



ANALYSIS OF INDIVIDUAL HOUSING UNITS FROM THE ASPECT OF BUILDING TECHNOLOGIES

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Individual housing units in Serbia have been studied from the aspect of applied technical solutions. Analyzed data have been collected during a field research in accordance with the current administrative regional division, and they represent a basis for definition of regional typology of individual housing units. Characteristic types of objects of each region's typology have been further analyzed. Upon these analyses regional characteristics of individual housing units regarding applied construction types, building technologies and materials have been defined and presented.

Key words: individual housing units, regional characteristics, typology, building technology.

INTRODUCTION

The basis for the research presented in this paper has been defined throughout several projects conducted by the team of faculty members and associates from the Faculty of Architecture in Belgrade. These projects have resulted in the establishment of the research methodology for creating the national typology of residential building stock. Part of the data collected in the process of defining the national typology serve as the basis for the research of the influences of regional characteristics on the characteristics of individual housing units from the aspect of applied building technologies. The term *individual housing unit* equals to the term *family dwelling* and refers to buildings that in their composition have mostly one and at most four independent residential units within a singular building.

The theoretical basis of this research lies in theories of regionalism. The paper establishes the thesis that through analyses of regional characteristics such as climate, geography, relief, and demographics, but also including historical,

economic, political and cultural aspects, one can examine the connections of architecture of the region's individual housing units, its applied technology, construction and materials.

RESEARCH METHODOLOGY

The chosen methodology upon which the typology was developed is the one presented within the international project TABULA², which was defined for Serbia through a research project of Energy Efficiency of buildings (Jovanović Popović *et al.*, 2011). This methodology defines characteristic building types, by construction period and performances related to architecture and urban design (layout on the lot or within a building development, the relations to the surrounding buildings, etc). The total number of 21 types is defined. In order to obtain relevant data for the typology, an independent, expert statistical survey was designed. The data required for the typology were defined and questionnaires were prepared in cooperation with the experts. The study considered questions related to the utilization of lofts and basements, types of

windows, volumetric characteristics of the buildings, and the percentage of window surfaces on the facades. The survey utilized the existing administrative division of Serbia into 6 regions (without Kosovo), defined as: East, West, Central, Southeast, North Serbia and Belgrade. The in-field inventory of the buildings was planned as two-fold. The first stage included approximately 6,200 buildings; there were 432 starting points; 16 buildings were entered against each starting point. The second stage included approximately 1,200 buildings. The first stage (Phase A) contained general-type questions that did not necessitate direct contact with the tenants, whereas the second stage (Phase B) was more detailed and required the tenants' cooperation.

Part of the results (related to individual housing units) of this thorough and significant research have been published recently (Jovanović Popović *et al.* 2012). Some of the

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² TABULA - Typology Approach for Building Stock Energy Assessment, <http://www.building-typology.eu/>

primary data analyses dealing with building characteristics are considered very important for the research presented in this paper:

- most of the residential block construction took place after World War II and lasted until the 1980s, when more than a half of the total residential building stock in Serbia was built,
- most common type of dwelling in Serbia is the detached single-family house, which comprises almost 90% of the total building stock, taking into account the *number* and not the *area* of the buildings.

Among other general conclusions from the survey are those that refer to the insufficient level of applied thermal insulation (84% of buildings lack any thermal insulation in walls, 87% in roofs), number of incomplete facades, or most common window type (wide or narrow double-window casings, over 50% older than 30 years).

In addressing the issues of regionalism, the research relies on the reference literature, from Vitruvius and architecture defined by geography (Petrović, 2002), Bernard Rudofsky's theory of unrehearsed regional architecture created by anonymous authors (Rudofsky, 1976), including the modern set of practices incorporated in Vincent Canizaro's book (Canizaro, 2007).

REGIONAL CHARACTERISTICS

West Serbia

The region of West Serbia is composed of three districts: Mačva, Kolubara and Zlatibor (the largest district in Serbia), and represents the most diverse among all analyzed regions in terms of its climate, geography and demographics.

Characteristics of the region

This region is characterized by low population density, ranging from 44.45 inh/km² in Zlatibor district to 91.12 inh/km² in Mačva. Depopulation is one of the fundamental problems in this region, as a consequence of contemporary lifestyle and economic and political conditions (last census showed depopulation rate of 13.6%). Rural settlements are dominantly prevailing in all districts (around 95% of the total number of settlements are rural).

The relief of the region ranges from low fertile land around rivers in Mačva district, to a slightly hilly landscape of Kolubara district and mountainous landscape of Zlatibor, which is rich in woods and wood material, used as a significant element of local regional architecture. Consequently, climate also differs throughout the region. Temperate continental climate is prevailing in Kolubara region, while

mountainous climate is characteristic for Zlatibor district and Pannonian climate in Mačva, with large temperature variations throughout the year. From these differences in relief and climate regional differences in local architecture have emerged. Therefore, the architecture of individual housing units in Mačva resembles the architecture of Vojvodina, while regional characteristics of Kolubara district are similar to those in Central Serbia. The district of Zlatibor has certain predispositions that significantly affect local architecture – climate conditions and abundance of wood as local material. However, small building density of this district led to the lost of representatives of this mountainous building types in the overall survey data.

Processed data analysis

Most (48.43%) of the surveyed buildings were built during the 1970s and 1980s, followed by the period between 1946 and 1970 (23.62%). The 1990s were characterized by reduced intensity of construction (11.36% of the total number of buildings was built then), and less than 5% of residential buildings were built in the first decade of the 21st century. In all construction periods, type of the free-standing house is absolutely predominant. From totally 21 theoretical types 12 were identified in the region of West Serbia, and the predominant one is shown in Figure 1.



Figure 1. Representative of some of the predominant individual housing unit types in West Serbia region (statistically), a free standing house built in the 1970s

Collected data analysis - building characteristics

Greater variety in building types and difference between urban and rural buildings, as well as greater sensitivity to local conditions is present

in buildings dating from the first half of the 20th century. Regional characteristics in terms of building technologies and applied materials are obvious in older buildings, but since the 1960s almost all local features of town and country houses in the region have been lost. Although examples of apparent local influences exist throughout the region, their number is irrelevant for the survey data. Older buildings in rural areas display variations of wattle and daub constructions, while town houses from the same periods are built of solid materials. Brick wall of 38cm thickness is the most common type of solid wall for construction in the first half of the 20th century. Although timber is an omnipresent local material, no timber houses appear in the data specimen. However, timber is in vast use as a secondary building material, as well as the predominant material for roof construction. The inner-story floors and ceiling construction towards the attic in older houses is also mostly wooden. Buildings from the second half of the 20th century were built mostly of brick, while in the 1970s and 1980s cellular clay blocks and *Siporex* blocks came into wider use. The floors are usually full concrete slabs, or a variation of semi-prefabricated structures with clay block infill. Over the last few decades of the 20th century, there was sporadic application of insulating materials within façade walls, but most buildings do not meet current requirements in terms of thermal comfort.

Central Serbia

Central Serbia includes four districts: Šumadija, Moravica, Rasina and Raška.

Characteristics of the region

This region contains 1,035 settlements, of which 24 are urban, which indicates evident domination of rural settlements. Highest population density in this region is in Šumadija district (121.8 inh/km²).

This region has a rich history. It was the territory of the first Serbian state in the 9th century, and the center of the medieval kingdom. Under the Ottoman Empire it was the central merchant road between Asia Minor and Bosnia and a main Ottoman merchant center in Europe.

Relief of this region is not compact but interspersed with many valleys, bends and gorges which enables deeper breakthrough of air masses in their directions and causes climate of temperate continental characteristics, except in the mountains (Kopaonik). Also, the Pešter limestone plateau, in the altitude of up to 1200 m, has a distinctive micro climate, characterized by very cold winters (Ducić, Radovanović, 2005). The lowest temperature in Serbia, -39.5°C was recorded here.

As the survey results show, the most intensive period of construction overlaps with the period of economic and production development of this region, from the end of World War II (WWII) until the 1990s. Favorable geographic position and relief caused the development of the main road route through Serbia (Ibarska magistrala), which influenced the further development of rural settlements and their transformation into small towns (Spasić and Petrić, 2006). Rich cultural history and development of several tourist centers (like Kopaonik and Vrnjačka Banja) also contributed the rapid development and building activity in the entire region.

Processed data analysis

In consequence of World War I (WWI) and WWII, as well as the fact that the region was even more rural in the past, there were less than 7% of buildings identified as dating before 1945. In terms of construction periods, the prevalence rate indicates that most buildings in the region were built between 1946 and 1970, but the most active period of construction was the following decade (24%). Construction activity in the following periods depicts the overall historic and socio-economic circumstances in Serbia, and it drops to approximately 17.5% and continues to decrease. Free standing units prevail in all periods of construction. In this region 13 types of single-family houses were identified, and selected types are shown in Figures 2a and 2b.



Figures 2a. and 2b. Representatives of the least (a) and the most (b) common individual housing unit types in Central Serbia region (statistically): (a) a house built in 1905 (b) a house built in 1955

Collected data analysis- building characteristics

The traditional construction solutions (rammed earth, post and petrail, logs, etc.) can be found in an insignificant number of buildings and were hence excluded from the survey. Among houses dating from the first half of the 20th century elements of style can be found, which are being preserved by contemporary reconstructions. Massive type of construction is prevailing in all periods of construction. Walls are predominantly made of brick (thickness ranging from 25–45 cm) and clay blocks. Roof construction is wooden, with clay roof tiling. Construction of inter-story floor slabs varies from wooden (found in houses built before WWII) to massive concrete or semi-prefabricated concrete and clay block slabs. Characteristic form of lofts, known as *karatavan* is found in older houses, characterized by the slab construction made of wood beams and planks covered with soil above and straw and plaster ceiling below. Loft area formed in this way can be used for storage, but usually has no function except to create a buffer zone towards the roof construction and improve thermal comfort. Windows are wooden with two single-pane sashes in a wide casement and wooden blinds. Also, compact floor plan and low ratio of façade openings characterizes houses from all construction periods and is even more expressed in newly built houses. Houses built before 1980s do not have any thermal insulation, and since then its application started modestly. Also, a significant number of houses used for dwelling, mostly built after 1980s, do not have the finished façade.

Southeast Serbia

Southeast Serbia includes five administrative districts: Nišavski, Toplički, Pirotski, Jablanički and Pčinjski district.

Characteristics of the region

Southeast Serbia is characterized by low density, with climax in Pirot (only 33.4 inh/km²). Throughout the region villages are predominant over cities (1,465 villages in total), and they are grouped close to the main district centers (Niš, Prokuplje, Pirot, Leskovac and Vranje).

The relief of this region is compact, and as in most parts of Serbia continental climate is prevailing, with the exception of the cities of Niš and Leskovac, which have the characteristics of steppe climate (Ducić and Radovanović, 2005).

The development of regional architecture of the area is influenced by rich historical past. This is a region that for centuries constituted the main transit route, linking the west of the continent to its south and southeast, and on to Asia. Today,

this equally important connecting transversal, through which a highway E-75 overpasses, contributes to the specific economic development of the region in which the third largest city in Serbia, Niš, is located. In this region also, the conditions for the construction of new individual dwellings have been created after WWII, and although a large number of units was built before, many destructive wars and unstable history of the country had caused their destruction. Years of active construction of the housing stock of Yugoslavia, including this region, is the period of its growth, economic and political power, and is considered to be after 1946 (especially after the fifties and early sixties when the rate of industrial growth and rapid development of Yugoslavia was among the fastest in the world) (Štraus, 1991), until the 1990s and the disintegration of Yugoslavia.

Processed data analysis

Most of the surveyed buildings were built in the period between 1946 and 1970 (even 82%). Much less objects were built during the 1990s (10%) because of the unstable political and economic situation in the country, similar to the period of WWI and WWII (only 8.2%). As much as 49.8% of analyzed houses are found in the rural environment, which explains significant presence of single family houses (even 86.19%) in the analyzed model and confirms the region's rural character. From totally 21 theoretical types 19 were identified, and their representatives are shown in Figures 3a and 3b.



Figures 3a. and 3b. Representatives of the least (a) and the most (b) common individual housing unit types in Southeast Serbia region (statistically): (a) a house built before 1918 (b) a house built in 1958

Collected data analysis- building characteristics

The traditional individual housing units in the rural environment of the region, built before the 1950s, were so-called *čatmare*. The construction of these objects was a combination of wooden skeleton (such as in post-and-petral buildings) and earth infill, by traditional building technique such as wattle-and-daub. Although construction of houses in these traditional ways gave way to massive construction after WWII, these houses still exist and some are in exceptionally good condition.

The main material in massive construction for walls was brick and other clay products, dominantly for walls, but also for slab construction. Floor construction is very similar to those in other regions of Serbia, at first made from wooden structures, and later from the new types of concrete slabs or ribbed structures (including complex ribbed structures such as *Avramenko* ribbed slab, mostly used in construction of larger multi-family buildings). Windows are dominantly wooden, with exterior blinds, and of rather small size. Also, as in other regions, thermal properties of houses built after the appearance of first thermal regulations are not satisfying, and often have no thermal insulation applied.

East Serbia

This region occupies the area of five administrative districts: Podunavski, Pomoravski, Braničevski, Borski and Zaječar district.

Characteristics of the region

The region is characterized by the rivers of Danube and Morava to the northern and western edge, the Carpathian mountain range in central, and the Negotinska Krajina depression in the far southeast of its territory.

Most districts (except Podunavlje district) have low population density (around 56 inh/km²) due to specific economic and geopolitical situation. The region is predominantly rural in character, with many villages and only 20% percent of the urbanized territory.

Continental climate prevails on the whole territory of the region. The exception is Negotinska Krajina, where due to the specific geographic location and impact of the surrounding mountain ranges, climate takes form of a special local character, manifested through extreme temperatures throughout the year. Precipitation is uniform throughout the year, with a slight increase in intensity during spring and summer (Ducić and Radovanović, 2005).

The richest parts of the territory in terms of

history and culture can be found along the watercourses of the Danube, where there are numerous remains dating from Roman, and even from the prehistoric period (back to 6,500 BC). The formation of the first Slavic settlements dates from the early 5th century. The culmination of immigration and settlement construction is associated with the formation of the first Serbian state (end of the 5th century). Since then, turbulent history was first characterized by constant struggle for dominance over this territory between Serbs, Hungarians and Bulgarians, and then the rule of the Great Ottoman Empire (from the 15th until the late 18th century). The liberation from the Turks and the proclamation of the Serbian government finally came in 1867.

Processed data analysis

Most houses (35%) were built between 1946 and 1970, while the least represented were the houses built before 1919 (mere 0.20%). Also, construction intensity in family housing decreased dramatically since 1980s, which explains the overall data that more than 90% of all units were built before 1990. With regard to the defined housing typology, free standing houses have the absolute prevalence in the region (98.65% of the sample). Most buildings of this type are clustered around major cities. From totally 21 theoretical types 13 were identified in this region, of which selected types are shown in Figures 4a and 4b .



Figures 4a. and 4b. Representatives of the least (a) and the most (b) common individual housing unit types in East Serbia region (statistically): (a) a house built after 2001 (b) a house built between 1946 and 1970

Collected data analysis – building characteristics

Similar to the previous region, traditional building techniques, such as post-and-petral with wattle and daub infill, characterized houses built before WWII, especially in rural areas., of which some are still in good condition and partially used for living. Later on, dominant building material becomes brick, used for massive wall construction (25-38 cm thick), and replaced by hollow clay blocks in the last few decades. Also, regarding the inter-floor slabs, in older houses wooden construction was widely used, with characteristic earthen infill in the floor to roof slab, forming the characteristic form of attic construction, present also in other regions of Serbia. These constructions are also replaced by reinforced concrete slabs as well as semi-prefabricated constructions with hollow clay infill. The façade openings are mostly double sashes with single panes, which, although outdated, can be considered much more efficient than the classic single sash window. Most buildings, regardless of the period of construction, still have no, or very little thermal insulation applied.

Vojvodina

Geographically, this area is divided by rivers Danube, Sava and Tisa into Srem, Banat and Bačka districts, which are further subdivided.

Characteristics of the region

Terrain is mostly low-altitude, with the exception of two mountainous elevations: Fruška Gora in the north of Srem and Vršački Breg to the south-east of Banat. The region's wealth in rivers, the Danube water potential and the possibility of a strategic alliance with the dominant points of Europe, have enabled its continuous development. Also, large amounts of clay impose its use for the construction purposes. It is important to note that, although the second largest city in Serbia, Novi Sad, is located in Vojvodina, rural settlements prevail in relation to the urban ones.

A moderate continental climate prevails in Vojvodina. Disposition of precipitation has the characteristics of the Central European, Danubian regime with an uneven monthly distribution. The southeastern wind *košava*, northern and southern winds are typical for this area.

The region is rich in history that dates back to the Paleolithic period. Throughout history it has been under the rule of the Kingdom of Hungary, the Ottoman and Austro-Hungarian Empire. It is during the last one that the planning organization of urban and rural

settlements was set, which caused the emergence of typological group of row houses. Another crucial period which clearly influenced the shaping of regional architecture in Vojvodina is its constitution as the Socialist Autonomous Province by the Yugoslav Constitution of 1974. Throughout this period, after WWII to the 1980s, an increase in the number of constructed objects is noted.

Processed data analysis

The main characteristic that distinguishes housing units of Vojvodina from the other regions is a significant percentage of row houses (15.53%). This has emerged as a direct result of regional influences, the already mentioned urban planning of the Austro-Hungarians. The other significant characteristic is the fact that far more objects than in the other regions were built before 1919 and in the interwar period (24.14% that exist today). However, most of the surveyed buildings were built in the periods between 1946 and 1980 (even 79%). This is a direct consequence of the already explained socio-economic situation in that period. From totally 21 theoretical types all 21 were identified in Vojvodina (representatives shown in Figures 5a and 5b).



Figures 5a. and 5b. Some of the least (a) and the most (b) common individual housing unit types in Vojvodina region (statistically): (a) a house built in 1990s (b) a house built in 1925

Collected data analysis- building characteristics

Buildings built in the earlier periods (before 1919 and until WWII) were constructed by

traditional building techniques and materials such as rammed earth (rammed clay) and unbaked loam brick, mainly in rural environment but also in urban ones. In this, the connection to the region's natural aspects and its traditional architecture is visible. As much as 31% out of Vojvodina's present housing stock accounts for houses built in traditional techniques using rammed earth or unbaked brick (less frequently, baked brick). These houses are single-story, with the attic space that was not used for living, with the ceiling made from wooden structures and rammed earth on top, similar to the characteristic attic form of *karatavan* in Central Serbia.

After WWII, changes in materials are evident. The most common material in this period is baked brick, and later hollow clay block. Floor constructions to unheated roof are still made from wooden structures, but from the 1970s the new types of concrete slabs or ribbed structures are used. The most common material for roof covering is tile, flat pepper-tile on buildings dating before 1945 and grooved tile on the newer ones.

Generally, thermal insulation is applied on houses built in last 20 years, but could be traced even earlier, with the subsequent installation of thermal insulation in older buildings that were built after 1945 with massive brick walls. The ones built earlier, with clay and adobe walls have good thermal storage capacity, and natural regulation of indoor moisture, and therefore do not need additional insulation for achieving satisfactory thermal comfort.

Belgrade

Belgrade is an independent territorial unit of local government consisting of 17 municipalities. In this research it is singled out as an independent region for its specific political, cultural, economic and social development, and because of that its regional characteristics of architecture and construction methods cannot fully be identified with any other region in Serbia. There have been previous researches of Belgrade building stock (Jovanović Popović et al., 2007), but they were mostly dealing with buildings for collective housing.

Characteristics of the region

Today the city is a center of political power, culture, tourism and international transportation hub. The average population density is 508.87 inh/km². The climate of this area is moderate continental (with the strong periodical *košava* wind), and its relief is diverse.

The oldest traces of settlement in the Belgrade area date from the Neolithic period (7,000

years BC). Its strategic position in the Balkans, on the banks of rivers Sava and Danube, has led to the development of numerous turbulent historical moments. Belgrade was first mentioned as a fortified settlement (*Singidunum*) in 279 BC, and later it was an edge city of the Byzantine Empire. Serbian rule over Belgrade begins in 1284. Finally, Belgrade became the capital of Serbia since the establishment of the Kingdom, in 1882.

What distinguishes Belgrade from other five regions is the strong influence of architectural styles and movements in all of its periods of construction, affecting significantly the individual housing architecture. In the beginning of the 20th century architecture was based on ideas about the revival of the nation. The period after WWI can be considered as a period of intensive building. Changes that occurred much later, after WWII, during the 1960s, caused by high economic growth and the inflow of money in the former Yugoslavia, are evident. This resulted in a sudden increase in construction, with the main objective of achieving multiplicity and high capacity of new objects. The state began to invest in large-scale projects, building new parts of the city, like New Belgrade. It is inevitable that the Conference of Yugoslav architects in Dubrovnik (1950), which marked the end of socialistic style domination (Štraus, 1991), was a crucial point for the development of author-based architecture of the 1960s. In the following period (1970s) of false economic prosperity of Yugoslavia, with a large number of foreign borrowings (Štraus, 1991), one can analyze mature critical position facing the elements of traditional values in Serbian architecture.

Last observed period covered by this survey is the period after the disintegration of Yugoslavia in the 1990s and important political changes in Serbia after 2000. This interval is marked by numerous social, political and economic instabilities in the country.

Processed data analysis

Free standing units also prevail in Belgrade region (95.61%). The largest number of units was built between 1946 and 1970 (31.03%), while number of buildings built in the next three decades is similar (around 17% per each). Only 0.31% of survey specimen is dating before WWI, and another 12.22% from the inter-war period, which is direct consequence of the turbulent and devastating history. In the last decade only 6.27% of units were built, which can be explained by the unfavorable socio-political and economic situation, but also by the fact that large number of individual housing units is being replaced by multifamily

buildings. From totally 21 theoretical types 15 were identified, of which the most common is shown in Figure 6.



Figure 6. The most common individual housing unit type in Belgrade region (statistically): a free standing house built between 1946 and 1970

Collected data analysis – building characteristics

The main difference between characteristics of Belgrade region in terms of construction techniques and materialization compared to other regions is that massive building techniques are used throughout all periods of construction, including the oldest ones. Here not only brick (which still prevails), but also stone and concrete massive construction assemblies appear. Inter-story slabs found in older houses are mainly concrete ribbed and wooden, while in the last few decades concrete slabs and partially prefabricated slabs with clay block infill dominate. Roofs are dominantly pitched, with wooden construction and clay coverings, and flat roofs are rare even in cubic form houses (pitched roof is hidden behind wall endings). In houses built before the 1990s windows are mostly wooden with two single-pane sashes in a wide casement or double single-pane sashes with exterior blinds, while newer houses have thermal glazing in PVC or wooden single frames. Since 1980s thermal insulation can be found sporadically applied, but units with satisfying thermal properties are still rare.

CONCLUSIONS

Based on the analysis of selected building types and characteristic of place several key conclusions can be drawn. Natural aspects of the regions significantly influenced the building technology and materialization until the period of massive housing construction in the post war periods. Since then, unification of construction technologies and applied materials is

omnipresent. By the statistical data, in this period (1946–1980) the greatest part of Serbian individual housing stock was built. Typology analyses show that the most common type of individual housing units is the free-standing house, while row houses exist in negligible number in all regions, except in Vojvodina.

Throughout all regions, the dominant building material is brick, used for massive wall construction (usually 38 cm thick), replaced by hollow clay blocks in the last few decades. Wooden construction for inter-floor slabs is widely used in older houses, replaced by reinforced concrete slabs as well as semi-prefabricated constructions with hollow clay infill in later periods. Roof construction is wooden almost in all cases, with clay roof tiling. Windows are rather small in size, with the assembly made of wooden double sashes with single panes and exterior blinds. Nowadays, this type is replaced by thermal insulating glass with diverse frame structure. Most buildings, regardless of the period of construction, still have no, or very little thermal insulation applied.

By tracing theories of regionalism in architecture (from Vitruvius statement that architecture is originally defined by geography to contemporary theories in which regionalism is defined by borders of region) this paper comes to conclusion that in the presented regions of Serbia, in addition to geographical features, the historical, economic and cultural aspects had the most profound effects on the regional characteristics of the architecture of individual housing units in Serbia. But those influences are most visible on those houses built until WWII, when it appears that architecture was more defined by place.

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