FUNCTIONAL DEMANDS OF CONTEMPORARY HOUSING AS AN INDUCEMENT FOR DEVELOPMENT OF NEW FLOOR STRUCTURE SYSTEMS BASED ON CLAY PRODUCTS - YUGOSLAV EXPERIENCE

M. Jovanovic-Popovic¹, A. Radivojevic¹
¹Faculty of Architecture, University of Belgrade, Bulevar revolucije 73/II, 11000 Beograd, Yugoslavia

ABSTRACT

Due to the quality of natural resources, brick and other clay products represent a traditional building material in Yugoslav region, especially in its north, Panonic part. However, being intensive and mass, post-war housing construction, led to a wide use of reinforced concrete prefabrication, while restrictive regulations imposed construction of minimal dwellings and consequently the use of small or moderate span structures, disabling flexibility and adaptability of housing units. In the last fifteen years, thanks to decreased need for dwelling spaces, less, but bigger residences are being built. At the same time, instead of prefabrication, there is again a more extensive use of clay products in building systems, adapted to new building regulations (thermal, seismic, etc.), but also to individual requirements of tenants. Presenting semi-mounting floor structures that have been used in Yugoslavia, development and innovation of such systems has been analyzed in this paper, concerning their mass, span, thermal and acoustic characteristics, and primary their applicability in housing and other construction types.

Key words: clay elements, floor structure, housing, ribbed floors, semi-mounting, span.
1. INTRODUCTION

Apartment buildings as a type within the housing typology have always expressed movements and tendencies of one society. This considers not only the social and economical impact, but the technological development of one society as well. Having this in mind, the development of apartment buildings in the region of Yugoslav countries has followed the general European tendencies, although there were aspects that were typical for this particular region and Yugoslav society itself.

The development of the housing could also be considered through the development of the floor plan of an apartment or through the development of a certain building type, which were the most common ways of analyzing this problem. However, this could be equally observed by analyzing the technological potential and development of one country, offering in this way another view to this aspect. The most probably, there is a mutual impact of these two parameters to each other.

The constant tendency of any human civilization to rely to the maximum rate on the local resources influenced the use of ceramic products in this region, as clay was a traditional material for centuries, especially in northern, Panonic parts. On the other hand, since there always are some limiting factors, which in the case of floor structure are its span, weight and building technology, and for structural walls first of all their weight and bearing capacity, the use of clay products was closely connected to the development of production and building technologies.

Having all this in mind, this paper deals with a relation between a typology of building types that have been used in the Yugoslav regions during the last century and applied building technology, or more specifically, the building materials which were used for the construction of walls and floor structures.

Four typical chronological periods have been distinguished:
- up to the Second World War (1941)
- post-war period from 1945 – 1960
- 1960-1980
- 1980 up today

2. PERIOD BETWEEN THE TWO WORLD WARS (UP TO 1941)

This period was characterized by the construction of individual apartment buildings, located on the edges of urban blocks. Although at this time there were two different types of apartment buildings depending on the fact whether the edifice was meant for renting or as a residence of the owners, a typical layout of the apartment was created, known as a “Belgrade apartment”. It was characterized by grouping the rooms around a large apartment core, represented in a dinning
room. Such organizational scheme offered various opportunities for the maximal usage of narrow plots on which the buildings were built.

The applied vertical structural systems were almost exclusively massive masonry brick walls, organized either in a longitudinal or in a transversal direction. Depending on the height of the buildings, their thickness varied from 51, 64 cm on. This kind of walls that had a large mass and thermal inertia, created comfortable living conditions especially during the summer which was stimulated by the organization of a housing unit that offered a cross ventilation.

Among the large variety in floor structure types concerning their structural characteristics (concrete slabs, ribbed floors) which were used in this period, there were many of them representing ribbed floors that used different clay products in some way. They can be classified as follows:

floors with steel girders:
- with ceramic products around the steel girders and straw ceilings
- with ceramic products around the steel girders and as a filling between the girders ("Klajn", "Hurdis", "Sekura")

with segmental brick vaults ("Prussian" vault, flat vault) between steel girders

floors with hollow "bricks"
- as a filling between the concrete ribs ("Akerman")
- as a constitutional supporting part of a floor ("Rezeler")
Systems of the floor structures that were used in this periods in Yugoslavia were adopted from other, developed European countries and simply applied on the buildings.

3. POST-WAR PERIOD, FROM 1945 – 1960

During the post-war period demographic movements in the country, which was ruined to the great extent during the war, lead to the concentration of population in urban areas with a rate of growth of 4.79% during the first twenty years.

Table 1. Social impact to the mass housing construction (in Serbia).

<table>
<thead>
<tr>
<th>Urban population (in thousands)</th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>1. 1948.</td>
<td>1.294</td>
</tr>
<tr>
<td>2. 1971.</td>
<td>3.412</td>
</tr>
<tr>
<td>3. Annual growth rate</td>
<td>4.33%</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Demographic deficit</th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>Number of dwellings (in thousands)</td>
<td>2.154</td>
</tr>
<tr>
<td>Households (in thousands)</td>
<td>2.253</td>
</tr>
<tr>
<td>Difference</td>
<td>-.99</td>
</tr>
</tbody>
</table>
This was followed with the lack of apartments compared to the number of households.

The development of the country immediately after the war imposed the investment into an economical revival, while the housing problem was slightly off the priority. Up to 1956, the part of the gross national product that was reserved for the housing construction was approximately 3%, increasing to 7-8% in the 60s and leading to its improvement. At the same time, in other European country the same kind of percentage varied from 3,5 – 6,5%. However, considering the amortization of the housing fund, the necessity for a destruction of its worn out and non-hygienic parts, as well as the rise of demands regulated by standards, it could be concluded that the achieved rate of housing construction did not satisfy the growing needs.

In 1947, the Ministry of Buildings has endorsed the first normative which regulated some questions of mass housing construction. These regulations have determined spatial characteristics of apartments, while thermal, acoustical and lighting comforts were not considered at all.

In this period there are still the same organizational schemes of apartments which were in use in the previous period, before the war, as well as the same structural system. By the early 50s, the construction of first larger housing complexes and colonies has begun, mostly on free spaces at the edges of the cities (first housing blocks for 3000 inhabitants in Novi Beograd, Zeleznik, etc.). In 1958, new regulations were prepared, defining a rational designing and economical construction of housing buildings. Simultaneously, normative which determined the usage of modular coordination in the housing construction was prepared.

Since the industry of clay products was recovering very slowly after the war, apart from the use of simple bricks, the use of other clay products has diminished compared to the previous pre-war period. Different semi-mounting ribbed floor structures, but based on concrete were in extensive use, while some types of floors with hollow bricks rarely represented those based on the ceramics.


The housing shortage that was still present fifteen years after the war, augmented investment from the gross national product and technological development which lead to the industrial and prefabricated building construction resulted with a construction of large housing complexes for several thousands of inhabitants. These complexes were located either in completely new parts of the cities, like Novi Beograd, or at the edge of the ancient urban core.

The prefabricated systems which were applied for the housing construction were both those which were Yugoslav inventions, or imported ones that were accommodated to our building regulations, primary those that concerned seismic.
The majority of the buildings had facades that were made as a multi layered reinforced concrete panels. Brick was rarely applied on the facade surfaces in this period, and mostly as a revetment on the building that were built in the urban core. Efforts were made to apply ceramic products as a core of prefabricated facade panels but with no real success.

On the other hand, individual housing construction which was always present in some way and which relied on small private investors was based on the completely opposite building principles. Expensive for the small series which should have been when applied to small and low individual houses (up to 2 storeys), industrialized, prefabricated building construction was not suitable for this purpose. Therefore these buildings were built almost exclusively by the use of ceramic products.

For the purpose of construction of vertical structural elements, brick has partly seaded its place to hollow ceramic blocks of larger scale and of better thermal characteristics, the production of which has started by the end of 50s. The thickness of these walls was mostly 19, 25 or 29cm offering sufficient bearing capacity for the height of such buildings.

Floor structures in this period are almost exclusively made of semi-mounting floors based on ceramic elements, such as:

"Monta"
"TM"
"Rapid"

Monta is a floor structure based on hollow bricks of the following dimensions: 12-20/25/40cm, with two longitudinal grooves on its bottom side. On the ground, elements were bonded to each other with armature which was put into the grooves and coated with cement mortar and then put over the supporting walls. In the ribbs which were formed between these elements a special armature was put and then coated with concrete. The spans of these floor structures were 6m at most.

![Cross section of the "Monta" floor structure.](image-url)
Figure 6. Cross section of the “TM” floor structure.

Made on the same principles as Monta, TM is a floor structure which was a Yugoslav invention. The clay elements are made in two optional heights of 16 or 20cm and bonded together with an armature that is put into the grooves on the top of the element, as well as into those on the both lateral sides and coated with cement mortar. Formed in this way, such beams were put over the structural walls, forming a space for the future ribbs into which an armature is put, and coated with concrete afterwards. The thin plate of 4 or 5cm was made at the same time. This floor structure which is still in an extent use is applicable on the maximal spans of 6m.

Rapid floor structure is also a semi-mounting one. It consists of two types of clay elements different by their form and purpose:

the triangular ones that create a structural floor ribb which is put over the structural walls, and

trapezoidal ones which serve as a filling between the ribbs.

Figure 7. Axonometrical view of “Rapid” floor structure.
After putting the floor elements into their final position over the structural walls, the inter spacing is filled with concrete, creating a zone under a normal stress. This floor structure is made in heights of 15-22cm, and it is also used for the spans up to 6m.

5. FROM 1980 UP TODAY

Change of an economical system of housing construction, which concerned a transformation towards a private sector, has stopped the previously intensive housing construction that was based on the strict standards of spatial characteristics of apartments. Instead of constructing the whole urban complexes, this period is characterized by the construction of individual apartment buildings on free locations within the already formed urban blocks. The urban renewal and other tendencies which were common in Western European countries since the mid 80s have entered the Yugoslav regions with a time lag of ten to fifteen years. Individual and unique buildings, created for the free market and therefore formed in different manner concerning standards, comfort and prize, have completely excluded serial building production and prefabrication which was common in a previous time sequence.

At the same time, this is a period when great care has been given to ecological aspects of life, and consequently to the more extensive use of natural building materials, avoiding of a building concepts that led to the creation of “Faraday’s cage”, and general improvement of thermal conditions and building comfort, both in winter and in summer conditions. Architectural style which is mostly in trend when apartment buildings are concerned is a post-modernism which brings back a classical treatment of facades, both in form and material. All these factors together, as well as a cheap labour price compared to the price of building materials led to the revival of ceramic elements in a building practise.

Apart from the reinforced concrete slabs which were created on the site, the floor structure which is the most often in use nowadays is a so called “LMT” floor structure. This is again a semi-mounting structure whose production in Yugoslav regions began by the mid 80s and up to now practicly ejected other, similar floor types.

Figure 8. Cross section of the “LMT” floor structure.
This floor consists of two types of ceramic elements, the one which is used for the creation of ribbs and another one which serves as a filling. The principle of its construction is as follows:

Depending on the span, the ribb parts are bonded with concrete and an armature in a form of a triangular truss, forming in this way completed ribs of the floor structure which are put over the structural walls on the distance of 41 cm. The filling parts of the height of 16 cm are put over them and then filled with concrete, forming a ribbed reinforced concrete floor with a 4 cm thick thin plate over the ceramic parts.

Figure 9. Axonometrical view of the "Potisje M&K" floor structure.

Disregarding the structural system and a type of a floor structure, from the very beginning of this period the external walls are created completely in accordance with a more strict thermal standards which imposed their multi layered structure with a thermal insulation (most often as 8-10 cm of polystyren or mineral wool) as its midd part. Since the general tendency is a revival of conventional facade treatment, very often the final facade surface is made of a high-quality mortar layers over the 7 or 12 cm thick brick walls.

In the second half of the 90s, poor economical situation in the country, impossibility of investments of the infrastructural equipment of the locations led to the trend of a construction onto the existing buildings, especially those with a flat roofs. Very often, instead of a simple transformation of a flat roof into the inclined one by building only one storey above the existing roof floor, when statical calculations prove the higher bearing capacity of the building, even two or three floors covered with inclined roof could be added.

Since such construction is done on the buildings that keep their prior purpose during the whole period of the building process, the most usual solution for this problem is the use of different ceramic elements for the construction of walls and partitions, and semi-mounting floor structure based on clay products, such as previously mentioned TM, or even more often, LMT structure.
Construction of the apartment buildings intended for the free market, with apartments that exceeded the previously used minimal housing standards, led to the need for the buildings with wider spans offering a complete flexibility and adaptability of the space. Positive experience with semi-mounting floor systems and wide use of of LMT floors provoked further researches towards the further improvement of such systems. One direction of such research was directed towards the improvement of existing floor structure systems by their transformation from the one-way, to the two-way ribbed floors, which mostly considered some modifications in their building technology. Another direction of researches could be recognised as an intention for creation of completely new types of floor with new solutions that would improve the structural characteristics of floors on the level of a system itself.

The best example of these intentions is a completely new floor system which was created by the team of researches from the ceramic plant “Potisje” from Kanjiza which created a floor structure, “Potisje M&K”, specially intended for the wide spans. Mounting trusses of this structure create ribs, between which hollow ceramic elements of different heights and forms are put, enabling a good bond with a support after pouring over with concrete. Depending on the span, upper, lighten ceramic elements that serve as a filling are put over, creating a sufficient thickness of the floor structure over which a concrete layer is made creating a thin slab of 5cm. In this way it is possible to form a floor of a thickness of 37, 54, 72 or 90cm, which is capable for spanning the distance of maximum 20m. This fact makes “Potisje M&K” floor applicable not only to apartment buildings but also to all types of public buildings, and, according to the manufacturer, even as a bridge construction.

6. CONCLUSIONS

Although this paper shows that in Yugoslav regions during the last century, development and application of floor structures based on clay products was mostly oriented, or closely related to the state and development phase of housing construction and economical and social development of the country, the latest example shows the opposite impact. Provoked by the general intention of improvement of structural characteristics of this kind of semi-mounting floor structures, whose scope of application due to the limited spanning possibilities was previously oriented mostly to housing, expansion of the spans on which new floor structures could be applied make them usefull and applicable for practically any building type.

7. REFERENCES