COST Action TU0901:
Integrating and Harmonizing Sound Insulation Aspects
in Sustainable Urban Housing Constructions

Building acoustics throughout Europe
Volume 2: Housing and construction types country by country

Chair: Birgit Rasmussen
SBi, Danish Building Research Institute
Aalborg University
Denmark

Vice Chair: María Machimbarrena
Architecture School; Applied Physics Dpt.
University of Valladolid
Spain

Australia | Austria | Belgium | Canada | Croatia | Czech Republic | Denmark | Estonia | Finland | France | Germany
Greece | Hungary | Iceland | Italy | Lithuania | Macedonia | Malta | Netherlands | New Zealand | Norway
Poland | Portugal | Romania | Serbia | Slovakia | Slovenia | Spain | Sweden | Switzerland | Turkey | United Kingdom

COST
EUROPEAN COOPERATION
IN SCIENCE AND TECHNOLOGY

COST Action
TU0901

ESF provides the COST Office through a European Commission contract

COST is supported by EU RTD Framework Programme

COST Action TU0901

Cover design:
Stefano Pedersoli

This book may be cited as:
Birgit Rasmussen & María Machimbarrena (editors), COST Action TU0901 – *Building acoustics throughout Europe. Volume 2: Housing and construction types country by country.*

This publication is supported by COST
e-ISBN: 978-84-697-0159-1

Layout: DiScript Preimpresion, S. L.

Publisher: DiScript Preimpresion, S. L.

Contents

COST
EUROPEAN COOPERATION
IN SCIENCE AND TECHNOLOGY

COST Action TU0901

Building acoustics throughout Europe
Volume 2: Housing and construction types country by country

22

Serbia

Authors:
Miomir Mijić[1]
Ana Radivojević[2]
Dragana Šumarac Pavlović[1]
Draško Mašović[1]
Milica Jovanović Popović[2]
Dušan Ignjatović[2]
Aleksandar Rajčić[2]

[1] University of Belgrade, School of Electrical Engineering, Belgrade, Serbia
e-mail: emijic@etf.rs

[2] University of Belgrade, School of Architecture, Belgrade, Serbia

CHAPTER 22 Serbia

22.1. Introduction

Population

According to the results of the national census from 2011, Serbia then had 7,186,862 inhabitants [1]. Results from a previous national census, together with the results of the extensive field survey of housing stock organised in 2012. and 2013. [2] revealed that Serbian citizens live in 2,246,320 buildings in which there are 3,188,414 dwellings, and the total area of Serbian housing stock covers 289,687,720 m^2 (average 90 m^2 per dwelling).

The most populated cities

The most populated cites are Belgrade, the capital of Serbia, with 1,659,440 inhabitants (about 1/4 of population in the country). All other settlements are much smaller. Among them, there are two larger cities: Novi sad with 341,625 and Niš with 260,237 inhabitants. There are also 11 cities in Serbia with population between 100,000 and 200,000 inhabitants.

22.2. Overview of housing stock

The history of housing construction in Serbia

In the history of housing construction in Serbia the years after World War II were the most prosperous. Building in Serbia had its historical maximum between 1960 and 1980.

Regarding building types, single-family houses dominate in total number of buildings. Available data reveal that family housing in Serbia dominates, representing 60.77% of housing stock, vs. 39.23% of multifamily housing.

Multidwelling houses in existence today were built approximately in the last 100 years. Older houses are very rare. Important socio-political events such as wars (World War I and World War II, war in the region during the 1990's) brought both periods of stagnation in construction and also in some periods significant demolition. This was most evident during World War II due to repeated bombing of the largest cities.

Quantitative presentation of new dwellings production in the period after II World War up to the year 2000 is shown in Figure 22.1. In the diagram the average number of new dwellings built per year is shown. The historical moment of introducing the first code of sound insulation in building is also marked in the diagram (in the middle of the year 1982). Before then buildings were built without consideration of sound insulation between dwellings.

The production of new dwellings in last decade has been almost constant. Its quantitative presentation of new dwelling numbers per year is shown in Figure 22.2. The diagram covers period of five years between 2006. and 2010. It shows that contemporary production of new dwellings was nearly constant with approximately 18-20,000 new dwellings per year.

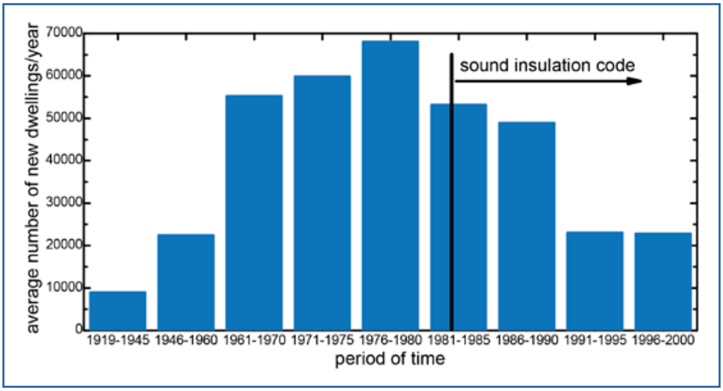


Figure 22.1. *Production of new dwellings per year (average number in marked periods of time).*

Structure of housing stock in Serbia

Contemporary research established typology of single-family and multifamily housing with respect to its architectural and urban planning parameters [2,3]. Six building types were recognised:

- Family housing:
  1. Free standing single-family house
  2. Single-family house in a row
- Multi-family housing:
  3. Free standing residential building
  4. Residential building - lamella
  5. Residential building in a row
  6. High-rise residential building.

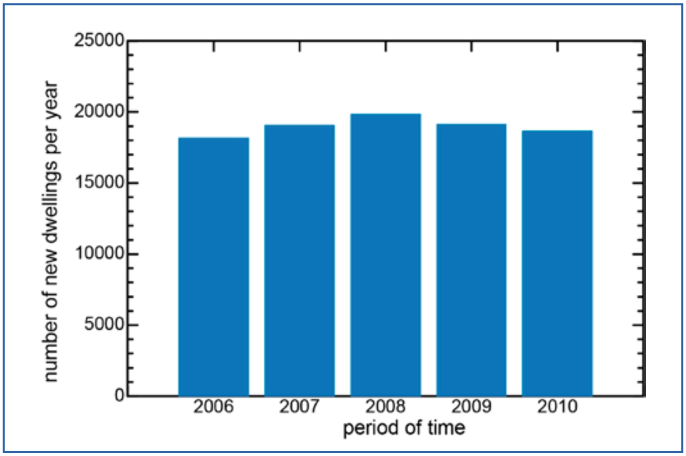
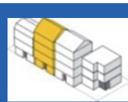
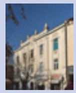
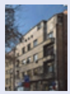
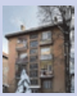
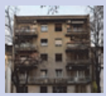
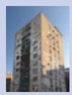
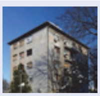
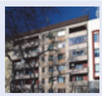
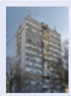
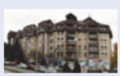
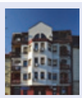
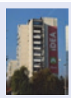
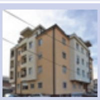
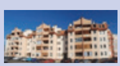
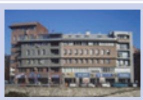


Figure 22.2. *Production of new dwellings per year in the period between 2006 and 2010.*

Some examples of Serbian housing are presented in Figure 22.3. All that houses in the Figure were built in last decades. Among multi-family houses buildings considered as lamellas are the most present.

Figure 22.3. *Some examples of houses in Serbia built in last decades.*

Table 22.1. *Structure of Serbian residential housing stock referring to multidwelling buildings.*

Type	 Free standing	 Lamela	 In a row	 High-rise	Total per period
A (< 1919)					
%	0.16%	0.11%	0.28%	–	0.55%
B (1919-1945)					
%	0.93%	0.30%	1.61%	–	2.84%
C (1946-1960)					
%	1.25%	2.38%	1.40%	0.11%	5.14%
D (1961-1970)					
%	5.67%	5.46%	1.96%	0.91%	14.00%
E (1971-1980)					
%	8.95%	15.38%	2.78%	2.13%	29.24%
F (1981-1990)					
%	9.56%	14.02%	2.99%	0.72%	27.29%
G (1991-2011)					
%	7.36%	9.16%	4.39%	–	20.91%
total per building type	33.88%	46.81%	15.41	3.87%	100%

The chronological classification of housing stock is based on characteristic periods in evolution of the building constructions. The residential buildings in Serbia can be grouped into seven periods:

A until 1919	**C** 1946–1960	**E** 1971-1980	**G** 1991-2012
B 1919-1945	**D** 1961-1970	**F** 1981-1990	

Table 22.1 shows relevant multi-family building types from the Serbian residential building typology and percentage among the total floor area of multifamily housing for each type and each period of time.

22.3. Typical constructions in existing housing stock in Serbia

The structure of partitions between dwellings in existing housing stock reflects the historical period of construction. Besides regulatory sound insulation, evident in ex-Yugoslavia countries for the last 30 years and dictating partition design, several more factors had some influence on building constructions in Serbia, such as [2]:

- Introduction of prefabrication during the period of mass building construction started in the 1970's and lasted until 1990,
- Introduction of a building code concerned with seismic requirements,
- Introduction and development of relevant thermal regulation.

Estimation of seismic hazard at the territory of Serbia reveals that there is a probability of earthquake of up to 6 degrees of Mercalli scale. Thus seismic code requirements have very strong influence on building constructions. Concrete constructions became more widespread in architectural practice. As a result, concrete walls and floors are common in contemporary buildings today, and thus in most buildings there are concrete walls between dwellings.

Light constructions in multi-dwelling houses in Serbia today are not used at all (some rare exceptions are feasible). They can be found as interior partitions in public and business buildings (gypsum boards on metal frames), but only in last decade. This can be explained partially by existing standards for nonacoustic aspects of buildings, but also as some kind of tradition in civil engineering. Wooden constructions are extremely rare. In Serbia wood is not a widespread material for wall constructions, even in single-family houses. That is probably according to the same reasons as for other types of light constructions. Wood is only used for roof construction, and only in single-family houses.

Mandatory thermal insulation between dwellings in Serbia was introduced at the end of the year 2012. Thus, in almost all existing housing stock the request for thermal insulation had no influence on design of walls between dwellings. Thus concrete walls without any additional insulating layer are common practice.

Structure of walls between dwellings

The use of certain types of walls between dwellings was a result of the common practice in a design process to combine structural requirements with other aspects of building quality. The representation of certain types of partition walls in the Serbian national typology of the housing stock is shows in Figure 22.4 (0,7% of walls are of some different types).

Due to the practice of dominant use of either massive masonry walls or a concrete panel system as the main load-bearing vertical structures of a house rather than a skeleton system, in most of the multi-dwelling buildings the structural walls were used as partitions between the dwellings. Solid brick was a dominant building material until the 1980's, and massive, load-bearing walls in earlier construction periods were in the most of the cases made as brick masonry walls. From the 1980's this practice has been substituted with either hollow clay block walls, or in most cases of today's building practice with reinforced concrete wall.

In some of the buildings there was also a practice of using double layer walls. Such constructions could have inner core either in a form of an air gap, or with the gap filled with a thermal insulation layer.

In about 15% of the existing buildings between dwellings there are multi-layer walls with an air-gap inside. Such walls were in use from the 1920's onwards, until the 1980's. The width of the air-gap varied from 4 cm to 25 cm, depending on non-acoustic factors in the building construction. Wider gaps can be found where the installations are placed between two dwellings. Their schematic pictures and structure are presented in the Table 22.2.

In about 17,3% of the existing buildings there are thermal insulating layers inside double layer walls, instead of an air-gap. This practice started from

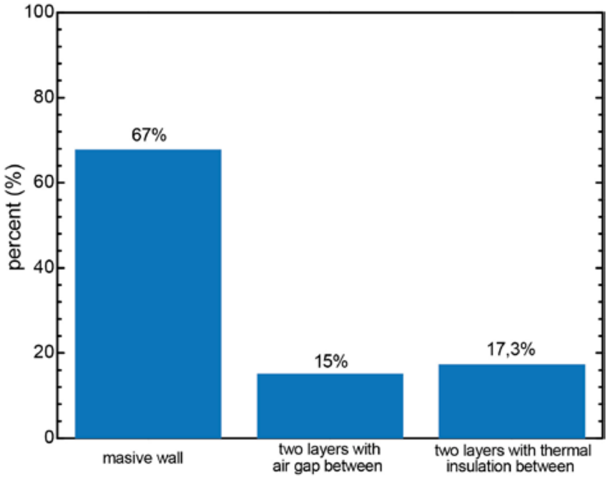


Figure 22.4. *Representation of different types of walls between dwellings in the Serbian housing stock.*

the 1970's onwards. Their schematic pictures and structure are presented in the Table 22.3.

Structure of floors between dwellings

Floor structures between dwellings have more variations in types compared with walls. There are different types of concrete ribbed structures (30%), as well as concrete slab structures, which is the most used type of floor construction today (38%). From the time of the 1960's onwards there is also a significant use of semi-prefabricated hollow clay block floor constructions (30%), which are still in frequent use in family houses. The representation of different types of floor constructions in multi-family houses is shown in Figure 22.5. The main types of ribbed concrete slab floor structures are presented in Table 22.4, and semi-prefabricated hollow clay block structures in Table 22.5.

There are also some other types of floors, but at a very small percentage of the total housing stock, such as different types of prefabricated hollow concrete slab structures. In the oldest buildings there are also typical floor structures of that time, either with wooden rafters or vaulted structures, usually represented as a so-called Prussian vault.

Table 22.2. *Types and structure of typical two layer partition walls between dwellings with an air-gap.*

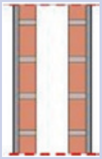
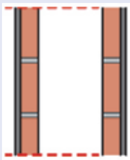
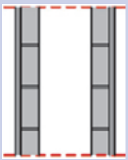
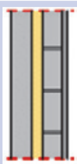
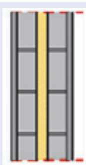
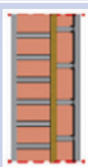
type of structure	Description
	plaster 2 cm, brick wall 6,5 cm, air gap 4-12 cm, brick wall 6,5 cm, plaster 2 cm
	plaster 2 cm, breeze block 7 cm, air gap up to 25 cm, breeze block 7 cm, plaster 2 cm
	plaster 2 cm, hollow concrete block 7 cm, air gap up to 20 cm, hollow concrete block 7 cm, plaster 2 cm

Table 22.3. *Types and structure of typical two layer partition walls between dwellings with a thermal insulating core layer.*

type of structure	Description
	gypsum block 7 cm, woodwool slab 4 cm, hollow concrete block 7 cm, plaster 2 cm
	plaster 2 cm, hollow concrete block 7 cm, wood wool slab 4 cm, hollow concrete block 7 cm, plaster 2 cm
	plaster 2 cm, brick 12 cm, thermal insulation 2 cm, brick 6,5 cm, plaster 2 cm

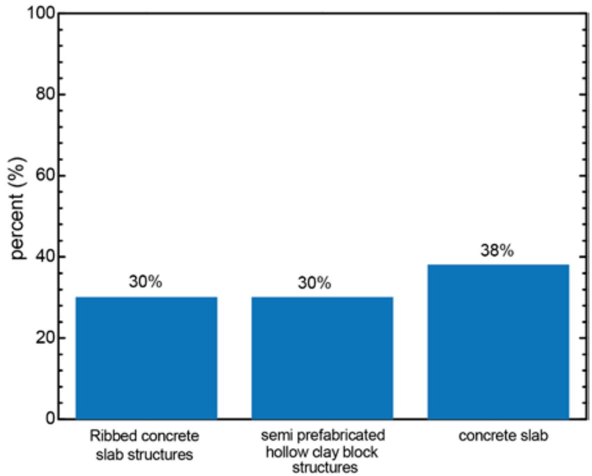


Figure 22.5. *Representation of different types of floors between dwellings in the Serbian housing stock.*

The typical constructions of semi prefabricated hollow clay block floor used in Serbia are presented in Table 22.5. These constructions can be found in multi-family houses in two variations: as a so-called TM floor construction which is the older version and one of the favourite floor structures of the period 1960-1990 when they were replaced in the most cases with improved version known as a the LMT floor construction.

22.4. Sound insulation of typical constructions between dwellings

Sound insulation of typical walls

A 15-16 cm thick concrete slab is a common type of partition between dwellings today in high-rise buildings because it is also the structural wall. To estimate the effects on sound insulation in analysed buildings the results of sound insulation index measurement obtained for the walls with the same structure, in this case concrete slab 16 cm thick, are presented in Figure 22.5. A total of 18 walls of that type in different buildings were measured. The mean value is presented in the diagram below.

Table 22.4. *Types and structure of typical ribbed concrete slab structures between dwellings.*

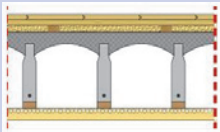
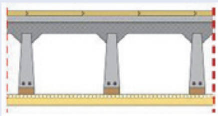
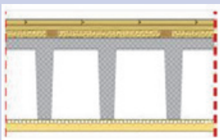
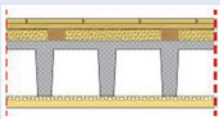
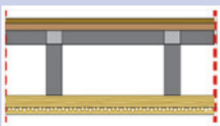
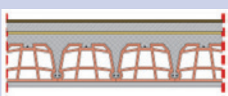
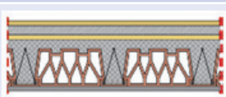
type of structure	Description
	parquet 2,2 cm, wooden subfloor 2,5 cm, wooden sleepers 8/5 in sand bedding 5 cm, semi prefabricated *Herbst* ribbed concrete slab 30 cm + air gap, straw - plaster ceiling 5 cm
	parquet 2,2 cm glued, cement screed 3 cm, ribbed semi prefabricated concrete slab *Avramenko* 30 cm, straw - plaster ceiling 5 cm
	parquet 2,2 cm, wooden subfloor 2,5 cm, wooden sleepers 8/5 in sand bedding 5 cm, ribbed concrete slab 35 cm, straw - plaster ceiling 5 cm
	parquet 2,2 cm, wooden subfloor 2,5 cm, wooden sleepers 8/5 in sand bedding 5 cm, ribbed concrete slab 5+20 cm, straw - plaster ceiling 5 cm
	parquet 2,2 cm, wood cement screed 3 cm, ribbed concrete slab *Standard* 28 cm, straw-plaster ceiling 5 cm
	parquet 1,2 cm, wood fibre board base 3 cm, *natron* paper, IMS prefabricated concrete slab 22 cm

Table 22.5. *Types of typical semi prefabricated hollow clay block structures between dwellings.*

type of structure	Description
	parquet 2,2 cm, wood cement screed 2,5 cm (or parquet 1 cm, cement screed 3 cm, elastic layer 1-3 cm,), TM slab with hollow clay block 20 cm, plaster 2 cm
	parquet 2,2 cm, cement screed 3 cm, elastic layer 2 cm, LMT slab with hollow clay block 20 cm, plaster 2 cm

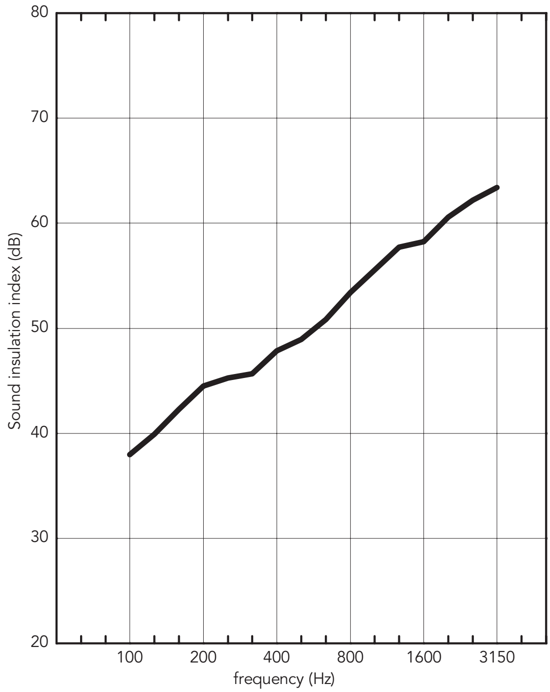


Figure 22.6. *Mean value of sound reduction index for 16 cm concrete wall between dwellings measured in 18 buildings.*

The diagram presented in Figure 22.6 as an average includes all influences in real buildings as flanking transmission, difference in rebar structure inside the concrete slab and installations breakthrough [3].

Normalised impact sound

To estimate influence of those effects on sound insulation in analysed buildings the results obtained for the walls with the same structure, in this case concrete slab 16 cm thick, are presented in Figure 22.7. That type of wall is the most frequent as the partition between dwellings in high-rise buildings today, because it also the structural wall. Total of 16 walls of that type in different buildings were found and measured. The mean value is also presented in a diagram.

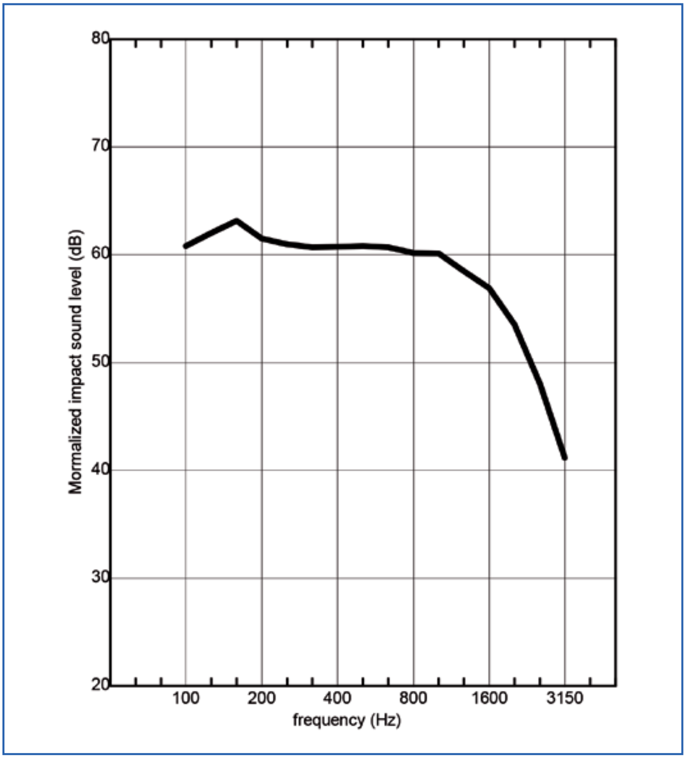


Figure 22.7. *Mean value of normalized impact sound level of 16 cm concrete slab with floating floor.*

22.5. Typical errors in design and in workmanship practice

Solid masonry partitions, as a widespread type in multidwelling buildings in Serbia, are less sensitive to potential incorrect approaches during building construction, compared to more complex structures. But there is still enough tolerance for some characteristic errors in design and in workmanship practice.

Most frequent errors in design stage with strong influence on the sound insulation inside the buildings are:

- Selection of partitions between dwellings by the data of laboratory measured sound insulation, without taking into account flanking transmission and type of junctions (calculation of sound insulation according to EN12354 is still not mandatory);

- Stairs rigidly connected to the side walls;
- Lack of floating floor in terraces and balconies above dwellings.
- Design of inappropriate material for resilient layer in floating floors;
- Lack of details concerned sound insulation in design of installations.

At the design stage a common error is the specification of incorrect materials as the elastic layer in floating floors. There is some misunderstanding among architects about appropriate materials for that purpose, which is difficult to overcome. Favoured materials often make the resonant frequency of floors too high and increase the impact sound level. It seems that there is a misguided verbal "tradition" between architects which propagates the same mistakes at a number of buildings all around the county. Such details in building design are not covered in university architecture courses, nor are good sources of reliable information available to them.

Most frequent workmanship errors with consequences on sound insulation are:

- Connection between floating floor and walls with acoustic bridge along perimeter; in nearly 100% of existing buildings floating floor in bathrooms exhibits this error (see Figure 22.4);
- Lack of mortar in vertical joints between bricks and clay blocks;
- Sound absorbing material not continuous in the cavity of cavity walls;
- Missing plaster on one side of the cavity in the cavity walls;
- Floor surface below the floating floor not perfectly flat, or not properly cleaned from brick pieces;
- Sometimes workers make special efforts to "improve" the floor and fill the gap around floating floor with mortar (see Figure 22.4);
- Unfiled holes and slits around HVAC installation.

Besides installations, the "weakest" part in buildings from the point of view of incorrect design and mistakes in workmanship practice are floating floors. In a number of analysed buildings two levels of errors in floating floors were detected: in the design stage and in their implementation.

In the practice main problems arise with appearance of parasitic sound bridges between floating layer and concrete slab or floating layer and walls around the room perimeter. The results of various measurements proved that is hard to find floating floors with ceramic floor coverings without sound bridges around the perimeter. There is a lack of good practice in implantation of such details.

At Figure 22.8 two characteristic workmanship errors with floating floor are presented. An example from a bathroom (picture on left) reveals a rigid contact between ceramic tiles on the floor and on the wall. An additional example (picture on the right) shows the consequence of workers special efforts to "improve" the floor and fill the gap around floating floor with mortar.

Figure 22.8. *Two examples of workmanship errors on floating floor: rigid contact between ceramic tiles on floor and wall (left), gap around a floating floor intentionaly filled with mortar (right).*

22.6. References

[1] http://popis2011.stat.rs/

[2] Jovanović Popović M. et al.: *Stambene zgrade Srbije/Residential Buildings in Serbia*. Belgrade: Faculty of Architecture, University of Belgrade, 2013.

[3] M.Mijić, D.Šumarac-Pavlović, D.Todorović, A.Radivojević, "Sound insulation between dwellings in existing housing stock in Serbia", Euronoise, Prag, 2012, Proceedings, 1254-1259

[4] http://www.costtu0901.eu/