0.02 | 0.00 |
| One-family dwelling | 0.12 | 0.41 | 0.11 | 0.04 |
| Other small residential building | 0.03 | 0.04 | 0.02 | 0.01 |
| Non-residential building with dwelling(s) | 0.00 | 0.00 | 0.00 | 0.00 |
| RURAL | | | | |
| Apartment building | 0.01 | 0.04 | 0.00 | 0.00 |
| One-family dwelling | 0.41 | 0.27 | 0.15 | 0.08 |
| Other small residential building | 0.01 | 0.02 | 0.01 | 0.00 |
| Non-residential building with dwelling(s) | 0.00 | 0.00 | 0.00 | 0.00 |

Dwellings by type and year of construction, 2011:

| DWELLINGS | Before 1946 | 1946-1990 | After 1991 | Unknown |
|---|---|---|---|---|
| Apartment building | 0.07 | 0.55 | 0.07 | 0.00 |
| One-family dwelling | 0.10 | 0.11 | 0.04 | 0.02 |
| Other small residential building | 0.01 | 0.01 | 0.01 | 0.00 |
| Non-residential building with dwelling(s) | 0.00 | 0.00 | 0.00 | 0.00 |
| URBAN | | | | |
| Apartment building | 0.09 | 0.66 | 0.08 | 0.00 |
| One-family dwelling | 0.02 | 0.07 | 0.02 | 0.01 |
| Other small residential building | 0.01 | 0.01 | 0.01 | 0.00 |
| Non-residential building with dwelling(s) | 0.00 | 0.00 | 0.00 | 0.00 |
| RURAL | | | | |

| | | | | |
|---|---|---|---|---|
| Apartment building | 0.02 | 0.30 | 0.03 | 0.00 |
| One-family dwelling | 0.27 | 0.18 | 0.10 | 0.05 |
| Other small residential building | 0.01 | 0.02 | 0.02 | 0.00 |
| Non-residential building with dwelling(s) | 0.00 | 0.00 | 0.00 | 0.00 |

2. TABULA Project:

- The first apartment buildings composed of precast concrete elements were constructed at the beginning of 1960.
- An overview of apartment buildings in the 1960-1990 period in Rakvere city:

Period 1960-1970: Silicate brick houses

- The exterior walls are made with silicate bricks, precast concrete slabs are used for floors.
- Non-bearing walls are made of bricks with concrete elements.
- Buildings have flat roofs with sand or stone dust, sawdust or glass wool insulation.



Period 1971-1980: Prefabricated small block apartment buildings

- The exterior walls are prefabricated smaller blocks and floors are concrete panels.
- Non-bearing walls are in concrete block or silicate bricks.
- Buildings have mostly flat roofs with stone dust or sand insulation layer.



Period 1981-1990: 1st type/ Prefabricated small block apartment buildings/3-storey small panel houses:

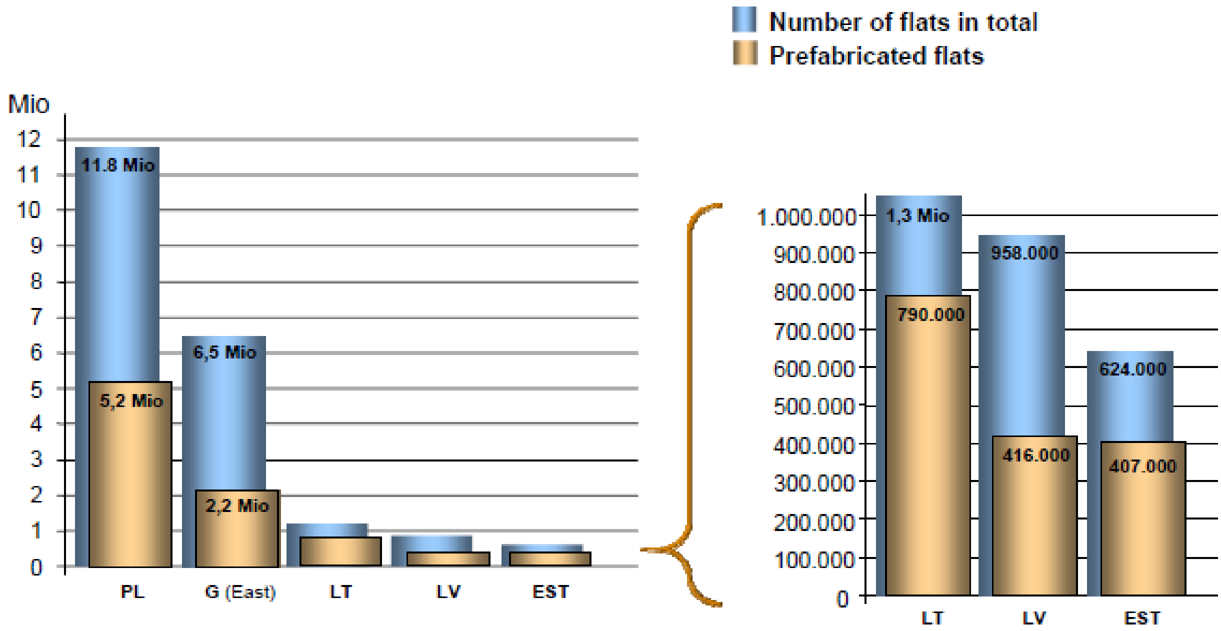
- The exterior walls and floors are prefabricated smaller panels.
- Non-bearing walls are small plocks and bricks.
- Buildings have mostly flat roofs and roof with traces insulation layer.




Period 1981-1990: 2nd type-Narva/ Apartment buildings/5-storey large panel houses:

- The exterior walls and floors are prefabricated smaller panels.
- Non-bearing walls are small plocks.
- Buildings have mostly flat roofs insulation and waterproofing layer.

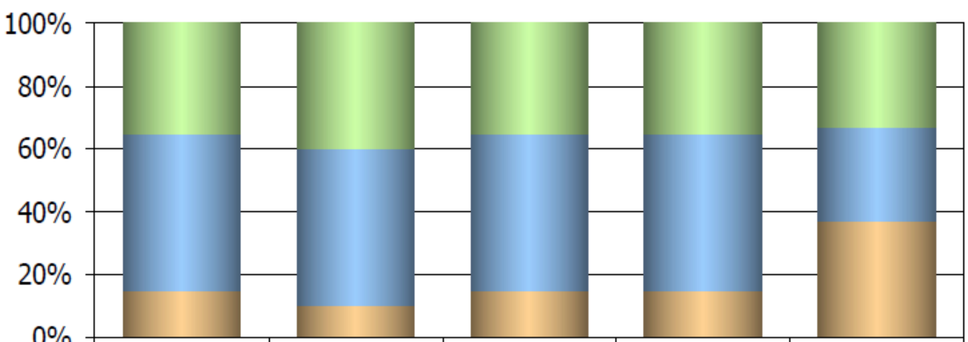

3. BEEN Project:




<u>Standardized multi-storey residential buildings (Prefabricated Flats) constructed 1950-1990:</u>

Types of Prefabricated Flats:

1. Type 1: Brickwork and block construction
2. Type 2: Single-layer concrete slabs (1962 to 1980, in Eastern Europe up to 1988)
3. Type 3: Triple-layer concrete slabs (sandwich panels)



| | EST | LV | LT | PL | D (Ost) |
|---|---|---|---|---|---|
| Typ 1 | 35 | 40 | 35 | 35 | 33 |
| Typ 2 | 50 | 50 | 50 | 50 | 30 |
| Typ 3 | 15 | 10 | 15 | 15 | 37 |

**10) <u>FINLAND:</u>**

1) Statistical Institute, 2012:

| | Detached house | Attached house | Block of flats |
|---|---|---|---|
| By buildings | 0.89 | 0.06 | 0.05 |
| By dwellings | 0.41 | 0.14 | 0.45 |

| | By dwellings | By buildings |
|---|---|---|

| | Detached house | Attached house | Block of flats | Detached house | Attached house | Block of flats |
|---|---|---|---|---|---|---|
| - 1920 | 0.02 | 0.00 | 0.01 | 0.05 | 0.00 | 0.00 |
| 1921 - 1939 | 0.02 | 0.00 | 0.02 | 0.05 | 0.00 | 0.00 |
| 1940 - 1959 | 0.08 | 0.00 | 0.04 | 0.19 | 0.00 | 0.01 |
| 1960 - 1969 | 0.04 | 0.01 | 0.08 | 0.09 | 0.00 | 0.01 |
| 1970 - 1979 | 0.05 | 0.03 | 0.12 | 0.12 | 0.01 | 0.01 |
| 1980 - 1989 | 0.07 | 0.05 | 0.06 | 0.15 | 0.02 | 0.01 |
| 1990 - 1999 | 0.04 | 0.03 | 0.05 | 0.09 | 0.01 | 0.01 |
| 2000 - 2009 | 0.05 | 0.02 | 0.05 | 0.10 | 0.01 | 0.00 |
| 2010 - | 0.01 | 0.00 | 0.02 | 0.03 | 0.00 | 0.00 |
| Unknown | 0.01 | 0.00 | 0.00 | 0.01 | 0.00 | 0.00 |

| (by residential buildings) | Stone | Wood | Other, unknown |
|---|---|---|---|
| Construction material of vertical system | 0.13 | 0.84 | 0.03 |

| | 1-2 storey | 3-9 storey | 10+ storey | unknown |
|---|---|---|---|---|
| All buildings | 0.95 | 0.04 | 0.00 | 0.01 |
| Dwellings | 0.60 | 0.40 | 0.00 | 0.00 |
| Blocks of flats | 0.30 | 0.69 | 0.00 | 0.01 |

2) NORDEN study:

External walls in these houses are solid or based on a wooden frame construction.

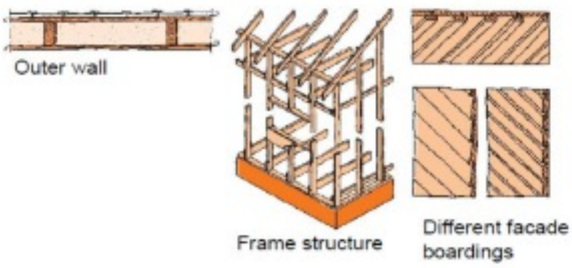



*Figure 17. Main construction principle of typical Finnish single-family houses. [12]*

Veteran houses from 1940's and 1950's have typically 1,5 stories, a cellar and a characteristic steep roof. The floor area is typically below100 $m^2$, about 60-80 $m^2$.

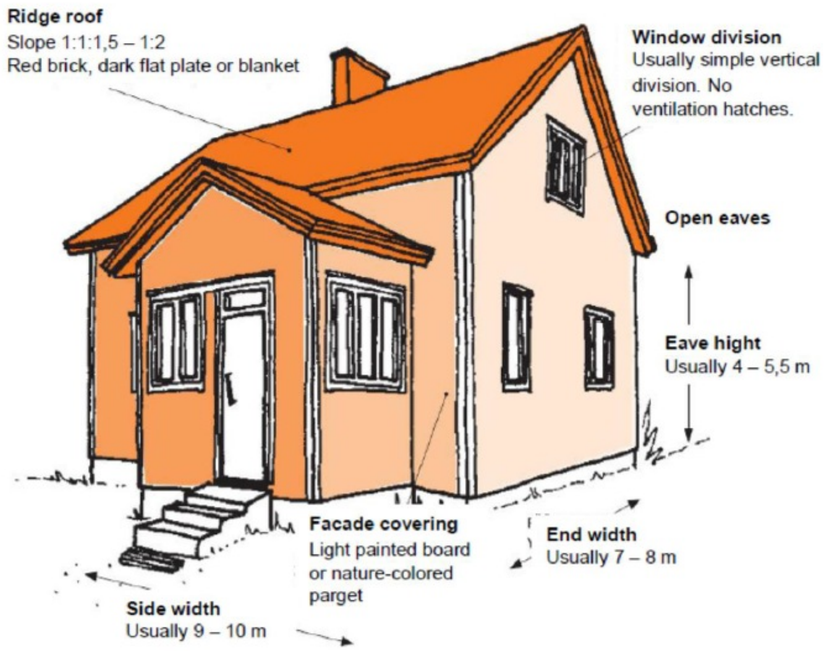



*Figure 18. Typical house from 1940's and 1950's, so called Veteran house. [2]*

The typical single-family houses from 1960's have a floor area about 60-80 m$^2$ and instead of a steep roof as for Veteran houses, they are characterized by a more gently sloped roof.

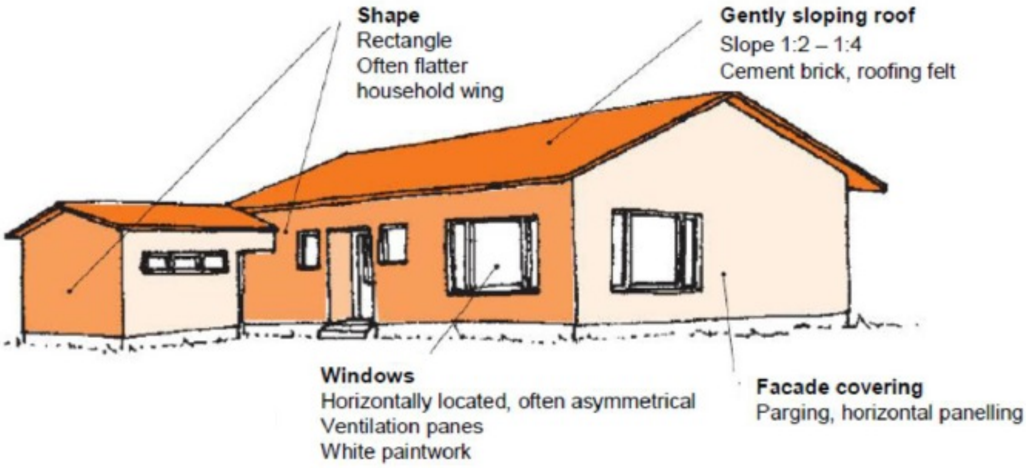



*Figure 19. Typical single-family houses from 1960's. [13]*

The typical single-family houses from 1970's usually have a floor area about 100 m$^2$ and have windows with triple glazing. Two variants for this type of typical single-family house can be distinguished (see Figure 20). A first variant, in L-shape or rectangular, with a flat roof, has usually one story but can be build with 2 stories for hillside solutions. The second variant has a rectangular shape, is 1,5 stories high and sometimes has a part cellar. However, the two variants both have large windows, a covered balcony and are finished similarly by use of fairfaced brick or dark staining.

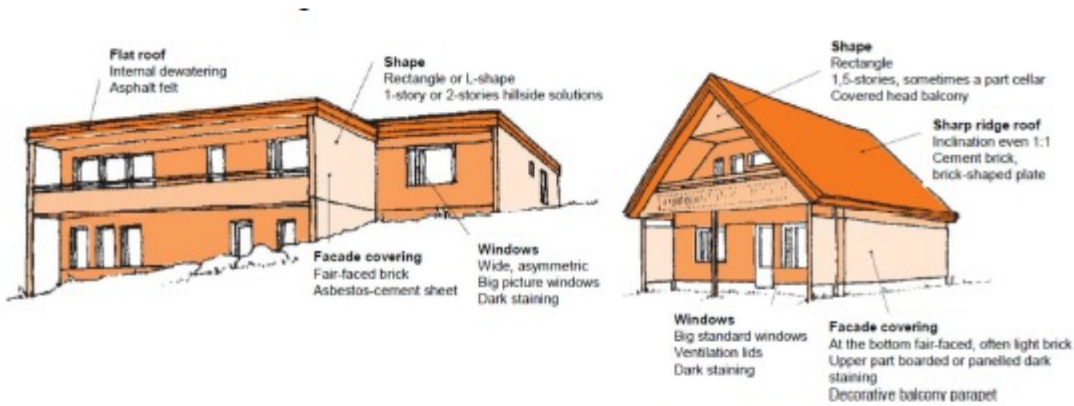



*Figure 20. Typical single-family houses from 1970's [13].*

3) SBI 2012:

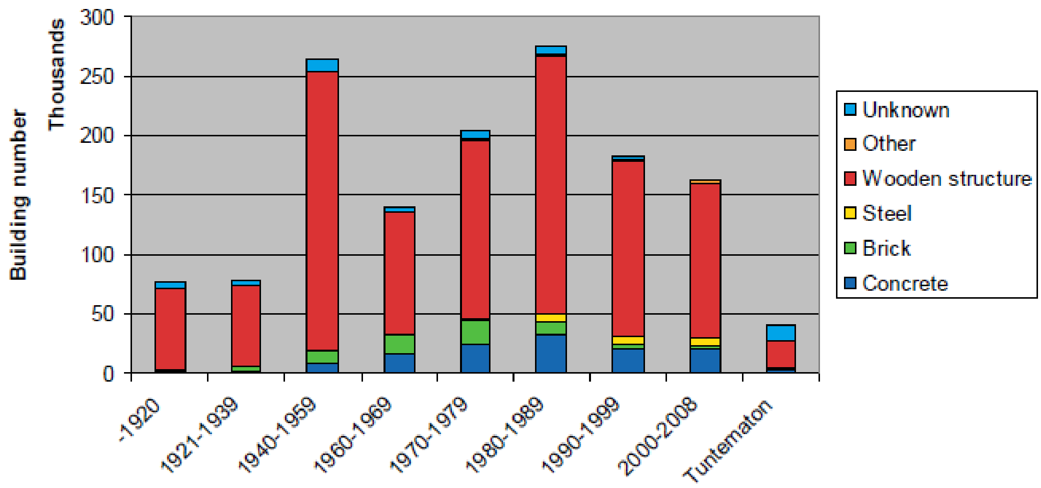



Figure 26. Load-bearing material by building number and construction year (background data obtained from Arja Tiihonen, Statistics Finland, and personal contact).

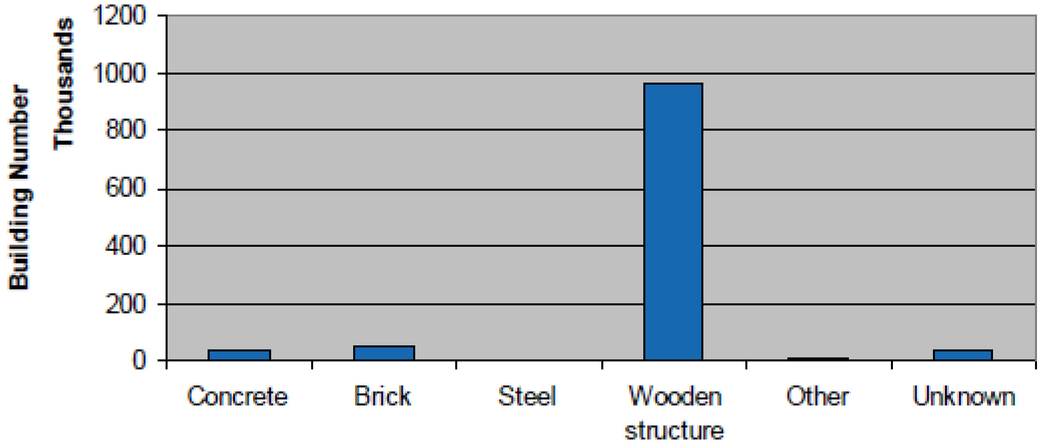



Figure 28. Load-bearing material for detached houses and by building number (background data obtained from Arja Tiihonen, Statistics Finland, and personal contact).

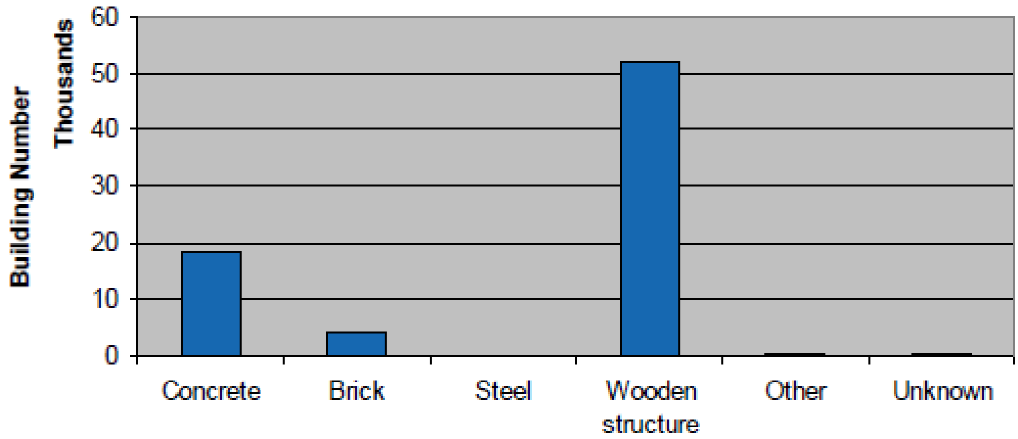



Figure 29. Load-bearing material for Attached houses and by building number (background data obtained from Arja Tiihonen, Statistics Finland, and personal contact).

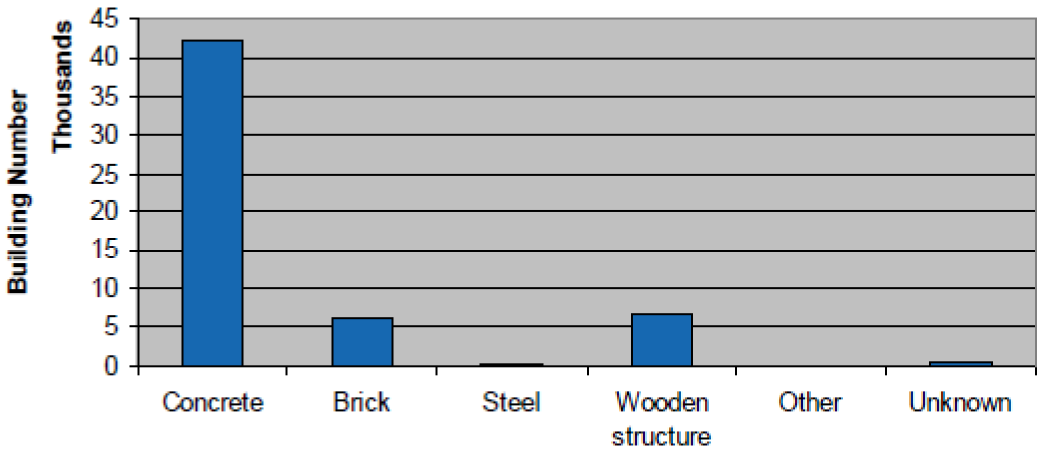



Figure 30. Load-bearing material for Residential block of flats and by building number (background data obtained from Arja Tiihonen, Statistics Finland, and personal contact).

**Suggested typologies:**

(by buildings, Statistical Institute, 2012)

| | |
|---|---|
| M99+CL99+MO99/LWAL/RES/EWMA | 0.05 |
| CR+CT99/L99/RES | 0.07 |
| W+W99/LFM/RES | 0.84 |
| MAT99/L99/RES | 0.04 |

**11) FRANCE:**

1. Statistical Institute:

Principal residences, 0.84 of dwelling stock, 2008:

| | Before 1949 | 1949-1974 | 1975- 1989 | 1990-2005 | 2005- 2008 |
|---|---|---|---|---|---|
| **Houses** | 0.16 | 0.10 | 0.12 | 0.09 | 0.10 |
| **Apartments** | 0.09 | 0.14 | 0.07 | 0.06 | 0.08 |

2. NERA Workshop:

- Strong regional variabilities of historical buildings: e.g., **Wooden buildings** only in Normandie and Alsace Region - **Adobe** in the Alps - Not Rubble Stones in Bretagne and Centre....
- Few Steel buildings for housings
- Few RC-Frame buildings, more RC-SW
- 1950-1970: urbanization in RC using Tunnel techniques (cheap and fast)
- Historical center: masonry with low level of quality
- French cities have the same scheme: old down-town with old regional material (wooden, rubble stones, adobe ...), first ring with mixed buildings, second/third with individual masonry building (manufactured Cement units) and RC-SW buildings

3. PAGER:

| France | C1L | C1M | C3L | C3M | UFB1 | UFB3 | UFB4 | UNK |
|---|---|---|---|---|---|---|---|---|
| Urban/Rural | 0.05 | 0.05 | 0.12 | 0.20 | 0.14 | 0.14 | 0.22 | 0.09 |

4. COST C16:
    - The traditional apartment block in 'Haussman period' and 1900s period: Heavy construction with stone and brick walls, wooden floors and pitched roofs, located in historical urban centres. The number of storeys is up to 4 or 5.
    - In 1952, large use of concrete system with large panels and formed concrete in residential buildings
    - After 1964, the main building systems are mainly based on concrete technologies.
    - The more common system used especially in multiple dwellings is a load bearing structure composed of RC shells arranged according to parallel layout grid and concrete slabs. This system enables reusable forms and used with a fixed grid with, the tunnel formwork enables the simultaneous concreting of walls and slab. This tunnel formwork system was frequently used in the period 1955-1965 for the building of 'grand ensembles'. Generally, at this period, the roof was a concrete roof.
    - A variant of these systems consists in replacing concrete walls by concrete block walls and the concrete slab by a floor made with beams and filler blocks. It is largely used, actually, for low rise buildings up to 5 floors and in building of individual houses and pavilions. The roof is either a flat or pitched.
    - The average floor space in dwellings/apartments is around 42 $m^2$/person.

## 12) HUNGARY:

1. Census 2011:

WALLS OF THE BUILDINGS:

According to the technology and the materials used in the construction of external walls, the following categories have been used:

***Traditional walls***:

- brick, stone, manual walling element
- adobe, clay, stamped earth
- wood
- other material, like sheet iron, roofing iron etc.

In case of walls of adobe, clay and wood, a distinction between walls with or without not solid basement has been made.

The data with the label „wood without solid basement" show the respective dwellings and seasonal/holiday housing units together.

***Modern building technologies***:

- medium or large block: prefabricated elements with a size of a half or full floor, that cannot be placed manually. The material used is lightweight concrete, concrete, armoured concrete, ceramic etc.

- cast concrete: cast concrete filled on site, into formworks
- panel: highly elaborated, prefabricated, structured wall, usually placed with an elevating machine, the walls are fixed to each other at the edges.

The data with the label „wood without solid basement" show the respective dwellings and seasonal/holiday housing units together.

(Occupied Dwellings)

| Material of outer walls | before 1946 | 1946–1960 | 1961–1970 | 1971–1980 | 1981–1990 | 1991–2000 | 2001–2005 | 2006–2011 |
|---|---|---|---|---|---|---|---|---|
| brick, stone, manual walling element | 0.12 | 0.07 | 0.10 | 0.12 | 0.09 | 0.06 | 0.05 | 0.03 |
| middle or large block, cast concrete | 0.00 | 0.00 | 0.01 | 0.02 | 0.02 | 0.00 | 0.00 | 0.00 |
| panel | 0.00 | 0.00 | 0.01 | 0.07 | 0.05 | 0.00 | 0.00 | 0.00 |
| wood | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 |
| adobe, mud, etc. with solid basement | 0.04 | 0.03 | 0.02 | 0.01 | 0.00 | 0.00 | 0.00 | 0.00 |
| adobe, mud, etc. without solid basement | 0.03 | 0.01 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 |
| other | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 |
| | **0.19** | **0.12** | **0.15** | **0.22** | **0.16** | **0.07** | **0.05** | **0.04** |

| | Residential buildings built | | | | | | | |
|---|---|---|---|---|---|---|---|---|
| | before 1946 | 1946–1960 | 1961–1970 | 1971–1980 | 1981–1990 | 1991–2000 | 2001–2005 | 2006–2011 |
| **Height (ground-floor, floors)** | | | | | | | | |
| **Only ground-floored** | **0.20** | **0.15** | **0.15** | **0.16** | **0.14** | **0.08** | **0.05** | **0.03** |
| **More floors together** | **0.01** | **0.00** | **0.01** | **0.01** | **0.01** | **0.00** | **0.00** | **0.00** |
| Of which: | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 |
| 1 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 |
| 2 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 |
| 3 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 |
| 4 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 |
| 5– | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 |
| Total | **0.21** | **0.15** | **0.15** | **0.17** | **0.15** | **0.08** | **0.05** | **0.04** |

- 99.6% Residential buildings
- Of residential buildings:
  - 95 % family house, 1-3 dwelling residential building; 4% residential building of 4–dwellings; 1% holiday building
  - 96 % Ground floor (0 floor), 1% in each floor from 1 to 4
- Of dwellings in residential buildings:
  - 63% at ground floor, 7% at 1-2 floors, 18% at 3-4 floors, 12% at 5 or more floors

2. Statistics Institute:

Built dwellings by vertical load bearing capacity of wall, 1971–2011

| Period, year | Of which wall type | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|
| | panel | cast | block | brick-(ceramic) | manual building unit | adobe, cob wall | wooden frame structure | frame structure prepared on site | other and mixed |
| 1971– | 0.05 | 0.00 | 0.02 | 0.08 | 0.03 | 0.01 | 0.00 | 0.00 | 0.02 |

| | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|
| 1975 | | | | | | | | | |
| 1976–1980 | 0.07 | 0.01 | 0.01 | 0.07 | 0.03 | 0.00 | 0.00 | 0.00 | 0.01 |
| 1981–1985 | 0.06 | 0.01 | 0.01 | 0.06 | 0.03 | 0.00 | 0.00 | 0.00 | 0.00 |
| 1986–1990 | 0.03 | 0.01 | 0.00 | 0.04 | 0.04 | 0.00 | 0.00 | 0.00 | 0.00 |
| 1991–1995 | 0.00 | 0.00 | 0.00 | 0.02 | 0.03 | 0.00 | 0.00 | 0.00 | 0.00 |
| 1996–2000 | 0.00 | 0.00 | 0.00 | 0.03 | 0.02 | 0.00 | 0.00 | 0.00 | 0.00 |
| 2001–2005 | 0.00 | 0.00 | 0.00 | 0.07 | 0.00 | 0.00 | 0.00 | 0.01 | 0.00 |
| 2005-2011 | 0.00 | 0.00 | 0.00 | 0.07 | 0.00 | 0.00 | 0.00 | 0.02 | 0.00 |
| | **0.22** | **0.04** | **0.04** | **0.45** | **0.17** | **0.02** | **0.01** | **0.02** | **0.04** |

| Among all dwellings | Of which wall type | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|
| | panel | cast | block | brick-(ceramic) | manual building unit | adobe, cob wall | wooden frame structure | frame structure prepared on site | other and mixed |
| | **0.11** | **0.02** | **0.02** | **0.22** | **0.08** | **0.01** | **0.00** | **0.01** | **0.02** |

3. Pager:

(Urban/Rural)

| | |
|---|---|
| **W** | 0.15 |
| **C** | 0.07 |
| **A** | 0.22 |
| **UFB** | 0.57 |

4. Cost C16:
    - 65% of Hungarian population live in towns
    - The average size of flats is 68 $m^2$.The average size of household is 2.7person/family.
    - The post-war housing in numbers:

| In thousands | 1960-1969 | 1970-1979 | 1980-1989 | 1990-1992 |
|---|---|---|---|---|
| Precast concrete houses | 41 | 275 | 227 | 8 |
| Houses built with highly Industrialized methods | 237 | | | |
| Houses built with brick or other Traditional methods | 3292 | | | |

- The housing stock has three main type of buildings:
    - Buildings for one/two families: Detached houses; in all villages, in suburbs of towns and in outskirts of cities. (100 years old earthen building, decorative art-novac villa, more simple designed cube-forms from 60s). This part is 58% of total stock.
    - Buildings for 4-30 families: Tenement houses; 4-8-12 to 30 dwellings in 2-4 storey buildings, mostly built before WWII, in historic parts of cities. Small amount was built during 60s and 70s. in the last decade, new generation of tenement houses emerged partly in rural areas and partly in detached housing areas. This part is 24% of total stock.
    - Housing estates, big-scale buildings: Units of housing estates; 5-11 storey buildings, built with RC Panels and light-concrete blocks or in situ-concrete. This part is around 18% of total used flats.
- Large-panel buildings, 1st generation :1960-1979

    - In 1960-1969 is 7.4% and in 1970-1979 49.9 % of large panel units.
    - Small flats, average built up area for four persons were 48 $m^2$.
- Large-panel buildings, 1st generation :1980-1989
    - 41.2% of large panel units
    - Slightly bigger flats, average built up area for four persons were 54-63 $m^2$.
- Almost 98% of these blocks with flat roofs
- Slabs are concerete.

5. Various: Building types:
- Panel buildings" - one-fifth of building stock built with industrial technology during the 60s-80s
    - Conventional technology (brick buildings) - multi-family
    - Conventional technology - single-family houses

**Suggested typologies:**

(by occupied dwellings, Census 2011)

| | |
|---|---|
| M99+MUN99+MO99/LWAL/RES/EWMA | 0.63 |
| CR+CT99/L99/RES | 0.07 |
| CR+PC/LWAL /RES/EWC | 0.13 |
| W+W99/LFM/RES/EWW | 0.01 |
| M99+ADO+MO99/LWAL/RES /EWMA | 0.15 |
| MAT99/L99/RES | 0.01 |

**13) LATVIA:**

1. Census , 2011:

(byconventional dwellings)

| | until 1918 | 1919 - 1945 | 1946 - 1960 | 1961 - 1970 | 1971 - 1980 | 1981 - 1990 | 1991 - 2000 | 2001 - 2005 | 2006 - 2011 | Not stated |
|---|---|---|---|---|---|---|---|---|---|---|
| Individual houses | 0.02 | 0.08 | 0.04 | 0.03 | 0.03 | 0.04 | 0.02 | 0.01 | 0.01 | 0.00 |
| Two-dwelling buildings | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 |
| Semi-detached houses | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 |
| Row houses | 0.00 | 0.00 | 0.00 | .00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 |
| Apartment houses | 0.08 | 0.04 | 0.05 | 0.14 | 0.18 | 0.16 | 0.02 | 0.01 | 0.02 | 0.00 |
| Non-residential buildings | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 |
| Not stated | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.01 |
| | **0.10** | **0.12** | **0.09** | **0.17** | **0.21** | **0.20** | **0.05** | **0.01** | **0.04** | **0.01** |

2. Statistical Institute:

Housing Stock by floor space, 2009

| | 2009 |
|---|---|
| HOUSING STOCK - TOTAL | 61.1 |

| | |
|---|---|
| Average per inhabitant, m² | 27.2 |
| Urban housing stock - total | 39.7 |
| Average per urban inhabitant, m² | 26.1 |
| Rural housing stock - total | 21.4 |
| Average per rural inhabitant, m² | 29.5 |

Population by type of building containing dwellings, 2000:

| Single dwelling house | Two dwelling house | 3-9 dwelling house | 10-19 dwelling house | 20-29 dwelling house | 30-49 dwelling house | 50 and more dwelling house |
|---|---|---|---|---|---|---|
| 0.26 | 0.04 | 0.10 | 0.09 | 0.05 | 0.11 | 0.34 |

Population by type of material of outer walls of buildings constructed, 2000:

| brick or stone external walls | concrete or reinforced concrete external walls | reside in buildings with wood external walls | external walls constructed from several materials | external walls constructed from other material |
|---|---|---|---|---|
| 0.39 | 0.32 | 0.18 | 0.10 | 0.01 |

3. Pager:

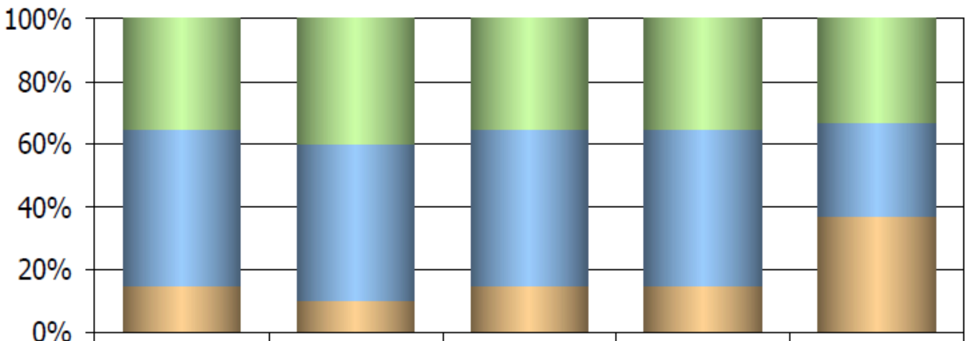
| Latvia | **W1** | **W4** | **S2** | **S5** | **PC1** | **A** | **UCB** |
|---|---|---|---|---|---|---|---|
| Urban/Rural | 0.02 | 0.02 | 0.09 | 0.44 | 0.17 | 0.05 | 0.22 |

4. BEEN Project:

Standardised multi-storey residential buildings (Prefabricated Flats) constructed 1950-1990:

Types of Prefabricated Flats:

4. Type 1: Brickwork and block construction
5. Type 2: Single-layer concrete slabs (1962 to 1980, in Eastern Europe up to 1988)
6. Type 3: Triple-layer concrete slabs (sandwich panels)




| | EST | LV | LT | PL | D (Ost) |
|---|---|---|---|---|---|
| Typ 1 | 35 | 40 | 35 | 35 | 33 |
| Typ 2 | 50 | 50 | 50 | 50 | 30 |
| Typ 3 | 15 | 10 | 15 | 15 | 37 |

**14) LITHUNIA:**

1. Census 2001:

Buildings by period of construction and construction materials of the outer walls:

(by buildings)

| | Brick, stone , block | Wood | Various materials | Other |
|---|---|---|---|---|
| Total | | | | |
| ..before 1919 | 0.01 | 0.05 | 0.00 | 0.00 |
| ..1919-1945 | 0.02 | 0.18 | 0.01 | 0.00 |
| ..1946-1960 | 0.04 | 0.13 | 0.02 | 0.00 |
| ..1961-1970 | 0.08 | 0.05 | 0.02 | 0.00 |
| ..1971-1980 | 0.12 | 0.03 | 0.02 | 0.01 |
| ..1981-1990 | 0.10 | 0.01 | 0.02 | 0.02 |
| ..1991-2000 | 0.05 | 0.01 | 0.01 | 0.00 |
| ..2001 | 0.00 | 0.00 | 0.00 | 0.00 |
| Urban | | | | |
| ..before 1919 | 0.01 | 0.03 | 0.00 | 0.00 |
| ..1919-1945 | 0.03 | 0.12 | 0.01 | 0.00 |
| ..1946-1960 | 0.08 | 0.12 | 0.03 | 0.00 |
| ..1961-1970 | 0.10 | 0.03 | 0.02 | 0.01 |
| ..1971-1980 | 0.12 | 0.01 | 0.01 | 0.02 |
| ..1981-1990 | 0.11 | 0.01 | 0.01 | 0.02 |
| ..1991-2000 | 0.10 | 0.00 | 0.01 | 0.01 |
| ..2001 | 0.00 | 0.00 | 0.00 | 0.00 |
| Rural | | | | |
| ..before 1919 | 0.01 | 0.06 | 0.00 | 0.00 |
| ..1919-1945 | 0.01 | 0.21 | 0.01 | 0.00 |
| ..1946-1960 | 0.02 | 0.14 | 0.01 | 0.00 |
| ..1961-1970 | 0.06 | 0.07 | 0.02 | 0.00 |
| ..1971-1980 | 0.12 | 0.03 | 0.02 | 0.00 |
| ..1981-1990 | 0.09 | 0.01 | 0.03 | 0.02 |
| ..1991-2000 | 0.03 | 0.01 | 0.00 | 0.00 |
| ..2001 | 0.00 | 0.00 | 0.00 | 0.00 |

2. Census 2011:

Type of conventional dwellings by date of construction:

| TOTAL | one-dwelling building | dwelling in a two-dwelling building | dwelling in an apartment building | |
|---|---|---|---|---|
| <1919 | 0.02 | 0.00 | 0.01 | **0.03** |
| 1919–1945 | 0.06 | 0.01 | 0.03 | **0.10** |
| 1946–1960 | 0.06 | 0.01 | 0.03 | **0.10** |
| 1961–1970 | 0.05 | 0.01 | 0.12 | **0.17** |
| 1971–1980 | 0.05 | 0.00 | 0.17 | **0.23** |
| 1981–1990 | 0.05 | 0.00 | 0.17 | **0.22** |
| 1991–2000 | 0.02 | 0.00 | 0.04 | **0.07** |

| | | | | |
|---|---|---|---|---|
| 2001–2005 | 0.01 | 0.00 | 0.01 | **0.02** |
| ≥2006 | 0.02 | 0.00 | 0.02 | **0.04** |
| Not indicated | 0.02 | 0.00 | 0.00 | **0.02** |
| | **0.36** | **0.04** | **0.60** | |

| URBAN | one-dwelling building | dwelling in a two-dwelling building | dwelling in an apartment building | |
|---|---|---|---|---|
| <1919 | 0.00 | 0.00 | 0.02 | **0.02** |
| 1919–1945 | 0.02 | 0.01 | 0.04 | **0.07** |
| 1946–1960 | 0.03 | 0.01 | 0.03 | **0.07** |
| 1961–1970 | 0.02 | 0.01 | 0.16 | **0.19** |
| 1971–1980 | 0.02 | 0.00 | 0.23 | **0.25** |
| 1981–1990 | 0.02 | 0.00 | 0.23 | **0.25** |
| 1991–2000 | 0.02 | 0.00 | 0.06 | **0.08** |
| 2001–2005 | 0.01 | 0.00 | 0.01 | **0.02** |
| ≥2006 | 0.01 | 0.00 | 0.03 | **0.04** |
| Not indicated | 0.00 | 0.00 | 0.00 | **0.00** |
| | **0.15** | **0.04** | **0.81** | |

| RURAL | one-dwelling building | dwelling in a two-dwelling building | dwelling in an apartment building | |
|---|---|---|---|---|
| <1919 | 0.04 | 0.01 | 0.01 | **0.05** |
| 1919–1945 | 0.15 | 0.01 | 0.01 | **0.17** |
| 1946–1960 | 0.13 | 0.01 | 0.01 | **0.15** |
| 1961–1970 | 0.10 | 0.01 | 0.04 | **0.14** |
| 1971–1980 | 0.12 | 0.01 | 0.05 | **0.18** |
| 1981–1990 | 0.11 | 0.00 | 0.04 | **0.15** |
| 1991–2000 | 0.04 | 0.00 | 0.01 | **0.05** |
| 2001–2005 | 0.01 | 0.00 | 0.00 | **0.02** |
| ≥2006 | 0.03 | 0.00 | 0.00 | **0.04** |
| Not indicated | 0.05 | 0.00 | 0.00 | **0.05** |
| | **0.78** | **0.05** | **0.17** | |

| | Average useful floor area per occupant, $m^2$ | Average useful floor area per dwelling, $m^2$ |
|---|---|---|
| Total | 26.2 | 63.1 |
| Urban | 24.9 | 59.6 |
| Rural | 28.6 | 70.3 |

3. TABULA:

More than 60% of Lithuanian population resides in multi-apartment buildings constructed during 1961-1990.

| Population (in mil.) | Number of Dwellings | Of these in prefabricated buildings | Occupants per flat |
|---|---|---|---|
| 3.5 | 1295000 | 790000 | 2.7 |

Main building types in Lithuania:

| Type | Construction Years | Construction Features | Percent of three different types of prefabricated housing |
|---|---|---|---|
| Type 1 | 1950 to 1965 | Masonry construction (bricks), Modular | 35.0% |

| | | | |
|---|---|---|---|
| | | construction (blocks) | |
| Type 2 | 1962 to approx. 1990 | Exterior walls constructed of one-storey, single layer concrete slabs | 50.0% |
| Type 3 | From 1975 | One storey, triple-layer concrete slabs (sandwich panels) | 15.0% |
| New Buildings | From 1990 | Usually individual constructions rather than prefabricated housing | |

4. PAGER:

| Lithuania | W | PC4 | RS5 | DS | UFB | UCB | UNK |
|---|---|---|---|---|---|---|---|
| Urban | 0.11 | 0.17 | 0.07 | 0.00 | 0.07 | 0.55 | 0.03 |
| Rural | 0.26 | 0.11 | 0.00 | 0.06 | 0.06 | 0.46 | 0.05 |

**Suggested typologies:**

(by buildings, Census, 2012)

| | Urban | Rural |
|---|---|---|
| M99+MUN99+MO99/LWAL/RES/EWMA | 0.55 | 0.34 |
| W+W99/LFM /RES | 0.31 | 0.53 |
| MAT99/L99/RES | 0.14 | 0.13 |

**15) LUXEMBOURG:**

1) Census 2011:

Buildings by type and date of construction:

| | Single family house | Double detached house | Row house | Multi family house | |
|---|---|---|---|---|---|
| Before 1919 | 0.04 | 0.04 | 0.04 | 0.01 | **0.12** |
| 1919-1945 | 0.02 | 0.05 | 0.07 | 0.01 | **0.15** |
| 1946-1960 | 0.03 | 0.04 | 0.04 | 0.01 | **0.14** |
| 1961-1970 | 0.04 | 0.03 | 0.02 | 0.01 | **0.10** |
| 1971-1980 | 0.07 | 0.03 | 0.02 | 0.01 | **0.13** |
| 1981-1990 | 0.07 | 0.02 | 0.01 | 0.01 | **0.11** |
| 1991-2000 | 0.08 | 0.03 | 0.01 | 0.01 | **0.13** |
| 2001-2010 | 0.05 | 0.03 | 0.02 | 0.02 | **0.12** |
| | **0.41** | **0.27** | **0.22** | **0.09** | |

| Average dwelling size ( m²) | Average size of households | Average dwelling size per capita ( m²) |
|---|---|---|
| 105.5 | 1.94 | 59.4 |

**16) MALTA:**

1. Census, 2005:

(by occupied dwellings)

| | Terraced House | Semi-detached House | Fully-detached House | Maisonette | Flat/ Penthouse | Other | |
|---|---|---|---|---|---|---|---|
| Before1918 | 0.07 | 0.00 | 0.00 | 0.02 | 0.01 | 0.02 | **0.12** |
| 1919-1945 | 0.05 | 0.00 | 0.00 | 0.03 | 0.01 | 0.01 | **0.10** |
| 1946-1955 | 0.03 | 0.00 | 0.00 | 0.02 | 0.02 | 0.01 | **0.07** |
| 1956-1960 | 0.01 | 0.00 | 0.00 | 0.01 | 0.01 | 0.00 | **0.04** |
| 1961-1965 | 0.01 | 0.00 | 0.00 | 0.01 | 0.01 | 0.00 | **0.04** |
| 1966-1970 | 0.02 | 0.00 | 0.00 | 0.01 | 0.02 | 0.00 | **0.06** |
| 1971-1980 | 0.06 | 0.01 | 0.01 | 0.03 | 0.05 | 0.01 | **0.16** |
| 1981-1990 | 0.09 | 0.01 | 0.01 | 0.04 | 0.04 | 0.01 | **0.19** |
| 1991-1995 | 0.03 | 0.01 | 0.00 | 0.02 | 0.03 | 0.00 | **0.10** |
| 1996-2000 | 0.01 | 0.00 | 0.00 | 0.02 | 0.03 | 0.00 | **0.07** |
| 2001-2005 | 0.00 | 0.00 | 0.00 | 0.01 | 0.02 | 0.00 | **0.03** |
| | **0.39** | **0.04** | **0.03** | **0.22** | **0.23** | **0.08** | |

2. COST C16:
    - Maltese housing stock is based on stone tradition, the local indigenous material globigerina limestone, commonly called 'franka' stone.
    - All walls are load-bearing with no frame structures, so building rarely exceed four floors, comprising units of two storey houses and flats.
    - The post-war housing stock composed of terraced houses.
    - Apartments are very rare.

Figure 13: Mix of four and two storey housing in Qormi, Malta.

3. ELIH MED Study:

| | Dwellings | | Buildings | | | | | |
|---|---|---|---|---|---|---|---|---|
| | Single | Multi | Single | Multi | Masonry | Interior Wall | Floors | Roof |
| Before 1945 | 28400 | 2081 | 25279 | 260 | Limestone | Limestone | Limestone | Flat |
| After 1945 | 77374 | 30488 | 65049 | 3811 | Limestone/ Concrete brick | Limestone/ Concrete brick | Concrete | Flat |

According to the Maltese national statistics office (2005) as provided by the Maltese partner, the building stock in Malta differs slightly from the typologies presented by the IMPRO Building study. These differences are listed below:

- there are single-family houses and multi-family houses, but no high-rise buildings
- all buildings have a flat roof
- all buildings constructed before about 1945 were made of limestone (external walls, internal walls and floors)
- after about 1945 concrete was used for the floors, and walls were constructed both of limestone and concrete bricks, often using a mixture of the two in the same construction.

After analyzing the typologies presented, the results showed that the most commonly used materials in the region included: masonry bearing walls for earlier housing, and concrete frame with masonry (brick) infill or precast concrete units for most of the post war construction.

4. Various sources:
   I. Web source:
      *(http://www.academia.edu/1071928/A_comparative_study_of_the_implementation_of_the_energy_certification_of_residential_properties_in_Malta_in_compliance_with_the_Energy_Performance_of_Buildings_Directive)*
      - Residential property in Malta is generally constructed with a flat concrete roof, with walls in either limestone or concrete brick.
      - The traditional construction consists of a double leaf limestone wall.

Statistics for 2005 indicate a total of 139,178 (71%) occupied dwellings, 10,028 (5%) holiday homes and 43,108 (23%) vacant dwellings in Malta. (National Statistics Office, Malta, 2005) Out of the occupied dwellings a total of 123,195 (91%) are terraced houses (57,037), maisonettes (32,206), or flats (33,952).Since flats and maisonettes are predominantly terraced, it can be concluded that detached and semi-detached properties constitute approximately 9% of total occupied dwellings. This is significantly less than the EU average which is 34.3% for detached houses and 23% for semi-detached houses in 2009.(Eurostat, 2011)According to the 2009 Eurostat statistics, the average number of rooms per capita in Maltese dwellings is 2.0, which compares favourably with the EU average of 1.7. To summarise therefore, it would appear that although property in Malta is generally more spacious internally, the predominantly terraced nature of construction allows for the more effective use of space, with an inherently energy efficient mode of construction. The exposed wall area of a semi-detached property is generally more than twice as large as the exposed wall area of a terraced property with the same floor area, and this value is even higher for a detached property.

   II. Paper:
      *The seismic risk of buildings in Malta, COST ACTION C26 –Session 5: Risk Assessment of Catastrophic Scenarios, Borg Ruben Paul, Borg Randolph Carl, Borg Axia, Glorianne, University of Malta,*

In general, residential buildings consist primarily of load-bearing un-reinforced masonry walls, and reinforced concrete roofs. Reference is also made to reinforced concrete frame structures.

**17) MOLDOVA:**

1. Statistical Institute:

(total area implemented of dwelling houses)
(Information is presented without the data on districts from the left side of the river Nistru and municipality Bender)

| Wall materials (%) | Bricks and stone | Large-panels and frame-panels | Large-block and prefabricated forms | Other types |
|---|---|---|---|---|
| 2000 | 71 | 8 | 6 | 15 |
| 2001 | 78 | 10 | 3 | 9 |
| 2002 | 87 | 6 | 1 | 6 |
| 2003 | 93 | 1 | 1 | 5 |
| 2004 | 89 | 2 | 4 | 5 |
| 2005 | 87 | 4 | .. | 9 |
| 2006 | 85 | 2 | 1 | 12 |
| 2007 | 74 | 3 | .. | 23 |
| 2008 | 68 | .. | .. | 32 |
| 2009 | 61.1 | 6.7 | .. | 32.2 |
| 2010 | 49.4 | 5.7 | ... | 44.9 |

| | | | | |
|---|---|---|---|---|
| 2011 | 65.5 | 4.1 | ... | 30.4 |

(Data for 2004-2008 are presented without individual dwelling houses, according to the total area implemented of dwelling houses)

| | With 1-2 storeys | With 3-4 storeys | With 5 storeys | With 9 storeys | With 6, 7, 8, 10, 15 storeys | With 12-14 storeys | With 16 storeys and over |
|---|---|---|---|---|---|---|---|
| 2000 | 1 | 5 | 24 | 37 | - | 17 | 16 |
| 2001 | 1 | 3 | 29 | 32 | 23 | 12 | - |
| 2002 | 2 | 8 | 58 | 24 | 8 | - | - |
| 2003 | 1 | 4 | 35 | - | 60 | - | - |
| 2004 | 3 | 10 | 19 | 6 | 49 | - | 13 |
| 2005 | - | 2 | 20 | 9 | 55 | 11 | 3 |
| 2006 | 1 | 4 | 24 | 28 | 43 | - | - |
| 2007 | 0.4 | 4.6 | 8.6 | 22.6 | 61.9 | - | 2 |
| 2008 | 0.3 | 2.9 | 9.4 | 15.1 | 62.2 | - | 10.2 |
| 2009 | 46.8 | 1.2 | 3 | 20.7 | 26.3 | - | 2 |
| 2010 | 40.3 | 1.5 | 1.1 | 16.8 | 27.1 | - | 13.2 |
| 2011 | 48.4 | 4.1 | 0.6 | 8.7 | 38.2 | - | - |

| | Urban | Rural |
|---|---|---|
| By dwelling area | 0.39 | 0.61 |

2. UN:

- Moldova’s housing stock consists of permanent buildings – there are no temporary buildings used to house people.
- The Soviet-era urban system-built blocks of flats are based on reinforced concrete panels, cast in-situ reinforced concrete (“monolithic” construction) and cut limestone.
- Starting in 1994, the construction of large panels and prefabricated elements has decreased considerably.
- The current trend is for low-rise housing built from stone on cast in-situ concrete frames to protect against earthquakes.
- In 1995, about 49% of all the apartments in urban areas were in buildings with nine storeys or more.
- By contrast, in the countryside 96.7% of dwellings are privately owned, detached single-family houses.
- Traditional Moldovan houses are built of clay bricks, but today cut-stone blocks are more usual.
- Some 72% (204,000 m2) of total new housing space was in brick and stone buildings.
- The rest included concrete in-situ and concrete frame buildings with large panels or blocks.
- No timber frame buildings were built.

Overall, 65% of the existing housing stock dates back to 1970, and 84% to 1960.

| Proportion of apartment blocks (in percent of total) | | | | |
|---|---|---|---|---|
| Before 1961 | 1961-1970 | 1971-1980 | 1981-1990 | 1991 and after |
| 14.6 | 18.6 | 21.2 | 31.4 | 7.9 |

(Source: UNDP, National Human Development Report: republic of Moldova)

During the Soviet period the construction industry used technologies based on reinforced concrete panels, cast in-situ reinforced concrete (“monolithic” construction) and cut limestone. As a result of the substantial reduction in funds for the construction of dwellings, starting in 1994, the construction of large panels and prefabricated elements has decreased considerably. The current trend is for low-rise housing built from stone on cast in-situ concrete frames to protect against earthquakes.

Some 72% (204,000 m2) of total new housing space was in brick and stone buildings. The rest included concrete in-situ and concrete frame buildings with large panels or blocks. No timber frame buildings were built.

**Suggested typologies:**

(by total area implemented of dwelling houses, Census, 2004)

| | |
|---|---|
| M99+MUN99+MO99/LWAL/RES/EWMA | 0.71 |
| CR+CT99/L99 /RES | 0.14 |
| MAT99/L99/RES | 0.15 |

**18) NETHERLANDS:**

1. Census, 2001:

(by dwellings in residential buildings)

| | before 1919 | 1919-1945 | 1946-1960 | 1961-1970 | 1971-1980 | 1981-1990 | 1991-1995 | 1996 or later |
|---|---|---|---|---|---|---|---|---|
| SFH | 0.06 | 0.09 | 0.09 | 0.10 | 0.14 | 0.11 | 0.05 | 0.04 |
| MFH | 0.02 | 0.04 | 0.06 | 0.06 | 0.05 | 0.05 | 0.02 | 0.02 |

2. COST C16:
   - Early post-war housing (the first two decades after war) is characterized by small multi-family buildings (post-war apartment block) of 3-4 floors high, with flat or sloped roofs, contains 24-64 dwellings per building block,
   - Since mid-60s, multi-family housing was mainly realized as high-rise building blocks, containing up to several hundred apartments and up to 10-storey high with flat roofs. The average area of an apartment (with three bedrooms) went up to 85 $m^2$. The ground floor, storages are situated. These types of apartment blocks are always realized with in situ concrete.
   - Approximately 70% of early post-war multi-family housing has been completed with traditional building materials which are brickwork/ load bearing transversal walls.
   - 30% early post-war multi-family housing has been completed with of non-traditional building systems such as: block unit building systems (large concrete blocks), panel building systems and building systems using in situ concrete.
     a. Block unit building system/ Muwi-system with over 30000 completions between years 1951-1968 was originally designed for low-rise building. If used, more than five floors, additional reinforced in situ concrete columns were applied in the outer walls. The building principle is stacked construction of load bearing walls. Muwi-floor system consists of supporting reinforced prefabricated concrete beams and matching concrete filling blocks.
     b. Panel building system/BMB building system (Simplified Brick Construction) was originated from England, originally designed for low-rise but can be used up to 12 floors. Both load bearing and separation walls are made of prefabricated concrete elements. Over 10000 dwellings were built with this system (last completions dated back 1969). Floor system was also made of prefabricated concrete slabs (as well as roofs).
     c. In –situ concrete building systems/Korrelbeton: The first apartments completed in 1946. In situ concrete was mixed with broken bricks. This system has been used for single family houses as well as low-rise multi-family housing. For low rise building blocks, no reinforcement is used. For high-rise building blocks, RC columns are added on the joints of the outer walls and load bearing walls. The floor system consists of two layers of concrete (a composition used for walls and a top layer of high density concrete). The roof system is also in the same principle.
   - High-rise building blocks: The ones from the 60s, 70s are always realized as in situ concrete. During the 70s, this building method became the new traditional method for

apartment stock, as well as single family dwellings. The load bearing walls are made with traveling formwork (tunnel moulds or wall formwork). Light blocks (gypsum blocks or gas concrete blocks) are used for the non-bearing separation walls. Two floor systems are used: (1) Concrete on 50mm thick prefab wide slab flooring elements (used as a mould for in situ concrete). (2) The floors are poured at the same time with the load bearing walls using steel tunnel moulds. The façades are mainly prefabricated (storey-high prefabricated timber frames or façade with an inner layer of gas concrete blocks together with an outer layer of brick).

- The most frequently used floor system (Cusveller floors) in early post-war housing stock consists of prefabricated non-reinforced concrete beams. Reinforcement is placed between beams and incorporated in the structure with in situ concrete.
- In general, flat roofs are constructed in the same way as construction of floors. Flat and slightly inclined roofs are often finished with asphalt felt and gravel. Sloped roofs are constructed with deal rafters and covered with roof tiles.
- Façades were traditionally made of brickwork.


Figure 2 (left): Façade of a typical Dutch early post-war apartment block with basement for storage.
Figure 3 (right): typical Dutch early post war floor plans of a two- and a three bedroom apartment.



Figure 4 (left): façade of typical Dutch high rise building block from the sixties and seventies. Figure 5 (right): typical floor plan of a high-rise apartment block from the sixties.

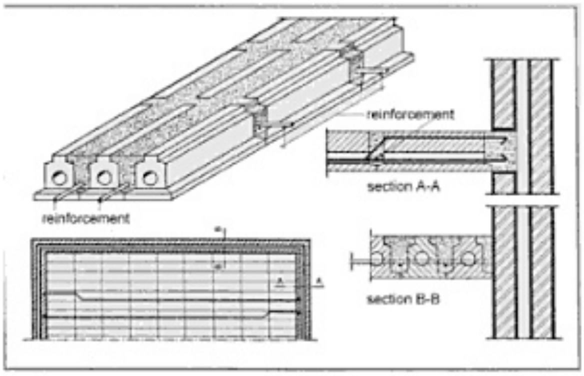
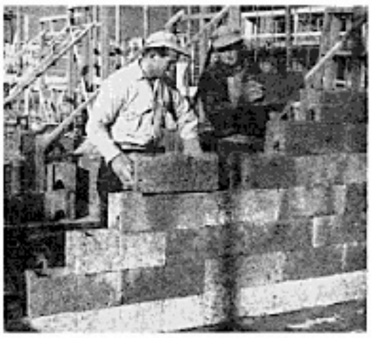



Figure 6: Section through a Cusveller floor (Jellema, 1958).



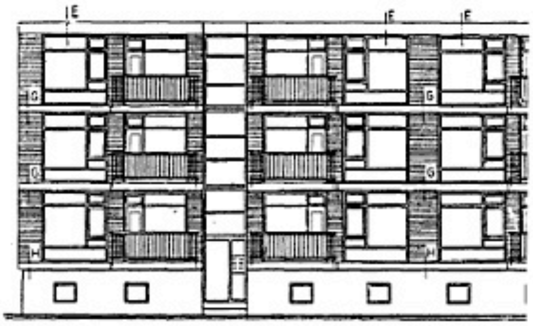
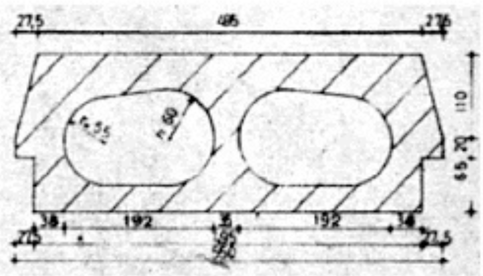


Figure 7: Dry stacking of Muwi building blocks (5 ) Figure 8: typical look of an early post-war building block completed in the Muwi building system with visible belt courses (14)



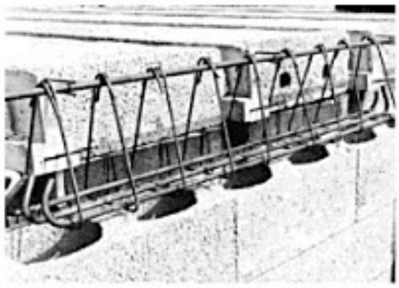


Figure 9 (left): filling block in Muwi floor system. Figure 10 (right): incorporation of Muwi floor system in the structure.

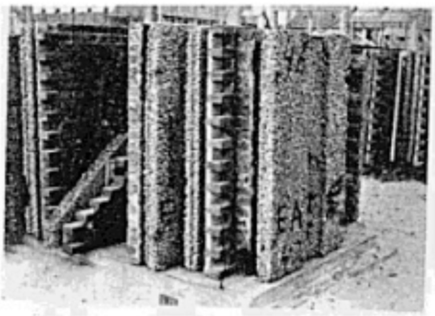


Figure 11 (left): Cavity wall elements of the BMB building system with concrete inside layer and an outside layer of mechanically laid bricks. Figure 12 (right): Typical façade of an early post-war building block completed in the BMB building system.

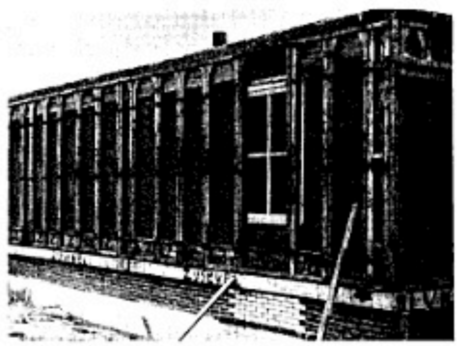


Figure 13 (left): Korrelbeton, standardized shuttering for outer wall (5). Figure 14 (right): façade of a building block completed in Korrelbeton with a single layer concrete façade.

**19) <u>POLAND:</u>**

1. Yearbook 2012:

| (by dwellings) | in % |
|---|---|
| Before 1945 | 20.4 |
| 1945-1970 | 24.2 |
| 1971-1978 | 15.6 |
| 1979-1988 | 16.2 |
| 1989-2002 | 11.6 |
| 2003-2011 | 8 |
| Not known | 3.7 |
| under construction | 0.3 |

2. PAGER:

| Poland | W1 | W4 | S2 | S5 | PC1 | A | UCB |
|---|---|---|---|---|---|---|---|
| Urban/Rural | 0.02 | 0.02 | 0.09 | 0.44 | 0.17 | 0.05 | 0.22 |

3. TABULA:

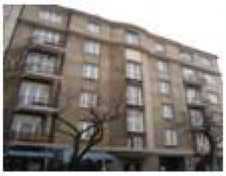
Polish building stock was divided into four types and seven periods of construction. Four types buildings are the same as adopted by the TABULA consortium, and represents most typical buildings in the Polish building set:

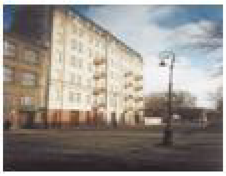
- single family (SF) – buildings with 1 apartment
- terraced (TH) – buildings with 2 – 4 apartments,
- multifamily (MFH) – buildings with more than 4 apartments – up to 8 floors
- tower buildings – apartment blocks (AB) - buildings higher than 8 floors

| (by buildings) | Up to 1944 | 1945-1970 | 1971-2002 | 2002-2010 |
|---|---|---|---|---|
| SFH | 0.17 | 0.22 | 0.35 | 0.10 |
| TH | 0.03 | 0.02 | 0.02 | 0.00 |
| MFH | 0.03 | 0.01 | 0.01 | 0.01 |
| AB | 0.01 | 0.01 | 0.02 | 0.00 |

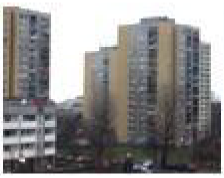
| (by dwellings) | Up to 1944 | 1945-1970 | 1971-2002 | 2002-2010 |
|---|---|---|---|---|
| SFH | 0.07 | 0.09 | 0.14 | 0.04 |

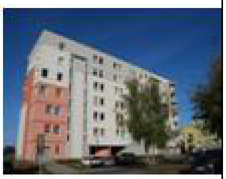
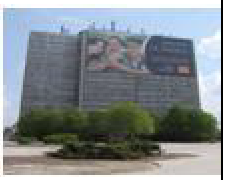
| | | | | |
|---|---|---|---|---|
| TH | 0.02 | 0.02 | 0.02 | 0.00 |
| MFH | 0.07 | 0.02 | 0.01 | 0.02 |
| AB | 0.05 | 0.12 | 0.27 | 0.05 |

| Construction Period | Occupancy Type | | Number of Floors | Number of Dwellings | Wall | Roof | Percent of buildings in building stock |
|---|---|---|---|---|---|---|---|
| Before 1945 | Residential Single Family House |  | 2 | 1 | Wood | Pitched | 16.6% |
| | Residential Terrace House |  | 1 | 2 | Wood | Pitched | 3% |
| | Residential Multi Family House |  | 4 | 18 | Brick | Flat | 3.4% |
| General | The most common way to build a **massive system of load-bearing walls**, but at the end of the nineteenth century began to try to separate the functions of the carrier and filler function, although initially only in the form of load-bearing brick pillars with greater capacity and window areas with better insulating properties. | | | | | | |
| Walls | **The walls of the oldest buildings are made of brick wall and slate stone**. In later periods, the stone was used only for the performance of the buildings, which were considered less important - usually basements, walls and brick on the upper floors were full of burnt bricks or blocks, bricks hole, blocks of lightweight concrete (usually steel or pumice żużlobetonu) and blocks.<br>Also used (unburnt bricks of clay mixed with paździerzami clay, straw, hay or sedge, especially in rural and niskokondygnacyjnych buildings. Thickness of the supporting brick walls varied depending on the number of floors of the building. The minimum thickness of the walls on the top floor because of the frost was usually 450 mm, the lower floors were growing | | | | | | |
| Roof | Roofs were performed mainly as **roof trusses units of wood and coated with burnt tiles**, possibly with **thatched with straw or wood shingles**, most of which have not been preserved. Coverage of the metal (copper and lead) were used only in exceptional cases. Attic were mostly uninhabited (unheated attic room). If the buildings were cellars, basements were vaulted ceilings with brick. | | | | | | |
| Floor | Floor buildings without cellars on the **ground floor were made of packed clay with stone or ceramic tiles, wooden beams used as a base** of protection against moisture from the ground. **In most cases, the original floors were replaced with concrete topping** of different compositions and different layers of wiping. Frequently used in linoleum, then the PVC.<br><br>**Floor structures were performed as wooden beams with plaster on reed mats**, with a raise and the ballast of gravel or debris. In the villages of the ceiling beams were made powałowym. | | | | | | |

| Construction Period | Occupancy Type | | Number of Floors | Number of Dwellings | Wall | Roof | *Percent of buildings in building stock |
|---|---|---|---|---|---|---|---|
| 1946-1966 | Residential Single Family House |  | 1 | 1 | Brick | Pitched | 22.4% |
| | Residential Terrace House |  | 3 | 2 | Hollow Brick | Flat | 2.2% |
| | Residential Multi Family House |  | 4 | 40 | Brick | Flat | 0.8% |
| General | In the post-war years saw the **rapid development of mass housing.** The nationwide housing regulated by a two-year plan, which was announced at the end of 1946. **Often built from recycled materials, quickly and, unfortunately, often sloppy**. | | | | | | |
| Walls | **The external walls of burnt bricks** were full thickness usually 450 mm. For buildings with more floors (5 to 6 floors) external walls due to the load-bearing properties of the first and sometimes the second storey brick ground a thickness of 600 mm. Some of the end walls have a thickness of only 300 mm.<br>If you used **a brick with holes or wall żużlobetonowe (hallow blocks-)** elements have a thickness of 375 mm, and the thickness of the gable was less than - 250 or 300 mm. Zone balustrade in some buildings also were thinner.<br>In case of full brick thickness of the zone under the windows was 300 mm or 350 mm, when using bricks honeycomb (CDM) 250 mm.<br><br>The walls under the windows are in some cases performed as diaphragm walls (2 x 150 mm with a wall full of bricks and 50 mm air gap) sometimes performed from the inside of the insulation boards suitable for plastering.<br>**In the early 60's developed a number of systems in Poland wielkopłytowego construction during this period, however, a great disc still dominated Polish construction sites.**<br>**For example, of all the homes that were built in 1966 in Warsaw, only 24.6% were apartments in buildings of panel.**<br>During the more popular was called. wielkoblokowa technology, which came into use in Poland in the mid-50's, and that the "real" large panel technology was | | | | | | |
| Roof | **Roofs "T" were generally inclined with wooden trusses in the later stages of the trusses, in which some parts are made of precast concrete**. **From about the mid-50s came to a greater extent, particularly in urban areas, use flat roofs.** Thermal insulation of the roof was generally a light cast concrete of varying thickness, allowing the formation of the roof pitch. The minimum thickness of 40 mm was to be. | | | | | | |
| ***Fractions are based on years 1945-1970** | | | | | | | |

| | |
|---|---|
| Floor | The oldest type of floor to enable walking were performed as in buildings pre - usually slag ballast, or concrete layer and the wearing layer żużlobetonu plate brick with a thickness of about 30 mm.<br><br>In later periods, stopped the use of brick flooring and a top coat performed exclusively on ballast slag layer of concrete or żużlobetonu, or żużlobeton with a layer of cement screed. The total thickness of the floor ranged from 100 to 150 mm. In the case of floors without the possibility of walking on a layer of concrete ballast only performed "rugs" to allow access to the chimney. Thickness podsypek speedway was originally about 100 mm and a layer of about 50 mm żużlobetonu.<br><br>Wearing layers of flooring in the living quarters were usually made of wood (mosaic, parquet, plank, etc.), in other areas (hallways, utility rooms and sanitary facilities, pantries) tile (tile, ceramics, ksylolit etc.). The total thickness of the floor was initially 150 mm, but followed gradually decreased to 100 or even 50 mm. |

| Construction Period | Occupancy Type | | Number of Floors | Number of Dwellings | Wall | Roof |
|---|---|---|---|---|---|---|
| 1967-1985 | Residential Single Family House |  | 2 | 1 | Hollow brick | Flat |
| | Residential Terrace House |  | 3 | 2 | Hollow Brick | Pitched |
| | Residential Multi Family House |  | 4 | 40 | Prefabricated Concrete Panels | Flat |
| | Residential Apartment Blocks |  | 15 | 98 | Prefabricated Concrete Panels | Flat |
| Walls | The system is based on a modular grid 60 × 60 cm. The basic solution was **cross-system design load-bearing walls**. For W-70 core elements were slabs channel, unidirectionally reinforced fr. 22 cm thick internal walls. 15 cm - storey residential and 20 cm - basement walls, exterior walls thick sandwich. 27 cm. or gr. Keramzytobetonu 40 cm. Typical span roofs (load-bearing wall spacing) were: 240, 360, 480 and 600 cm. | | | | | |

| Construction Period | Occupancy Type | | Number of Floors | Number of Dwellings | Wall | Roof | Floor |
|---|---|---|---|---|---|---|---|
| 1986-1992 | Residential Single Family House |  | 1 | 1 | Brick | Pitched | Suspended floor |
| | Residential Terrace House |  | 2 | 2 | Brick | Pitched | Solid ground floor |
| | Residential Multi Family House |  | 4 | 26 | H-Frame | Pitched | Solid ground floor |
| | Residential Apartment Blocks |  | 11 | 80 | Prefabricated Concrete Panels | Flat | Solid ground floor |
| General | Another popular system design during this period was called. **H-frame technology structures, consisting of elevated reinforced concrete skeleton, which filled a brick or bricks**. For reinforced concrete skeleton, acting as a support structure, consisting the columns, beams and supporting them in the floor slabs. In buildings erected on the technology, there are no load-bearing walls (which allows virtually any arrangement design), but it happens that the visible components - these columns and substrings. | | | | | | |

| Construction Period | Occupancy Type | | Number of Floors | Number of Dwellings | Wall | Roof | Floor |
|---|---|---|---|---|---|---|---|
| 1993-2002 | Residential Single Family House |  | 2 | 1 | Brick | Pitched | - |
| | Residential Terrace House |  | 2 | 2 | Hollow Brick | Pitched | Solid ground floor |

| | | | | | | | |
|---|---|---|---|---|---|---|---|
| | Residentia l Multi Family House |  | 7 | 71 | Aerated Concret e | Flat | - |
| | Residentia l Apartment Blocks |  | 13 | 98 | H-Frame | Flat | Solid groun d floor |
| General | After the reforms of 1989, replacing the large private construction cooperative construction or development activity resulted in the collapse of building wielkopłytowego. Reducing the scale of investment in the early 90s Twentieth century did not allow for cost-effective production of precast concrete and led to the closure of factories homes.<br>investors to move away from the use of precast concrete outdated technology (the so-called characteristic. Wielkopłytowego construction) for a monolithic technology. | | | | | | |

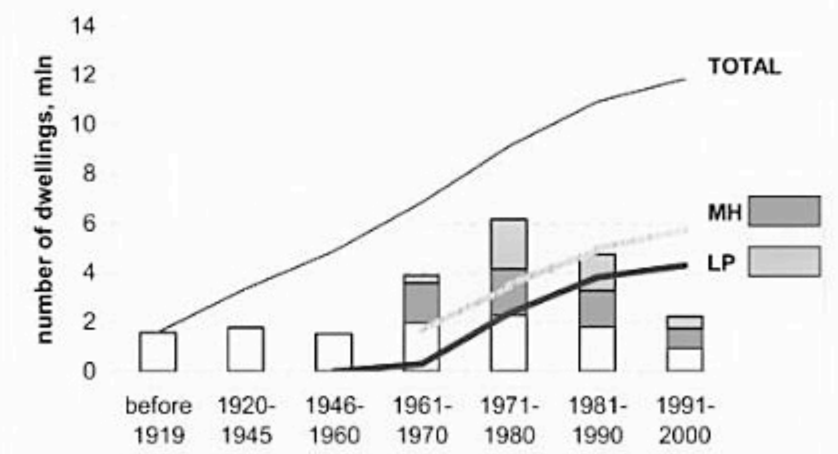
| Construction Period | Occupancy Type | | Number of Floors | Number of Dwellings | Wall | Roof | Floor |
|---|---|---|---|---|---|---|---|
| 2003-2008 | Residential Single Family House |  | 2 | 1 | Brick | Pitched | - |
| | Residential Terrace House |  | 2 | 2 | 3 Layers construction | Pitched | - |
| | Residential Multi Family House |  | 7 | 71 | Silica brick | Flat | - |
| | Residential Apartment Blocks |  | 11 | 101 | Aerated concrete | Flat | Solid ground floor |
| General | Exterior load-bearing walls and interior can also be made of molded polystyrene combined with special locks and flooded the building with concrete.<br>Ever-growing popularity of frame wooden houses now. | | | | | | |

| | |
|---|---|
| Walls | The construction of walls: The most common solution today masonry walls are the walls of single, double and triple. building materials such as concrete blocks and aerated concrete cell, blocks keramzytowe whose holes are filled with polystyrene foam or porous ceramics.<br>For the construction of exterior walls shall also apply to bricks or blocks of lime-sand (silicate). They are produced from natural raw materials sand, lime and water<br><br>The outer wall of wood-frame construction, it may have a cross section representing only half the thickness of a brick wall |

| Construction Period | Occupancy Type | | Number of Floors | Number of Dwellings | Wall | Roof | Floor |
|---|---|---|---|---|---|---|---|
| After 2008 | Residential Single Family House |  | 2 | 1 | Brick | Pitched | - |
| | Residential Terrace House |  | 2 | 2 | Brick | Pitched | - |
| | Residential Multi Family House |  | 4 | 48 | Silica brick | Flat | - |
| | Residential Apartment Blocks |  | 11 | 303 | Aerated concrete | Flat | Solid ground floor |
| General | The construction of walls<br>The most common solution today masonry walls are the walls of single, double and triple.<br>Single-layer walls are those that are of the same type were built elements through the thickness. It is assumed that the walls should have a single-layer which necessitates the use of appropriate building materials such as concrete blocks and aerated concrete cell, blocks keramzytowe whose holes are filled with polystyrene foam or porous ceramics.<br><br>The outer wall of wood-frame construction, it may have a cross section representing only half the thickness of a brick wall | | | | | | |

| | |
|---|---|
| Walls | Exterior load-bearing walls and interior can also be made of molded polystyrene combined with special locks and flooded the building with concrete. From inside the finish they gipsowokartonowymi plates and outside tynkuje or clinker brick cladding or veneer. Pursuant to the requirements cited above, this wall should at the outset be insulated.<br>Cavity walls are made as single-layer walls with the exception that<br>s insulation continue unchecked jeodz ewnątrz.W inner layer double-layer walls, bearing<br>a construction materials - bricks and blocks full, and the outer layer - the material insulation, such as polystyrene and mineral wool protected by thin structural plaster.<br>For the construction of exterior walls shall also apply to bricks or blocks of lime-sand (silicate). They are produced from natural raw materials sand, lime and water, and exhibit a high resistance to frost, water and fire, as well as fungi and mold. Like the ceramic brick, have high heat storage capacity. |

4. COST C16:




(M Multi-dwelling buildings, LP–MH Buildings incorporating large-panel technology)

- From the mid 60s onwards, the construction of non-traditional housing based on large-panel technology has started. By the end of 70s 2.04 million large-panel dwellings had been completed.
- In 1995, the total area of flats reached about 700 million $m^2$ including 430 million $m^2$ constructed using large-slab technology and the rest using other methods.
- Post-war period 1947-1956: Up to mid 50s, housing was based on use of traditional brick-walls, with concrete slabs on steel girders and ceramic or concrete filling. The first use of precast wall elements has started.
- First stage of prefabrication 1956-1967: The construction of typical residential blocks was based on wide use of large-block precast elements for walls as well as for slabs and introduction of lightweight and cellular concrete. Traditional technology (even using precast floor) is still used in smaller towns. Typical residential blocks consisted of 4-5 storeys and higher blocks up to 11 storeys.
- Era of large-panel building: First constructed in 1957 and from 1967 this technology became standard (OWT-67, WUF-T, Szezecin, W-70) for residential buildings. Two types of large-panel systems: (1) Closed systems (OWT-67, WUF-T, Szezecin); older systems with most of the walls being structural bearing walls and leading fixed-floor modules. (2) Open systems (W-70, OWT-75); have more flexible structural mesh and limited number of structural walls.
- Non-traditional technologies:
    - Large-block technology: Z-system is the one of the most popular one, in small towns for single buildings. Typically, it consists of storey height wall blocks and hallow –core slabs. The precast elements of the main system

are hallow-core panels made of plain concrete. This system allows up to 11 storeys, typically with a transverse structure.

- Large-panel technology: The common feature is that the wall elements are storey-high and extends max to 6m. External walls are precast as three layer sandwich panels. Usually, shallow foundations were used with concrete or reinforced strips under basement walls. Sometimes system-built precast basement walls were used and In-situ concrete was also popular. Three types of structural form can be distinguished: transverse, longitudinal and mixed. All elements are prefabricated. Bearing internal walls are made of precast concrete with or without reinforcement (for newer systems, RC walls). Bearing external walls for Szezecin system were made of lightweight concrete. Ceiling slabs were made of RC as hollow-core. Flat roofs are constructed from concrete panels supported on brick walls.

• In 1975-1970, significant increase in the number of large-panel element occurred while a regression in large block technology and very small increase in the use of precast-frame and in-situ concrete building technology was observed.

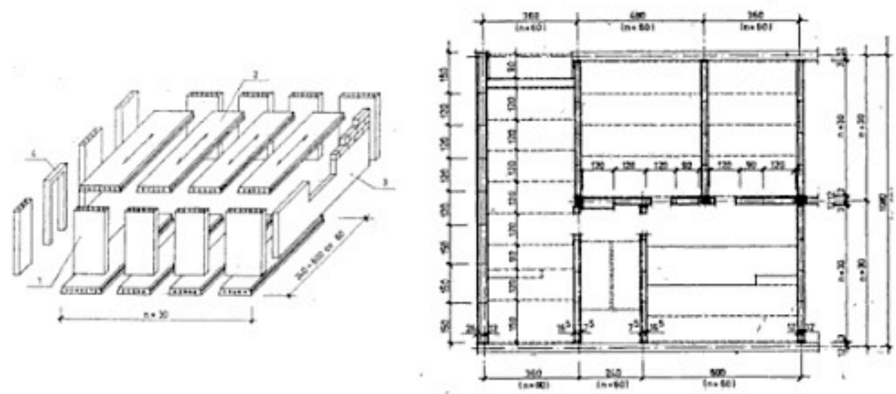
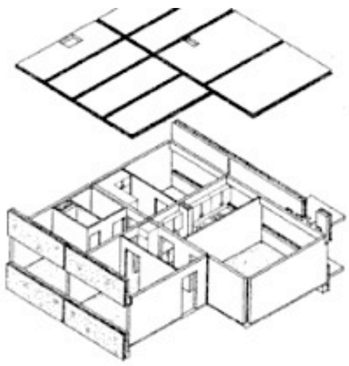
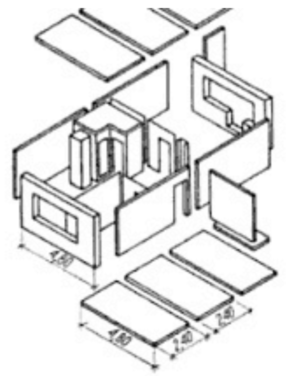


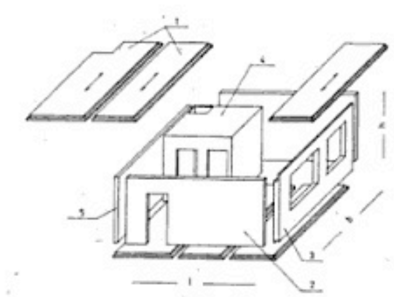
Figure 5. Structure of *Żerań-brick* large block system (Biliński & Gaczek, 1982)



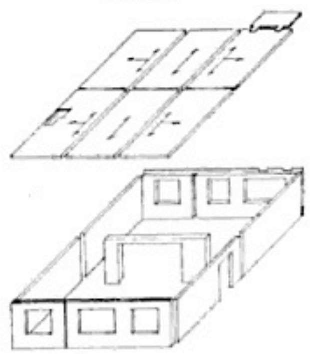
OWT



*Szczecin*



W-70



WUF-T

**20) <u>SLOVAKIA:</u>**

1) Census, 2001

External wall material (Total, by dwellings):

| | |
|---|---|
| Stone, bricks | 0.48 |
| Wood | 0.01 |
| Urburnt bricks | 0.03 |
| Other and not specified | 0.36 |

2) NERA Workshop:

| | Multi dwelling buildings | Family Houses (single family buildings) |
|---|---|---|
| Before 1990 | precast panel structures, 4-13 floors, Designed according to the old Slovak national standards | Solid masonry structures, timber deck |
| After 1990 | RC structures, cast-in-place concrete, frame structure with masonry infill, up to 24 stories, Designed according to Slovak national standard and Eurocode | Air-brick masonry, RC or ceramic deck |

3) Pager (Urban-Rural):

| Country Name | Slovakia |
|---|---|
| **W** | 0.15 |
| **C** | 0.07 |
| **A** | 0.22 |
| **UFB** | 0.57 |

**Suggested typologies:**

(by permanently occupied dwellings, 84% of all dwellings, Census, 2002)

| | |
|---|---|
| M99+STRUB+MO99/LWAL/RES/EWMA | 0.03 |
| W+W99/LFM/RES | 0.02 |
| M99+CL99+MO99/LWAL/HBET:1,3/RES /EWMA/FW+FW99+FWC99 | 0.06 |
| M99+CL99+MO99/LWAL/HBET:1,3/RES /EWMA/FM+FM99+FWC99 | 0.10 |
| M99+CL99+MO99/LWAL/HBET:1,3/RES/EWMA/FC+FC99+FWC99 | 0.28 |
| M99+CL99+MO99/LWAL/HBET:4,6/RES/EWMA/FW+FW99+FWC99 | 0.03 |
| M99+CL99+MO99/LWAL/HBET:4,6/RES/EWMA/FC+FC99+FWC99 | 0.08 |
| M99+CB99+MO99/LWAL/HBET:4,6/RES/EWMA/FC+FC99+FWC99 | 0.08 |
| CR+CT99/LWAL/HBET:4,6/RES/EWC | 0.08 |
| CR+CT99/LWAL/HBET:6+/RES/EWC | 0.23 |

**21) <u>SLOVENIA:</u>**

1. Census 2002:

| By Buildings |
|---|

| SFH | MFH |
|---|---|
| 0.94 | 0.06 |

**Material of the bearing structure of the building** is the material which constitutes the most of the construction (bearing) walls and in the case of the skeleton construction the frame of the building.

| (by buildings) | Brick | Concrete, reinforced concrete | Stone | Wood | Other |
|---|---|---|---|---|---|
| Total | 0.60 | 0.06 | 0.12 | 0.03 | 0.18 |
| Urban | 0.63 | 0.10 | 0.06 | 0.02 | 0.19 |
| Rural | 0.59 | 0.04 | 0.15 | 0.04 | 0.18 |

| (by buildings) | Brick | Concrete, reinforced concrete | Stone | Wood | Other |
|---|---|---|---|---|---|
| Detached individual house | 0.51 | 0.04 | 0.09 | 0.03 | 0.15 |
| Semi-detached or row house | 0.04 | 0.01 | 0.01 | 0.00 | 0.01 |
| House with agricultural premises | 0.04 | 0.00 | 0.02 | 0.00 | 0.01 |
| Multi-dwelling building | 0.02 | 0.01 | 0.00 | 0.00 | 0.01 |
| Other | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 |
| Urban | | | | | |
| Detached individual house | 0.48 | 0.04 | 0.04 | 0.01 | 0.14 |
| Semi-detached or row house | 0.09 | 0.02 | 0.01 | 0.00 | 0.03 |
| House with agricultural premises | 0.01 | 0.00 | 0.00 | 0.00 | 0.00 |
| Multi-dwelling building | 0.05 | 0.04 | 0.00 | 0.00 | 0.02 |
| Other | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 |
| Rural | | | | | |
| Detached individual house | 0.52 | 0.04 | 0.12 | 0.03 | 0.15 |
| Semi-detached or row house | 0.01 | 0.00 | 0.01 | 0.00 | 0.00 |
| House with agricultural premises | 0.05 | 0.00 | 0.03 | 0.00 | 0.02 |
| Multi-dwelling building | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 |
| Other | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 |

2. PAGER:

| **Slovenia** | **C2** | **C3** | **RM2** | **RS2** | **UFB2** | **UNK** |
|---|---|---|---|---|---|---|
| Urban | 0.11 | 0.07 | 0.30 | 0.05 | 0.24 | 0.23 |
| Rural | 0.04 | 0.03 | 0.28 | 0.13 | 0.23 | 0.29 |

3. TABULA:

| number of buildings | number of apartments | Wall | Roof | Floor |
|---|---|---|---|---|
| 140605 | 150283 | Natural stone with or without plaster | Wooden roof with plaster on paneling | Concrete slab, concrete screed, wood under |
| 91163 | 99013 | Votlličasta bricks 29 cm | Concrete slab, concrete screed, wood under | Foundation concrete rubble, blind - Mon wood |

| | | | | |
|---|---|---|---|---|
| 82684 | 88604 | Votlličasta bricks 29 cm | Concrete slab, concrete screed, wood under | Ground floor |
| 114561 | 118970 | Votličava bricks 19 cm, plaster, brick facade | The ceiling of the cell concrete | Ground floor |
| 21567 | 22093 | Votlličasta bricks 29 cm | Pitched roof | Ground floor |
| 99 | 102 | Votlličasta bricks 29 cm | Flat roof | Ground floor |
| 12974 | 14897 | Natural stone with or without plaster | wooden tramovni ceiling, rubble, concrete screed, the blind | Concrete slab, concrete screed, wood under |
| 11383 | 12800 | Votlličasta bricks 29 cm | Pitched roof | Foundation concrete, flooring, cladding |
| 7505 | 8354 | Votlličasta bricks 19 cm, plaster, brick facade | Pitched roof | Ground floor |
| 8301 | 9078 | Votlličasta bricks 29 cm | Flat roof | Ground Floor |
| 2394 | 2575 | Votlličasta bricks 29 cm | Pitched roof | Ground Floor |
| 47 | 56 | Concrete wall | Pitched roof | Ground Floor |
| 10693 | 60531 | Full brick, plaster | wooden tramovni ceiling, rubble, concrete screed, the blind | Concrete pressure of 30 cm with or without a floor |
| 5142 | 39591 | Concrete block, plaster | Concrete slab, concrete screed, wood under | Foundation concrete rubble, blind - wooden floor |
| 2105 | 16238 | Concrete block, plaster | Concrete slab, concrete screed, wood under | Ground floor |
| 2248 | 18320 | Concrete wall | Concrete slab, concrete screed, wood under | Ground floor |
| 1152 | 9233 | Concrete wall | Concrete slab, concrete screed, wood under | Ground floor |
| 14 | 84 | Concrete wall | Concrete slab | Ground floor |
| 930 | 43683 | Concrete wall | Concrete slab, concrete screed, wood under | Concrete slab, concrete screed, wood under |
| 885 | 35085 | Concrete wall | Concrete slab, concrete screed, wood under | Concrete slab, concrete screed, wood under |
| 1060 | 50667 | Concrete wall | Concrete slab, concrete screed, wood under | Concrete slab, concrete screed, wood under |
| 826 | 38962 | Concrete wall | Concrete slab, concrete screed, wood under | Concrete slab, concrete screed, wood under |
| 256 | 12397 | Concrete wall | Flat roof | Concrete slab |
| 4 | 1077 | Votlličasta bricks 29 cm | Pitched roof | Concrete slab |
| 518598 | 852693 | | | |

**Suggested typologies:**

(by buildings, Census, 2002)

| | Urban | Rural |
|---|---|---|
| M99+CL99+MO99/LWAL/RES/EWMA | 0.63 | 0.59 |
| CR+CT99/L99/RES | 0.10 | 0.04 |
| M99+ST99+MO99/LWAL/RES/EWMA | 0.06 | 0.15 |
| W+W99/L99/RES | 0.02 | 0.04 |
| MAT99/L99/RES | 0.19 | 0.18 |

**22) SWEDEN:**

1. Tabula:

(by buildings)

| By total | … 1960 | 1961-1975 | 1976-1985 | 1986-1995 | 1996-2005 | |
|---|---|---|---|---|---|---|
| SFH | 0.41 | 0.24 | 0.15 | 0.07 | 0.04 | **0.92** |
| MFH | 0.04 | 0.02 | 0.01 | 0.02 | 0.01 | **0.08** |

(by dwellings)

| By total | … 1960 | 1961-1975 | 1976-1985 | 1986-1995 | 1996-2005 | |
|---|---|---|---|---|---|---|
| SFH | 0.20 | 0.12 | 0.07 | 0.04 | 0.02 | **0.45** |
| MFH | 0.24 | 0.18 | 0.03 | 0.08 | 0.02 | **0.55** |

2. Reports (Swedish National Board of Housing, Building and Planning Boverket):

Single-family houses
The average single-family house was built in 1953 and is a 1.5-storey house with a basement. The facade is made of wood (163 ± 16 million m2) and the roof is a pitched roof with concrete tiles. Detached houses are most common, with 82 ± 4%. The largest proportion of detached houses is found amongst those that were built before 1960. 2.3 people live in the house.

Apartment buildings
The average apartment building was built in 1959 and consists of a basement and three floors above ground. The facade is brick or stucco (41 ± 27 million m2) and the roof is a pitched roof with concrete tiles.
The building has 14.55 apartments and an average of 1.7 people live in each apartment. About 40% of the apartment building stock is lamellar buildings.

Many buildings have a combination of several foundation structures. Basement is the most common type of foundation for all types of buildings.
About 80 % of all residential buildings have a pitched roof. The most common roofing material for residential buildings are concrete tiles.

*Figure 4 Roofing material for residential buildings in million m².*

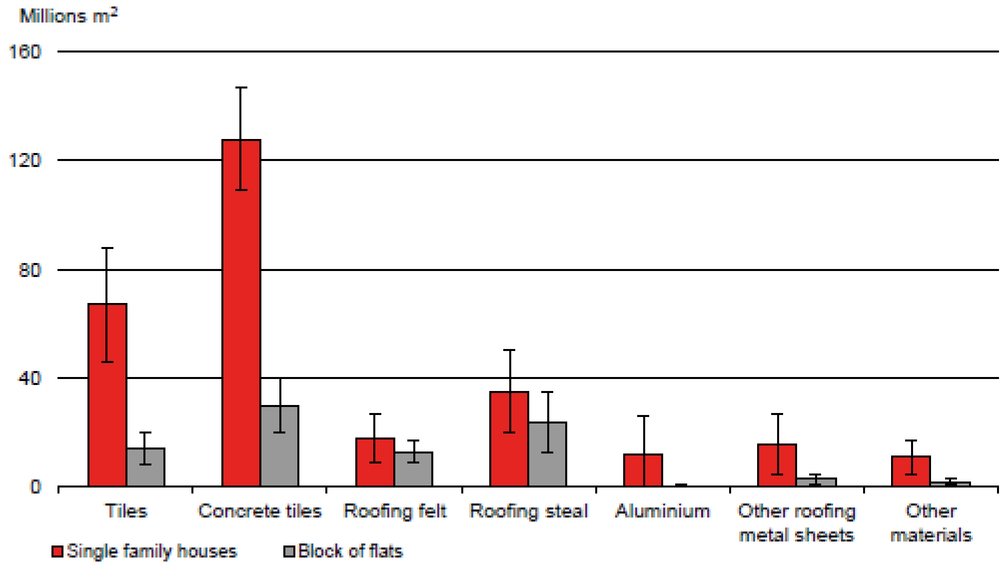
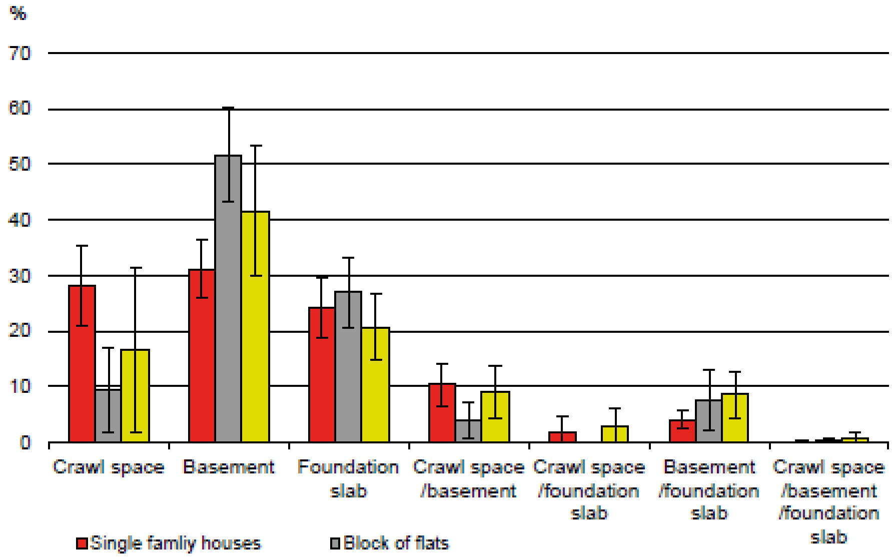
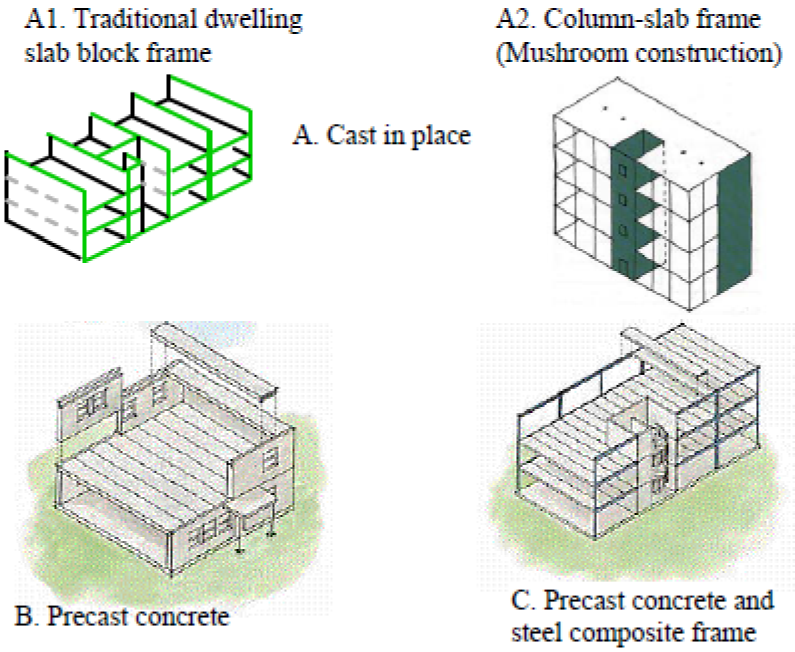



*Figure 3 Foundations for single-family houses, block of flats and commercial and public buildings, percentage*




3. Thesis (Mats Öberg, Swedish concrete multi-dwelling buildings):

Approximately 65% of the Swedish multi-dwelling frames were of type A, including combinations with prefabricated floor slabs. 15% of the frames were of type B, 10 % of type C and 10% of other types, such as steel with lightweight floors or timber frames.




<u>Cast in place concrete slab blocks with curtain walls</u>
In-situ cast concrete frames for residential buildings are normally produced either with tunnel-forms or in combination with prefabricated floor slabs and/or wall units. The thickness of the concrete is typically 200 to 250 mm, allowing spans up to 6 m, and 160 to 200 mm in walls. The common structural concept is the slab- block, presented in the figure above as 'A1'. Other types, such as the column-slab frame, adopted from office buildings, according to the figure above 'A2', are also used.

The 'curtain wall' facades are prefabricated or built on site, with studs of sheet steel or wood, and cladding of bricks or rendering on mineral wool, cf. Annex 6.A.

<u>Precast concrete structure with load carrying sandwich facade elements</u>
A main feature of the precast frame is the use of the prestressing technique in floor elements, which can be either hollow core slabs or massive elements. This allows spans over the entire width of the building. Compare Figure 4.A.1 'B'. The hollow core slabs for residential buildings typically have the profiles 1200x200 or 1200x265 mm, allowing for spans up to 13 m. The elements are produced with extrusion technique, typically on 100 m long beds, and sawn to the specific length. The joints between hollow core slabs are filled with concrete on site. Usually a topping of self-levelling grout, (10-30 mm) is applied on the slabs. Alternatively a raised floor, for instance parquet on joists is used. The latter solution allows for installations to be placed in the floors.
The exterior walls usually consists of sandwich wall panels consisting of an exterior, painted, concrete leave (70 mm), usually with a texture similar to rendering, an insulation layer (100-150 mm) and an internal load carrying concrete leave (100-150 mm).
Systems with short span, reinforced massive floor elements and load carrying internal walls, in a layout according to the in situ cast concrete in Figure 4.A.1 'A', are also used.

<u>Concrete and steel composite structures</u>
Steel and concrete composite structures, were introduced by the end of the 1980's, copying the concept from the office-building sector. The structure normally consists of steel columns of hot rolled rectangular hollow or H-section and steel beams of hot rolled H or special welded profiles. The floor are of prefabricated concrete hollow core slabs, as described above, or of massive cast in place concrete, often on prefabricate floor slabs are. For stabilisation, prefabricated, concrete stair enclosures are often used. The facade is a curtain wall similar to that of the in-situ concrete frame, described above, and the interior walls are lightweight structures of plasterboards on sheet steel studs except for the stabilising concrete stair enclosures. Compare Figure 4.1.'C'.

4. Cost C16

| | |
|---|---|
| 1946-60 | more traditional |
| 1961-75 | more industrialized |

| | |
|---|---|
| | 1/5 of dwellings precast concrete |
| | slab blocks, towers of eight stories were frequent |
| | 60% of dwellings three-storey slab houses or lower |
| | Most multi-family houses slab blocks in three, four storeys |
| | other dominant types, slab blocks or tower blocks in 6-8 storeys or more |
| | slab blocks short and long, attached to each other, curved, twining over the land |
| | tower blocks compact and more slender, square or star-shaped |
| Since 1930s | 1940s RC in multi-family houses: in slabs supported by masonry walls or in entire structures |
| | All houses in situ |
| 1950s | Precast Construction |
| Beginning of 1960s | almost all multi-family houses still built in situ, along with increasing precast construction |
| 1960-1975 | 20% of total building construction precast construction |

| | |
|---|---|
| In Situ multifamily houses: | 2-4 houses, multi storey, 6-8 storey tower blocks |
| | Often no basement |
| | Bearing transverse internal walls, gable walls and RC floors |
| | Facades often brick |
| | Roofs gable-formed and built up in wood covered with roofing felt, asbestos cement tiles, brick tiles, other materials or flat, covered with roofing felt |
| | |

| | |
|---|---|
| Precast houses: | Exterior concrete wall panels,interior formed after precast slab and wall units |
| | Basement storeys in situ, if any |
| | Structural systems: |
| | room sized slab units: solid, non-tensioned reinforced slabs with structural dividing walls |
| | Skarne 66 system: structural external walls and internal columns |
| | Skanska Cementgjuteriet: right-angled units with slab and wall panel cast in one piece |
| | slab units,more than room size: prestressed slabs with hollow section or a TT-section |
| | external wall panels: room-sized sandwich units, internal self-supporting wall panel, external facade |
| | 15% of facade concrete, others brick, plaster, metal sheets |

5. (Sonja Vidén. Urvalsprinciper för TYPISKA FLERBOSTADSHUS byggda efter 1945. 1998-03-27 BOOM-gruppen KTH.)

Suggested building typologies regarding multi-family buildings in Sweden

| Construction Year | Type | # of dwellings | Construction method | Structure | Facade | Roof cover |
|---|---|---|---|---|---|---|
| 1946-1960 | Slab blocks | 3 | On site | Masonry | Masonry | Tile roof |
| 1946-1960 | Tower block | 6+ | On site | | Plastered aerated concrete | |
| 1961-1975 | Slab blocks | 3 | On site | | Masonry | Roofing felt |
| 1961-1975 | Slab blocks | 8 | Prefabricated building blocks | | Concrete | Roofing felt |
| 1976- | Access balcony | 2-5 | On site | | Masonry/ Stone | Sheet metal |

| | | | | | | |
|---|---|---|---|---|---|---|
| | building | | | | | |
| 1976- | Row house/Slab block | 2 | Prefabricated building blocks | Wood | Wood | Tile roof |
| 1961-1975 | Slab blocks | 2-4 | Prefabricated building blocks | | Concrete | Roofing felt |
| 1946-1960 | Slab blocks | 3-4 | On site | Aerated concrete | Aerated Concrete | |
| 1976- | Slab/tower blocks | 6+ | On site/ prefabricated | Concrete | | |

6. PAGER:

| Sweden | C3 | UFB3 | UFB4 |
|---|---|---|---|
| Urban | 0.02 | 0.35 | 0.63 |
| Rural | 0.00 | 0.50 | 0.50 |

**JRC IMPRO-Building Project**

The aim of this project was to analyse the residential buildings in EU-25 regarding their environmental potentials. The most ‘representative’ buildings which compose of around 80% of the residential stock in EU-25 were defined using several attributes such as building structure, material, age, population density, area etc.  These building typologies are grouped by type (single-family, multi-family houses, high rise buildings), age (until 1945; old buildings, between 1946 and 1990; post-war buildings, after 1991; new buildings) and geographical location (South Europe: Malta, Cyprus, Portugal, Greece, Spain, Italy, France; Central Europe: Belgium, the Netherlands, Ireland, Hungary, Slovenia, Luxembourg, Germany, United Kingdom, Slovakia, Denmark, Czech Republic, Austria, Poland; North Europe: Lithuania, Latvia, Estonia, Sweden, Finland).

The building typologies defined in JRC IMPRO-Building Project are used in case of limited information to infer building typologies in some countries. Due to the different goal of the project, the results are processed to serve for the purposes of NERA Project. Each defined typology in group of countries is re-evaluated and compared with some countries (Italy, France, Portugal) where census data is available. The typologies which share the higher fractions in building stock compares reasonably among those countries.

Table 2 Comparison of building typologies between JRC-IMPRO Building project and census data

| | Italy | Greece | Portugal | Slovenia |
|---|---|---|---|---|
| JRC IMPRO-Building | | | | |
| RC | 0.30 | 0.41 | 0.45 | 0.18 |
| Masonry | 0.64 | 0.59 | 0.55 | 0.77 |
| Wood | 0.05 | 0.00 | 0.00 | 0.05 |
| Census | | | | |
| RC | 0.25 | 0.47 | 0.49 | 0.15 |
| Masonry | 0.61 | 0.5 | 0.50 | 0.79 |
| Other | 0.14 | 0.03 | 0.01 | 0.07 |

**Appendix D: Data from expert elicitation in WHE and PAGER-WHE initiatives**

**World Housing Encyclopaedia**

| **CYPRUS** | *V. Levtchitch* | *Notes* |
|---|---|---|
| Type of the building | Gravity-Designed Reinforced Concrete Frame buildings with URM Infill Walls | |
| Where to be found | Entire country, in both rural and urban areas | |
| Approximate composition in building stock | More than 30% of the total dwelling stock<br>(in urban areas 45%) | |
| Material | Structural concrete, steel | Characteristic strengths;<br><br>- Frames: Concrete:15-25MPa, Steel: S220-S500 |
| Lateral load resisting system | Moment resisting frame/designed for gravity loads only, with URM infill walls | - RC frame acts as stabilizing lateral load resisting system.<br>- Rigid, brittle infill walls have two times smaller inter-story drift capacities than columns.<br>- Joint response of infill walls can be utilized only within low levels of lateral displacements<br>- Floors behave as diaphragms |
| Typical story height | 3.0 meters | |
| Number of stories | 3-5 stories | |
| Date of construction | In practice for less than 50 years (widely after 1974 until 1995) | |
| Irregularity | - Columns are often located irregularly; do not form a definite grid.<br>- Soft ground stories for car-parks and shops.<br>- Staircases and lift shafts are not located symmetrically.<br>- Re-entrant corners<br>- Set-backs | - Buildings do not share common walls with adjacent buildings<br>- There are clearly defined seismic separation joints<br>- Several modifications to the building causing |

| | | |
|---|---|---|
| | | irregularities |

| **GREECE-1/3** | *T.P. Tassios, Kostas Syrmakezis* | *Notes* |
|---|---|---|
| Type of the building | Multistory reinforced concrete frame building | |
| Where to be found | Mainly in Greek suburbs | |
| Approximate composition in building stock | More than 30% of the entire housing stock | |
| Material | Structural concrete | Characteristic strengths;<br><br>- Frames: Concrete:16-25MPa, Steel: S500 (fy=500MPa) |
| Lateral load resisting system | Moment resisting frame/Dual system-Frame with shear wall | - The lateral drift is governed by the stiffness of the columns and walls<br>- Walls located at the perimeter of the building in both directions minimize the torsional effects<br>- Floors behave as diaphragms |
| Typical story height | 3.0 meters | Generally medium-rise |
| Number of stories | 4-6 stories | |
| Date of construction | In practice for less than 25 years | |
| Irregularity | Soft story | - Do not share common walls with adjacent buildings |

| **GREECE-2/3** | *T.P. Tassios, Kostas Syrmakezis* | *Notes* |
|---|---|---|
| Type of the building | Load-bearing stone masonry building | |
| Where to be found | Mainly in the historical centers of Greek cities and provinces (in both rural and urban areas) | |
| Approximate composition in | around 10% of the housing | |

| | | |
|---|---|---|
| building stock | stock in the region | |
| Material | Masonry | Characteristic strengths;<br><br>- Walls: Stone; fc:80MPa, Mortar; ft=0.1 to 0.2 MPa |
| Lateral load resisting system | Unreinforced stone masonry bearing walls/ Rubble stone (field stone) in mud/lime mortar or without mortar (usually with timber roof) | - Wall layout, wall connections, roof/floor-to-wall connections are critical for the lateral performance<br>- Floors and roofs are considered to be rather flexible |
| Typical story height | 4.0 meters | |
| Number of stories | 2-3 stories | |
| Date of construction | In practice for more than 200 years | |
| Irregularity | - The building plan is mainly rectangular; regular in both plan and elevation | - Do not share common walls with adjacent buildings<br>- Usually demolition (or partial demolition) of interior load bearing walls as modifications |

| **GREECE-3/3** | *Vlasis Koimousis* | *Notes* |
|---|---|---|
| Type of the building | Reinforced concrete frame building with an independent vertical extension | |
| Where to be found | In the suburbs of large Greek cities and in smaller towns (in both urban and rural areas) | Typical building in the central Greece (Thrakomakedones-suburb of Athens) |
| Approximate composition in building stock | | |
| Material | Structural concrete | Characteristic strengths;<br><br>- RC walls: C12/16, S400<br><br>-RC frames: C12/16, S220 (1960s)<br><br>RC frames: C12/19, S400 |

| | | |
|---|---|---|
| | | (1980s) |
| Lateral load resisting system | Moment resisting frame/ designed for seismic effects with URM infill walls | - The older (first two floors-1960s) portion is RC frame with limestone masonry infill walls designed according to the building code of the period<br>- The newer (top floor-1980s) portion is a dual system/RC Frame with shear walls designed according to the seismic provisions<br>- Floors and roofs act as a diaphragm |
| Typical story height | 3.5 meters | |
| Number of stories | 3 stories | |
| Date of construction | In practice for less than 50 years | Traditional concrete construction of 1960s and improved construction practices in 1980s |
| Irregularity | - The building plan is mainly rectangular; regular in both plan and elevation | - Do not share common walls with adjacent buildings<br>- Top floor is added as a vertical extension |

| **ITALY-1/7** | *DinaD'Ayala, Elena Speranza* | *Notes* |
|---|---|---|
| Type of the building | Single Family stone masonry house | |
| Where to be found | Centro Italia, Umbria, Toscana, Alto Lazio, Marche (commonly in urban areas, most frequently in medieval hilltop small and medium size town centers) | Also with some modification in other parts of Italy |
| Approximate composition in building stock | | |
| Material | Masonry | Characteristic strengths;<br><br>- Walls: rubble stone fc=1MPa, ts=0.02MPa |

| | | |
|---|---|---|
| | | - Lime mortar 1:3 or 1:2:9 |
| Lateral load resisting system | Stone masonry walls/Rubble stone(field stone) in mud/lime mortar or without mortar (usually with timber floor) | - Masonry walls with or without metal ties<br>- Floors and roofs does not act as rigid |
| Typical story height | 2.5-3.2 meters (typically 3 meters) | |
| Number of stories | 2-5 stories | |
| Date of construction | In practice for less than 200 years<br><br>(with updates and modifications during last 100 years) | |
| Irregularity | - Very often irregular from one floor to the next one | - Share common walls with adjacent buildings<br>- More floors, balconies added in time<br>- Some rearrangement of the interior walls are introduced |

| **ITALY-2/7** | *DinaD'Ayala, Elena Speranza, Francesco D'Ercole* | *Notes* |
|---|---|---|
| Type of the building | Single Family historic brick masonry house | |
| Where to be found | Centro Italia, Marche, Emilia Romagna (commonly in urban areas, most frequently in medieval hill towns) | Also with some modification in other parts of Italy |
| Approximate composition in building stock | | |
| Material | Masonry | Characteristic strengths;<br><br>- Walls: Brick masonry fc=4MPa, ft=0.22MPa, g= 18 kN/$m^3$<br><br>- Lime mortar 1:3 Lime/sand mortar |
| Lateral load | Confined masonry wall system-Adobe/ Earthen Walls, | - Brick masonry walls with or without metal ties |

| | | |
|---|---|---|
| resisting system | mud walls | - Floors and roofs does not act as rigid |
| Typical story height | 2.5-3 meters (typically 3 meters) | |
| Number of stories | 2-3 stories | |
| Date of construction | In practice for less than 200 years<br><br>(with updates and modifications during last 100 years) | |
| Irregularity | - Regular in both plan and elevation | - Share common walls with adjacent buildings<br>- Alteration of door and window opening is the most typical modification |

| **ITALY-3/7** | *Maurizio Leggeri, Giuseppe Lacava, Eugenio Viola* | *Notes* |
|---|---|---|
| Type of the building | Reinforced concrete frame building | |
| Where to be found | Common in the region of Potenza( Basilicata) | Common in urban areas, also present in suburban areas |
| Approximate composition in building stock | | |
| Material | Structural concrete | Characteristic strengths;<br><br>- Walls: fc=300kg/cm2, fy=4400kg/cm2<br><br>- Frame: fc=300kg/cm2, fy=4400kg/cm2 |
| Lateral load resisting system | Moment resisting frame/ designed for gravity loads only, with URM infill walls | - The strengthening was carried out after 1980, by installing new RC shear walls, L-shaped concrete columns, strengthening the foundation<br>- Floors and roofs are considered as rigid |
| Typical story height | 3.5-4.0 meters (typically 3 | |

| | | |
|---|---|---|
| | meters) | |
| Number of stories | 4-10 stories | |
| Date of construction | In practice for less than 50 years | - Currently not in practice |
| Irregularity | - Regular in both plan and elevation | - Don't share common walls with adjacent buildings |

| **ITALY-4/7** | *Agostino Goretti, Daniela Malvolti, Simona Papa* | *Notes* |
|---|---|---|
| Type of the building | Brick masonry farmhouse with a 'dead door' | Composed of two sections; residential and agricultural |
| Where to be found | In the south of Padania plain (Reggio Emilia Province) | Common in rural areas |
| Approximate composition in building stock | 20% of entire stock in Reggio Emilia municipality | Total number of this type of building is less than 9000 |
| Material | Masonry | Characteristic strengths;<br>- Walls: solid bricks with lime mortar normal stress=6MPa, shear stress=0.3MPa,<br>1:3 lime/sand mortar |
| Lateral load resisting system | Unreinforced masonry walls/ Brick masonry in mud/lime mortar | - Floors and roofs are not considered as rigid |
| Typical story height | 2.5-3.0 meters (typically 3 meters) | Agricultural section's 1$^{st}$ floor height is 2.5-3.0 meters, 2$^{nd}$ floor height is 5.0-9.0 meters. |
| Number of stories | 2 stories | |
| Date of construction | In practice for less than 200 years<br>(19$^{th}$ and 20$^{th}$ centuries) | - Currently not in practice |
| Irregularity | - Regular in plan<br>- Vertical irregularity | - Don't share common walls with |

| | | |
|---|---|---|
| | (offset of the floors in the residential and agricultural sections) | adjacent buildings |

| **ITALY-5/7** | *Mauro Sassi, Chiara Cei* | *Notes* |
|---|---|---|
| Type of the building | Multistory tower masonry with stone pillars and wood or arched beams- 'Casa Torre' | |
| Where to be found | In Tuscany and adjacent districts | Common in rural areas |
| Approximate composition in building stock | | |
| Material | Masonry | Characteristic strengths;<br><br>- Walls: 'Verrucano' or limestone masonry for blocks; fc=20-50MPa (verrucano or limestone) fcm=1-4MPa (mortar)<br><br>- Frames: Clay units masonry arches or wood beams; fc=10-20MPa (clay unit) fcm=1-4MPa (mortar) |
| Lateral load resisting system | Stone Masonry Walls-Rubble stone(field stone) in mud/lime mortar or without mortar (usually with timber floor) | - Plane frames formed by stone pillars and wood beams or wood-masonry arches<br>- Moment resisting connections between pillars and beams or arches<br>- High strength stones<br>- No moment resisting connections between the floors and the walls or arches<br>- Floors and roofs are not considered as rigid |
| Typical story height | typically 5 meters | |
| Number of stories | 3-4 stories | |
| Date of construction | In practice for more than 200 years | - Currently not in practice<br>- Originated around 1100 AD and |

| | | |
|---|---|---|
| | | modified during 17th century by incorporating the single masonry towers into adjacent buildings. |
| Irregularity | - Regular in both plan and elevation | |

| **ITALY-6/7** | *Riccardo Vetturini, Anacleto Cleri, Fabrizio Mollailoli, Paolo Bazzuro* | *Notes* |
|---|---|---|
| Type of the building | Unreinforced stone wall rural housing (upper income) | |
| Where to be found | In Central Italy (Umbria) | Common in rural areas |
| Approximate composition in building stock | 60% of the entire building stock in the rural areas of Umbria | |
| Material | Masonry | Characteristic strengths;<br>- Walls: stone blocks; fc=2MPa, shear= 50-70kPa<br>Lime/sand=1/3, block dimensions max. 60*30*30cm, min. 10*5*3cm |
| Lateral load resisting system | Earthen Walls/Stone Masonry Walls-Rubble stone(field stone) in mud/lime mortar or without mortar (usually with timber floor) | - Stone masonry walls are made of dressed rectangular stones of regular size for wythes and debris of smaller size for between the walls ‘a sacco’<br>- Bond between stones are often absent<br>- Lime mortar is poor quality<br>- Floors and roofs are not considered as rigid; fairly flexible |
| Typical story height | typically 5.2 meters | |
| Number of stories | 4 above ground and an underground basement | |
| Date of | In practice for less than 200 | - Currently in |

| | | |
|---|---|---|
| construction | years | practice with some details' and materials' modifications |
| Irregularity | - Irregular in both plan and elevation | -Share common walls with adjacent buildings |

| **ITALY-7/7** | *Riccardo Vetturini, Fabrizio Mollailoli, Paolo Bazzuro* | *Notes* |
|---|---|---|
| Type of the building | Unreinforced stone wall rural housing (lower and middle income) | |
| Where to be found | In Central Italy (Umbria region/Perugia province/ Nocera Umbra municipality) | Common in rural areas; on hilly and flat areas throughout central Italy |
| Approximate composition in building stock | 60% of the entire building stock in the rural areas of Umbria | |
| Material | Masonry | Characteristic strengths;<br>- Walls: stone blocks, shear= 30kPa<br>Lime/sand=1/3, block dimensions max. 50*30*30cm, min. 10*5*3cm |
| Lateral load resisting system | Earthen Walls/Stone Masonry Walls-Rubble stone(field stone) in mud/lime mortar or without mortar (usually with timber floor) | - Stone masonry walls are made of fairly regularly cut stones of regular size for exterior wythes and stone of smaller size and rounder in shape for interior wythe with debris of smaller size for between the walls 'a sacco'<br>- Bond between stones are often absent<br>- Lime mortar is poor quality<br>- Steel ties are rarely present<br>- Floors and roofs are not considered as rigid; fairly flexible |

| | | |
|---|---|---|
| Typical story height | typically 3.2 meters | |
| Number of stories | 4 stories | |
| Date of construction | In practice for less than 100 years | - Currently in practice with some details' and materials' modifications |
| Irregularity | - Irregular in both plan and elevation | -Share common walls with adjacent buildings |

| **PORTUGAL** | *Rafaela Cardoso, Mario Lopes, Rita Bento, Dina D'Ayala* | *Notes* |
|---|---|---|
| Type of the building | Historic, braced frame timber buildings with masonry infill ('Pambalino' buildings) | |
| Where to be found | In downtown Lisbon, area near Tagus River (Baixa) | Common in urban areas |
| Approximate composition in building stock | | |
| Material | Masonry | Characteristic strengths;<br><br>- Walls: irregular blocks of calcareous masonry set in lime mortar, low tensile and shear strength characteristics<br><br>- Frames: timber braced frame (pine and oak) gaiola |
| Lateral load resisting system | Stone Masonry Walls | - Masonry walls and a 3D wood frame structure (gaiola) above the $1^{st}$ floor, double braced with diagonal timber elements<br>- Gaiola exhibits ductile behavior and allows some energy dissipation<br>- Floors and roofs are not considered as rigid<br>- Wood floors can be considered as flexible diaphragm |

| | | |
|---|---|---|
| Typical story height | Ground floor is higher than other floors, 4.5 meters<br><br>typically 3.5-4.0 meters | |
| Number of stories | 4-5 stories | - Due to regulations of the time, max. 4 stories including ground floor plus an habitable attic under the roof |
| Date of construction | In practice for more than 200 years | - Currently not in practice |
| Irregularity | - Very regular | -Share common walls with adjacent buildings |

| **ROMANIA-1/8** | *Maria D. Bostenaru, Ilie Sandu* | *Notes* |
|---|---|---|
| Type of the building | Reinforced concrete frame structure with diagonal bracing and brick infill walls | |
| Where to be found | In Bucharest | Common in urban areas |
| Approximate composition in building stock | A few existing | |
| Material | Structural concrete | Characteristic strengths;<br><br>- Frames: fc=21MPa (28-day cube compressive strength, quality A)<br><br>fy= 240MPa |
| Lateral load resisting system | Moment resisting frame/Designed for seismic effects with URM infill walls | - RC frame with RC diagonal bracing<br>- The floor structure consists of two-way RC slabs supported by beams cast in place<br>- Floors and roofs are considered as rigid |
| Typical story height | typically 2.75 meters | |
| Number of stories | 5-8 stories | |
| Date of | In practice for less than 75 | - Currently not in practice |

| | | |
|---|---|---|
| construction | years | - These buildings are retrofitted after 1977 EQ |
| Irregularity | - Not regular; mostly rectangular but exceptions with triangular shaped plan | -Do not share common walls with adjacent buildings |

| **ROMANIA-2/8** | *Maria D. Bostenaru, Ilie Sandu* | *Notes* |
|---|---|---|
| Type of the building | Reinforced concrete cast-in situ shear wall buildings (OD-Type, with 'fagure' plan) | |
| Where to be found | In all part of Romania, particularly in Bucharest (six quarters: Militari, Colentina, Drumul Taberli, Pantelimon, Berceni, Iancului) | - Except Iancului, others are located in suburban area of the city, consist mainly newer settlements (built after World War II) |
| Approximate composition in building stock | 60% of the new buildings | - 8000 apartments in Bucharest |
| Material | Structural concrete | Characteristic strengths;<br><br>- Walls: fc=25MPa, fy=370 or 520 MPa<br><br>- Frames: fc=25MPa fy=370 or 520 MPa |
| Lateral load resisting system | Structural wall/ Moment frame with in-situ shear walls | - RC walls supported by RC slabs<br>- Walls are continuous throughout the building height, laid in two directions, with only one centrally located in the longitudinal direction and eight walls in the transverse direction (4 over buildings width, 4 over smaller length)<br>- Floors and roofs are considered as rigid |
| Typical story height | typically 2.6 meters | |
| Number of stories | 10-11 stories | |

| | | |
|---|---|---|
| Date of construction | In practice for less than 50 years<br><br>From 1965 to 1989 | - Currently not in practice |
| Irregularity | - regular; mostly rectangular with a very large length/width aspect ratio (over 10)<br>- large cantilever balconies | -Do not share common walls with adjacent buildings |

| **ROMANIA-3/8** | *Maria D. Bostenaru, Ilie Sandu* | *Notes* |
|---|---|---|
| Type of the building | Precast concrete panel apartment buildings | |
| Where to be found | In all major urban areas in Romania | |
| Approximate composition in building stock | | |
| Material | Structural concrete | Characteristic strengths;<br><br>- Walls: fc=25MPa (around 1970s, cube strength), fy=350MPa (PC52) |
| Lateral load resisting system | Precast concrete/Large panel precast walls | - The load-bearing walls are laid in two principal directions; two interior walls in the longitudinal direction and nine walls in the transverse direction<br>- Four transverse walls are continuous over the building width, five walls are shorter<br>- The lateral stability is provided by columns tied to the wall panels<br>- Floors and roofs are considered as rigid |
| Typical story height | typically 2.6 meters | |
| Number of stories | 4-11 stories | |
| Date of | In practice for less than 25 | - Currently not in practice |

| | | |
|---|---|---|
| construction | years<br><br>From 1960s to 1990s | - 1959-1960: 5-storey<br>- 1961-1963: 8-storey<br>- 1963-1973: 4-storey<br>- After 1973: 9-storey |
| Irregularity | - regular; mostly rectangular | -Do not share common walls with adjacent buildings |

| **ROMANIA-4/8** | *Maria D. Bostenaru, Ilie Sandu* | *Notes* |
|---|---|---|
| Type of the building | A single-family, two-storey house with brick walls and timber floors | |
| Where to be found | In all major urban areas in Romania; Zimnicea, Cralova, Ploesti, Buzau, Iasi, Bucharest, in some smaller townships in these counties, Prahova county | Typical for urban areas and only very old buildings in rural areas |
| Approximate composition in building stock | 13% of all buildings | |
| Material | Masonry | Characteristic strengths;<br><br>- Walls: bricks: 6.25x12.5x25cm |
| Lateral load resisting system | Unreinforced masonry walls/ brick masonry in mud/lime mortar | - in 3-storey hybrid systems: top storey is in timber, intermediate storey in reinforced brickwork or even reinforced concrete and bottom storey is of original brick masonry construction<br>- Floors and roofs are not considered as rigid |
| Typical story height | 2.6 meters | |
| Number of stories | Typically 2 stories, rarely 3 stories | |
| Date of construction | In practice for less than 75 years | - Currently not in practice<br>- Discontinued in |

| | | |
|---|---|---|
| | Built in the first half of the 20th century | 1940s |
| Irregularity | - regular; mostly rectangular<br>- (no torsional effects) | -Share common walls with adjacent buildings |

| **ROMANIA-5/8** | *Maria D. Bostenaru, Ilie Sandu* | *Notes* |
|---|---|---|
| Type of the building | One family one storey house 'wagon house' | |
| Where to be found | In small towns, near center districts<br>(especially in the southern part, former Wallachia) | Commonly in suburban and urban areas |
| Approximate composition in building stock | 13% of all buildings | |
| Material | Masonry | Characteristic strengths;<br><br>- Walls: clay bricks: C75, fc=7.5-10MPa (min 5MPa), bending strength= 1.8MPa (min 0.9MPa); strength of masonry, C50+M10=2.8, C75+M10=3.4, C100+M10=4.0 (further values in UAIM, 2000) |
| Lateral load resisting system | Unreinforced masonry walls/ brick masonry in lime/cement mortar | - All walls have sufficient stiffness to contribute to resisting lateral loads, both in terms of load capacity and deformation<br>- Stiffness is not evenly distributed among walls, however no torsional effects<br>- Floors and roofs are not considered as rigid |
| Typical story height | 3.5 meters | |
| Number of stories | 1 storey | |
| Date of construction | In practice for less than 200 years | - Currently not in practice<br>- Practiced until |

| | | |
|---|---|---|
| | From the end of 19th century until the Second World War | 1947 |
| Irregularity | - regular; mostly rectangular<br>- (no torsional effects) | -Don't share common walls with adjacent buildings |

| **ROMANIA-6/8** | *Maria D. Bostenaru* | *Notes* |
|---|---|---|
| Type of the building | Block of flats with 11 floors of cast-in-situ concrete, gliding frameworks | |
| Where to be found | In the peripheral areas of bigger towns, especially Bucharest | Commonly urban areas |
| Approximate composition in building stock | | |
| Material | Structural concrete | Characteristic strengths;<br><br>- Structural walls, RC: concrete,B200, fc=3-4MPa, fy=PC52, PC60, OB37 |
| Lateral load resisting system | Structural wall/moment frame with in-situ shear walls | - Shear walls in both longitudinal and transverse direction<br>- Additional rigidity is provided by cat-in-situ RC slabs<br>- The 12 transversal and 3 longitudinal walls are continuous through the whole building height<br>- Floors and roofs are considered as rigid |
| Typical story height | 2.86 meters | |
| Number of stories | 11 storey | High rise |
| Date of construction | In practice for less than 50 years<br><br>Practiced during 1960-1990 | - Currently not in practice |
| Irregularity | - regular; mostly rectangular | -Don't share common walls with adjacent buildings |

| **ROMANIA-7/8** | *Maria D. Bostenaru* | *Notes* |
|---|---|---|
| Type of the building | Early RC frame condominium building with masonry infill walls designed for gravity loads only | |
| Where to be found | In the center and other parts of Bucharest | Commonly urban areas |
| Approximate composition in building stock | | |
| Material | Structural concrete | Characteristic strengths;<br>- Walls: clay brick masonry, C50, fc= 5-7.5MPa (min 2.6), bending strength= 1.5 (min 0.75); bricks, C75, fc=7.5-10 MPa (min 5.0), bending strength=1.8 (min 0.9); bricks C100, fc= 10MPa (min 7.5), bending strength= 2.1 (min 1.05)<br>- Frames: RC, concrete B120 (avg. 120-130 N/cm2); steel: round smooth steel of the quality OBOO(?) |
| Lateral load resisting system | Moment resisting frame/designed for gravity loads only, with URM infill walls | - Columns are unevenly distributed and beams are distributed in a way not forming moment resisting frames<br>- Beams have a reduced sections, columns are not adequately reinforced for lateral loads<br>- Floors and roofs are considered as rigid |
| Typical story height | 3 meters | |
| Number of stories | 5-10 storeys | - Mid or High rise<br>- Often two basements where first is half basement |

| | | |
|---|---|---|
| Date of construction | In practice for less than 50 years<br><br>Practiced during 1907-1945, dominantly in 1930s | - Currently not in practice |
| Irregularity | - Irregular in plan and elevation; U,H,L shaped in plan and recesses at upper floors | -Share common walls with adjacent buildings |

| **ROMANIA-8/8** | *Maria D. Bostenaru* | *Notes* |
|---|---|---|
| Type of the building | Medium/high rise moment resisting reinforced concrete frame buildings | |
| Where to be found | In whole Romania | Commonly urban areas |
| Approximate composition in building stock | 4% of medium rise constructions which is 2/3 of 400.000 residential buildings constructed after 1950 | |
| Material | Structural concrete | Characteristic strengths;<br><br>- Frames: initially B170 and B200, later (1974-76) B300, |
| Lateral load resisting system | Moment resisting frame/designed for gravity loads only, with URM infill walls | - Columns are unevenly distributed and beams are distributed in a way not forming moment resisting frames<br>- Beams have a reduced sections, columns are not adequately reinforced for lateral loads<br>- Floors and roofs are considered as rigid |
| Typical story height | Typically 2.75 meters | 4 meters for soft ground storey, lower height basement 2.005m |
| Number of stories | Mid-rise: ground floor+ 3-4 | - Ground floor for commercial |

| | | |
|---|---|---|
| | upper floors and mostly high-rise: ground floor+8-14 (or more)upper floors | purposes, upper floors for residential units |
| Date of construction | In practice for less than 25 years | - Currently not in practice |
| Irregularity | - Irregular; any shape in plan typically rectangular, square, L or U layout<br>- Soft storey mechanism due to higher story height for the lower floor | -Don't share common walls with adjacent buildings |

| **SLOVENIA-1/3** | *Marjana Lutman, Miha Tomazevic* | *Notes* |
|---|---|---|
| Type of the building | Rubble-stone masonry house | |
| Where to be found | In Upper Posocje | Commonly in both urban and rural areas |
| Approximate composition in building stock | 24% of dwelling stock in that area | |
| Material | Masonry | Characteristic strengths;<br><br>- Walls: rubble stone mortar masonry, fc=150MPa, low strength fc=0.98MPa, tensile strength=0.06-0.08MPa |
| Lateral load resisting system | Stone masonry walls/ rubble stone (field stone) in mud/lime mortar or without mortar (usually with timber floor) | - Exterior and interior stone walls uniformly distributed in both orthogonal directions<br>- Walls are not connected by means of wooden or iron ties<br>- Beams have a reduced sections, columns are not adequately reinforced for lateral loads<br>- Floors and roofs are not considered as rigid |

| | | |
|---|---|---|
| Typical story height | Typically 2.7 meters<br><br>Between 2.5-2.7 meters | 4 meters for soft ground storey, lower height basement 2.005m |
| Number of stories | 2-3 storey(s) | |
| Date of construction | In practice for less than 75 years<br><br>Practiced between World War I and II | - Currently not in practice |
| Irregularity | - Usually regular plan | -Don't share common walls with adjacent buildings |

| **SLOVENIA-2/3** | *Marjana Lutman, Miha Tomazevic* | *Notes* |
|---|---|---|
| Type of the building | Unreinforced brick masonry apartment building | |
| Where to be found | In all Slovenian towns | Commonly in urban areas |
| Approximate composition in building stock | Up to 30% of entire housing stock in Slovenia | |
| Material | Masonry | Characteristic strengths;<br><br>- Walls: solid clay brick units with cement mortar, fc=10-15MPa (clay brick), 0.5-5MPa (cement mortar), 2-4MPa (masonry), tensile strength 0.12-0.25MPa (masonry) |
| Lateral load resisting system | Unreinforced masonry walls/ brick masonry in lime/cement mortar | - Exterior and interior brick masonry walls<br>- Mortar mix varies through building height<br>- Due to large openings in longitudinal direction, lateral resistance in this direction is significantly inferior as compared to transverse direction<br>- Floors and roofs are |

| | | |
|---|---|---|
| | | considered as rigid |
| Typical story height | Typically 2.85 meters<br><br>Between 2.7-3 meters | 4 meters for soft ground storey, lower height basement 2.005m |
| Number of stories | 4-6 storey(s) | |
| Date of construction | In practice for less than 100 years<br><br>Practiced between 1920 and 1965 | - Currently not in practice |
| Irregularity | - Typically rectangular | -Don't share common walls with adjacent buildings |

| **SLOVENIA-3/3** | *Marjana Lutman, Miha Tomazevic* | *Notes* |
|---|---|---|
| Type of the building | Confined brick masonry house | |
| Where to be found | In most part of Slovenia | Commonly in both urban and rural areas |
| Approximate composition in building stock | 40% of entire housing stock in Slovenia | |
| Material | Masonry | Characteristic strengths;<br><br>- Walls: perforated clay blocks, mortar, masonry, fc=10-15MPa, 2.5-5MPa, 3-6MPa,respectively; tensile strength 0.18-0.3MPa (masonry)<br><br>- Frames: fc=20MPa (cube strength), fy/fu=400/500MPa |
| Lateral load resisting system | Confined masonry/ clay brick masonry, with concrete posts/tie columns and beams | - Exterior and interior block masonry walls, uniformly distributed in both direction<br>- Floors and roofs are considered as rigid |
| Typical story height | Typically 2.75 meters<br><br>Between 2.6-2.9 meters | 4 meters for soft ground storey, lower height |

| | | |
|---|---|---|
| | | basement 2.005m |
| Number of stories | 1-2 storey(s) | - This type of buildings has an attic |
| Date of construction | In practice for less than 50 years<br><br>Started in 1970s | - Currently in practice |
| Irregularity | - Typically rectangular | -Don’t share common walls with adjacent buildings |

| **SWITZERLAND-1/2** | *Maria D. Bostenaru* | *Notes* |
|---|---|---|
| Type of the building | Half-timbered house in the ‘border triangle’ (Fachwerkhaus im Dreilandereck) | |
| Where to be found | In regions located at a specific distance from the mountainous areas, in northern France, in southern to central Germany and Tirol | Commonly in both urban and rural areas |
| Approximate composition in building stock | | |
| Material | Timber | Characteristic strengths;<br><br>- Walls: wall infill (mountainous region): Elasticity modulus of 70000-120000, tension strength of 1310 kg/cm2, compression strength of 510 kg/cm2, bending strength of 1020 kg/cm2 and shear strength of 79 kg/cm2<br><br>- Frames: Timber frame (old buildings- oak, sometimes fir, wood) Elasticity modulus of 70000-120000, tension strength of 1310 kg/cm2, compression strength of 510 kg/cm2, bending |

| | | |
|---|---|---|
| | | strength of 1020 kg/cm2 and shear strength of 79 kg/cm2<br><br>Timber frame (new buildings- Douglas fir or laminated wood) Elasticity modulus of 72000-144000, tension strength of 250 kg/cm2, compression strength of 1080 kg/cm2, bending strength of 840 kg/cm2 and shear strength of 79 kg/cm2 |
| Lateral load resisting system | Load-bearing timber frame/ Wood frame (with special connections) | - The outside walls consist out of an array of pillars and supported from a threshold on the bottom and stiffened by crossbars and struts in the middle. In the upper part, they are connected by a Rahmhoiz. Pillars are firmly connected with a threshold and Rahmhoiz, so there is no out-of-plane failure risk.<br>- Floors and roofs are not considered as rigid |
| Typical story height | Typically 2.5 meters | Average height of 2.1m or 4.0m (the higher stone ground floor) |
| Number of stories | 1-8 storey(s) | - Typically there are two normal stories and a two-story of attic. |
| Date of construction | In practice for 700 years | - Currently in practice |
| Irregularity | - Typically rectangular but irregular in both plan and height | -Share common walls with adjacent buildings |

| **SWITZERLAND-2/2** | *Kerstin Lang, Hugo Bahmann* | *Notes* |
|---|---|---|
| Type of the building | Urban residential buildings of the 19th century in the city of Basel | |
| Where to be found | In urban residential areas of Basel and in other cities of Switzerland and in German cities | Commonly in urban areas |
| Approximate composition in building stock | | |
| Material | Masonry | Characteristic strengths;<br><br>- Walls: unreinforced masonry with lime mortar; brick: fc=1.2-1.6MPa, simple stone: fc=0.8-1.6MPa, lime mortar: 1/3 |
| Lateral load resisting system | Stone Masonry Walls/Rubble stone(field stone) in mud/lime mortar or without mortar(usually with timber floor) | - Consists of unreinforced masonry walls as bricks, simple stone and rubble stone at different combinations.<br>- Often for the outer layer of the façade walls, larger cut stones are used, especially at the lower floors, with simple stones and bricks behind.<br>- Lime mortar is used.<br>- Walls from the upper floors rest on the basement walls which are made of brick or simple stone masonry with lime mortar.<br>- Floors and roofs are not considered as rigid |
| Typical story height | Typically 3.0 meters<br><br>Range between 2.8-3.5m | - The story height of the ground floor is often bigger than the story height of the upper floors.<br>- Usually have a basement |

| | | |
|---|---|---|
| Number of stories | 4-5 storey(s) | - Typically there are two normal stories and a two-story of attic. |
| Date of construction | In practice for less than 100 years<br><br>Practice in the second half of $19^{th}$ century until the beginning of $20^{th}$ century | - Currently not in practice |
| Irregularity | - Typically rectangular and regular in both plan and height | -Share common walls with adjacent buildings |

| **TURKEY-1/2** | *Polat Gulkan, Mark Ascheim, Robin Spence* | *Notes* |
|---|---|---|
| Type of the building | Reinforced concrete frame building with masonry infills | |
| Where to be found | Entire Turkey | Commonly in urban areas |
| Approximate composition in building stock | 80% of urban households | - In three largest cities (Istanbul, Izmir, Ankara), over 50% of the buildings are of RC frame construction and over %75 of these are more than three stories<br>- 90% of new housing units are being built in this type |
| Material | Structural Concrete | Characteristic strengths;<br><br>- Walls: concrete, fc=10-20Mpa<br><br>- Frames: concrete, fc= 10-20MPa |
| Lateral load resisting system | Moment resisting frame/ designed for seismic effects, with structural URM infill walls | - Some structural systems are 'flat slab structure' or rarely 'frame with concrete shear walls-dual system'.<br>- Tunnel form RC |

| | | |
|---|---|---|
| | | buildings are common during the last 20 years.<br>- Older buildings are designed for gravity loads only, without seismic considerations<br>- Recent construction has been expected to be designed with seismic features<br>- RC slabs cast monolithically with RC beam and column framing<br>- Masonry infill is mortared in place to form partition walls<br>- Floors and roofs considered as rigid |
| Typical story height | Typically 3.0 meters<br><br>Range between 2.7-3.0m | - Mid-rise<br>- Usually have a basement |
| Number of stories | 3-7 storey(s) | |
| Date of construction | In practice for less than 50 years | - Currently in practice |
| Irregularity | - Typically rectangular or nearly so but irregular in both plan and elevation<br>- Some conceivable shape may be encountered<br>- Irregular column arrangements leading disparities in lateral resistance<br>- Soft-storey mechanism<br>- Eccentric loading | - Don't share common walls with adjacent building<br>- Use of the lowest floor for commercial purposes creates soft stories<br>- $1^{st}$ and upper floors are commonly cantilevered out from the ground floor resulting in undesirable framing arrangements<br>- Large window openings and cantilevered balconies are common<br>- Beams frame into columns eccentrically |

| **TURKEY-2/2** | *Polat Gulkan, Ahmet Yakut* | *Notes* |
|---|---|---|

| | | |
|---|---|---|
| Type of the building | Tunnel form building | |
| Where to be found | Densely populated areas with limited land available for development | Commonly in urban areas and sub-urban areas where newly developed parts of urban areas located on the outskirts or peripheries of existing settlements |
| Approximate composition in building stock | | |
| Material | Structural Concrete | Characteristic strengths;<br><br>- Walls: concrete, fc=25Mpa, fy=500MPa |
| Lateral load resisting system | Structural wall/ Moment frame with in-situ shear walls | - Structural walls provide lateral-load resistance<br>- The slab and walls are cast monolithically forming a joint<br>- RC slabs cast monolithically with RC beam and column framing<br>- Floors and roofs considered as rigid |
| Typical story height | Typically 2.8 meters<br><br>Range between 2.3-3.0m | |
| Number of stories | - Earthquake-affected areas have 2-6 stories<br>- 10-15 storey(s) for multi residential houses | |
| Date of construction | In practice for less than 25 years<br><br>Since the late 1970s and early 1980s | - Currently in practice |
| Irregularity | - A wide variety of plan and elevation shapes | - Don’t share common walls with adjacent building |

**PAGER-WHE Project**

| Construction Material | Construction Subtype | Fraction of population who LIVE in this building type (%) | | Fraction of population who WORK in this building type (%) | | Peak average # of occupants per building |
|---|---|---|---|---|---|---|
| | | Urban | Rural | Urban | Rural | |
| | **CYPRUS** | | | | | |
| Masonry | Massive stone masonry (in lime/cement mortar) | 2 | 5 | 4 | 5 | 6 |
| Masonry | Adobe block walls | 7 | 10 | 7 | 11 | 6 |
| Masonry | Unreinforced brick masonry in cement mortar with reinforced concrete floor/roof slabs | 3 | 5 | 3 | 5 | 6 |
| Structural Concrete | Concrete moment resisting frames designed for gravity loads only | 48 | 43 | 42 | 34 | 40 |
| Structural Concrete | Concrete moment resisting frames with unreinforced masonry infill walls | 30 | 35 | 28 | 39 | 60 |
| Structural Concrete | Concrete moment resisting frames with concrete shear walls-dual system | 10 | 1 | 14 | 5 | 70 |
| Steel | Steel braced frame eccentric | 0 | 0 | 2 | 0 | 70 |
| Wood | Load-bearing timber stud wall frame with plywood/gypsum board sheathing | 0 | 1 | 0 | 1 | 5 |
| | **FRANCE** | | | | | |
| Masonry | Rubble stone in mud or lime mortar or without mortar | - | - | - | - | 2.1-3.3 |
| Masonry | Massive stone masonry (in lime/cement mortar) | - | - | - | - | 2.1-3.3 |
| Masonry | Unreinforced brick masonry in cement mortar with reinforced concrete floor/roof slabs | - | - | - | - | 2.1-3.3 |
| Masonry | Confined brick/block masonry in cement mortar with reinforced concrete posts/tie columns and beams | - | - | - | - | 2.1-3.3 |
| Masonry | Unreinforced block masonry in lime/cement mortar | - | - | - | - | 2.1-3.3 |
| Masonry | Reinforced concrete block masonry in cement mortar | - | - | - | - | 2.1-3.3 |
| Structural Concrete | Concrete moment resisting frames designed for gravity loads only | 60-100 | 60-100 | - | - | 2.1-3.3 |
| Structural Concrete | Concrete moment resisting frames designed with seismic features | 0-1 | <1 | - | - | 2.1-3.3 |
| Structural Concrete | Concrete moment resisting frames with unreinforced masonry infill walls | - | - | - | - | 2.1-3.3 |
| Structural Concrete | Concrete shear walls cast in-situ | - | - | - | - | 2.1-3.3 |
| | **GREECE 1/2** | | | | | |
| Masonry | Rubble (field) stone masonry usually on lime mortar with wooden floors (it also contains cut-stone masonry and some buildings of class 2 in urban areas). 86% built-pre1960. Usually 1 or 2 storeys. Also contains some adobe (4) buildings (all pre-1960) | 1.1 | 20.6 | 5.1 | 23.8 | 0.6-8 |

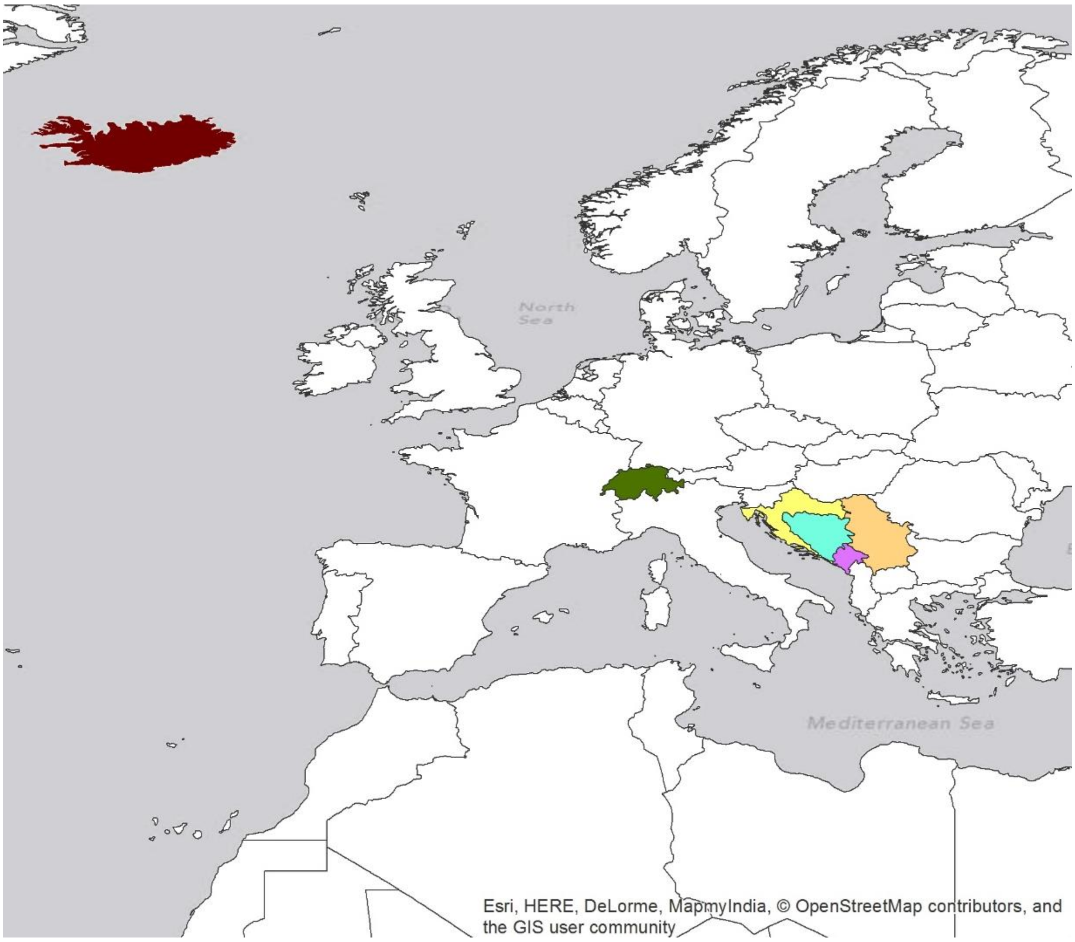
| | | | | | | |
|---|---|---|---|---|---|---|
| Masonry | Unreinforced brick masonry usually with cement mortar and RC floors (it also contains in smaller fractions some class 7.8 buildings). Mostly pre-1960. Usually 1-2 storeys. Also contains Concrete block (13) masonry (usually unreinforced) with RC floors (it also contains in smaller fractions some class 11, 13 buildings). Usually post-1960. Usually 1-2 storeys. | 2.3 | 20.6 | 9.7 | 28.6 | 0.6-8.5 |
| Timber | Wooden (post and beam frame). It also contains some class 31 buildings. Usually 1-2 storeys. | 0.1 | 0.3 | 0.3 | 0.5 | 0.6-8.5 |
| Steel | Steel MRF with unreinforced clay brick masonry infill- partition walls (usually up to 3 floors). 96% after 1960 (30% after 1995) | 0.0 | 0.0 | 0.4 | 0.4 | 2.0-7.5 |
| Structural Concrete | RC MRF with unreinforced clay brick masonry infill-partition walls. Built prior to 1961 (no code). Low rise. (1-2 floors) | 0.0 | 0.0 | 0.4 | 0.4 | 1.6-5.5 |
| Structural Concrete | RC MRF with unreinforced clay brick masonry infill-partition walls. Built in 1961-1995 (low code). Low rise. (1-2 floors) | 12.0 | 22.1 | 12.2 | 19.6 | 1.5-6.5 |
| Structural Concrete | RC MRF with unreinforced clay brick masonry infill-partition walls. Built after 1995 (high code). Low rise. (1-2 floors) | 2.1 | 7.1 | 2.9 | 6.8 | 1.8-8.5 |
| Structural Concrete | RC MRF with unreinforced clay brick masonry infill-partition walls. Built prior to 1961 (no code). Mid rise. (3-8 floors) | 7.9 | 2.0 | 6.5 | 1.0 | 17-51 |
| Structural Concrete | RC MRF with unreinforced clay brick masonry infill-partition walls. Built in 1961-1995 (low code). Mid rise. (3-8 floors) Very few 9-11 storeys also contained. (Greece has only 51 buildings that exceeded 11 soreys) | 62.2 | 18.9 | 49.5 | 13.2 | 17-51 |
| Structural Concrete | RC MRF with unreinforced clay brick masonry infill-partition walls. Built after 1995 (high code). Mid rise. (3-8 floors) Very few 9-11 storey buildings also contained. | 10.9 | 6.1 | 11.8 | 4.6 | 17-70 |
| **GREECE 2/2** | | | | | | |
| 16 | R/C Moment Resisting Frames Old Codes-Pre 1985 | 50 | 25 | | | |
| 16 | R/C Moment Resisting Frames Old Codes-Post 1985 | 7.5 | 9 | | | |
| 19 | R/C Dual Structures (Frames &Shear Walls) Old Codes-Pre 1985 | 12.5 | 3 | | | |
| 19 | R/C Dual Structures (Frames &Shear Walls) Old Codes-Post 1985 | 22 | 9 | | | |
| 1 | Stone Masonry | 1.5 | 23 | | | |
| 9 | Unreinforced brick masonry | 5.5 | 30 | | | |
| ESTIMATES MAKING DIFFERENT ASSUMPTIONS ABOUT COLLAPSE | | | | | | |
| 16 | R/C Moment Resisting Frames Old Codes-Pre 1985 | 50 | 25 | | | |
| 16 | R/C Moment Resisting Frames Old Codes-Post 1985 | 7.5 | 9 | | | |
| 19 | R/C Dual Structures (Frames &Shear Walls) Old Codes-Pre 1985 | 12.5 | 3 | | | |

| | | | | | | |
|---|---|---|---|---|---|---|
| 19 | R/C Dual Structures (Frames &Shear Walls) Old Codes-Post 1985 | 22 | 9 | | | |
| 1 | Stone Masonry | 1.5 | 23 | | | |
| 9 | Unreinforced brick masonry | 5.5 | 30 | | | |
| **ITALY** | | | | | | |
| | Masonry- bad quality | 13.5 | 2 | | | 1.8 |
| | Masonry- medium quality | 13.8 | 2 | | | 2.1 |
| | Masonry- good quality | 22.1 | 2.8 | | | 3.3 |
| | RC, GLD, <= 3 storeys | 12.3 | 1 | | | 4.6 |
| | RC, GLD, >= 4 storeys | 19.5 | 0.1 | | | 19.2 |
| | RC, MSD, <= 3 storeys | 5.4 | 0.8 | | | 4.7 |
| | RC, MSD, >= 4 storeys | 4.7 | 0.1 | | | 17.1 |
| | Masonry- bad quality | 13.5 | 2 | | | 1.8 |
| **MACEDONIA** | | | | | | |
| Masonry | Rubble stone in mud or lime mortar or without mortar | 1 | 5 | 0 | 0 | 3-5 |
| Masonry | Mud walls | 1 | 5 | 0 | 0 | 3-5 |
| Masonry | Unreinforced brick masonry in mud mortar | 5 | 15 | 0 | 0 | 3-5 |
| Masonry | Unreinforced brick masonry in cement mortar with reinforced concrete floor/roof slabs | 5 | 15 | 1 | 5 | 12-15 |
| Masonry | Confined brick/block masonry with concrete posts/tie colums and beams | 20 | 30 | 5 | 40 | 20-25 |
| Structural Concrete | Concrete moment resisting frames designed for gravity loads only | 15 | 5 | 25 | 2 | 80-100 |
| Structural Concrete | Concrete moment resisting frames designed with seismic features | 25 | 5 | 20 | 10 | 150-200 |
| Structural Concrete | Concrete moment resisting frames with concrete shear walls-dual system | 25 | 3 | 30 | 5 | 200-300 |
| Structural Concrete | Concrete shear walls cast in-situ | 5 | 0 | 2 | 0 | 300-350 |

## Appendix E: Iceland, Switzerland and Balkans Countries Contribution and Montenegro Field Trip

# NERA Deliverable 7.5: CAR contribution for Iceland, Switzerland and Balkan Countries

Hannah Baker, Robin Spence, Roxane Foulser-Piggott Cambridge Architectural Research Ltd.




| | |
|---|---|
| Iceland | Bosnia and Herzegovina |
| Switzerland | Montenegro |
| Serbia | Croatia |

# Table of Contents

Table of Contents ..... 2
Figure Numbers ..... 4
Table Numbers ..... 6
Acknowledgements ..... 7
1. Introduction ..... 8
2. Definition Urban and Rural ..... 8
2.1 Justification distinguishing between urban and rural areas ..... 8
2.2 Definition of urban areas used for questionnaire ..... 10
3. Methods for Data Collection ..... 10
3.1 Statistical data collection and inferences ..... 10
3.2 Questionnaire ..... 11
3.2.1 Selection of building typologies ..... 12
3.3 Street View Survey ..... 12
3.4 Field Study ..... 14
3.5 Comparison of Results ..... 15
3.5.1 Metric of Error ..... 16
3.5.2 Updating Building Typology Using a Bayesian Approach ..... 16
4. Results and analysis ..... 17
4.1 Iceland ..... 19
4.1.1 Data collection and inferences ..... 19
4.1.2 Questionnaire ..... 21
4.1.3 Comparison of methods and final dwelling fractions ..... 23
4.2 Switzerland ..... 23
4.2.1 Data collection and inferences ..... 24
4.2.2 Questionnaires ..... 28
4.2.3 Comparison of methods and final dwelling fractions ..... 28
4.3 Balkan Countries ..... 29
4.3.1 Serbia ..... 31
4.3.1.1 Data collection and inferences ..... 31
4.3.1.2 Questionnaires ..... 35
4.3.1.3 Comparison of methods ..... 38
4.3.1.4 Final Dwelling Fractions ..... 40
4.3.2 Croatia ..... 41

4.3.2.1 Data collection and inferences ........ 41

4.3.2.2 Questionnaires ........ 43

4.3.2.3 Street View Survey ........ 46

4.3.2.4 Comparison of methods........ 48

4.3.2.5 Updating questionnaire survey results using Street View surveys ........ 51

4.3.2.6 Final Dwelling Fractions ........ 53

4.3.3 Bosnia and Herzegovina........ 55

4.3.3.1 Data collection and inferences ........ 55

4.3.3.2 Questionnaire ........ 56

4.3.3.3 Comparison of methods and final dwelling fractions ........ 57

4.3.4 Montenegro ........ 58

4.3.4.1 Data collection and inferences ........ 59

4.3.4.2 Questionnaire ........ 60

4.3.4.3 Field Trip........ 63

4.3.4.4 Comparison of methods........ 65

4.3.4.5 Final Dwelling Fractions ........ 70

4.4 Future Methodology and Improvements/Critical Analysis of method ........ 71

5. Conclusions ........ 72

6. References ........ 73

Appendix 1: Rural and Urban Land Areas ........ 76

Appendix 2: SEDAC Tables ........ 78

Appendix 3: Questionnaire templates ........ 80

Appendix 4: Switzerland Structure Types – GEVES report........ 88

Appendix 5: Switzerland – Urban and Rural Areas ........ 90

Appendix 6: Switzerland – Individual Canton's Age Distribution ........ 91

Appendix 7: Croatia- Street View Results ........ 95

Urban Areas ........ 95

Rural Areas........ 98

# Figure Numbers

Figure 1: Urban area defined by CORINE in Croatia overlaid by population raster file –When using the definition for urban areas by CORINE, high values for population (GRUMP dataset) lie outside of the defined urban extent and skew the results for the number of people living in rural areas (Baker, H. et al. 2013) ... 9
Figure 2 Comparison between GRUMP and CORINE datasets and Google aerial imagery ... 9
Figure 3 Selected zones in Croatia for Google Street View analysis ... 12
Figure 4: Urban Area, Zagreb, Croatia.. Map showing buildings remotely analysed using Google Street View ... 14
Figure 5: Cities surveyed in Montenegro: Podgorica, Nikšić, Cetinje, Budva. Source: (FMECD, 2006, p. 9) ... 15
Figure 6: Iceland: Number of homes by residence and type of dwelling. Data Source: Hagtíðindi Verðlag og neysla Statistical Series (2011) ... 19
Figure 7: Age distribution of low-rise, concrete, timber and pumice buildings in the Ölfus region, Southern Iceland. Source: p. 5 Hagtíðindi Verðlag og neysla Statistical Series (2011) ... 20
Figure 8 Iceland: Percentage of dwellings in each building class in urban and rural areas. Source: Questionnaire response: Bjarni Bessason and Jón Örvar Bjarnason ... 22
Figure 9: Switzerland: Estimated typologies of residential structures. Data Source: Spence et al. 2006 ... 24
Figure 10: Switzerland: Estimated typologies of residential structures using structure types used in the questionnaire. ... 25
Figure 11: Switzerland - Average age distribution of dwellings ... 26
Figure 12 Switzerland: Average age distribution of dwellings in cantons which are predominantly rural ... 27
Figure 13 Switzerland: Average age distribution of dwellings in cantons which are predominantly urban ... 27
Figure 14: Balkan Countries - Proportion of dwellings made from solid material in 1989. Data Source: Savezui Zavod Za Statistifu (1989) ... 30
Figure 15: Balkan Countries – State Capital Cities - Proportion of dwellings made from solid material in 1989. Data Source: Savezui Zavod Za Statistifu (1989) ... 30
Figure 16: Age Distribution of hard and soft materials in the Republic of Serbia ... 31
Figure 17 Age distribution of hard and soft materials in the City of Belgrade, Serbia ... 32
Figure 18 Age distribution of hard and soft materials in Belgrade-Naselje, Serbia ... 32
Figure 19: Serbia Building Typology Matrix Source: Institut Wohnen und Unwelt Gmbh (2014) ... 33
Figure 20: Serbia: Overall percentage of dwellings in each building class. CAR's interpretation of Popović et al (2013) study ... 34
Figure 21: Serbia: Percentage of dwellings in each building class in urban and rural areas. Source: Questionnaire response: Petar Anagnosti ... 36
Figure 22: Serbia: Percentage of dwellings in each building class in urban and rural areas. Source: Questionnaire response: Ivan Gomez ... 37
Figure 23 Serbia dwelling fractions: Average (mean) all three studies ... 39
Figure 24 Serbia dwelling fractions: Average (mean) of questionnaire responses ... 40

Figure 25 Croatia: Age distribution of dwelling stock. Data Source: Croatian Bureau of Statistics (2011)........ 42
Figure 26 Croatia: Completed Dwellings Private Ownership and Other forms of ownership. Source: Spevec (2009 p.458) ........ 42
Figure 27 Croatia: Percentage of dwellings in each building class in urban and rural areas. Source: Questionnaire response: Drazen Anicic ........ 44
Figure 28 Croatia: Percentage of dwellings in each building class in urban and rural areas. Source: Questionnaire response: Damir Lazarević et al........ 45
Figure 29: Map of Croatia identifying areas surveyed using Google Street View survey........ 46
Figure 30: Croatia Street View Survey: Percentage of dwellings in each building class in urban and rural areas........ 47
Figure 31: Prior (questionnaire), likelihood (street-view survey) and posterior (revised) probability distributions for the proportion of dwellings in masonry buildings in urban areas of Croatia. ........ 53
Figure 32 Bosnia and Herzegovina: Dwellings by Year of Construction. Data Source: Nastić et al (2008 p.7)........ 55
Figure 33 Bosnia and Herzegovina - Households by main dwelling's construction type. Data Source: Milinović (2011 p.13)........ 56
Figure 34 Bosnia and Herzegovina: Percentage of dwellings in each building class in urban and rural areas. Source: Questionnaire response: Dr. Naida Ademović ........ 57
Figure 35 Montenegro: Dwellings year of construction up to 1989. Data source: Savezui Zavod Za Statistifu (1989) ........ 59
Figure 36 Montenegro: Distribution of dwellings in urban and rural areas. ........ 60
Figure 37: Montenegro: Percentage of dwellings in each building class in urban and rural areas........ 61
Figure 38: Montenegro: Simplified Questionnaire Response - Percentage of dwellings in each building class in urban and rural areas........ 62
Figure 39: Montenegro Field Trip Results - Percentage of dwellings in each building class in urban areas ........ 64
Figure 40: Montenegro Field Trip Results - Percentage of buildings in each building class in urban areas ........ 64
Figure 41: Montenegro: Percentage of dwellings in each building class - overall distribution: Comparison between questionnaire response and CAR's interpretation of data ........ 66
Figure 42: Montenegro - Distribution of Dwellings by Building Type in Urban Areas - Comparison of Questionnaire Results and Field Trip. *Questionnaire results are post and pre 1990 ........ 67
Figure 43: Montenegro - Distribution of Dwellings by Building Type in Urban Areas - Comparison of Questionnaire Results and Re-calculated Dwellings from the Field Trip. *Questionnaire results are post and pre 1990........ 69

# Table Numbers

Table 1: Data Sources (excluding sources only used for literature review) ........ 10
Table 2: Categorisation of buildings in survey zones ........ 13
Table 3: Questionnaire contributors and data sources ........ 18
Table 4: Average number of dwellings in each building class. Source: Questionnaire response: Bjarni Bessason and Jón Örvar Bjarnason ........ 21
Table 5: Dwelling Fractions in Iceland. Values have been rounded to the nearest whole number. ........ 23
Table 6: Dwelling Fractions in Switzerland. Values have been rounded to the nearest whole number. ........ 28
Table 7: Serbia: Urban/Rural housing stock in thousands ........ 35
Table 8: Comparison of results for Serbian dwelling fractions ........ 38
Table 9: Serbia dwelling fractions – Average of all three results. Values have been rounded to the nearest whole number. ........ 41
Table 10: Croatia: Urban – Rural distribution of dwellings ........ 43
Table 11: Street View Survey, Croatia. Number of buildings and dwellings surveyed in different areas. ........ 46
Table 12: Croatia Dwelling Fractions –Street View results ........ 47
Table 13: Average number of dwellings per building belonging to each building class (obtained from Street View surveyed buildings) ........ 48
Table 14: Dwelling fractions for Croatia ........ 50
Table 15: Numbers of dwellings in each of the 5 urban Street View surveys in Croatia, with proportions of dwellings (%) in each of the three principal building inventory classes. ........ 51
Table 16: Results of the Bayesian updating process for the three principal building classes. ........ 52
Table 17: Combined dwelling fractions Croatia. Values have been rounded to the nearest whole number. ........ 54
Table 18: Bosnia and Herzegovina – Rural Urban Distribution - 2007 ........ 56
Table 19: Bosnia and Herzegovina Dwelling Fractions. Values have been rounded to the nearest whole number. ........ 58
Table 20: Montenegro – Total number of dwellings constructed in different age categories. Source: Savezui Zavod Za Statistifu (1989) ........ 59
Table 21: Montenegro - Number of dwellings for permanent living Source: Montenegro Statistical Office (2013) ........ 59
Table 22: Montenegro - Average number of dwellings per building in each class - questionnaire response ........ 63
Table 23: Average number of dwellings in a building for different building classes/structure types ........ 65
Table 24: Montenegro: Comparison between the average number of dwellings in a building for different building classes/structure types from the field trip and questionnaire response ........ 68
Table 25: Montenegro Dwelling Fractions. Values have been rounded to the nearest whole number. ........ 70

# Acknowledgements

Cambridge Architectural Research Ltd. (CAR) would like to express their appreciation and thanks to Dr. Vladimir Ladinski and Dr. Thomas Wenk for helping with the preparation of the questionnaires and all of those who completed the questionnaires: Bjarni Bessason, Jón Örvar Bjarnason, Petar Anagnosti, Ivan Gomez, Drazen Anicic, Damir Lazarević & collaborators, Dr. Naida Ademović and Jelena Pejovic. CAR would also like to thank Professor Bozidar Pavicevic, Jelena Pejovic and Nina Serdar from the Faculty of Civil Engineering at the University of Montenegro, for generously giving their time and assisting with the field trip to Montenegro.

# 1. Introduction

This report presents the methodology and findings of Cambridge Architectural Research Ltd.'s (CAR's) contribution to the Level 0 and Level 1 European Building Inventory Database, deliverable 7.5 of the Network of European Research Infrastructures for Earthquake Risk Assessment and Mitigation (NERA).

The overall aim is to define dwelling fractions (the proportion of the dwelling stock categorised by different structure types) in urban and rural areas for individual countries.

Six European countries were identified for analysis by CAR – Iceland, Switzerland, Serbia, Croatia, Bosnia and Herzegovina and Montenegro. These were chosen because there is a lack of data publically available describing the current building stock and further research needed to be conducted. They have been analysed through the use of various data collection methods: literature reviews, an interpretation of available data e.g. building stock age classifications; and expert questionnaires. A field trip took place to Montenegro in August 2014 and in Croatia, results were validated through a remote survey using Google Street View.

Expert consultation was used for the preparation of the questionnaires and to gain an initial understanding of the building stock through Dr. Thomas Wenk, head of the Swiss Society for Earthquake Engineering and Structural Dynamics and Dr. Vladimir Ladinski, an urban planner whose PhD focused on post-earthquake reconstruction following the 1963 Skopje earthquake.

This report describes CAR's previous investigation of how to distinguish between urban and rural areas (Baker et al, 2013); the methods used for dwelling fraction data collection; the results of this investigation and then provides conclusions.

# 2. Definition Urban and Rural

## 2.1 Justification distinguishing between urban and rural areas

In Switzerland, Croatia and Iceland, a higher proportion of the population live in urban areas, whereas in Bosnia and Herzegovina, Montenegro and Serbia, a higher proportion live in rural areas. Due to a significant proportion of the selected countries populations living outside urban areas, it is important to distinguish between rural and urban areas when analysing building typology and earthquake vulnerability.

CAR's previous investigation: "NERA: Land Use and Population Analysis" (Baker et al, 2013) identified different methods of defining urban/rural areas and the populations living within them using Geographic Information Systems (GIS) and online resources.

The analysed datasets included the Coordination of Information on the Environment (CORINE); Global Rural-Urban Mapping Project (GRUMP) and Socioeconomic Data and Applications Center (SEDAC) tables. The report concluded the best method to use when analysing the proportion of the population in urban/rural areas in each country is the SEDAC tables as GIS is not required to obtain the figures.

If using GIS to calculate the population within urban and rural areas, the GRUMP definitions of urban and rural areas should be used alongside the GRUMP population density data as the two are compatible. When analysing the results (see Appendix 1), the GRUMP data appeared to be more realistic and correlated with the SEDAC tables (Appendix 2). The calculated proportions of the CORINE dataset seemed too high for the rural areas. As shown by Figure 1, this is because the urban areas defined by CORINE were much smaller than areas with high populations defined by the GRUMP dataset. When the population data was extracted from the raster files, pixels with large population values lay outside the CORINE boundary and were included in the calculation for rural population which skewed results.

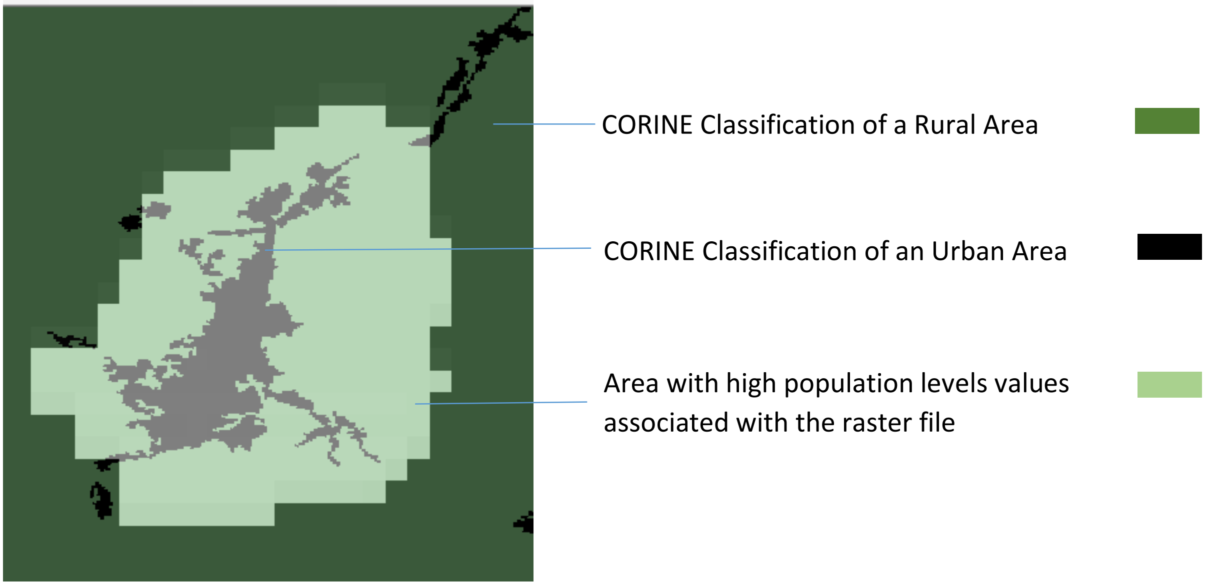



*Figure 1: Urban area defined by CORINE in Croatia overlaid by population raster file –When using the definition for urban areas by CORINE, high values for population (GRUMP dataset) lie outside of the defined urban extent and skew the results for the number of people living in rural areas (Baker, H. et al. 2013)*

Although CORINE should not be used for the population analysis, it has been used to define the spatial distribution of rural and urban areas in the Street View investigation (discussed in Section 3.3) as it is more compatible with aerial imagery and densely populated areas - shown in Figure 2. The GRUMP datasets cover too large an area and it is difficult to identify rural areas for analysis.

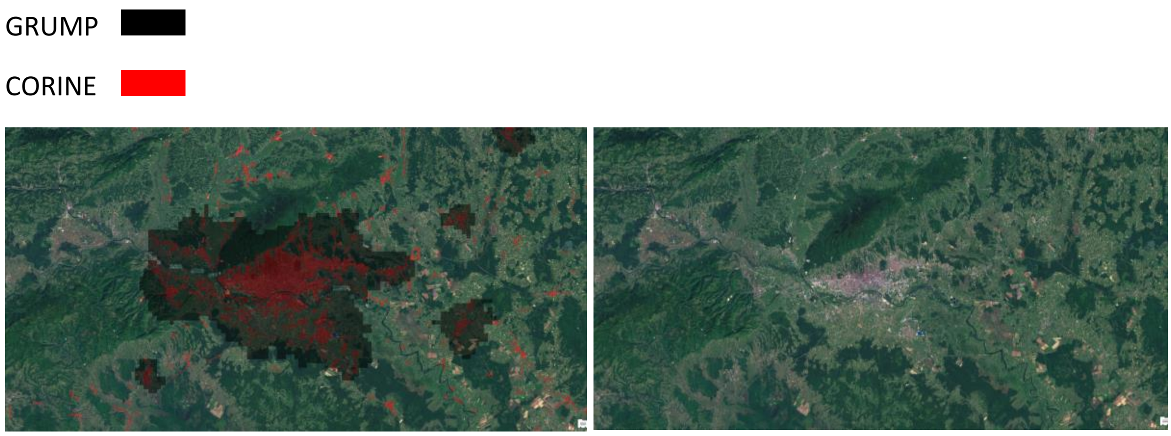



*Figure 2 Comparison between GRUMP and CORINE datasets and Google aerial imagery*

### 2.2 Definition of urban areas used for questionnaire

Spatial definitions using GIS could not be used for the expert questionnaires as respondents may not have access. The urban areas were defined using a number e.g. areas with a population over a certain number of people. Within the United Nation's (2005) Democratic Yearbook, the definition in terms of population is stated for a number of countries. This can vary significantly from country to country e.g. urban areas in Portugal are agglomerations of 10,000 or more inhabitants, whereas in Norway an urban area is defined as localities with 200 or more inhabitants.

When the questionnaires were initially distributed, a population of 1000 was chosen. Following feedback from expert consultants, this was increased to areas with over 5000 inhabitants for the Balkan countries. This is the same figure used in Slovakia, located in the Balkans, to define an urban area – Cities with 5000 inhabitants or more (UN, 2005).

## 3. Methods for Data Collection

The following section outlines the methodology used for analysing the dwelling fractions in urban and rural areas in the six countries identified - Iceland, Switzerland, Serbia, Croatia, Bosnia and Herzegovina and Montenegro. This included the collection and analysis of statistical data; the distribution of a questionnaire, a field trip to Montenegro and a Google Street View analysis in Croatia.

### 3.1 Statistical data collection and inferences

Initially, a literature review was conducted and statistical data was collected and analysed. This method allowed estimates to be made regarding the building stocks for each country. The data sources are displayed in Table 1.

*Table 1: Data Sources (excluding sources only used for literature review)*

| Country | Data | Source |
|---|---|---|
| Iceland | Number of homes by residence and type of dwelling | Hagtíðindi Verðlag og neysla Statistical Series (2011) |
| | Age distribution of low-rise concrete, timber and pumice buildings in the Ölfus region. | Hagtíðindi Verðlag og neysla Statistical Series (2011) |
| Switzerland | Structural Typology Distribution of Buildings in Switzerland | Spence et al (2006) |
| | Age Distribution of dwelling stock – 26 Cantons | STAT-TAB (2014) |

| Country | Data | Source |
|---|---|---|
| Balkan Countries - Overview | Proportion of dwellings made from solid materials in 1989 | Savezui Zavod Za Statistifu (1989) |
| | State Capitals – Proportion of dwellings made from solid materials 1989 | Savezui Zavod Za Statistifu (1989) |
| Serbia | Age distribution of ‘hard’ and ‘weak’ materials | Serbia and Montenegro Statistical Office (2002a) |
| | Housing stock in rural and urban areas | Economic Commission for Europe (2006 p.13) |
| | National Typology of Residential Buildings in Serbia | Popović et al (2013) |
| Croatia | Age Distribution | Croatian Bureau of Statistics (2011) |
| | Private ownership and other forms of ownership | Spevec (2009 p.458) |
| | Dwellings in urban settlements | Spevec (2009 p.460) |
| Bosnia and Herzegovina | Age Distribution | Milinović (2011 p.13) |
| | Households by main dwelling’s construction type | Nastić et al (2008 p.7) |
| | Households by settlement type and geographical area | Agency for Statistics of Bosnia and Herzegovina (2007 p.14) |
| Montenegro | Current housing stock in rural and urban areas | Statistical Office of Montenegro (2011) |
| | Distribution of dwellings in urban and rural areas. | Census Data |

## 3.2 Questionnaire

Questionnaires were circulated to selected experts associated with the six countries. Respondents included members and representatives of the Earthquake Engineering Research Institute (EERI) and European Association for Earthquake Engineering (EAEE) and people identified and contacted through the literature review.

The questionnaires varied for the different countries due to prior consultation with experts and research into the building stock. Switzerland and Iceland both had separate questionnaires and a further questionnaire was circulated to the Balkan countries – See Appendix 3.

CAR explored ways to encourage people to complete the questionnaires. One of the first steps was to provide a summary of the data collected beforehand and stated in Table 1. The questionnaire circulated to the Balkan countries was simplified in comparison to the Icelandic and Swiss questionnaires which were circulated earlier. The response for Montenegro uses the original version, resulting in more detailed data.

### 3.2.1 Selection of building typologies

The building typologies within the questionnaires were carefully researched and refined. Initially literature reviews and discussion with experts of the building stock in the different countries were undertaken and a list was defined. It was vital this list met the following criteria:

- There was a sufficient number of main structure types to cover all variants of vulnerability
- Needed to ensure significant subdivisions were captured. For example, pre and post the introduction of earthquake codes.
- The number of categories needed to be minimised to ensure the questionnaire was feasible for respondents to answer.

Definitions of the building typologies are shown in Appendix 3.

## 3.3 Street View Survey

Google Street View is available in Switzerland and Croatia. It was used in Croatia to remotely survey the building stock in different areas.

Using the CORINE dataset and spatial distinction between rural and urban areas, ten 500m$^2$ zones (five urban, five rural) were selected for analysis. The zones were selected by identifying residential areas through aerial imagery. Their location is shown in Figure 3.

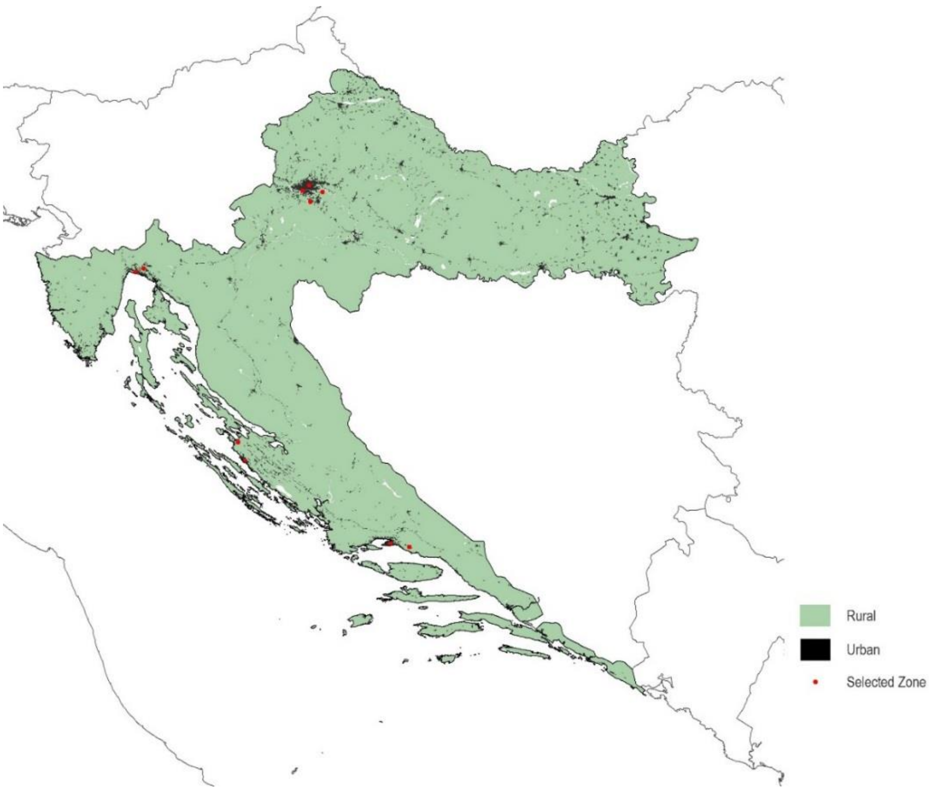



*Figure 3: Selected zones in Croatia for Google Street View analysis*

Once a zone was selected, an aerial image was printed off. Screenshots were taken of individual buildings and assigned a number, which were then marked on the map (Figure 4). The buildings/dwellings within the pictures were then categorised using the attributes shown in Table 2:

*Table 2: Categorisation of buildings in survey zones*

| **Categorisation** | **Description** |
|---|---|
| Building Number | Each building was given a number and identified on a map. |
| Number of Floors | Number of Floors within a building |
| Basement Visible (Y/N) | Indication on whether or not the building had a basement |
| Approximate number of dwellings | An approximation of the number of dwellings (e.g. flats/apartments) within each building. |
| Structural Categorisation/Building Class | Indication of the building's structure type from pre-defined options:<br>• Timber or Log<br>• Load Bearing Masonry<br>    o Adobe/fieldstone/rubble stone<br>    o Unit masonry with timber floors<br>    o Unit masonry with concrete floors<br>    o Reinforced/Confined Masonry<br>• Reinforced Concrete<br>    o Concrete frame – pre 1981<br>    o Concrete frame – post 1981<br>    o Concrete wall – pre 1981<br>    o Concrete wall – pot 1981<br>• Other |
| Additional Details | Additional details about the building which may affect its vulnerability in an earthquake |

In total, 1630 buildings (8078 estimated dwellings) were surveyed.

A limitation of this method was that Street View was not available in all areas, particularly remote ones and views of some buildings were blocked e.g. by vegetation or large fences.


*Figure 4: Urban Area, Zagreb, Croatia. Map showing buildings remotely analysed using Google Street View*

## 3.4 Field Study

From the 20th – 24th August, a field trip took place in Montenegro. The aim of the trip was to validate and compare results to other methods used within the NERA project. The field trip included the analysis of 111 buildings (2934 dwellings) in 10 different areas of Montenegro – cities shown in Figure 5.

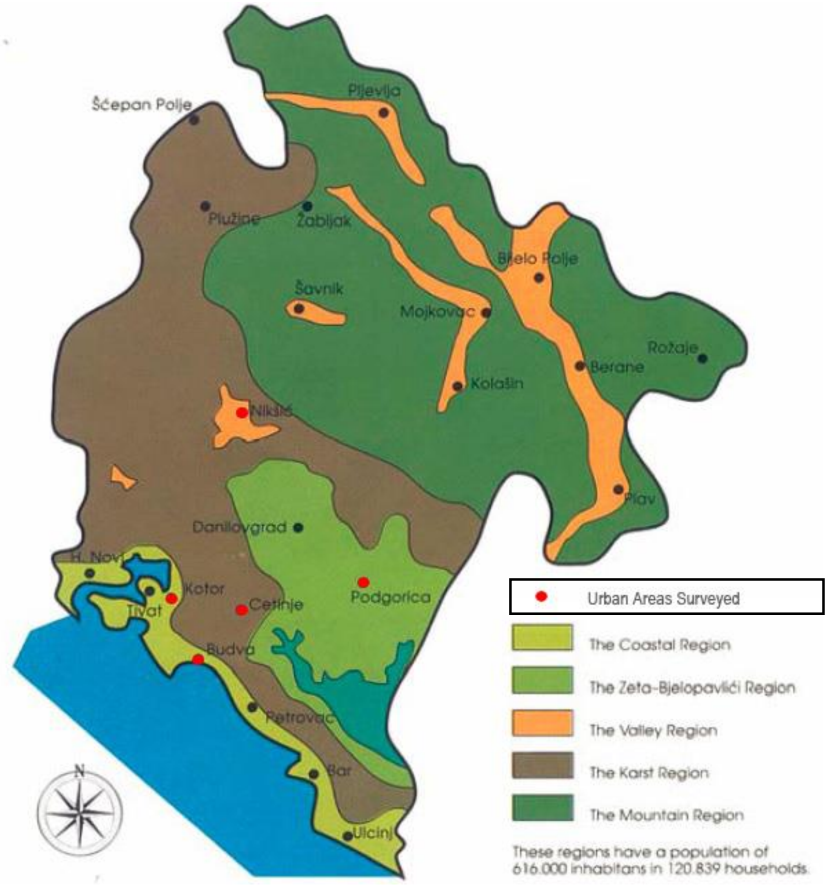



*Figure 5: Cities surveyed in Montenegro: Podgorica, Nikšić, Cetinje, Budva. Source: (FMECD, 2006, p. 9)*

The individual buildings were analysed in the same way as those in Croatia's Street View Survey (Section 3.3).

A full report describing the field trip, the methodology, results and validation procedure is available in a separate report:

**Baker, H., Foulser-Piggott, R., Spence, R., Montenegro Field Trip: 20th – 24th August 2014, Cambridge Architectural Research Ltd. [Unpublished]**

## 3.5 Comparison of Results

At the end of each section of country results in this report, building/dwelling typologies and dwelling fractions have been calculated by combining statistical fractions of buildings based on CAR's statistical interpretation, the expert opinion obtained from the questionnaires and other data collection methods. These are expressed in tables using the Global Earthquake Model (GEM) Taxonomy strings.

### 3.5.1 Metric of Error

To compare the differences in error between different methods and results, a metric will be used which takes into account the differences between two dataset's values e.g. when comparing the results for the distribution of dwellings from questionnaire results to the results produced from a Street View/Field survey.

The following equation will be used:

$$E_{av} = \sqrt{\frac{\sum(E_1 - E_2)^2}{N}}$$

Where:

$E_{av}$ = Average Error

$E_1$ = Value in Dataset 1 e.g. questionnaire results

$E_2$ = Value in Dataset 2 e.g. field survey results

N = Number of building classes

### 3.5.2 Updating Building Typology Using a Bayesian Approach

The results of field investigations or Street View surveys of building typology distributions can in principle be used to improve estimates based on a questionnaire survey, using a Bayesian approach. This section describes how this was done, and discusses implications. The concepts used are as set out in general by Ang and Tang (1975), and recently adapted for earthquake vulnerability estimation by Jaiswal, Wald and D'Ayala (2011), and for earthquake damage surveys by Booth et al (2008).

In Bayesian analysis, a set of prior assumptions about the probability distribution of a given variable is updated on the basis of a set of observations. If a probability distribution for both the prior and the set of observations can be established, then, by Bayes' theorem, a more informative posterior probability distribution can be defined. Each probability distribution is associated with an expected value, and the initial expected value can therefore also be modified by use of the data.

This study investigates the probability that a dwelling belongs to one of a fixed number of alternative classes. The prior assumed distribution is derived from the results of questionnaire surveys conducted as described in Section 3.2, page 11.

The questionnaire responses do not include an estimate of the probability distribution of proportions in each building typology. Thus, to facilitate the analysis it will be assumed that the prior distribution follows a beta distribution of the form $f(p_{hd}) = \beta(p_{hd}, q, r, a, b)$[1], where $p_{hd}$ is the

[1] The density function of the beta distribution $\beta(x, q, r, a, b)$ is

probability of a dwelling being in a building of a particular building typology, and a and b are the limits of the distribution, which are here taken as 0 and 1. Spence *et al* (2008) propose that where data quality is poor, a beta distribution for which q+r=6 is appropriate, and this is considered suitable for a prior distribution.

Updating these distributions using the observed data from a Street View survey is now possible. For each building class, the mean and variance of the proportion of dwellings of each building typology across a number of survey locations was used to find the likelihood function for the distribution of the observed data, assuming this also is a beta distribution.

With this prior and likelihood function defined, it is possible to define the posterior collapse probability distribution. Where both prior and likelihood functions have the form of a beta distribution, the posterior function also has a beta distribution, whose parameters, q, r, turn out to be the arithmetic sum of those for the prior and likelihood function (Jaiswal *et al*, 2011).

The application of this method to survey data from urban areas of Croatia is discussed in Section 4.3.2.5, page 51.

# 4. Results and analysis

The following section discusses the results from the six countries using the different methodologies on a country by country basis. Seven responses to the questionnaires have been received from five out of the six countries – shown in Table 3.

---

$$f_X(x) = \frac{1}{B(q,r)} \frac{(x-a)^{q-1}(b-x)^{r-1}}{(b-a)^{q+r-1}}, \quad a < x < b,$$

in which $q$ and $r$ are parameters of the distribution and $B(q, r)$ is the beta function:

$$B(q, r) = \frac{\Gamma(q)\,\Gamma(r)}{\Gamma(q+r)}$$ and $\Gamma$ is the gamma function (Ang and Tang 1975).

The parameters $q$ and $r$ of the beta distribution given depend on the mean $\mu_x$, and variance $\sigma^2_x$ of the variable, such that

$$\mu_x = q/(q+r); \qquad \sigma^2_x = qr/((q+r)^2(q+r+1))$$

*Table 3: Questionnaire contributors and data sources*

| Country | Name of Contributors | Self-rating of expertise or confidence (1=low and 5=high) | Affiliation (Organisation) | Data Sources |
|---|---|---|---|---|
| Iceland | 1) Bjarni Bessason<br>2) Jón Örvar Bjarnason | 5 | 1) University of Iceland, Hjardarhagi 2-6, 107 Reykjavík, Icleand<br>2) Iceland Catastrophe Insurance, Borgartúni 6, 105 Reykjavik, Iceland | Information is taken from a complete and detailed official building inventory for Iceland (Registers Iceland: www.skra.is) as listed in 2010.<br>Information about the main structural characteristic of Icelandic residential buildings can be found in:<br>• Bjarni Bessason, Jón Örvar Bjarnason, Ari Guðmundsson, Júlíus Sólnes og Scott Steedman, (2012).<br>• Probabilistic damage curves for low-rise buildings based on field data. Earthquake Spectra, Vol. 28, Nr. 4, pp. 1353-1378. |
| Switzerland | n/a | n/a | n/a | n/a |
| Serbia | Petar Anagnosti | 3 | Civil Engineering Faculty, Belgrade University | Serbia census 2002: Government statistical office. The extension of data to the end of 2013 year made by the contributor. |
| | Ivan Gomez | 4 | AIR Worldwide | Serbia 2002 Census, Building Inventory Data for Republic of Macedonia (Shendova, 2011), FYR of Macedonia: Summary of Building Types, Vulnerability to Collapse and Occupancy (Milutinovic) |
| Croatia | Drazen Anicic | n/a | Croatian Academy of Engineering | www.dzs.hr |
| | Damir Lazarević & collaborators | 4 | Faculty of Civil Engineering, University of Zagreb | • Državni zavod za statistiku, "Popis stanovništva 2011", Nastanjeni stanovi prema godini gradnje, vrsti zgrade i broju kućanstava u stanu. (www.dzs.hr, stanRH_01_HR.xls)<br>• Državni zavod za statistiku, "Statistički ljetopis 2013", Zagreb, 2013.<br>• Državna uprava za zaštitu i spašavanje, "Procjena ugroženosti RH od prirodnih i tehničko-tehnoloških katastrofa i velikih nesreća", Zagreb, 2009. |
| Bosnia and Herzegovina | Dr. Naida Ademović | 3 | Faculty of Civil Engineering in Sarajevo | n/a |
| Montenegro | Jelena Pejovic | 5 | Faculty of Civil Engineering, University of Montenegro | Publications, websites and statistical data were used as sources of information. All data is approximate because there is no complete data on the number and construction types of buildings. |

## 4.1 Iceland

In Iceland, all buildings are registered within a national database as insurance against natural disasters is mandatory (Bessason et al. 2012). The database documents characteristics such as date of construction, floor area, building height and main building material. Unfortunately, this is not publically accessible.

Seismic codes were initially introduced in 1976 and since 1980 all concrete buildings have been constructed with appropriate reinforcement (Bessason et al. 2012).

### 4.1.1 Data collection and inferences

In 2010, there were approximately 130,000 residential properties in Iceland (Jónsdóttir, 2011). Data indicating the annual construction rate since 1960 within Reykjavik (capital city) and 1970 at a national scale allows a rough estimate of dwellings built since the introduction of seismic codes to be made. On a national scale, 65,580 residential buildings began to be constructed between 1980 and 2010 equating to 50% of the building stock.

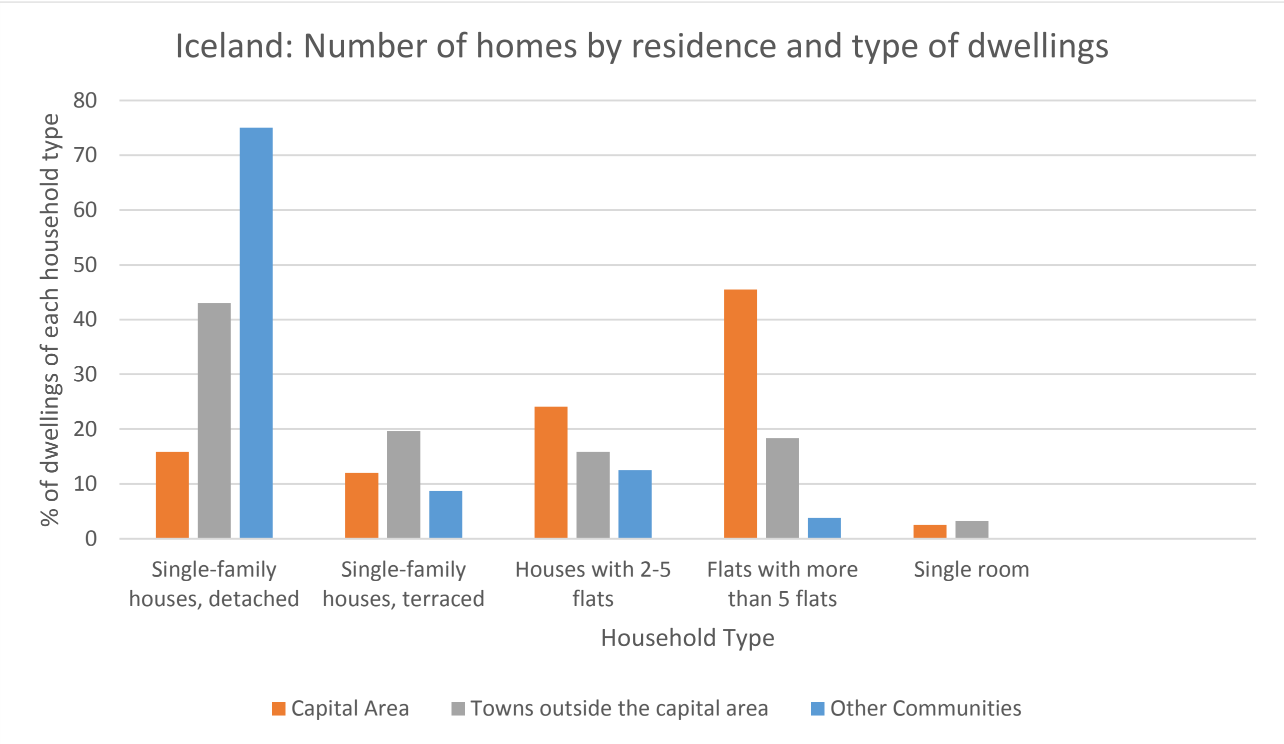



*Figure 6: Iceland: Number of homes by residence and type of dwelling. Data Source: Hagtíðindi Verðlag og neysla Statistical Series (2011)*

As shown by Figure 6, single-family dwellings, often associated with low-rise residential structures are predominant in rural areas. In urban areas, excluding Reykjavik (capital city), single-family dwellings are the most common, but the stock is more diverse. In Reykjavik, where the majority of Iceland’s population are situated, apartment blocks, often constructed using concrete dominate.

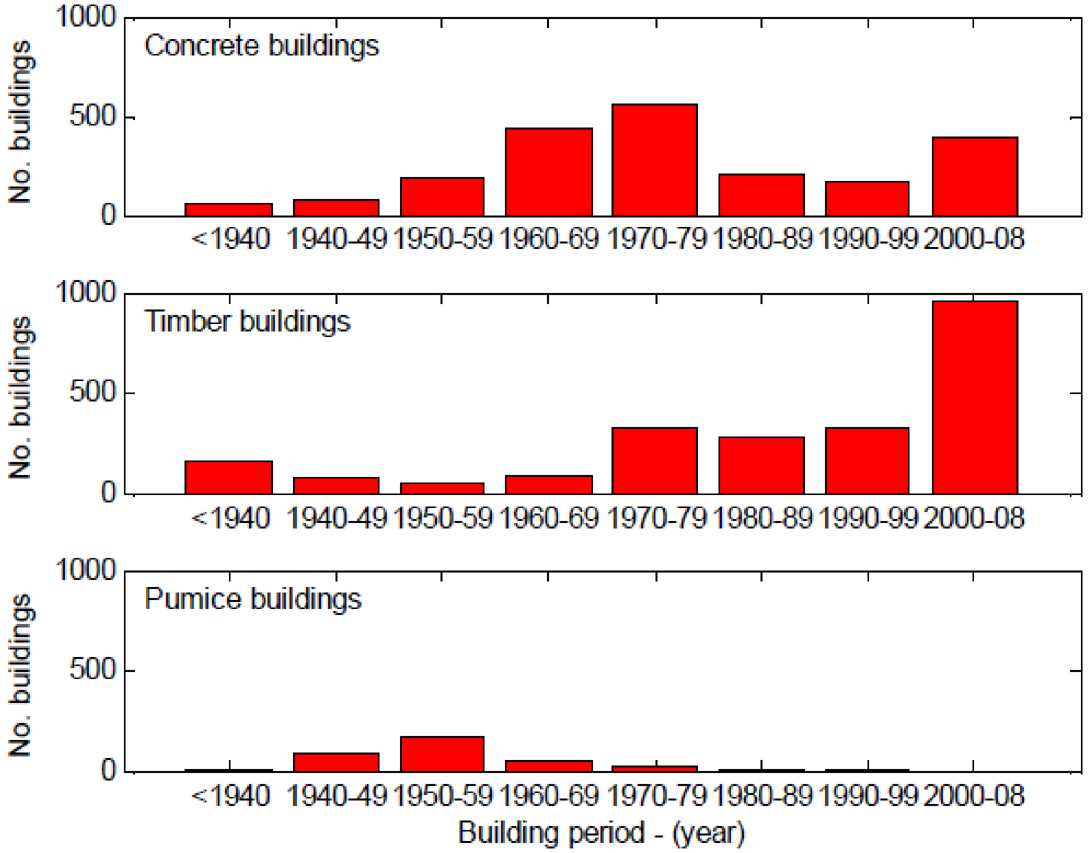



*Figure 7: Age distribution of low-rise, concrete, timber and pumice buildings in the Ölfus region, Southern Iceland. Source: p. 5 Hagtíðindi Verðlag og neysla Statistical Series (2011)*

Figure 7 indicates timber and concrete buildings are the general building types in the Ölfus region, Southern Iceland. This data was collected following an earthquake in this region in 2008.

During the 1960s-70s there was an increase in construction, in particular concrete buildings. The construction of timber buildings rapidly increased post-2008.

Similarly, throughout Iceland, the main building type is in-situ reinforced concrete wall constructions. Masonry brick buildings do not exist, but from 1940-1970 pumice blocks were used, ceasing to be used in the 1980s (ibid.). The hollow pumice blocks are similar to concrete blocks as the pumice is used as an aggregate.

### 4.1.2 Questionnaire

One response was received regarding the building typologies in Iceland from Bjarni Bessason and Jón Örvar Bjarnason from the University of Iceland and Iceland Catastrophe Insurance. They completed the questionnaire using information from the official building inventory for Iceland. Results are shown in Figure 8.

Table 4 displays the average number of dwellings per building for each building type.

*Table 4: Average number of dwellings in each building class. Source: Questionnaire response: Bjarni Bessason and Jón Örvar Bjarnason*

| Construction material and construction technology | Age | Height | Estimated average number of dwellings in each building class |
|---|---|---|---|
| **Reinforced concrete wall/Pre cast concrete panel** | pre 1990 | low-rise | 1.5 |
| | | medium-rise | 6.4 |
| | | high-rise | 38.2 |
| | post 1990 | low-rise | 1.8 |
| | | medium-rise | 12.1 |
| | | high-rise | 33.5 |
| **Lightweight timber frame** | - | - | 1.2 |
| **Other (e.g. hollow pumice blocks)** | - | - | 1.2 |

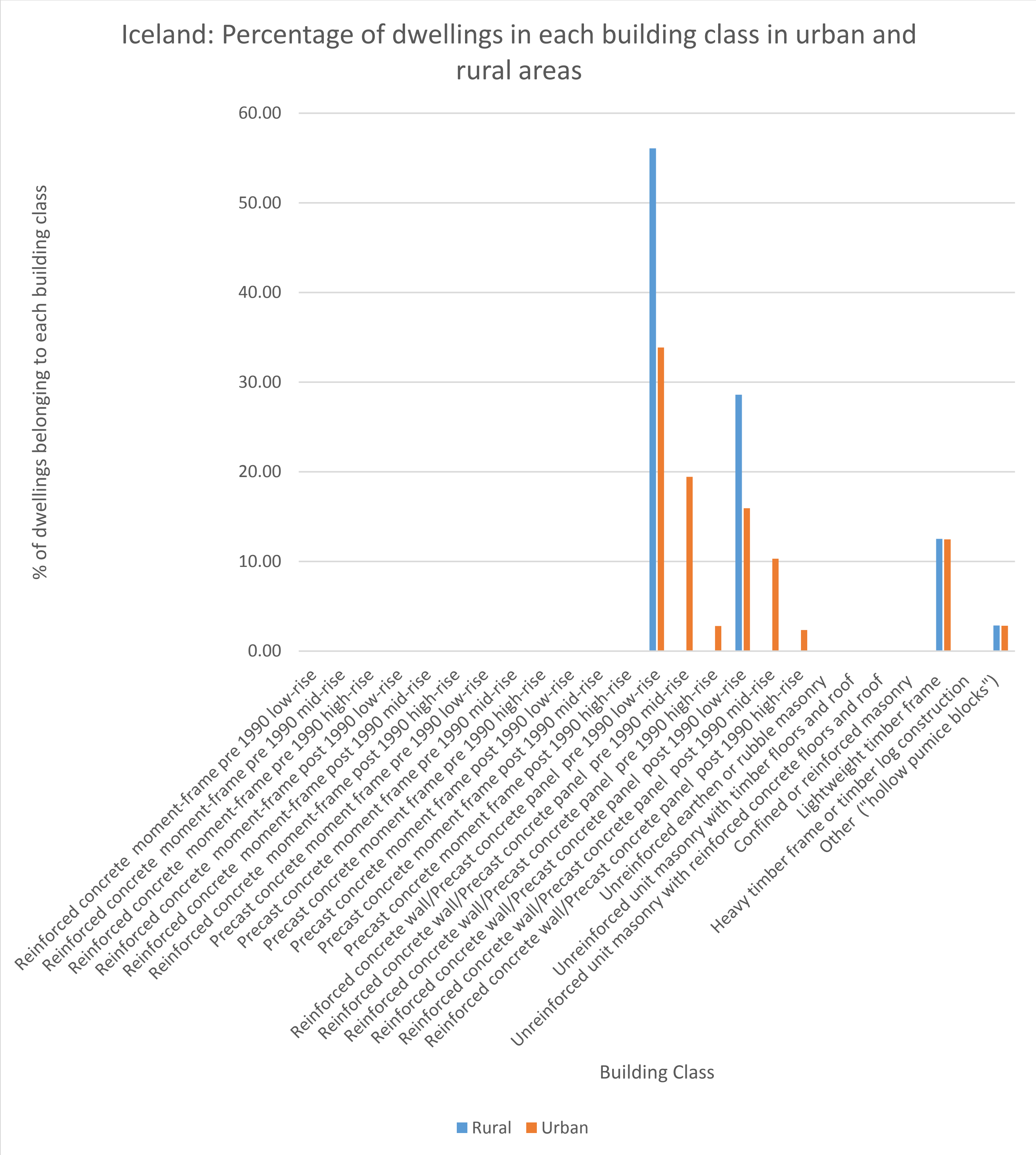



*Figure 8 Iceland: Percentage of dwellings in each building class in urban and rural areas. Source: Questionnaire response: Bjarni Bessason and Jón Örvar Bjarnason*

The predominant building typology in both urban and rural areas is low-rise reinforced concrete wall/precast concrete panel pre 1990. Rural building typologies are less diverse than urban. In urban areas, values have been assigned to eight different typologies, whereas in rural there are only four. These are mainly different types of concrete construction in terms of age and building height.

The main building types in both urban and rural areas are concrete, timber and hollow pumice blocks (a form of concrete blocks).

### 4.1.3 Comparison of methods and final dwelling fractions

Due to the expertise of the questionnaire respondents and their access to the official database, their responses should be used without alteration. The overall figures are shown in Table 5.

*Table 5: Dwelling Fractions in Iceland. Values have been rounded to the nearest whole number.*

| Structural Typology | GEM Taxonomy String | Percentage of Dwellings in Urban Areas (%) | Percentage of Dwellings in Rural Areas (%) |
|---|---|---|---|
| Total Dwelling Stock | | 89 | 11 |
| Reinforced concrete wall/Precast concrete panel pre 1990 low-rise | CR/LWAL/HBET:3,1/YPRE:1990/RES | 34 | 56 |
| Reinforced concrete wall/Precast concrete panel pre 1990 mid-rise | CR/LWAL/HBET:7,4/YPRE:1990/RES | 19 | 0 |
| Reinforced concrete wall/Precast concrete panel pre 1990 high-rise | CR/LWAL/HBET:8+/YPRE:1990/RES | 3 | 0 |
| Reinforced concrete wall/Precast concrete panel post 1990 low-rise | CR/LWAL/HBET:3,1/YBET:2014,1990/RES | 16 | 29 |
| Reinforced concrete wall/Precast concrete panel post 1990 mid-rise | CR/LWAL/HBET:7,4/YBET:2014,1990/RES | 10 | 0 |
| Reinforced concrete wall/Precast concrete panel post 1990 high-rise | CR/LWAL/HBET:8+/YBET:2014,1990/RES | 2 | 0 |
| Lightweight timber frame | W+WLI/LPB/H99/Y99/RES | 12 | 13 |
| Other ("hollow pumice blocks") | M99+CBH/L99/H99/Y99/RES | 3 | 3 |

## 4.2 Switzerland

Switzerland is divided into 26 cantons and 7 regions. The building stock does not vary significantly among cantons. Instead, variation occurs between the mountain areas and the plains and to a lesser extent the eastern and western regions (Wenk, 2013). The regulation of seismic codes is the responsibility of the individual cantons, sometimes being deregulated to a community level. In Basel-Stadt, one of the most densely populated cantons, seismic codes have been respected and enforced since the 1970s. However, throughout the rest of Switzerland, codes were generally neglected until 2003 when the new structural SIA-codes were implemented (Wenk, 2013).

Residential properties are mainly individual homes such as villas and chalets or part of multi-story apartment buildings, which includes prefabricated concrete construction. Individual houses are often low rise with a pitched roof. Apartments are generally medium-rise (3-5 storeys) but sometimes higher. Apartment blocks are either converted properties or purpose built. Converted properties are often characterised by masonry construction, whereas those purpose built are pre-cast concrete. As of 2006, there were 110 buildings with more than 11 storeys in Switzerland, These were all located in urban areas (Spence et al. 2006).

### 4.2.1 Data collection and inferences

A previous report by CAR, contributing to the development of property portfolios in order to assess vulnerability, included Switzerland. The study included a literature review and analysis of data on dwelling types, age of construction and building height. In the original study, dwelling fractions were provided for single family-residential dwellings, multi-family residential and residential combined properties. For this study, residential combined has been used – a weighted sum of the single-family and multi-family values. At the time of the previous study, 31.7% of the floor area in Switzerland was located in single-family dwellings and 68.3% in multi-family (Spence et al. 2006).

The results of the distribution and proposed structure types are shown in Figure 9. An explanation of the structure types is displayed in Appendix 4.

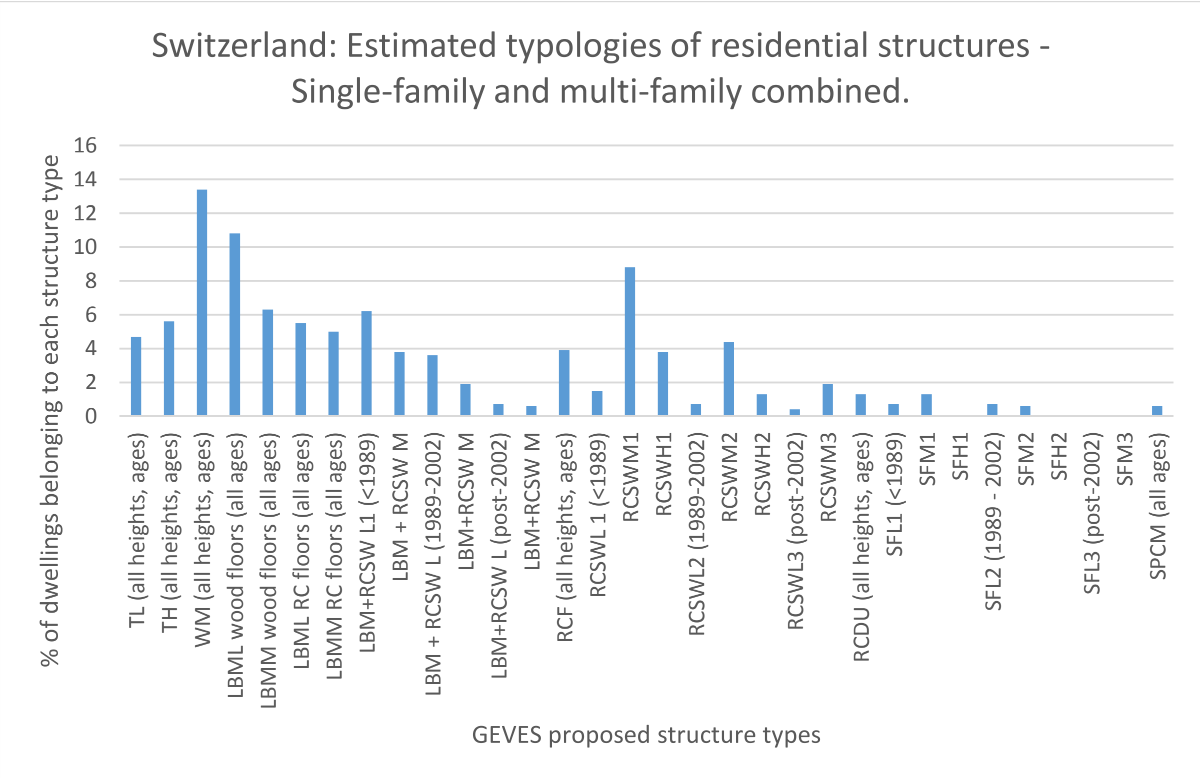



*Figure 9: Switzerland: Estimated typologies of residential structures. Data Source: Spence et al. 2006*

The results indicated that two of the structure types had the largest proportion of dwellings assigned to them:

- old rubble or simple stone masonry with wooden floors
- low-rise manufactured or massive stone brick or concrete block unreinforced masonry

These buildings are most likely to be older constructions.

The results were mapped onto the categories selected for the questionnaire to allow for a comparison and simplification purposes.

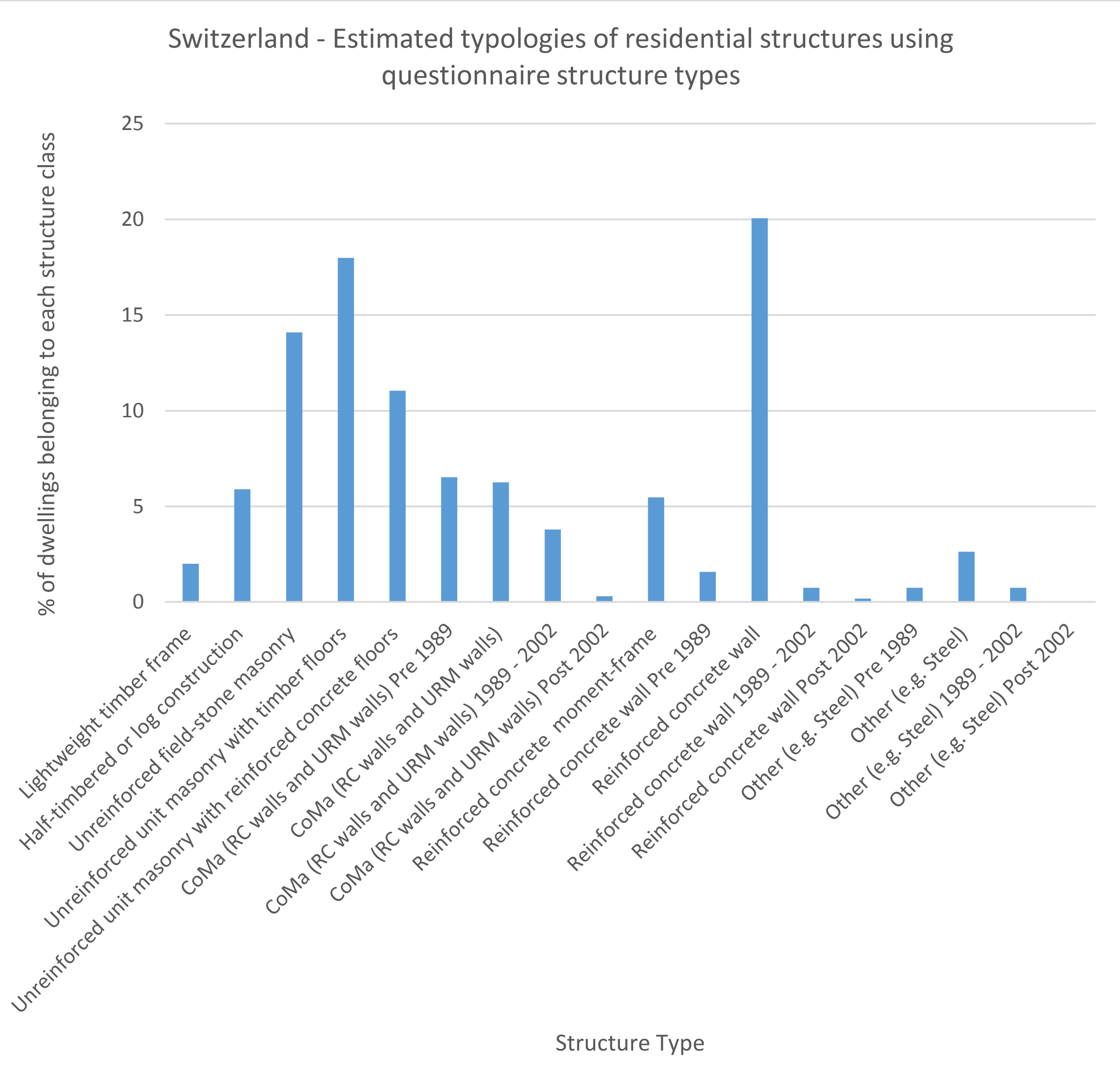



*Figure 10: Switzerland: Estimated typologies of residential structures using structure types used in the questionnaire.*

Census data has been analysed separately to access the variation of structural typologies within the different cantons. Data is provided on the age distribution of different building types (single family, multi family, residential ancillary use and other use residential) for different building heights. The overall age distribution is displayed in Figure 11.

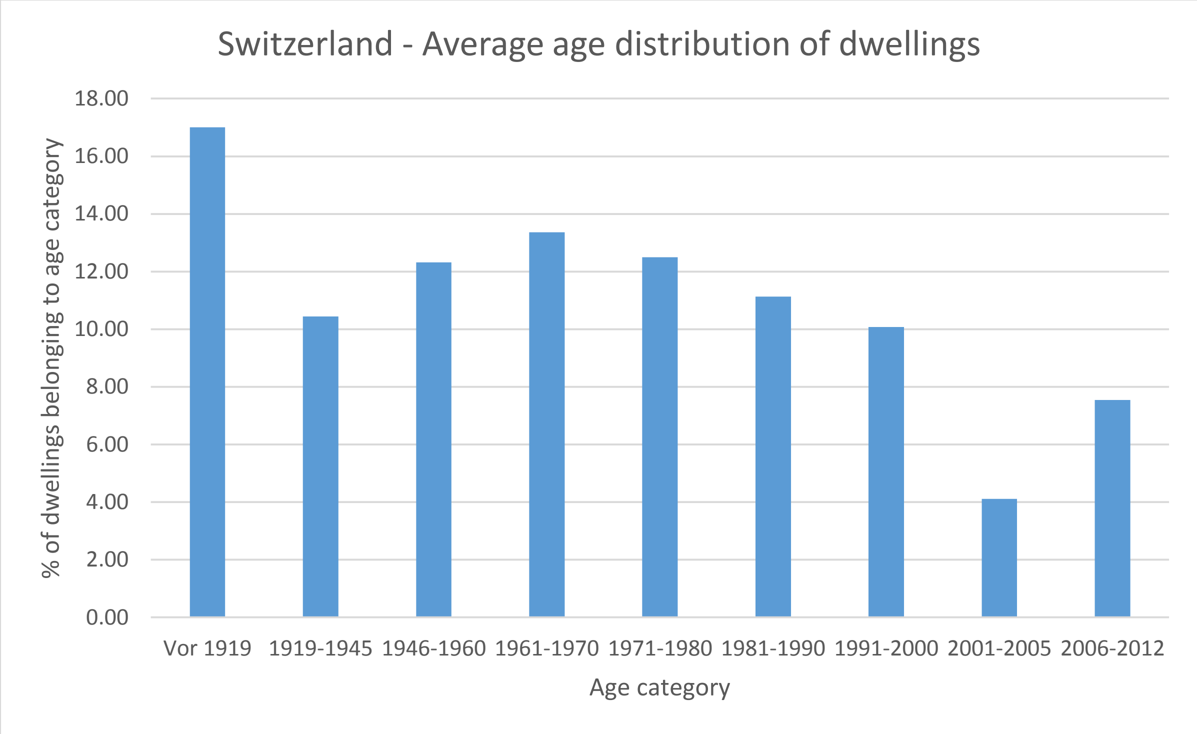



*Figure 11: Switzerland - Average age distribution of dwellings*

Using spatial analysis techniques in GIS, the GRUMP dataset was used to analyse the proportion of urban and rural land within each Canton. Pixels which were associated with urban areas, were assigned the number two and rural areas number one. The mean value of pixels was calculated for each canton. The higher the number (mean within a canton), the higher the proportion of pixels assigned as urban. Appendix 5 displays these figures. The four cantons with extreme values of either rural or urban where chosen to analyse the average age distribution. Basel-Stadt was later removed due to the unique nature of the building stock. Graphs displaying the urban and rural distribution are shown in Figure 12 and Figure 13 (Individual breakdowns are shown in Appendix 6).

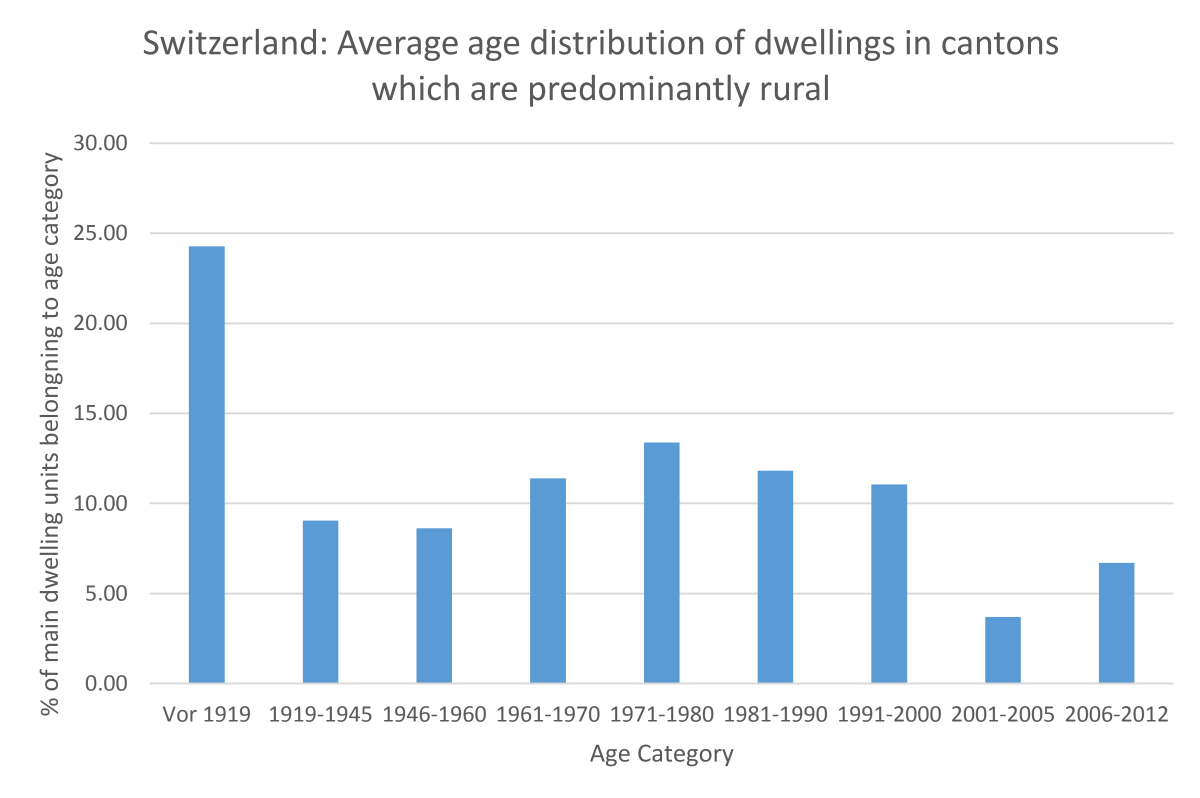



*Figure 12 Switzerland: Average age distribution of dwellings in cantons which are predominantly rural*

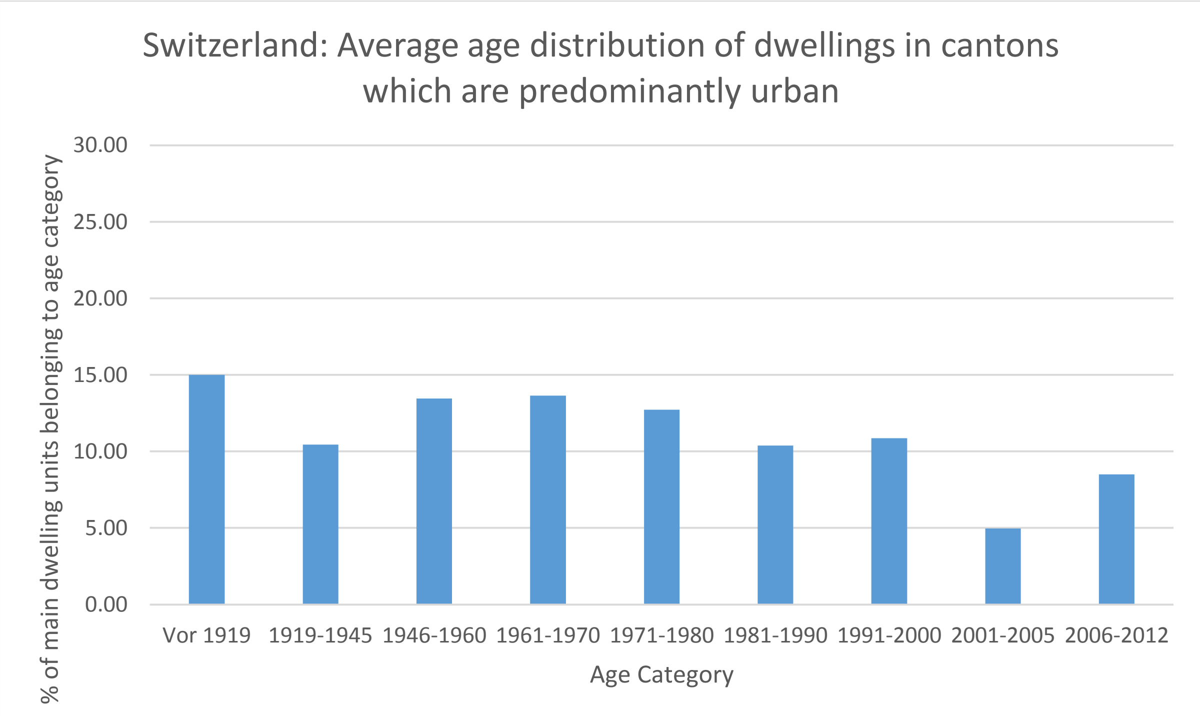



*Figure 13 Switzerland: Average age distribution of dwellings in cantons which are predominantly urban*

At a rural level, the dominant dwelling type appears to be pre 1919 age, which is often associated with field stone masonry or timber constructions. Post 1919, masonry buildings tended to use more regularly cut stones (Spence et al. 2006). Since 1950, unreinforced masonry buildings began to be replaced by mixed concrete and masonry constructions and since 2004, CoMa (Reinforced concrete walls and unreinforced masonry walls) has been the most common construction type (Wenk, 2013). In these constructions the loads are carried by a mix of reinforced concrete and unreinforced masonry walls, with reinforced floor slabs and roofs.

In urban areas, the construction rate has been more constant due to urbanisation and the building stock is more diverse. Throughout the entirety of Switzerland, census statistics suggest, 13% of the national dwelling stock is built post 2003, when seismic codes were enforced.

### 4.2.2 Questionnaires

In spite of contact with a number of people in Switzerland, no responses were received.

### 4.2.3 Comparison of methods and final dwelling fractions

There is very limited data on the distribution of structural typologies between urban and rural areas. Although age distributions are available for individual cantons which have been categorised as urban and rural, the areas are too large to make accurate assumptions regarding the dwelling fractions, as urban areas will still be in a canton described as rural and skew the results. Nationwide dwelling fractions for Switzerland using CAR's previous study are shown in Table 6.

*Table 6: Dwelling Fractions in Switzerland. Values have been rounded to the nearest whole number.*

| **Structural Typology** | **GEM Taxonomy** | **Percentage of dwellings (%)** |
|---|---|---|
| Lightweight timber frame | W+WLI/LPB/H99/Y99/RES | 2 |
| Half-timbered or log construction | W/LPB/H99/Y99/RES | 6 |
| Unreinforced field-stone masonry | MUR+STRUB+MO99/LWAL/H99/Y99/RES | 14 |
| Unreinforced unit masonry with timber floors | MUR/LWAL/H99/Y99/RES/FW | 18 |
| Unreinforced unit masonry with reinforced concrete floors | MUR/LWAL/H99/Y99/RES/FC | 11 |
| CoMa (RC walls and URM walls) Pre 1989 | MATO/LH/YPRE:1989/RES/RC/FC/ | 7 |
| CoMa (RC walls and URM walls) | MATO/LH/RES/RC/FC/ | 6 |
| CoMa (RC walls and URM walls) 1989 - 2002 | MATO/LH/YBET:2002,1989/RES/RC/FC/ | 4 |
| CoMa (RC walls and URM walls) Post 2002 | MATO/LH/YBET:2014,2002/RES/RC/FC/ | 0 |
| Reinforced concrete moment-frame | CR/LFM/H99/Y99/RES | 5 |
| Reinforced concrete wall Pre 1989 | CR/LWAL/H99/YPRE:1989/RES | 2 |
| Reinforced concrete wall | CR/LWAL/H99/Y99/RES | 20 |
| Reinforced concrete wall 1989 - 2002 | CR/LWAL/H99/YBET:2002,1989/RES | 1 |

| Structural Typology | GEM Taxonomy | Percentage of dwellings (%) |
|---|---|---|
| Reinforced concrete wall Post 2002 | CR/LWAL/H99/YBET:2014,2002/RES | 0 |
| Other (e.g. Steel) Pre 1989 | S+S99/L99/H99/YPRE1989/RES | 1 |
| Other (e.g. Steel) | S+S99/L99/H99/Y99/RES | 3 |
| Other (e.g. Steel) 1989 - 2002 | S+S99/L99/H99/YBET:2002,1989/RES | 1 |
| Other (e.g. Steel) Post 2002 | S+S99/L99/H99/YBET:2014,2002/RES | 0 |

## 4.3 Balkan Countries

Four of the countries selected within this report were all formerly part of Yugoslavia, which split up in the 1990s. There will inevitably be similarities in the building stock, therefore the same building stock distribution questionnaire has been used for Serbia, Bosnia and Herzegovina, Croatia and Montenegro.

In former Yugoslavia, Slovenia was the first region to introduce seismic design regulations (Ladinski, 2014). Following the 1963 Skopje earthquake, the first Yugoslavian Code for Construction in Seismic Regions was formulated by a group of experts. A second generation of regulations was released in 1981, Technical Regulations for Design and Construction of Buildings in Seismic Regions (Jurukovski 1994). The new code considered findings from the 1969 Banja Luka and 1979 Montenegro earthquakes. Minor adjustments were made to the code throughout the 80’s.

Census data was collected from the archives in Skopje for Former Yugoslavia. Figure 14 and Figure 15, display a summary of this data. Montenegro and Croatia have a higher proportion of dwellings made from ‘solid’ materials (referring to brick, concrete etc...) than Serbia and Bosnia and Herzegovina. Since the 1980s it is unlikely, due to the enforcement of seismic codes that new constructions would not be made from these solid materials.

Data for State Capital cities gives a rough indication of the distribution of dwellings constructed from solid materials in large urban areas. In comparison to Figure 14, Figure 15 shows a significantly higher proportion of dwellings are constructed from solid materials in urban environments.

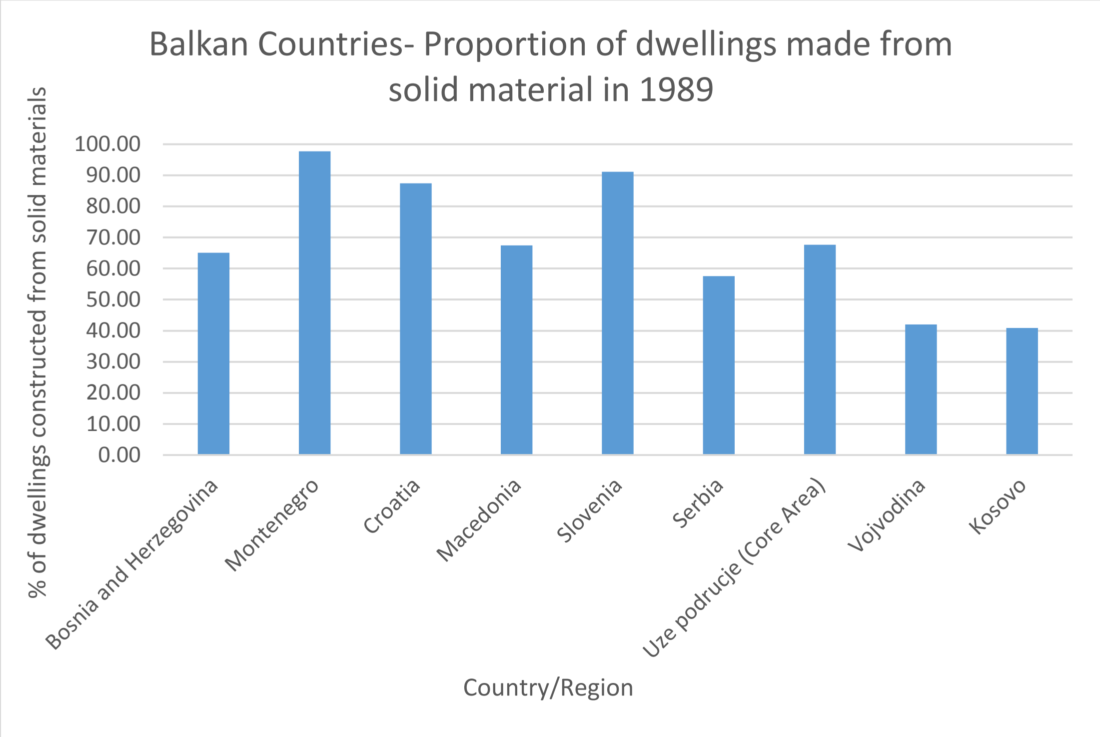



*Figure 14: Balkan Countries - Proportion of dwellings made from solid material in 1989. Data Source: Savezui Zavod Za Statistifu (1989)*

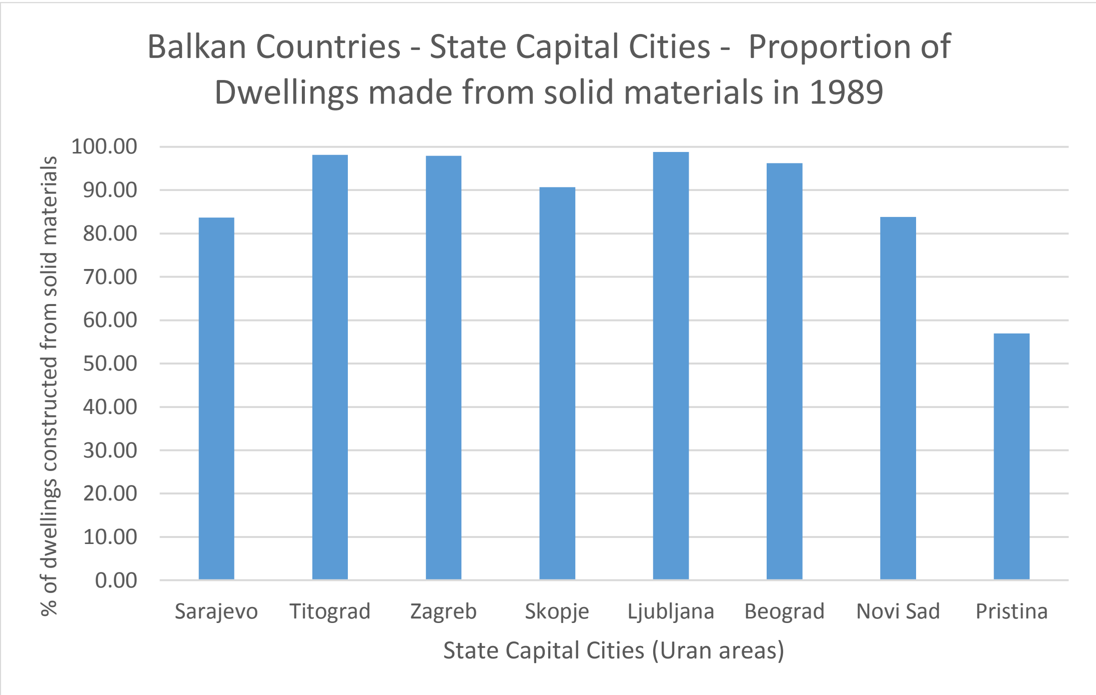



*Figure 15: Balkan Countries – State Capital Cities - Proportion of dwellings made from solid material in 1989. Data Source: Savezui Zavod Za Statistifu (1989)*

### 4.3.1 Serbia

#### *4.3.1.1 Data collection and inferences*

In Serbia, the housing stock is considered relatively new compared to other countries within the European Union as only 5.6% of dwellings were built prior to 1916 (Economic Commission for Europe, 2006). As shown by Figure 16, construction flourished in the 1970s. Within the Serbian Census, they distinguish between ‘hard’ and ‘soft’ materials. ‘Soft’ materials are associated with weak materials such as adobe blocks, earth, wattle and plank and ‘hard’ materials are characterised by brick, stone, concrete and other materials incorporating modern elements (Gomez, I. 2014).There is a gradual decline in weak material construction since 1946.

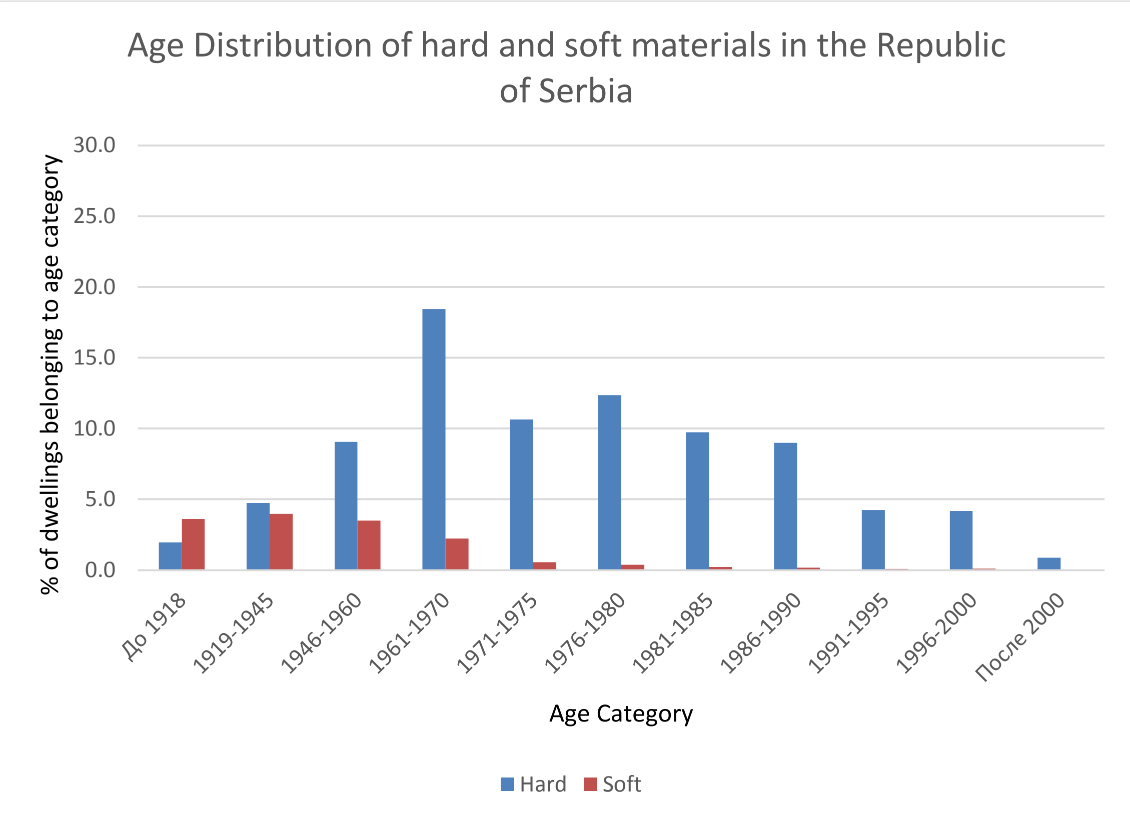



*Figure 16: Age Distribution of hard and soft materials in the Republic of Serbia*

The census data, does not distinguish between urban and rural areas. However, an age distribution of Belgrade’s building stock and the distribution of hard and soft materials is available and can be used as an indication– see Figure 17 and Figure 18. The majority of Belgrade is constructed from masonry or concrete (Cukovic-Ignjatovic, u.d.). In other urban areas the downtown areas are characterised by medium height-apartment buildings (Economic Commission for Europe, 2006). In comparison to the national statistics, construction was greater in urban areas in the 1960s-80s due to urbanisation and there are fewer dwellings constructed from soft materials.

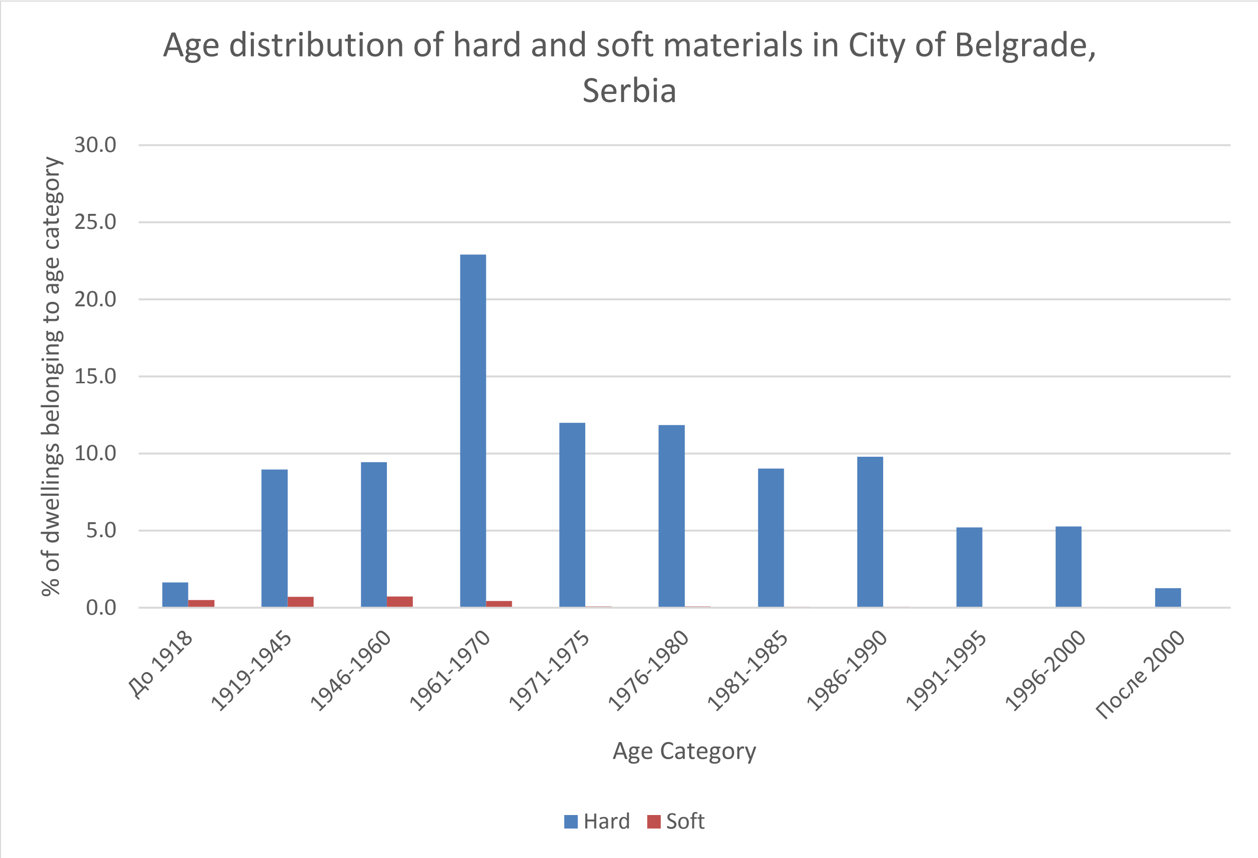



*Figure 17 Age distribution of hard and soft materials in the City of Belgrade, Serbia*

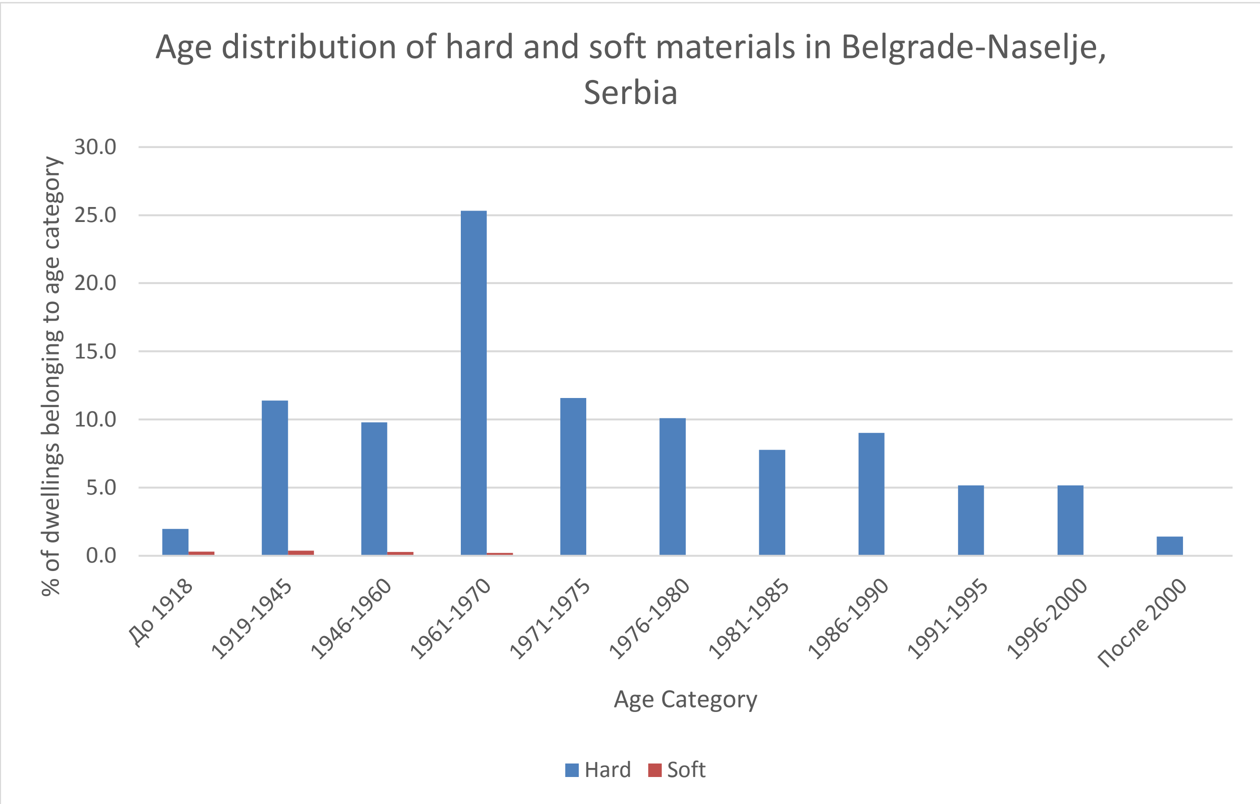



*Figure 18 Age distribution of hard and soft materials in Belgrade-Naselje, Serbia*

Popović et al (2013) completed a study regarding the national typology of residential buildings in Serbia, focusing on energy efficiency. Within this study more than 250,000 buildings were surveyed (Popović, 2014). As shown by Figure 19, a matrix has been designed which categorises dwellings by the housing type (e.g single family dwelling) and age. Within the document, each category is discussed in more detail, including the material of external walls and flooring alongside the proportion of dwellings surveyed belonging to that class. These categories have been analysed by CAR and mapped onto the structural typologies used within the questionnaire because the paper focused on the thermal integrity of the buildings rather than structural integrity. For example, reinforced concrete frames with masonry infill walls were within the same category as unreinforced masonry buildings as they had similar external envelopes. The results are shown in Figure 20.

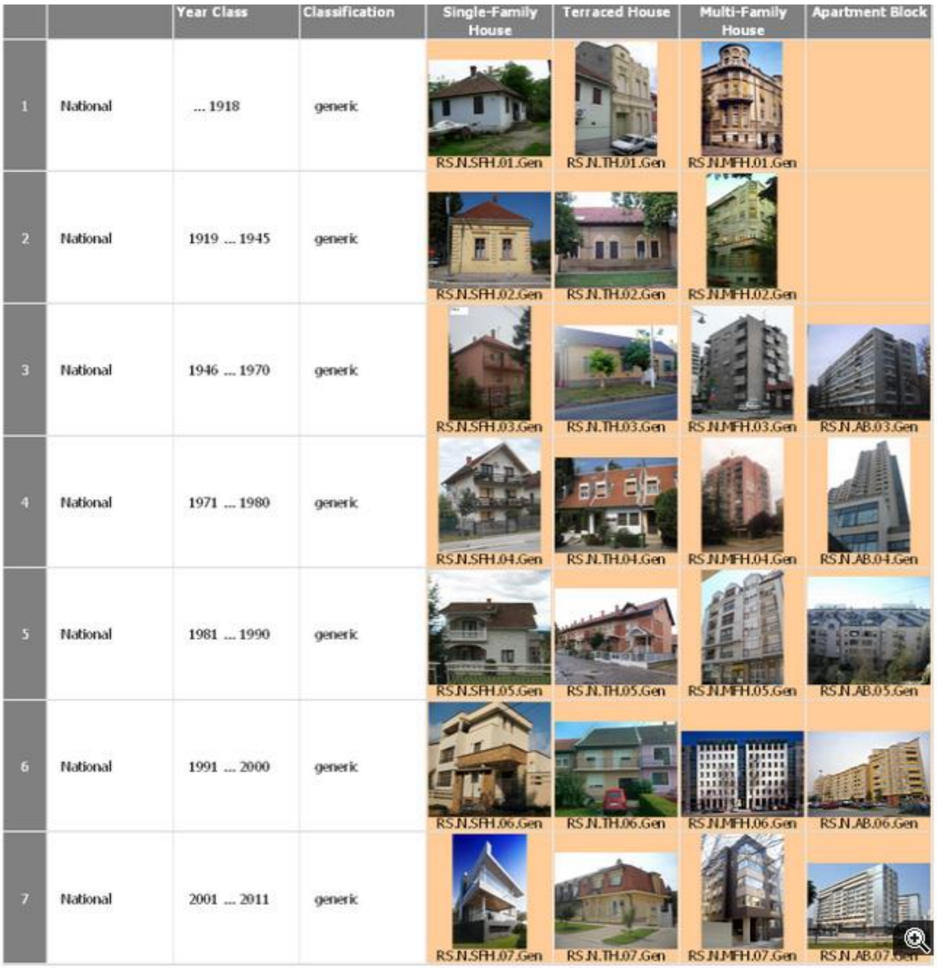



*Figure 19: Serbia Building Typology Matrix Source: Institut Wohnen und Unwelt Gmbh (2014)*

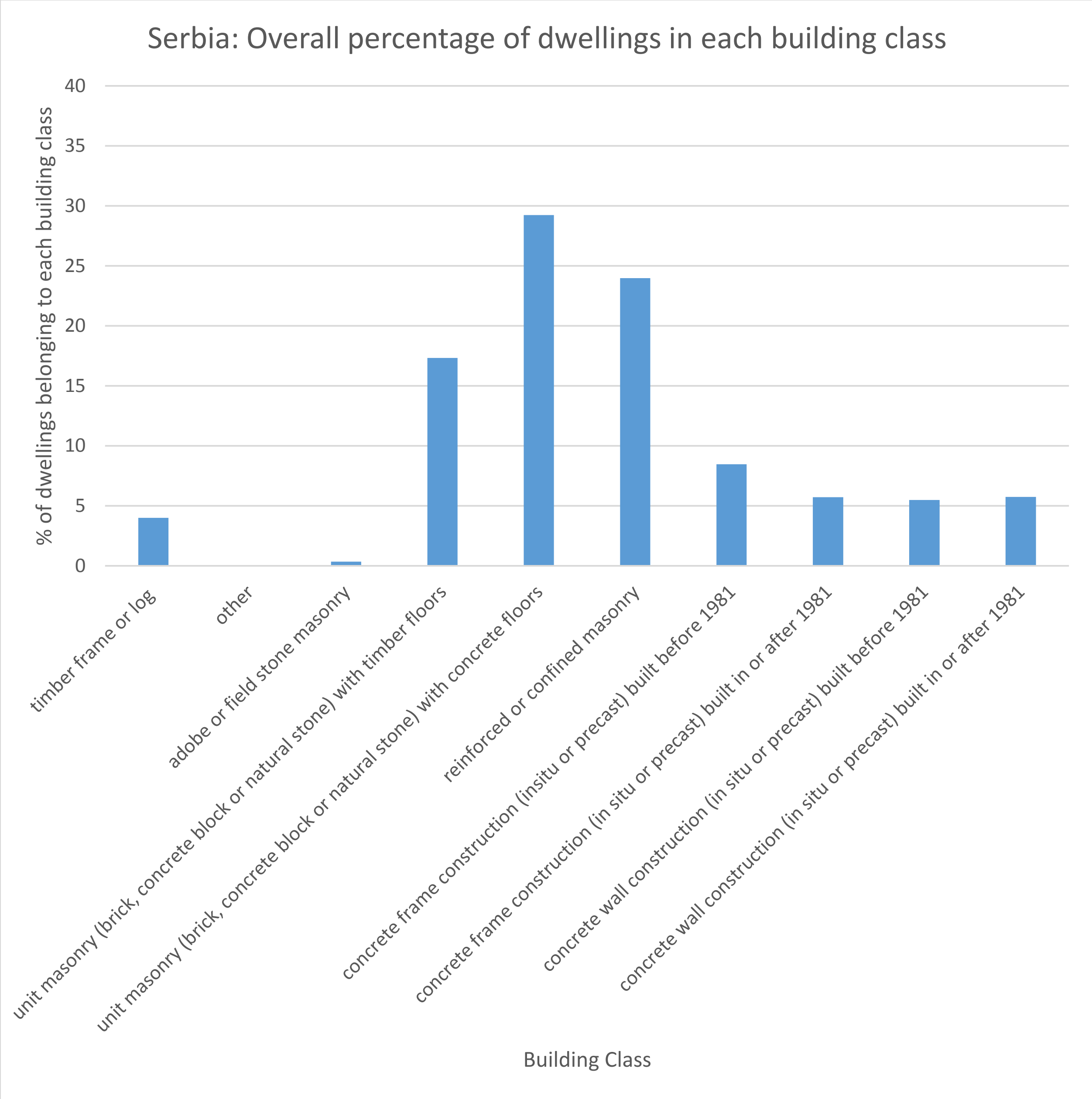



*Figure 20: Serbia: Overall percentage of dwellings in each building class. CAR's interpretation of Popović et al (2013) study*

There is clearly a predominance of masonry construction, in particular unit masonry with concrete floors and confined masonry.

The Economic Commission for Europe (2006) indicates that in 2002, 53.9% of Serbia's housing stock was located in urban areas and 46.1% in rural.

*Table 7: Serbia: Urban/Rural housing stock in thousands*

| | **2002** | **1991** | Increase |
|---|---|---|---|
| Total housing stock | 2,956.5 | 2,735.3 | 8.1% |
| Urban | 1,592.6 | 1,445.1 | 10.2% |
| Rural | 1,363.9 | 1,290.2 | 5.7% |
| **% Urban** | **53.9%** | **52.8%** | **-** |

Source: Adapted from Economic Commission for Europe (2006) citing Serbia and Montenegro Statistical Office (2002b)

#### *4.3.1.2 Questionnaires*

Two questionnaire responses have been received focusing on the building stock in Serbia. These were from Petar Anagnosti, an EAEE representative for Serbia and Ivan Gomez, a senior engineer at AIR Worldwide. The results are shown in Figure 21 and Figure 22.

The responses have been adjusted to an integer percentage values by CAR and this is what is shown in Figure 22 and in Table 8.

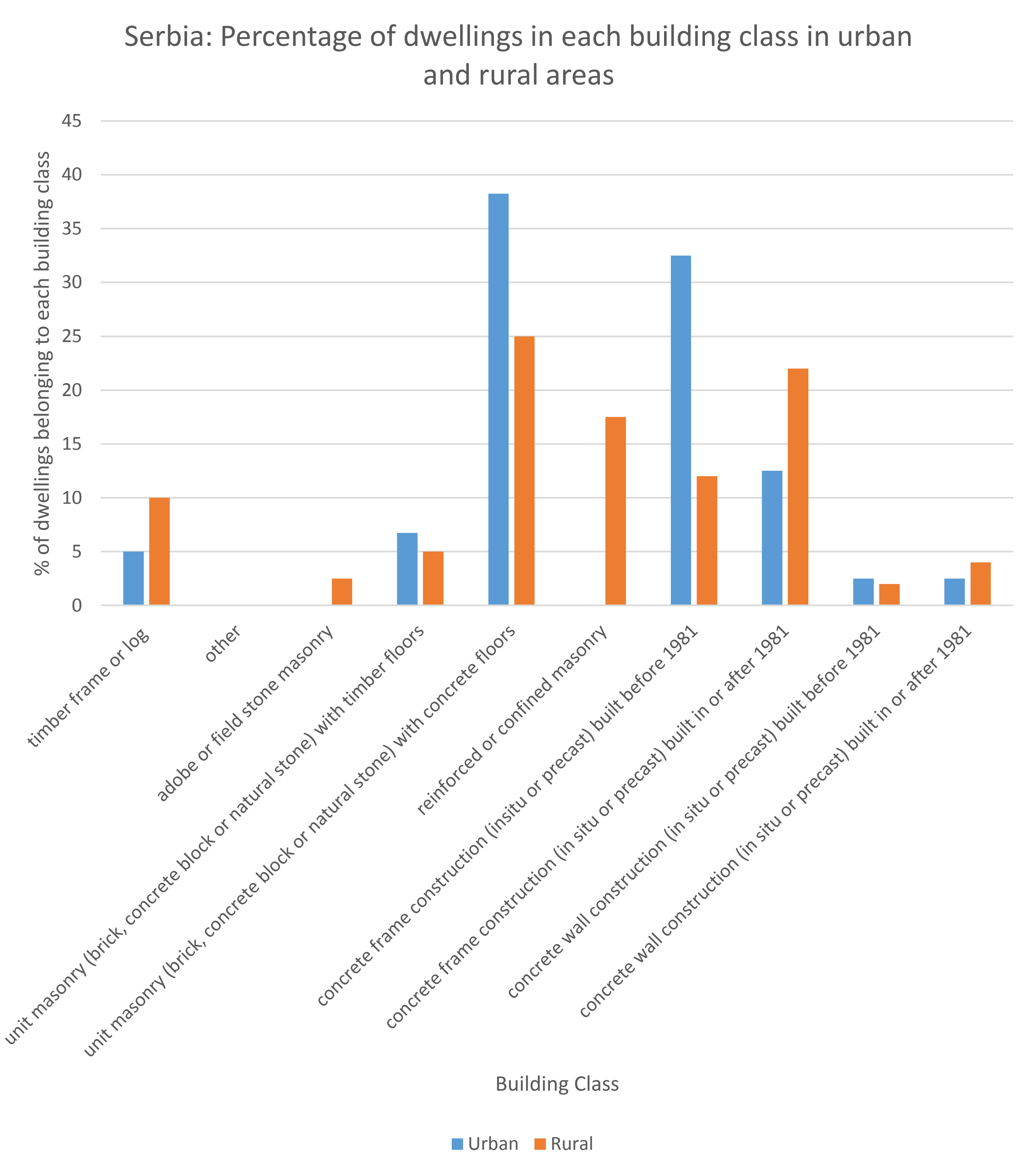



*Figure 21: Serbia: Percentage of dwellings in each building class in urban and rural areas. Source: Questionnaire response: Petar Anagnosti*

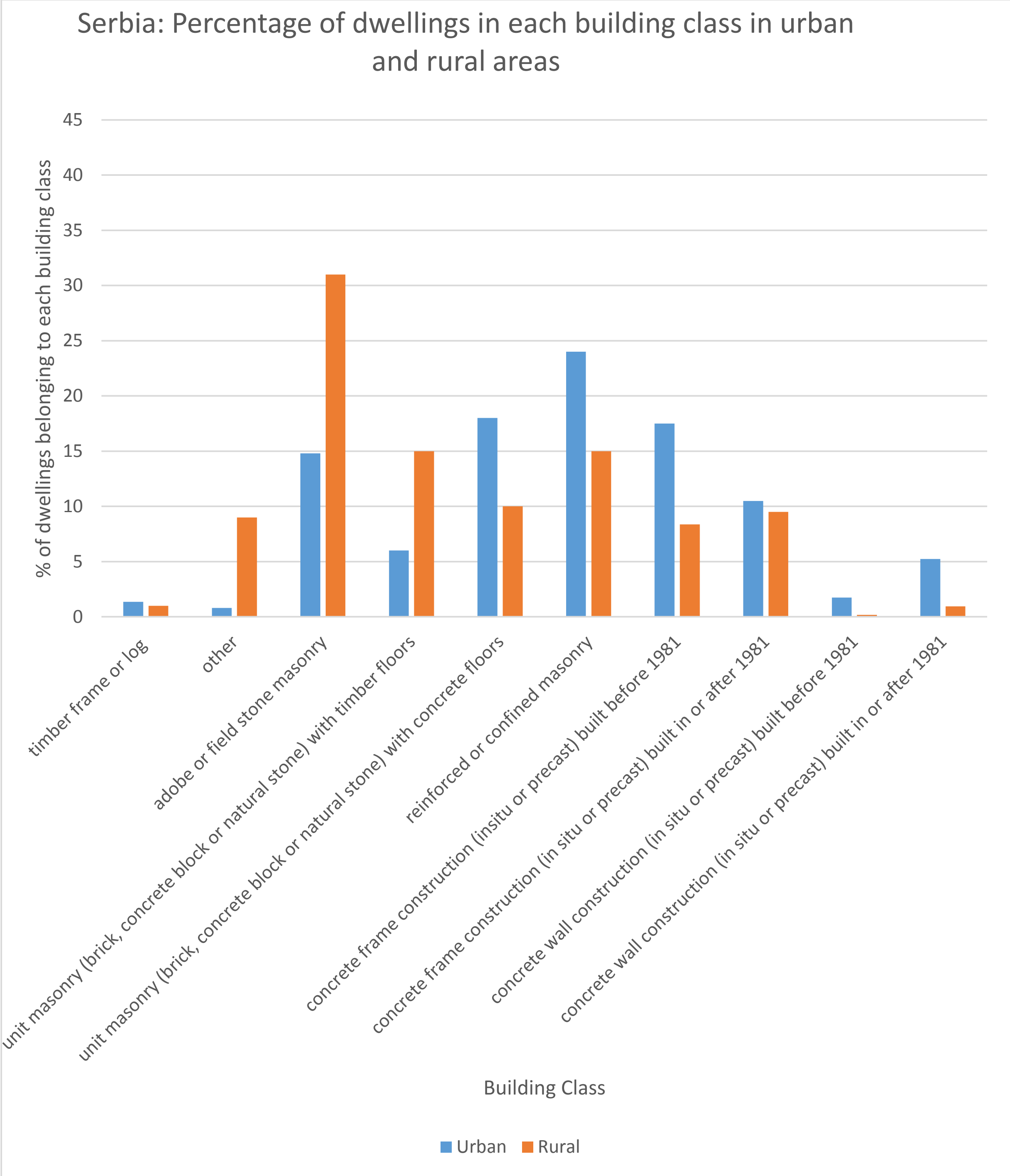



*Figure 22: Serbia: Percentage of dwellings in each building class in urban and rural areas. Source: Questionnaire response: Ivan Gomez*

#### *4.3.1.3 Comparison of methods*

Table 8 displays the three sets of results and the mean values for all three studies and the questionnaire responses. Bar Charts of the average (mean) results are shown in Figure 23 and Figure 24.

Using the metric of error, the average error/difference between the two questionnaire results is 12.0% in urban areas and 12.1% in rural areas. The average error between all three results (the questionnaires and the Popović study) is 10.8% in urban areas and 10.9% in rural areas.

*Table 8: Comparison of results for Serbian dwelling fractions*

| Structure Type | Percentage of dwellings | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|
| | Gomez Questionnaire | | Anagnosti Questionnaire | | CAR using Popović (2013) study | | Average (mean) all three studies | | Average (mean) questionnaire responses only | |
| | Urban (%) | Rural (%) | Urban (%) | Rural (%) | Urban (%) | Rural (%) | Urban (%) | Rural (%) | Urban (%) | Rural (%) |
| timber frame or log | 1 | 1 | 5 | 10 | 4 | 4 | 3 | 5 | 3 | 6 |
| other | 1 | 9 | 0 | 0 | 0 | 0 | 0 | 3 | 0 | 5 |
| adobe or field stone masonry | 15 | 31 | 0 | 3 | 0 | 0 | 5 | 11 | 7 | 17 |
| unit masonry (brick, concrete block or natural stone) with timber floors | 6 | 15 | 7 | 5 | 17 | 17 | 10 | 12 | 6 | 10 |
| unit masonry (brick, concrete block or natural stone) with concrete floors | 18 | 10 | 38 | 25 | 29 | 29 | 28 | 21 | 28 | 18 |
| reinforced or confined masonry | 24 | 15 | 0 | 18 | 24 | 24 | 16 | 19 | 12 | 16 |
| concrete frame construction (insitu or precast) built before 1981 | 18 | 8 | 33 | 12 | 8 | 8 | 19 | 10 | 25 | 10 |
| concrete frame construction (in situ or precast) built in or after 1981 | 11 | 10 | 13 | 22 | 6 | 6 | 10 | 12 | 12 | 16 |
| concrete wall construction (in situ or precast) built before 1981 | 2 | 0 | 3 | 2 | 5 | 5 | 3 | 3 | 2 | 1 |
| concrete wall construction (in situ or precast) built in or after 1981 | 5 | 1 | 3 | 4 | 6 | 6 | 4 | 4 | 4 | 2 |

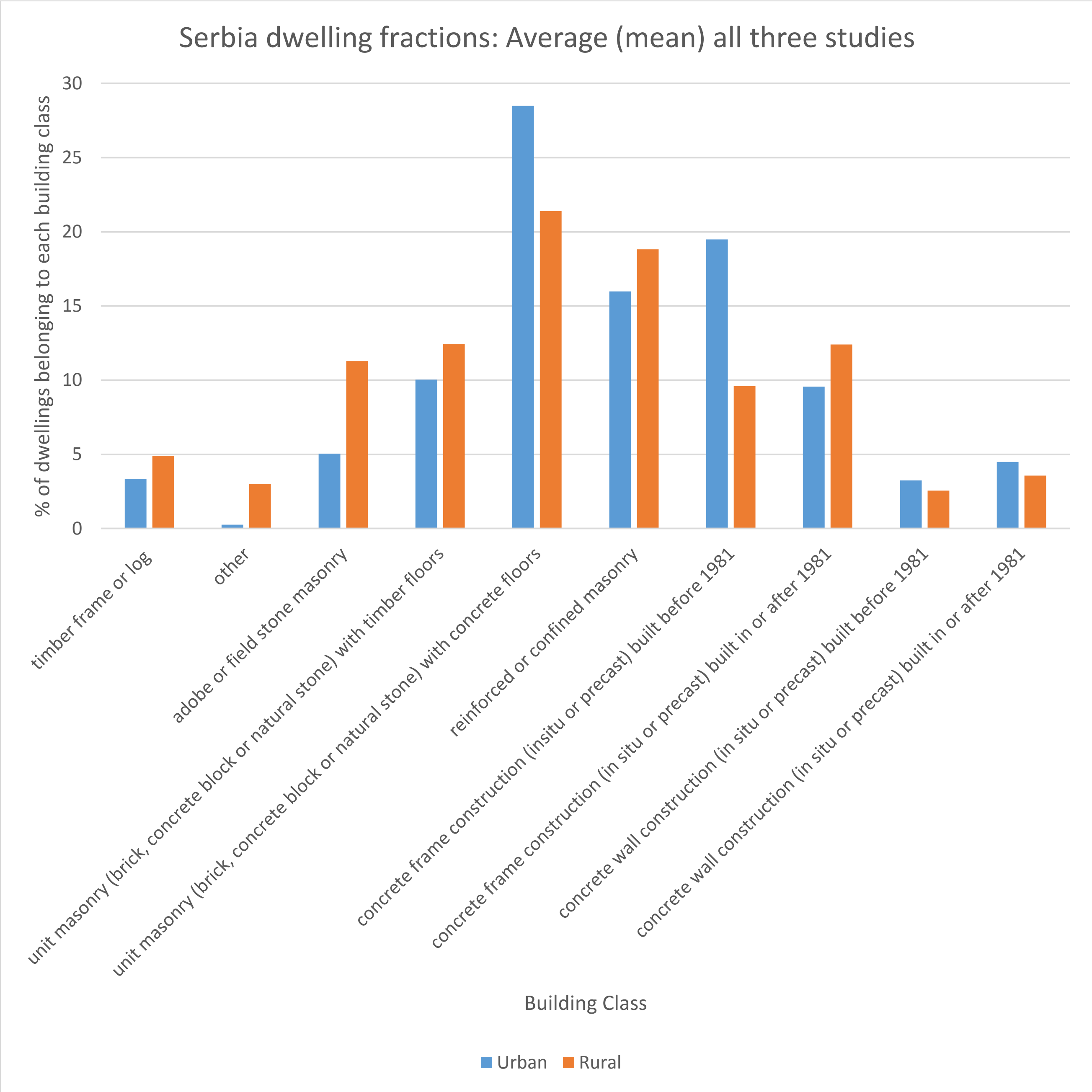



*Figure 23 Serbia dwelling fractions: Average (mean) all three studies*

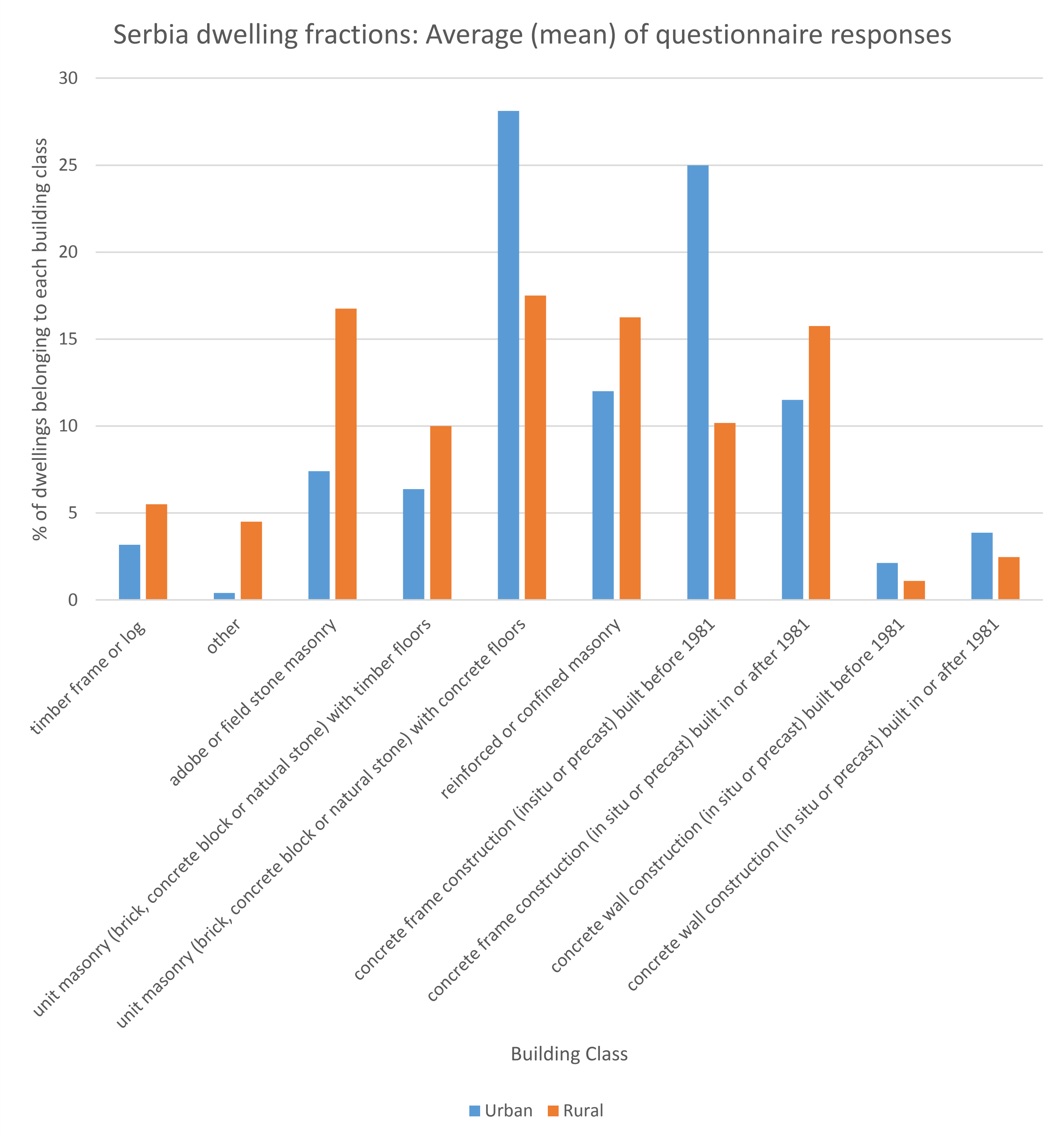



*Figure 24 Serbia dwelling fractions: Average (mean) of questionnaire responses*

Some significant differences have been noted between the questionnaire results. Gomez has a much higher proportion of adobe and field stone masonry constructions in comparison to Anagnosti. In addition, Gomez has a much higher proportion of confined masonry in urban areas than Anagnosti.

#### *4.3.1.4 Final Dwelling Fractions*

An average of all three studies has been chosen for the final dwelling fractions to try and eliminate anomalies – Table 9.

*Table 9: Serbia dwelling fractions – Average of all three results. Values have been rounded to the nearest whole number.*

| Structural Typology | GEM Taxonomy | Percentage of Dwellings in Urban Areas (%) | Percentage of Dwellings in Rural Areas (%) |
|---|---|---|---|
| Total | | 54 | 46 |
| timber frame or log | W+W99/LPB/H99/Y99/RES | 3 | 5 |
| other | MATO/L99/H99/Y99/RES | 0 | 3 |
| adobe or field stone masonry | MUR+ADO+MO99/LWAL/H99/Y99/RES<br>MUR+STRUB+MO99/LWAL/H99/Y99/RES | 5 | 11 |
| unit masonry (brick, concrete block or natural stone) with timber floors | MUR+STDRE+MO99/LWAL/H99/Y99/RES/FW<br>MUR+CL99+MO99/LWAL/H99/Y99/RES/FW<br>MUR+CB99+MO99/LWAL/H99/Y99/RES/FW | 10 | 12 |
| unit masonry (brick, concrete block or natural stone) with reinforced concrete floors | MUR+STDRE+MO99/LWAL/H99/Y99/RES/FC<br>MUR+CL99+MO99/LWAL/H99/Y99/RES/FC<br>MUR+CB99+MO99/LWAL/H99/Y99/RES/FC | 28 | 21 |
| reinforced or confined masonry | MCF/LWAL/H99/Y99/RES<br>MR/LWAL/H99/Y99/RES | 16 | 19 |
| concrete frame construction (insitu or precast) built before 1981 | C99+CT99/LFM/H99/YPRE:1981/RES<br>C99+CT99/LFINF/H99/YPRE:1981/RES | 19 | 10 |
| concrete frame construction (in situ or precast) built in or after 1981 | C99+CT99/LFM/H99/YBET: 2014,1981/RES<br>C99+CT99/LFINF/H99/ YBET: 2014,1981/RES | 10 | 12 |
| concrete wall construction (in situ or precast) built before 1981 | C99+CT99/LWAL/H99/YPRE:1981/RES | 3 | 3 |
| concrete wall construction (in situ or precast) built in or after 1981 | C99+CT99/LWAL/H99/YBET: 2014,1981/RES | 4 | 4 |

## 4.3.2 Croatia

### *4.3.2.1 Data collection and inferences*

A high proportion of Croatia's building stock was built after World War II. The majority of these were either masonry or concrete (Erbach 1996). As shown by Figure 25 and Figure 26, during the 1960s and 70s there was a rapid growth in public housing, which is commonly associated with high-density multi-storey constructions (Spevec 2009).

In general, socially owned property (many of which are now privatised) are situated within urban areas (Erbach 1996).

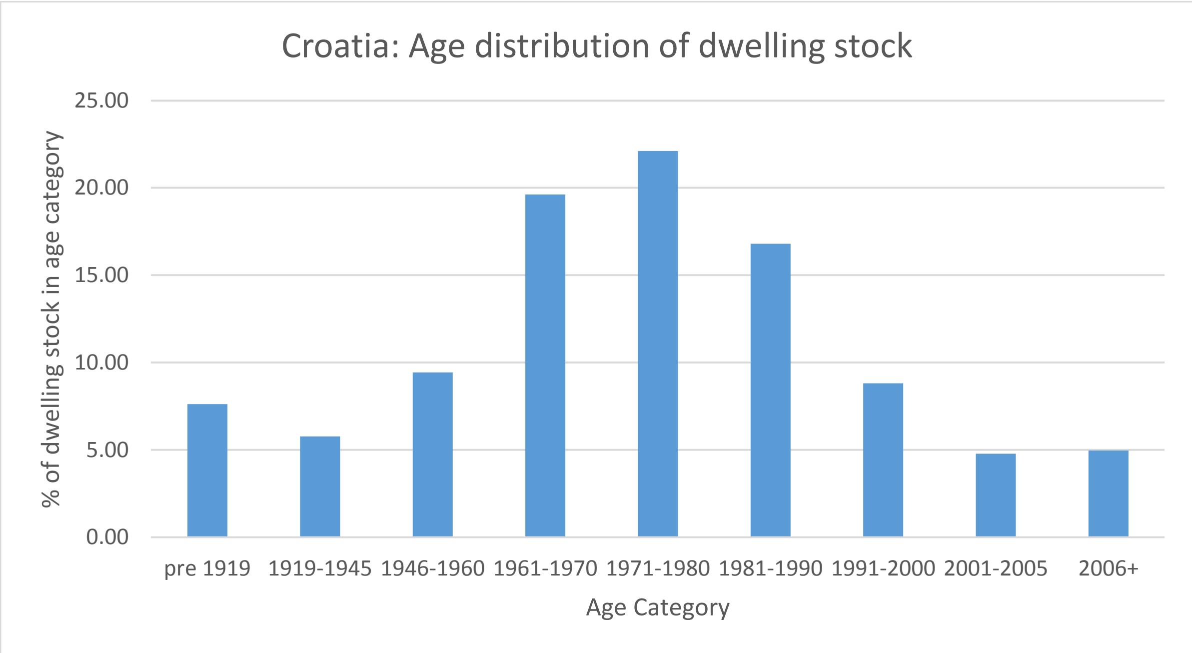
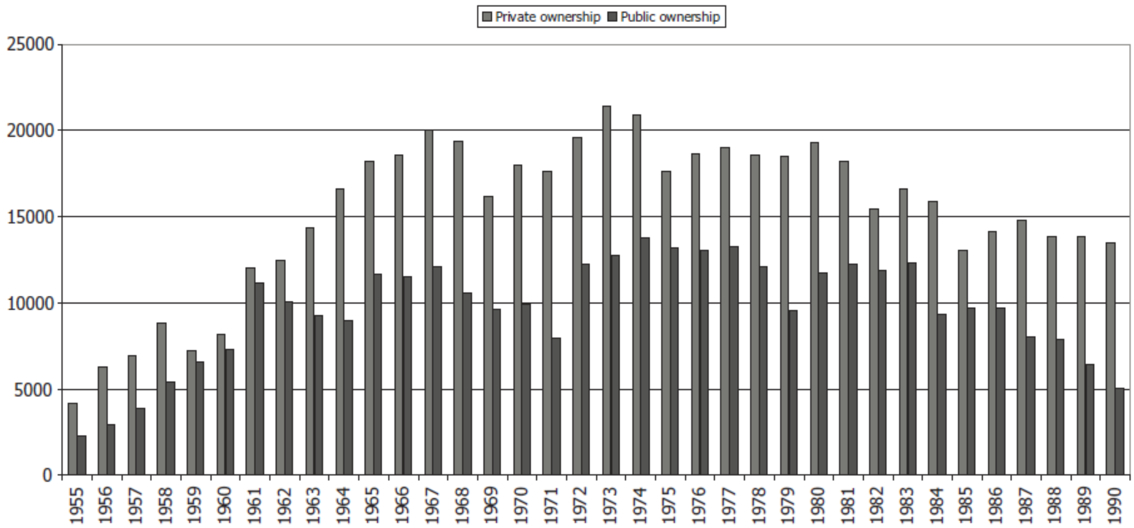



*Figure 25 Croatia: Age distribution of dwelling stock. Data Source: Croatian Bureau of Statistics (2011)*




*Sources*: SZS (1959); DZS (1993).

*Figure 26 Croatia: Completed Dwellings Private Ownership and Other forms of ownership. Source: Spevec (2009 p.458)*

In Zagreb, 56% of dwellings are within apartment blocks and 44% are individual houses (Erbach, J. 1996). This can be used as a rough estimate to characterise an urban area, as there is a higher ratio of apartment blocks (assuming these are associated with public ownership) than individual dwellings on a national scale.

Overall, statistics suggest, 57% of dwellings are situated in urban settlements (2001 data) – Table 10.

*Table 10: Croatia: Urban – Rural distribution of dwellings*

| | **1971** | **1981** | **1991** | **2001** |
|---|---|---|---|---|
| Dwellings for permanent residence | 1,188,743 | 1,381,434 | 1,575,644 | 1,660,649 |
| Dwellings in urban settlements | 513,534 | 727,683 | 878,968 | 941,330 |
| % dwellings in urban settlements | 46% | 53% | 56% | 57% |

Source: Adapted from Spevec (2009 p. 460) citing DZS (1996, 2005)

#### *4.3.2.2 Questionnaires*

Two questionnaire responses were received regarding Croatia's building stock. One from Professor Anicic, an EAEE member, one of a very small group of eminent/honouree members. Another from Damir Lazarević and collaborators at the Faculty of Civil Engineering, University of Zagreb. The results are shown in Figure 27 and Figure 28.

Lazarević's response used the drop-down menus provided in the questionnaire. For this reason, they have been adjusted to an integer percentage value by CAR and this is what is shown in Figure 28.

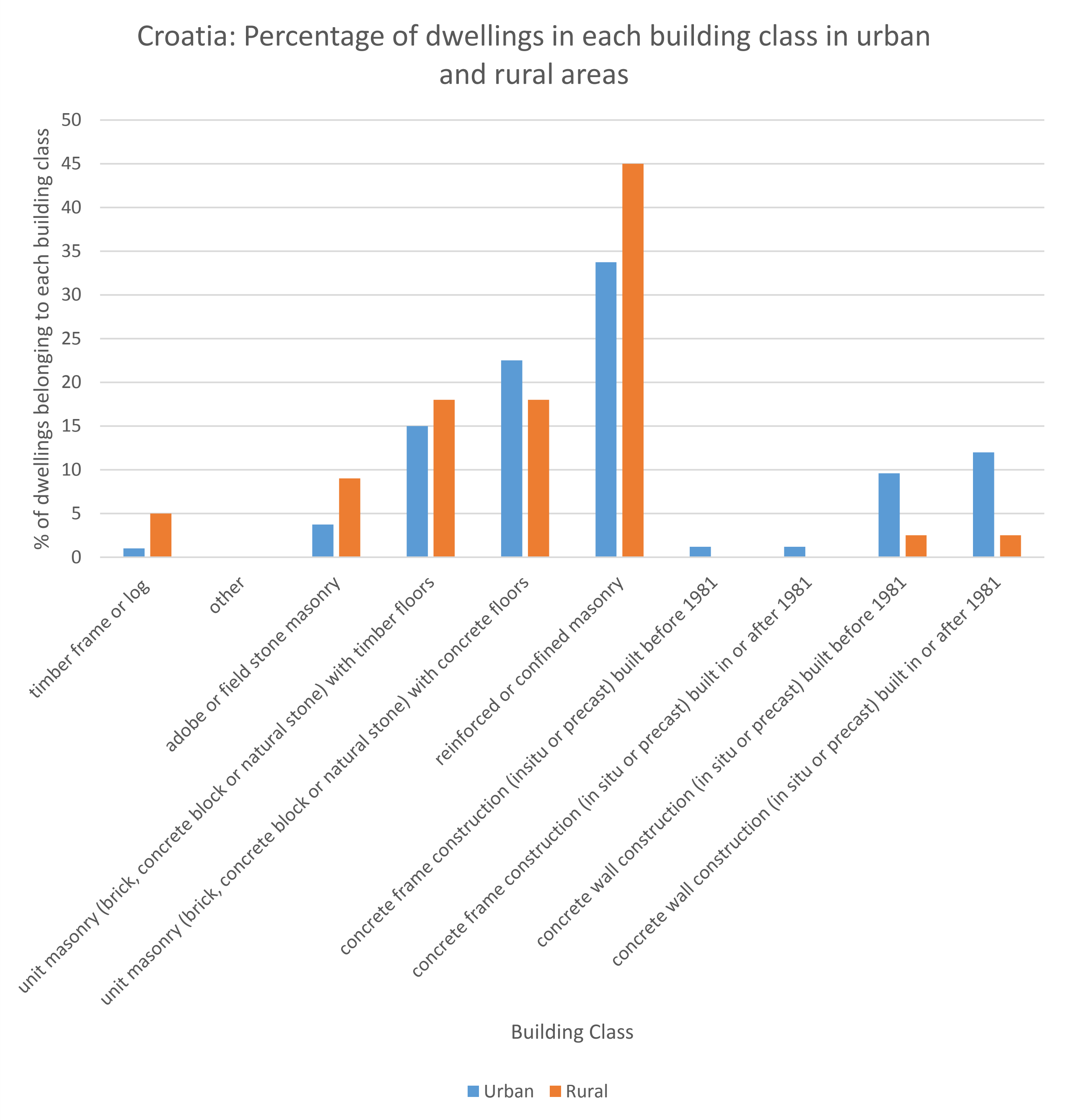



*Figure 27 Croatia: Percentage of dwellings in each building class in urban and rural areas. Source: Questionnaire response: Drazen Anicic*

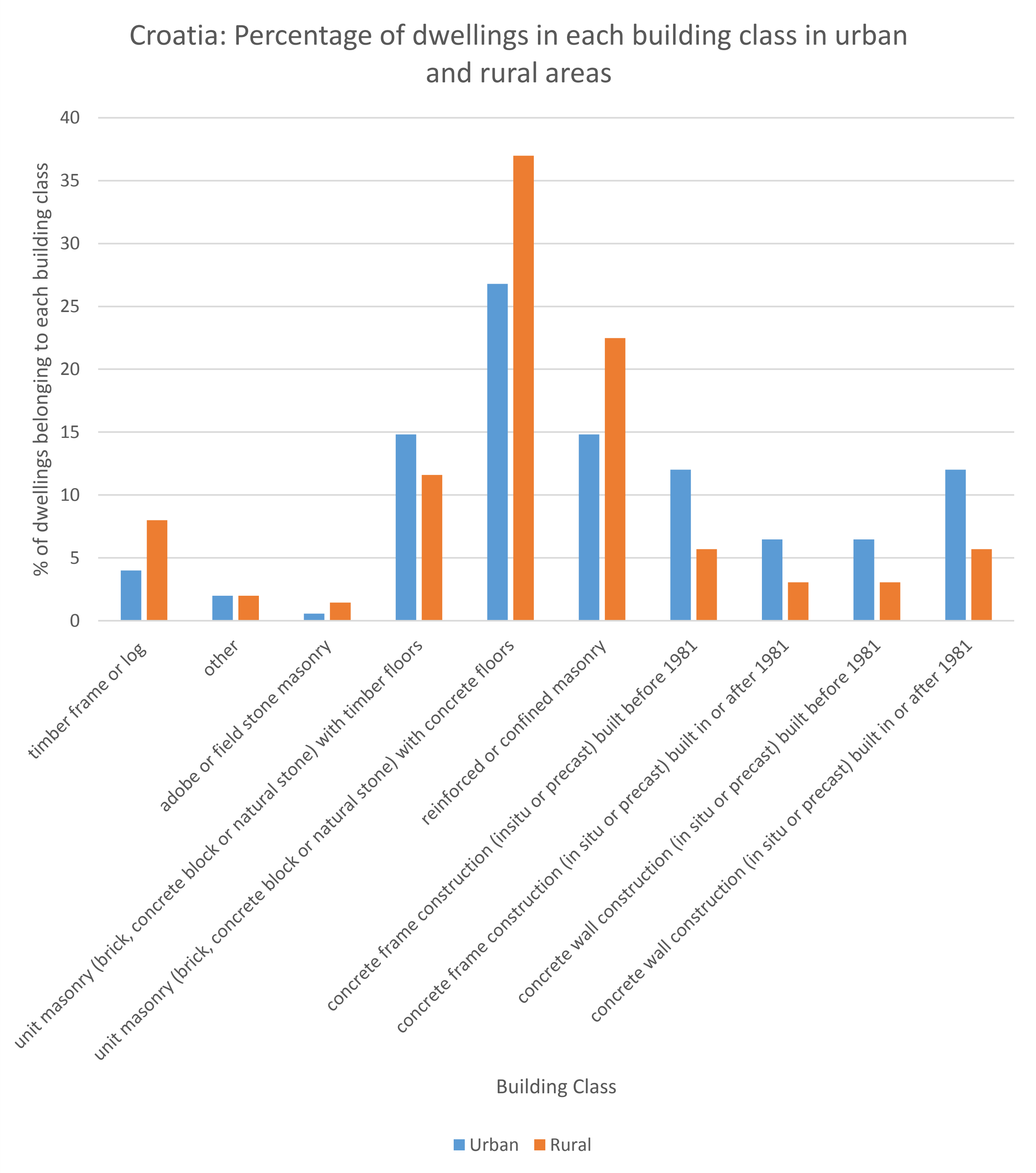



*Figure 28 Croatia: Percentage of dwellings in each building class in urban and rural areas. Source: Questionnaire response: Damir Lazarević et al*

Both questionnaire results show that a large proportion of dwellings are masonry constructions. Using the metric of error, in urban areas the average error/difference is 7.5% and in rural areas it is 10.3%.

Anicic's response shows there is more confined masonry, whereas Lazarević identifies a larger proportion of masonry dwellings with concrete floors. Both results indicate that concrete wall dwellings are less common than concrete frame. In urban areas there is a higher proportion of concrete dwellings than in rural areas.

### *4.3.2.3 Street View Survey*

Ten different zones (5 urban, 5 rural) were surveyed using Google Street View. In total 1630 buildings (8078 dwellings) were surveyed, a breakdown of these is displayed in Table 11. A map identifying the locations of the areas is shown in Figure 29.

*Table 11: Street View Survey, Croatia. Number of buildings and dwellings surveyed in different areas.*

| Area | Number of buildings surveyed | | | | | |
|---|---|---|---|---|---|---|
| | **Zagreb 1** | **Zagreb 2** | **Rijeka** | **Split** | **Zadar** | **Total** |
| **Urban** | 265 | 369 | 102 | 360 | 217 | 1313 |
| **Rural** | 139 | 84 | 39 | 50 | 5 | 317 |
| | **Number of dwellings surveyed** | | | | | |
| **Urban** | 2553 | 1026 | 660 | 2776 | 652 | 7667 |
| **Rural** | 151 | 113 | 69 | 72 | 6 | 411 |

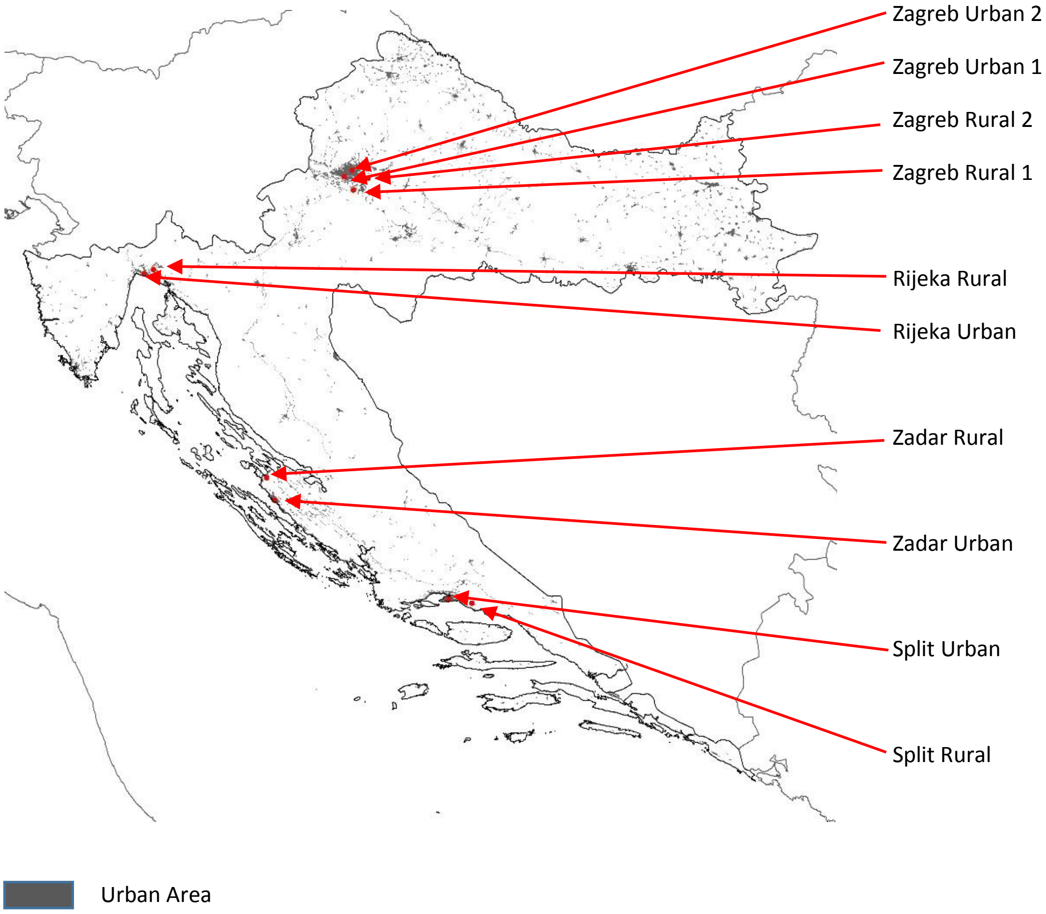



*Figure 29: Map of Croatia identifying areas surveyed using Google Street View survey*

The collated results for urban and rural are shown in Figure 30 and Table 12. Individual results for each area surveyed are displayed in Appendix 7.

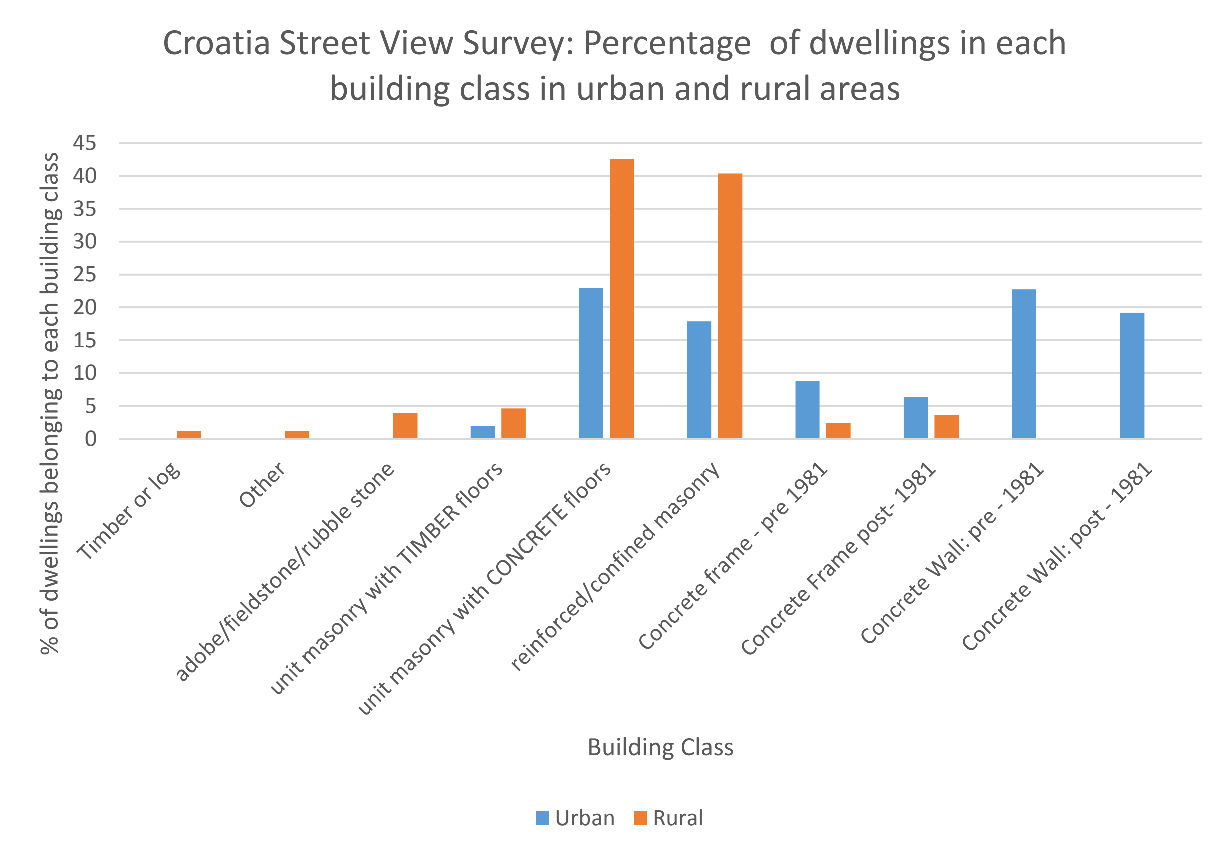



*Figure 30: Croatia Street View Survey: Percentage of dwellings in each building class in urban and rural areas*

*Table 12: Croatia Dwelling Fractions –Street View results*

| **Structural Typology** | **Percentage of Dwellings in Urban Areas (%)** | **Percentage of Dwellings in Rural Areas (%)** |
|---|---|---|
| Total | 0 | 0 |
| timber frame or log | 0 | 0 |
| adobe or field stone masonry | 2 | 7 |
| unit masonry (brick, concrete block or natural stone) with timber floors | 29 | 57 |
| unit masonry (brick, concrete block or natural stone) with reinforced concrete floors | 1 | 1 |
| reinforced or confined masonry | 16 | 7 |
| concrete frame construction (insitu or precast) built before 1981 | 28 | 29 |
| concrete frame construction (in situ or precast) built in or after 1981 | 8 | 0 |
| concrete wall construction (in situ or precast) built before 1981 | 16 | 0 |
| concrete wall construction (in situ or precast) built in or after 1981 | 0 | 0 |

The Street View results show a high proportion of masonry buildings, both unit masonry with concrete floors and confined masonry - particularly in rural areas. Within urban areas, although there was still a high proportion of masonry, there were also a significant number of reinforced concrete wall buildings (both pre and post 1981) surveyed. These tended to be multi-family buildings and contain a large number of dwellings.

The average number of dwellings in a building for each building class (calculated from the survey results) is shown in Table 13.

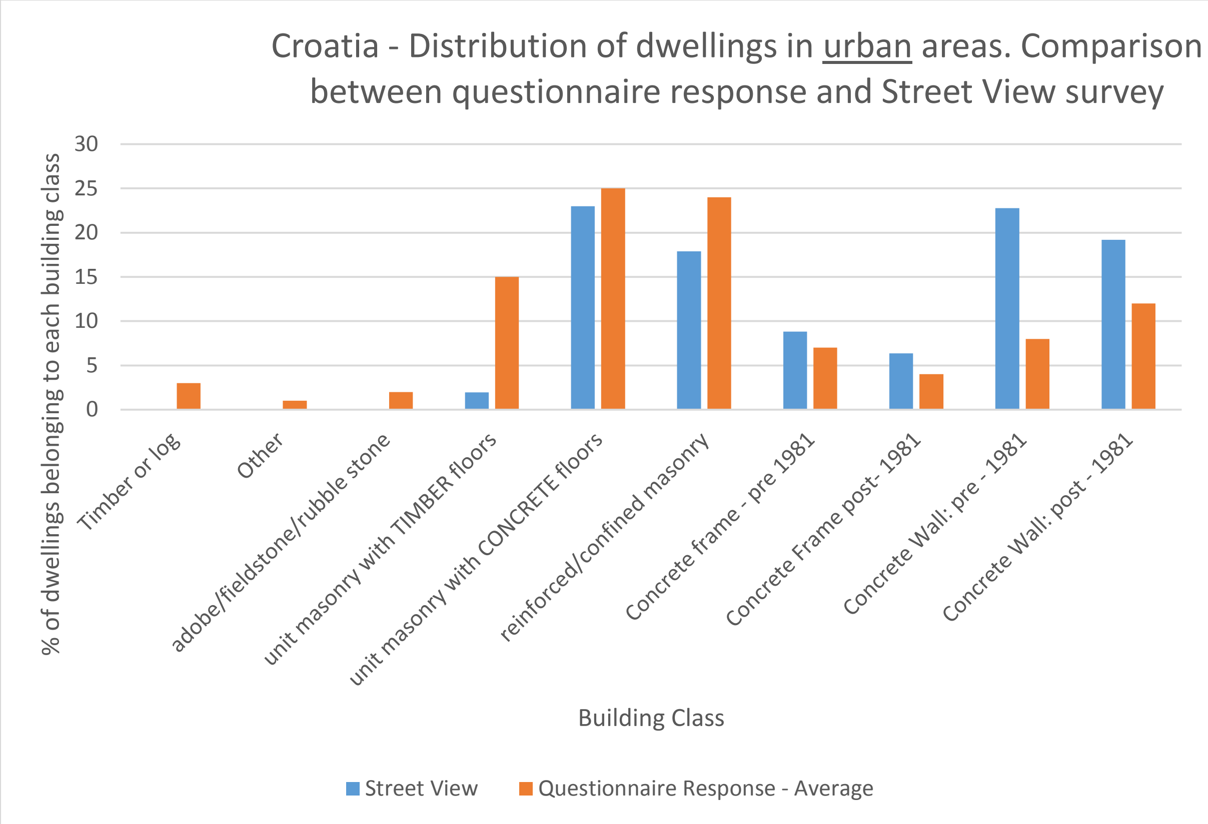
*Table 13: Average number of dwellings per building belonging to each building class (obtained from Street View)*

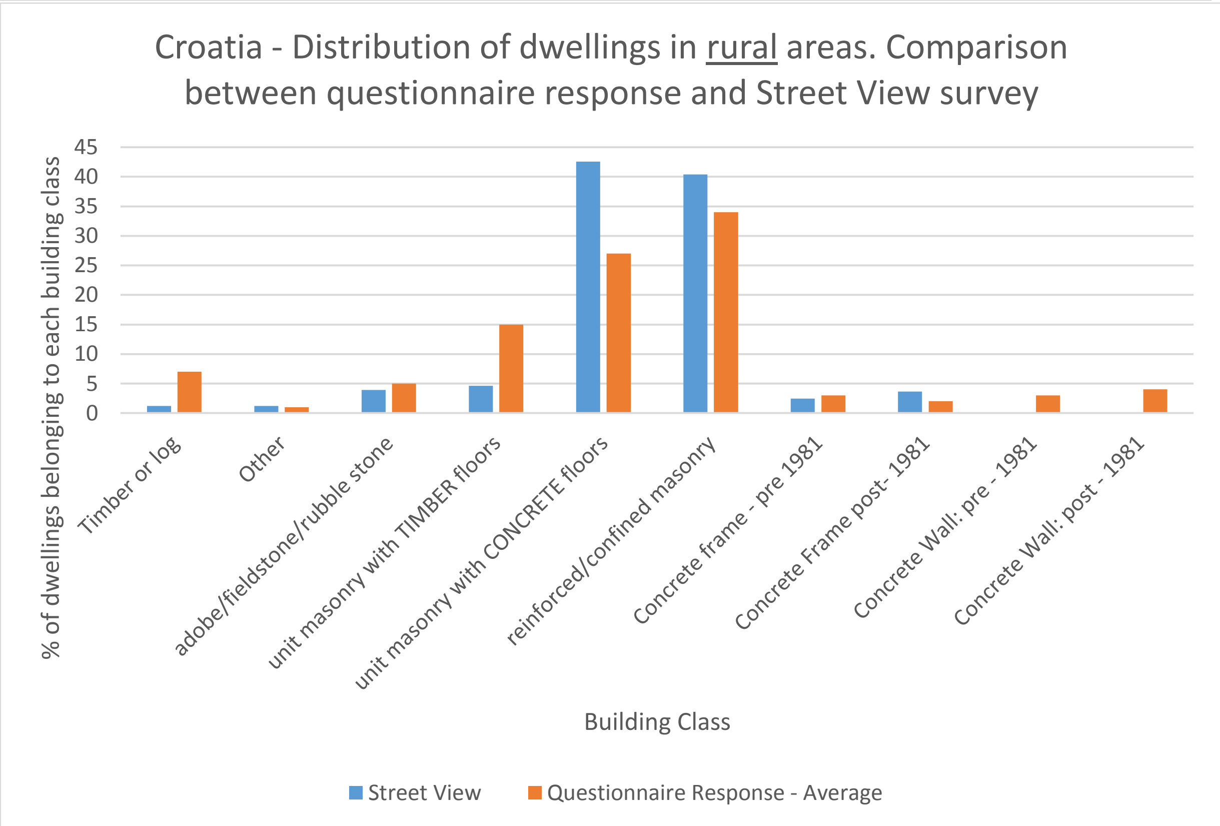
| | | **Building Class** | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|
| | | **Timber or log** | **Other** | **adobe/fieldstone/rubble** | **unit masonry with TIMBER** | **unit masonry with CONCRETE** | **reinforced/ confined masonry** | **Concrete frame - pre 1981** | **Concrete Frame post- 1981** | **Concrete Wall: pre - 1981** | **Concrete Wall: post - 1981** |
| **Average number of dwellings per building in each building class** | **Urban** | 1 | 1 | 4 | 1 | 3 | 4 | 13 | 8 | 43 | 42 |
| | **Rural** | 1 | 1 | 3 | 1 | 1 | 1 | 2 | 1 | 0 | 0 |

The individual results in Appendix 7, show that the character of rural areas appears to be relatively consistent as most are dominated by masonry constructions. These vary depending on the age of the area – newer constructions tend to be confined masonry, whereas older tend to be unit masonry with timber or concrete floors. The character of urban areas surveyed has more variation depending on the density of the building stock and its age. E.g. Urban zone 1 in Zagreb had a high proportion of concrete buildings which where multi-family dwellings, whereas urban zone 2, was characterised by masonry construction which were small multi-family or single-family dwellings.

#### *4.3.2.4 Comparison of methods*

The data collection for Croatia has been successful due to receiving more than one questionnaire response and the availability of Street View.




Using the metric of error, for both urban and rural areas, the average error is 6.7% between the Street View survey results and the questionnaire.

The main difference between the Street View survey results and the questionnaire responses is that in urban areas there is:

- A larger proportion of concrete wall dwellings in the Street View survey than suggested in the questionnaire response (average of results)
- A smaller proportion of unit masonry buildings with timber floors are present in the Street View Survey than suggested in the questionnaire.

The results for rural areas are fairly compatible but with some small differences:

- No concrete wall buildings were observed during the Street View survey
- The questionnaire response suggests more unit masonry buildings with timber floors than observed and less unit masonry with concrete floors and reinforced masonry than observed.

Possible reasons for these discrepancies in results include:

- Only large urban areas were analysed, whereas the questionnaire response considers urban areas as areas with more than 5000 inhabitants. In these areas, there would be fewer concrete wall multi-family buildings than observed during the Street View Survey. As these areas were not included, the results were skewed by the large number of dwellings within the concrete buildings.
- Difficulty distinguishing between some building types due to lack of expert consultation and context regarding the area e.g. age of the building stock and when it was developed.
- Lack of Street View access in less developed/more remote rural areas. These areas are where there is likely to be an older building stock and higher proportion of unit masonry with timber floors.

Table 14 displays both questionnaire results, the average percentages of structural typologies and the Street View survey results.

*Table 14: Dwelling fractions for Croatia. Values have been rounded to the nearest whole number*

| **Building Class** | **Percentage of dwellings belonging to each building class** | | | | | | | |
|---|---|---|---|---|---|---|---|---|
| | **Drazen Anicic Questionnaire Response** | | **Damir Lazarević & collaborators** | | **Average (mean) questionnaire responses only** | | **Street View Survey** | |
| | **Urban (%)** | **Rural (%)** | **Urban (%)** | **Rural (%)** | **Urban (%)** | **Rural (%)** | **Urban (%)** | **Rural (%)** |
| timber frame or log | 1 | 5 | 4 | 8 | 3 | 7 | 0 | 1 |
| other | 0 | 0 | 2 | 2 | 1 | 1 | 0 | 1 |
| adobe or field stone masonry | 4 | 9 | 1 | 1 | 2 | 5 | 0 | 4 |
| unit masonry (brick, concrete block or natural stone) with timber floors | 15 | 18 | 15 | 12 | 15 | 15 | 2 | 5 |
| unit masonry (brick, concrete block or natural stone) with | 23 | 18 | 27 | 37 | 25 | 27 | 23 | 43 |

| | | | | | | | | |
|---|---|---|---|---|---|---|---|---|
| reinforced concrete floors | | | | | | | | |
| reinforced or confined masonry | 34 | 45 | 15 | 22 | 24 | 34 | 18 | 40 |
| concrete frame construction (insitu or precast) built before 1981 | 1 | 0 | 12 | 6 | 7 | 3 | 9 | 2 |
| concrete frame construction (in situ or precast) built in or after 1981 | 1 | 0 | 6 | 3 | 4 | 2 | 6 | 4 |
| concrete wall construction (in situ or precast) built before 1981 | 10 | 3 | 6 | 3 | 8 | 3 | 23 | 0 |
| concrete wall construction (in situ or precast) built in or after 1981 | 12 | 3 | 12 | 6 | 12 | 4 | 19 | 0 |

#### *4.3.2.5 Updating questionnaire survey results using Street View surveys*

As discussed in Section 3.5.2, questionnaire surveys can, in principle, be updated with more specific survey data from field survey or Street View survey using a Bayesian approach. In this section an illustration of the approach as applied to the Street View survey data for urban areas in Croatia is given. The prior data is derived from the questionnaire responses for Croatia, Table 14; but for the purpose of this analysis a smaller number of building typology classes has been defined, identifying just three separate classes namely masonry, reinforced concrete pre-1981, and reinforced concrete post-1981. The proportions of the dwellings in each of these survey classes across the 5 urban survey locations are shown in Table 15.

*Table 15: Numbers of dwellings in each of the 5 urban Street View surveys in Croatia, with proportions of dwellings (%) in each of the three principal building inventory classes.*

| | Dwellings | Masonry | RC pre 81 | RC post 81 |
|---|---|---|---|---|
| **Zagreb 1** | 2553 | 14.6 | 59.6 | 25.8 |
| **Zagreb 2** | 1026 | 59.1 | 25.4 | 15.5 |
| **Rijeka** | 660 | 28.3 | 36.8 | 34.8 |
| **Split** | 2776 | 58.7 | 12.5 | 28.8 |
| **Zadar** | 652 | 75.5 | 7.5 | 17.0 |
| **Total** | 7667 | | | |
| **Average** | | 42.9 | 31.6 | 25.6 |
| **Standard deviation** | | 25.0 | 20.9 | 8.1 |
| **Questionnaire** | | 69.0 | 15.0 | 16.0 |

The average and standard deviation of the proportions in each class are reported in Table 15 as % values, and these are compared with the comparable proportions estimated in the questionnaire responses.

Table 16 shows the results of the Bayesian updating process carried out as described in Section 3.5.2. The table shows mean, variance and equivalent beta distribution parameters for the questionnaire survey (prior), the observed Street View survey data (likelihood) and the revised (posterior distributions) for each class, assuming beta distributions as explained in Section 3.5.2.

*Table 16: Results of the Bayesian updating process for the three principal building classes.*

| | | **Masonry** | **RC pre 81** | **RC post 1981** |
|---|---|---|---|---|
| **Prior (questionnaire)** | mean | 69% | 15% | 16% |
| | variance | 0.036 | 0.021 | 0.022 |
| | q | 3.45 | 0.75 | 0.8 |
| | r | 1.55 | 4.25 | 4.2 |
| **Observed (street view survey)** | mean | 43% | 32% | 26% |
| | variance | 0.062 | 0.044 | 0.007 |
| | q | 1.259 | 1.250 | 7.099 |
| | r | 1.676 | 2.711 | 20.685 |
| **Revised estimate (posterior)** | mean | 59% | 22% | 24% |
| | variance | 0.027 | 0.017 | 0.005 |
| | q | 4.7 | 2.0 | 7.9 |
| | r | 3.2 | 7.0 | 24.9 |

For the masonry classes, for example, an initial questionnaire estimate of 69% was combined with an observed proportion of 43% in the Street View survey, and the updating process gave a revised estimate of 59%. Similar updated results are provided for pre-1981reinforced concrete (22%) and post 1981 (24%). Note that the revised estimate has in all cases a smaller standard deviation than the questionnaire estimate or the Street View survey data, implying it is a better estimate. Figure 31 shows the prior, observed and posterior distributions for the combined masonry classes.

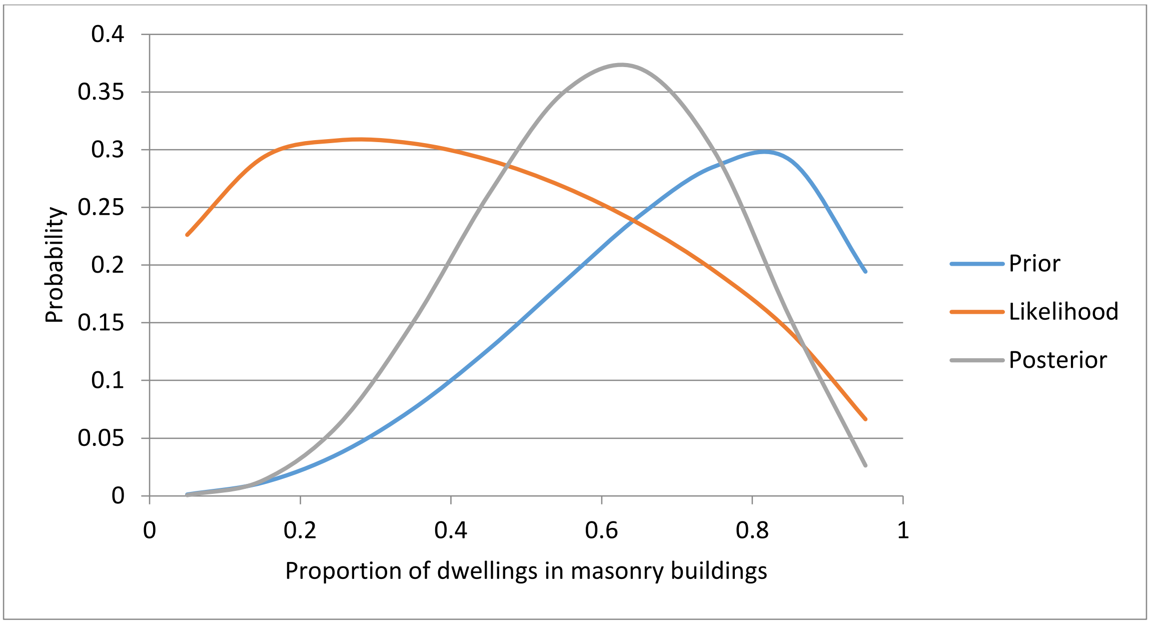



*Figure 31: Prior (questionnaire), likelihood (street-view survey) and posterior (revised) probability distributions for the proportion of dwellings in masonry buildings in urban areas of Croatia.*

Some limitations of this approach should be noted. It cannot usefully be applied in cases where the observed data do not approximate to a standard probability distribution (such as a beta distribution); in many cases where the observed proportion for a particular class is either zero, or 100%, this is clearly not the case.

A significant number of dwellings in each class for each survey used is needed. For the Street View surveys where the number of observed dwellings ranged from 650 to 2700 in the 5 survey locations, (and only 3 building typology classes are distinguished) the beta distribution assumption is reasonable. However, for field surveys, discussed in section 4.3.4.3, in which no more than 20 to 50 buildings were observed in an area, it is not reasonable to assume a beta distribution.

The revised proportions are, of course applicable only to the group of cities for which the observed data was collected, unless it can reasonably be assumed that these cities are typical of the whole country.

#### *4.3.2.6 Final Dwelling Fractions*

The final dwelling fractions have been calculated using the average (mean) results from the questionnaire responses – see Table 17. The Street View survey, was fairly compatible with the results and deemed them realistic.

*Table 17: Combined dwelling fractions Croatia. Values have been rounded to the nearest whole number.*

| **Structural Typology** | **GEM Taxonomy** | **Percentage of Dwellings in Urban Areas (%)** | **Percentage of Dwellings in Rural Areas (%)** |
|---|---|---|---|
| Total | | 57 | 43 |
| timber frame or log | W+W99/LPB/H99/Y99/RES | 3 | 7 |
| other | MATO/L99/H99/Y99/RES | 1 | 1 |
| adobe or field stone masonry | MUR+ADO+M099/LWAL/H99/Y99/RES<br>MUR+STRUB+M099/LWAL/H99/Y99/RES | 2 | 5 |
| unit masonry (brick, concrete block or natural stone) with timber floors | MUR+STDRE+M099/LWAL/H99/Y99/RES/FW<br>MUR+CL99+M099/LWAL/H99/Y99/RES/FW<br>MUR+CB99+M099/LWAL/H99/Y99/RES/FW | 15 | 15 |
| unit masonry (brick, concrete block or natural stone) with reinforced concrete floors | MUR+STDRE+M099/LWAL/H99/Y99/RES/FC<br>MUR+CL99+M099/LWAL/H99/Y99/RES/FC<br>MUR+CB99+M099/LWAL/H99/Y99/RES/FC | 25 | 27 |
| reinforced or confined masonry | MCF/LWAL/H99/Y99/RES<br>MR/LWAL/H99/Y99/RES | 24 | 34 |
| concrete frame construction (insitu or precast) built before 1981 | C99+CT99/LFM/H99/YPRE:1981/RES<br>C99+CT99/LFINF/H99/YPRE:1981/RES | 7 | 3 |
| concrete frame construction (in situ or precast) built in or after 1981 | C99+CT99/LFM/H99/YBET: 2014,1981/RES<br>C99+CT99/LFINF/H99/YBET: 2014,1981/RES | 4 | 2 |
| concrete wall construction (in situ or precast) built before 1981 | C99+CT99/LWAL/H99/YPRE:1981/RES | 8 | 3 |
| concrete wall construction (in situ or precast) built in or after 1981 | C99+CT99/LWAL/H99/YBET: 2014,1981/RES | 12 | 4 |

### 4.3.3 Bosnia and Herzegovina

#### *4.3.3.1 Data collection and inferences*

Traditionally the buildings in Bosnia and Herzegovina were unreinforced masonry. After WWII, concrete buildings became prominent. The new (post WWII) masonry buildings tended to be built using new construction standards (Mustafa 2010). For this reason, it has been assumed that buildings built post WWII are either concrete or masonry with concrete floors. Masonry buildings built prior to WWII tended to have timber floor constructions (ibid). A typical construction type within Bosnia and the other Balkan countries is medium rise unreinforced masonry constructions with concrete floors (Ademović 2011).

Confined masonry began to be introduced after the Skopje earthquake of 1963 and became the usual type of masonry construction following the introduction of seismic codes in 1981 (ibid.).

In terms of an urban and rural split, rubble stone or adobe structures are located in villages and rural areas and rarely in urban areas (Ademović 2011).

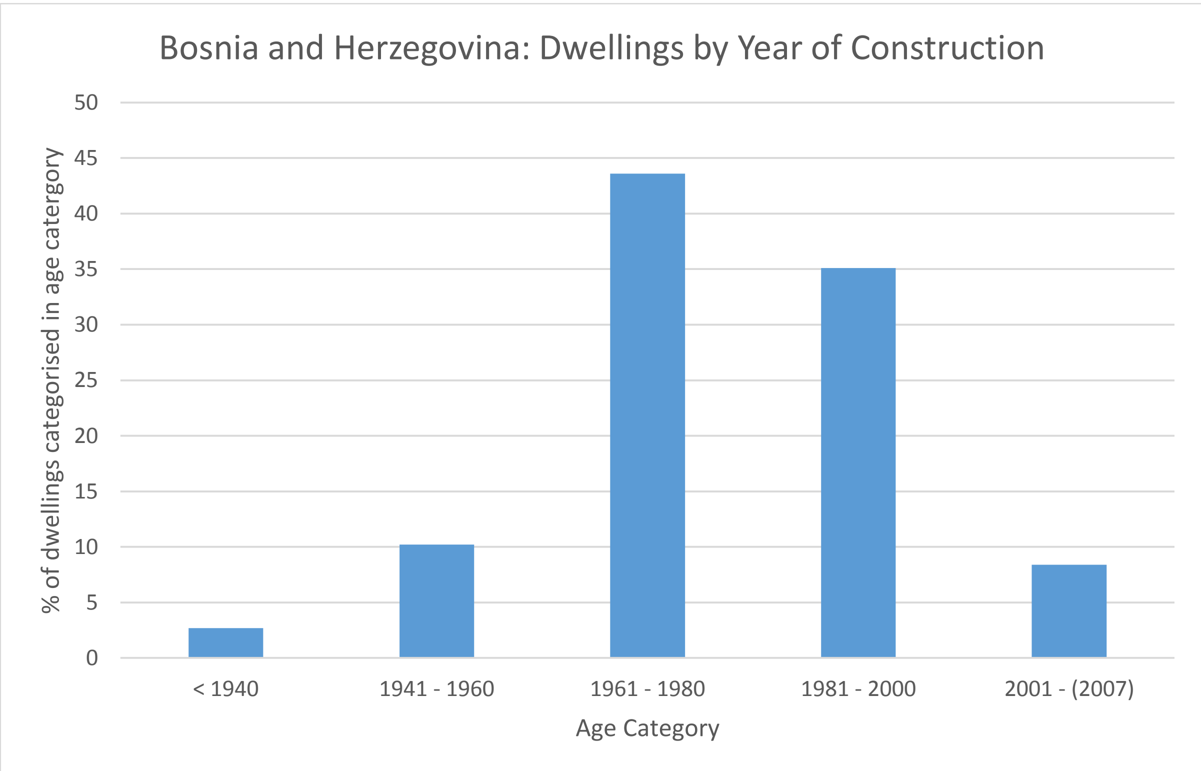



*Figure 32: Bosnia and Herzegovina: Dwellings by Year of Construction. Data Source: Nastić et al (2008 p.7)*

As shown by Figure 32, rapid construction occurred in the 1960s and 80s. In terms of private and social ownership, in 1991, approximately three quarters of the overall housing stock were privately owned and the remainder was socially owned (Figure 33). The socially owned dwellings are often associated as being flats in multi-storey apartment buildings (Ministry for Human Rights and Refugees, 2006).

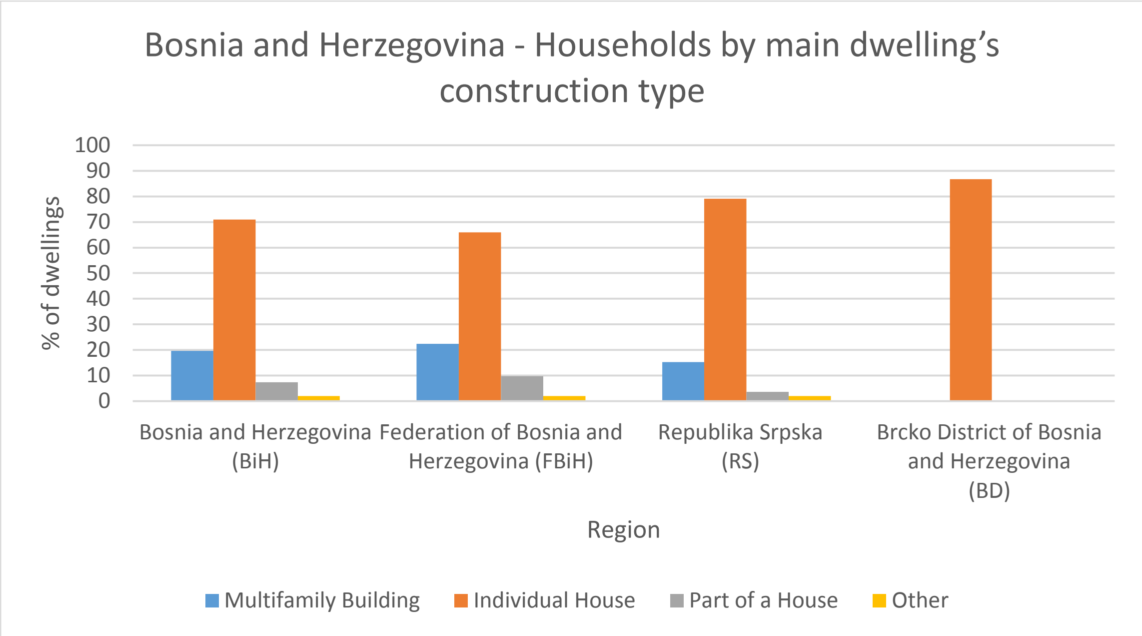



*Figure 33: Bosnia and Herzegovina - Households by main dwelling's construction type. Data Source: Milinović (2011 p.13)*

According to available statistics, approximately 41.5% of dwellings are located in urban areas (Table 18).

*Table 18: Bosnia and Herzegovina – Rural Urban Distribution - 2007*

| **Settlement Type** | **Geographical area** | | | **Bosnia and Herzegovina (BiH)** |
|---|---|---|---|---|
| | **Federation of Bosnia and Herzegovina (FBiH)** | **Republika Srpska (RS)** | **Brcko District of Bosnia and Herzegovina (BD)** | |
| Urban % | 45.3 | 34.5 | 46.8 | 41.5 |
| Rural/Semi Urban % | 54.7 | 65.5 | 53.2 | 58.5 |
| **Total (=100%)** | **657,984** | **374,715** | **21,914** | **1,054,613** |

Source: Agency for Statistics of Bosnia and Herzegovina (2007 p.14)

### *4.3.3.2 Questionnaire*

A questionnaire response regarding the dwelling stock distribution of Bosnia and Herzegovina was received from Dr. Naida Ademović and her colleagues at the Faculty of Engineering in Sarajevo. The results are displayed in Figure 34.

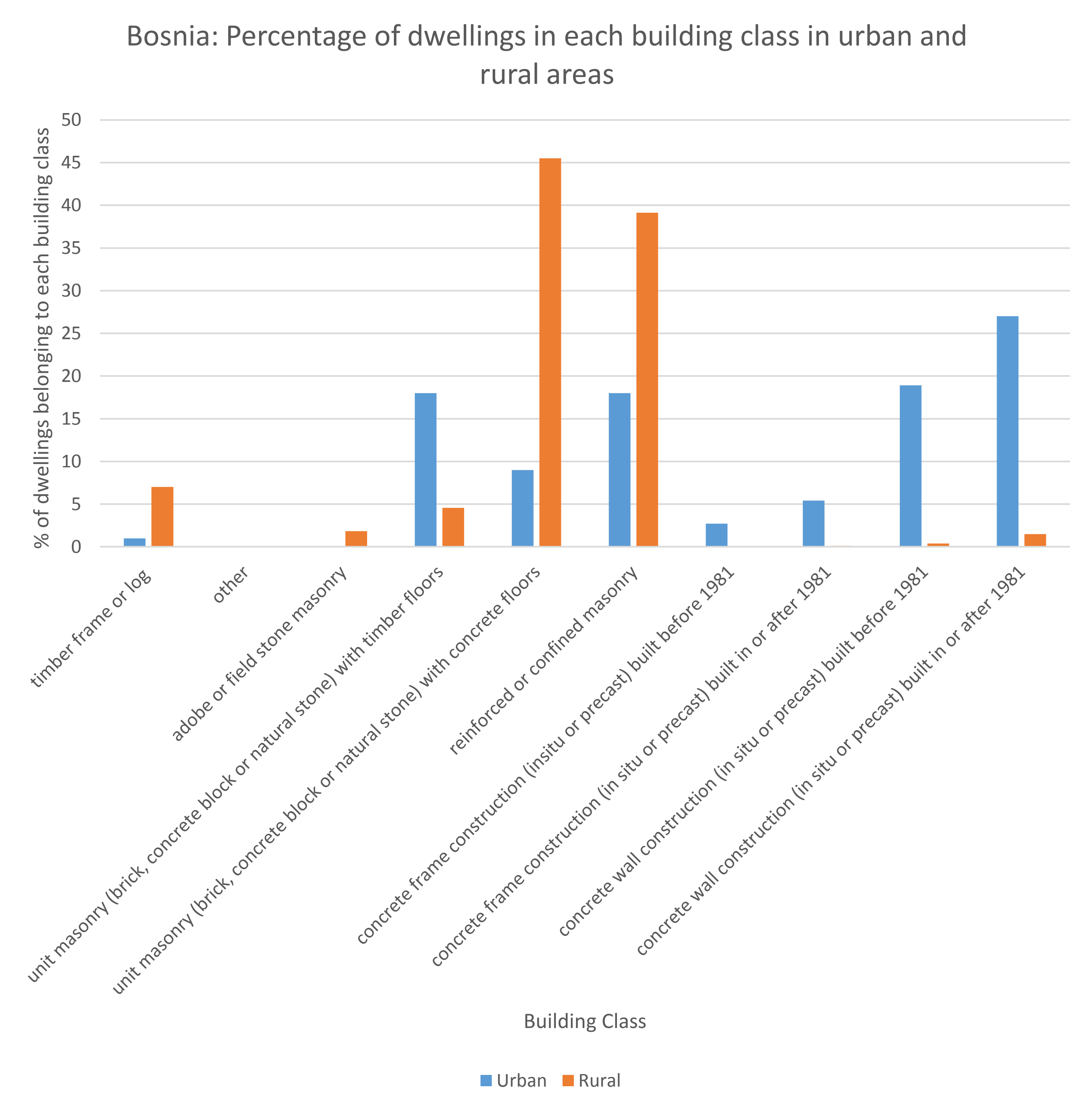



*Figure 34 Bosnia and Herzegovina: Percentage of dwellings in each building class in urban and rural areas. Source: Questionnaire response: Dr. Naida Ademović*

Within Bosnia and Herzegovina, masonry constructions dominate in rural areas and concrete constructions are more common in urban areas. Similar to Croatia, concrete wall construction is more common than concrete frame and there is a high proportion of both unit masonry with concrete floors and reinforced/confined masonry.

#### *4.3.3.3 Comparison of methods and final dwelling fractions*

The interpretation of data collected correlates with the questionnaire response, therefore this will be used as an estimate of the overall dwelling fractions. Results are shown in Table 19.

*Table 19: Bosnia and Herzegovina Dwelling Fractions. Values have been rounded to the nearest whole number.*

| **Structural Typology** | **GEM Taxonomy** | **Percentage of Dwellings in Urban Areas (%)** | **Percentage of Dwellings in Rural Areas (%)** |
|---|---|---|---|
| Total | | 42 | 58 |
| timber frame or log | W+W99/LPB/H99/Y99/RES | 1 | 7 |
| adobe or field stone masonry | MUR+ADO+M099/LWAL/H99/Y99/RES<br>MUR+STRUB+M099/LWAL/H99/Y99/RES | 0 | 2 |
| unit masonry (brick, concrete block or natural stone) with timber floors | MUR+STDRE+M099/LWAL/H99/Y99/RES/FW<br>MUR+CL99+M099/LWAL/H99/Y99/RES/FW<br>MUR+CB99+M099/LWAL/H99/Y99/RES/FW | 18 | 5 |
| unit masonry (brick, concrete block or natural stone) with reinforced concrete floors | MUR+STDRE+M099/LWAL/H99/Y99/RES/FC<br>MUR+CL99+M099/LWAL/H99/Y99/RES/FC<br>MUR+CB99+M099/LWAL/H99/Y99/RES/FC | 9 | 46 |
| reinforced or confined masonry | MCF/LWAL/H99/Y99/RES<br>MR/LWAL/H99/Y99/RES | 18 | 39 |
| concrete frame construction (insitu or precast) built before 1981 | C99+CT99/LFM/H99/YPRE1981/RES<br>C99+CT99/LFINF/H99/YPRE1981/RES | 3 | 0 |
| concrete frame construction (in situ or precast) built in or after 1981 | C99+CT99/LFM/H99/YBET: 2014,1981/RES<br>C99+CT99/LFINF/H99/YBET: 2014,1981/RES | 5 | 0 |
| concrete wall construction (in situ or precast) built before 1981 | C99+CT99/LWAL/H99/YPRE:1981/RES | 19 | 0 |
| concrete wall construction (in situ or precast) built in or after 1981 | C99+CT99/LWAL/H99/YBET: 2014,1981/RES | 27 | 1 |

### 4.3.4 Montenegro

One questionnaire response was received for Montenegro and a field trip took place between 20th August – 24th August 2014 to validate the results and compare data collection methods.

#### 4.3.4.1 Data collection and inferences

A limited age distribution of dwellings is available for Montenegro – see Figure 35, Table 20 and Table 21. These can be broadly assigned a group of different building typologies e.g. in the 1960s-80s there would be a large proportion of concrete construction. However, the data is too limited for CAR to make an accurate interpretation.

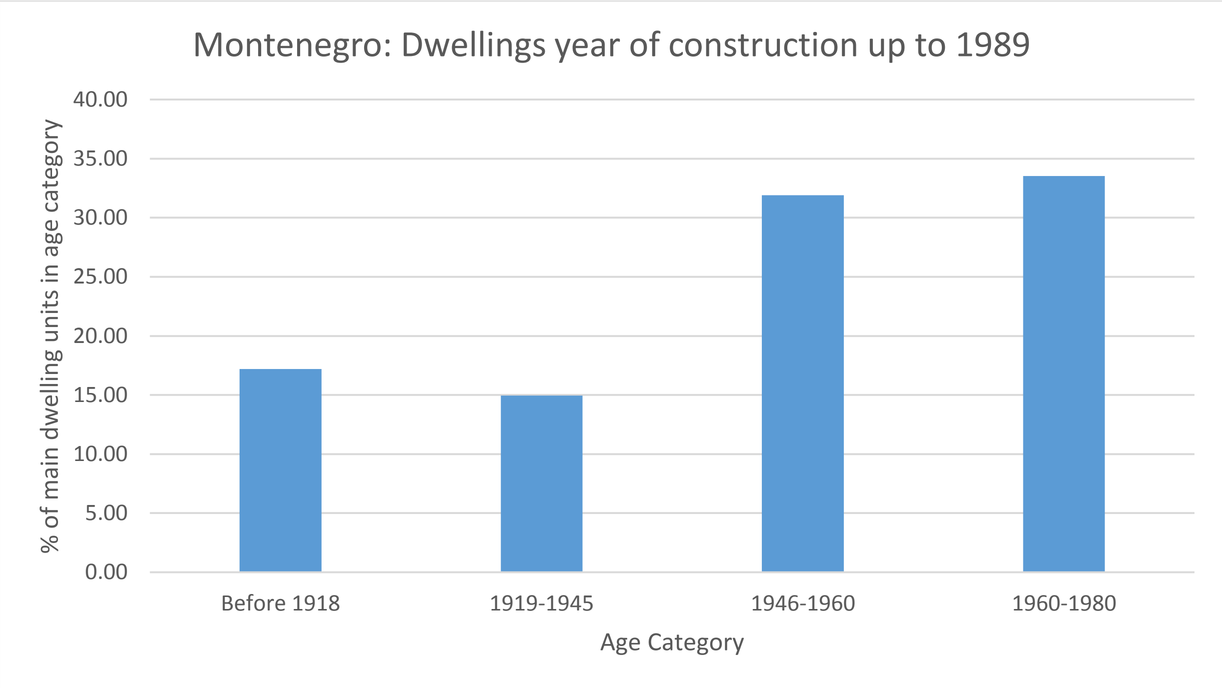



*Figure 35 Montenegro: Dwellings year of construction up to 1989. Data source: Savezui Zavod Za Statistifu (1989)*

*Table 20: Montenegro – Total number of dwellings constructed in different age categories. Source: Savezui Zavod Za Statistifu (1989)*

| Year | Total number of dwellings constructed |
|---|---:|
| Total (1989) | 111,604 |
| Pre 1918 | 19,179 |
| 1919-1945 | 16,684 |
| 1946 - 1960 | 35,604 |
| 1960 - 1980 | 37,423 |

*Table 21: Montenegro - Number of dwellings for permanent living Source: Montenegro Statistical Office (2013)*

| Year | Number of Dwellings | | |
|---|---|---|---|
| | **Total** | **Urban** | **Rural** |
| 1971 | 112000 | 42000 | 70000 |
| 1981 | 131000 | 70000 | 61000 |
| 1991 | 170000 | 99000 | 71000 |
| 2003 | 206000 | 125000 | 81000 |
| 2011 | 247000 | 155000 | 92000 |

The Economic Commission for Europe (2006) state that the majority of the housing stock in Montenegro was constructed in the last forty years and twenty percent has been since 1991. Similar to the other Balkan countries, single family dwellings are predominant – in Podgorica approximately 70% of dwellings are individual units and 30% are located in multi-apartment buildings (ibid.). It can be assumed these will either be in mid-rise unreinforced masonry buildings with concrete floors or buildings constructed from concrete frame or wall.

Figure 14, page 30 suggests that in comparison to Serbia and Bosnia and Herzegovina, a higher proportion of dwellings were constructed from solid materials.

Data is available from the national census for the number of dwellings in urban and rural areas throughout Montenegro, as shown in Figure 36.

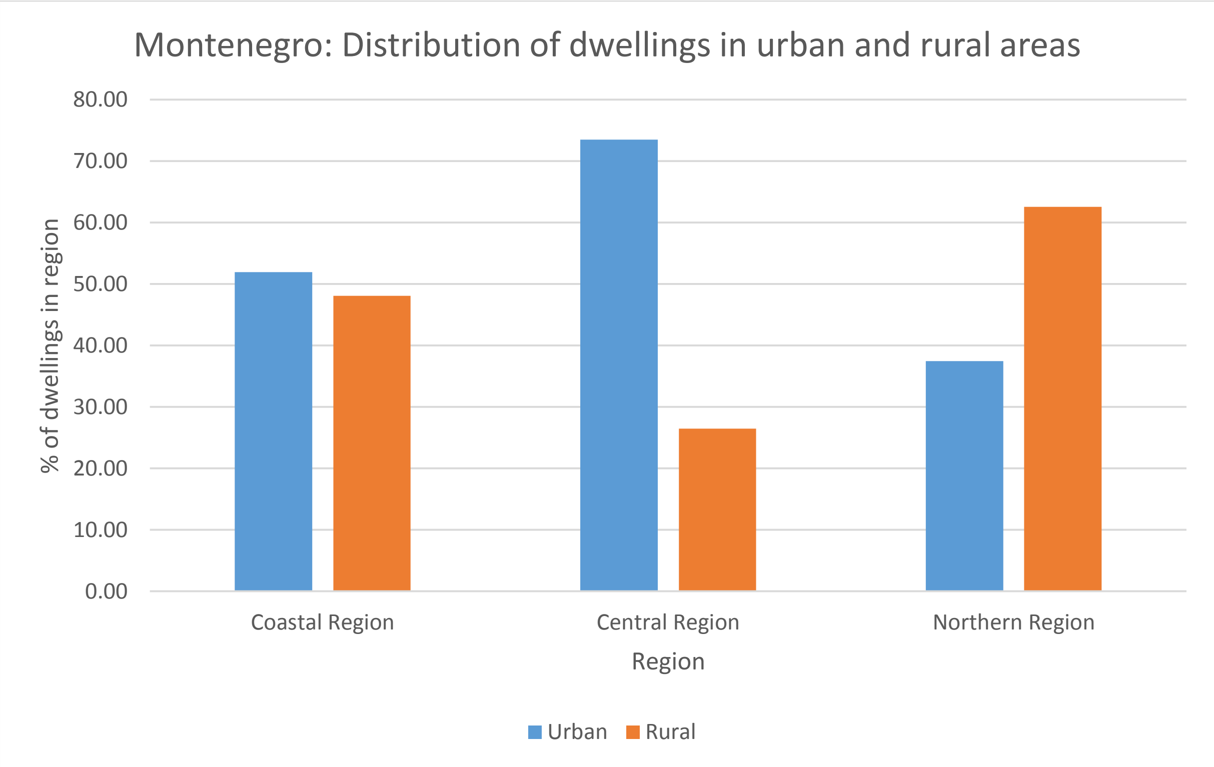



*Figure 36 Montenegro: Distribution of dwellings in urban and rural areas.*

#### *4.3.4.2 Questionnaire*

One questionnaire response was received for Montenegro. The version of the questionnaire answered, was the version circulated before it was simplified. Therefore, within the building classes, building heights are included and an estimation of the average number of dwellings in each building for different building types was provided.

The response was received from Jelena Pejovic at the University of Montenegro. The questionnaire was completed using publications, websites and statistical data. The results are shown in Figure 37 and a summary (using the same building classes as the other Balkan countries) is displayed in Figure 38.

A table displaying the average number of dwellings per building for each building type is displayed in Table 22.

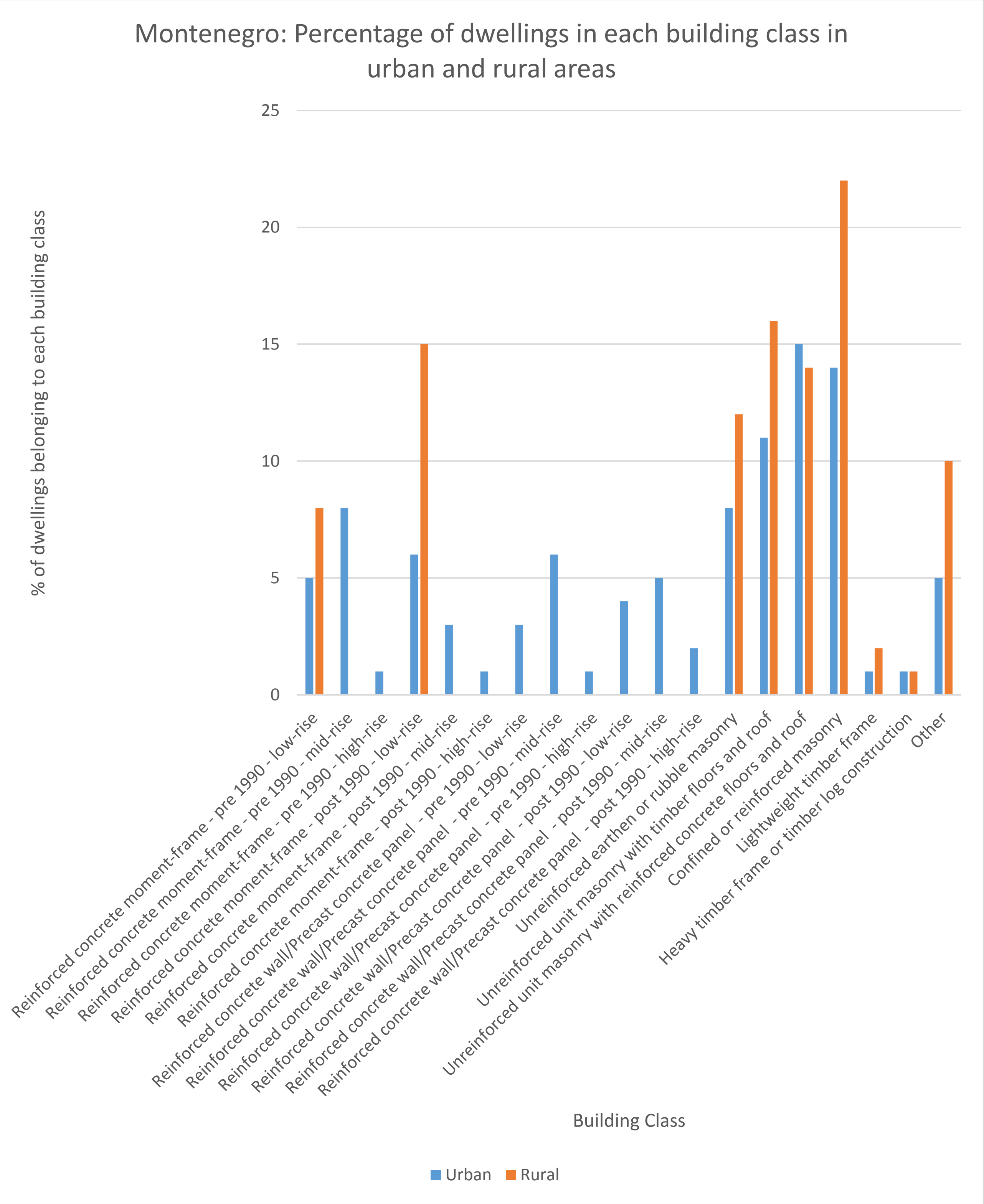



*Figure 37: Montenegro: Percentage of dwellings in each building class in urban and rural areas*

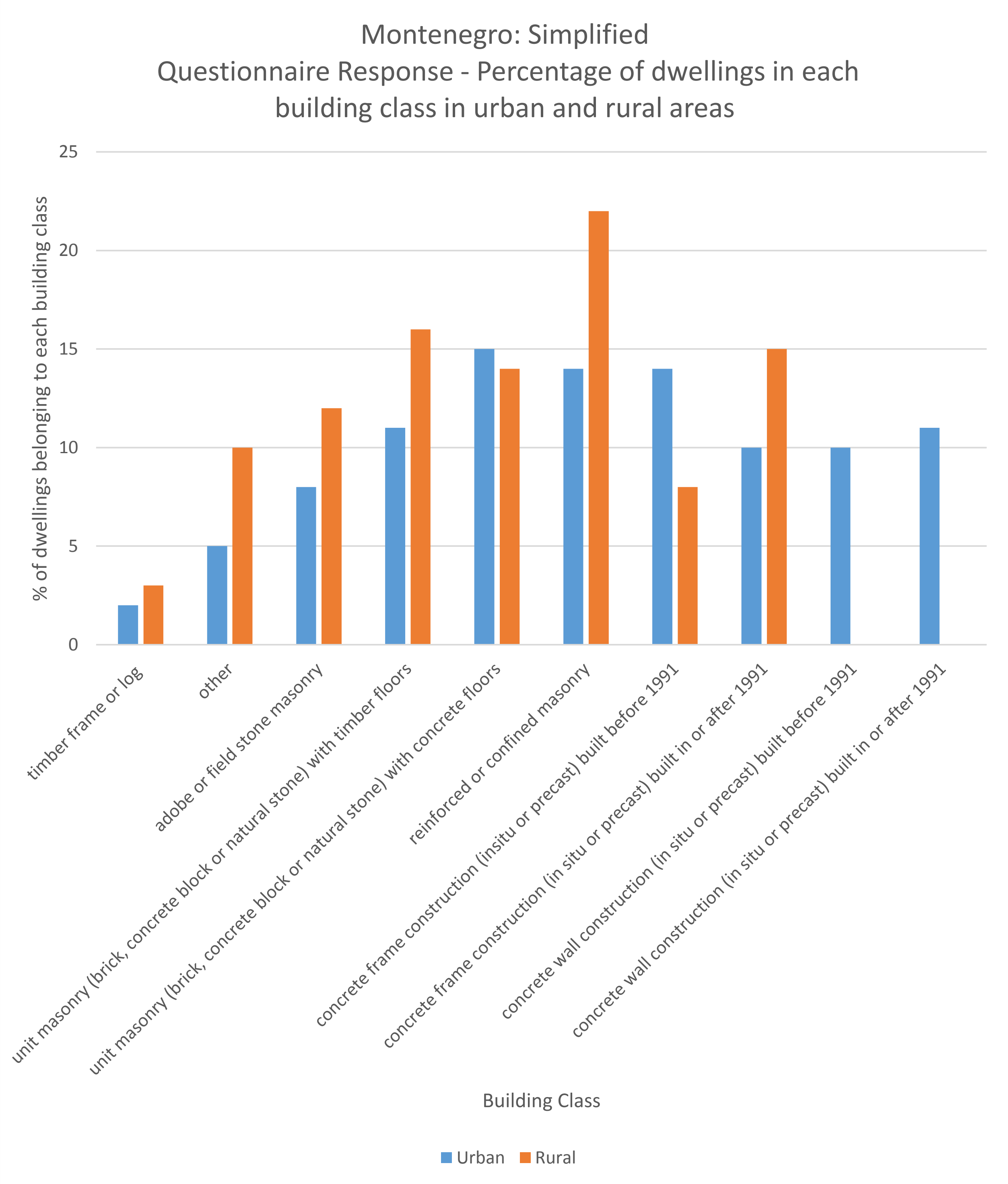



*Figure 38: Montenegro: Simplified Questionnaire Response - Percentage of dwellings in each building class in urban and rural areas*

*Table 22: Montenegro - Average number of dwellings per building in each class - questionnaire response*

| Construction material and construction typology | Age | Height | Estimated average number of dwellings per building in each class |
|---|---|---|---|
| Reinforced concrete moment-frame | pre 1990 | low-rise | 2 |
| | | mid-rise | 45 |
| | | high-rise | 60 |
| | post 1990 | low-rise | 2 |
| | | mid-rise | 60 |
| | | high-rise | 80 |
| Reinforced concrete wall/Precast concrete panel | pre 1990 | low-rise | 2 |
| | | mid-rise | 45 |
| | | high-rise | 60 |
| | post 1990 | low-rise | 2 |
| | | mid-rise | 60 |
| | | high-rise | 80 |
| Unreinforced earthen or rubble masonry | | | 1 |
| Unreinforced unit masonry with timber floors and roof | | | 1 |
| Unreinforced unit masonry with reinforced concrete floors and roof | | | 30 |
| Confined or reinforced masonry | | | 18 |
| Lightweight timber frame | | | 2 |
| Heavy timber frame or timber log construction | | | 6 |
| Other | | | 3 |

#### 4.3.4.3 Field Trip

The overall distribution of dwellings and buildings surveyed during the field trip is shown in Figure 39 and Figure 40. As can be seen by the graphs, there is a significant difference in the results. The distributions shows that there is a large proportion of reinforced concrete dwellings, whereas the distribution of buildings shows a larger proportion of masonry buildings. A possible reason for this may be because the reinforced concrete buildings surveyed contained a large number of dwellings. This is shown in Table 23.

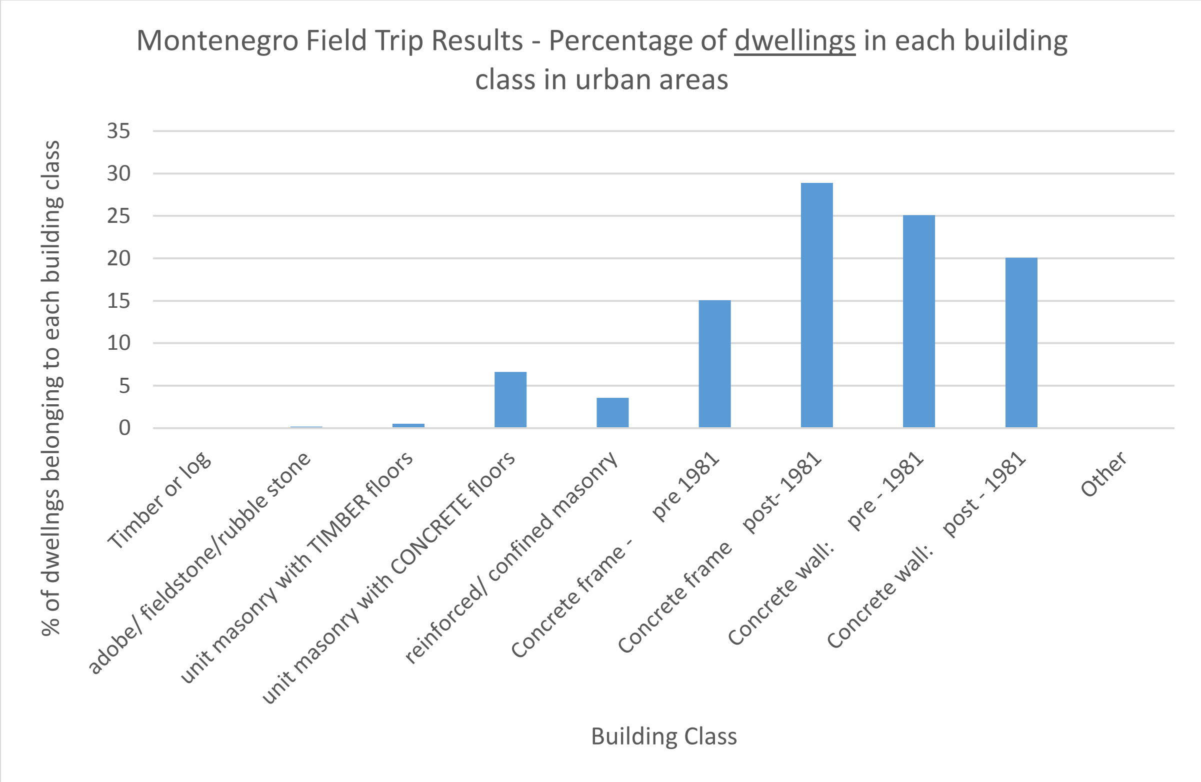



*Figure 39: Montenegro Field Trip Results - Percentage of dwellings in each building class in urban areas*

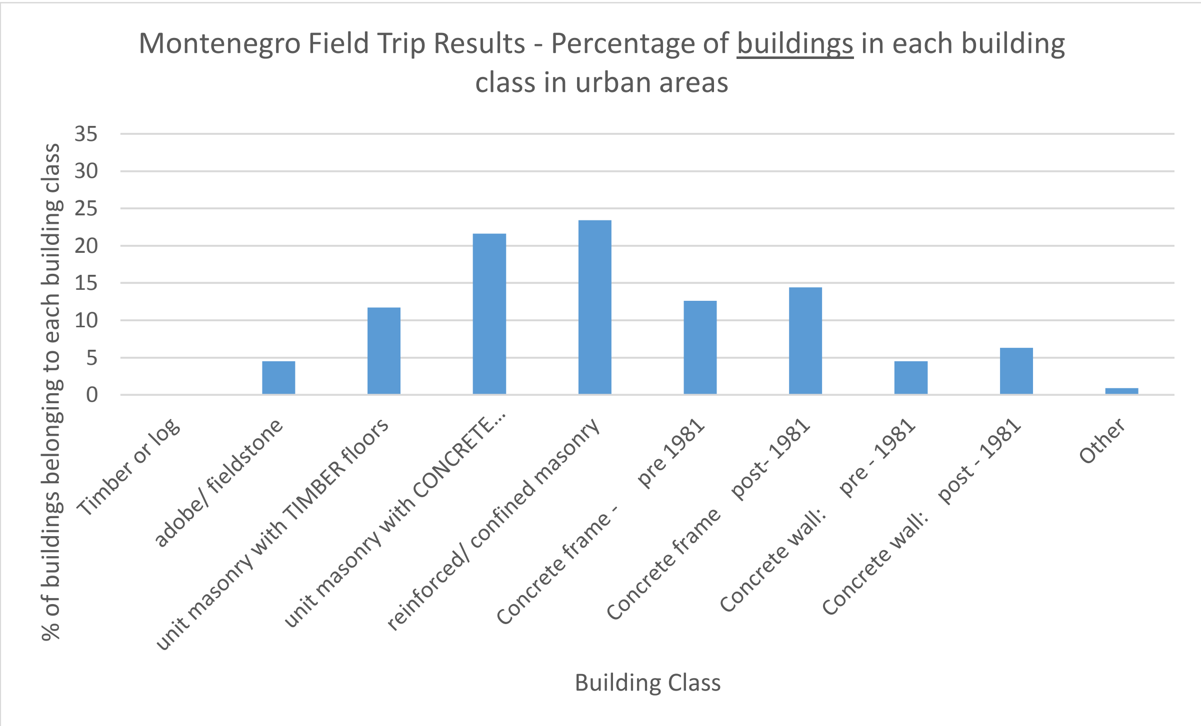



*Figure 40: Montenegro Field Trip Results - Percentage of buildings in each building class in urban areas*

*Table 23: Average number of dwellings in a building for different building classes/structure types*

| | Building Class | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|
| | **Timber or log** | **adobe/ fieldstone** | **unit masonry with TIMBER floors** | **unit masonry with CONCRETE floors** | **reinforced/ confined masonry** | **Concrete frame - pre 1981** | **Concrete frame post- 1981** | **Concrete wall: pre - 1981** | **Concrete wall: post - 1981** | **Other** |
| **Average number of dwellings in a building** | n/a | 1 | 1 | 8 | 4 | 32 | 53 | 147 | 84 | 0 |

Geo-located photographs of all buildings surveyed are available at:
http://eepimap.com/overview/?&zoomtoextent=True&eventid=196

#### 4.3.4.4 Comparison of methods

The data collection for Montenegro has been highly successful bearing in mind the lack of publically accessible data. Initially, the questionnaire response was compared to the data inferences made by using data from Montenegro and Serbia. If no data had been collected or received (in terms of a questionnaire response), CAR planned to infer what the building stock would be like using responses from different Balkan countries. The results found for the Serbian data were used to create an overall distribution for the country and adjusted according to the interpretation of available data. The SEDAC tables (Appendix 2) indicate that 39% of the population in Montenegro live in urban extents and 61% in rural areas. The results for Serbia were used and weighted to calculate the dwelling fractions for Montenegro. The urban distribution was multiplied by 0.39 and the rural by 0.61. The results were added together to form an overall national list of dwelling fractions.

When compared to the national distribution resulting from the questionnaire, the results were fairly similar. See Figure 41. The main difference is that CAR's interpretation predicted there would be more unit masonry with concrete floors. Using the metric of error described in Section 3.5.1, the average error between these two datasets is 3.8%.

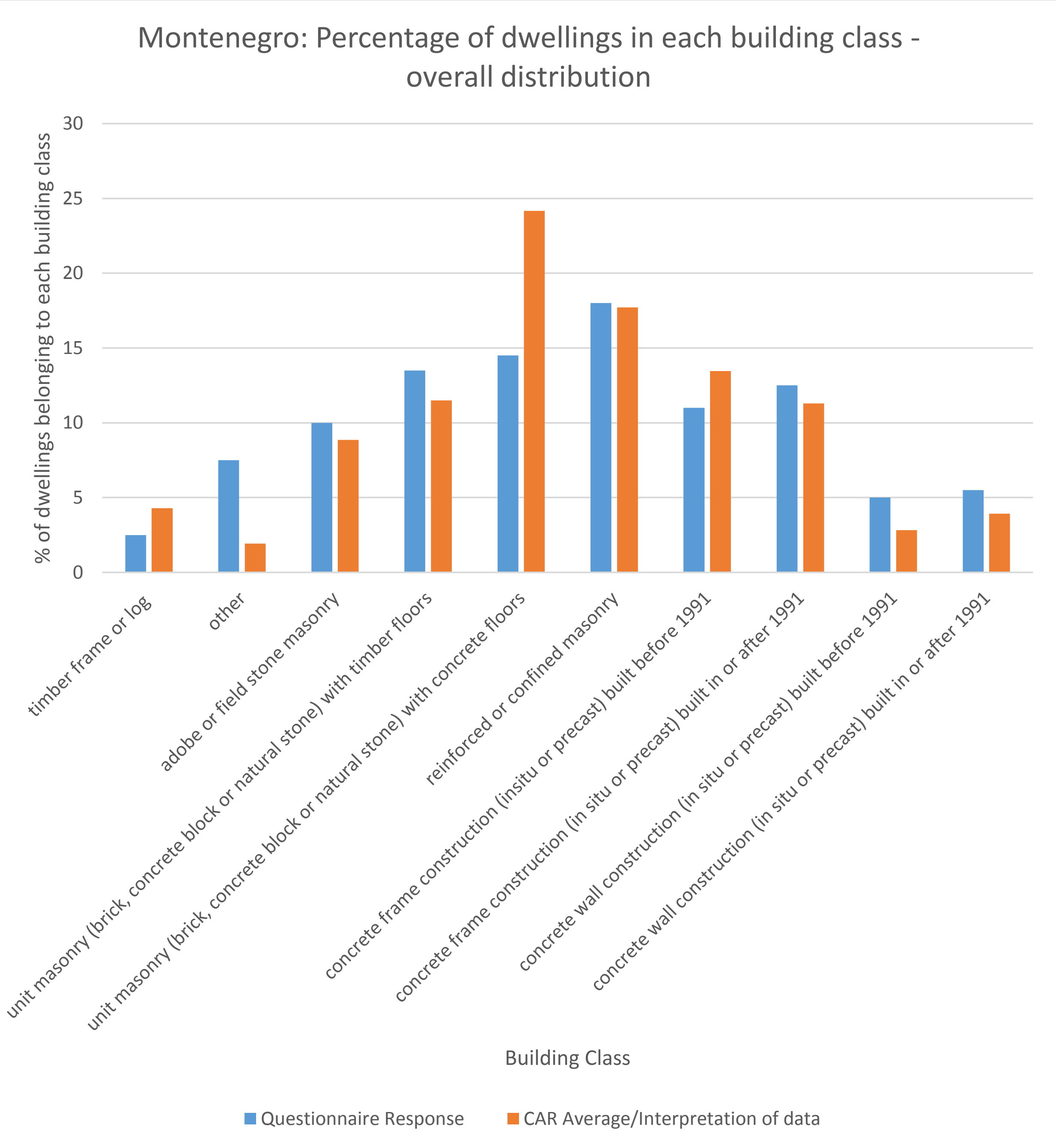



*Figure 41: Montenegro: Percentage of dwellings in each building class - overall distribution: Comparison between questionnaire response and CAR's interpretation of data*

Following the field trip, the survey data collected was compared to the questionnaire response. The aim of the trip was to allow CAR to gain an in-depth understanding of the building stock and to validate the questionnaire results.

Figure 42 compares the results from the questionnaire for simplified building classes (combining the different heights into one group) against the results from the field trip for the distribution of dwellings belonging to different building classes. It is clear, there are large discrepancies between the two datasets. Using the error metric described in Section 3.5.1, the average error for these results is 10.2%.

The reason for this is likely to be due to the small sample size. A high proportion of the concrete buildings surveyed contained a high number of dwellings which would skew results.

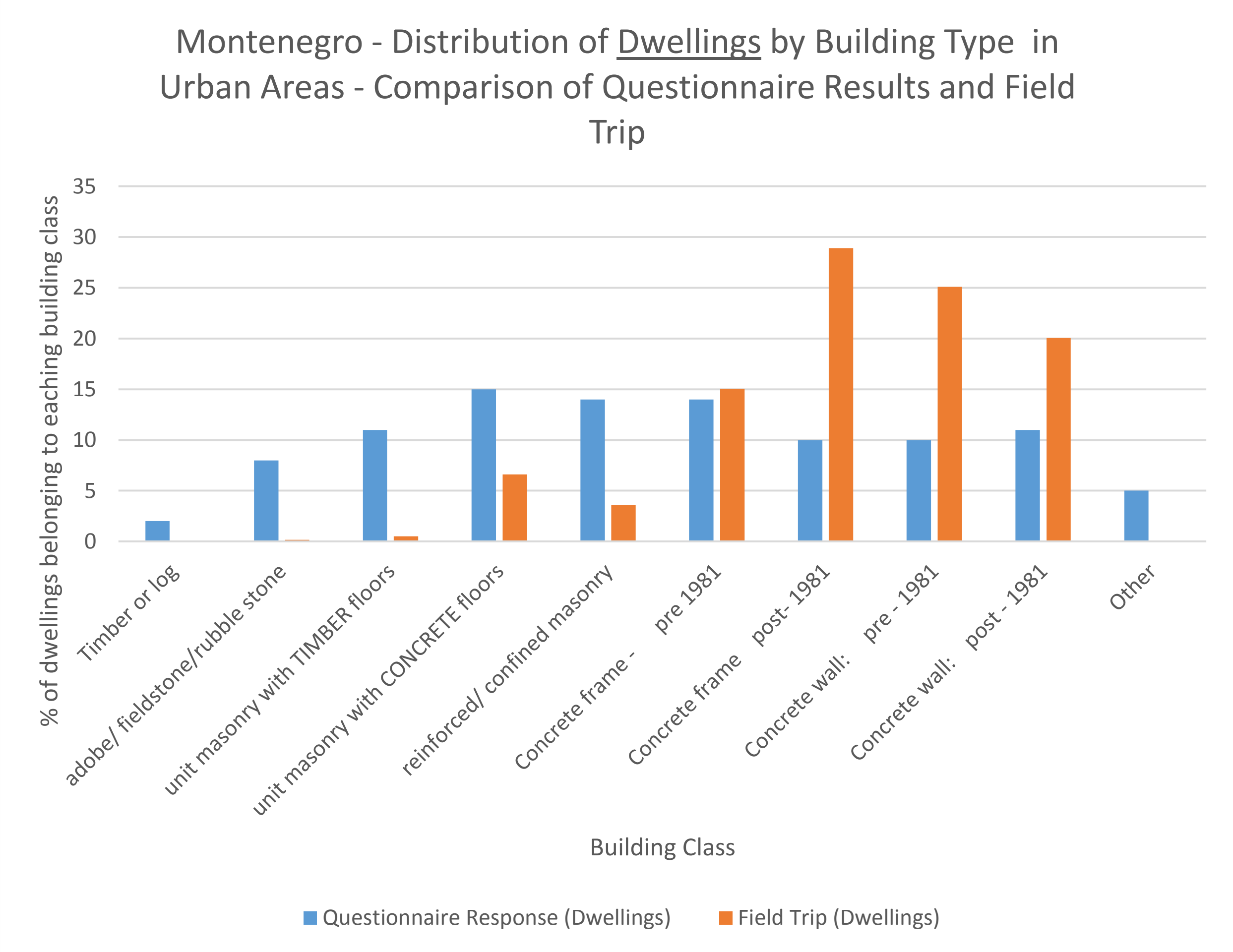



*Figure 42: Montenegro - Distribution of Dwellings by Building Type in Urban Areas - Comparison of Questionnaire Results and Field Trip. *Questionnaire results are post and pre 1990*

Table 24 displays a comparison between the estimated number of dwellings belonging to each building class and those surveyed during the field trip in <u>urban</u> areas. The differences are circled in red. It is clear the concrete wall buildings surveyed contained more dwellings than the countries' average and that the masonry buildings contained less. This helps to explain why the comparison between dwelling distribution contains large differences.

*Table 24: Montenegro: Comparison between the average number of dwellings in a building for different building classes/structure types from the field trip and questionnaire response*

| | Building Class | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|
| | **Timber or log** | **adobe/ fieldstone** | **unit masonry with TIMBER floors** | **unit masonry with CONCRETE floors** | **reinforced/ confined masonry** | **Concrete frame - pre 1981** | **Concrete frame post- 1981** | **Concrete wall: pre - 1981** | **Concrete wall: post - 1981** | **Other** |
| Average number of dwelling per building | n/a | 1 | 1 | 8 | 4 | 32 | 53 | 147 | 84 | 0 |
| Questionnaire Response (Estimated average number of dwellings per building in each class)* | 4 | 1 | 1 | 30 | 18 | 36 | 47 | 36 | 47 | 3 |

Figure 43 compares the distribution of dwellings in the questionnaire to a calculated number of dwellings in the field survey. These have been calculated by multiplying the number of buildings in each building class by the average number of dwellings per building provided by the questionnaire. This reduces the discrepancies however, there is still:

- Significantly fewer timber, adobe/fieldstone/rubble stone and masonry dwellings with timber floors than suggested in the questionnaire response.
- There are more masonry dwellings with concrete floors and post 1981 concrete frame buildings observed in the field survey than suggested by the questionnaire results.

Using the metric of error, the average error is 7.4%. Re-calculating the number of dwellings has reduced the average error, indicating that the original results are affected by buildings containing a large number of dwellings.

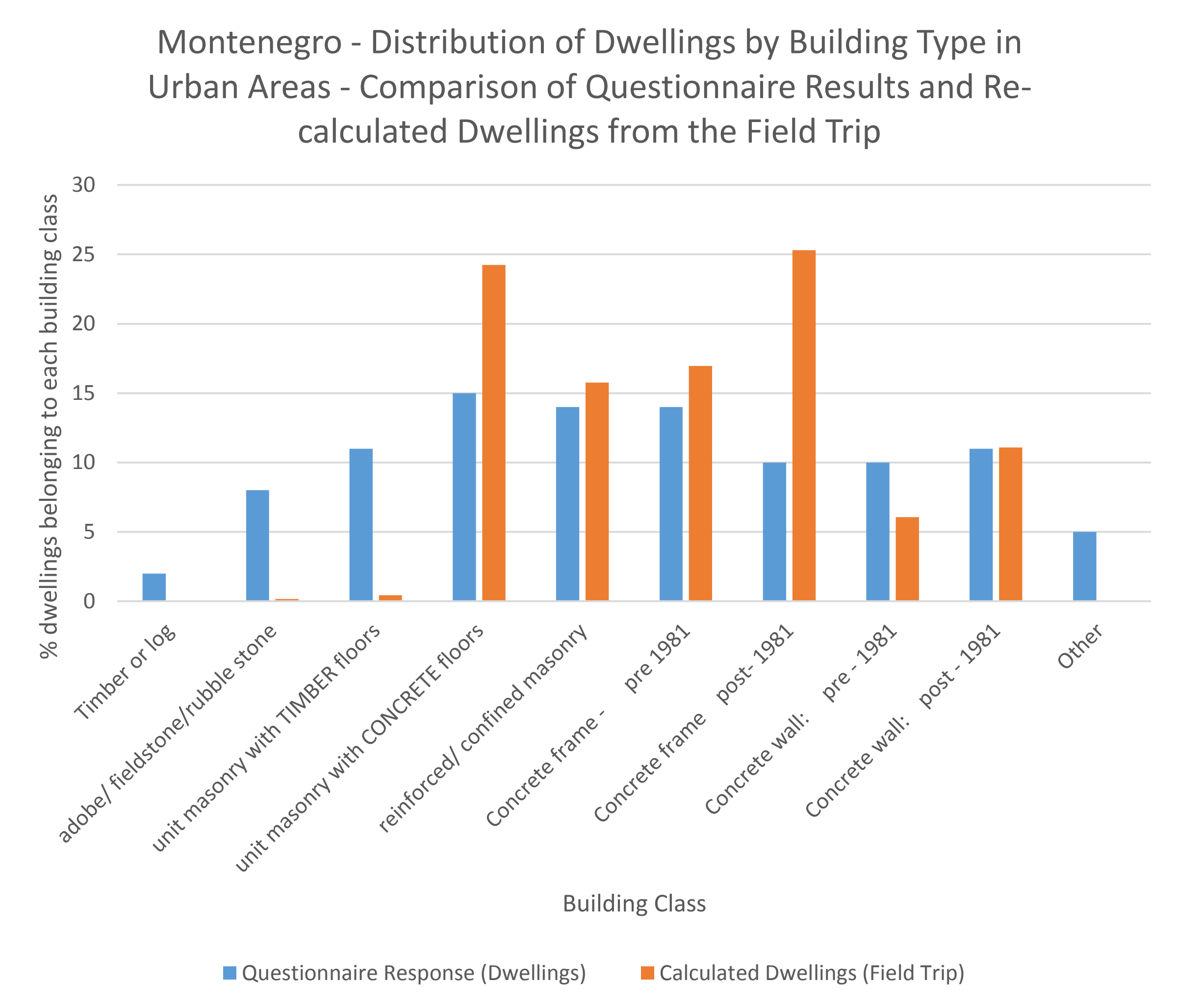



*Figure 43: Montenegro - Distribution of Dwellings by Building Type in Urban Areas - Comparison of Questionnaire Results and Re-calculated Dwellings from the Field Trip. *Questionnaire results are post and pre 1990*

Reasons for the differences in distribution may include:

- Similar to the Street View Survey, areas surveyed were larger urban areas, which may increase the proportion of large multi-family reinforced concrete buildings. The questionnaire response used, defined urban areas as areas with a population over 1000 people. These small towns were not included in the survey and are more likely to contain a higher proportion of masonry constructions.
- There will be some discrepancy as the questionnaire defined dwelling fractions post and pre 1990 (original questionnaire), whereas the survey used 1981 as this was the year used in questionnaire circulated to Balkan countries at a later date.
- The overall sample size was quite small (111 buildings) in comparison to the overall building stock of Montenegro.

As shown in section 4.3.4.2, page 60, the questionnaire response included a distribution of dwellings by building classes in rural areas. Due to logistical issues, an individual building by building survey was unable to take place in these remote areas. However, general overviews were obtained by driving through.

Masonry was the dominant construction type. The type of masonry construction varied from place to place. In some older areas, the buildings were made from rubble stone or unit masonry with timber floors whereas in other areas, which were newer developments, confined masonry was the main construction type. As would be expected, development in rural areas was less dense and there were considerably fewer multi-family concrete buildings. From the general analysis and driving through Montenegro, the questionnaire response seems feasible.

As discussed in section 4.3.2.5, the field survey did not contain enough data points to be able to assign a beta distribution and update the questionnaire data, using a Bayesian approach.

#### *4.3.4.5 Final Dwelling Fractions*

Following the field trip and the comparison of the questionnaire results to CAR's original data sources, and the expertise of the respondent, it is recommended the results obtained from the questionnaire should be used to define Montenegro's dwelling fractions.

*Table 25: Montenegro Dwelling Fractions. Values have been rounded to the nearest whole number.*

| Structural Typology | Building Height | GEM Taxonomy | Percentage of dwellings in urban areas (%) | Percentage of dwellings in rural areas (%) |
|---|---|---|---|---|
| Total Dwelling Stock | | | 39 | 61 |
| timber frame or log | | W+W99/LPB/H99/Y99/RES | 2 | 3 |
| adobe or field stone masonry | | MUR+ADO+M099/LWAL/H99/Y99/RES<br>MUR+STRUB+M099/LWAL/H99/Y99/RES | 8 | 12 |
| unit masonry (brick, concrete block or natural stone) with timber floors | | MUR+STDRE+M099/LWAL/H99/Y99/RES/FW<br>MUR+CL99+M099/LWAL/H99/Y99/RES/FW<br>MUR+CB99+M099/LWAL/H99/Y99/RES/FW | 11 | 16 |
| unit masonry (brick, concrete block or natural stone) with reinforced concrete floors | | MUR+STDRE+M099/LWAL/H99/Y99/RES/FC<br>MUR+CL99+M099/LWAL/H99/Y99/RES/FC<br>MUR+CB99+M099/LWAL/H99/Y99/RES/FC | 15 | 14 |
| reinforced or confined masonry | | MCF/LWAL/H99/Y99/RES<br>MR/LWAL/H99/Y99/RES | 14 | 22 |
| concrete frame construction (insitu or precast) built before 1990 | Low-Rise | C99+CT99/LFM/HBET:3,1/YPRE1990/RES<br>C99+CT99/LFINF/HBET:3,1/YPRE1990/RES | 5 | 8 |
| | Medium-Rise | C99+CT99/LFM/HBET:7,4/YPRE1990/RES<br>C99+CT99/LFINF/HBET:7,4/YPRE1990/RES | 8 | 0 |
| | High-Rise | C99+CT99/LFM/HBET:8+/YPRE1990/RES<br>C99+CT99/LFINF/HBET:8+//YPRE1990/RES | 1 | 0 |

| | | | | |
|---|---|---|---|---|
| concrete frame construction (in situ or precast) built in or after 1990 | Low-Rise | C99+CT99/LFM/ HBET:3,1/YBET: 2014,1990/RES C99+CT99/LFINF/HBET:3,1/YBET: 2014,1990/RES | 6 | 15 |
| | Medium -Rise | C99+CT99/LFM/HBET:7,4/YBET: 2014,1990/RES C99+CT99/LFINF/ HBET:7,4/YBET: 2014,1990/RES | 3 | 0 |
| | High-Rise | C99+CT99/LFM/HBET:8+//YBET: 2014,1990/RES C99+CT99/LFINF/HBET:8+//YBET: 2014,1990/RES | 1 | 0 |
| concrete wall construction (in situ or precast) built before 1990 | Low-Rise | C99+CT99/LWAL/HBET:3,1/YPRE:1990/RES | 3 | 0 |
| | Medium -Rise | C99+CT99/LWAL/HBET:7,4/YPRE:1990/RES | 6 | 0 |
| | High-Rise | C99+CT99/LWAL/ HBET:8+/YPRE:1990/RES | 1 | 0 |
| concrete wall construction (in situ or precast) built in or after 1990 | Low-Rise | C99+CT99/LWAL/HBET:3,1/YBET: 2014,1990/RES | 4 | 0 |
| | Medium -Rise | C99+CT99/LWAL/HBET:7,4/YBET: 2014,1990/RES | 5 | 0 |
| | High-Rise | C99+CT99/LWAL/ HBET:8+/YBET: 2014,1990/RES | 2 | 0 |
| Other | - | MATO/L99/H99/Y99/RES | 5 | 10 |

## 4.4 Future Methodology and Improvements/Critical Analysis of method

Overall, the responses to the questionnaires were highly beneficial to the investigation as the availability and interpretation of data was limited. However, the response rate for questionnaires was only 23%, despite efforts to make the questionnaires more user friendly. The quality of the response is dependent on the expertise and judgement of the respondents. In many cases, approximations have been made. As can be seen by the Serbian and Croatian surveys, results have differed between responses. Using the metric used to calculate average margins of error, the average difference/error between the Serbian questionnaires was 12.0% in urban areas and 12.1% in rural. In Croatia, the difference was 7.5% in urban areas and 10.3% in rural. This emphasises the point that the figures for dwelling fractions are approximations and not exact.

The collection of data and provision of data summaries to potential respondents alongside the addition of drop-down menus and a simpler questionnaire made the questionnaires less time consuming. Unfortunately, a drawback of adding the drop down menus meant that the ranges were quite large in some cases and during data comparisons, could cause some anomalies. On the other hand, the questionnaires were only intended as a best estimate.

The Google Street View analysis, although time consuming (in terms of collecting photographs) was beneficial because over 1600 buildings were surveyed. Once photographs had been obtained, categorisation was quick and there were limited costs associated with the process. Limitations included: not being able to identify some structure types easily e.g. confined masonry; difficulty classifying age and the need for the remote analyst to use their own judgement. Overall, the method was relatively successful as the margin of error with the questionnaire results (average) was only 6.7% for both urban and rural areas. Unfortunately, Street View is not available in all countries and sometimes has limited access.

Field Surveys as a method of analysis are also useful, especially if the team can meet experts in the field of earthquake engineering during the trip. This gives the surveyors accurate context for their analysis, whereas this is difficult using Street View. Field surveys allow buildings to be investigated in more depth, e.g. able to see at different angles and go inside. This is highly beneficial when identifying building classes and the number of dwellings. However, field surveys are more costly than remote surveys and fewer buildings can be surveyed within a given time-frame. In Montenegro, before dwellings were recalculated the average margin of error was 10.2% between the survey results and questionnaire. Once recalculated using building counts and estimations for the number of dwellings within each building class, the error was reduced to 7.4%. This indicates that results can be skewed by a small sample size.

If a field survey was to be the only source of data collection, it is vital that a range of sample areas are surveyed and that a larger number of buildings are surveyed to avoid this skewing of results by dwelling counts.

As shown by section 4.3.2.5, it is possible to use Street View survey data and Field survey data to update questionnaire responses using a Bayesian approach. However, a significant number of dwellings in each building class is needed for this. For this reason, the categories within the Street View survey were grouped together and CAR were unable to assume the beta distribution for the Field Survey results in Montenegro, as not enough buildings were observed.

Although, the field trip conducted was useful for validation purposes, it was not extensive enough to be the only source of data and for adaptation using the Bayesian approach.

# 5. Conclusions

Using a combination of data interpretations, literature reviews, expert opinion questionnaires, Google Street View remote analysis, and a field trip, dwelling fractions have been compiled for the six countries. The results for Iceland, Serbia, Croatia, Montenegro and Bosnia and Herzegovina have been highly influenced by the expert responses to questionnaires. Switzerland's dwelling fractions have used a previous study.

Overall the best method to collect data regarding a countries dwelling fractions is expert questionnaires and this can be validated or updated (Bayesian approach) through field trips, remote surveying and through data analysis and inferences.

# 6. References

Ademović Naida (2011) Structural and Seismic Behaviour of Typical Masonry buildings from Bosnia and Herzegovina, Erasmus Mundus, University of Minho

Ademovic, N.; Hrasnica, M.; Oliveira, D.; 2013; Pushover analysis and failure pattern of a typical masonry residential building in Bosnia and Herzegovina, Engineering Structures 50 p. 13-19

Agency for Statistics of Bosnia and Herzegovina, 2007, The BiH Household Budget Survey 2007, Agency for Statistics of Bosnia and Herzegovina, Sarajevo, 103 pp.

Ang, A. H-S, and Tang, W. H., 1975. *Probability Concepts in Engineering Planning and Design*,Vol 1 , John Wiley & Sons, Hoboken, NJ, pp. 420.

Baker, H., Foulser-Piggott, R., Spence, R. Montenegro Field Trip: 20th – 24th August 2014, Cambridge Architectural Research Ltd. [Unpublished]

Baker, H. Foulser-Piggott, R. 2013, NERA: Land Use and Population Analysis, Cambridge Architectural Research Ltd. [Unpublished]

Bessason, B. Sólnes, J. Bjarnason, J. Guðmundsson, A. Steedman, S. 2012. Comprehensive damage analysis of buildings affected by the 2008 South Iceland earthquake, 15 WCEE Lisboa 2012

Booth, E, Saito, K, Spence R, Madabhushi, G, Eguchi, R 2011. Validating Assessments of Seismic Damage Made from Remote Sensing, *Earthquake Spectra*, Volume 27, No. S1, pages S157–S177

Croatian Bureau of Statistics. 2011. Occupied dwellings by period of construction, type of building and number of households in dwelling, 2011 census, Croatian Bureau of Statistics, Republic of Croatia. http://www.dzs.hr/default_e.htm. [Accessed 26/02/2014]

Cukovic-Ignjatovic, N.; Idnjatovic, D. (u.d) Façade Refurbishment – Improving the energy Performance of the Existing Building Stock in Belgrade, Faculty of Architecture – University of Belgrade, Serbia and Montenegro.

DZS. 1993, Statistical Yearbook of the Republic of Croatia. 1992. DZS, Zagreb

DZS. 1996, Statistical Yearbook of the Republic of Croatia, 1996. DZS, Zagreb

DZS. 2005, Census 2001. DZS, Zagreb

Economic Commission for Europe, 2006, Country profiles on the housing sector – Serbia and Montenegro. United Nations, New York. 103 pp.

Erbach, J.; Zlatic, M. 1996. Croatia Housing Sector Assessment, United States Agency for International Development (USAID)

Federal Ministry for Economic Cooperation and Development (FMECD), 2006, architectural atlas of Montenegro

Hagtíðindi Verðlag og neysla Statistical Series (2011) Household expenditure survey 2008–2010, Hagstofa Íslands Statistics Iceland

Hrasnica, M.; Medic, S. 2012, Seismic Strengthening of historic stone masonry structures in Bosnia Herzegovina, 15 WCEE Lisboa 2012

Gomez, I. 2014, Balkan Building Typologies, 06/03/2014 [email correspondence]

Institut Wohnen und Unwelt Gmbh (2014) RS Serbia – Country Page. http://episcope.eu/building-typology/country/rs/ Last Accessed [05/06/2014]

Jaiswal, K., Wald, D., and D'Ayala, D., 2011. Developing empirical collapse functions for global building types, *Earthquake Spectra,* Vol 27, 3 pp 775 -795

Jurukovski, D.; Gavrilovic, P. (1994) (Former) Yugoslavia; International handbook of earthquake engineering M.Paz (ed.); p. 528 -535, Springer

Korjenic, A.; Klarić S. 2011. The revival of the traditional Bosnian wood dwellings; Energy Efficienty 4 pp.547-558

Ladinski, V. 2014, NERA Building Typologies, 10/02/2014 [email correspondence]

Milinović, Z. 2011. Bosnia and Herzegovina in figures 2011, Agency for Statistics of Bosnia and Herzegovina, Sarajevo, 48 pp.

Ministry for Human Rights and Refugees (2006) Housing and urban profile of Bosnia and Herzegovina – An outline of Devastations, Recovery and Development Perspectives. Department for housing and analytical planning.

Montenegro Statistical Office, 2013, STATISTIČKI GODIŠNJAK 2013 STATISTICAL YEARBOOK, Studio MOUSE, Podgorica [http://www.monstat.org/userfiles/file/publikacije/godisnjak%202013/GOD.%202013%20-FINAL,%20ZA%20SAJT-9.%20decembar2%20-sa%20linkovima.pdf]

Mustafa, H.; Muhamed, Z.; Slako, K.; Mustafa, H.; Muhamed, M. (2010) Seismic strengthening and repair of typical stone masonry historical buildings in Bosnia and Herzegovina; 8th International Masonry Conference, Dresden.

Nastić, V. Rebić, V. 2008, Bosnia and Herzegovina in figures 2008, Agency for Statistics of Bosnia and Herzegovina, Sarajevo, 23pp.

Pecar, M. 1999 Bosnian Dwelling Tradition: Continuity and Transformation in the Reconstruction of Sarajevo, Volume XI, number 1, TDSR

Popović, M.J, 2014, Residential Building Typology Distribution in Serbia, 11/04/2014 [email correspondence]

Popović, M.J. Ignjatović, D. Radivojević, A. Rajčić, A. Đukanovic, L. Ignjatović N.C., Nedić, M. 2013. National Typology of Residential Buildings in Serbia, Faculty of Architecture – University of Belgrade.

Savezui Zavod Za Statistifu (1989) Jugdslavia 1918-1988 Statistički Godišujak in Serbo-Croat, Savezni Zavod Za Statistiku, Beograd

Serbia and Montenegro Statistical Office. 2002. Census 2002:3-1. СТАНОВИ ЗА СТАЛНО СТАНОВАЊЕ ПО ГОДИНИ ИЗГРАДЊЕ, НАСТАЊЕНОСТИ И СВОЈИНИ ПРЕМА ОПРЕМЉЕНОСТИ ИНСТАЛАЦИЈАМА ПО ВРСТИ ПРИКЉУЧАКА И ВРСТИ МАТЕРИЈАЛА 3-1. APARTMENTS FOR

PERMANENT RESIDENCE BY YEAR OF CONSTRUCTION, AND OWNED BY Occupancy installations within BY TYPE AND TYPE OF MATERIAL CONNECTION. Republic of Serbia Statistical Office, Serbia

Spence, R., So, E., Jenny, S., Castella, H., Ewald, M., and Booth, E., 2008. The global earthquake vulnerability estimations system: An approach for earthquake risk assessment for in-surance applications, *Bulletin of Earthquake Engineering* 6, 463–483.

Spence, R. Pomonis, A. Leone, L. 2006. GEVES Switzerland Module (Version 2) – A Report for Willis Ltd., Cambridge Architectural Research Ltd.

Spevec, D.; Bogadi, S. 2009. Croatian Cities under transformation: New tendencies in Housing and Segregation, Tijdschrift voor Economische en Sociale Geografie – 2009, Vol 100(4) pp. 454-468

Spevec, D.; Bogadi, S. 2009. Croatian Cities under transformation: New tendencies in Housing and Segregation, Tijdschrift voor Economische en Sociale Geografie – 2009, Vol 100(4) pp. 454-468

Statistical office of Montenegro-MONSTAT. 2011. Census 2011. MONSTAT. Podgorica

Statistical office of Montenegro-MONSTAT. 2013. Chapter 13: Statistical Yearbook of Montenegro 2013. MONSTAT. Podgorica p.122 - 131

STAT-TAB, 2014, Gebäudestruktur: Gebäude bei Kanton, Gebäudekategorie, Anzahl, http://www.bfs.admin.ch/bfs/portal/en/index/infothek/onlinedb/stattab.html

SZS, 1959, Statistical Yearbook of Yugoslavia 1959. SZS, Beograd

United Nations Economic Commission for Europe (UNECE), 2012, National Action Plan of Montenegro for energy efficient measures in the residential sector, UNECE.

United Nations, 2005, Table 6 – Demographic Yearbook, https://unstats.un.org/unsd/demographic/products/dyb/dyb2005/notestab06.pdf

Wenk, T. 2013, NERA Swiss Building Stock, 15/04/2014 [email correspondence]

# Appendix 1: Rural and Urban Land Areas

Analytical results of percentage of rural and urban land areas and percentage of population for the different datasets: CORINE, GRUMP, SEDAC and the UN (Baker et al. 2013).

| | Bosnia | Croatia | Iceland | Montenegro | Serbia | Switzerland |
|---|---|---|---|---|---|---|
| Land Use | | | | | | |
| Land Area in $Km^2$ | 51187.0 | 55974.0 | 100250.0 | 13452.0 | 88246.0 | 39997.0 |
| | | | | | | |
| % Rural Land (CORINE) | **96.31** | **96.85** | **99.60** | **98.88** | **96.73** | **n/a** |
| % Urban Land (CORINE) | **3.69** | **3.15** | **0.40** | **1.12** | **3.27** | **n/a** |
| | | | | | | |
| Rural Area (CORINE) $Km^2$ | 49298 | 54214 | 99844 | 13301 | 85363 | **n/a** |
| Urban Area (CORINE) $Km^2$ | 1889 | 1760 | 406 | 151 | 2883 | **n/a** |
| | | | | | | |
| % Rural Land (GRUMP) | **96.66** | **90.51** | **98.88** | **92.71** | **91.65** | **79.35** |
| % Urban Land (GRUMP) | **3.34** | **9.49** | **1.12** | **7.29** | **8.35** | **20.65** |
| | | | | | | |
| Rural Area (GRUMP) $Km^2$ | 49476 | 50664 | 99124 | 12472 | 80878 | 70027 |
| Urban Area (GRUMP) $Km^2$ | 1711 | 5310 | 1127 | 980 | 7368 | 18221 |
| | | | | | | |
| % Rural Land (SEDAC tables) | **97.0** | **91.0** | **99.0** | **92.0** | **92.0** | **79.0** |
| % Urban Land (SEDAC tables) | **3.0** | **9.0** | **1.0** | **8.0** | **8.0** | **21.0** |
| | | | | | | |
| Population | | | | | | |
| % Rural Population (CORINE) | **96.51** | **84.30** | **86.75** | **93.49** | **91.11** | **n/a** |
| % Urban Population (CORINE) | **3.49** | **15.70** | **13.25** | **6.51** | **8.89** | **n/a** |
| | | | | | | |
| % Rural Population (GRUMP) | **96.48** | **47.00** | **56.90** | **55.74** | **63.61** | **28.03** |
| % Urban Population (GRUMP) | **3.52** | **53.00** | **43.10** | **44.26** | **36.39** | **71.97** |
| | | | | | | |
| % Rural Population (SEDAC tables) | **70.0** | **45.0** | **31.0** | **61.0** | **61.0** | **28.0** |
| % Urban Population (SEDAC tables) | **30.0** | **55.0** | **69.0** | **39.0** | **39.0** | **72.0** |
| | | | | | | |

| | | | | | | |
|---|---|---|---|---|---|---|
| % Rural Population (UN) | 51.2 | 41.9 | 6.2 | 36.5 | 43.3 | 26.2 |
| % Urban Population (UN) | 48.8 | 58.1 | 93.8 | 63.5 | 56.7 | 73.8 |
| | | | | | | |
| Population Density | | | | | | |
| | | | | | | |
| Rural Population Density (CORINE) Population/km$^2$ | 69.16 | 71.34 | 2.29 | 46.33 | 106.07 | n/a |
| Urban Population Density (CORINE) Population/km$^2$ | 233.86 | 438.97 | 145.36 | 266.99 | 310.42 | n/a |
| | | | | | | |
| Calculated Rural Population (CORINE) | 3409353 | 3867361 | 228892 | 616304 | 9054435 | n/a |
| Calculated Urban Population (CORINE) | 441777 | 772793 | 58961 | 40285 | 894843 | n/a |
| **% Population Rural** | **88.53** | **83.35** | **79.52** | **93.86** | **91.01** | **n/a** |
| **% Population Urban** | **11.47** | **16.65** | **20.48** | **6.14** | **8.99** | **n/a** |
| | | | | | | |
| Rural Population Density (GRUMP) Population/km$^2$ | 56.78 | 42.37 | 0.89 | 29.45 | 77.95 | 66.47 |
| Urban Population Density (GRUMP) Population/km$^2$ | 603.55 | 465.29 | 177.12 | 296.61 | 504.01 | 655.03 |
| | | | | | | |
| Calculated Rural Population (GRUMP) | 2809284 | 2146450 | 87920 | 367231 | 6304153 | 4654868 |
| Calculated Urban Population (GRUMP) | 1032502 | 2470782 | 199574 | 290807 | 3713287 | 11935167 |
| **% Population Rural** | **73.12** | **46.49** | **30.58** | **55.81** | **62.93** | **28.06** |
| **% Population Urban** | **26.88** | **53.51** | **69.42** | **44.19** | **37.07** | **71.94** |

# Appendix 2: SEDAC Tables

Preliminary Results: Breakdown of rural and urban land use in all countries within the NERA database using the SEDAC tables (Baker et al. 2013).

| Country | % Land area in urban extents ($km^2$) | % Land area in rural areas ($km^2$) | % Total Population in Urban Extents (2000, estimate) | % Total Population in Rural areas (2000 estimate) |
|---|---|---|---|---|
| **Albania** | 6 | 94 | 43 | 57 |
| **Andorra** | 70 | 30 | 97 | 3 |
| **Austria** | 13 | 87 | 65 | 35 |
| **Belarus** | 4 | 96 | 58 | 42 |
| **Belgium** | 41 | 59 | 83 | 17 |
| **Bosnia** | 3 | 97 | 30 | 70 |
| **Bulgaria** | 6 | 94 | 51 | 49 |
| **Croatia** | 9 | 91 | 55 | 45 |
| **Cyprus** | 25 | 75 | 78 | 22 |
| **Czech Republic** | 16 | 84 | 64 | 36 |
| **Denmark** | 22 | 78 | 67 | 33 |
| **Estonia** | 6 | 94 | 70 | 30 |
| **Finland** | 6 | 94 | 62 | 38 |
| **France** | 16 | 84 | 71 | 29 |
| **Germany** | 18 | 82 | 70 | 30 |
| **Greece** | 14 | 86 | 75 | 25 |
| **Greenland** | 0 | 100 | 24 | 76 |
| **Hungary** | 10 | 90 | 45 | 55 |
| **Iceland** | 1 | 99 | 69 | 31 |
| **Ireland** | 8 | 92 | 60 | 40 |
| **Italy** | 25 | 75 | 75 | 25 |
| **Kosovo** | n/a | n/a | n/a | n/a |
| **Latvia** | 5 | 95 | 73 | 27 |
| **Liechtenstein** | 66 | 34 | 94 | 6 |
| **Lithuania** | 7 | 93 | 61 | 39 |
| **Luxembourg** | 31 | 69 | 77 | 23 |
| **Macedonia** | 11 | 89 | 73 | 27 |
| **Malta** | 92 | 8 | 94 | 6 |
| **Moldova** | 8 | 92 | 56 | 44 |
| **Monaco** | 75 | 25 | 68 | 32 |
| **Montenegro** | 8 | 92 | 39 | 61 |
| **Norway** | 6 | 94 | 67 | 33 |
| **Poland** | 10 | 90 | 53 | 47 |
| **Portugal** | 14 | 86 | 69 | 31 |
| **Romania** | 7 | 93 | 58 | 42 |
| **Serbia** | 8 | 92 | 39 | 61 |

| Country | % Land area in urban extents (km$^2$) | % Land area in rural areas (km$^2$) | % Total Population in Urban Extents (2000, estimate) | % Total Population in Rural areas (2000 estimate) |
|---|---|---|---|---|
| **Slovakia** | 13 | 87 | 47 | 53 |
| **Slovenia** | 12 | 88 | 56 | 44 |
| **Spain** | 14 | 86 | 71 | 29 |
| **Sweden** | 7 | 93 | 64 | 36 |
| **Switzerland** | 21 | 79 | 72 | 28 |
| **The Netherlands** | 37 | 63 | 80 | 20 |
| **Turkey** | 6 | 94 | 60 | 40 |
| **Ukraine** | 5 | 95 | 54 | 46 |
| **United Kingdom** | 24 | 76 | 85 | 15 |

# Appendix 3: Questionnaire templates

Questionnaire Templates and Structure Type Definitions: Iceland, Switzerland and Balkan Countries

**Iceland and Montenegro (Original version circulated to Balkan Countries)**

EU-NERA PROJECT: EXPERT-OPINION SURVEY OF COUNTRY BUILDING TYPOLOGY

This form is divided into 3 parts:

**Part I:** **Contributors' Information**
**Part II:** **Summary of Building typologies**
**Part III:** **Additional Sources of Information Used and Comments**

**PART I: Contributors' Information**

1. Country or Region (if you are only responding for part of a country, please indicate which geographic region.

2. Name(s) of Contributors

3. Affiliation (Organization)

5. E-mail

6. Your self-rating of expertise or confidence: On a scale of 1=low and 5=high, please estimate your level of expertise:

**Part II: Summary of Construction Types**

| **Construction Material and construction typology** | **Age** | **Height** | % of dwellings in urban areas belonging to each class | % of dwellings in rural areas belonging to each class | Estimated average number of dwellings per building in each class |
|---|---|---|---|---|---|
| Reinforced concrete moment-frame | pre 1990 | low-rise | | | |
| | | mid-rise | | | |
| | | high-rise | | | |
| | post 1990 | low-rise | | | |
| | | mid-rise | | | |
| | | high-rise | | | |
| Precast concrete moment frame | pre 1990 | low-rise | | | |
| | | mid-rise | | | |
| | | high-rise | | | |
| | post 1990 | low-rise | | | |
| | | mid-rise | | | |
| | | high-rise | | | |
| Reinforced concrete wall/Precast concrete panel | pre 1990 | low-rise | | | |
| | | mid-rise | | | |
| | | high-rise | | | |
| | post 1990 | low-rise | | | |
| | | mid-rise | | | |
| | | high-rise | | | |
| Unreinforced earthen or rubble masonry | | | | | |
| Unreinforced unit masonry with timber floors and roof | | | | | |
| Unreinforced unit masonry with reinforced concrete floors and roof | | | | | |
| Confined or reinforced masonry | | | | | |
| Lightweight timber frame | | | | | |
| Heavy timber frame or timber log construction | | | | | |
| Other | | | | | |
| TOTAL | | | 0 | 0 | |

**Part III: Additional Sources of Information Used**

Sources of information you used (websites, publications, etc.) Please provide as much detail as possible.

Additional comments

Definitions

**1. Building construction typology definitions**

| *Definition on form* | *Description* |
|---|---|
| Reinforced concrete moment-frame, pre-1990 | Loads carried by reinforced concrete moment-resisting frame consisting of beams and columns; infill walls of masonry or other materials; floors and roof of reinforced concrete; built before 1990. |
| Reinforced concrete moment-frame, post-1990 | Loads carried by reinforced concrete moment-resisting frame consisting of beams and columns; infill walls of masonry or other materials; floors and roof of reinforced concrete; built after 1990. |
| Precast concrete moment frame pre-1990 | Loads carried by precast concrete moment-resisting frame consisting of beams and columns and slabs with infill walls of reinforced concrete panels (eg *IMS-Zhezhelj* system); built before 1990 . |
| Precast concrete moment frame post-1990 | Loads carried by precast concrete moment-resisting frame consisting of beams and columns and slabs with infill walls of reinforced concrete panels (eg *IMS-Zhezhelj* system); built after 1990 . |
| Precast concrete panel pre-1990 | Loads carried by precast concrete panel bearing-walls, floors and roofs of precast concrete ; built before 1990. |
| Precast concrete panel post-1990 | Loads carried by precast concrete panel bearing-walls, floors and roofs of precast concrete; built after 1990. |
| Unreinforced earthen or rubble masonry | Load-bearing walls of weak masonry, either earthen (adobe or rammed earth), or rubble stone in lime or mud mortar; flat or pitched roof of timber poles or joists, covered with clay tiles or stone tiles, sometimes metal sheet; generally single storey. |
| Unreinforced unit masonry with timber floors and roof | Load-bearing walls of unit masonry, brick, concrete block or stone, laid in courses with mortar of cement or lime; floors of timber joists supporting timber boards; roofs generally pitched and covered with clay tiles or asbestos cement (occasionally metal) roof sheets; generally up to 3 storeys, sometimes up to 6 stories. |
| Unreinforced unit masonry with reinforced concrete floors and roof | Load-bearing walls of unit masonry, brick, concrete block or stone, laid in courses with mortar of cement or lime; floors and roofs of reinforced concrete either insitu or precast slab units; generally up to 3 storeys, sometimes up to 6 stories. |
| Confined or reinforced masonry | Load-bearing walls of reinforced or confined masonry; floors either of reinforced concrete (or precast ribbed slab units) or timber joists supporting timber boards; roofs generally pitched and covered with tiles or metal roof sheet, occasionally reinforced concrete; generally up to 3 stories. |
| Lightweight timber frame | Loads carried by a timber frame, either with closely spaced stud walls with timber cladding or brick veneer; or more widely spaced post and beam construction with masonry or other infill; floors and roofs of timber joist construction, roofs normally pitched with covering of tiles or metal sheets; height up to 3 stories. |
| Heavy timber frame or timber log construction | These are of two types: either traditional log construction or modern manufactured timber log buildings e.g. those made by *Marles* of Slovenia or *Krivaja* of Bosnia-Herzegovina |
| Other | Other building typologies not covered (or nearly covered) by the above descriptions. For any types considered of importance in this country, please specify and give a brief description. These may include eg retrofitted buildings damaged in previous earthquakes, or large older buildings which |

| | |
|---|---|
| | have been extended vertically or horizontally with newer reinforced concrete technology. |

**2. Building height ranges**

| | |
|---|---|
| Low- rise | 1 to 3 stories |
| Mid-rise | 4 to 7 stories |
| High-rise | 8 stories and above |

**3 Urban and rural areas**

| | |
|---|---|
| Urban areas | Concentrated selttlements with greater than 1000 inhabitants |
| Rural areas | All land areas which are not urban as defined above |

## Switzerland

**EU-NERA PROJECT: EXPERT-OPINION SURVEY OF SWITZERLAND RESIDENTIAL CONSTRUCTION TYPOLOGY DISTRIBUTIONS**

This form is divided into 3 parts:

**Part I: Information about contributor**
**Part II: Estimates of construction type distributions , urban and rural areas**
**Part III: Additional Sources of Information Used**

**Part I: Information about contributor**

1. Country or Region (if you are only responding for part of a country, please indicate which geographic region.

2. Name(s) of Contributors

3. Affiliation (Organization)

5. E-mail

6. Your self-rating of expertise or confidence:
On a scale of 1=low and 5=high, please estimate your level of expertise:

**Part IIa: Estimates of Construction Type Distributions - URBAN Areas**

| | Construction Material and construction typology | estimated % of **pre 1971** dwellings in buildings of each class | estimated % of **1971-2003** dwellings in buildings of each class | estimated % of **post 2003** dwellings in buildings of each class |
|---|---|---|---|---|
| 1 | Reinforced concrete moment-frame | | | |
| 2 | Reinforced concrete wall | | | |
| 3 | CoMa (RC walls and URM walls) | | | |
| 4 | Precast concrete moment frame or panel | | | |
| 5 | Unreinforced field-stone masonry | | | |
| 6 | Unreinforced unit masonry with timber floors | | | |
| 7 | Unreinforced unit masonry with reinforced concrete floors | | | |
| 8 | Lightweight timber frame | | | |
| 9 | Half-timbered or log construction | | | |
| 10 | Other (please specify in Part III) | | | |
| | TOTAL | 100 | 100 | 100 |

**Part IIb: Summary of Construction Types - RURAL Areas**

| | Construction Material and construction typology | estimated % of **pre 1971** dwellings in buildings of each class | estimated % of **1971-2003** dwellings in buildings of each class | estimated % of **post 2003** dwellings in buildings of each class |
|---|---|---|---|---|
| 1 | Reinforced concrete moment-frame | | | |
| 2 | Reinforced concrete wall | | | |
| 3 | CoMa (RC walls and URM walls) | | | |
| 4 | Precast concrete moment frame or panel | | | |
| 5 | Unreinforced field-stone masonry | | | |
| 6 | Unreinforced unit masonry with timber floors | | | |
| 7 | Unreinforced unit masonry with reinforced concrete floors | | | |
| 8 | Lightweight timber frame | | | |
| 9 | Half-timbered or log construction | | | |
| 10 | Other (please specify in Part III) | | | |
| | TOTAL | 100 | 100 | 100 |

**Part III: Additional Sources of Information Used**

4 Any sources of information you used (websites, publications, etc.) Please provide as much detail as possible.

5 Additional comments

Definitions

| *Definition on form* | *Description* |
|---|---|
| Reinforced concrete moment-frame | Loads carried by reinforced concrete moment-resisting frame consisting of beams and columns; infill walls of masonry or other materials; floors and roof of reinforced concrete. |
| Reinforced concrete wall | Loads carried by reinforced concrete bearing wall, or by an infilled reinforced concrete frame with additional regularly-spaced reinforced concrete wall, floors and roofs. |
| CoMa (RC walls and URM walls) | Loads carried by a mix of reinforced concrete and unreinforced masonry walls; Reinforced floor slabs and roofs. |
| Precast concrete moment frame or panel | Loads carried by precast concrete moment-resisting frame consisting of beams and columns and slabs with infill walls of masonry or reinforced concrete panels; or load-bearing precast concrete wall and slab system. |
| Unreinforced field-stone masonry | Load-bearing walls of weak masonry field or rubble stone in lime or mud mortar; flat or pitched roof of timber poles or joists, covered with clay tiles or stone tiles, sometimes metal sheet; generally single storey. |
| Unreinforced unit masonry with timber floors | Load-bearing walls of unit masonry, brick, concrete block or natural stone, laid in courses with mortar of cement or lime; floors of timber joists supporting timber boards; roofs generally pitched and covered with clay tiles, or roof sheets; generally up to 3 storeys, sometimes up to 6 stories. |
| Unreinforced unit masonry with reinforced concrete floors | Load-bearing walls of unit masonry, brick, concrete block or stone, laid in courses with mortar of cement or lime; floors of reinforced concrete either insitu or precast slab units; roofs either of reinforced concrete slab or timber joists; generally up to 3 storeys, sometimes up to 6 stories. |
| Lightweight timber frame | Loads carried by a timber frame, either with closely spaced stud walls with timber cladding or brick veneer; or more widely spaced post and beam construction with masonry or other infill; floors and roofs of timber joist construction, roofs normally pitched with covering of tiles or metal sheets; height up to 3 stories. |
| Half timbered or log construction | Half Timbered - Loads carried by an exposed timber frame; clay, plastered wood, or masonry infill; floors and roof of timber joist construction; roofs normally have a steep pitch. Log construction – Vertical and lateral loading carried through stacked logs; logs joined by hand-sawn connections |
| Other | Other building typologies not covered (or nearly covered) by the above descriptions. For any types considered of importance in this country, please specify and give a brief description. |

**3 Urban and rural areas**

| | |
|---|---|
| Urban areas | Concentrated settlements with greater than 1000 inhabitants |
| Rural areas | All land areas which are not urban as defined above |

## Balkan Countries: Croatia, Serbia, Bosnia and Herzegovina

**EU-NERA PROJECT**

**EXPERT-OPINION SURVEY OF RESIDENTIAL CONSTRUCTION TYPOLOGY DISTRIBUTIONS IN FORMER YUGOSLAVIA**

This form is divided into 3 parts:

**Part I: Information about contributor**

**Part II: Estimates of construction type distributions, urban and rural areas**

**Part III: Additional Sources of Information Used**

**Part I: Information about contributor**

1. Country or Region
(if you are only responding for part of a country, please indicate which geographic region).
2. Name(s) of Contributors

3. Affiliation (Organization)

5. E-mail

6. Your self-rating of expertise or confidence:
On a scale of 1=low and 5=high, please estimate your level of expertise:

**Part IIa. Dwellings in urban areas**

*Urban areas include all settlements with populations exceeding 2000 inhabitants*

*Questions 1 to 5 concern the primary construction typology distribution*

Estimate the proportion of dwellings which are of construction type:

1 **timber frame or log**
2 **load-bearing masonry**
3 **reinforced concrete**
4 **other**
5 Please specify the construction typologies referred to in question 4

*Questions 6 to 13 concern the secondary construction typology distribution*

Of the masonry dwellings, estimate what proportion are:

6 **adobe or field stone masonry**
7 **unit masonry (brick, concrete block or natural stone) with timber floors**
8 **unit masonry (brick, concrete block or natural stone) with reinforced concrete floors**
9 **reinforced or confined masonry**

Of the reinforced concrete dwellings, estimate what proportion are:

10 **concrete frame construction (insitu or precast) built before 1981**
11 **concrete frame construction (in situ or precast) built in or after 1981**
12 **concrete wall construction (in situ or precast) built before 1981**
13 **concrete wall construction (in situ or precast) built in or after 1981**

**Part IIb. Dwellings in rural areas**

*Rural areas are all settlements not defined as urban*

*Questions 14 to 18 concern the primary construction typology distribution*

Estimate the proportion of dwellings which are of construction type:

14 **timber frame or log**
15 **load-bearing masonry**
16 **reinforced concrete**
17 **other**
18 Please specify the construction typologies referred to in question 4

*Questions 19 to 26 concern the secondary construction typology distribution*

Of the masonry dwellings, estimate what proportion are:

19 **adobe or field stone**
20 **unit masonry (brick, concrete block or natural stone) with timber floors**
21 **unit masonry (brick, concrete block or natural stone) with reinforced concrete floors**
22 **reinforced or confined masonry**

Of the reinforced concrete dwellings, estimate what proportion are:

23 **concrete frame construction (insitu or precast) built before 1981**
24 **concrete frame construction (in situ or precast) built in or after 1981**
25 **concrete wall construction (in situ or precast) built before 1981**
26 **concrete wall construction (in situ or precast) built in or after 1981**

**Part III: Additional Sources of Information Used**

Any sources of information you used (websites, publications, etc.) Please provide as much detail as possible.

Additional comments

Definitions

**1. Building construction typology definitions**

| *Primary structure type definition* | *Secondary Structure type Definition* | *Description* |
|---|---|---|
| Reinforced concrete | concrete frame construction | Loads carried by reinforced in situ or precast concrete moment-resisting frame consisting of beams and columns; infill walls of masonry or other materials; floors and roof of reinforced concrete. |
| | concrete wall construction | Loads carried by reinforced concrete in situ or precast concrete bearing wall, or by an infilled reinforced concrete frame with additional regularly-spaced reinforced concrete wall, floors and roofs. |
| Load-bearing masonry | Adobe or field stone masonry | Load-bearing walls of weak masonry, adobe or field stone or rubble stone in lime or mud mortar; flat or pitched roof of timber poles or joists, covered with clay tiles or stone tiles, sometimes metal sheet; generally single storey. |
| | Unit masonry with timber floors | Load-bearing walls of unit masonry, brick, concrete block or natural stone, laid in courses with mortar of cement or lime; floors of timber joists supporting timber boards; roofs generally pitched and covered with clay tiles, or roof sheets; generally up to 3 storeys, sometimes up to 6 stories. |
| | Unit masonry with reinforced concrete floors | Load-bearing walls of unit masonry, brick, concrete block or stone, laid in courses with mortar of cement or lime; floors of reinforced concrete either insitu or precast slab units; roofs either of reinforced concrete slab or timber joists; generally up to 3 storeys, sometimes up to 6 stories. |
| | Reinforced or confined masonry | Load-bearing walls of reinforced or confined masonry; floors either of reinforced concrete (or precast ribbed slab units) or timber joists supporting timber boards; roofs generally pitched and covered with tiles or metal roof sheet, occasionally reinforced concrete; generally up to 3 stories. |
| Timber frame or log | Timber frame | Loads carried by a timber frame, either with closely spaced stud walls with timber cladding or brick veneer; or more widely spaced post and beam construction with masonry or other infill; floors and roofs of timber joist construction, roofs normally pitched with covering of tiles or metal sheets; height up to 3 stories. Or Log construction – Vertical and lateral loading carried through stacked logs; logs joined by hand-sawn connections |

| | | |
|---|---|---|
| Other | Other | Other building typologies not covered (or nearly covered) by the above descriptions. For any types considered of importance in this country, please specify and give a brief description. |

**2 Urban and rural areas**

| | |
|---|---|
| Urban areas | Concentrated settlements with greater than 5000 inhabitants |
| Rural areas | All land areas which are not urban as defined above |

# Appendix 4: Switzerland Structure Types – GEVES report

GEVES (Spence et al. 2006) Switzerland structure type definitions

| Proposed Structure Type list for Switzerland | Brief description | Single Family Residence | Multi Family Residence | Residential Combined |
|---|---|---|---|---|
| TL (all heights, ages) | Modern timber frame housing (incl. chalet type) | 6 | 4 | 4.7 |
| TH (all heights, ages) | Old half-timbered construction (1-4 floors) | 5 | 6 | 5.6 |
| WM (all heights, ages) | Old rubble or simple hewn stone masonry with wooden floors (1-4 floors) | 14 | 13 | 13.4 |
| LBML wood floors (all ages) | Manufactured or massive stone, brick or concrete block unreinforced masonry with wooden floors; low-rise (1-3 floors) | 24 | 3 | 10.8 |
| LBMM wood floors (all ages) | Manufactured or massive stone, brick or concrete block unreinforced masonry with wooden floors; mid-rise (4-7 floors) | 0 | 10 | 6.3 |
| LBML RC floors (all ages) | Manufactured of massive stone, brick or concrete block unreinforced masonry with RC floors low-rise (1-3 floors) | 13 | 1 | 5.5 |
| LBMM RC floors (all ages) | Manufactured of massive stone, brick or concrete block unreinforced masonry with RC floors mid-rise (4-7floors) | 0 | 8 | 5 |
| LBM+RCSW L1 (<1989) | Mixed load-bearing masonry with RC wall construction, low-rise (1-3 floors); no earthquake resistant design prior to 1970, SIA-160 (1970 version) in 1970-1988 | 15 | 1 | 6.2 |
| LBM + RCSW M | Mixed load-bearing masonry with RC wall construction, mid-rise (4-7 floors); no earthquake resistant design prior to 1970, SIA-160 (1970 version) in 1970-1989 | 0 | 6 | 3.8 |
| LBM + RCSW L (1989-2002) | Mixed load-bearing masonry with RC wall construction, low-rise (1-3 floors); SIA-160 (1989 version) | 8 | 1 | 3.6 |
| LBM+RCSW M | Mixed load-bearing masonry with RC wall construction, mid-rise (4-7 floors); SIA-160 (1989 version) | 0 | 3 | 1.9 |
| LBM+RCSW L (post-2002) | Mixed load-bearing masonry with RC wall construction, low-rise (1-3 floors); SIA-261 | 2 | 0 | 0.7 |
| LBM+RCSW M | Mixed load-bearing masonry with RC wall construction, mid-rise (4-7 floors); SIA-261 | 0 | 1 | 0.6 |
| RCF (all heights, ages) | RC frame with infill masonry panels | 2 | 5 | 3.9 |
| RCSWL 1 (<1989) | RC shear wall low-rise (1-3 floors), no earthquake resistant design prior to 1970, SIA-160 (1970 version) in 1970-1988 | 4 | 0 | 1.5 |

| | | | | |
|---|---|---|---|---|
| RCSWM1 | RC shear wall mid-rise (4-7 floors), no earthquake resistant design prior to 1970, SIA-160 (1970 version) in 1970-1989 | 0 | 14 | 8.8 |
| RCSWH1 | RC shear wall mid-rise (8+ floors), no earthquake resistant design prior to 1970, SIA-160 (1970 version) in 1970-1990 | 0 | 6 | 3.8 |
| RCSWL2 (1989-2002) | RC shear wall low-rise (1-3 floors), SIA-160 (1989 revision) | 2 | 0 | 0.7 |
| RCSWM2 | RC shear wall mid-rise (4-7 floors), SIA-160 (1989 revision) | 0 | 7 | 4.4 |
| RCSWH2 | RC shear wall high-rise (8+ floors), SIA-160 (1989 revision) | 0 | 2 | 1.3 |
| RCSWL3 (post-2002) | RC shear wall low rise (1-3 floors), SIA-261 | 1 | 0 | 0.4 |
| RCSWM3 | RC shear wall mid rise (4-7 floors), SIA-262 | 0 | 3 | 1.9 |
| RCDU (all heights, ages) | Reinforced concrete frame mixed with RC shear walls | 0 | 2 | 1.3 |
| SFL1 (<1989) | Steel braced or unbraced frames with or without RC shear walls low-rise (1-3 floors); no earthquake resistnat design prior to 1970, SIA-160 (1970 version) in 1970-1988 | 2 | 0 | 0.7 |
| SFM1 | Steel braced or unbraced frames with or without RC shear walls mid-rise (4-7 floors); no earthquake resistnat design prior to 1970, SIA-160 (1970 version) in 1970-1989 | 0 | 2 | 1.3 |
| SFH1 | Steel braced or unbraced frames with or without RC shear walls high-rise (8+ floors); no earthquake resistnat design prior to 1970, SIA-160 (1970 version) in 1970-1990 | 0 | 0 | 0 |
| SFL2 (1989 - 2002) | Steel braced or unbraced frames with or without RC shear walls low-rise (1-3 floors); SIA-160 (1989 version) | 2 | 0 | 0.7 |
| SFM2 | Steel braced or unbraced frames with or without RC shear walls mid-rise (4-7 floors); SIA-160 (1989 version) | 0 | 1 | 0.6 |
| SFH2 | Steel braced or unbraced frames with or without RC shear walls high-rise (8+ floors); SIA-160 (1989 version) | 0 | 0 | 0 |
| SFL3 (post-2002) | Steel braced or unbraced frames with or without RC shear walls low-rise (1-3 floors); SIA-261 | 0 | 0 | 0 |
| SFM3 | Steel braced or unbraced frames with or without RC shear walls mid-rise (4-7 floors); SIA-262 | 0 | 0 | 0 |
| SPCM (all ages) | Steel encased in RC mid-rise (4-7 floors) | 0 | 1 | 0.6 |

# Appendix 5: Switzerland – Urban and Rural Areas

Defining urban and rural areas in Switzerland using GIS.

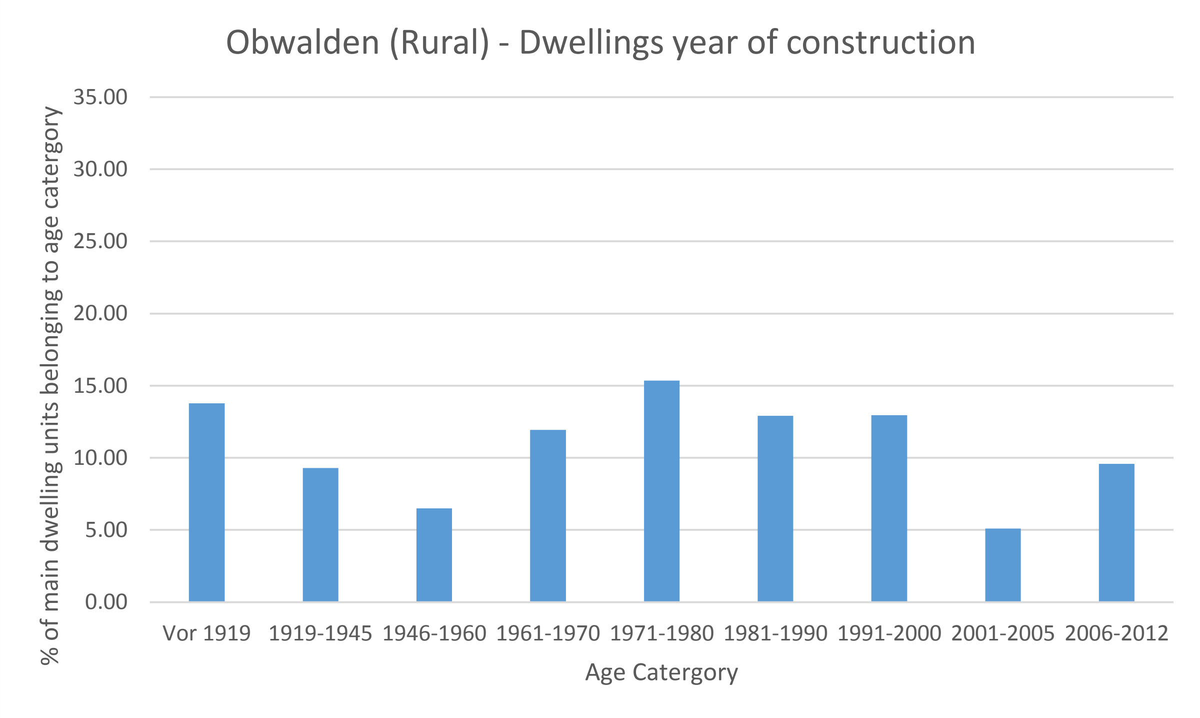
In Switzerland, a method has been tested by defining regions, known as Cantons as urban and rural using administrative boundaries and GIS software. Using spatial analysis techniques, the GRUMP dataset was used to analyse the proportion of urban and rural land within each Canton. Pixels which were associated with urban areas, were assigned the number two and rural areas number one. The mean value of pixels was calculated for each canton. The higher the number (mean within a Canton) the higher the proportion of pixels assigned as urban. The four cantons with extreme values of either rural or urban where chosen to analyse the average age distribution. Basel-Stadt was later removed due to the unique nature of the building stock.

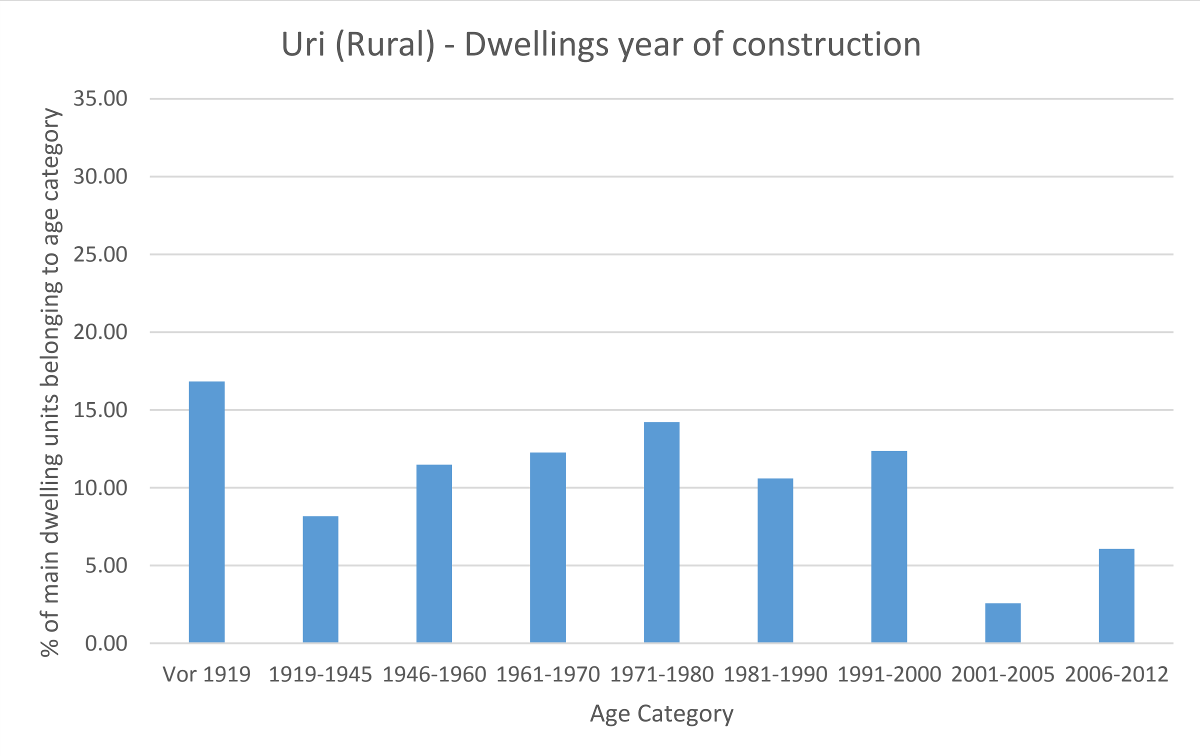
| Canton | Number of Pixels | Average values assigned to pixels | |
|---|---|---|---|
| Obwalden | 781 | 1.02 | RURAL |
| Uri | 1628 | 1.04 | |
| Glarus | 1089 | 1.07 | |
| Graubinden | 11214 | 1.07 | |
| Jura | 1337 | 1.11 | |
| Nidwalden | 417 | 1.12 | |
| Schaffhausen | 460 | 1.13 | |
| Schwyz | 1433 | 1.15 | |
| Fribourg | 2628 | 1.15 | |
| Lucerne | 2359 | 1.16 | |
| Bern | 9129 | 1.17 | |
| Valais | 7224 | 1.17 | |
| Ticino | 4462 | 1.18 | |
| Vaud | 4616 | 1.22 | |
| Appenzell Innerrhoden | 283 | 1.23 | |
| St. Gallen | 3203 | 1.29 | |
| Thurgau | 1425 | 1.31 | |
| Neuchatel | 1146 | 1.32 | |
| Basel-Landschaft | 828 | 1.35 | |
| Solothurn | 1272 | 1.39 | |
| Appenzell Ausserrhoden | 385 | 1.41 | |
| Zug | 354 | 1.49 | |
| Aargau | 2236 | 1.51 | |
| Zurich | 2731 | 1.62 | |
| Geneva | 394 | 1.95 | |
| Basel-Stadt | 52 | 2.00 | URBAN |

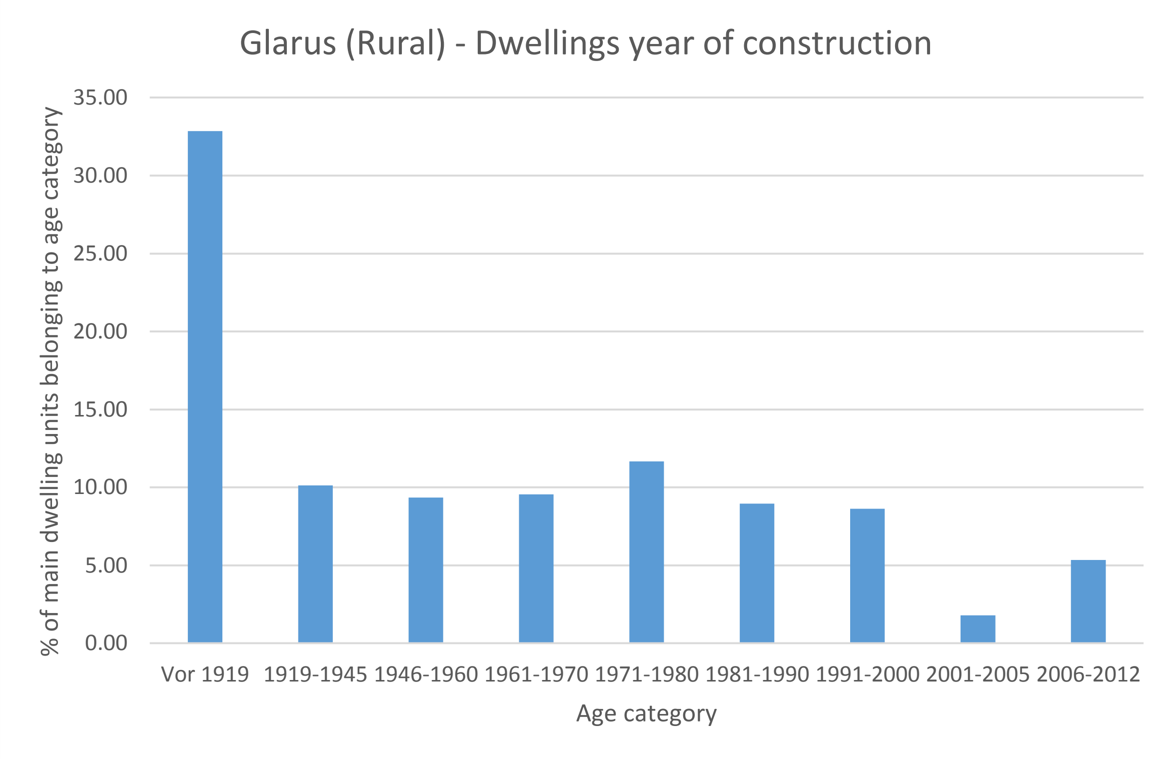
# Appendix 6: Switzerland – Individual Canton's Age Distribution

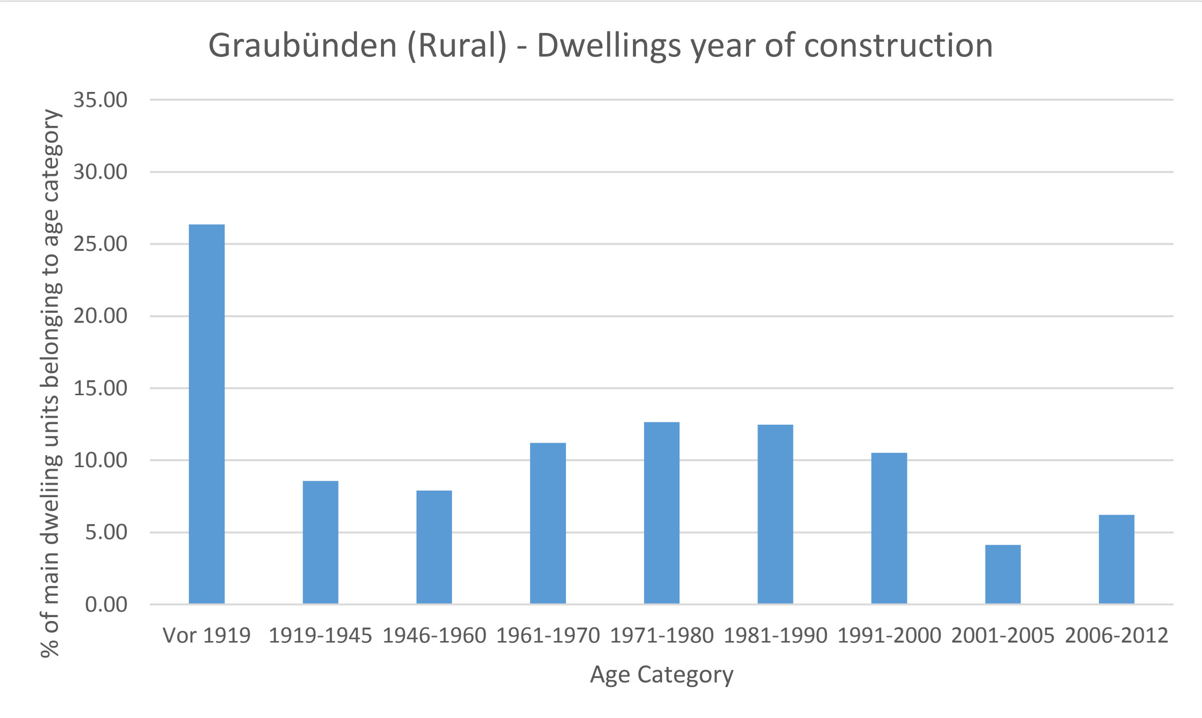
Age distribution of selected rural and urban Cantons in Switzerland – See Appendix 3 for selection process

**Rural**

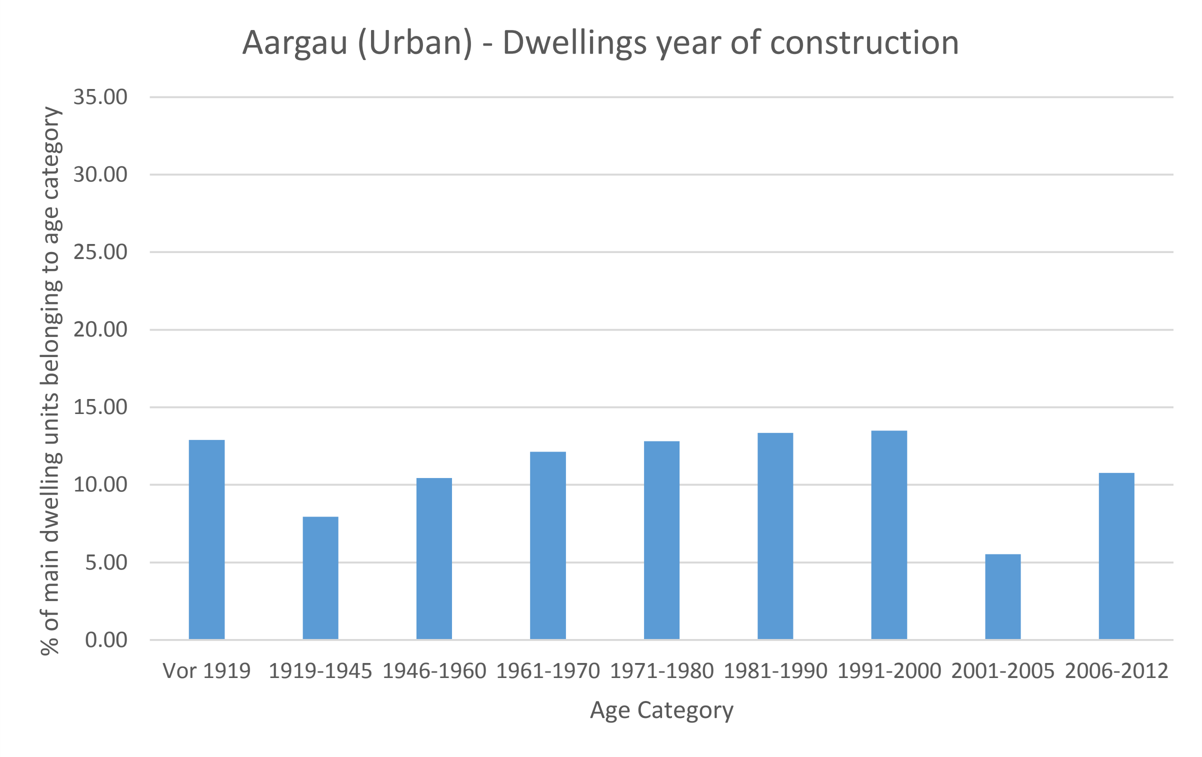


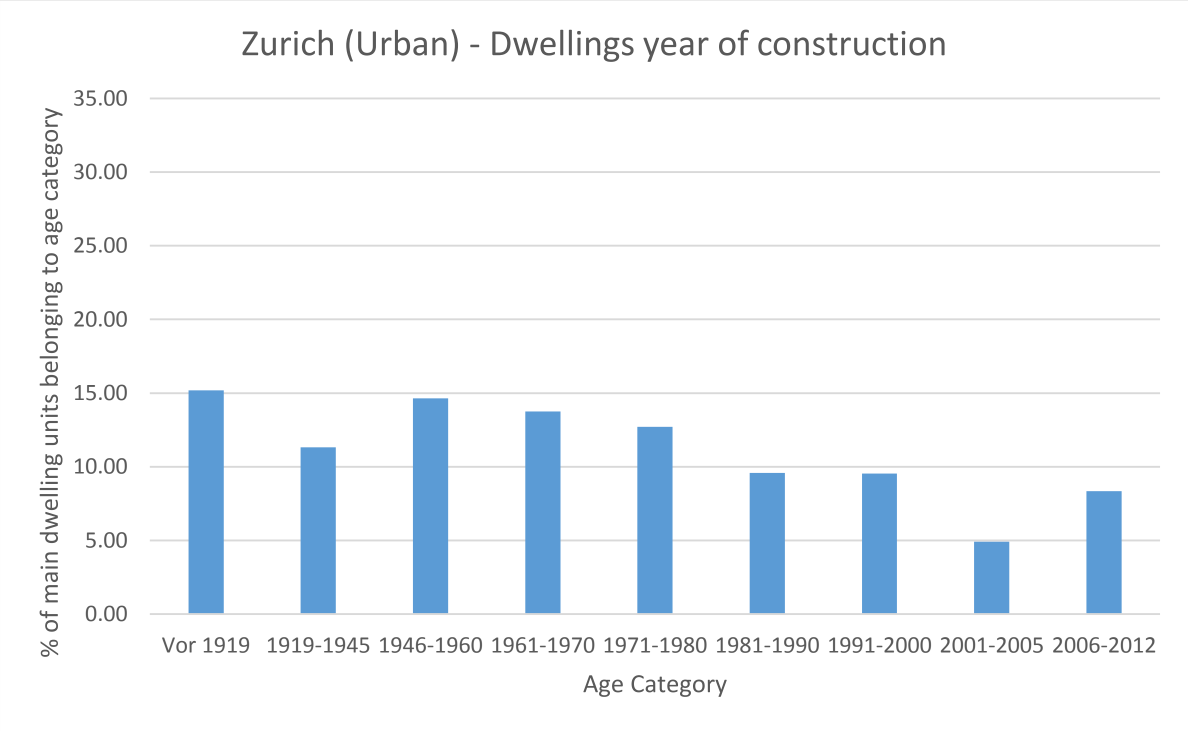



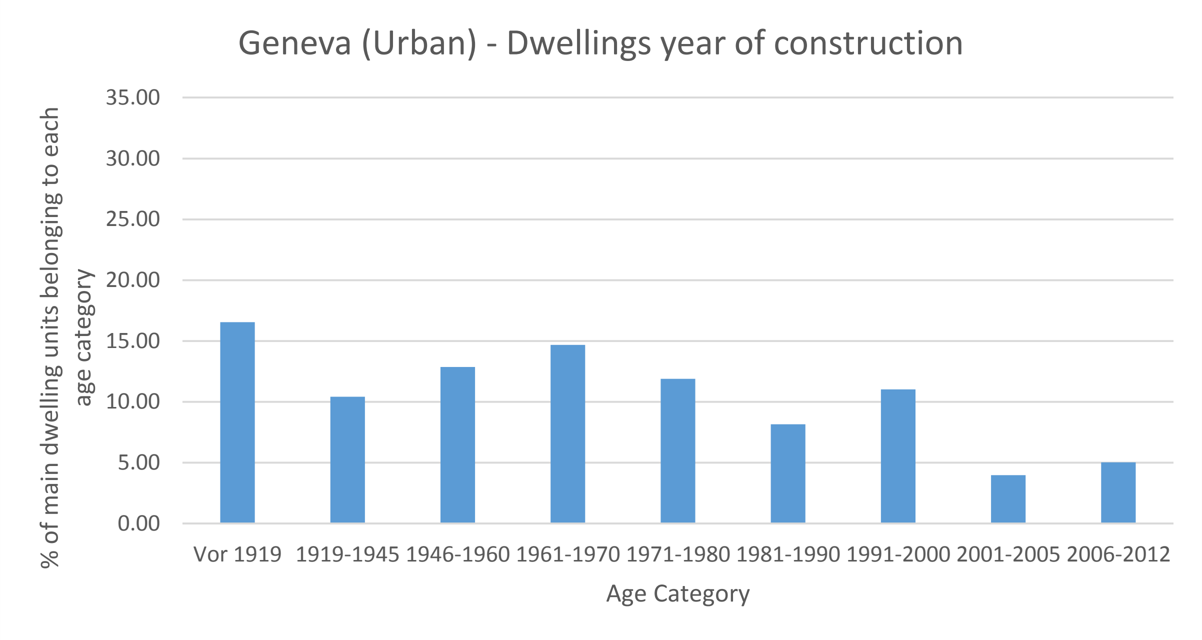

Glarus (Rural) - Dwellings year of construction
% of main dwelling units belonging to age category
35.00
30.00
25.00
20.00
15.00
10.00
5.00
0.00
Vor 1919
1919-1945
1946-1960
1961-1970
1971-1980
1981-1990
1991-2000
2001-2005
2006-2012
Age category

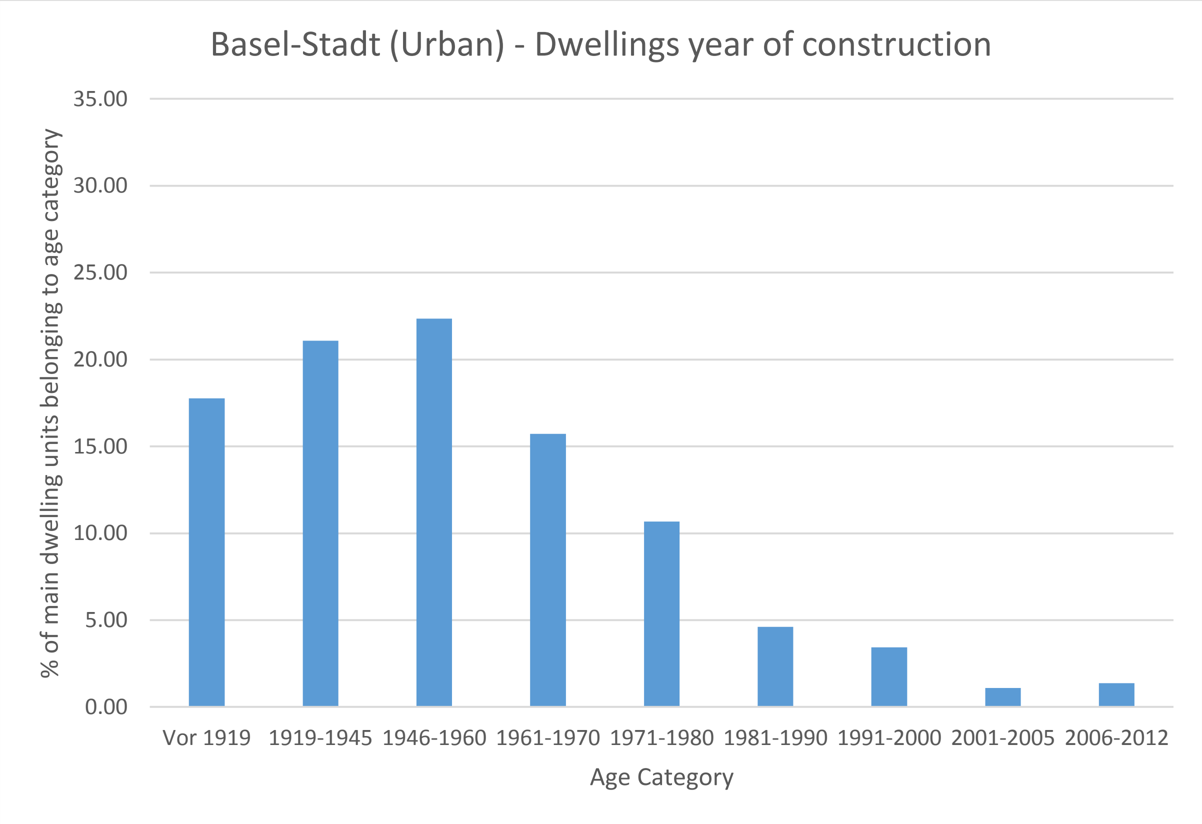

Graubünden (Rural) - Dwellings year of construction
% of main dwelling units belonging to age category
35.00
30.00
25.00
20.00
15.00
10.00
5.00
0.00
Vor 1919
1919-1945
1946-1960
1961-1970
1971-1980
1981-1990
1991-2000
2001-2005
2006-2012
Age Category

**Urban**


Aargau (Urban) - Dwellings year of construction
% of main dwelling units belonging to age category
35.00
30.00
25.00
20.00
15.00
10.00
5.00
0.00
Vor 1919
1919-1945
1946-1960
1961-1970
1971-1980
1981-1990
1991-2000
2001-2005
2006-2012
Age Category


Zurich (Urban) - Dwellings year of construction
% of main dwelling units belonging to age category
35.00
30.00
25.00
20.00
15.00
10.00
5.00
0.00
Vor 1919
1919-1945
1946-1960
1961-1970
1971-1980
1981-1990
1991-2000
2001-2005
2006-2012
Age Category

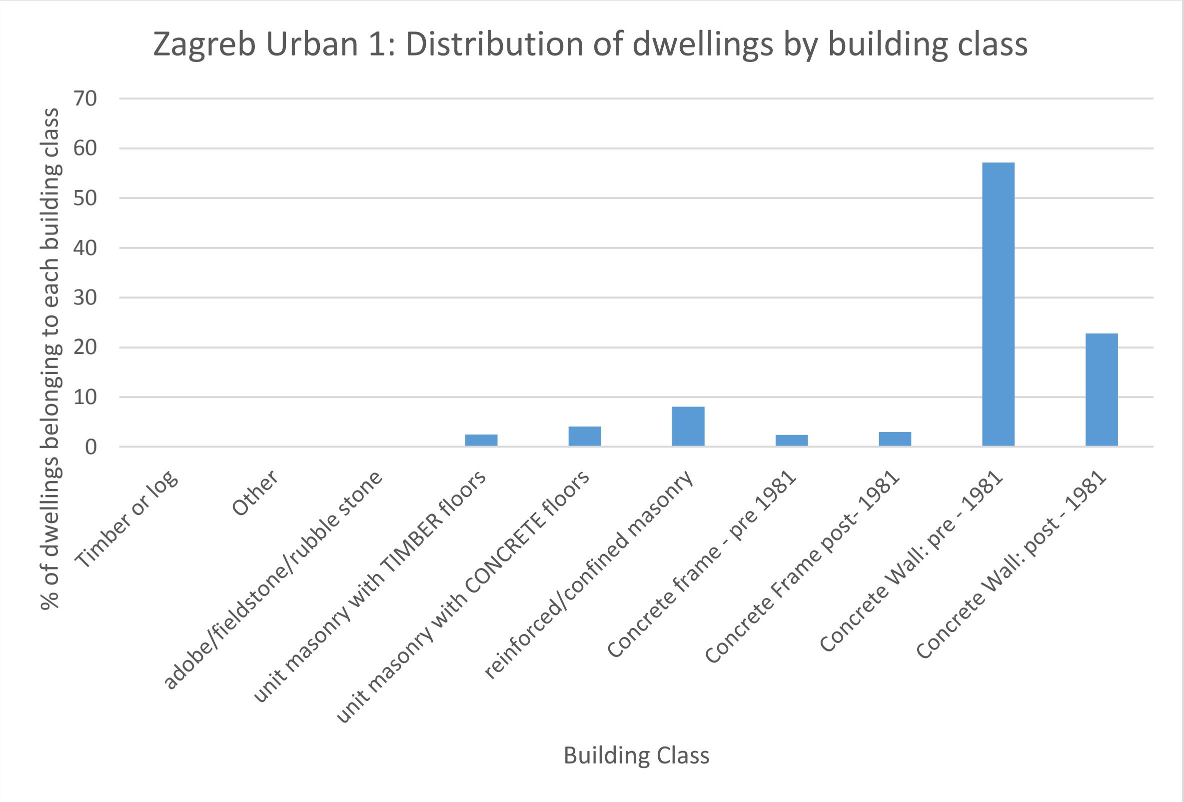

Geneva (Urban) - Dwellings year of construction
% of main dwelling units belonging to each age category
35.00
30.00
25.00
20.00
15.00
10.00
5.00
0.00
Vor 1919
1919-1945
1946-1960
1961-1970
1971-1980
1981-1990
1991-2000
2001-2005
2006-2012
Age Category

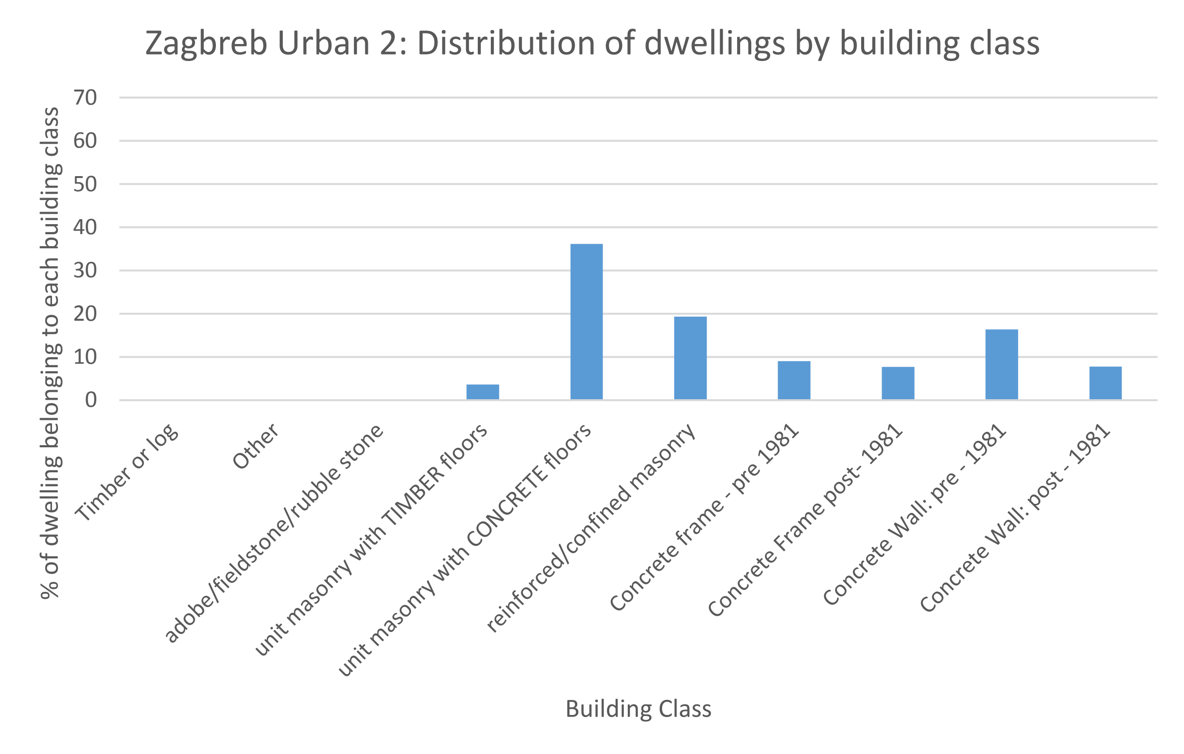

Basel-Stadt (Urban) - Dwellings year of construction
% of main dwelling units belonging to age category
35.00
30.00
25.00
20.00
15.00
10.00
5.00
0.00
Vor 1919
1919-1945
1946-1960
1961-1970
1971-1980
1981-1990
1991-2000
2001-2005
2006-2012
Age Category

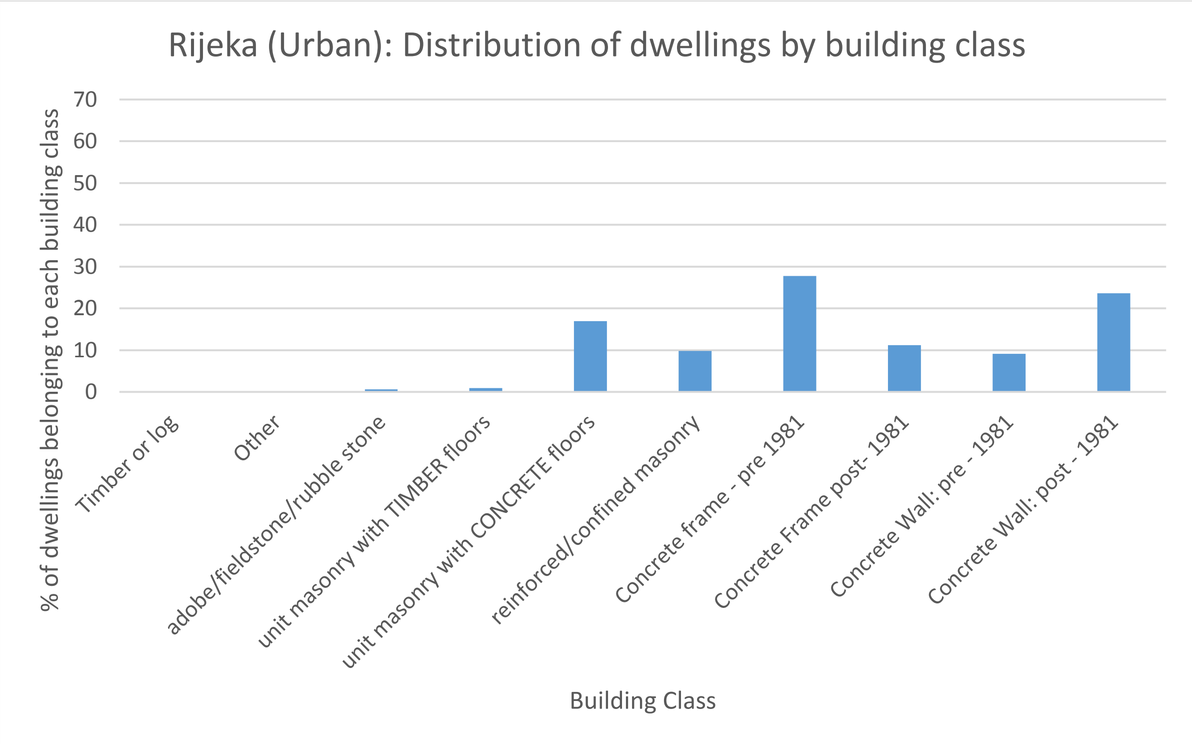
# Appendix 7: Croatia- Street View Results

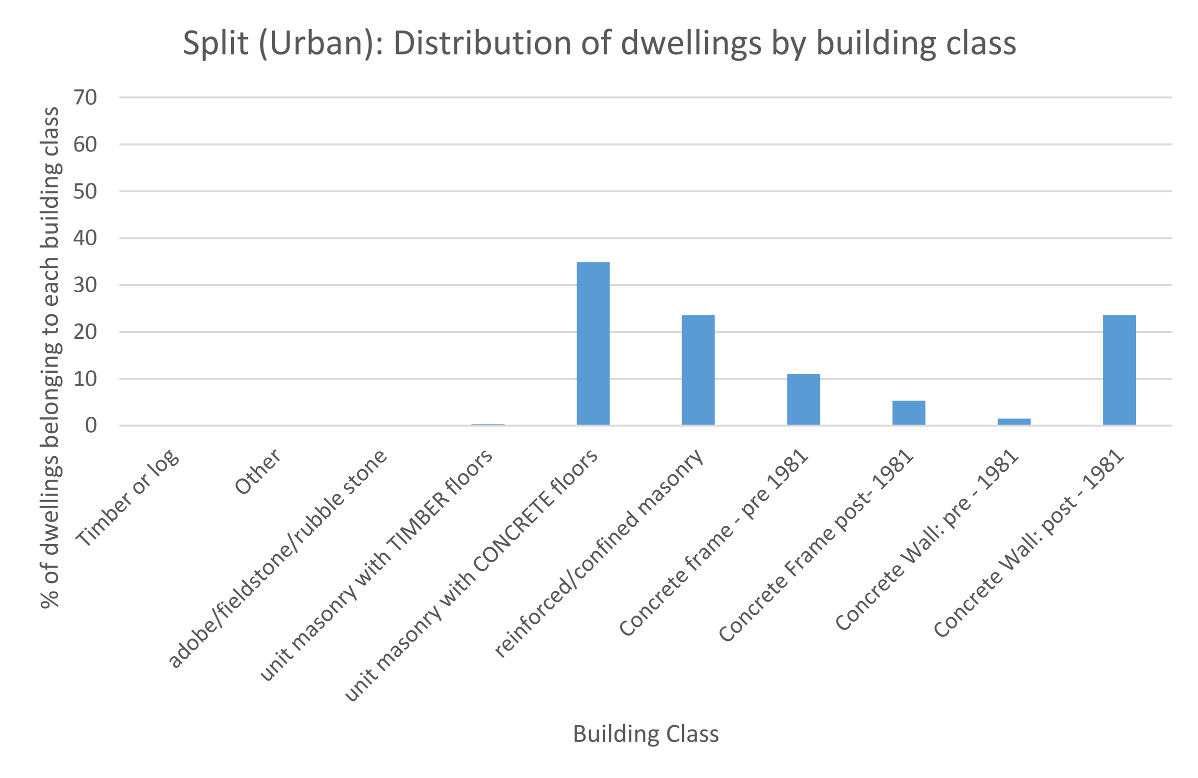
Distribution of dwellings by building class in different urban and rural zones in Croatia. Data collected using Street View Survey

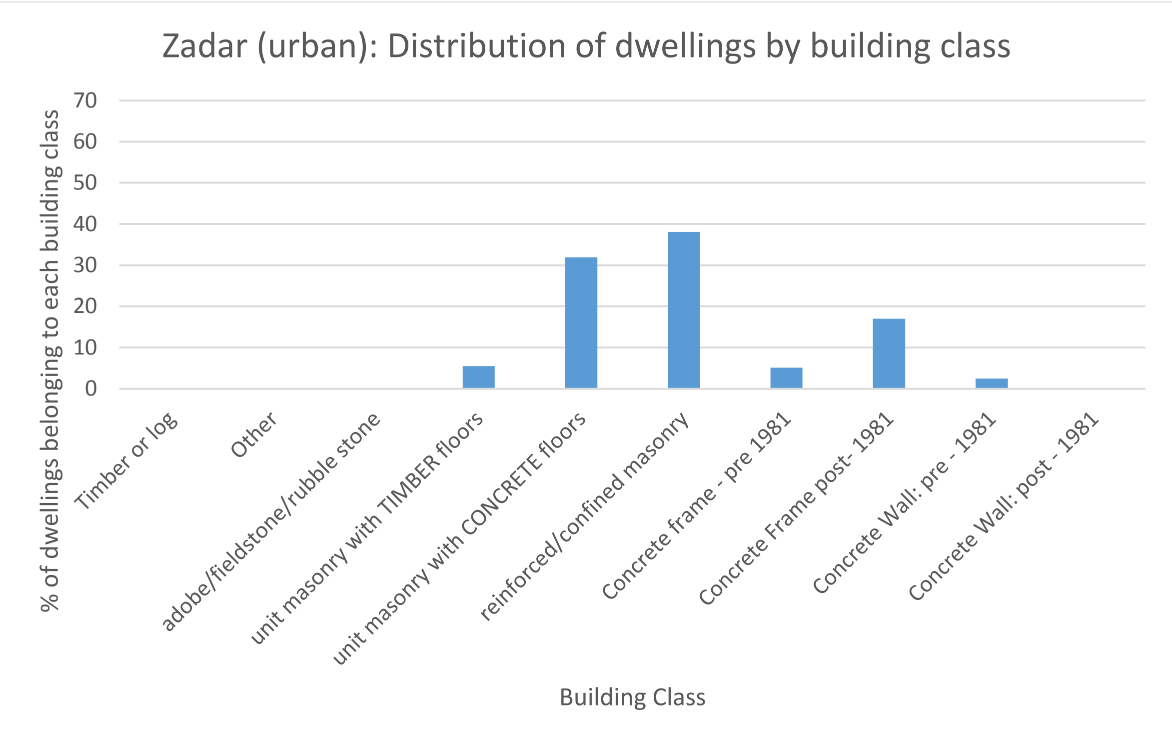
## Urban Areas



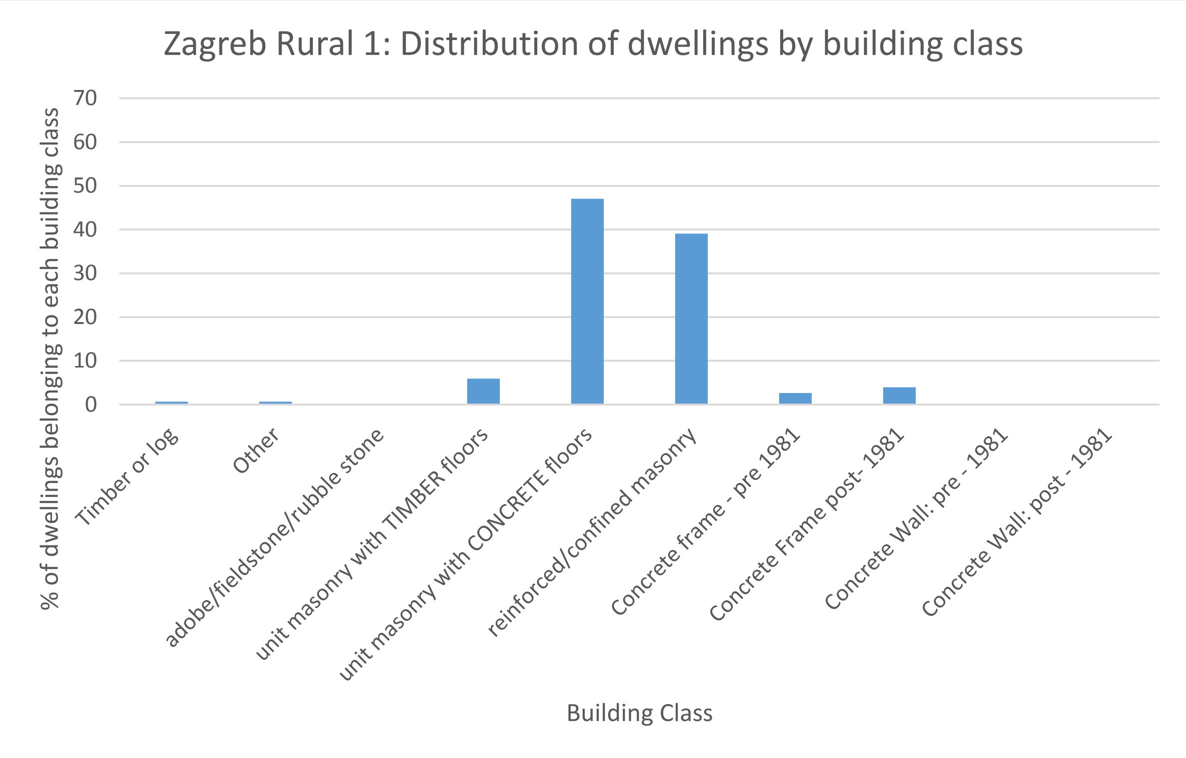

Zagbreb Urban 2: Distribution of dwellings by building class
% of dwelling belonging to each building class
70
60
50
40
30
20
10
0
Timber or log
Other
adobe/fieldstone/rubble stone
unit masonry with TIMBER floors
unit masonry with CONCRETE floors
reinforced/confined masonry
Concrete frame - pre 1981
Concrete Frame post- 1981
Concrete Wall: pre - 1981
Concrete Wall: post - 1981
Building Class

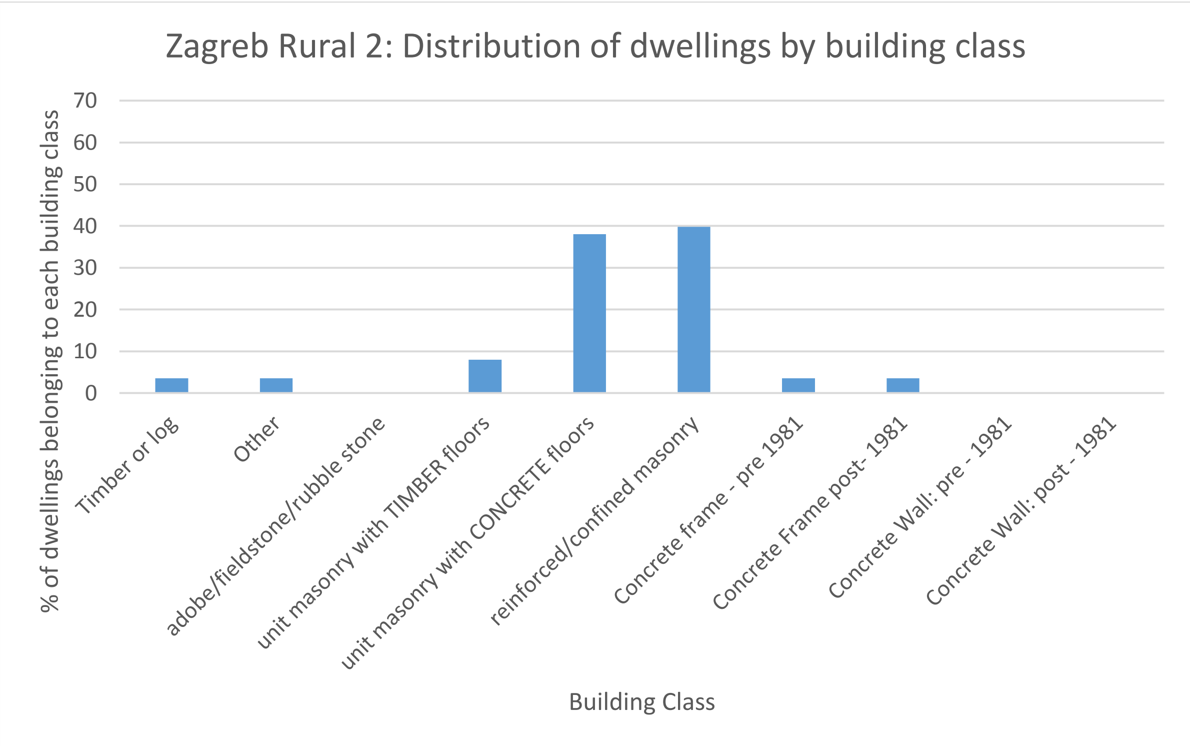

Rijeka (Urban): Distribution of dwellings by building class
% of dwellings belonging to each building class
70
60
50
40
30
20
10
0
Timber or log
Other
adobe/fieldstone/rubble stone
unit masonry with TIMBER floors
unit masonry with CONCRETE floors
reinforced/confined masonry
Concrete frame - pre 1981
Concrete Frame post- 1981
Concrete Wall: pre - 1981
Concrete Wall: post - 1981
Building Class

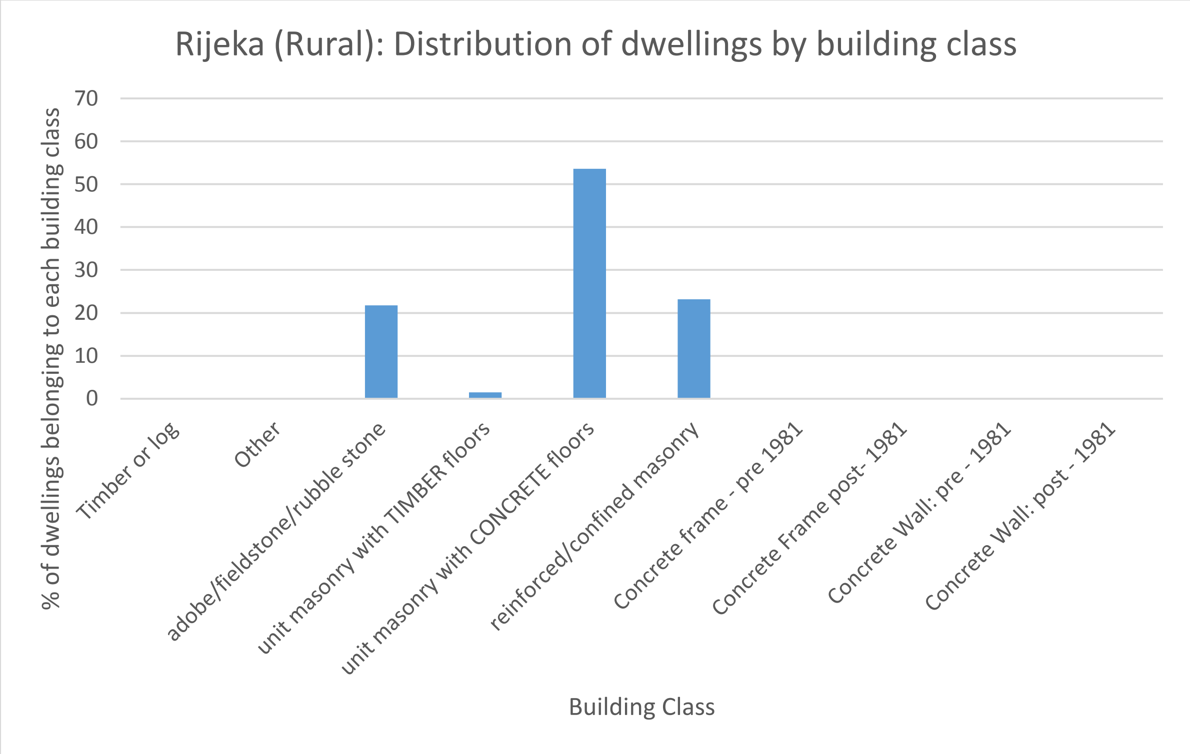

Split (Urban): Distribution of dwellings by building class
% of dwellings belonging to each building class
70
60
50
40
30
20
10
0
Timber or log
Other
adobe/fieldstone/rubble stone
unit masonry with TIMBER floors
unit masonry with CONCRETE floors
reinforced/confined masonry
Concrete frame - pre 1981
Concrete Frame post- 1981
Concrete Wall: pre - 1981
Concrete Wall: post - 1981
Building Class

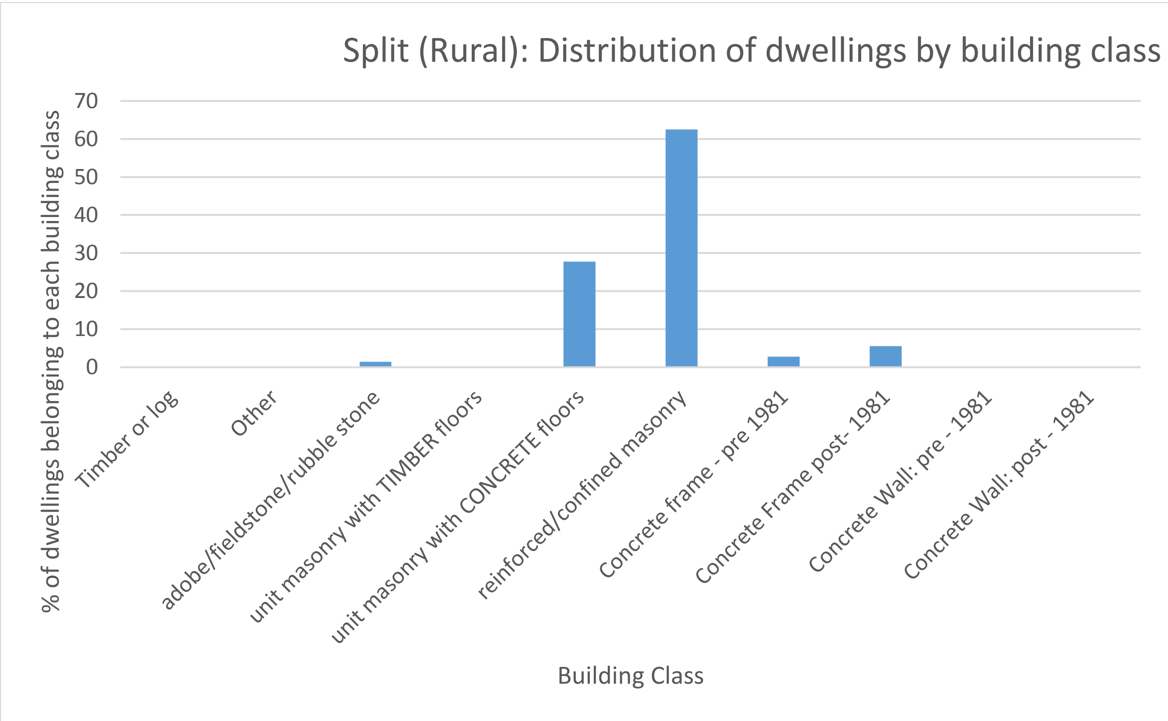

Zadar (urban): Distribution of dwellings by building class
% of dwellings belonging to each building class
70
60
50
40
30
20
10
0
Timber or log
Other
adobe/fieldstone/rubble stone
unit masonry with TIMBER floors
unit masonry with CONCRETE floors
reinforced/confined masonry
Concrete frame - pre 1981
Concrete Frame post- 1981
Concrete Wall: pre - 1981
Concrete Wall: post - 1981
Building Class

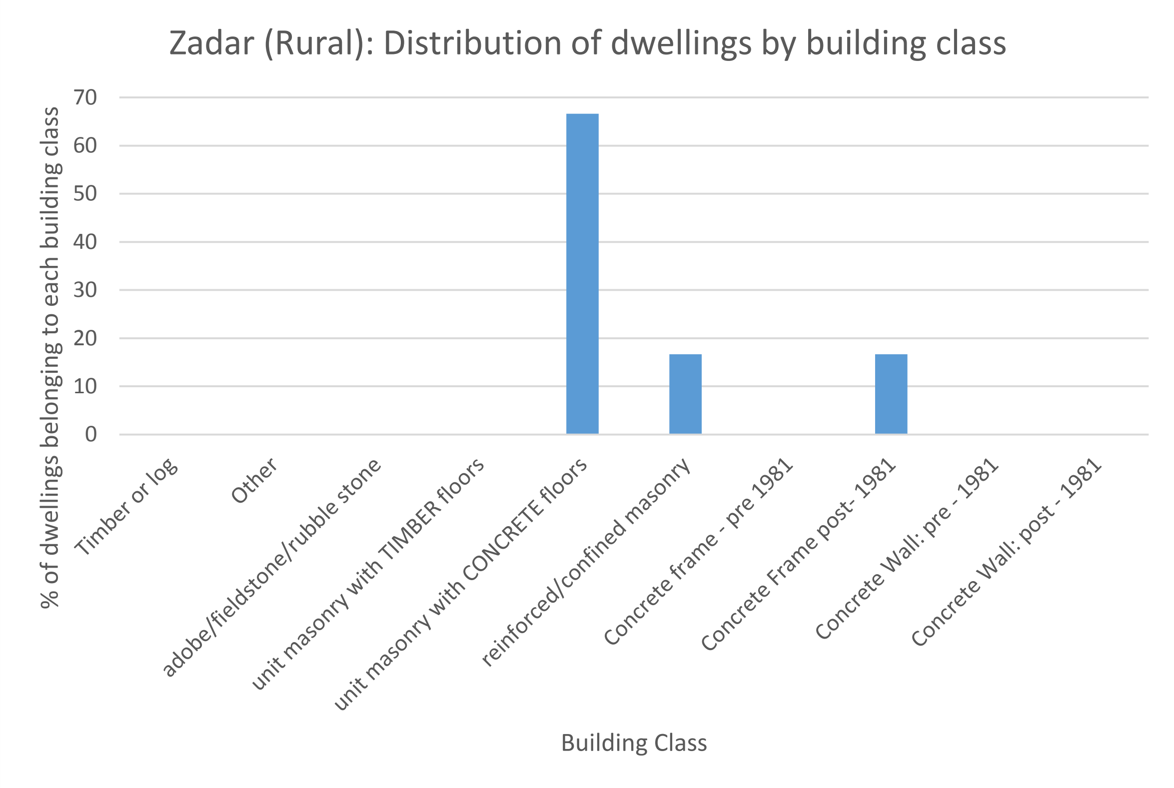
## Rural Areas


Zagreb Rural 1: Distribution of dwellings by building class
% of dwellings belonging to each building class
70
60
50
40
30
20
10
0
Timber or log
Other
adobe/fieldstone/rubble stone
unit masonry with TIMBER floors
unit masonry with CONCRETE floors
reinforced/confined masonry
Concrete frame - pre 1981
Concrete Frame post- 1981
Concrete Wall: pre - 1981
Concrete Wall: post - 1981
Building Class


Zagreb Rural 2: Distribution of dwellings by building class
% of dwellings belonging to each building class
70
60
50
40
30
20
10
0
Timber or log
Other
adobe/fieldstone/rubble stone
unit masonry with TIMBER floors
unit masonry with CONCRETE floors
reinforced/confined masonry
Concrete frame - pre 1981
Concrete Frame post- 1981
Concrete Wall: pre - 1981
Concrete Wall: post - 1981
Building Class


Rijeka (Rural): Distribution of dwellings by building class
% of dwellings belonging to each building class
70
60
50
40
30
20
10
0
Timber or log
Other
adobe/fieldstone/rubble stone
unit masonry with TIMBER floors
unit masonry with CONCRETE floors
reinforced/confined masonry
Concrete frame - pre 1981
Concrete Frame post- 1981
Concrete Wall: pre - 1981
Concrete Wall: post - 1981
Building Class


Split (Rural): Distribution of dwellings by building class
% of dwellings belonging to each building class
70
60
50
40
30
20
10
0
Timber or log
Other
adobe/fieldstone/rubble stone
unit masonry with TIMBER floors
unit masonry with CONCRETE floors
reinforced/confined masonry
Concrete frame - pre 1981
Concrete Frame post- 1981
Concrete Wall: pre - 1981
Concrete Wall: post - 1981
Building Class


Zadar (Rural): Distribution of dwellings by building class
% of dwellings belonging to each building class
70
60
50
40
30
20
10
0
Timber or log
Other
adobe/fieldstone/rubble stone
unit masonry with TIMBER floors
unit masonry with CONCRETE floors
reinforced/confined masonry
Concrete frame - pre 1981
Concrete Frame post- 1981
Concrete Wall: pre - 1981
Concrete Wall: post - 1981
Building Class

# Montenegro Field Trip: 20th – 24th August 2014

Hannah Baker, Roxane Foulser-Piggott, Robin Spence, Cambridge Architectural Research Ltd.


*Figure 1: Map of Europe indicating the location of Montenegro (Red)*

# Table of Contents

Figure List ........ 4

List of Tables ........ 6

Acknowledgements ........ 7

1. Introduction ........ 8

2. Methodology ........ 8

2.1 Selection of Zones ........ 8

2.2 Zonal Analysis ........ 10

2.3 Limitations/Problems Occurred ........ 11

3. Overview/Results ........ 12

3.1 Seismic activity in Montenegro ........ 12

3.2 Survey Results ........ 14

3.3 Podgorica ........ 16

3.3.1 Overview ........ 16

3.3.2 Survey Results ........ 17

3.3.3 Atypical Building Stock ........ 24

3.3.4 Other vulnerability Issues/Adaptations ........ 24

3.4 Nikšić ........ 25

3.4.1 Overview ........ 25

3.4.2 Survey Results ........ 26

3.5 Cetinje ........ 32

3.5.1 Overview ........ 32

3.5.2 Survey Results ........ 32

3.6 Budva & Kotor ........ 36

3.6.1 Overview ........ 36

3.6.2 Survey Results ........ 37

3.7 Rural Areas ........ 41

3.7.1 Overview ........ 41

3.7.2 Vulnerability Issues ........ 42

4. Comparison to questionnaire results/Validation ........ 43

4.1 Urban Areas ........ 43

4.2 Rural Areas ........ 47

5. Conclusions ........ 48

6. References ........ 49

Appendices.....50
Appendix 1: Individual Surveys.....50
Maps.....50
Surveys.....53
Day 1 – Zone 5.....53
Day 1 – Zone 4.....54
Day 1 – Zone 10.....55
Day 1 – Zone 6.....56
Day 1 – Zone Y.....57
Day 1 – Zone X.....59
Day 2 – Zone 1.....60
Day 2 – Zone 2.....61
Day 3 – Cetinje.....63
Day 3 - Budva.....65
Appendix 2: Montenegro Questionnaire Response and Analysis.....67

# Figure List

Figure 1: Map of Europe indicating the location of Montenegro (Red) ..... 1
Figure 2: Apparent building type can be inferred by aerial imagery. Left: Roof types would suggest buildings are small multi-family dwellings. Right: Image suggests buildings are high-rise reinforced concrete tower blocks ..... 8
Figure 3: Montenegro Map – Regions and urban areas surveyed. Source: (FMECD, 2006, p. 9)..... 9
Figure 4: Day 2, Zone 2. Area in Nikšić showing how each building was identified with a number using aerial imagery obtained before the field trip. Sources: (Bing, 2014 & Google Maps, 2014) 11
Figure 5: Example of a completed survey – Day 2, Nikšić – Zone 2 (area shown in Figure 4)..... 11
Figure 6: Proportion of building damage levels within cities following the 1979 Montenegro Earthquake. Data Source: (UNDP, 1985)..... 13
Figure 7: GSHAP - 10% in 50 years Peak Ground Acceleration. Source: (USGS, 2014)..... 14
Figure 8: Montenegro Field Trip Results - Percentage of dwellings in each building class in urban areas ..... 15
Figure 9: Montenegro Field Trip Results - Percentage of buildings in each building class in urban areas ..... 15
Figure 10: Map - Podgorica, capital of Montenegro. Source: (Maps, 2014) ..... 16
Figure 11: Map - Survey Zones in Podgorica. Zones surveyed: 4, 5, 6, 10, X and Y. Source: (Bing, 2014) ..... 17
Figure 12: Podgorica Survey Results - Percentage of dwellings in each building class ..... 18
Figure 13: Podgorica Survey Results - Percentage of buildings in each building class..... 19
Figure 14: Rubble Stone Masonry. Left: Day 1, Building 1, Zone 6. Right: Day 1, Building 3, Zone 10. 19
Figure 15: Unit masonry with timber floors. Day 1, Building 8, Zone 10..... 20
Figure 16: Unit masonry with concrete floors. Left: Day 1, Building 4, Zone 4. Right: Day 1, Building 1, Zone 4. ..... 20
Figure 17: Confined masonry. Day 1, Building 6, Zone 6 ..... 21
Figure 18: Reinforced concrete frame - pre 1981. Day 1, Building 5, Zone 6..... 21
Figure 19: Reinforced concrete frame - post 1981. Day 1, Buildings 4-16, Zone Y ..... 21
Figure 20: Reinforced concrete wall - pre 1981. Left: Day 1, Building 6, Zone 5. Day 1, Right: Zone 8 ..... 22
Figure 21: Reinforced concrete wall - post 1981. Day 1, Building 1, Zone X. ..... 22
Figure 22: Predominant building types in the different areas surveyed in Podgorica – Day 1. Map Source: (Bing, 2014)..... 23
Figure 23: Russian Towers - Day 1, Building 2, Zone 5. Atypical construction technique as structural core built first ..... 24
Figure 24: Plan view: Concrete elements added to masonry walls to accommodate large openings for commercial purposes on the ground floor of buildings. ..... 24
Figure 25: Drop-down slab and splayed concrete capitals increase the strength of the floor and column connection. Day 1, Building 1, Zone X ..... 25
Figure 26: Map- Nikšić. Source: (Maps, 2014) ..... 25
Figure 27: Map and Survey Zones in Nikšić. Zones surveyed: 1 and 2. Source: (Bing, 2014)..... 26
Figure 28: Development in Nikšić. Arrow indicates direction of development since the construction of the historical core in the late 19th century..... 27
Figure 29: Nikšić Survey Results - Percentage of dwellings in each building class ..... 28
Figure 30: Nikšić Survey Results - Percentage of buildings in each building class..... 28

Figure 31: Unit masonry with timber floors. Day 2, Building 9, Zone 1 – Older, uneven tiles on roof. 29
Figure 32: Unit masonry with concrete floors. Left: Day 2, Building 1, Zone 1. Right: Day 2, Building 4, Zone 1 ..... 29
Figure 33: Confined masonry buildings - recent development to the north-east of Nikšić ..... 30
Figure 34: Reinforced concrete frame - pre 1981. Day 2, Buildings 4 -6, Zone 2. Left: Façade. Right: Detail of reinforcement exposed due to lack of concrete cover ..... 30
Figure 35: Reinforced concrete frame - pre 1981. Left: Day 2, Building 10, Zone 2. Right: Day 2, Zone 3 ..... 30
Figure 36: Predominant building types in the different areas surveyed in Nikšić – Day 2. Map Source: (Bing, 2014) ..... 31
Figure 37: Map – Cetinje. Source: (Maps, 2014) ..... 32
Figure 38: Survey zone – Cetinje. Map Source: (Bing, 2014) ..... 33
Figure 39: Cetinje Survey Results - Percentage of dwellings in each building class ..... 34
Figure 40: Cetinje Survey Results - Percentage of buildings in each building class ..... 34
Figure 41: Unit masonry with timber floors. Day 3 - Cetinje, Buildings 14-16 ..... 35
Figure 42: Unit masonry with concrete floors. Day 3 - Cetinje, Building 13 ..... 35
Figure 43: Confined masonry. Day 3 - Cetinje, Buildings 4-7. Ground floor adapted to accommodate wider commercial openings. ..... 36
Figure 44: Maps. Left: Budva. Right: Kotor. Map Source: (Maps, 2014) ..... 36
Figure 45: Survey Area, Budva, Day 3. Source: (Bing, 2014) ..... 37
Figure 46: Budva Survey Results - Percentage of dwellings in each building class ..... 38
Figure 47: Budva Survey Results - Percentage of buildings in each building class ..... 38
Figure 48: Rubble stone masonry buildings. Day 3, Kotor's Old Town ..... 39
Figure 49: Unit masonry with timber floors. Day 3, Kotor. Wall ties visible on many of the buildings. ..... 39
Figure 50: Confined Masonry. Left: Day 3 - Budva, building 11. Right: Area north of survey spot in Budva - confined masonry building under construction ..... 40
Figure 51: Reinforced concrete frame - post 1981. Left: Day 3 - Budva, Building 6. Right: Day 3 - Budva, Building 9 ..... 40
Figure 52: Map - Rural Areas 1-3. Source: (Bing, 2014) ..... 41
Figure 53: Rubble Stone Masonry. Left & Right: Day 2, Rural Area 2 ..... 41
Figure 54: Unit masonry with timber floors. Left: Day 2, Rural Area 1. Right: Day 2, Rural area 2. Metal sheeting on roof ..... 42
Figure 55: Confined masonry. Left & Right: Day 2, Rural Area 3 ..... 42
Figure 56: Distribution of Dwellings by Building Type in Urban Areas - Comparison of Questionnaire Results and Field Trip ..... 44
Figure 59: Distribution of Dwellings by Building Type in Urban Areas - Comparison of Questionnaire Results and Re-calculated Dwellings from the Field Trip ..... 46
Figure 60: Distribution of dwellings in rural areas - Questionnaire Response ..... 47
Figure 61: Survey Area, Budva, Day 3. Source: (Bing, 2014) ..... 52

# List of Tables

Table 1 Housing characterisation zones and areas surveyed ............ 9
Table 2 Categorisation of buildings in survey zones – see Figure 5 for an example of a completed survey ............ 10
Table 3 Limitations/problems and how they were overcome ............ 12
Table 4: Average number of dwellings in a building for different building classes/structure types .... 16
Table 5: Comparison between the average number of dwellings in a building for different building classes/structure types from the field trip and questionnaire response ............ 45
Table 6: Comparison between the distribution of dwellings and buildings surveyed during the field trip and dwellings within the questionnaire response (urban areas) ............ 47

# Acknowledgements

Cambridge Architectural Research Ltd. would like the express their appreciation and thanks to Professor Bozidar Pavicevic, Jelena Pejovic and Nina Serdar from the Faculty of Civil Engineering at the University of Montenegro, for their valuable contribution to the field trip and willingness to give their time so generously.

# 1. Introduction

This report presents the methodology and findings of Cambridge Architectural Research Ltd.'s (CAR's) field trip to Montenegro as part of their contribution to Level 0 and 1 of the European Building Inventory Database, deliverable 7.5 of the Network of European Research Infrastructures for Earthquake Risk Assessment and Mitigation (NERA)

The aim of the field trip was to validate and compare results to other methods of data collection including data inferences, expert questionnaires and Street View surveys used within the NERA project, with the overall aim of defining dwelling fractions (the proportion of the dwelling stock categorised by different structure types) in urban and rural areas (Baker, et al., 2014).

The field trip took place from the 20th - 24th August 2014. It comprised of surveys categorising individual buildings by structure type and dwelling numbers in ten zones, in four different cities and the general analysis of urban and rural areas.

This report describes the methodology, results and the validation and comparison to other methods. It then provides conclusions.

# 2. Methodology

## 2.1 Selection of Zones

Before the field trip commenced, over thirty zones were selected in different areas of Montenegro. Aerial images of the buildings were printed alongside a map identifying the areas.

Zones were selected by identifying residential zones in a range of areas according to their apparent building types. As shown from Figure 2, types of urbanisation can be inferred from aerial imagery.


*Figure 2: Apparent building type can be inferred by aerial imagery. Left: Roof types would suggest buildings are small multi-family dwellings. Right: Image suggests buildings are high-rise reinforced concrete tower blocks*

More areas were selected than required as advice was sought by experts whilst in Montenegro to identify which areas were reflective of the typical building stock.

The Architectural Atlas of Montenegro (FMECD, 2006) divides Montenegro into five regions, as shown by Figure 3. Survey zones were selected within the different regions (excluding the least populated Mountain Region, due to time limitations).


*Figure 3: Montenegro Map – Regions and urban areas surveyed. Source: (FMECD, 2006, p. 9)*

In terms of housing characterisation and structure types, FMECD (2006) groups some of these regions together into three zones, as shown by Table 1.

*Table 1 Housing characterisation zones and areas surveyed*

| **Zones** | **Regions** | **Areas Surveyed/Visited** |
|---|---|---|
| Southern Region | The Coastal Region | • Budva<br>• Kotor |
| Central Region | The Karst Region<br>The Zeta-Bjelopavlici Region | • Podgorica<br>• Cetinje<br>• Rural Areas between Podgorica and Cetinje |
| Northern Region | The Mountain Region<br>The Valley Region | • Nikšić<br>• Areas surrounding Nikšić |

## 2.2 Zonal Analysis

The selected zones were analysed in a similar way to the Street View Survey conducted in CAR's previous investigations (Baker et al, 2014).The categories used for structure type are the same as those used within the expert questionnaires to allow for validation and comparison. A selection of buildings were selected around the centroid of a zone, as shown in Figure 4 and categorised in the following way:

*Table 2 Categorisation of buildings in survey zones – see Figure 5 for an example of a completed survey*

| **Categorisation** | **Description** |
|---|---|
| Building Number | Each building was given a number and identified on a map. See Figure 4 |
| Number of Floors | Number of Floors within a building |
| Basement Visible (Y/N) | Indication on whether or not the building had a basement |
| Approximate number of dwellings | An approximation of the number of dwellings (e.g. flats/apartments) within each building. |
| Structural Categorisation/Building Class | Indication of the building's structure type from pre-defined options:<br>• Timber or Log<br>• Load Bearing Masonry<br>  ○ Adobe/fieldstone/rubble stone<br>  ○ Unit masonry with timber floors<br>  ○ Unit masonry with concrete floors<br>  ○ Reinforced/Confined Masonry<br>• Reinforced Concrete<br>  ○ Concrete frame – pre 1981<br>  ○ Concrete frame – post 1981<br>  ○ Concrete wall – pre 1981<br>  ○ Concrete wall – pot 1981<br>• Other |
| Additional Details | Additional details about the building which may affect its vulnerability in an earthquake |

The survey data was assembled in a survey form specific to each survey area (Figure 5).

The CAR team was accompanied by researchers/practicing engineers from the Faculty of Civil Engineering, University of Montenegro for the first day in Podgorica to assist in identifying building typologies.

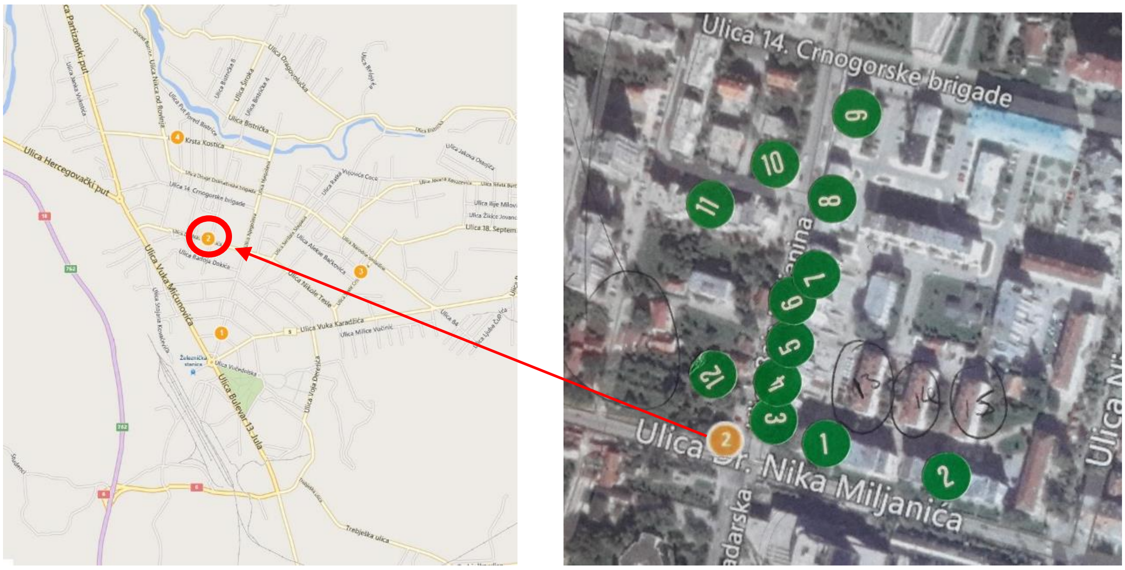



*Figure 4: Day 2, Zone 2. Area in Nikšić showing how each building was identified with a number using aerial imagery obtained before the field trip. Sources: (Bing, 2014 & Google Maps, 2014)*

| | |
|---|---|
| **Day** | 2 |
| **Zone Number** | 2 |

| Bu. No. | Number of Floors | Basement Visible (Y/N) | Approximate Number of Dwellings | **Timber or log** | **Load-Bearing Masonry** adobe/ fieldstone | unit masonry with TIMBER floors | unit masonry with CONCRETE floors | reinforced / confined masonry | **Reinforced Concrete** Concrete frame - pre 1981 | Concrete frame post-1981 | Concrete wall: pre - 1981 | Concrete wall: post - 1981 | **Other** | Additional Details |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 1 | 5 | y | 48 | | | | | | x | | | | | commercial ground floor.at least 4 entrance |
| 2 | 5 | y | 48 | | | | | | x | | | | | "" |
| 3 | 7 | y | 24 | | | | | | x | | | | | |
| 4 | 8 | y | 40 | | | | | | x | | | | | |
| 5 | 8 | y | 40 | | | | | | x | | | | | |
| 6 | 7 | y | 24 | | | | | | x | | | | | |
| 7 | 4 | y | 24 | | | | | | x | | | | | asbestos? cladding |
| 8 | 3 | y | 24 | | | | | | x | | | | | |
| 9 | 2 | n | 1 | | | | x | ? | | | | | | renovated shop in 70s |
| 10 | 5 | y | 68 (+57) | | | | | | x | | | | | yellow - wood outside |
| 11 | 2 (3) | | 2 | | | | x | | | | | | | concrete roof. maybe infer concrete beam fl |
| 12 | 4 | y | 32 | | | | | | x | | | | | 2 entrances. brick jnfill. Same as no.1 |
| 13 | 4 | y | 32 | | | | | | x | | | | | brick infill |
| 14 | 4 | y | 32 | | | | | | x | | | | | brick infill |

*Figure 5: Example of a completed survey – Day 2, Nikšić – Zone 2 (area shown in Figure 4)*

## 2.3 Limitations/Problems Occurred

Overall, the field trip was successful with few limitations/problems. Those which were faced are identified in Table 3:

*Table 3 Limitations/problems and how they were overcome*

| Limitation/Problem | How Overcome |
|---|---|
| Difficulty distinguishing between some building types e.g. masonry with timber or concrete floors | Consultation with practicing engineers in Montenegro and expert judgement |
| Restrictions taking photographs due to being in a residential area | In some cases, pictures were not taken as house owners were suspicious. To overcome this, a letter explaining the project in Montenegrin was shown if approached |
| Northern Montenegro not analysed due to time restrictions | Information on the building stock in these areas was obtained from expert consultation. |
| Maps not accurate – In many cases road networks were not well represented and the road signs were in Cyrillic script which did not correspond with maps. | In some areas, alternative survey zones had to be used - made note of name and housing layout |

# 3. Overview/Results

## 3.1 Seismic activity in Montenegro

As shown by Figure 6 and Figure 7, Montenegro is in a region of high seismicity. On 15th April 1979, at 07.19 local time, the coastal area of Montenegro was struck by a 6.9Ms earthquake, resulting in the death of 94 people in Montenegro and a further 35 in Albania. A number of the coastal towns including Budva and Kotor were severely damaged, the worst area being the Ulcinj municipality where 47% of the building stock was destroyed/collapsed ((UNDP), 1985). Figure 6 identifies areas where damage studies were undertaken and the proportion of buildings surveyed at different damage levels.

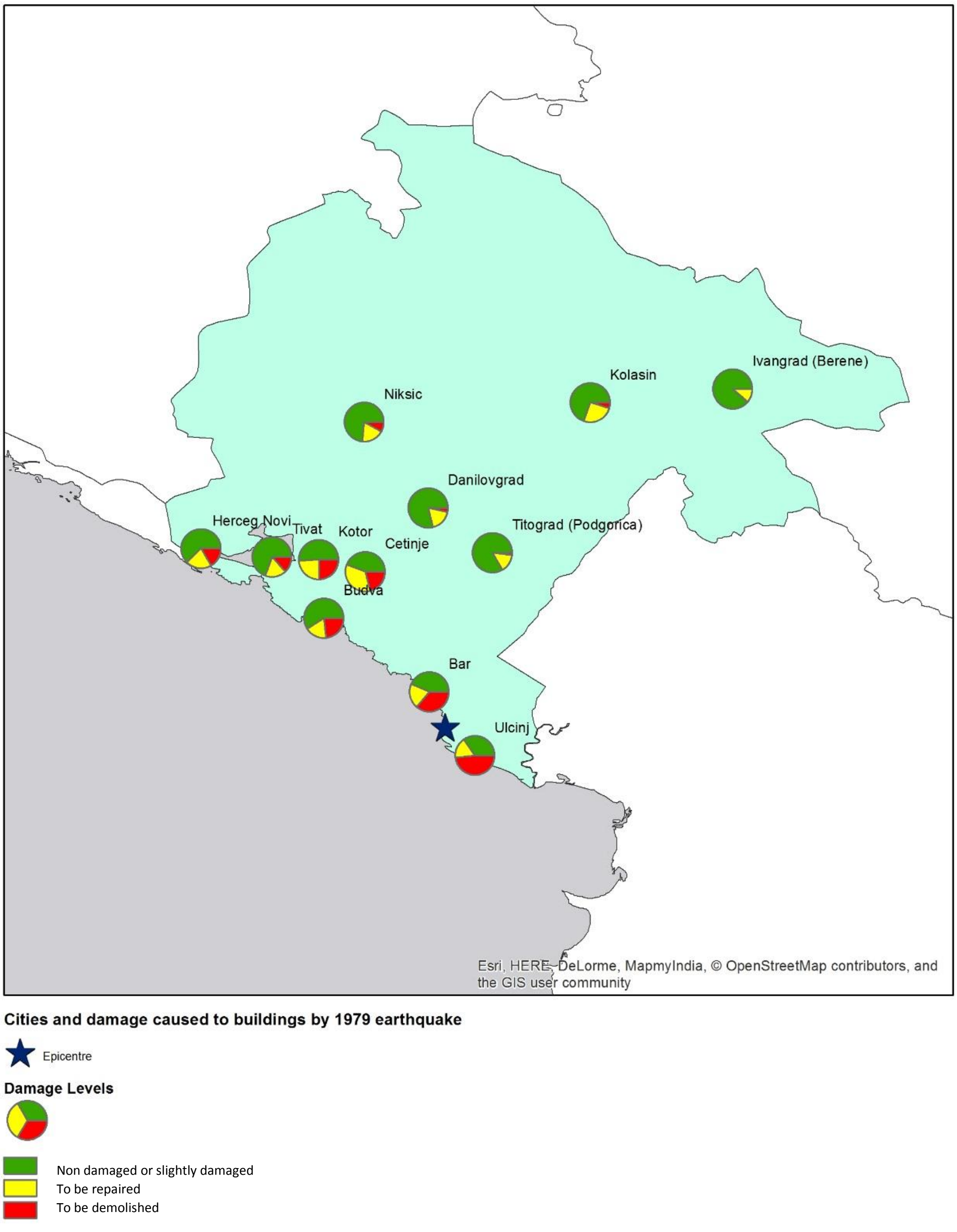



*Figure 6: Proportion of building damage levels within cities following the 1979 Montenegro Earthquake. Data Source: (UNDP, 1985)*

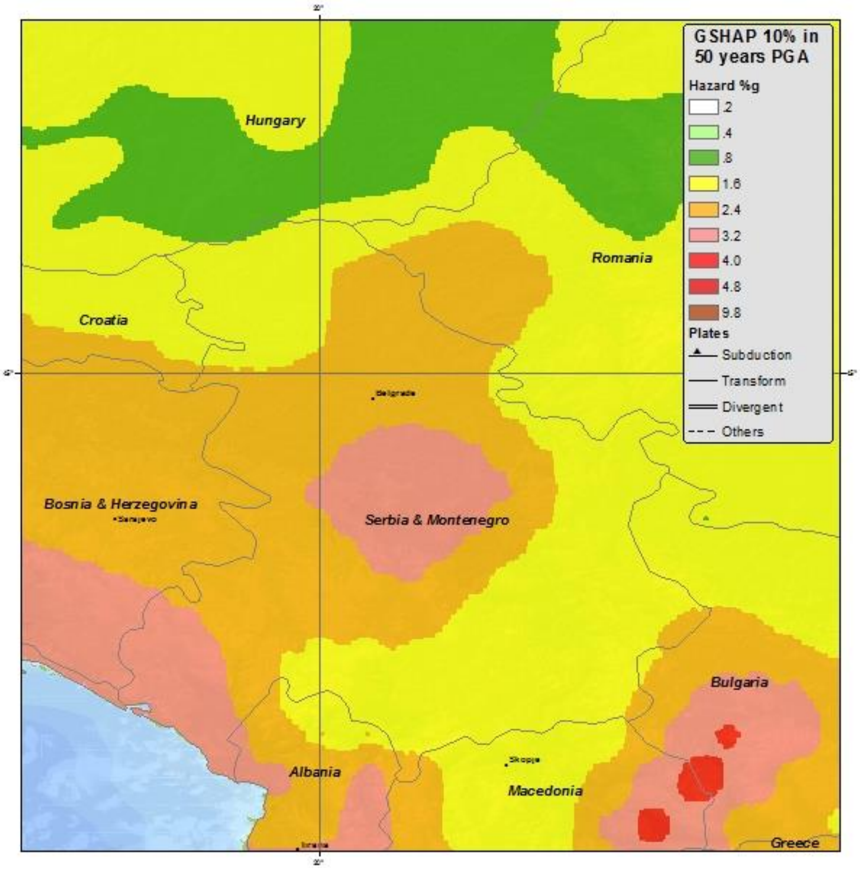



*Figure 7: GSHAP - 10% in 50 years Peak Ground Acceleration. Source: (USGS, 2014)*

The significance of seismic hazard is recognised by many in Montenegro (Glavatović, 2008). The building codes used are specific to Montenegro but were initially based on German codes. This was common practice following the 1963 Skopje earthquake, in present day Serbia. Currently earthquake engineers are trying to implement Eurocode 8 and are developing a Country Annex specific for Montenegro. However, this is not yet implemented.

## 3.2 Survey Results

During the field trip, 111 buildings were surveyed equating to 2934 dwellings in 10 different areas. Other areas were analysed via a general overview rather than a building by building survey.

Geo-located photographs are available at:
http://eepimap.com/overview/?&zoomtoextent=True&eventid=196

The overall distribution of buildings and dwellings in urban areas is shown in Figure 8 and Figure 9.

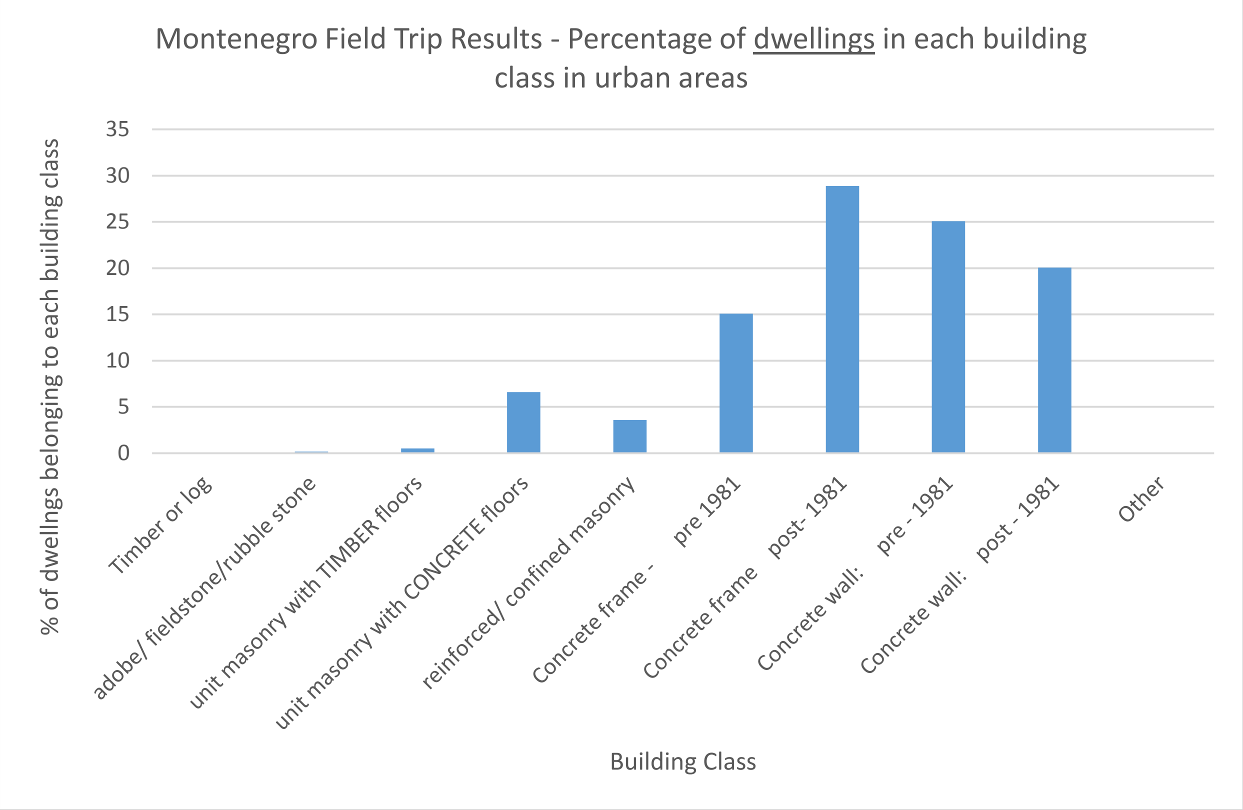



*Figure 8: Montenegro Field Trip Results - Percentage of dwellings in each building class in urban areas*

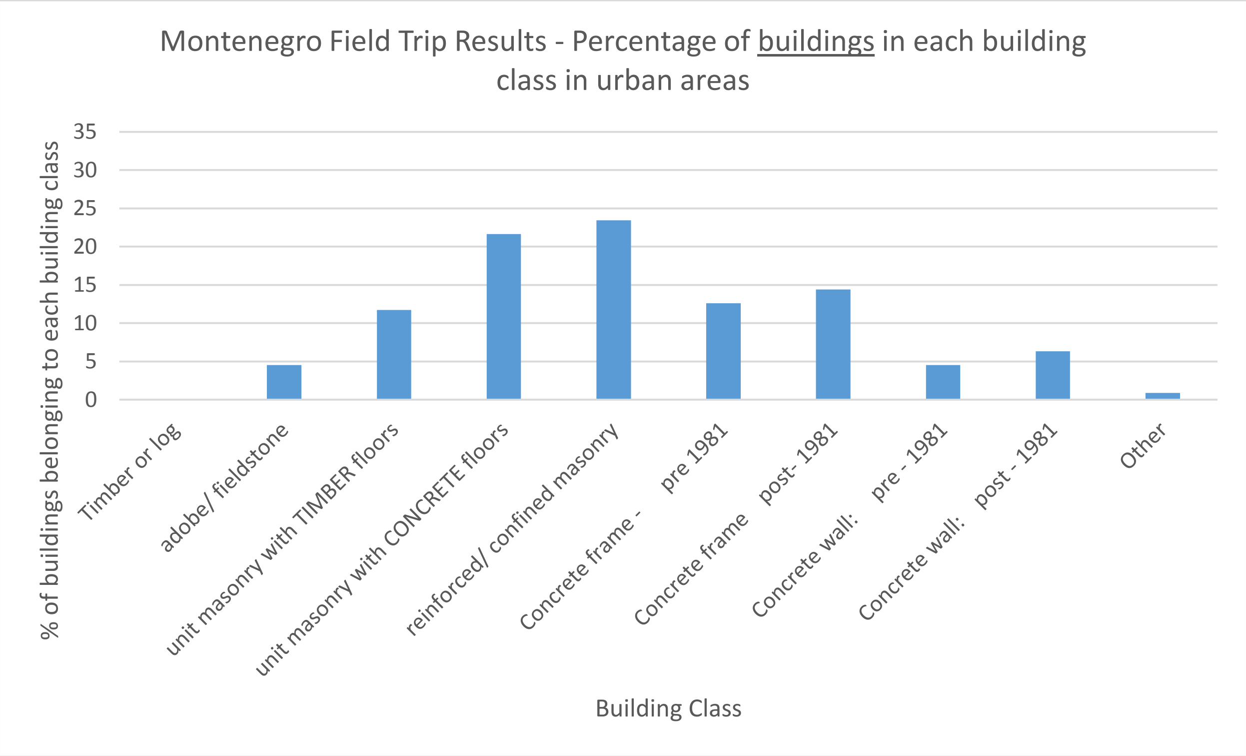



*Figure 9: Montenegro Field Trip Results - Percentage of buildings in each building class in urban areas*

Due to the high number of dwellings within some multi-family structures there is a significant difference between the distribution of buildings by building class and the distribution of dwellings by building class. When only considering dwellings, the sampled building stock appears to be dominated by reinforced concrete structures. When only considering buildings (and not the number of dwellings within them), there is a higher proportion of masonry buildings, which are often associated with individual family dwellings and small multi-family structures. Table 4 outlines the average number of dwellings for the 111 buildings surveyed.

*Table 4: Average number of dwellings in a building for different building classes/structure types*

| | **Building Class** | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|
| | **Timber or log** | **adobe/ fieldstone** | **unit masonry with TIMBER floors** | **unit masonry with CONCRETE floors** | **reinforced/ confined masonry** | **Concrete frame - pre 1981** | **Concrete frame post- 1981** | **Concrete wall: pre - 1981** | **Concrete wall: post - 1981** | **Other** |
| **Average number of dwellings in a building** | n/a | 1 | 1 | 8 | 4 | 32 | 53 | 147 | 84 | 0 |

## 3.3 Podgorica

### 3.3.1 Overview


*Figure 10: Map - Podgorica, capital of Montenegro. Source: (Maps, 2014)*

Podgorica is the current capital of Montenegro and has a population of approximately 140,000 people (Antonovic, et al., 2014). A large majority of Podgorica was destroyed in the Second World War, therefore it is characterised by a relatively new building stock.

### 3.3.2 Survey Results

Figure 11 shows the location of zones surveyed in Podgorica. In total of 37 buildings/2213 dwellings were surveyed in 6 different zones: 4, 5, 6, 10, X and Y.

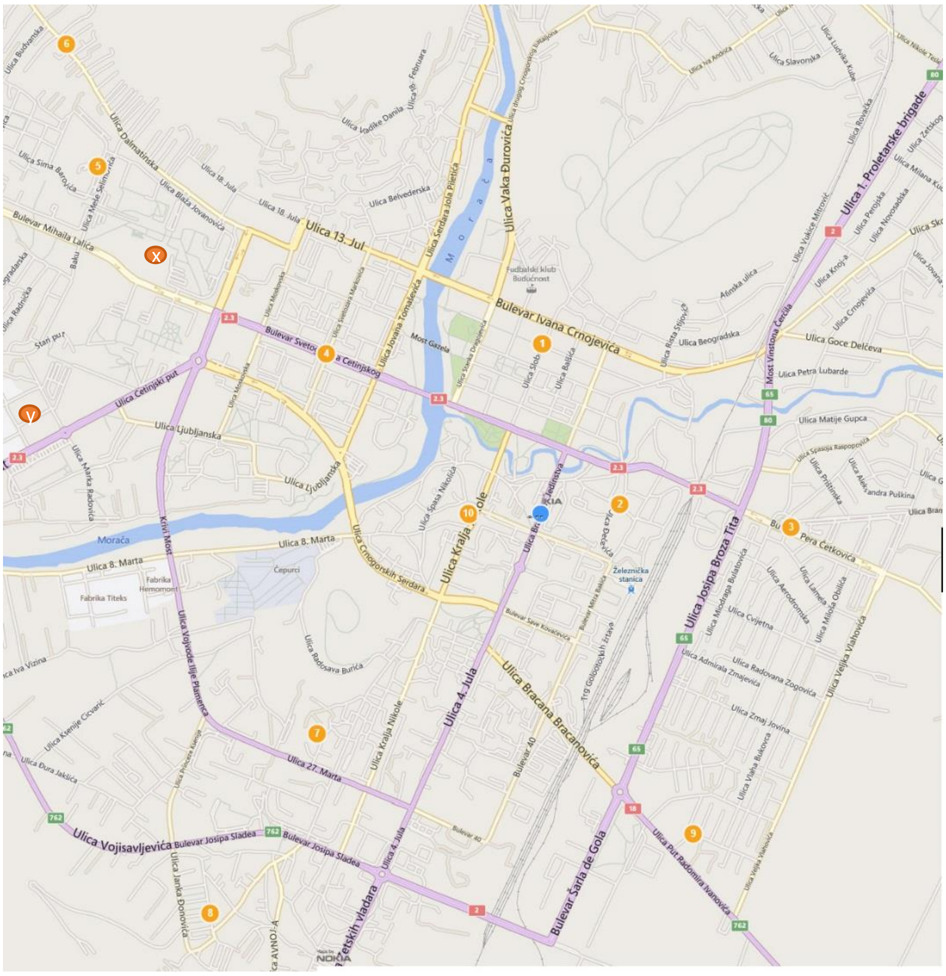



*Figure 11: Map - Survey Zones in Podgorica. Zones surveyed: 4, 5, 6, 10, X and Y. Source: (Bing, 2014)*

Figure 12 and Figure 13 show the overall distribution of dwellings and buildings by building classes using the survey results. Due to the high number of dwellings within concrete buildings, the dwelling distribution clearly shows high proportions of concrete constructions. However, when looking at the distribution of buildings, although there is still a larger proportion of concrete structures, there is a significant amount of masonry.

The oldest buildings are located in the Turkish Old Town (Zone 10) which contains small family dwellings constructed from rubble stone and unit masonry with timber floors. Elsewhere in Podgorica, single family dwellings tend to be newer and are constructed from masonry with concrete floors or confined masonry, for example Zone 6.

The majority of multi-family dwellings surveyed were constructed from reinforced concrete, both frame and wall. Often a dual system was used - a combination of frame and wall. In general, these have been categorised as frame as the key feature of a wall system is the regularity of the plan and many of the dual systems lacked this feature. Zone 5 was characterised by these concrete constructions.

There were a few examples of masonry multi-family constructions. These tended to have concrete floors and in many cases the ground floor had been converted for commercial use by adding concrete elements, Zone 4 was characterised in this way.

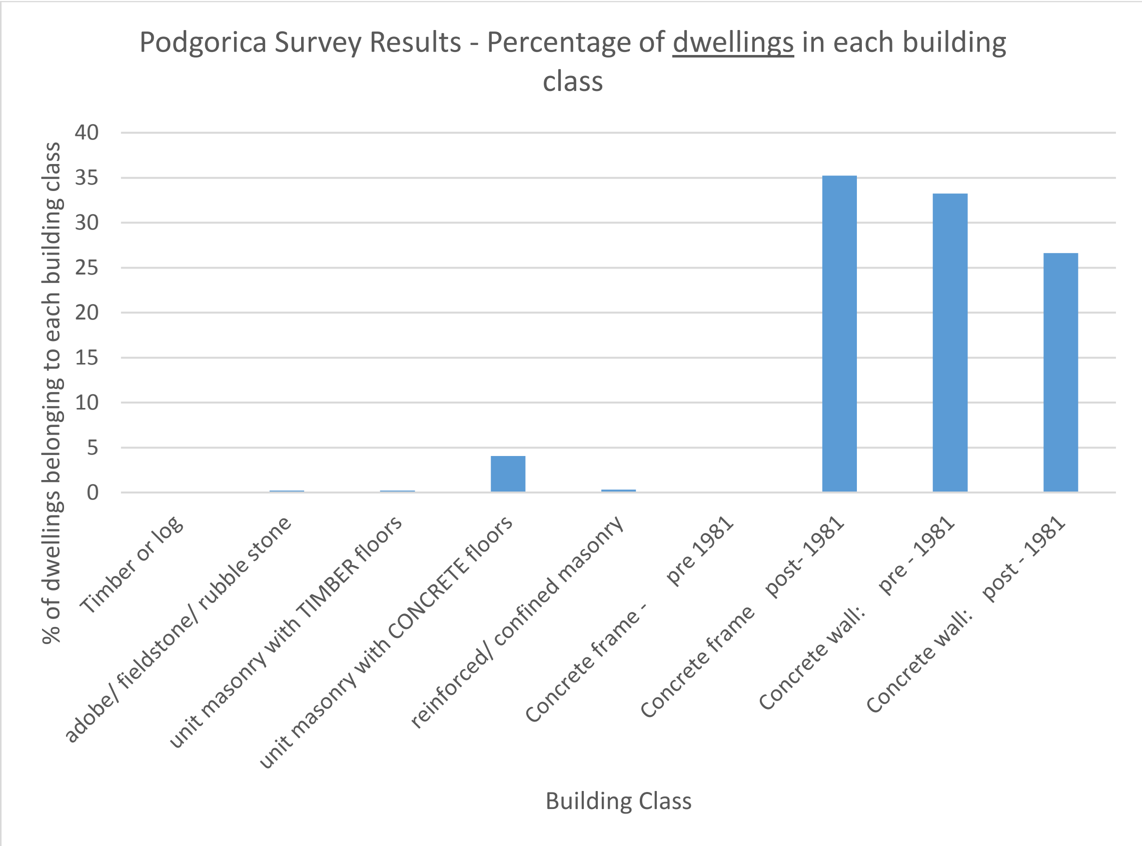



*Figure 12: Podgorica Survey Results - Percentage of dwellings in each building class*

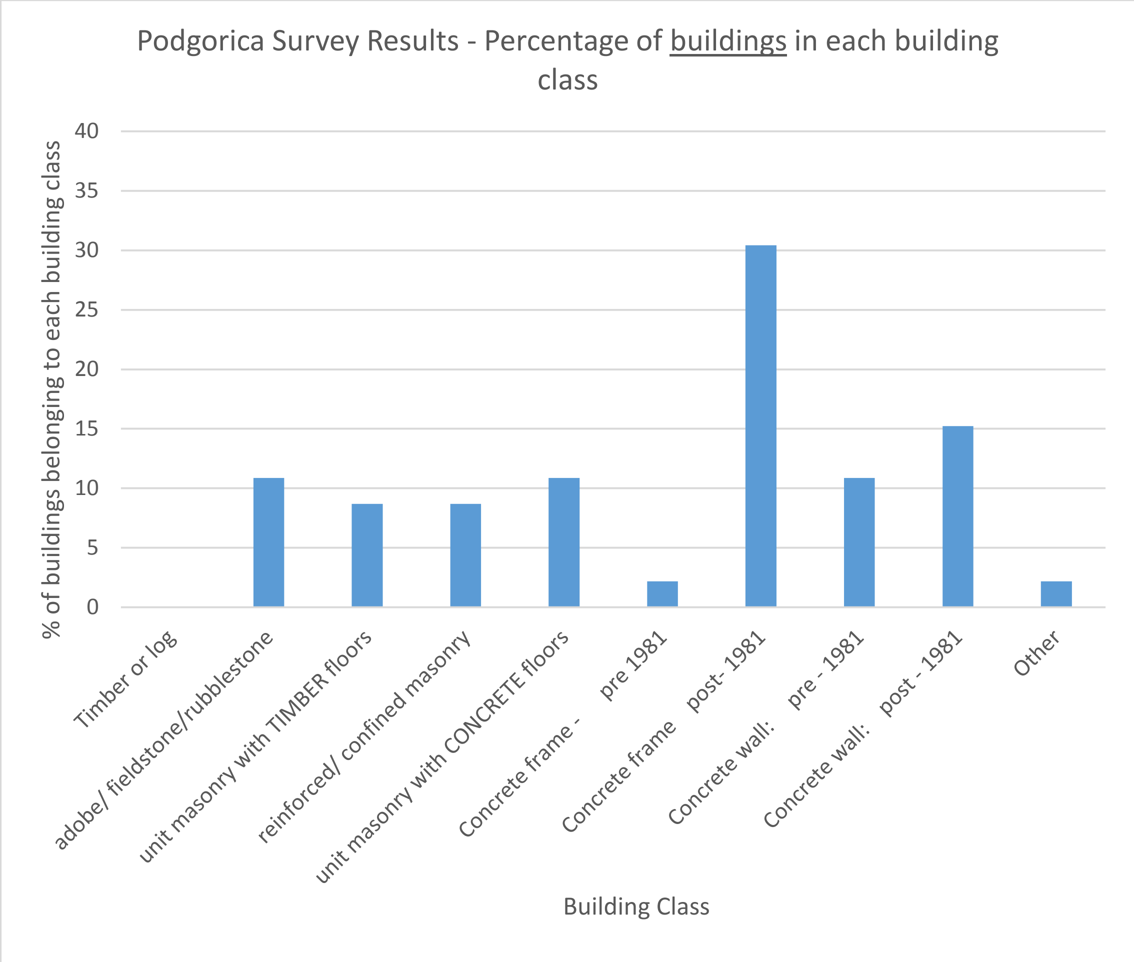



*Figure 13: Podgorica Survey Results - Percentage of buildings in each building class*

Examples of all the construction types identified in Podgorica are shown in Figure 14 to Figure 21.

**Rubble stone masonry**

Load bearing walls of rubble stone with lime or mud mortar. Often have a timber roof with clay tiles.

*Figure 14: Rubble Stone Masonry. Left: Day 1, Building 1, Zone 6. Right: Day 1, Building 3, Zone 10*

## Unit masonry with timber floors

Load-bearing walls of unit masonry. Masonry tended to be hollow clay blocks, concrete block and in some cases natural stone. Laid in courses with mortar of cement or lime. Roofs tend be pitched and constructed from timber, often covered by clay tiles. In many cases, these tiles appeared to be lighter in weight than those found on concrete roofs and the roof line appeared more uneven due to warping of the timber joists.

*Figure 15: Unit masonry with timber floors. Day 1, Building 8, Zone 10*

## Unit masonry with concrete floors

Similar to unit masonry with timber floors but with concrete floors and often a concrete roof. Buildings ranged in height, sometimes up to six stories.

*Figure 16: Unit masonry with concrete floors. Left: Day 1, Building 4, Zone 4. Right: Day 1, Building 1, Zone 4.*

## Confined Masonry

Popular construction technique starting in the 1990s. Load-bearing walls of confined masonry – masonry walls confined by concrete elements. Roofs tended to be pitched and constructed from either concrete or timber. Floors – hollow tile infill floors (Figure 17 - Right).

*Figure 17: Confined masonry. Day 1, Building 6, Zone 6. Left: Front elevation. Right: Hollow tile infill floor*

## Reinforced Concrete Frame – Pre 1981

Loads carried by reinforced concrete moment-resisting frame consisting of beams and columns. Infill walls tend to be of masonry. Floors and roof constructed from concrete. Built prior to 1981.

*Figure 18: Reinforced concrete frame - pre 1981. Day 1, Building 5, Zone 6*

## Reinforced Concrete Frame – Post 1981

Same construction technique as reinforced concrete frame built prior to 1981. However, more likely to be built according to building codes considering seismic risk.

*Figure 19: Reinforced concrete frame - post 1981. Day 1, Buildings 4-16, Zone Y*

**Reinforced Concrete Wall – Pre 1981**

Loads carried by reinforced concrete bearing wall, or by an infilled reinforced concrete frame with additional regularly-spaced reinforced concrete walls, floors and roofs. Built prior to 1981 and the enforcement of building codes.

*Figure 20: Reinforced concrete wall - pre 1981. Left: Day 1, Building 6, Zone 5. Day 1,  Right: Zone 8*

**Reinforced Concrete Wall – Post 1981**

Similar construction techniques as reinforced concrete wall - pre 1981, but more likely to be built adhering to building codes considering seismic risk.

*Figure 21: Reinforced concrete wall - post 1981. Day 1, Building 1, Zone X.*

-

Different areas within Podgorica were dominated by different building types. The individual survey results are shown in Appendix 1. Figure 22 provides a summary of the building types in each selected zone, emphasising how different areas of the city are characterised by different building types.

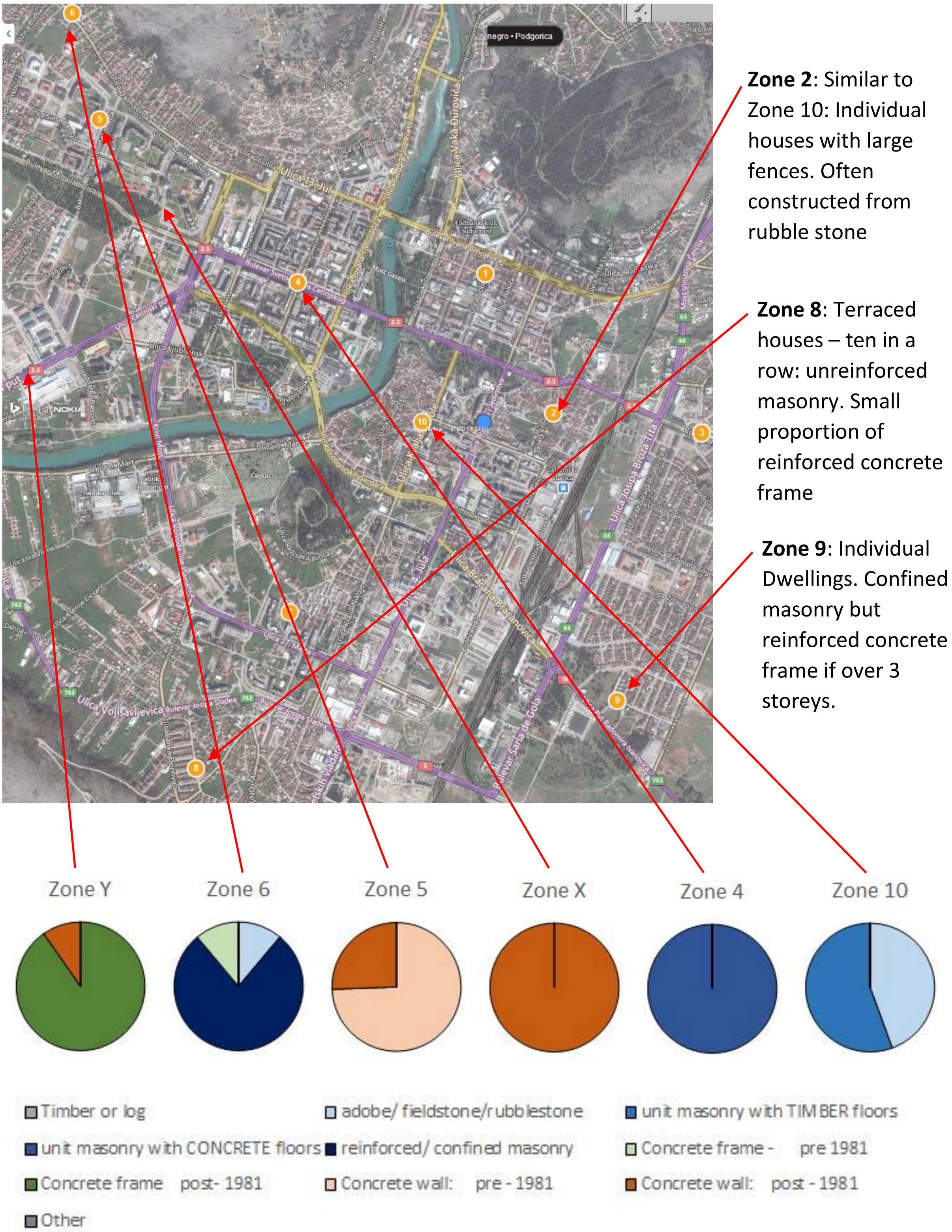



*Figure 22: Predominant building types in the different areas surveyed in Podgorica – Day 1. Map Source: (Bing, 2014)*

Podgorica is located in the Zeta-Bjelopavlici Region of Montenegro. The area appears to be of mixed used with residential properties, commercial and public buildings. As shown by Figure 22, these include a range of building types. In many areas, the population density is high and there are large –

multi-family dwellings, whereas in others, particularly towards the outskirts of the city, buildings tend to be smaller.

### 3.3.3 Atypical Building Stock

During the surveys, some atypical construction techniques were identified. The Russian Towers (Buildings 1 – 3) in Zone 5 (Figure 23) are unusual as the shaft/core was built first and the structure was expanded outwards. Normally in Montenegro, buildings are constructed storey by storey.

*Figure 23: Russian Towers - Day 1, Building 2, Zone 5. Atypical construction technique as structural core built first*

### 3.3.4 Other vulnerability Issues/Adaptations

Throughout Montenegro, numerous examples of the adaptation to the ground floor of masonry buildings was identified. Often, concrete elements are added in order to increase the size of openings for commercial use (Figure 24). This ensures the buildings conform to current building codes.

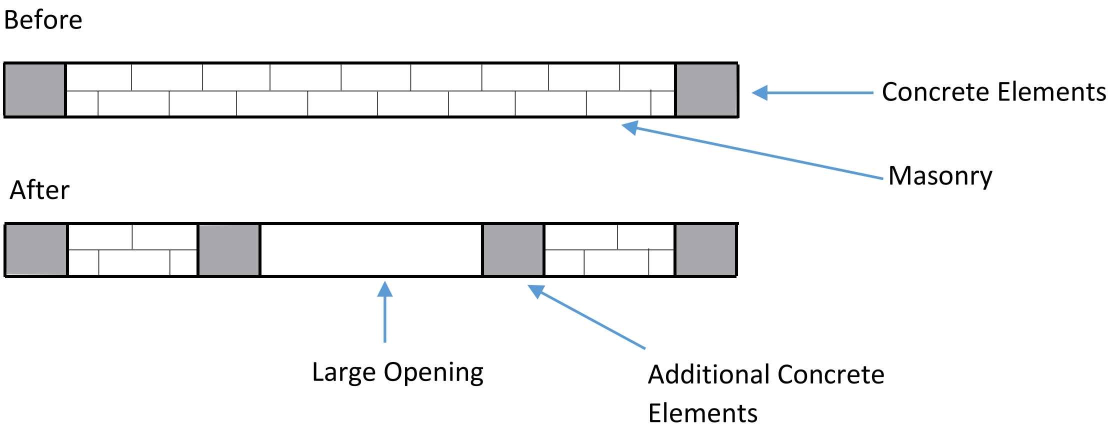



*Figure 24: Plan view: Concrete elements added to masonry walls to accommodate large openings for commercial purposes on the ground floor of buildings (not to scale).*

New constructions tend to be built to code and consider a structure's vulnerability to earthquakes. Due to the density of development, a number of the buildings have basements used as car parks. Whilst surveying buildings, on more than one occasion, the basements had a two-way flat slab with drop panels and splayed concrete capital. This increases the strength of the floor and column connection ((CRSI), 2014) . The shape of the capital increases the punching shear strength of the slab-column connection (G.J., 2012).

*Figure 25: Drop-down slab and splayed concrete capitals increase the strength of the floor and column connection. Day 1, Building 1, Zone X*

## 3.4 Nikšić

### 3.4.1 Overview

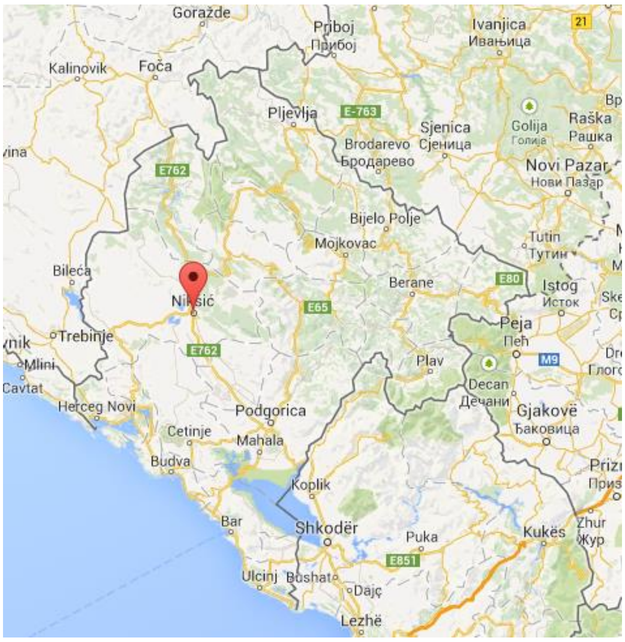



*Figure 26: Map- Nikšić. Source: (Maps, 2014)*

Following the Second World War the population of Nikšić increased from approximately 2000 before the war to 6000 people after (Adzic, 2014). The current population is 58,000 people, making Nikšić Montenegro's second largest city (Antonovic, et al., 2014). In the 1960s and 70s immigration continued due to the development of an iron factory, thus increasing the demand for housing in the area. Recently the number of workers at the factory has significantly declined from 7000 in the 1980s to 300 (Adzic, 2014). Nikšić has not benefitted in the same way as Podgorica in terms of redevelopment schemes and in many areas the living standard is lower than that in the capital.

The outskirts of the town have a number of informal settlements, these are not necessarily poor quality, but are built without permission.

### 3.4.2 Survey Results

Figure 27 shows the location of zones (1 and 2) surveyed in Nikšić. In total, 24 buildings (523 dwellings) where analysed.

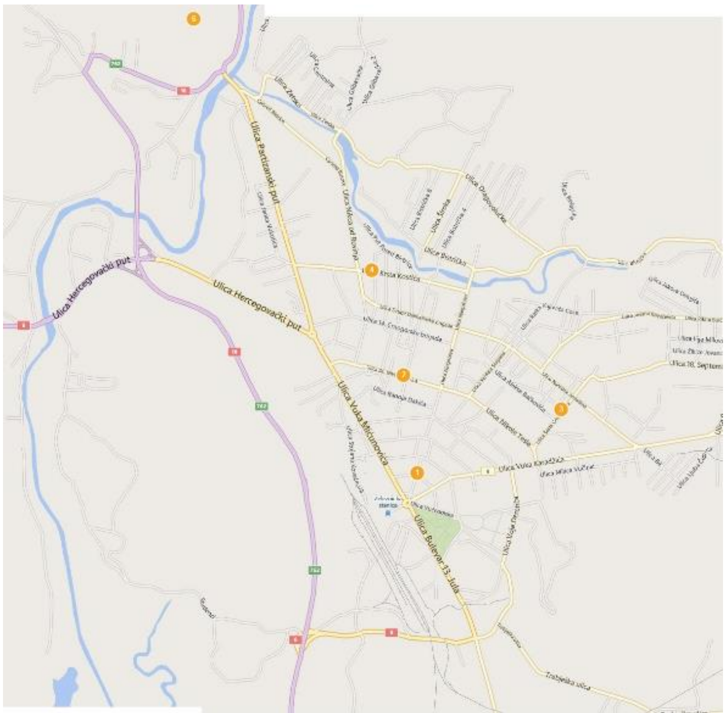


*Figure 27: Map and Survey Zones in Nikšić. Zones surveyed: 1 and 2. Source: (Bing, 2014)*

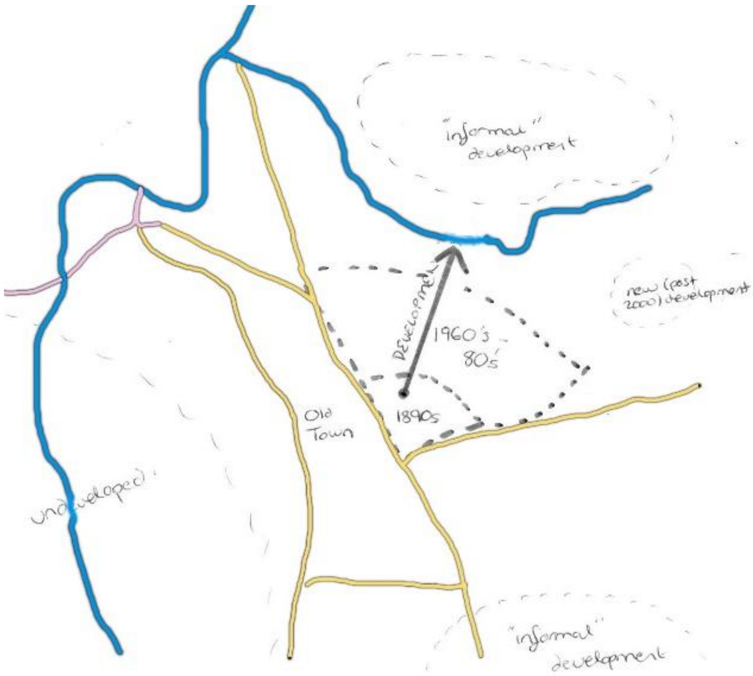



*Figure 28: Development in Nikšić. Arrow indicates direction of development since the construction of the historical core in the late 19th century. Information Source: (Adzic, 2014)*

Figure 29 and Figure 30 show the overall distribution of dwellings and building types by their building class.

Zone 1, was characterised by different forms of masonry construction, mainly unit masonry with concrete floors. This zone was near to the historic centre of Nikšić built in the late 19th century. Figure 28 displays the direction of development. Zone 2 is located in the area built in the 1960s – 80s developed due to the migration of factory workers. It was characterised by multi-family reinforced concrete frame buildings. In comparison to some of the buildings seen in Podgorica, these were in poor condition, e.g. exposed reinforcement bars due to a lack of concrete cover. In some areas, new development has begun to be constructed. This was good quality confined masonry. Examples of all these buildings are shown in Figure 31 to Figure 35.

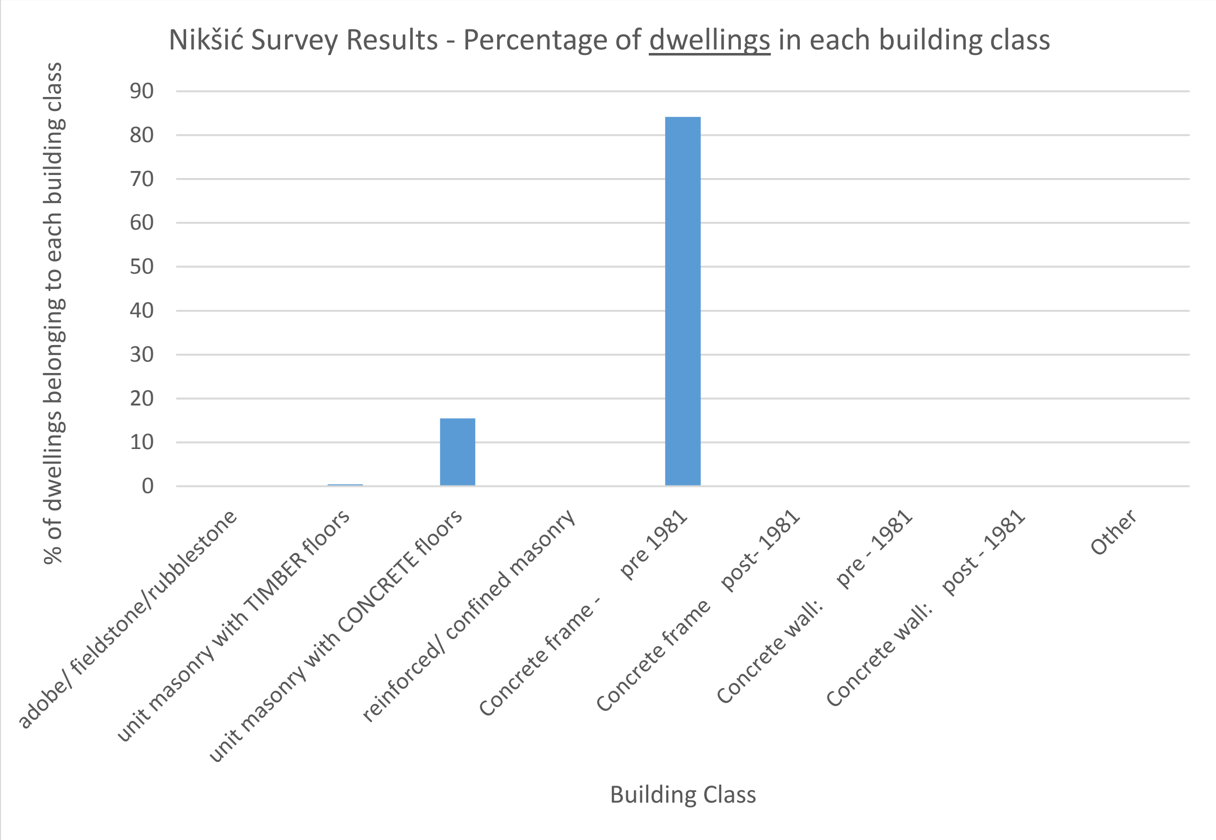



*Figure 29: Nikšić Survey Results - Percentage of dwellings in each building class*

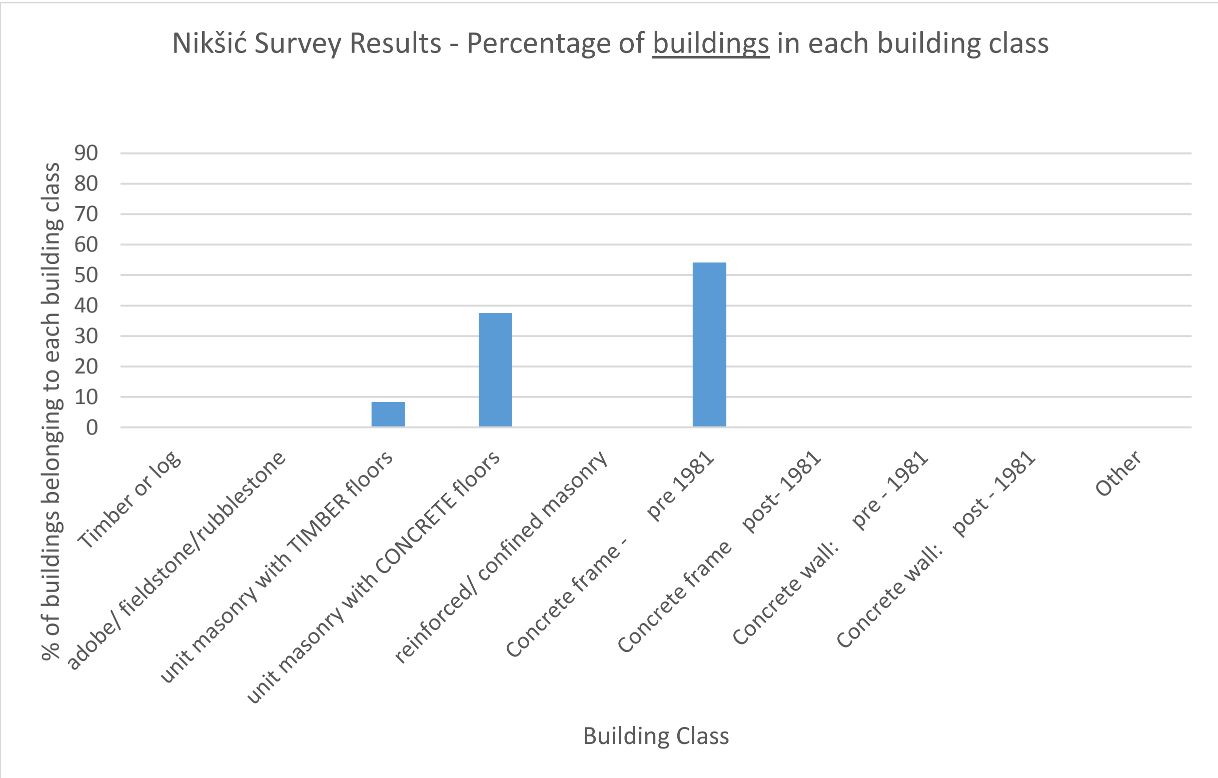



*Figure 30: Nikšić Survey Results - Percentage of buildings in each building class*

## Unit masonry with timber floors

Often associated with single family dwellings or small multi-family dwellings. Found in the historic core.

*Figure 31: Unit masonry with timber floors. Day 2, Building 9, Zone 1 – Older, uneven tiles on roof.*

## Unit masonry with concrete floors

*Figure 32: Unit masonry with concrete floors. Left: Day 2, Building 1, Zone 1. Right: Day 2, Building 4, Zone 1*

## Confined Masonry

The outskirts of the city has recently (post 2000) had development take place. In comparison to some of the buildings in the historic core, this is a much higher quality.

*Figure 33: Confined masonry buildings - recent development to the north-east of Nikšić*

**Reinforced Concrete Frame – Pre 1981**

In comparison to the concrete frame buildings in Podgorica, the buildings in Nikšić tended to be poor quality and would be vulnerable in an earthquake.


*Figure 34: Reinforced concrete frame - pre 1981. Day 2, Buildings 4 -6, Zone 2. Left: Façade. Right: Detail of reinforcement exposed due to lack of concrete cover*

*Figure 35: Reinforced concrete frame - pre 1981. Left: Day 2, Building 10, Zone 2. Right: Day 2, Zone 3*

As previously mentioned, different areas of the town were characterised by different building types. Figure 36 demonstrates the contrast between the two zones surveyed and other areas.

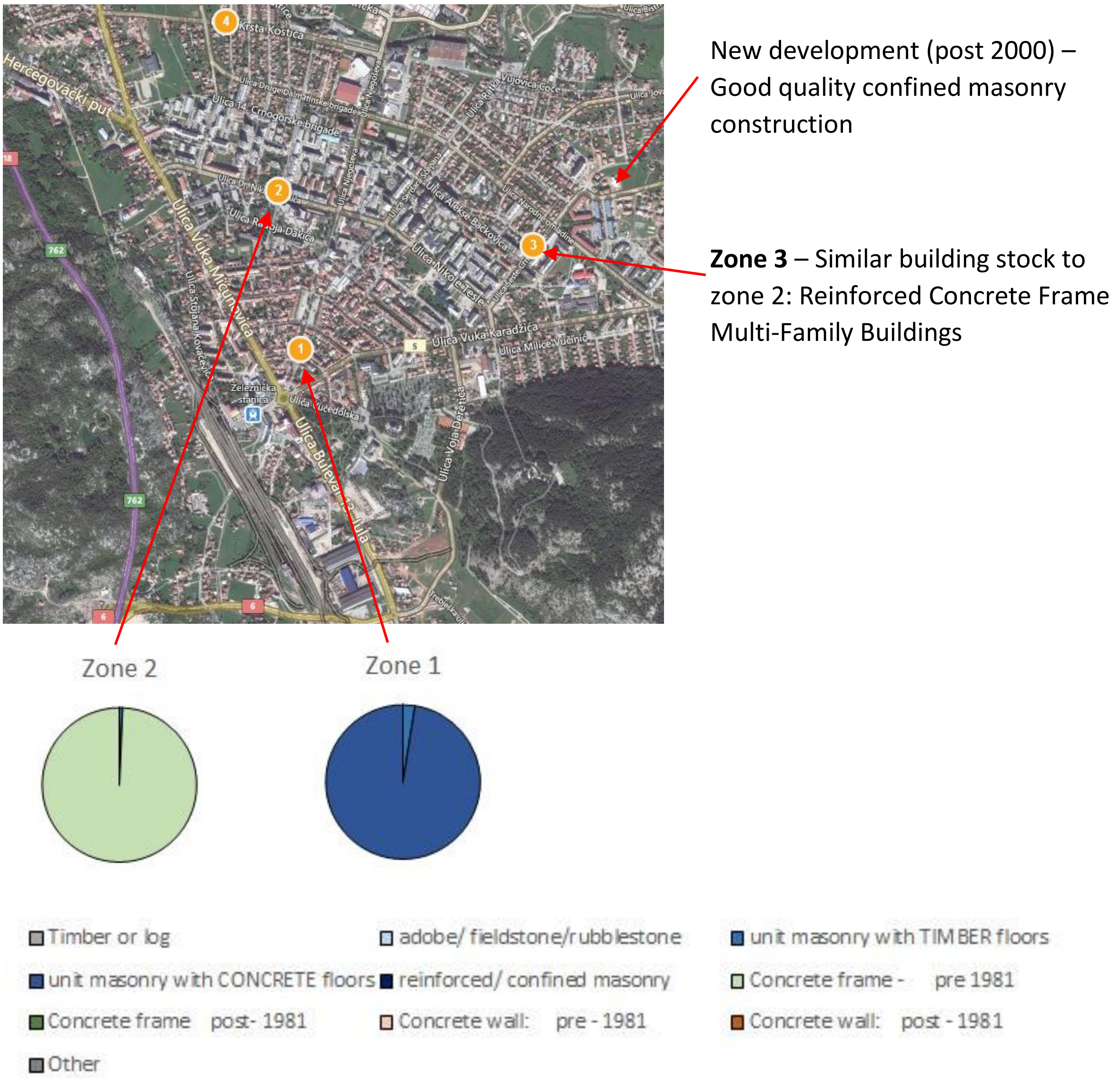



*Figure 36: Predominant building types in the different areas surveyed in Nikšić – Day 2. Map Source: (Bing, 2014)*

Nikšić is located in the Valley Region of Montenegro. Although the construction types were similar to Podgorica, they were of a poorer quality and there had been less investment in the area. Within Montenegro, there has been more investment and development in the South rather than the North: Valley and Mountain Regions.

# 3.5 Cetinje

## 3.5.1 Overview

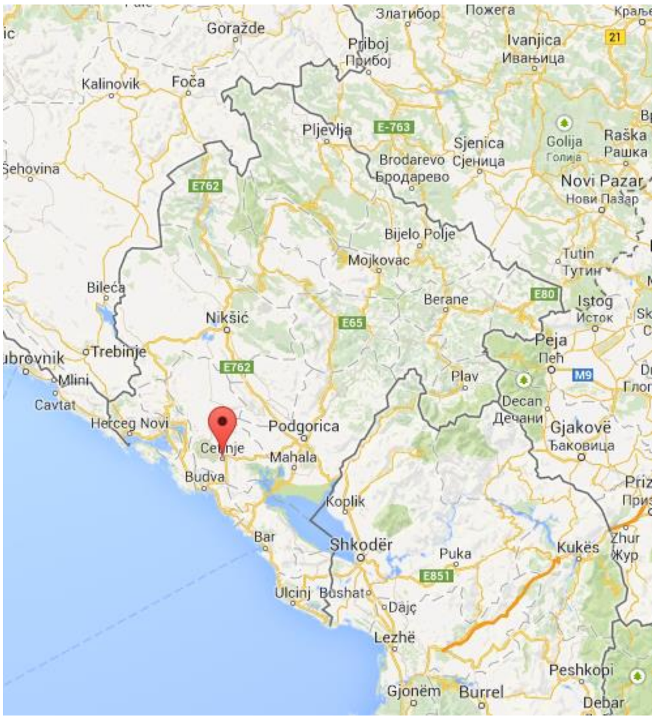



*Figure 37: Map – Cetinje. Source: (Maps, 2014)*

Cetinje is the historical capital of Montenegro with a population of approximately 15,000 people. There are traces back to 1878, the first independence of Montenegro and at the end of the 19th Century, new construction began to take place and the city was characterised by low-rise houses along straight streets (Antonovic, et al., 2014).

## 3.5.2 Survey Results

One area was surveyed in Cetinje (Figure 38), which was believed to be typical of the building stock and was located in the centre of the town. A total of 26 buildings (51 dwellings) were surveyed.


*Figure 38: Survey zone – Cetinje. Map Source: (Bing, 2014)*

The results indicated that all of the buildings surveyed were constructed using different masonry techniques, this is reflective of the age of the building stock. Unlike the previous urban areas, buildings tended to be low-medium rise and single or small multi-family dwellings. A small number of concrete constructions were located within the city, however those seen tended to be for public or large-scale commercial use, not residential.

Due to the survey area being in a commercial area, the majority of the masonry building's ground floors had been adapted to accommodate wide openings (as discussed in Section 3.3.4) for commercial use.

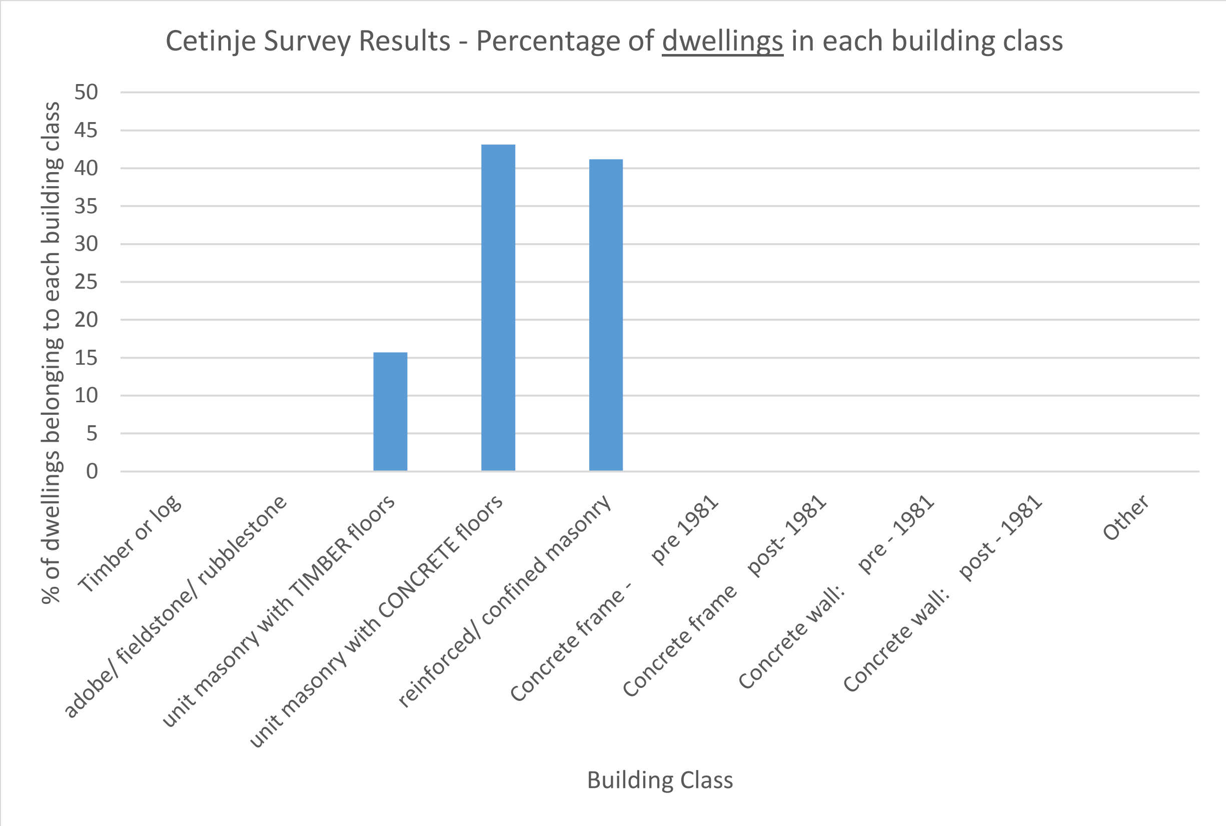



*Figure 39: Cetinje Survey Results - Percentage of dwellings in each building class*

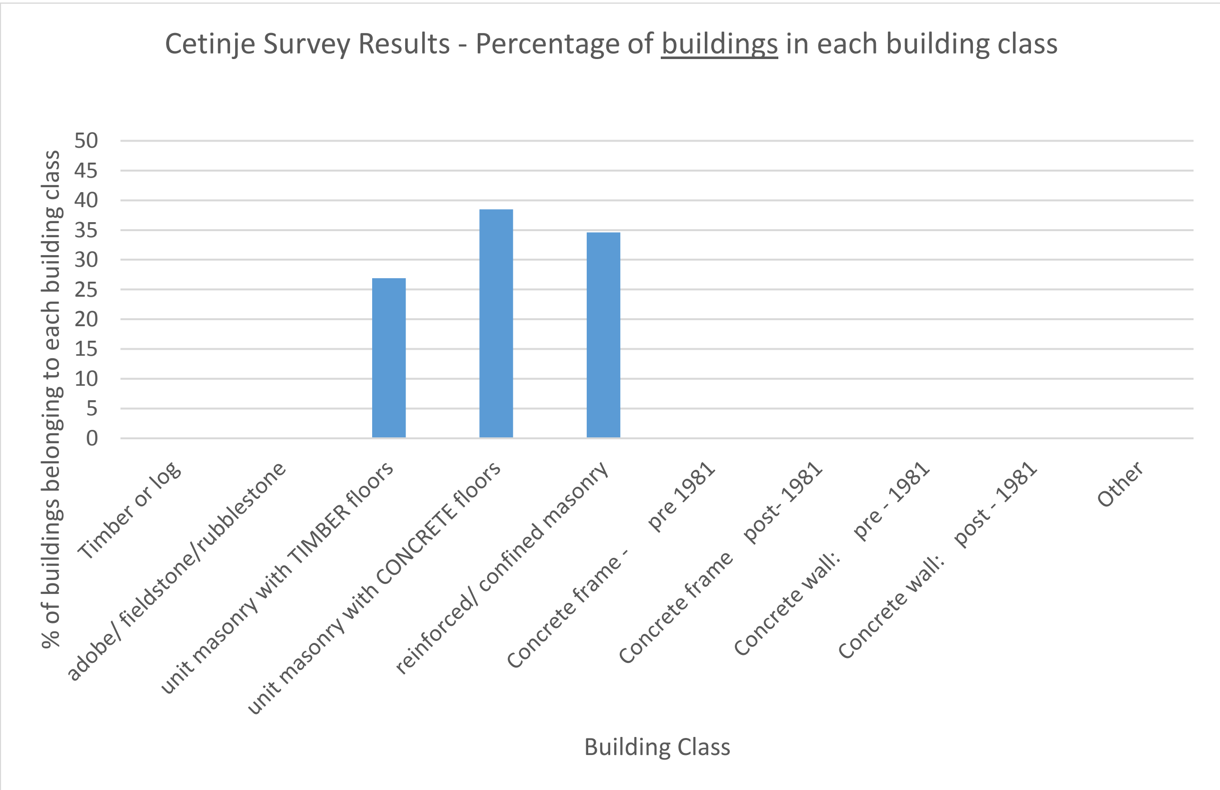



*Figure 40: Cetinje Survey Results - Percentage of buildings in each building class*

**Unit Masonry with Timber Floors**

The age of the building reflects the type of masonry construction used. Older, small family dwellings tended to have timber floors, whereas newer constructions had concrete floors and those built since 1990 are likely to be confined masonry.

*Figure 41: Unit masonry with timber floors. Day 3 - Cetinje, Buildings 14-16*

**Unit Masonry with Concrete Floors**

*Figure 42: Unit masonry with concrete floors. Day 3 - Cetinje, Building 13*

**Confined Masonry**


*Figure 43: Confined masonry. Day 3 - Cetinje, Buildings 4-7. Ground floor adapted to accommodate wider commercial openings*

## 3.6 Budva & Kotor

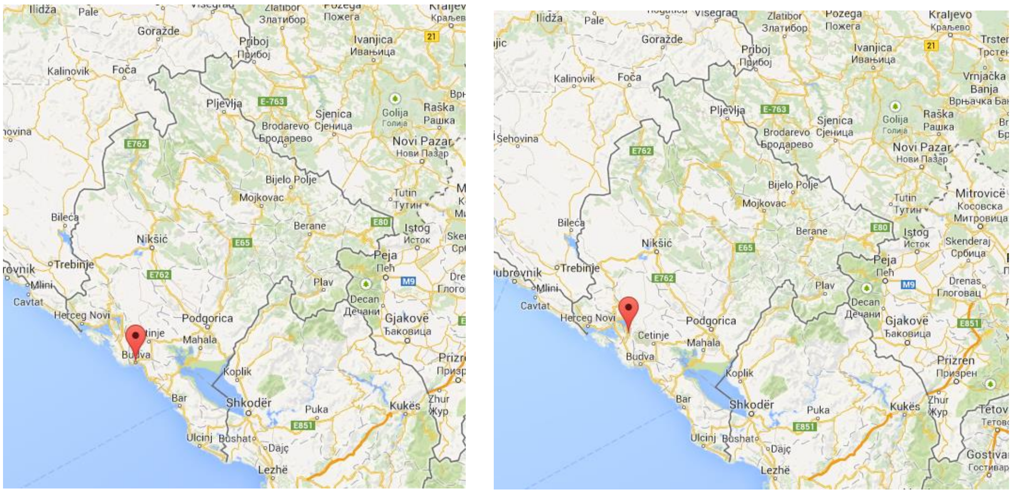



*Figure 44: Maps. Left: Budva. Right: Kotor. Map Source: (Maps, 2014)*

### 3.6.1 Overview

Both Kotor and Budva were severely damaged in the 1979 earthquake. As reported by post-earthquake surveys, in Budva, from the 2468 buildings surveyed, 18% needed to be repaired and 23% had to be demolished. In Kotor, from the 5766 buildings surveyed, 24% had to be repaired and 25% demolished ((UNDP), 1985). Traces of the destruction from the earthquake in Budva are said to have disappeared (Antonovic, et al., 2014). Following the earthquake, the historical part of Kotor was declared a UNESCO World Heritage Site to ensure it was reconstructed (ibid.).

Both Budva and Kotor are coastal towns, which have received investment from holiday makers. Budva is the fastest growing town in Montenegro with a current population of 10,000 people (ibid.).

### 3.6.2 Survey Results

During the field trip, one area was surveyed in Budva (Figure 45) – there was a total 15 buildings (146 dwellings) surveyed. The analysis of Kotor was a general overview.

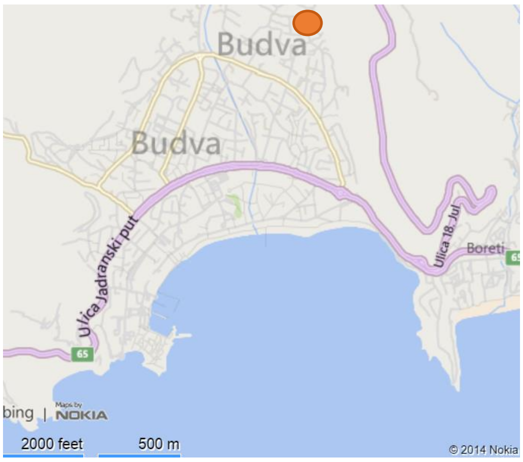



*Figure 45: Survey Area, Budva, Day 3. Source: (Bing, 2014)*

Figure 46 and Figure 47 display the distribution of dwellings and buildings in a residential area of Budva by their building class. The majority of the buildings were either confined masonry or reinforced concrete frame. These tended to be good quality.

The coast of Budva was dominated by dense high-rise reinforced concrete buildings.

In Kotor, the historical town was characterised by rubble stone masonry or unit masonry with timber floors. In some places, traditional metal wall ties were visible as an attempt to strengthen the structures against earthquakes. Photographs of structure types in both cities are displayed in Figure 50 to Figure 53.

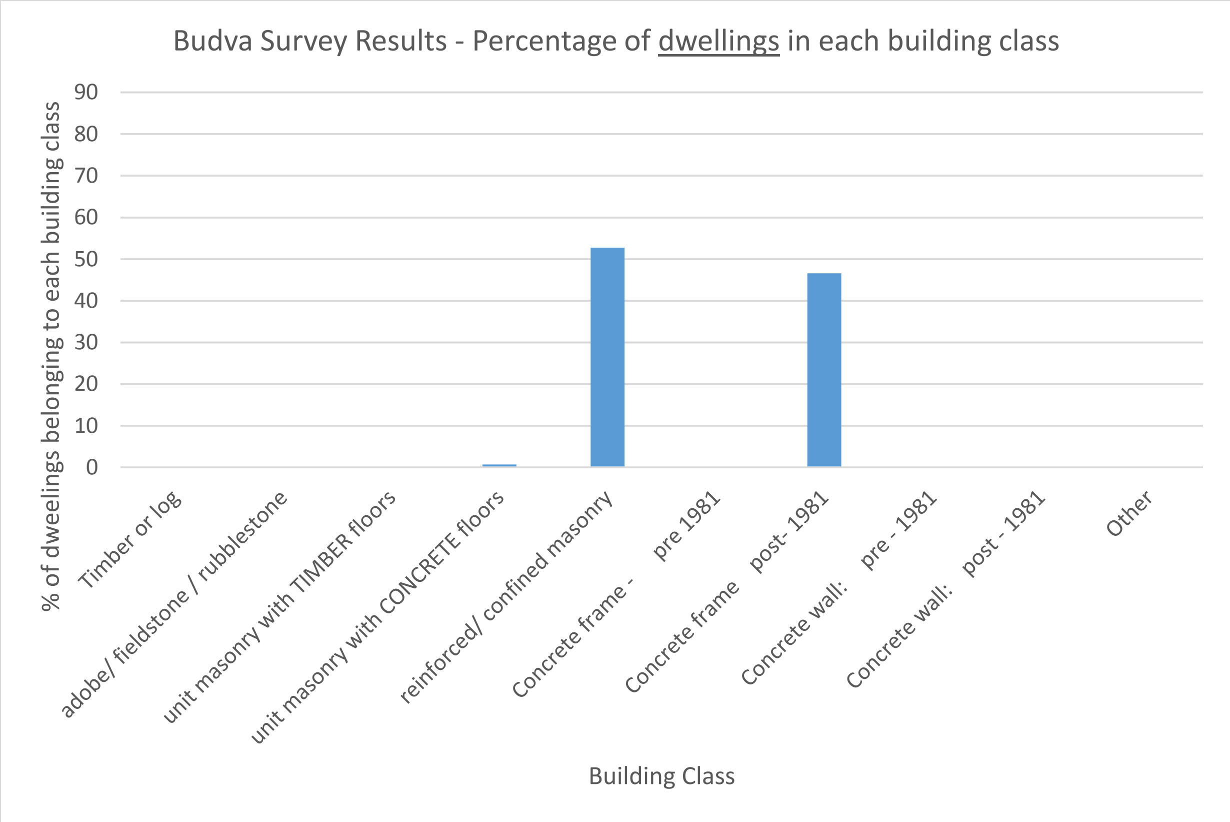



*Figure 46: Budva Survey Results - Percentage of dwellings in each building class*

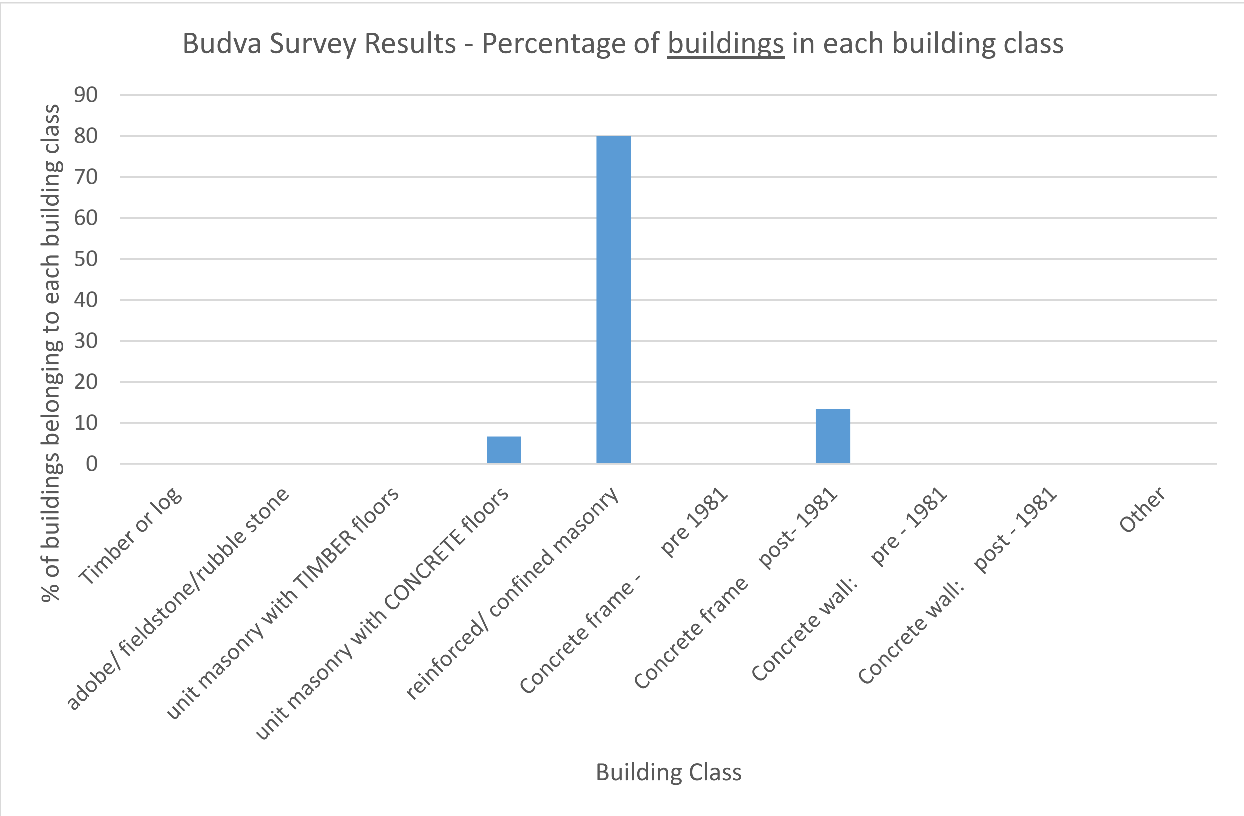



*Figure 47: Budva Survey Results - Percentage of buildings in each building class*

**Rubble Stone**

Within Kotor's old town (UNESCO World heritage site) there were numerous examples of rubble stone masonry buildings built closely together with narrow streets.

*Figure 48: Rubble stone masonry buildings. Day 3, Kotor's Old Town*

**Unit Masonry with Timber Floors**

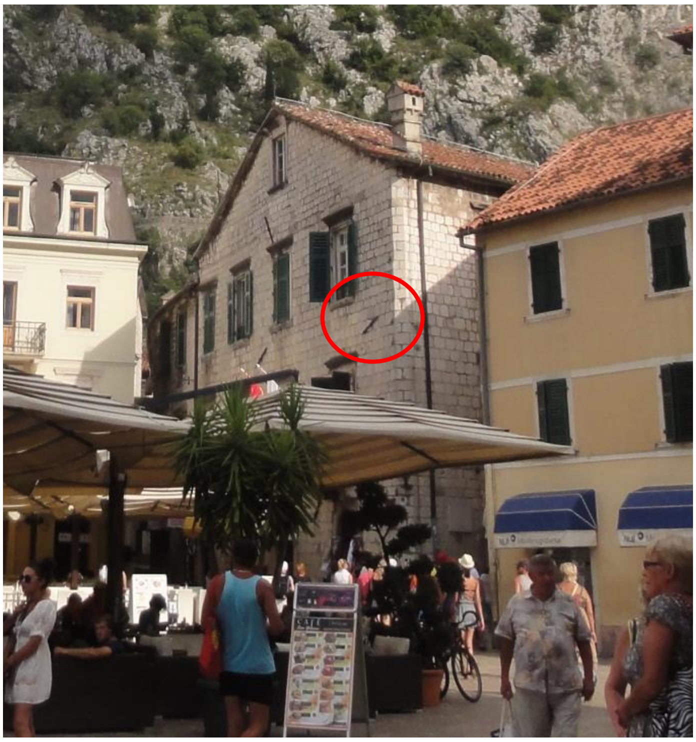


*Figure 49: Unit masonry with timber floors. Day 3, Kotor. Wall ties visible on many of the buildings.*

## Confined Masonry

Low-rise and medium-rise structures tended to be constructed from confined masonry, whereas medium to high-rise buildings were reinforced concrete frame.

*Figure 50: Confined Masonry. Left: Day 3 - Budva, building 11. Right: Area north of survey spot in Budva - confined masonry building under construction*

## Reinforced Concrete Frame - Post 1981

*Figure 51: Reinforced concrete frame - post 1981. Left: Day 3 - Budva, Building 6. Right: Day 3 - Budva, Building 9*

Kotor and Budva are both located in the coastal region of Montenegro. There were two main types of development. The historical centres were constructed from rubble stone or unit masonry with timber floors, whereas new residential development tended to be confined masonry or reinforced concrete frame. Due to the location of the cities, near to the coast, investment and development is visible. In some cases, such as Budva's coastline, this is particularly dense with high-rise buildings close together due to the value of the land. This will be vulnerable if an earthquake occurs.

Compared to the other regions, there were fewer examples of single-family buildings due to the high land value in the area.

## 3.7 Rural Areas

### 3.7.1 Overview

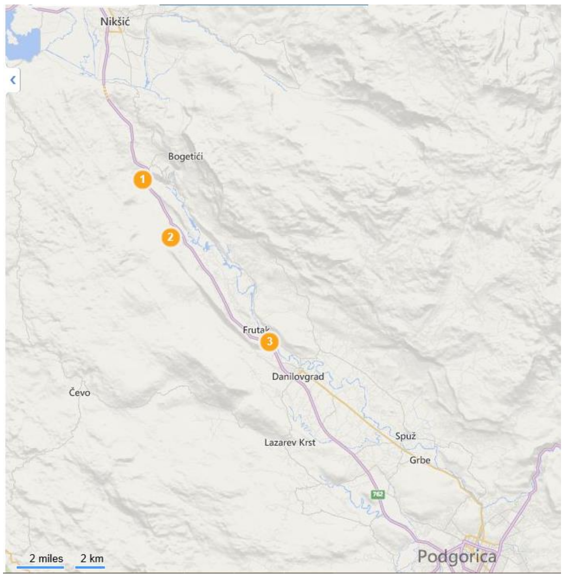



*Figure 52: Map - Rural Areas 1-3. Source: (Bing, 2014)*

The density of development in rural areas was lower than in urban centres. Individual surveys were not conducted, however a general analysis was undertaken by driving through different zones and identifying the different building types. The structures were predominantly different forms of masonry construction, and a couple of timber buildings were identified.

Rural zones 1 and 2 (Location shown in Figure 52), were generally older constructions and therefore rubble stone masonry or unit masonry with timber floors. Whereas, rural zone 3, was newly developed and the buildings were constructed using confined masonry. Photographs are shown in Figure 53 to Figure 55.

**Rubble Stone Masonry**

*Figure 53: Rubble Stone Masonry. Left & Right: Day 2, Rural Area 2*

**Unit masonry with timber floors**

*Figure 54: Unit masonry with timber floors. Left: Day 2, Rural Area 1. Right: Day 2, Rural area 2. Metal sheeting on roof*

**Confined Masonry**

*Figure 55: Confined masonry. Left & Right: Day 2, Rural Area 3*

The rural areas analysed were located in Montenegro's Central Region (The Karst Region and The Zeta-Bjelopavlici Region). During drives throughout Montenegro and to the other zones, the other rural areas seemed similar in character to those described.

### 3.7.2 Vulnerability Issues

Access to some of the rural areas was difficult and via narrow lanes on steep hill sides. If an earthquake was to occur in these areas, the road would be vulnerable to rock falls and access to the village would be difficult.

# 4. Comparison to questionnaire results/Validation

The overall aim of the field trip was to gain a better understanding of the building stock in Montenegro and compare the results to those produced by data inferences and expert questionnaires.

It must be acknowledged that sampling 111 buildings, will not be reflective of the entire building stock of Montenegro and the results should be used alongside the other data methods used in CAR's contribution to the NERA project.

CAR used Bayesian updating techniques following a Street View survey in Croatia, where over 1600 buildings were surveyed, to modify national building stock estimates suggested by the questionnaire response (Baker, H. et al. 2014). There is also potential to use this technique with field surveys. However, it is not reasonable to assume a beta distribution with only 111 buildings surveyed and this field trip was not extensive enough for this purpose.

## 4.1 Urban Areas

Figure 56 compares the results from the questionnaire response and the field trip for the distribution of dwellings by building class in urban areas. There are some significant discrepancies.

- Field trip results show significantly larger proportion of concrete dwellings than questionnaire results.
- Survey results contain few masonry dwellings in comparison to the questionnaire results. In particular unit masonry with timber floors and adobe/field stone/rubble stone.

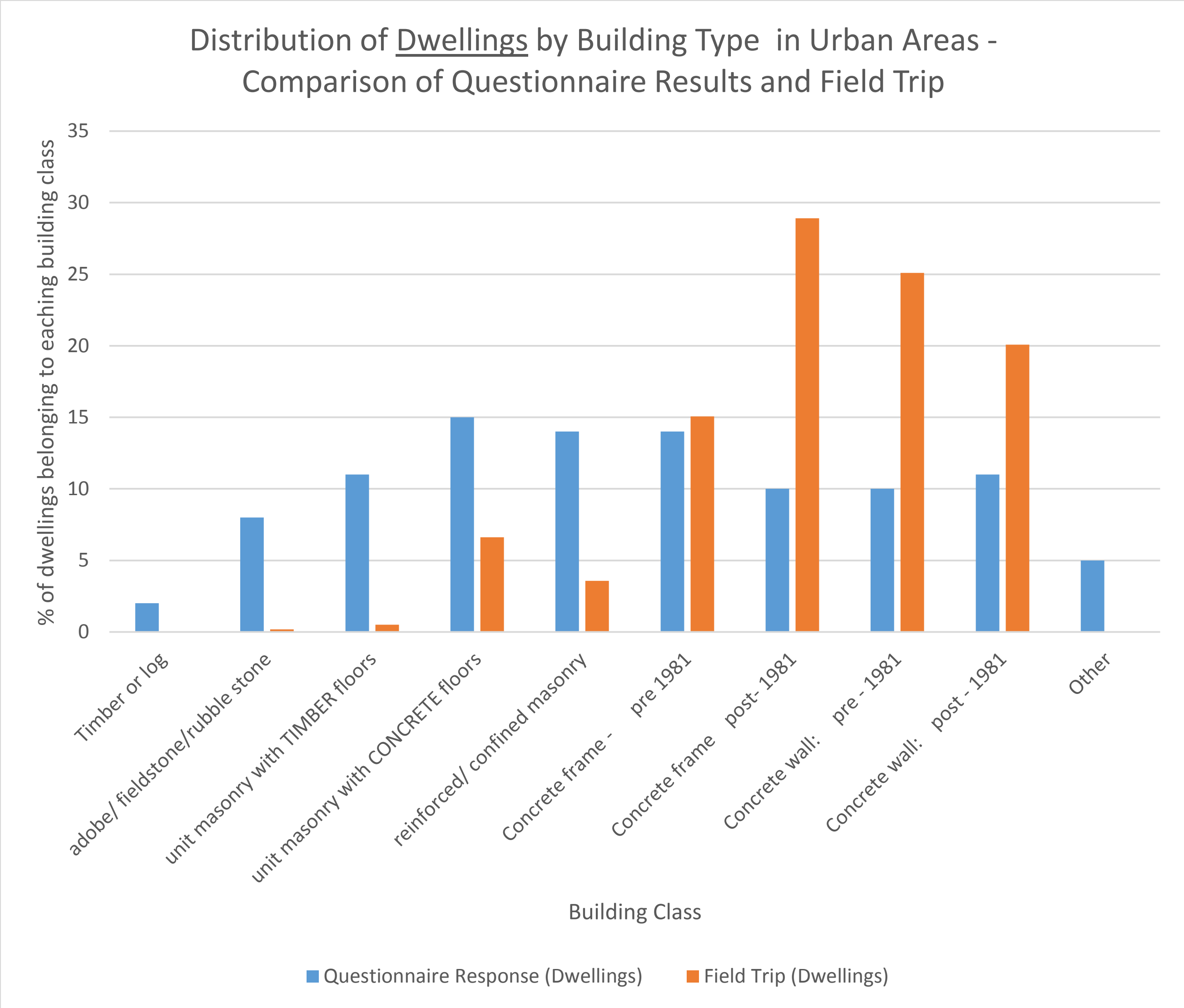



*Figure 56: Distribution of Dwellings by Building Type in Urban Areas - Comparison of Questionnaire Results and Field Trip. * Questionnaire results are post and pre 1990*

In order to compare results, a matric to estimate the average error, which was used for comparison between other methods of data collection with CAR's contribution to the NERA project, has been applied to the two data sets. This is calculated in the following way (Baker, et al., 2014):

$$E_{av} = \sqrt{\frac{\sum(E_1 - E_2)^2}{N}}$$

Where:

$E_{av}$ = Average Error

$E_1$ = Value in Dataset 1

$E_2$ = Value in Dataset 2

N = Number of building classes

The value obtained for the average error between these two datasets (questionnaire and field survey) was 10.2%

Within the questionnaire response, an estimated average number of dwellings per building was provided. Table 5, compares these values to those calculated using the buildings surveyed during the field trip.

Discrepancies in values are circled. The average number of dwellings for concrete wall buildings is significantly higher for the buildings viewed during the field trip, and the value for confined masonry is significantly lower than the estimated figures from the questionnaire. This supports the reasoning that, the dwellings analysed (Figure 56) has significant discrepancies with the questionnaire response for dwellings, as the data has become skewed.

*Table 5: Comparison between the average number of dwellings in a building for different building classes/structure types from the field trip and questionnaire response*

| | **Building Class** | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|
| | **Timber or log** | **adobe/ fieldstone** | **unit masonry with TIMBER floors** | **unit masonry with CONCRETE floors** | **reinforced/ confined masonry** | **Concrete frame - pre 1981** | **Concrete frame post- 1981** | **Concrete wall: pre - 1981** | **Concrete wall: post - 1981** | **Other** |
| Average number of dwelling per building | n/a | 1 | 1 | 8 | 4 | 32 | 53 | 147 | 84 | 0 |
| Questionnaire Response (Estimated average number of dwellings per building in each class)* | 4 | 1 | 1 | 30 | 18 | 36 | 47 | 36 | 47 | 3 |

* Some of the classes have been combined. In the original questionnaire, buildings were defined by low, medium and high rise buildings. See Appendix 2 for the original response and analysis.

Figure 57 compares the dwelling numbers calculated by multiplying the number of buildings analysed during the field trip by the estimated average number of dwellings per building class, provided by the questionnaire to the dwelling distribution stated within the questionnaire response. There are still some discrepancies, but not as extreme. The margin of error has been reduced from 10.2% to 7.4%.

The most important of these discrepancies are:

- There were significantly fewer timber, adobe/fieldstone/rubble stone and masonry dwellings with timber floors observed in the field survey than suggested by the questionnaire results.
- There were more masonry dwellings with concrete floors and post 1981 concrete frame buildings observed in the field survey than suggested by the questionnaire results.

Reasons for this may include:

- Areas surveyed tended to be large urban areas e.g. Podgorica and Nikšić are the largest and 2nd largest urban areas in Montenegro. Within the questionnaire answered for Montenegro, urban areas are classified as areas with a population over 1000 people. This may explain why there is a larger proportion of large multi-family buildings in the field survey and thus, more concrete frame post-1981. Smaller urban areas are more likely to have a higher proportion of older masonry buildings. This will also include the northern region of the country, which was not surveyed.
- There will be some discrepancy as the questionnaire defined concrete frame and wall buildings post 1990 (value provided in original survey) rather than 1981, which was used for the field trip and the questionnaire answered by other Balkan countries.
- The overall sample size was quite small in comparison to the overall building stock, therefore data was easily skewed.

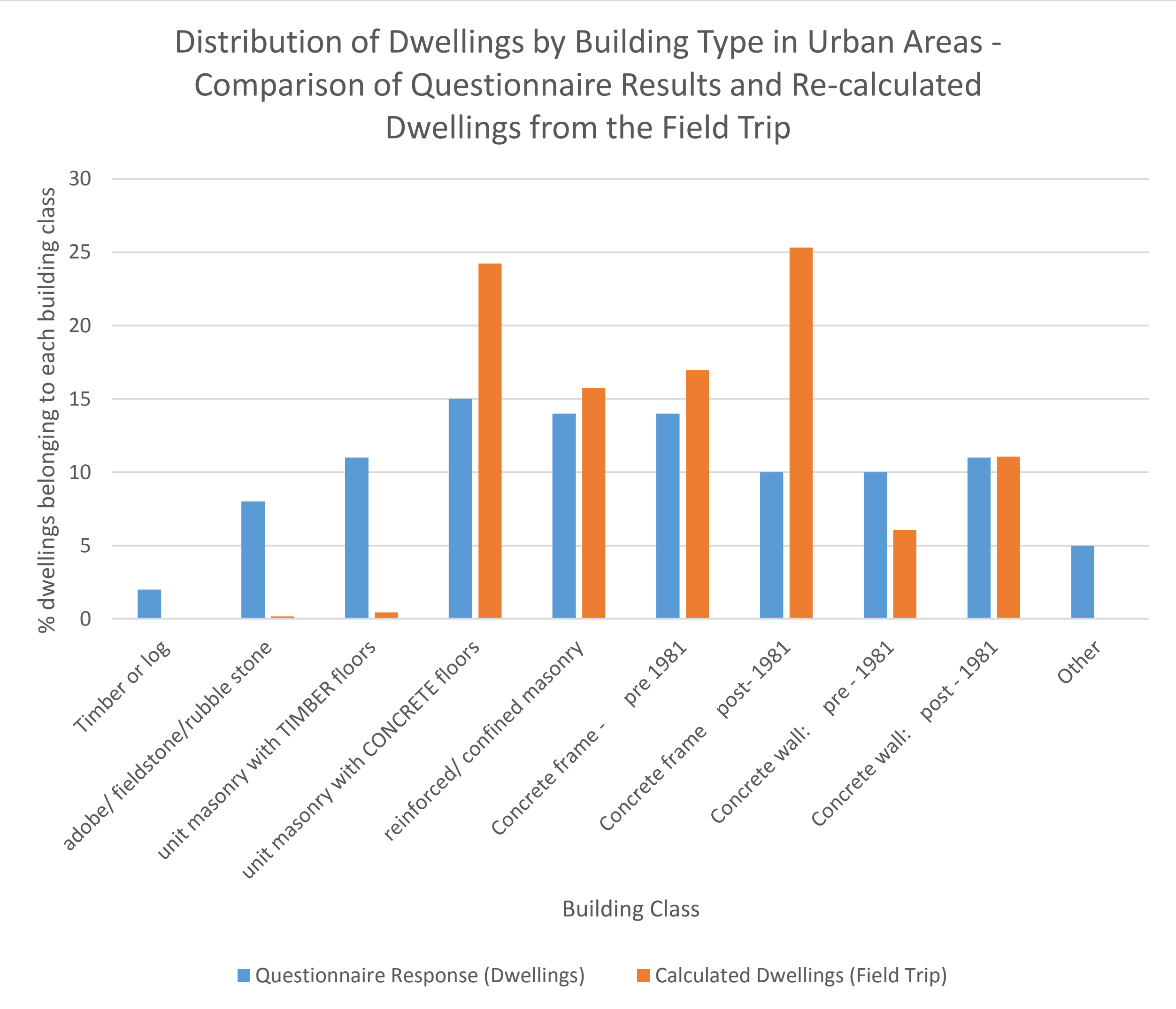



*Figure 57: Distribution of Dwellings by Building Type in Urban Areas - Comparison of Questionnaire Results and Re-calculated Dwellings from the Field Trip. * Questionnaire results are post and pre 1990*

Table 6 displays the results for the dwelling distribution from the questionnaire results and the distribution of dwellings and calculated dwellings (buildings multiplied by the estimated average number of dwellings).

*Table 6: Comparison between the distribution of dwellings and buildings surveyed during the field trip and dwellings within the questionnaire response (urban areas)*

| Building Class | % of buildings/dwellings belonging to each building class | | |
|---|---|---|---|
| | Questionnaire Response (Dwellings) | Field Trip (Dwellings) | Field Trip (Calculated Dwellings) |
| Timber or log | 2 | 0 | 0 |
| Adobe/fieldstone/rubble stone | 8 | 0 | 0 |
| Unit masonry with TIMBER floors | 11 | 1 | 0 |
| Unit masonry with CONCRETE floors | 15 | 7 | 24 |
| Reinforced/ confined masonry | 14 | 4 | 16 |
| Concrete frame: pre - 1981 | 14 | 15 | 17 |
| Concrete frame: post - 1981 | 10 | 29 | 25 |
| Concrete wall: pre-1981 | 10 | 25 | 6 |
| Concrete wall: post-1981 | 11 | 20 | 11 |
| Other | 5 | 0 | 0 |

## 4.2 Rural Areas

The questionnaire response included a distribution of dwellings by building classes in rural areas - shown in Figure 58.

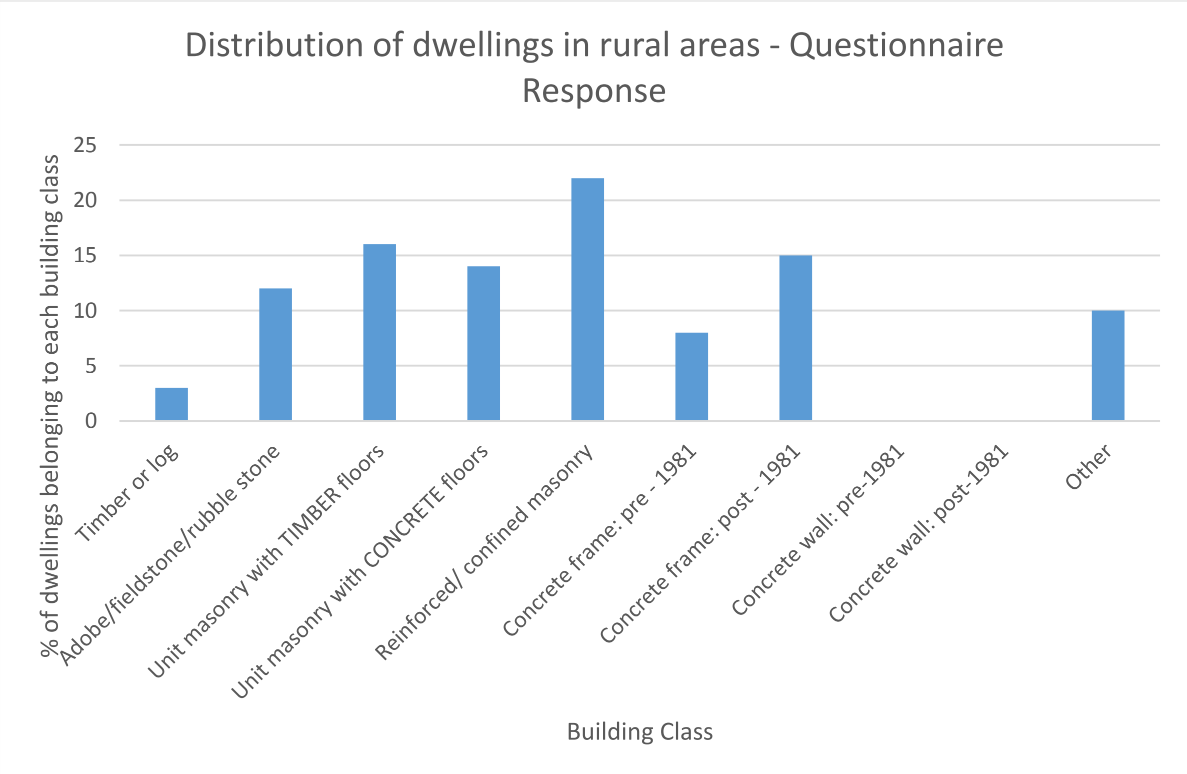



*Figure 58: Distribution of dwellings in rural areas - Questionnaire Response*

Although, individual surveys were not conducted in rural areas due to logistical issues (in remote areas, presence was obvious and raised suspicion). General overviews were obtained by driving through. As shown by section 3.7, masonry was the dominant construction type and depending on the rural areas, the predominant construction technique differed, e.g. rural zone 3 was dominated by confined masonry, whereas rural zones 1 and 2, tended to be older masonry constructions – rubble stone and unit masonry with timber floors.

Although, concrete frame buildings (low-rise) were not photographed in these areas, others were seen when driving from location to location and it seems feasible that they do reflect a significant amount of the building stock, as indicated in the questionnaire survey.

# 5. Conclusions

Overall, the field trip allowed CAR to increase their understanding of the building stock in Montenegro and was useful as a validation exercise within the NERA project.

As a data collection technique, a field trip would still be useful if the other data collection techniques were not possible. During the NERA project, it has been found expert questionnaires are the most useful way of collecting data due to the local knowledge and access to data sources. However, the value of these depends on the expertise and judgement of the responder. Remote data inferences are limited, due to the lack of access to data in the public domain. Field surveys and Street view surveys are a good way to gain a general understanding of the building stock and validate results.

If a field trip survey was to be the only source of data collection, it is vital that a range of sample areas are surveyed and that a number of buildings are surveyed to avoid the skewing of results by buildings containing a large number of dwellings. The field trip conducted was not extensive enough for this purpose.

# 6. References

**(CRSI) Concrete Reinforcing Steel Institute** Concrete Structural Floor Systems [Online] // Concrete Reinforcing Steel Institute. - 2014. - 12 9 2014. - http://www.crsi.org/index.cfm/engineering/floor.

**(UNDP) United Nations Industrial Development Organization (UNIDO) executing agency for the United Nations Development Programme** Damage Study for 1979 Monenegro Earthquake [Online] // GEMECD. - 01 01 1985. - 11 09 2014. - http://gemecd.org/study/135.

**Adzic N.** City Planner [Interview]. - Niksic : [s.n.], 22 8 2014.

**Antonovic D and Bickel M.** Montenegro - With Insider Tips [Book]. - Hampshire : Marco Polo Travel Publishing Ltd., 2014. - Vol. 1.

**Baker H., Spence R. and Foulser-Piggott R.** NERA Deliverable 7.5: CAR contribution for Iceland, Switzerland and Balkan Countries [Report]. - [s.l.] : Unpublished, 2014.

**Bing** Bing Maps [Online]. - 2014. - http://www.bing.com/maps/.

**FMECD Federal Ministry for Economic Cooperation and Development** Architectural Atlas of Montenegro [Report]. - [s.l.] : German Technical Cooperation, 2006.

**G.J. Parra-Montesinos.** Punching Shear Resistance of Slab-Column Connections under Monotonic and Reversed Cyclic Loading [Online] // Ecole Polytechnique Federerale de Lausanne. - 2012. - 12 9 2014. - http://memento.epfl.ch/event/punching-shear-resistance-of-slab-column-connectio/.

**Glavatovic B.** BALKAN HARMONISATION OF SEISMIC HAZARD MAPS - NATO SfP Project 983054 [Conference] // Security Science Forum on Enviremental Security Security Science Forum on Enviremental Security. - Brussels : NATO, 2008.

**Maps Google** Google Maps [Online]. - 2014. - https://www.google.co.uk/maps/.

**USGS** Serbia and Montenegro - Political Map [Online] // Earthquake Hazards Program. - 2014. - 09 2014. - http://earthquake.usgs.gov/earthquakes/world/yugoslavia/gshap.php.

# Appendices

## Appendix 1: Individual Surveys

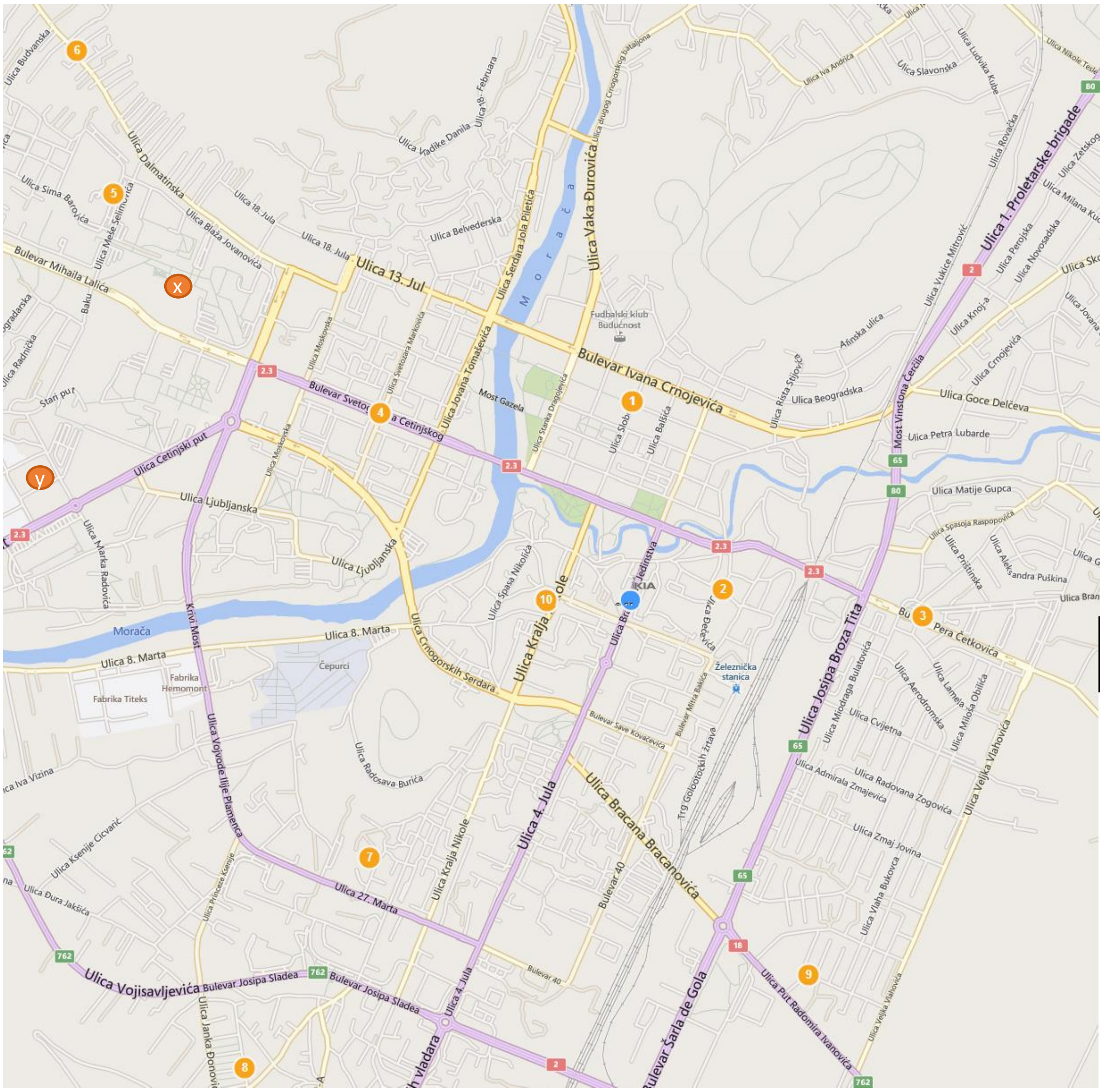
Appendix 1, outlines the individual building surveys in different zones throughout Montenegro. Each zone surveyed displays a table of results. Their location can be identified on the maps for each city – shown below. Note: There is not a table for each zone marked as some were surveyed by a general analysis driving through the area.

Geo-located photographs are available from the following website:
http://eepimap.com/overview/?&zoomtoextent=True&eventid=196

### Maps

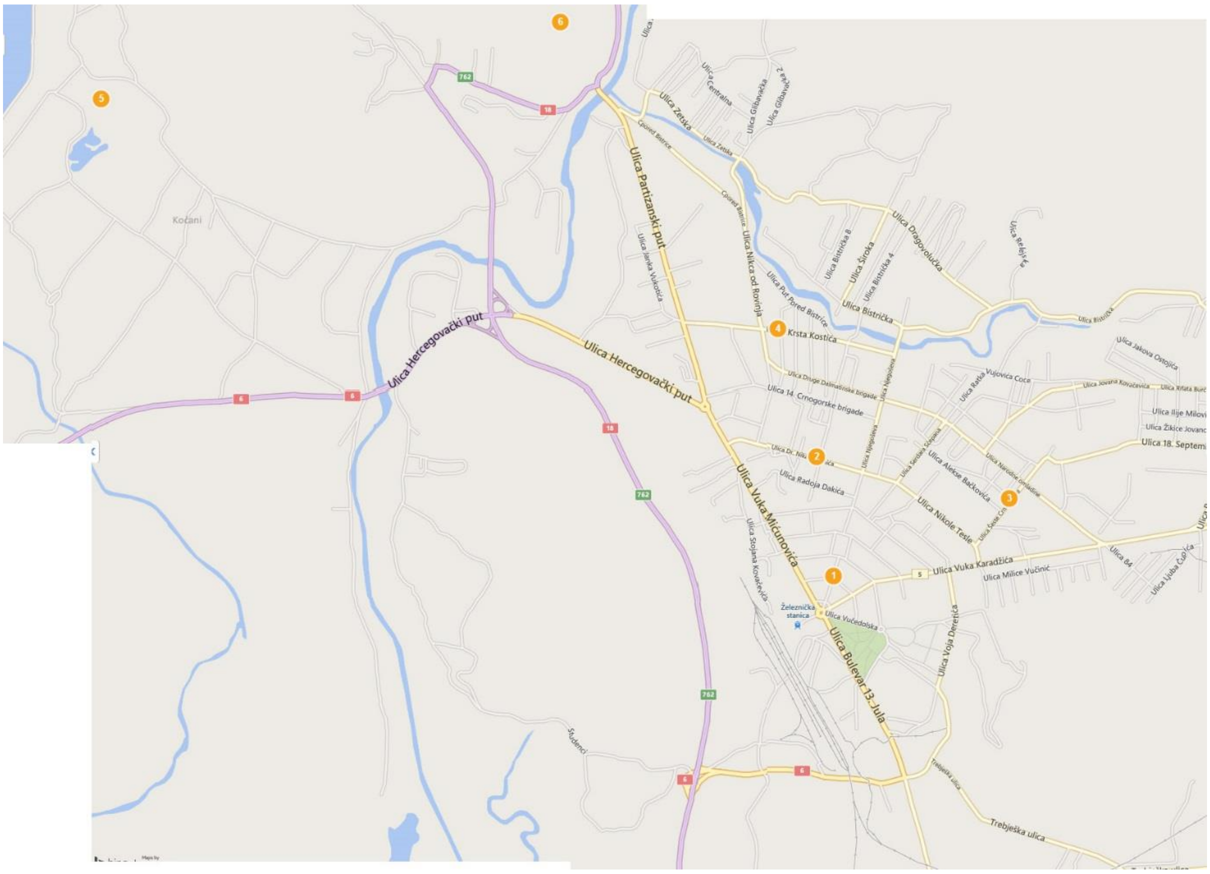
Source: (Bing, 2014)

#### *Day 1 - Podgorica*




Zones Surveyed: 5, 4, 10, 6, Y, & X

## *Day 2 - Nikšić*




Zones Surveyed: 1 & 2.

## *Day 3 – Cetinje*

## *Day 3 – Budva*

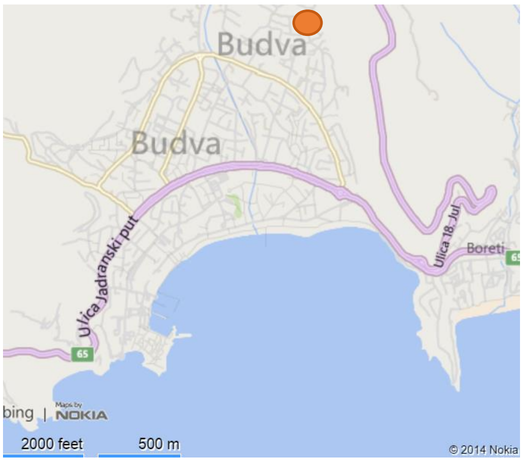



*Figure 59: Survey Area, Budva, Day 3. Source: (Bing, 2014)*

# Surveys

## Day 1 – Zone 5

| | |
|---|---|
| **Day** | 1 |
| **Zone Number** | 5 |

| Bu. No. | Number of Floors | Basement Visible (Y/N) | Approximate Number of Dwellings | **Timber or log** | **Load-Bearing Masonry** | | | | **Reinforced Concrete** | | | | **Other** | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | | | **adobe/ fieldstone/ rubblestone** | unit masonry with TIMBER floors | unit masonry with CONCRETE floors | reinforced/ confined masonry | Concrete frame - pre 1981 | Concrete frame post-1981 | Concrete wall: pre - 1981 | Concrete wall: post - 1981 | | Additional Details |
| 1 | 11 | Y | 77 | | | | | | | | | x | | 1990s. Russian Towers. Not typical of the building stock. Monolithic slab + pre-cast. Unique type of construction as the shaft was built first, then rest of the structure. Normally construct storey by storey.55-80m2 |
| 2 | 12 | Y | 88 | | | | | | | | | x | | Russian Towers - flat roof, lightweight masonry (concrete blocks) often built on top |
| 3 | 12 | Y | 88 | | | | | | | | | x | | "" |
| 4 | 9 | Y | 288 | | | | | | | | x | | | 1975/76 - Under Renovation - Shear wall, monolithic slab - No columns, not pre-cast. 8 entrances, 4 floors |
| 5 | 16 | Y | 64 | | | | | | | | x | | | Late 1970s - not renovated. Highly irregular elevation, shear wall, no beams. Shelter below |
| 6 | 16 | Y | 256 | | | | | | | | x | | | |
| 7 | 16 | Y | 64 | | | | | | | | x | | | Good quality interior works |
| 8 | 16 | Y | 64 | | | | | | | | x | | | Good quality interior works |

## Day 1 – Zone 4

| | |
|---|---|
| **Day** | 1 |
| **Zone Number** | 4 |

| Bu. No. | Number of Floors | Basement Visible (Y/N) | Approximate Number of Dwellings | **Timber or log** | **Load-Bearing Masonry** | | | | **Reinforced Concrete** | | | | **Other** | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | | | **adobe/ fieldstone/ rubblestone** | unit masonry with TIMBER floors | unit masonry with CONCRETE floors | reinforced/ confined masonry | Concrete frame - pre 1981 | Concrete frame post-1981 | Concrete wall: pre - 1981 | Concrete wall: post - 1981 | | Additional Details |
| 1 | 6 | N | 50 | | | | x | | | | | | | Floor Structure = pre-cast beams with thin slab. Ground Floor = Commercial. 5 entrances. Reinforced concrete and masonry. Originally masonry but renovated and ground floor converted to a concrete frame |
| 2 | 4 | N | 0 | | | | x | | | | | | | Police Department |
| 3 | 4 | N | 20 | | | | x | | | | | | | Some construction as no.1 - Ground Floor = commercial |
| 4 | 4 | N | 20 | | | | x | | | | | | | "" |

## Day 1 – Zone 10

| | |
|---|---|
| **Day** | 1 |
| **Zone Number** | 10 |

| Bu. No. | Number of Floors | Basement Visible (Y/N) | Approximate Number of Dwellings | **Timber or log** | **Load-Bearing Masonry** | | | | **Reinforced Concrete** | | | | **Other** | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | | | **adobe/ fieldstone/ rubblestone** | unit masonry with TIMBER floors | unit masonry with CONCRETE floors | reinforced/ confined masonry | Concrete frame - pre 1981 | Concrete frame post-1981 | Concrete wall: pre - 1981 | Concrete wall: post - 1981 | | Additional Details |
| 1 | 2 | N | 2 | | | x | | | | | | | | |
| 2 | 2 | N | 1 | | | x | | | | | | | | |
| 3 | 2 | N | 1 | | x | | | | | | | | | |
| 4 | 2 | N | 1 | | x | | | | | | | | | |
| 5 | 2 | N | 1 | | x | | | | | | | | | |
| 6 | 2 | N | 1 | | x | | | | | | | | | |
| 7 | 2 | N | 1 | | | x | | | | | | | | |
| 8 | 2 | N | 1 | | | x | | | | | | | | Corner Stones |

| | |
|---|---|
| General | Turkish Old Town, few regulations |

## Day 1 – Zone 6

| | |
|---|---|
| **Day** | 1 |
| **Zone Number** | 6 |

| Bu. No. | Number of Floors | Basement Visible (Y/N) | Approximate Number of Dwellings | **Timber or log** | **Load-Bearing Masonry** | | | | **Reinforced Concrete** | | | | **Other** | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | | | **adobe/ fieldstone/ rubblestone** | unit masonry with TIMBER floors | unit masonry with CONCRETE floors | reinforced/ confined masonry | Concrete frame - pre 1981 | Concrete frame post-1981 | Concrete wall: pre - 1981 | Concrete wall: post - 1981 | | Additional Details |
| 1 | 1 | N | 1 | | x | | | | | | | | | Rubble Stone. Approximately 1950s |
| 2 | 2 | N | 1 | | | | | x | | | | | | 1980s |
| 3 | 3 | N | 2/3 | | | | | x | | | | | | |
| 4 | 2 | N | 1 | | | | | x | | | | | | |
| 5 | 1+ | Y | 1 | | | | | | x | x | | | | 30 cm column. 1980s |
| 6 | 2+ | Y | 1 | | | | | x | | | | | | Under construction - Beams and Tiles visible on roof. Concrete block basement. Columns not regular. Concrete Roof |
| 7 | 7 | N | 1 | | | | | x | | | | | | Has been renovated |
| 8 | 1 | N | 0 | | | | | | | | | | x | Commercial Building |

General Maybe 20% frame - difficult to tell.

## Day 1 – Zone Y

| | |
|---|---|
| Day | 1 |
| Zone Number | Y - New Student Area - not an original zone |

| Bu. No. | Number of Floors | Basement Visible (Y/N) | Approximate Number of | Timber or log | Load-Bearing Masonry | | | | Reinforced Concrete | | | | Other | Additional Details |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | | | adobe/ fieldstone/ rubblestone | unit masonry with TIMBER floors | unit masonry with CONCRETE floors | reinforced/ confined masonry | Concrete frame - pre 1981 | Concrete frame post-1981 | Concrete wall: pre - 1981 | Concrete wall: post - 1981 | | |
| 1 | 9 | N | 28 | | | | | | | | | x | | Commercial Ground Floor |
| 2 | 9 | N | 28 | | | | | | | | | x | | "" |
| 3 | 9 | N | 28 | | | | | | | | | x | | "" |
| 4 | 6 | Y | 60 | | | | | | | x | | | | Dual System - Commercial Ground Floor. Underground parking. Cantilever balconies. Euro 8. |
| 5 | 6 | Y | 60 | | | | | | | x | | | | 2 blocks per building |
| 6 | 6 | Y | 60 | | | | | | | x | | | | |
| 7 | 6 | Y | 60 | | | | | | | x | | | | |
| 8 | 6 | Y | 60 | | | | | | | x | | | | |
| 9 | 6 | Y | 60 | | | | | | | x | | | | |
| 10 | 6 | Y | 60 | | | | | | | x | | | | |
| 11 | 6 | Y | 60 | | | | | | | x | | | | |
| 12 | 6 | Y | 60 | | | | | | | x | | | | |
| 13 | 6 | Y | 60 | | | | | | | x | | | | |

| | | | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 14 | 6 | Y | 60 | | | | | | | x | | | | |
| 15 | 6 | Y | 60 | | | | | | | x | | | | |
| 16 | 6 | Y | 60 | | | | | | | x | | | | |

## Day 1 – Zone X

| | |
|---|---|
| **Day** | 1 |
| **Zone Number** | x - Jelena - University Housing |

| Bu. No. | Number of Floors | Basement Visible (Y/N) | Approximate Number of Dwellings | **Timber or log** | **Load-Bearing Masonry** | | | | **Reinforced Concrete** | | | | **Other** | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | | | **adobe/ fieldstone/ rubblestone** | unit masonry with TIMBER floors | unit masonry with CONCRETE floors | reinforced/ confined masonry | Concrete frame - pre 1981 | Concrete frame post-1981 | Concrete wall: pre - 1981 | Concrete wall: post - 1981 | | Additional Details |
| 1 | 7 | Y* | 252 | | | | | | | | | x | | Double height ground floor. 6 flats per floor, 6 entrances. Dual System. Monolithic slab. Garage underneath has columns with capital and includes concrete walls. Garage is separate but adjacent - separate in construction |

| | |
|---|---|
| General | * Basement = separate structure |

## Day 2 – Zone 1

| | |
|---|---|
| **Day** | 2 |
| **Zone Number** | 1 |

| Bu. No. | Number of Floors | Basement Visible (Y/N) | Approximate Number of Dwellings | **Timber or log** | **Load-Bearing Masonry** | | | | **Reinforced Concrete** | | | | **Other** | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | | | **adobe/ fieldstone/ rubblestone** | unit masonry with TIMBER floors | unit masonry with CONCRETE floors | reinforced/ confined masonry | Concrete frame - pre 1981 | Concrete frame post-1981 | Concrete wall: pre - 1981 | Concrete wall: post - 1981 | | Additional Details |
| 1 | 2 | n | | | | | x | | | | | | | Probably brick - large stone at bottom. 1930? |
| 2 | 2 | | 1 | | | | x | | | | | | | corner detail not good quality |
| 3 | 3 | n | 16 | | | | x | | | | | | | lightweight added on top |
| 4 | 3 (4) | n | 24 | | | | x | | | | | | | 2 entrances |
| 5 | 3 (4) | | 32 | | | | x | | | | | | | irregular in plan |
| 6 | 2 | n | 2 | | | | x | | | | | | | Newer maybe 90s. commercial ground floor. |
| 7 | 3 | n | 0 | | | | | | x | | | | | Government building or bank? looks like it is masonry which has been renovated and is now a concrete frame |
| 8 | 2 | n | 1 | | | x | | | | | | | | |
| 9 | 1 | n | 1 | | | x | | | | | | | | |
| 10 | 2 | n | 2 | | | | x | | | | | | | Commercial ground floor. Similar to building 6. looks as if masonry has been renovated and now concrete frame |

## Day 2 – Zone 2

| | |
|---|---|
| **Day** | 2 |
| **Zone Number** | 2 |

| | | | | | Load-Bearing Masonry | | | | Reinforced Concrete | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Bu. No. | Number of Floors | Basement Visible (Y/N) | Approximate Number of Dwellings | **Timber or log** | **adobe/ fieldstone/ rubblestone** | unit masonry with TIMBER floors | unit masonry with CONCRETE floors | reinforced/ confined masonry | Concrete frame - pre 1981 | Concrete frame post-1981 | Concrete wall: pre - 1981 | Concrete wall: post - 1981 | **Other** | Additional Details |
| 1 | 5 | y | 48 | | | | | | x | | | | | Commercial ground floor.at least 4 entrances. infill frame |
| 2 | 5 | y | 48 | | | | | | x | | | | | "" |
| 3 | 7 | y | 24 | | | | | | x | | | | | |
| 4 | 8 | y | 40 | | | | | | x | | | | | |
| 5 | 8 | y | 40 | | | | | | x | | | | | |
| 6 | 7 | y | 24 | | | | | | x | | | | | |
| 7 | 4 | y | 24 | | | | | | x | | | | | Asbestos? cladding |
| 8 | 3 | y | 24 | | | | | | x | | | | | |
| 9 | 2 | n | 1 | | | | x | ? | | | | | | renovated shop in 70s |
| 10 | 5 | y | 68 (+5?) | | | | | | x | | | | | yellow - wood outside |
| 11 | 2 (3) | | 2 | | | | x | | | | | | | concrete roof. maybe infer concrete beam floor |
| 12 | 4 | y | 32 | | | | | | x | | | | | 2 entrances. brick infill. Same as no.1 |

| | | | | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 13 | 4 | y | 32 | | | | | | x | | | | | | brick infill |
| 14 | 4 | y | 32 | | | | | | x | | | | | | brick infill |

## Day 3 – Cetinje

| | |
|---|---|
| **Day** | 3 |
| **Zone Number** | Cetinje |

| Bu. No. | Number of Floors | Basement Visible (Y/N) | Approximate Number of Dwellings | **Timber or log** | Load-Bearing Masonry: **adobe/ fieldstone** | Load-Bearing Masonry: unit masonry with **TIMBER** floors | Load-Bearing Masonry: unit masonry with **CONCRETE** floors | Load-Bearing Masonry: **reinforced/ confined** masonry | Reinforced Concrete: Concrete **frame - pre** 1981 | Reinforced Concrete: Concrete frame **post**- 1981 | Reinforced Concrete: Concrete **wall: pre** - 1981 | Reinforced Concrete: Concrete **wall: post** - 1981 | **Other** | Additional Details |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 1 | 3 | N | 4 | | | | | x | | | | | | Commercial Ground Floor - therefore RC frame on ground floor; Timber Roof; |
| 2 | 2 | N | 2 | | | | x | | | | | | | Commercial Ground Floor - Renovated ground floor with RC frame |
| 3 | 3 | N | 3 | | | | x | | | | | | | Wooden roof - uneven; Garage included in ground |
| 4 | 3 | N | 1 | | | | x | | | | | | | Newer top floor - renovation. Commercial Ground Floor |
| 5 | 3 | N | 2 | | | | | x | | | | | | Commercial Ground Floor - Reinforced Concrete Frame; metal roof |
| 6 | 3 | N | 1 | | | | | x | | | | | | "" |
| 7 | 3 | N | 2 | | | | | x | | | | | | "" |
| 8 | 3 | N | 1 | | | | | x | | | | | | Pink building; Commercial Ground Floor - RC frame |
| 9 | 2 | Y | 1 | | | ? | ? | | | | | | | Slightly different shape - older than other buildings - no indication of floor type |
| 10 | 2 | N | 2 | | | | x | | | | | | | Masonry not in great condition |
| 11 | 2 | N | 2 | | | | x | | | | | | | Commercial ground Floor; Behind plaster = rough |
| 12 | 2 | N | 2 | | | | x | | | | | | | Metal Roof |
| 13 | 3 | Y | 5-8 | | | | x | | | | | | | |

| | | | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 14 | 1 | N | 1 | | | x | | | | | | | | Two Businesses |
| 15 | 2 | N | 2 | | | x | | | | | | | | |
| 16 | 2 | N | 1 | | | x | | | | | | | | |
| 17 | 1 | N | n/a | | | x | | | | | | | | |
| 18 | 4 | N | n/a | | | | x | | | | | | | Very irregular floor plan - hotel |
| 19 | 2 | N | 1 | | | x | | | | | | | | |
| 20 | 2 | N | 2 | | | x | | | | | | | | Not good quality |
| 21 | 2 | N | 1 | | | x | | | | | | | | |
| 22 | 3 | N | 1 | | | | x | | | | | | | Not occupied |
| 23 | 3 | N | 2 | | | | | x | | | | | | Newer part = poorer constructed |
| 24 | 4 | N | 3 | | | | | x | | | | | | Poor Quality - mixture of concrete and unit masonry. Residential on top, seems to be built with very little consideration |
| 25 | 4 | N | 3 | | | | | x | | | | | | "" |
| 26 | 4 | N | 3 | | | | | x | | | | | | "" |

General Comment: mixture of concrete and unit masonry - sometimes well designed, sometimes not. If shop on ground floor, seems that regulations for commercial are adhered to

## Day 3 - Budva

| | |
|---|---|
| **Day** | 3 |
| **Zone Number** | Budva |

| Building No. | Number of Floors | Basement Visible (Y/N) | Approximate Number of Dwellings | **Timber or log** | **Load-Bearing Masonry** | | | | **Reinforced Concrete** | | | | **Other** | Additional Details |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | | | **adobe/ fieldstone/ rubblestone** | unit masonry with **TIMBER** floors | unit masonry with **CONCRETE** floors | **reinforced/ confined** masonry | Concrete **frame - pre** 1981 | Concrete **frame post**- 1981 | Concrete **wall: pre** - 1981 | Concrete **wall: post** - 1981 | | |
| 1 | 5 | N | 18 | | | | | X | | | | | | 1990 - 2000 |
| 2 | 4 | N | 16 | | | | | X | | | | | | 1990 - 2000 |
| 3 | 4 | N | 4 | | | | | X | | | | | | 1990 - 2000 |
| 4 | 2 | Y | 1 | | | | | X | | | | | | 1990 - 2000 |
| 5 | 3 | N | 9 | | | | | X | | | | | | 1990 - 2000 |
| 6 | 6 | N | 18 | | | | | | | X | | | | 2000-2010; Commercial Ground Floor |
| 7 | 3 | N | 1 | | | | | X | | | | | | 1980 - 1990 |
| 8 | 3 | N | 6 | | | | | X | | | | | | 1990 - 2000 |
| 9 | 6 | N | 50 | | | | | | | X | | | | 2010?; Commercial Ground Floor - |
| 10 | 3 | N | 6 | | | | | X | | | | | | 1980s - commercial ground floor |
| 11 | 2 | N | 2 | | | | | X | | | | | | 1980s |
| 12 | 2 | N | 1 | | | | X | | | | | | | 1970s - Older in appearance; external staircase |

| | | | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 13 | 2 | N | 6 | | | | | X | | | | | | 1980s |
| 14 | 4 | N | 5 | | | | | X | | | | | | 1980s;external stairs |
| 15 | 3 | N | 3 | | | | | X | | | | | | 1980s |

General Comment: Hotels on bay = big concrete high rise modern developments

# Appendix 2: Montenegro Questionnaire Response and Analysis.

| Construction Material and construction typology | Age | Height | % of dwellings in urban areas belonging to each class | % of dwellings in rural areas belonging to each class | Estimated average number of dwellings per building in each class |
|---|---|---|---|---|---|
| Reinforced concrete moment-frame | pre 1990 | low-rise | 5 | 8 | 2 |
| | | mid-rise | 8 | | 45 |
| | | high-rise | 1 | | 60 |
| | post 1990 | low-rise | 6 | 15 | 2 |
| | | mid-rise | 3 | | 60 |
| | | high-rise | 1 | | 80 |
| Precast concrete moment frame | pre 1990 | low-rise | | | |
| | | mid-rise | | | |
| | | high-rise | | | |
| | post 1990 | low-rise | | | |
| | | mid-rise | | | |
| | | high-rise | | | |
| Reinforced concrete wall/Precast concrete panel | pre 1990 | low-rise | 3 | | 2 |
| | | mid-rise | 6 | | 45 |
| | | high-rise | 1 | | 60 |
| | post 1990 | low-rise | 4 | | 2 |
| | | mid-rise | 5 | | 60 |
| | | high-rise | 2 | | 80 |
| Unreinforced earthen or rubble masonry | | | 8 | 12 | 1 |
| Unreinforced unit masonry with timber floors and roof | | | 11 | 16 | 1 |
| Unreinforced unit masonry with reinforced concrete floors and roof | | | 15 | 14 | 30 |
| Confined or reinforced masonry | | | 14 | 22 | 18 |
| Lightweight timber frame | | | 1 | 2 | 2 |
| Heavy timber frame or timber log construction | | | 1 | 1 | 6 |
| Other | | | 5 | 10 | 3 |
| **TOTAL** | | | 100 | 100 | |

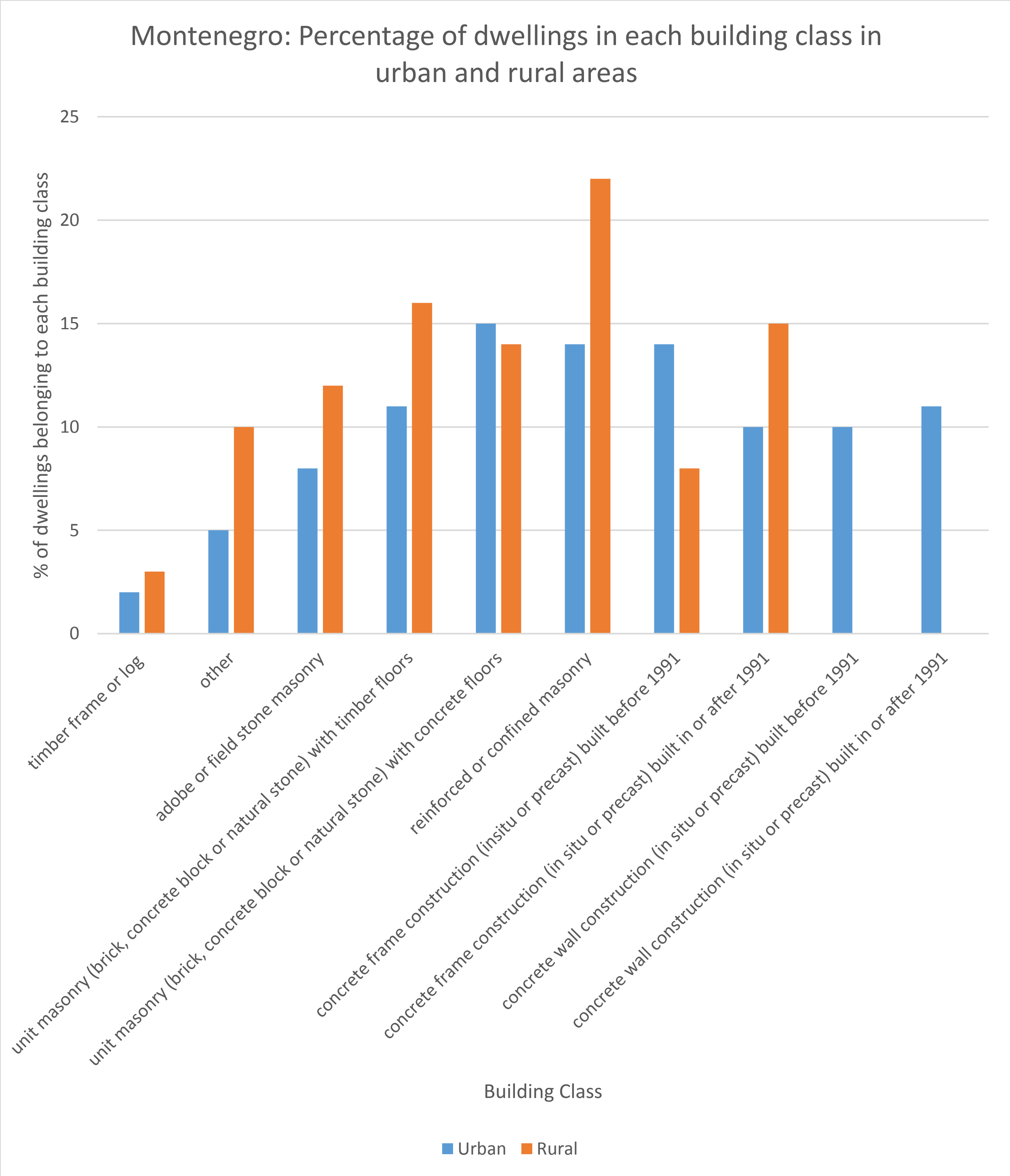
**Part III: Additional Sources of Information Used**

Sources of information you used (websites, publications, etc.) Please provide as much detail as possible.

Publications, websites and statistical data were used as sources of information.
All data are approximate because there are no complete data on the number and construction types of objects.

Additional comments

The other buildings are buildings that were damaged by the earthquake and subsequently repaired, buildings that were reconstructed and buildings with combinated construction types.


Montenegro: Percentage of dwellings in each building class in urban and rural areas
% of dwellings belonging to each building class
25
20
15
10
5
0
timber frame or log
other
adobe or field stone masonry
unit masonry (brick, concrete block or natural stone) with timber floors
unit masonry (brick, concrete block or natural stone) with concrete floors
reinforced or confined masonry
concrete frame construction (insitu or precast) built before 1991
concrete frame construction (in situ or precast) built in or after 1991
concrete wall construction (in situ or precast) built before 1991
concrete wall construction (in situ or precast) built in or after 1991
Building Class
Urban
Rural