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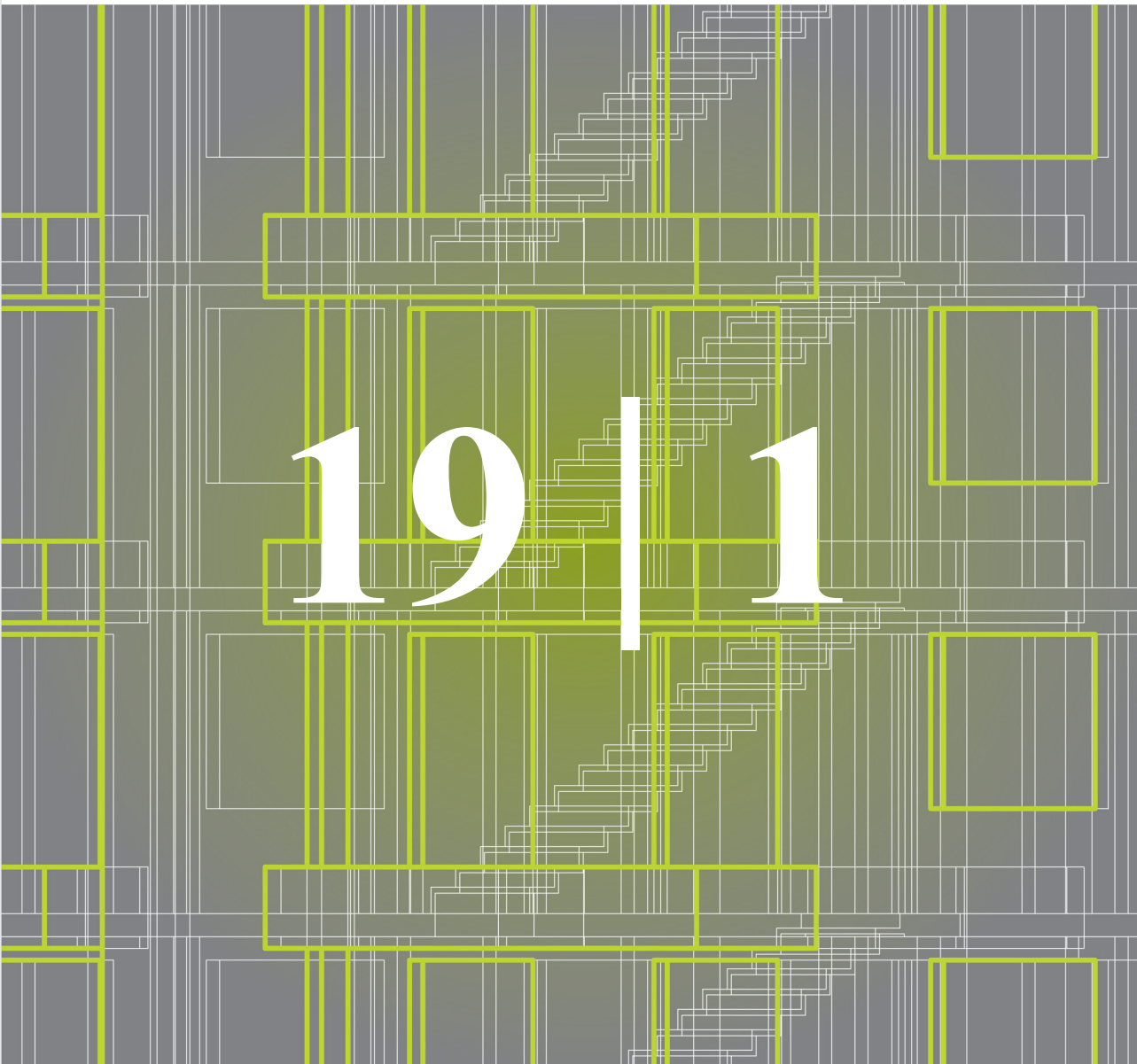

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3. Živković D.: Influence of front excavation on the state and deformity of montage lining of hydraulic pressure tunnels, Ph. D. University of Niš, 1988, pp. 95-108.
4. Kurtović-Folić N.: Typology of Architectural Forms-Strong and Weak Typological Characteristics, Facta Universitatis, University of Niš, Vol. 1, N^{o} 2, 1995, pp. 227-235.

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Contents

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Original Scientific Paper

CONTEMPORARY MEETS OLD IN REHABILITATING HISTORIC BUILDINGS

UDC 69.059.7:725.94

Aleksandra Cvetanović, Ana Momčilović Petronijević

University of Niš, Faculty of Civil Engineering and Architecture, Niš, Serbia

Abstract. *Protection of architectural heritage is a very delicate mission that needs to be supported by a big set of knowledge and experience. Adding a new, dissimilar element to a historic building of big importance in a rehabilitation process is particularly disputed and needs to be addressed with even more research and justification. Contrasting architectural styles in one building can be even a controversial matter. In some cases, modern additions successfully preserve the originals while bringing something fresh and creative, while others fail to do so. The main question is: does a current trend of adding a new, modern extension to the architecture monument distinctly mean that it is obliterated, or can a mixture of contemporary and historic in old buildings produce good architecture?*

Key words: *rehabilitation, contemporary additions, modern meets old*

1. INTRODUCTION

When adding to an existing building, or designing within a rich historical context, there is always a key question: to what extent should the new structure look and feel like the surrounding ones? Does it make sense for the new structure to stand out or fit in? What are the advantages and disadvantages of both approaches? This paper originated from an ever-existing interest in determining whether the mixture between modern and old in historic buildings is good or bad. In order to answer this research question, the literature will be reviewed and the exemplary case studies from the practice will be analyzed.

Contrasting architectural styles is a very delicate issue, in some cases even controversial. The addition can outshine the historic buildings, while, on the other hand, these new elements can honor the original's heritage. Truly, in some cases, modern rehabilitations successfully preserve the originals while bringing something fresh and new, while others create a very unsatisfactory outcome [2]. The opinions about preservation and reconstruction differ, the

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Corresponding author: Aleksandra Cvetanović
Faculty of Civil Engineering and Architecture, Aleksandra Medvedeva 14, 18106 Niš, Belgrade
E-mail: aleksandracv.arch@gmail.com

strong opinions are often supported by political and social views, and, often, projects that include new, visible, different elements are perceived as controversial [5].

Fig. 1 a) Castle of Matrera before and after the restoration, b) One of the proposals for Notre Dame's reconstruction

The subject became even more interesting with a controversial restoration in 2015 in Spain. The restored medieval Castle of Matrera from the 9th century is a national monument and an example of Heritage of Cultural Interest (see Fig. 1a). Rather than replicating the original stonework, the architect Carlos Quevedo has decided to fill in the missing sections with a contemporary addition. There have been three basic aims behind it: to structurally consolidate the elements at risk, to create a distinction between old and new (thus avoiding the imitative reconstructions that are prohibited by law), and to recover the volume, texture, and tonality that the tower would originally have had. The castle's restored tower has provoked many negative reactions. The Spanish heritage and conservation group, Hispania Nostra, has stood that the "consolidation and restoration is truly lamentable and has left locals and foreigners deeply shocked". By locals, it has been labelled as the world's worst restoration project, but by the architectural community, on the other hand, the project has been praised and won the 2016 Architizer A+ Award, in the Architecture Preservation category. Despite everything, the castle has now become a new tourist attraction in the area [6, 27].

The subject revived again when the debate was started about whether Paris's Notre Dame cathedral should be reconstructed in a traditional or in a contemporary way after the fire in 2019 (see Fig. 1b). The whole world argued about this burning matter. The idea of the modern undertaking was met with skepticism from numerous architects, conservationists, and academics, and polls showed that the majority of Parisians favored restoring Viollet-le-Duc's design. In the end, it was decided that Notre Dame Cathedral will be rebuilt just the way it stood before the devastating fire. The plan includes recreating the 19th century spire designed by architect Eugene Viollet-le-Duc that collapsed in the fire and "favors fidelity to the monument's form and a restoration of the cathedral in its latest state". The reconstruction plan states that the project will replicate original materials "to guarantee the authenticity, harmony, and coherence of this masterpiece of Gothic art" [16].

2. LITERATURE REVIEW

Architecture, both modern and old, defines city skylines and has a lasting impact on one's perception of a place. While historic architecture has its own charm, modern architecture also has the ability to be inspiring. Generally, people enjoy old buildings. Their

composition and massing are easy to understand, and their familiar ornamentation adds a richness of texture often absent in modernist architecture. As Adolf Loos claims in his 1908 essay “Ornament and Crime” modernists do tend to have an aversion towards ornamentation. Loos advocates that the application of ornament is "unnecessary and merely embodies fashion that will go quickly out of style". Many modern architects agree with Loos, but it is a fact that modernist buildings completely devoid of ornament are rarely embraced by the general public. It must be said that current architectural thinking has transcended modernism by light-years. The emerging contemporary architects of the twenty-first century have embraced the digital tools that allow the building elements to be combined in ways that resist categorization into any particular architectural style. The result is a captivating and stunning work, that is far from the familiar language of classical style both in appearance and theoretically. An obvious example of these claims is the Eiffel Tower. Now it is a symbol of French culture, but when it was newly installed it was declared as a monstrosity by many. The strength of emotional attachment that people have towards old buildings is in part due to a reaction against forms they do not find appealing [5].

The technical protection of historic buildings maintains the original aesthetic and provides us with an educational tool for the history, art, architecture, and engineering of the time period when the building was originally constructed. Also, every monument needs to be brought to life, to be revitalized, because an abandoned monument with a surviving purpose decays faster than a living monument. The technical protection of the architectural heritage would not be particularly difficult, given today's possibilities of using modern technology and modern materials, if we always knew everything that is needed about the architecture and forms of the monument's heritage. The problem lies in the fact that it is very rare to know what the monuments, which have been damaged or destroyed, once looked like. From these conditions and circumstances arise all the problems in the technical protection of monuments of architectural heritage.

The high level of modern technology in construction and a very rich selection of both old and new materials allows us to apply the most diverse methods in preserving monuments [14]. Choosing the most appropriate method depends on many [8] circumstances, and mostly from the condition of the monument and the documentation about it that we have [14]. The methodology choice requires careful decision making about a building’s historical significance, considering the level of significance, physical condition, proposed use, code, and other regulations [8]. It is not possible to prescribe which method will be applied, because the choice of that method results from the mentioned criteria and it must be determined on a case-by-case basis.

The methods and treatments for the protection of architectural heritage are divided by their character in many different ways, but the [14] most common forms of technical protection are Preservation or Conservation, Restoration, Reconstruction, and Rehabilitation or Revitalization. Of the four treatments, only Rehabilitation allows alterations and the construction of a new addition, if necessary, for continuing or new use for the historic building. Rehabilitation is defined as the act or process of making possible a compatible use for a property through repair, alterations, and additions while preserving those portions or features which convey its historical, cultural, or architectural values [8].

The application of technical protection methods on a building with monumental properties only ensures the monument's existence and prolongs its lifespan, but if the monument is not brought to life and given a specific purpose, that lifespan will be much shorter. Therefore, the international charter from Venice stipulates that it is always better

for a monument to have a useful purpose for society. If it has one, the maintenance of the monument is also much easier because the means of maintenance are usually obtained from the user. On the other hand, if the monument is left without a purpose, it becomes a burden to a specialized profession, which is usually overloaded and not able to take care of it further, since the technical protection measures have already been performed. The monument remains to some extent left to itself and its destiny, that is, insufficiently protected. The use of historic architecture for modern purposes, or its revitalization, is a challenging problem and it takes a lot of enthusiasm, inventiveness, and economic resourcefulness to bring the monument to life. Anyway, the use of a monument is allowed only under the condition that its monumental properties are not damaged or destroyed [14].

Rehabilitation is the only treatment that allows expanding a historic building by enlarging it with an addition. However, the Rehabilitation guidelines emphasize that new additions should be considered only after it is determined that meeting specific new needs cannot be achieved by altering "non-character-defining" interior spaces. If the new use of the space cannot be accommodated in this way, then an attached exterior addition may be considered. New additions should be designed and constructed so that the "character-defining" features of the historic building, its site, and setting are not negatively impacted. Generally, a new addition should be to the historic building. A new addition should be compatible but differentiated enough so that it is not confused as historic or original to the building. The same guidance applies to new construction so that it does not negatively impact the historic character of the building or its site. When the rehabilitation is being implemented, there are some guidelines: new additions, exterior alterations, or related new construction can not destroy historic materials, features, and spatial relationships that characterize the property. The new work must be differentiated from the old and must be compatible with the historic materials, features, size, scale, and proportion, and massing to protect the integrity of the property and its environment. New additions and adjacent or related new construction should be undertaken in such a manner that, if removed in the future, the essential form and integrity of the historic property and its environment would be unimpaired [8].

Another problem when an architect is given the task to adapt a building can arise if the architect tries too hard to affirm his own work on that building and to give it a stamp of his own personality. Without thinking about it, the architect is thereby violating the authorship of one of the creators. Due to such relations, great damage was inflicted on many monuments of architectural heritage, especially in periods of changes in architectural styles and the emergence of eclectic styles. Without much restraint, new elements were added to the old monuments, which in most cases corresponded to the current fashion, the current taste, and time has shown how ignorant these procedures were. The creative abilities of an architect in protection must rest on other foundations and must be developed only with full respect for the integrity of the monument or the whole [14].

3. CASE STUDIES

Criteria for the valorization of buildings originated from the literature review, guidelines, and general principles in the application of technical protection of construction heritage monuments. Some of the criteria based on these principles:

1. The Question of Context
2. The Authenticity and monumental values preservation - the value of the original

3. Design Integrity and testimony of current style
4. Form
5. Scale
6. Color and material
7. Contrast

One of the most important questions when designing a building is the question of how that building should relate to its surrounding context. When new forms are physically joined to old forms the question of context is even more important. In this architectural fusion, it is very important if architects propose dissimilar individualistic interventions or designs that are seamlessly integrated into the existing urban fabric [5]. The basic principles of respecting the authenticity of monuments automatically lead to the requirement that technical interventions should be reduced to the most necessary measure [14]. The question of integrity is about whether the new addition testifies correctly about the time in which it is created, and whether it has value as a representative of the current style and trends. For a design to have integrity, it must be a product of its own time, an honest expression of the cultural forces active when the design was executed [5]. There is a rule that during the Rehabilitation everything that is added to the monument should be separated from the original parts. It should be presented in such a way that observers can easily notice what has been restored and what is original [14]. Contrast can lead to a better appreciation of both new and old.

The selected case studies are both good and bad examples from the practice, analyzed, and categorized by the defined criteria.

3.1. "Good" examples

This chapter intends to explore successful design approaches for visible interaction between modern and old architectural styles by conducting case studies of exemplary interventions made to old buildings. The common thread among the designs selected is a thoughtful and clear vision of how the new can interact with the old. These are historic buildings and their contemporary additions that work cohesively, respecting and advancing each other's architectural significance.

3.1.1. Shoreham Street / Project Orange

192 Shoreham Street is a Victorian industrial brick building sited at the edge of the Cultural Industries Quarter Conservation Area of Sheffield. It is not listed but it is considered locally significant. Surrounded by other old brick buildings with dark roofs, this project is very finely incorporated into the urban tissue but also creates a new and vibrant context.

The idea was to rehabilitate the once redundant building and allow it to be once again relevant for use. The brief was to provide mixed-use combining a double-height restaurant within the original shell with duplex studio office units above. The raw industrial character of the existing building is preserved in a way that celebrates its industrial heritage.

Architects explain: "The new extension is contemporary yet laconic in form and an abstract evocation of the industrial roofscapes that used to dominate this part of the city. It is a contrasting but complementary volume, a replacement for the original pitched roof." The upward extension replaces a pitched roof, creating three duplex studio offices within a powder-coated steel volume that both overlaps and bites through the original brick structure and looks like another building stacked on top (see Fig. 2). This project

creates a striking landmark on the inner ring road, a symbol both of the area's past and its aspirations for the future [1, 20, 21].

Fig. 2 The old brick house with a contemporary addition

3.1.2. Elbphilharmonie Hamburg / Herzog & de Meuron

The Elbphilharmonie, a new cultural landmark, lies in Hamburg's HafenCity, within the historic city port. It comprises three concert halls, a hotel, 45 private apartments, and a publicly accessible plaza.

This profile of the building is meant, according to Herzog & de Meuron, to contrast with the horizontality of Hamburg, "as an expression of reaching out into new territory". Around it, the HafenCity continues to come to life, with renovations progressing in the Elbphilharmonie's historic warehouse district along with futuristic new museums, offices, and housing [22]. The district is now set to become a new centre of social, cultural, and daily life for the people of Hamburg and for visitors from all over the world.

Fig. 3 The new and shiny Elbphilharmonie

The old part, the magnificent neo-Gothic Kaispeicher building keeps the original and archaic feel. The external structure of the warehouse has been retained in its original form. It is a heavy, massive brick building like many other warehouses in the Hamburg harbour, but its archaic façades are abstract and aloof. The new glass part, consisting of curved panels, some of them carved open, transforms the building into a gigantic, iridescent crystal, whose appearance keeps changing as it catches the reflections of the sky, the water, and the city (see Fig. 3). The curvature of each panel depends on the particular area of the building [24]. The richly evocative edifice seems to represent mountains, waves, and sailing

ships. Old and new conjoin in an exciting synthesis that is exceptionally radical. The two parts have contrasting facades. The warehouse below has a strong and robust appearance, whereas the new project has a glass structure extruding from and floating above the warehouse [23].

3.1.3. Antwerp Port House / Zaha Hadid Architects

The Mexico Island in Antwerp's Kattendijk dock on Quay 63, the threshold between the city and its vast port, is the site for the new head office for the Port of Antwerp. Zaha Hadid Architects' design is informed by detailed historical research and a thorough analysis of both the site and the existing redundant fire station. The design is an elevated extension, rather than a neighboring volume which would have concealed at least one of the existing facades. Like the bow of a ship, the new extension points towards the Scheldt, connecting the building with the river on which Antwerp was founded. With its dynamic, ambitious, and innovative design it stands as a symbol for the port.

The original building is preserved and it recalls the 16th century, Antwerp's "golden century", all the facades are restored in a very low-tech way. The existing building provides the base for the entire project, an equal part of the constellation.

Surrounded by water, the new extension's façade is a glazed surface that ripples like waves and reflects the changing tones and colors of the city's sky. Triangular facets allow the apparently smooth curves at either end of the building to be formed with flat sheets of glass. They also facilitate the gradual transition from a flat facade at the south end of the building to a rippling surface at the north. The striking and contemporary superstructure is in a shape similar to a diamond (see Fig. 4).

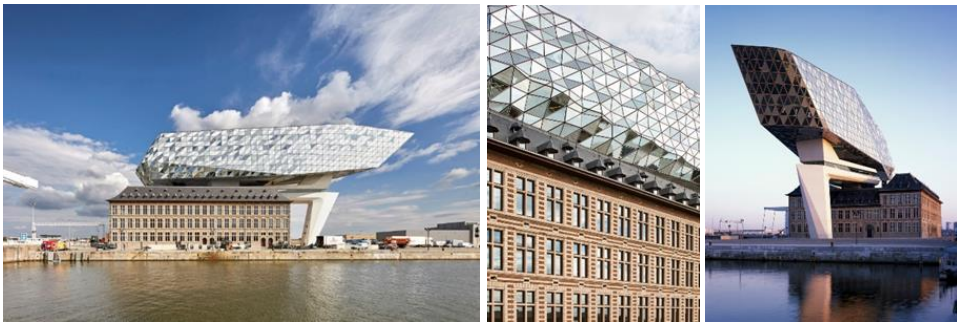

Fig. 4 The new head office for the Port of Antwerp with a diamond like addition

A new volume that 'floats' above the old building, observing each of the old facades and completing the verticality of the original design's unrealized tower. The existing building and the new building are two entities, where one cannot work without the other. The new volume has a dynamic appearance in contrast to the static dignity of the existing building [4, 17].

3.1.4. Louviers Music School Rehabilitation and Extension / Opus 5 Architectes

The antique convent of the Penitents, in the city centre of Louviers -Normandy, is a very exceptional complex assembly of successive constructions, it is a monastery situated on the water, unique in Europe. This seventeenth-century convent has served a variety of uses over

the years and has housed a church, a prison, and a tribunal court, but was converted into a music school in 1990. The brief with a rehabilitation project was to offer Louviers a new modern, functional, and attractive musical school, and to highlight the archaeological heritage and its exceptional site in the heart of the city [11].

A plot is very tight so the architects had to fill all free spaces and raising extensions on top of existing walls. The south extension exposes its front to the water, towards the cloister and the city. Its incredible position represents the key to the project. It hosts the major element of the program: the big orchestra hall. This facade fits in a simple rectangular glass box with chrome stripes reflecting the surrounding environment and fading in the sky. The North façade is made of laminated glazed panels within the inside layer that has been coated with a mirror finish, and the frontier façades are made of prefabricated concrete panels. They are cut out to follow the surface of the ancient masonry [13].

The juxtaposition of old and new is clearly recognizable in the envelope (see Fig. 5). This is a compact project where the new parts dominate the ancient elements; however, the historical construction is still governing. Modern structural and material possibilities, shown through an acute geometrical form, permit the reflection of historical elements in the new addition [12].

Fig. 5 The 3d model and the built extension

3.1.5. Musealization of the Archaeological Site of Praça Nova of São Jorge Castle / JLCG Arquitectos

Set on a prominent hill overlooking the Tagus estuary, Lisbon's Castelo de São Jorge is the site of the first known human settlement dating to the Iron Age. The task was to devise structures that would make this fragile and disjointed palimpsest both physically presentable and museologically comprehensible to visitors. A series of new elements were added, all very consciously of their time, but inculcated with a reductivist, neutral spirit that plays against the desiccated remains and subtly enhances the relationship between old and new.

The blade-like planes of Corten thread precisely around and through the site, lining the sides of shallow excavation pits and forming a hovering structure to protect the remnants of a mosaic floor that once formed part of the Bishop of Lisbon's palace (see Fig 6). The underside of the cantilevered Corten structure is covered in a black mirror, enabling visitors to inspect a reflected image of the mosaics at closer quarters. Counterpointing the roughness and friability of the excavated remains, the same formal and material precision characterizes other new elements, such as limestone steps, landings, and seating. The most conspicuous

new addition is a pristine, white-walled box, itself resembling the temporary structures of archaeological digs, constructed over the foundations of a pair of Moorish houses. The white walls float above the visible foundations, touching the ground on a mere six points.

Not only do the new parts safeguard the site, but they also add an experiential dimension that brings its rich history more resonantly to life. This project radiates with clarity, sensitivity, and refinement of the new additions, and the way in which they connected with the existing archaeological remains and addressed the wider landscape of the castle is extraordinary [19].

Fig. 6 A hovering protecting new structure

3.1.6. Kalø Tower Visitor Access / MAP Architects + Mast Studio

This is a project of an observational staircase within a 700-year-old medieval ruin (see Fig. 7). The ruin is one of Denmark's best maintained medieval castles and a part of the Realdania "Stedet Tæller" and "Steder i Landskabet", located on the south of Djursland, close to Århus. The building site was extremely challenging since the whole area is a cultural heritage and strictly protected, therefore, no damage to the tower was allowed and the process was closely monitored.

Behind the visual simplicity of the project lie layers of narratives and complex structural decisions, in order to create a staircase that is sensitive to the historical importance of the site. The Staircase is based on a steel frame construction, supported on the ruin at only four points to minimize damage to the historical monument. The sides and underside are clad in ash wood, specially treated with heat to maximize durability to up to 60 years without the paint. The stairs and handrail are metal, painted in matt black to ensure maximum durability since the site is at the coast and therefore under tough weather conditions [10].

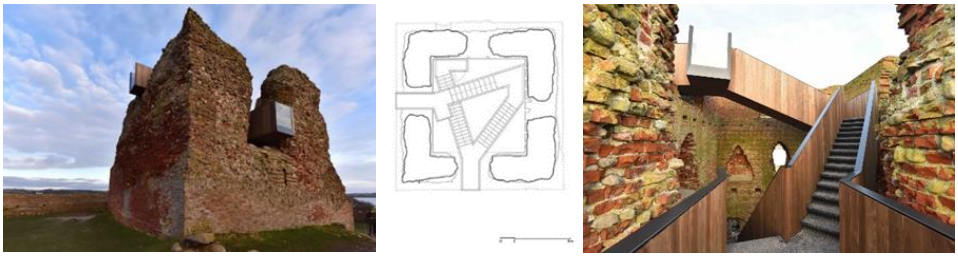

Fig. 7 Observational staircase

3.2. "Bad" examples

It is rather hard to determine whether a mixture of old and new is done positively or negatively. One can argue that this is very subjective and depends on someone's preferences. In this chapter, bad examples from practice are listed based on earlier mentioned criteria.

3.2.1. The Union of Romanian Architects / Dan Marin and Zeno Bogdanescu

The building that houses the Union of Architects in Bucharest is situated at the intersection of Boteanu and Demetru Dobrescu streets, right in the heart of the capital. This controversial building from the 19th century has a long history, but nowadays it has become a tourist attraction due to its unique architecture. This building does not fit with the surrounding Revolution Square and is considered one of the strangest buildings in the whole country [25].

The lower part of the building, a historical landmark, has been consolidated, and behind the brick walls, a steel and glass tower was erected (see Fig. 8a and 8b). It is very peculiar that the architects decided that the historic facade should stay simply a shell, with a whole new 28 meters high glass building inside [26].

Some argue that the new construction appeared as a result of neglecting a historical monument, but others claim that the architects were limited by local laws about architectural styles and historic landmarks. But it is clear that the original building could have been restored to its full beauty and complemented by a more appropriate extension [2].

Fig. 8 a) and b) The Union of Romanian Architects, c) Bagrati Cathedral

3.2.2. Bagrati Cathedral / Andrea Bruno

The 11th-century medieval Bagrati Cathedral is sited in the Georgian province of Imereti in the city of Kutaisi. The story of this renovation is a political one. Heritage professionals like UNESCO thought the Cathedral would be better left alone, but the President decided to go with a renovation.

It was not known what the church originally looked like, making a full restoration impossible, so a modern component was added to the side of the building that was destroyed in past. This modern addition of the Touch and Peltrox finishes combined with glass was not welcome, because it significantly changed the character of the existing structure (see Fig. 8c).

After the renovation was complete, UNESCO even changed the church's status from a historic site to a cultural site to reflect the fact that the project was not completed with sensitivity to the structure's heritage in mind [2].

3.2.3. The Renaissance office building / Vero-Art Bojanowski & Jean Jacques Ory

Raised in the Plac Zbawiciela square, a trendy downtown spot full of cafes, restaurants, and traffic, the building stands in place of a tenement house called the Pawłowicz House. The Renaissance building does a good job at mimicking historical architecture and does not really seem alien to the square's outline (see Fig. 9a).

This reconstruction stirred a lot of controversies back when it was being done. The 19th century ornate neo-renaissance building managed to partially survive the war. After being renovated, it stood in the square until the 2000s, when it underwent reconstruction. Under the pretext of construction work (adding new stories, reshaping the interiors while retaining the exteriors) the house, amidst a scandal, was partially demolished in February 2002. In January 2003 it was demolished completely – only the front walls in Mokotowska Street and in the Square were left. In 2005 the reconstructed building was completed – the house gained a third story, but over it, two additional ones were built, with full-glass exteriors. Also, the historical balconies, that had been preserved, were torn down [15].

It is a successful reinterpretation of tradition, one that harmonizes with its surrounding, the extension does not deviate, but it could be done in a better way to be more complementary to the existing building.

Fig. 9 a) The extension of the Pawłowicz House, b) and c) Studio extension of a church in Hoboken

3.2.4. Studio extension of a church in Hoboken / Marchetto Higgins Stieve Architects

This project is located in Hoboken, New Jersey, USA and it is an extension for the architecture studio, that resides on a historic location of a former church. It is a very extravagant design that is standing out from the former church and neighborhood.

The extension does not follow the same lines as the main structure and creates a dramatic contrast (see Fig. 9b and c). The architects used modern materials that contrast with the natural brick and stone that were used to build the original building. It is a very different strange shaped design from the original [7]. There is a view that the extension is "built on the thin line between kitsch and work of art" [3].

4. CONCLUSION

The relationship between historic buildings and contemporary additions has always been a big issue in the historic preservation field, but old buildings, besides their historic value, also have a functional one. By reusing existing buildings, not only can we preserve the history behind them, but also, we can save the resources required to build new, prevent pollution, avoid the unnecessary accumulation of solid waste, and prevent the growth of urban sprawl [9]. Modern or not, the new addition can give a historic building a second life. Today, rehabilitation with contemporary elements is indeed permissible, but it should enhance the experience of the concept and not erase the story of the building for aesthetic reasons [18].

With a contemporary addition, the styles expressed on historic buildings represent the language of the past and the new styles represent the present. For this reason, it is important to create an environment where both can coexist and correlate with each other, building additions using contemporary architecture styles with an honest representation of the current social situation while protecting the historic structure which represents the social situation of the past [9].

The analyzed case studies presented many creative solutions, but rather by the personal preferences and taste, the good example is determined by detailed historical research and respect for architectural significance of both old and new. According to research, approaches evaluated as positive ones showed interventions that are integrated into the existing urban fabric, respecting the architectural context. It is a cohesive relationship between a historic building and its contemporary addition with the proper use of all architectural elements, in particular the surface articulations. They are respectful to the history, but also represent the current trends in architecture. The scale and used materials made a big impact on determining what is good and what is a bad intervention. All the examples had a good sense for contrast, there was a clear distinction between old and new, but that is not enough for one intervention to be successful. The best examples celebrate their surroundings and bring new life and people to the site and the building itself. After all, it is about the social usage, about a lively city.

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SPOJ SAVREMENOG I STAROG U REHABILITACIJI ISTORIJSKIH ZGRADA

Zaštita graditeljskog nasleđa je veoma delikatna misija koja treba da bude potkovana velikim spektrom znanja i iskustva. Dodavanje novog, različitog elementa istorijskoj zgradi od velikog značaja, u procesu rehabilitacije, naročito je sporno, i tom postupku se treba pristupiti sa još više istraživanja i obrazloženja. Spajanje kontrastnih arhitektonskih stilova u jednoj zgradi može biti čak i kontroverzna stvar. U nekim slučajevima, moderne dogradnje uspešno čuvaju originale, donoseći nešto sveže i kreativno, dok se u drugim slučajevima to ne uspeva. Glavno pitanje koje se nameće jeste: da li aktuelni trend dodavanja nove, moderne dogradnje spomeniku arhitekture obavezno znači da je on zbrisan ili kombinacija savremenog i istorijskog u starim zgradama može proizvesti i dobru arhitekturu?

Ključne reči: *rehabilitacija, savremene dogradnje, spoj savremenog i starog*

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ANALYTICAL STUDY OF THE SECTION OF THE RC BEAMS STRENGTHENED FOR FLEXURE WITH FRP MATERIALS

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Žarko Petrović[1], Slobodan Ranković[1], Marina Mijalković[1], Bojan Milošević[2]

[1]University of Niš, Faculty of Civil Engineering and Architecture of Niš, Niš, Serbia
[2]University of Kragujevac, Faculty of Mechanical and Civil Engineering in Kraljevo, Kraljevo, Serbia

Abstract. *Strengthening of concrete structures is applied as a solution for various deterioration problems in civil engineering practice. This paper presents an analytical study of the behaviour of cross-section of reinforced concrete (RC) beam, strengthened for flexure with fiber reinforced polymer (FRP) materials. Using the balance of internal forces in the cross section through all phases of stress through which the section passes, a program was written in the MATLAB software, the execution of which produced a curve of dependence between bending moment and curvature, which is one of the most important indicators of cross section behaviour. The parameters varied in this study are the amount and type of FRP reinforcement and the obtained results indicate a significant influence of additional FRP reinforcement both on the yielding and ultimate bending moment, and on the bending stiffness of the strengthened cross section.*

Key words: *reinforced concrete beams, cross-section analysis, fiber reinforced polymer materials, strengthening*

1. INTRODUCTION

Fiber reinforced polymer (FRP) materials are a subset of a class of materials called composites or composite materials. Composite materials are made of two or more materials that form a new material with improved properties that are superior to the properties of the individual components individually. FRP materials are relatively new, high-strength, low-

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Corresponding author: Žarko Petrović
Faculty of Civil Engineering and Architecture, Aleksandra Medvedeva 14, 18106 Niš, Serbia
E-mail: zarko.petrovic@gaf.ni.ac.rs

weight composite materials made up of carbon (CFRP), glass (GFRP) or aramid (AFRP) fibers embedded in a polymer matrix [1].

Interest in the use of FRP materials in building structures is constantly increasing, so nowadays there is a large number of applications of these materials in structures around the world. Some of the most common applications in civil engineering include:

- strengthening and repair of structural elements made of reinforced concrete, steel, aluminium and wood.
- concrete reinforcement with bars and cables made of FRP material,
- production of structures from FRP material,
- production of hybrid constructions.

Strengthening of civil engineering infrastructure has gained significant attention due to deterioration problems of structures and need for meeting up-to-date design requirements [2]. One of the basic factors that causes the unsatisfactory condition of the existing infrastructure is corrosion of reinforced steel in concrete, which causes damage of concrete, loss of reinforcing steel and in some cases failure of construction [3]. Taking into consideration the existing concrete infrastructures both in Europe and worldwide, there is a large interest for the research in the field of strengthening of concrete structures. In addition, the most common reasons for strengthening the existing structures are damage to structures due to earthquakes, changes in the purpose of structures and the implementation of additional loads.

The two basic methods most commonly used in strengthening RC beams with FRP material are: strengthening by gluing laminates of FRP material on the surface of concrete beams—EB method; and strengthening by mounting bars or narrow strips of FRP material in grooves made in the cover of concrete—NSM method.

The largest number of researches of RC beams strengthened to bending by FRP reinforcement are experimental or numerical researches. Conclusions of the experimental researches presented in literature, indicate both increases in bearing capacity and reduction of deformations of strengthened beams [4, 5]. In addition to the papers that generally deal with experimental research of strengthened beam girders, there is a significant number of papers in which methods for modeling reinforced RC beams using FEM analysis are proposed [6, 7].

There are many analytical methods for analysing reinforced concrete (RC) beams strengthened with FRP materials [8, 9]. An analytical approach based on cross-sectional analysis can easily determine the ultimate load of a strengthened beam. The approach is based on the principles of strain compatibility, internal force balance and idealized constitutive relations for concrete, steel and FRP reinforcement. These idealized relations, together with the assumption that slip on the contact surface between concrete and FRP systems can be neglected, form the basis for the analysis of the ultimate state of strengthened RC beams [10].

The aim of this paper is the development of a mathematical model for the calculation of the load-bearing capacity of the cross section of a RC beam strengthened with fiber FRP materials, subjected to bending, at characteristic states of the beam girder:

- until cracks appear,
- from the appearance of cracks to the yielding of steel reinforcement
- after the occurrence of steel reinforcement yielding, up to failure.

Notation

The following symbols are used in this paper:

b	beam width	h	beam height
A_c	cross sectional area of concrete	A_{cc}	compressed part of concrete cross-section
A_{ct}	tensioned part of concrete cross-section	A_{s1}	cross sectional area of tensioned steel reinforcement
A_{s2}	cross sectional area of compressed steel reinforcement	A_{frp}	cross sectional area of the FRP reinforcement
E_c	modulus of elasticity of concrete	E_s	modulus of elasticity of steel before yielding
E_{sp}	modulus of elasticity of steel after yielding	E_{frp}	modulus of elasticity of the FRP reinforcement
σ_c	stress in the concrete	σ_{cu}	stress in the concrete at the ultimate strain
σ_{cc}	stress on the compressed edge of the concrete	σ_{ct}	stress on tensioned edge of concrete
σ_s	stress in the steel reinforcement	σ_{s1}	stress in tensioned steel reinforcement
σ_{s2}	stress in compressed steel reinforcement	σ_{frp}	stress in the FRP reinforcement
f_c'	compressive strength of concrete	f_{ct}	tensile strength of concrete
f_t	tensile strength of steel reinforcement	f_y	yield strength of steel reinforcement
f_{frp}	tensile strength of the FRP reinforcement		
ε_c	strain in concrete	ε_{c1}	compressive strain in the concrete at the peak stress f_c'
ε_{cu}	ultimate compressive strain in concrete	ε_{cc}	compressive strain in the concrete
ε_o	appropriate strain in the concrete	ε_s	strain in steel reinforcement
ε_{su}	ultimate tensile steel strain	ε_y	steel strain at the steel yield strength
ε_{s1}	strain in tensioned steel reinforcement	ε_{s2}	strain in compressed steel reinforcement
ε_{frp}	strain in FRP reinforcement	$\varepsilon_{frp,u}$	ultimate tensile strain in FRP reinforcement
M	bending moment	M_{cr}	cracking moment of concrete
M_y	yielding moment of tensile steel reinforcement	M_u	ultimate bending moment
M_{ext}	external bending moment		
C_c	compressive force in the concrete	C_{s2}	force in the compressed steel reinforcement
T_c	tensile force in the concrete	T_{s1}	force in the tensioned steel reinforcement
T_{frp}	force in the FRP reinforcement		
y	neutral axis distance from the corresponding force	y_{Cs2}	neutral axis distance from the force C_{s2}
y_{Tfrp}	neutral axis distance from the force T_{frp}	y_{Ts1}	neutral axis distance from the force T_{s1}
κ	curvature	κ_y	yielding curvature
κ_u	ultimate curvature		
α_1	compressive stress reduction coefficient in the concrete	β_1	coefficient of reduction of the height of the stress diagram
λ	factor for calculating the bulk density of the concrete		

2. BASIC POSTULATES

The assumptions introduced in the cross-sectional analysis of RC beams strengthened with FRP reinforcement are as follows [9]:

1. The distribution of strains by section height is linear - Bernoulli's hypothesis of straight sections.
2. No slipping between longitudinal reinforcing steel and concrete;
3. No slipping between FRP system and concrete;
4. Beam failure occurs either due to reaching the ultimate strain of concrete under compression or due to failure of the FRP strengthening system.

When designing the strengthening system, the influence of the previous load should be taken into account. The distribution of dilatations in the cross section of the RC beam during the action of the moment before the installation of the strengthening system (M_o) can be determined on the basis of the theory of elasticity. As the moment (M_o) is usually greater than the moment of crack appearance (M_{cr}), the calculation should be based on the cracked cross section. If the moment M_o is less than the moment M_{cr}, its influence in the design of the strengthening system can be neglected [1].

To illustrate the state of strains in the cross section of RC beams strengthened with FRP reinforcement, they can be shown as a superposition of strains before and after the installation of FRP strengthening system (Fig. 1)

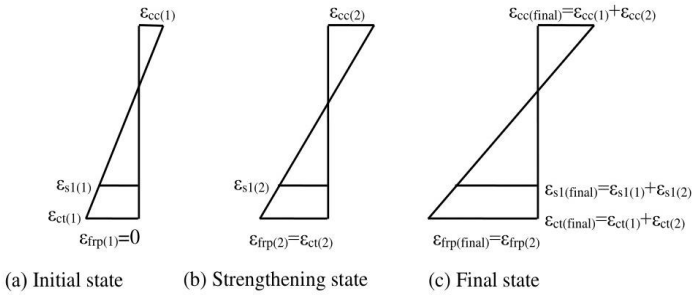


Fig. 1 Superposition of strain in EB strengthening method [11]

The strain states shown are:

1. Initial state, before the installation of the strengthening system, when strains $\varepsilon_{(1)}$ due to load are considered at the time of installation of the strengthening system, Fig. 2a;

2. Strengthened state, after installation of strengthening system, when strains $\varepsilon_{(2)}$ due to load applied after installation of strengthening system (hypothetical situation) are considered, Fig. 2b;

3. Final state, after the installation of the strengthening system when strains ε_{final} are considered due to the load that exists at the time of installation of the strengthening system as well as from the additional load, Fig. 2c.

The final state of strains is obtained by superposition of the initial strains and strains that occur in FRP reinforcement, whereby the neutral axis changes position [11].

3. ADOPTED MODELS OF CONSTITUENT MATERIALS

3.1. Concrete

In the analysis of the cross section of the RC beam strengthened with the FRP reinforcement, the parabolic relation between stress and strain for concrete was adopted

(Fig. 2). The mathematical formulation of this relation can be described by the expressions (1-3) [12]:

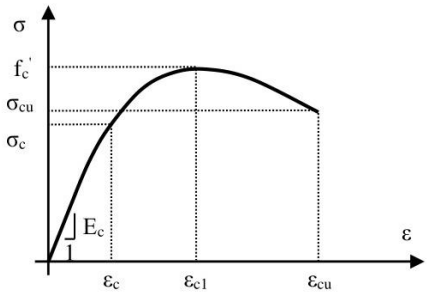


Fig. 2 Idealised stress- strain curve for concrete at axial pressure

$$\sigma_c = f_c^{'}\left[\frac{2\varepsilon_c}{\varepsilon_{c1}} - \left(\frac{\varepsilon_c}{\varepsilon_{c1}}\right)^2\right] \tag{1}$$

$$\varepsilon_{c1} = \frac{2f_c^{'}}{E_c} \tag{2}$$

$$E_c = 4500\sqrt{f_c^{'}} \tag{3}$$

A simplified distribution of compressive stresses in the concrete cross section shown in Fig. 3 was given by Collins and Mitchell [12]. Coefficients of rectangular compressive stress distribution in concrete (α_1 and β_1) are determined according to the following expressions:

$$\alpha_1\beta_1 = \frac{\varepsilon_{cc}}{\varepsilon_0} - \frac{1}{3}\left(\frac{\varepsilon_{cc}}{\varepsilon_0}\right)^2 \tag{4}$$

$$\beta_1 = \frac{4 - \frac{\varepsilon_{cc}}{\varepsilon_0}}{6 - \frac{2\varepsilon_{cc}}{\varepsilon_0}} \tag{5}$$

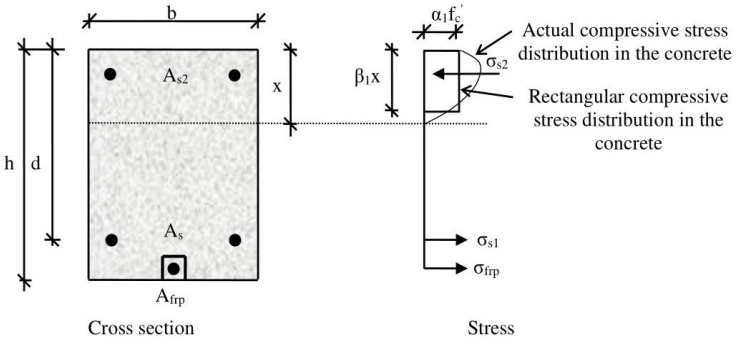


Fig. 3 Stress distribution in the cross section of the RC beam strengthened with FRP reinforcement

The compressive force in concrete (C_c) and its position relative to the neutral axis (y_{Cc}) are given by the following expressions [12]:

$$C_c = \alpha_1 \beta_1 f_c^{'} x b \tag{6}$$

$$y_{Cc} = x - \frac{1}{2}\beta_1 x \tag{7}$$

When the stress on the tensioned edge of concrete is less than the tensile strength of concrete, the value of the tensile force in concrete and its position relative to the neutral axis are given in terms of:

$$T_c = \frac{1}{2} b \sigma_{ct} (h - x)\,, \tag{8}$$

$$y_{Tc} = \frac{2}{3}(h - x)\,, \tag{9}$$

$$f_{ct} = 0.6\lambda\sqrt{f_c^{'}}\,. \tag{10}$$

3.2. Steel reinforcement

In the analysis of the cross section of the RC beam strengthening with FRP reinforcement, a bilinear dependence between stress and strain for reinforcing steel (elastoplastic behaviour) with a 1% slope inclination was adopted (Fig. 4). The mathematical formulation of this dependence can be described by expressions (11-12).

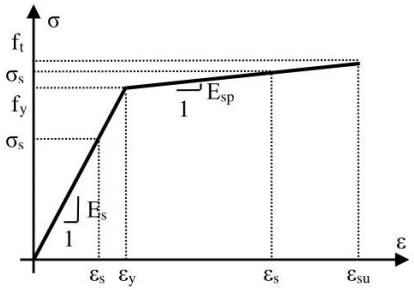


Fig. 4 Idealised stress-strain curve for reinforcing steel

$$\sigma_s = \begin{cases} \varepsilon_s E_s & for \quad \varepsilon_s \le \varepsilon_y \\ f_y + E_{sp}(\varepsilon_s - \varepsilon_y) & for \quad \varepsilon_s \ge \varepsilon_y \end{cases} \tag{11}$$

$$E_{xp} = 0.01 E_s \tag{12}$$

3.3. FRP reinforcement

In the analysis of the cross section of the RC beam strengthening with FRP reinforcement, the linear-elastic relation between stress and strain for FRP reinforcement was adopted, as in Fig. 5. The mathematical formulation of this dependence can be described by the expression (13).

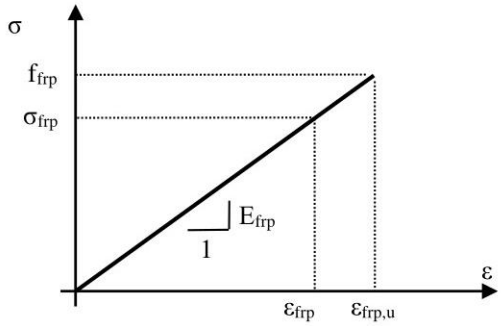


Fig. 5 Idealised stress-strain curve for FRP reinforcement

$$\sigma_{frp} = \varepsilon_{frp} E_{frp} \tag{13}$$

4. Stress-Strain Stages of the Cross Section of the RC Beam Strengthened with FRP Reinforcement

Figure 6 shows a diagram of the dependence between the bending moment (M) and the curvature (κ) in the cross section of the RC beam strengthened with the FRP reinforcement, which is subjected to bending. The dependence is idealized by a nonlinear curve consisting of three parts:

- zone before cracks appear,
- zone after the appearance of cracks and before the appearance of steel yielding and
- zone after the occurrence of steel yielding to the cross-section failure.

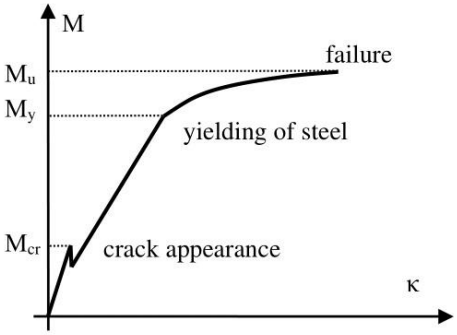


Fig. 6 Diagram of dependence between bending moment (M) and curvature (κ) in the cross-section of RC beam strengthened with FRP reinforcement

In the cross-sectional analysis of reinforced concrete beams strengthened with the FRP reinforcement, the principles of calculation of complex (composite) cross-sections used in structural theory are applied in this paper [13]. The distribution of strains and stresses by section height is shown in Fig. 7 [14]:

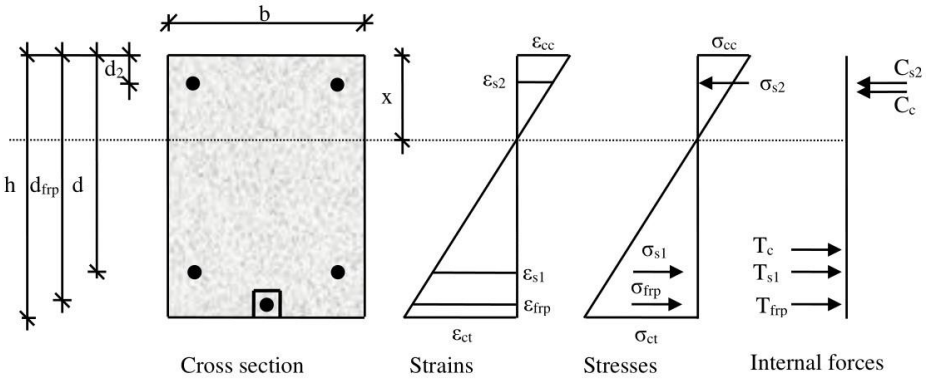


Fig. 7 Assumed distribution of strains, stresses and internal forces in the cross section of RC beams strengthened with FRP reinforcement (with neglection of initial strains)

The corresponding equations of equilibrium of internal forces are based on the assumption that the resultant of internal forces in the cross section is equal to zero (ΣX=0):

$$\int_{A_{cc}} \sigma_c dA_{cc} + \int_{A_{s2}} \sigma_{s2} dA_{s2} - \int_{A_{ct}} \sigma_c dA_{ct} - \int_{A_{s1}} \sigma_{s1} dA_{s1} - \int_{A_{frp}} \sigma_{frp} dA_{frp} = 0\,, \tag{14}$$

that is:

$$C_c + C_{s2} - T_c - T_{s1} - T_{frp} = 0\,, \tag{15}$$

as well as that the moment of internal forces is equal to the external bending moment (ΣM=M_{ext}):

$$\int_{A_{cc}} \sigma_c y dA_{cc} + \int_{A_{s2}} \sigma_{s2} y dA_{s2} - \int_{A_{ct}} \sigma_c y dA_{ct} - \int_{A_{s1}} \sigma_{s1} y dA_{s1} - \int_{A_{frp}} \sigma_{frp} y dA_{frp} = M_{ext}\,, \tag{16}$$

that is:

$$C_c y_c + C_{s2} y_{s2} - T_c y_{Tc} - T_{s1} y_{Ts1} - T_{frp} y_{Tfrp} = M_{ext}\,, \tag{17}$$

4.1. Pre-cracking stage

Before the appearance of cracks, the tensile stress on the tensioned edge of the concrete is less than the tensile strength of the concrete, so the entire cross-section participates in accepting the external load. Therefore, the moment of inertia of the whole cross section (I_g) is used for the calculation.

For the stage before the appearance of cracks, the equations of equilibrium of internal forces (ΣX = 0 and ΣM = M_{ext}) can be written in the following form:

$$bx\frac{\sigma_{cc}}{2} + A_{s2}\sigma_{s2} - b(h-x)\frac{\sigma_{ct}}{2} - A_{s1}\sigma_{s1} - A_{frp}\sigma_{frp} = 0 \tag{18}$$

$$\frac{1}{3}bx^2\sigma_{cc} + A_{s2}\sigma_{s2}(x-d_2) - \frac{1}{3}b(h-x)^2\sigma_{ct} - A_{s1}\sigma_{s1}(d-x) - A_{frp}\sigma_{frp}(d_{frp}-x) = M_{ext} \tag{19}$$

4.2. Pre-yielding stage

When the tensile stress on the tensioned edge of the concrete exceeds the tensile strength of the concrete, cracks appear due to bending, and the beam is viewed as if it were composed of cracked cross-sections.

The equations of equilibrium of internal forces ($\Sigma X = 0$ and $\Sigma M = M_{ext}$) before the occurrence of yielding of the reinforcement take the following form:

$$\alpha_1\beta_1 bxf_c^{'} + A_{s2}\sigma_{s2} - A_{s1}\sigma_{s1} - A_{frp}\sigma_{frp} = 0 \tag{20}$$

$$\alpha_1\beta_1 bx^2 f_c^{'}(x - \frac{1}{2}\beta_1) + A_{s2}\sigma_{s2}(x - d_2) - A_{s1}\sigma_{s1}(d - x) - A_{frp}\sigma_{frp}(d_{frp} - x) = M_{ext} \tag{21}$$

4.3. Post-yielding stage

After the beginning of the yielding of the steel reinforcement, a state arises in which the equations of equilibrium of internal forces have the following form:

$$\alpha_1\beta_1 bxf_c^{'} + A_{s2}\sigma_{s2} - A_{s1}[f_y + 0.01E_{sp}(\varepsilon_{z1} - \varepsilon_y)] - A_{frp}\sigma_{frp} = 0 \tag{22}$$

$$\alpha_1\beta_1 bx^2 f_c^{'}(x - \frac{1}{2}\beta_1) + A_{s2} f_{s2}(x - d_2) - A_{s1}[f_y + 0.01E_{sp}(\varepsilon_{z1} - \varepsilon_y)](d - x) - \\ -A_{frp}\sigma_{frp}(d_{frp} - x) = M_{ext} \tag{23}$$

5. Analysis of the Moment-Curvature Relationship in the Cross Section of the RC Beam Strengthened with FRP Reinforcement

5.1. M_k.m program for determining bending moment-curvature relationship

The shape of the moment-curvature diagram is an important characteristic of the cross-section on which the behaviour of the RC beam as a whole significantly depends [15].

The relationship between the moment and curvature can be most easily determined by varying the values of edge strains in concrete. Based on the strain on the compressed edge of concrete (ε_{cc}), other characteristic values of strain can be determined according to the following expressions (Fig. 7):

$$\varepsilon_{s2} = \varepsilon_{cc}\frac{x - d_2}{x} \quad \varepsilon_{s1} = \varepsilon_{cc}\frac{d - x}{x} \quad \varepsilon_{frp} = \varepsilon_{cc}\frac{d_{frp} - x}{x} \quad \varepsilon_{ct} = \varepsilon_{cc}\frac{h - x}{x} \tag{24}$$

By substituting the expressions (24) in the equilibrium condition (14), the distance of the neutral axis from the compressed edge of the concrete (x) can be determined, after which the equilibrium condition (16) can be determined. and the bending moment (M) corresponding to the strain at the compressed edge of the concrete (ε_{cc}).

Using the straight section hypothesis, the magnitude of the curvature in the cross section (κ) can be determined by dividing the strain of the compressed edge of the concrete section (ε_{cc}) by the distance of that edge from the neutral axis (x):

$$\kappa = \frac{\varepsilon_{cc}}{x} \tag{25}$$

In this way, the relationship between the bending moment and the curvature (M-κ) in the cross section of the RC beam strengthened with FRP reinforcement is obtained. The diagram of dependence between the moment and curvature can be determined by incremental increase of strain of the compressed edge of concrete until one of the following conditions is fulfilled:

1. The value of the strain on the compressed edge of concrete is equal to the strain of concrete crushing,
2. The strain value in the FRP reinforcement is equal to its ultimate strain.

In the paper [16] for the analysis of the cross section of the RC beam strengthened with FRP reinforcement, the program M_k.m in Matlab (MATLAB R2014a) was written.

The program is based on the previously described procedure for determining the dependence between moment and curvature in the cross section of an RC beam strengthened with FRP reinforcement, subjected to bending. Execution of this program determined the curves of dependence between bending moment and curvature. The strain of the compressed edge of the concrete cross section was increased in each step by 10 microstrains (0.00001 mm / mm).

5.2. Numerical example

The focus of the analytical investigation in this paper is on the RC beam with a cross section of 120/200 mm.

Mechanical characteristics of concrete and steel reinforcement are:

- Compressive strength of concrete is $f_{c'} = 40$ MPa;
- Beam is reinforced in both compressed and tensioned zones with steel reinforcement 2BØ8 ($A_s = 100$ mm2, $\mu_s \approx 0.5\%$, $f_y = 400$ MPa, $E_s = 210$ GPa).

In order to analyse the influence of the FRP reinforcement on the magnitude of the cracking moment (M_{cr}), yielding moment (M_y) and ultimate bending moment (M_u), using the program M_k.m, diagrams of the dependence between the moment and the curvature were obtained for:

1. Cross section without FRP reinforcement;
2. Cross sections strengthened with different amount of CFRP reinforcement (A_{cfrp}=10-100mm^2) with tensile strength $f_{frp,u} = 2000$ MPa, modulus of elasticity $E_{frp} = 150$ GPa and ultimate strain $\varepsilon_{frp,u} = 0.0133$;
3. Cross sections strengthened with different amount of GFRP reinforcement (A_{gfrp}=10-100mm^2) with tensile strength $f_{frp,u} = 760$ MPa, elastic modulus $E_{frp} = 40.8$ GPa and ultimate strain $\varepsilon_{frp,u} = 0.0186$.

5.3. Results

The values of the yielding moment, as well as the ultimate bending moment obtained by the program M_k.m are shown in Table 1.

In addition to the value of the yielding moment of steel reinforcement and the ultimate bending moment, as it was said, the diagram of the dependence between the moment and the curvature speaks a lot about the behaviour of the RC section. Among other things, the change in the bending stiffness of the cross-section can be clearly seen on it with different amounts of added FRP reinforcement.

Table 1 Yielding and ultimate bending moment for the examined cross-sections

	CFRP		GFRP	
A_{frp} [mm^2]	M_y	M_u	M_y	M_u
control	6.00	6.78	6.00	6.78
10	6.58	10.19	6.18	8.44
20	7.17	13.47	6.35	9.69
30	7.75	16.72	6.53	10.93
40	8.34	19.29	6.70	11.95
50	8.93	21.05	6.79	12.86
60	9.52	22.58	6.96	13.71
70	10.00	23.95	7.14	14.50
80	10.60	25.17	7.31	15.24
90	11.19	26.29	7.49	15.94
100	11.78	27.31	7.68	18.50

A diagram of dependence between bending moment and curvature for control, unstrengthen cross-section is shown in Fig. 8, while diagrams for cross-sections strengthened with the CFRP and GFRP reinforcement are shown in Fig. 9 and Fig. 10 respectively.

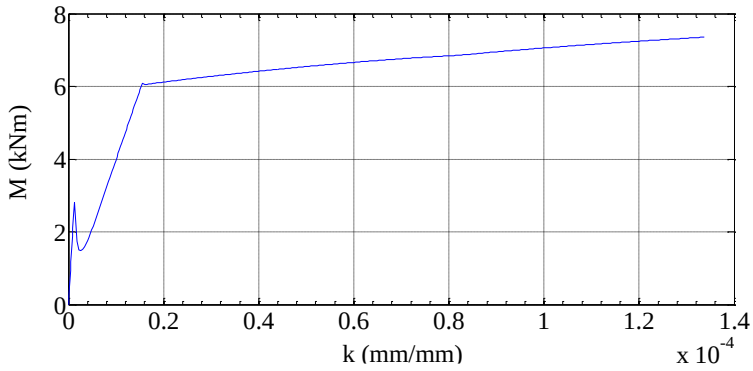
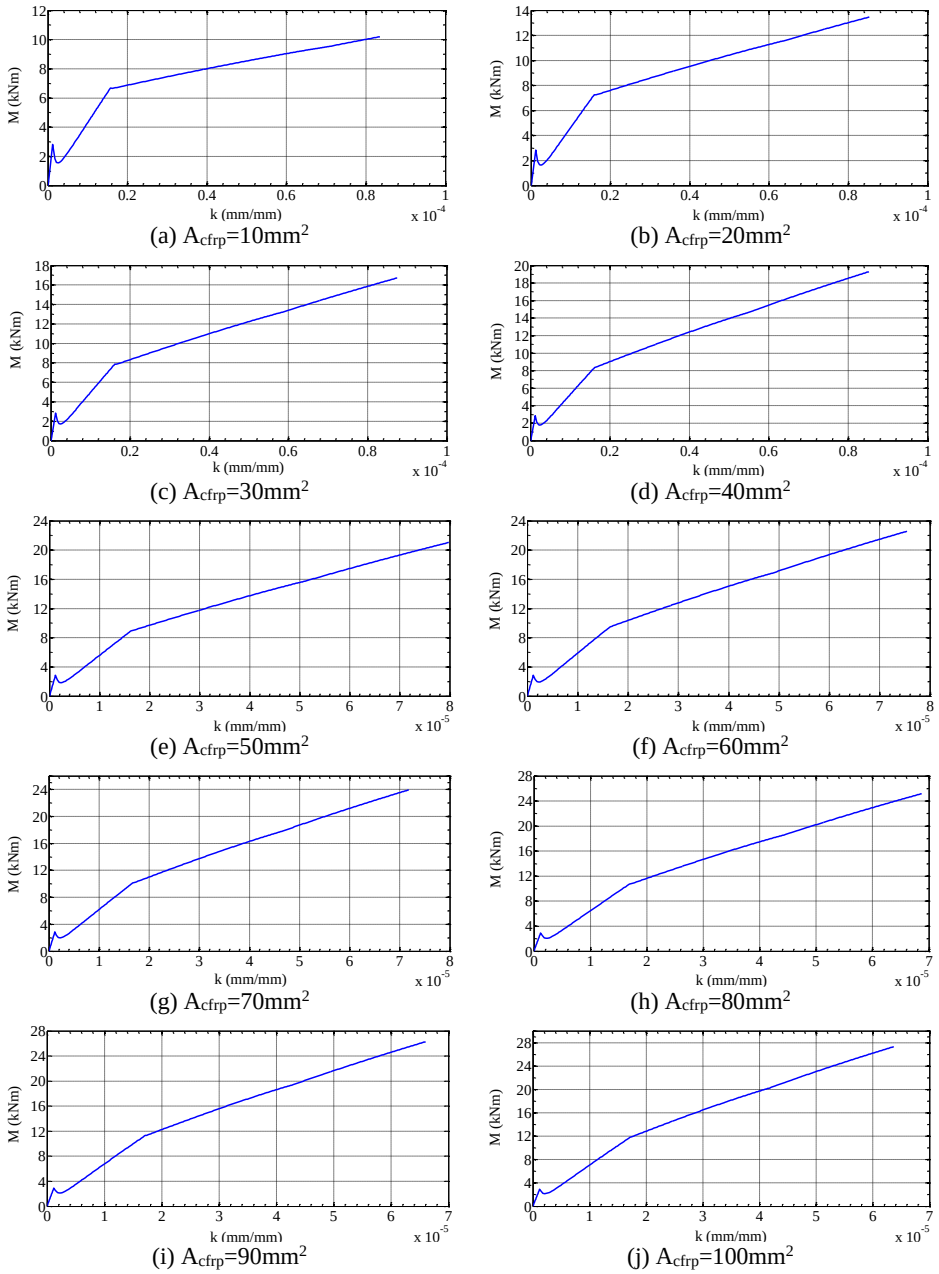


Fig. 8 Diagram of dependence between bending moment and curvature for control, unstrengthen cross-section [16]



(a) A_{cfrp}=10mm^2 (b) A_{cfrp}=20mm^2

(c) A_{cfrp}=30mm^2 (d) A_{cfrp}=40mm^2

(e) A_{cfrp}=50mm^2 (f) A_{cfrp}=60mm^2

(g) A_{cfrp}=70mm^2 (h) A_{cfrp}=80mm^2

(i) A_{cfrp}=90mm^2 (j) A_{cfrp}=100mm^2

Fig. 9 Diagram of dependence between bending moment and curvature for cross-section strengthened with CFRP reinforcement [16]

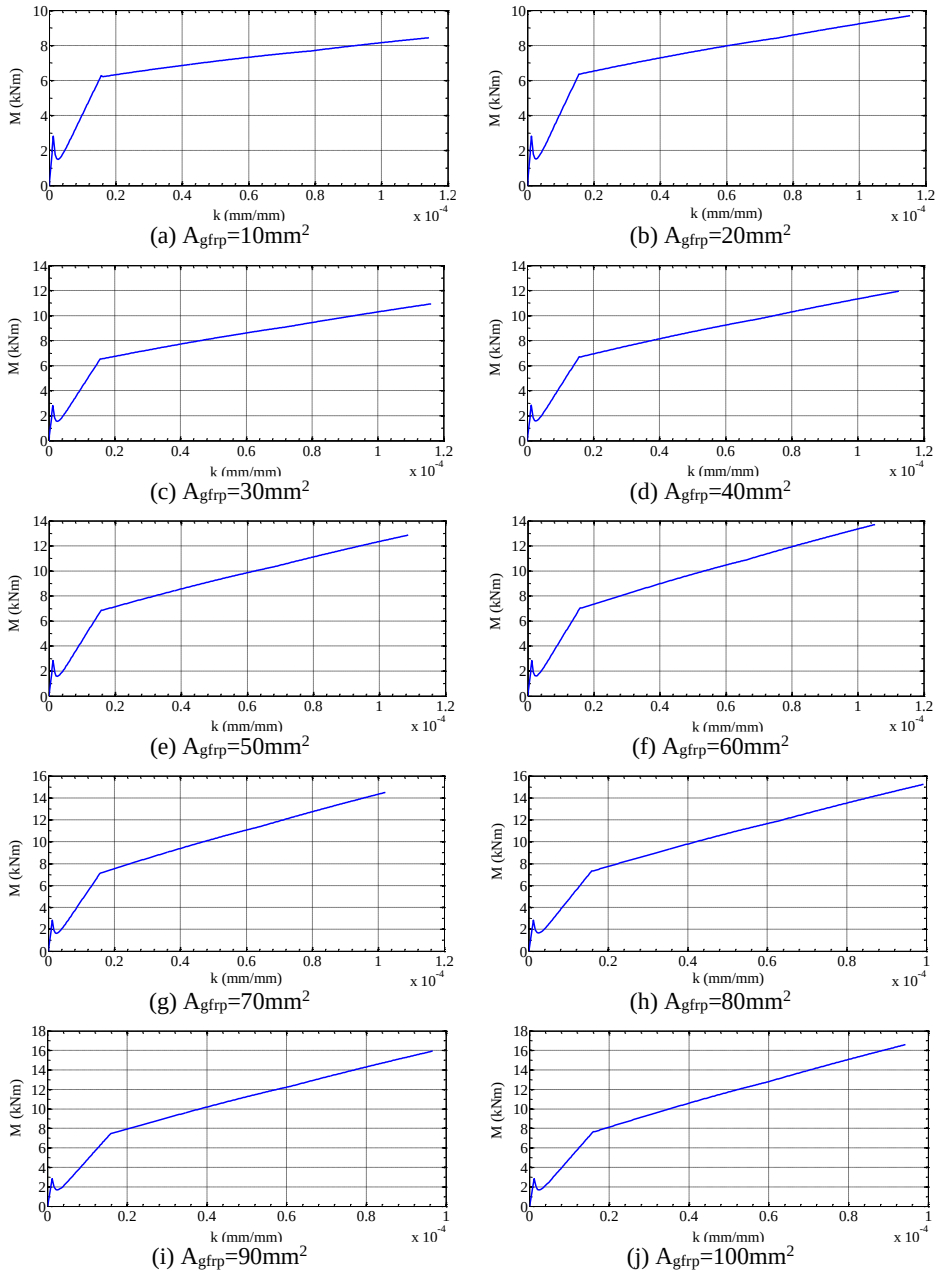


Fig. 10 Diagram of dependence between bending moment and curvature for cross-section strengthened with GFRP reinforcement [16]

6. CONCLUSION

Based on the obtained diagrams of the dependence between the moment and the curvature (Figure 5-12, 5-13 and 5-14), and the obtained values of the cracking moment (M_{cr}), the yielding moment (M_y) and the curvature of the section at the beginning of the yielding of steel reinforcement (κ_y), the ultimate bending moment (Mu) and the curvature of the section at the moment of failure (κ_u), as well as their relations, the following conclusions were drawn:

1. The external FRP reinforcement does not have a significant effect on the value of the cracking moment, as well as on the bending stiffness of the section before cracking:
   - in the case of beams strengthened with the CFRP reinforcement, the increase in the cracking moment (M_{cr}) is a maximum of 4.41%, in the case when the percentage of reinforcement with the external FRP reinforcement is equal to the percentage of reinforcement with internal steel reinforcement,
   - for beams reinforced with the GFRP reinforcement, the increase in the cracking moment (M_{cr}) is a maximum of 0.24%, in the case when the percentage of reinforcement with the external FRP reinforcement is equal to the percentage of reinforcement with internal steel reinforcement.
2. The external FRP reinforcement affects the value of the yielding moment, as well as the bending stiffness of the section:
   - for beams strengthened with the CFRP reinforcement, the increase in yielding moment (My) is a maximum of 96.33%, while the maximum increase in bending stiffness at the beginning of the yielding of steel reinforcement is 77.56%,
   - for beams strengthened with the GFRP reinforcement, the increase in yielding moment (My) is a maximum of 26.17%, while the maximum increase in bending stiffness at the moment of the start of yielding of steel reinforcement is 22.30%.
3. The external FRP reinforcement significantly affects the ultimate bending moment, as well as the bending stiffness of the cross section:
   - in the case of a beam strengthened with the CFRP reinforcement, the increase in the ultimate bending moment (M_u) is a maximum of 302.8%, while the maximum increase in bending stiffness at the moment of failure is 298.07%,
   - in the case of a beam strengthened with the GFRP reinforcement, the increase in the ultimate bending moment (M_u) is a maximum of 144.84%, while the maximum increase in bending stiffness at the moment of failure is 64.70%.

The obtained results indicate a significant influence of FRP reinforcement on the cross - sectional behaviour of the strengthened RC beam, considering that even with small amounts of additional reinforcement, the bearing capacity, as well as the bending stiffness, significantly increases.

However, the required percentage of the additional reinforcement should be determined in each individual case, given that in the case when the compressive strength of the concrete is small, as well as in the case of high percentage of steel reinforcement, the use of additional FRP reinforcement loses importance because due to concrete crushing, with little utilization of the load-bearing capacity of FRP reinforcement. In general, strengthening of an RC beam is possible only if there is an additional capacity of the compressed part of the concrete cross-section that would allow an increase in the internal bending moment in the cross-section [16].

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ANALITIČKI PRORAČUN PRESEKA AB GREDE OJAČANE NA SAVIJANJE FRP MATERIJALIMA

Ojačavanje betonskih konstrukcija se primenjuje kao rešenje pri rešavanju različitih problema u građevinskoj praksi. U radu je prikazano analitičko istraživanje ponašanja poprečnog preseka armirano-betonske (AB) grede, ojačane na savijanje vlaknima armiranim polimernim (eng. FRP) materijalima. Korišćenjem uslova ravnoteže unutrašnjih sila u poprečnom preseku grede, kroz sve faze naprezanja kroz koje ona prolazi, napisan je program u softveru MATLAB, čijim se izvršenjem dobija kriva zavisnosti između momenta savijanja i krivine, koja predstavlja jedan od osnovnih pokazatelja ponašanja poprečnog preseka grede. Parametri koji su varirani u ovom istraživanju su količina i vrsta FRP armature, a dobijeni rezultati ukazuju na značajan uticaj dodate FRP armature kako na moment tečenja i granični moment savijanja, tako i na krutost na savijanje ojačanog poprečnog preseka.

Ključne reči: *armirano-betonske grede, analiza poprečnog preseka, vlaknima armirani polimerni materijali, ojačavanje*

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Original Scientific Paper

PERFORMANCE OF ASPHALT MIXTURES WITH A NEW TYPE OF RUBBER MODIFIED BITUMEN

UDC 665.775

Kornel Almássy[1], András Geiger[2], András Holló[2], László Gáspár[3]

[1]Department of Highway and Railway Engineering and Faculty of Civil Engineering, Budapest University of Technology and Economics, Budapest, Hungary
[2]Downstream Refining Product Development and Service Center, MOL Group, Százhalombatta, Hungary
[3]KTI Institute for Transport Sciences Non-Profit Ltd., Budapest, Hungary

Abstract. *The rubber modified bitumen 45/80-55 (RMB 45/80-55) product has been used in Hungary as bituminous binder for asphalt mix production since 2013. It is a new kind of rubber bitumen manufactured using patented technology. Over the past 8 years, it has been used to construct or renovate more than 100 asphalt road sections. Originally RMB 45/80-55 was used to replace paving grade bitumen 50/70 in some road construction projects. However, asphalt laboratory results and road construction experience showed that its quality can also achieve or in terms of some parameters exceed that of asphalt mixtures manufactured with polymer modified bitumen 25/55-65 (PMB 25/55-65). Primarily, its excellent resistance to low temperatures and fatigue are outstanding, in this respect; it surpasses the results of asphalts made with polymer-modified bitumen. Its favourable fatigue resistance compensates for its lower stiffness; therefore, favourable results were obtained in the case of track structure design too in comparison with PMB. Considering the road construction benefits of this new type of rubber bitumen, as well as the support of the environmentally friendly recovery of waste tyres and fitting into a circular economy, a wider spread of the RMB product is realistically expected in the future.*

Key words: *rubber bitumen, rubber modified bitumen, rubber bitumen bound asphalt, asphalt mechanical laboratory tests, road section monitoring, pavement scaling*

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Corresponding author: Kornel Almássy
Faculty of Civil Engineering, Budapest University of Technology and Economics, Budapest, Hungary
E-mail: almassy.kornel@emk.bme.hu

1. INTRODUCTION

Road pavement structures, especially those in direct contact with road vehicles, are becoming increasingly important for their durability, cost-effectiveness, road safety, travel comfort, etc. levels. The other worldwide trend is the pursuit of sustainability in various branches of the national economy. The essence of sustainability is to exploit win-win opportunities, to find and apply tools and solutions that are good for both societies. The improvement of the pavement structure of roads and sustainable development can be set as a joint objective, among others, by using rubber waste in asphalt mixtures.

Ten years ago, about 1.4 to 1.5 billion tyres were produced annually in the world and about the same amount became waste (ETRMA 2011, Sienkiewicz 2012, Presti 2013). This number is equal to approximately 17 million tons. In its publication, the European Tire and Rubber Manufacturers' Association mentioned 324 million sold tires in Europe and five times that around the world, i.e., around 1.62 billion in 2020 (ETRMA 2020). The life cycle and management of these used tires are not entirely solved yet.

Energy recovery utilizes a significant amount; however, it cannot be considered the most favourable method. The utilization of crumb rubber in road construction is a potential method for the material recovery of the rubber component of waste tyres by dry process (crumb rubber is used during asphalt-mixing) or wet process (rubber first blended with the bitumen) (Takallou 1991, Zareh 2006).Wet processes are more commonly used techniques than the dry ones, but they are also limited by application issues and potential health, safety and environment (HSE) difficulties (Burr et al. 2001).

The development of a Hungarian patent for chemically stabilized rubber bitumen (CSRB) a decade earlier can be considered a significant qualitative step forward in this field (Biró et al. 2009). The favourable laboratory and site performance results substantiate stakeholder expectations and operators that asphalt layers with rubber modified bitumen 45/80-55 (RMB 45/80-55) binder will play an important role in Hungarian road technology selection. A manufacturing plant with a capacity of 20,000 tons/year, in operation since September 2020 produces the amount of chemically stabilized rubber bitumen that makes even the export of the binder a realistic option.

This article aims to evaluate and predict the performance of chemically stabilized rubber bitumen and the asphalt (mixtures) produced with it using different methods; its application areas are also identified.

1.1. Types of preliminary testing of experimental technologies

Following the development of a novel road construction material or technology, one of the most important and not always easy tasks is to demonstrate reliably; to confirm that the material or process in question can indeed achieve the expected long-term performance under the synergistic effect of estimated traffic and environmental loads.

The following main options are available for the preliminary verification of the suitability of innovative road construction materials and technologies (Gáspár et al. 2014):

a) computer performance software (running time is extremely short –a few hours -, but the reliability of the results is rather limited due to the moderate accuracy of the inputs),
b) laboratory tests (they require a short time, typically some days; the composition of the test and reference material samples may be close to the planned one, but the loading

conditions, especially environmental loading, are generally significantly different from the actual ones, which has an adverse effect on the accuracy of the results obtained),

c) accelerated load tests (accelerated load testing - ALT - equipment, using artificial traffic, usually provide more accurate results in a few months, however, their reliability is limited by the difficulties of realistically modelling the environmental load),

d) long term monitoring of condition evolution of experimental phases (although it may take more than a decade, this monitoring is the only type of study that can provide fully reliable results on the expected performance of the innovative material or technology).

In characterizing the expected performance of asphalt mixtures made with chemically stabilized rubber bitumen, the processes listed as options a), b) and d) above-provided information that is reported in this article.

2. Utilization of the Rubber Component of Used Tyres in Road Construction

The application of crumb rubber for asphalt-mix production and road construction dates to the 1960s (Caltrans 2006, Presti 2013). In Sweden, a surface asphalt mixture with the addition of a small quantity of ground rubber from discarded tyres as a substitute for a part of the mineral aggregate in the mixture was used. The goal was to obtain an asphalt mixture with improved resistance to studded tyres as well as to snow chains (Presti 2013). During the same period, in the United States, crumb rubber application started by blending it with bitumen followed by maturation times of 45-60 minutes and then using the rubber-bitumen obtained as a binder instead of bitumen (Caltrans 2006, Presti 2013, Zanzotto 1996). It was observed that this method could beneficially change the properties of bitumen. The method used in Sweden is called the dry, while the other used in the USA is called the wet process (Zanzotto 1996, Zareh 2006, Caltrans 2006).

2.1. Dry process

In the dry process, the crumb rubber does not come into direct contact with the bitumen; it is added to the mineral aggregate (Weidong 2007), and then the bitumen is sprayed onto this mixture. In this case, it cannot be considered rubber bitumen, as only a partially reacted system is created. This means that the intense contact time at high temperature between bitumen and crumb rubber is very short, practically limited to the duration of the asphalt mixing. Therefore, the technical character-improving effect of crumb rubber on the binder is significantly less than the elastomer content (i.e., polymer content) of the rubber would allow (Gooswilligen 2000).

In other words, during the application of the dry process, the crumb rubber can be considered as an inactive filler rather than as an active modifier that can significantly improve the properties of bitumen. The beneficial effect of crumb rubber is manifested in the asphalt mixture to a limited extent, even when mixing and road construction are carried out with appropriate technology. It is important that the particle size of the crumb rubber used should fit the structure of the mineral aggregate.

2.2. Wet process

In contrast to the dry process, when the wet process is used, the bitumen and the crumb rubber are first blended resulting in rubber bitumen before the asphalt is mixed. It can be stated that the crumb rubber has 'time to wet'. The crumb rubber swells by adsorption of the oily components of the bitumen. The rate of this swelling process is influenced by the blending parameters (temperature, mixing time and intensity) of the bitumen and the crumb rubber, as well as the chemical composition of both components and the grain size and surface properties of rubber (Caltrans 2006, Fontes et al. 2006). If crumb rubber and bitumen blending occur at high temperatures with intensive stirring for a long time, the swelling of the crumb rubber can be followed by depolymerisation and vulcanization processes, the crumb rubber dissolves in the bitumen (Zanzotto 1996, Gawel 2006 et al.). The swelling and subsequent dissolution of crumb rubber can be demonstrated through rheological characteristics, e.g., the change in viscosity (see Fig. 1) (Sabita 2015, Presti 2013).

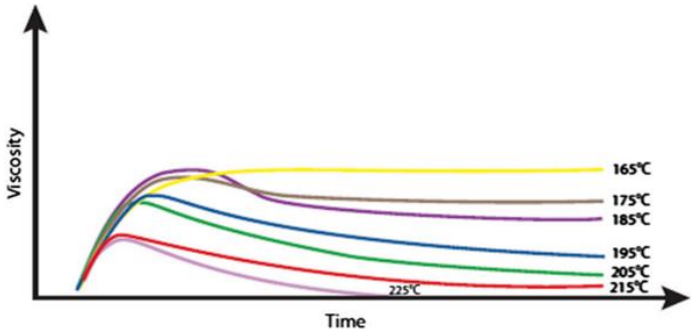

Fig. 1 Change of rubber bitumen viscosity as a function of blending temperature and duration

Several wet process types are known depending on the quality of the rubber bitumen produced and the manufacturing conditions. However, two significantly different rubber bitumen types and their manufacturing technologies can be distinguished (FHWA 2014, Caltrans 2006):

- wet process – high viscosity (rubber bitumen produced at asphalt mixing plant),
- wet process – no agitation (rubber bitumen produced at bitumen factory, sometimes called terminal blend).

2.2.1. Wet process - High viscosity rubber bitumen

The original American manufacturing technology, developed in the 1960s, produces a rubber bitumen product of high viscosity. Production is typically carried out in special rubber bitumen mixing units (e.g., mobile plant installed next to an asphalt mixing plant) typically at 175-200°C for 45-60 minutes (Caltrans 2006). Extender oil can also be used for production, to promote the swelling of the crumb rubber and achieve increased viscosity. As required by ASTM 6114, the viscosity of the rubber bitumen manufactured must be at least 1500 mPas at 175°C. Based on Caltrans data, this viscosity value must be obtained at 190°C. Crumb rubber concentration in the product is up to 15-22 wt% and the particle size used is not bigger than 2.00 mm, or maximum 2.36 mm according to other requirements.

The manufacturing conditions only cause a little dissolution of the rubber crumb; the primary process that takes place is the swelling of the crumb rubber due to the adsorption of certain bitumen components, resulting in an increase in viscosity. If the product is not used immediately, mixing is required during storage due to the intense sedimentation of non-dissolved rubber particles. In this case, due to the dissolution of rubber a decrease in viscosity may occur, which should be improved by blending additional crumb rubber to the rubber bitumen. High viscosity rubber bitumen allows the formation of a significantly thicker binder film on the aggregate surface than conventional bitumen. There are advantages (e.g., a more durable road due to slower aging, a thinner asphalt layer) and disadvantages (special asphalt formula required, more expensive due to higher binder content in the asphalt mixture) of high viscosity rubber bitumen.

The asphalt mixtures and laid asphalt roads containing high viscosity rubber bitumen thus resulted in significant improvements in quality and durability compared to asphalt and roads produced with normal road bitumen (Presti 2013). However, due to the difficulties inherent in the technology and involving special requirements, it is mostly used in the USA only.

2.2.2. Wet process – no agitation rubber bitumen

The application of this technology began in the 1980s in Texas, USA, about 20-25 years later than the production of high viscosity rubber bitumen presented in the previous section. This process uses small, particle sized crumb rubber (up to 0.3 mm), typically 5-10 % by weight, but there are also examples of larger mixing rates (Caltrans 2006, Presti 2013). It is typically manufactured at the site of bitumen production and the product is shipped to the asphalt production site (Caltrans 2006, Shatnawi 2010). The so-called terminal blend is also commonly used for this product, but it can also be manufactured at the asphalt mixing plant and does not need to meet the condition of storage without agitation.

The production, transportation and use at asphalt mixing plant of the agitation-free rubber bitumen product make it similar to PMB. Because of the manufacturing conditions used, the small particle size and the low concentration of crumb rubber, a considerable part of the rubber particles are dissolved in bitumen. It allows the application of the same asphalt formula/composition as the use of PMB. Its similarity to PMB (regarding production, transport, asphalt mixing and asphalt recipe) is an advantage, but the quality of the asphalt mix is below that of the asphalt road built with the rubber bitumen product of high viscosity (Shatnawi 2010). At the same time, it is important to highlight that while no agitation rubber bitumen is used mainly for dense graded asphalt concrete, the high viscosity rubber bitumen product is considered a binder especially for gap-graded or open-graded asphalt types because of its high viscosity. Unlike a high viscosity product, the wet process - no agitation product, like PMB types, can be classified according to the performance grade (PG) system.

3. Rubber Modified Bitumen (RMB 45/80-55) Manufactured by Modified WET Process

The advantages and disadvantages of the two types of rubber bitumen described in Section 3 can be clearly identified. In Hungary, MOL Plc. and the University of Pannonia carried out research and development work on rubber bitumen aiming at efficiently combining the advantages of the two products presented in the previous section and eliminating or at least reducing their disadvantages. The developed new production process, the so-called modified

wet process, takes place at the bitumen production site in a specially designed production unit. Based on the relevant patent (Biró et al. 2009), the product is chemically stabilized rubber bitumen (CSRB). In what follows, the RMB 45/80-55 designation is used, as the product is available under this name on the Hungarian bitumen market. The modified wet process by which RMB can be produced is summarized below (Geiger et al. 2012):

In the first technological step, 14-18 wt% (for the final product) crumb rubber below 1.25 mm particle size is added to high-temperature bitumen (>210ºC), then subjected to intense stirring, resulting in swelling and partial dissolution of the crumb rubber.

In the next technological step, the intense mixing of rubber and bitumen continues at a lower temperature (<190ºC). Here a crosslinking additive is also used, which improves the rheological properties of the RMB product. A further advantageous effect of the additive is that it promotes the dispersion of the carbon black and inorganic fillers dissolved from the crumb rubber.

The aim of production technology development was to elaborate a production method to produce rubber bitumen, which possesses the advantages of already known rubber bitumen, has a positive effect on the quality of asphalt roads, and can also be used in the same way as well-known PMB binders. The main condition for applicability identical to PMB is to have the high-temperature viscosity of the product (180°C) similar to that of PMB. This can be achieved if, in addition to the swelling processes of the crumb rubber added to bitumen taking place in the hot bitumen, the polymer components of the rubber are also transferred to the liquid bitumen phase, i.e. the crumb rubber dissolves and acts as an active modifying agent. However, the dissolution of crumb rubber cannot take place completely, because in this case our experience has shown that a loss of quality of the rubber bitumen occurs, and the rubber bitumen produced has asphalt properties similar to those of the original starting bitumen.

For this reason, only an optimal dissolution rate can be allowed, just to the extent necessary to eliminate CSRB usage difficulties. This process can be tracked by checking the viscosity during production; in practice, the on-line measurement of the viscosity change shown in Figure 1 is required. RMB produced by the modified wet process is transported, discharged, and used in asphalt production exactly as in the case of polymer-modified bitumen (PMB 25/55-65). Asphalt mixing, and then paving and compaction are just slightly different from using asphalt produced with PMB since the viscosities of the two binders are almost identical. The aggregate composition of the asphalt is also the same. Thus, it can be concluded that the asphalt production and road construction processes are the same, only PMB is replaced by RMB. During RMB production, the polymers released into bitumen by rubber dissolution improve the properties of bitumen as active modifiers. Unsolved, swollen rubber particles partially retain their elastic properties. As a result, the fatigue and low-temperature properties of the binder are improved, which also has a positive effect on the quality of the asphalt. If the product is used within 24 hours from unloading, it is not necessary to store it in a tank equipped with a mixer, but mixing is required for longer-term storage.

The introduction of the RMB product to the Hungarian market was made more difficult by the fact that RMB 45/80-55 did not meet normal (EN 12591) or modified bitumen (EN 14023) standards either. Due to unsolved rubber particles, plus the carbon black and inorganic filler content released from crumb rubber, the RMB product does not meet the 99.0 wt% toluene solubility requirement set for road construction bitumen in accordance with EN 12591. The cohesion energy and elastic recovery tests required by EN 14023 in the case of PMB products cannot be carried out, as the sample is broken along unsolved rubber particles during stretching. As a result, a new standard (MSZ 930) was developed for the rubber

modified bitumen product in Hungary. RMB 45/80-55 meets this standard. The quality requirements, together with the typical quality parameters of the product manufactured in a plant with a capacity of 20 000 t/year in Hungary are shown in Table 1. The existing standard allowed the RMB binder to be included in asphalt standards as an applicable type of binder, so RMB can now be used in road construction in Hungary the same way as well-known paving grade bitumen and polymer modified bitumen products.

Table 1 RMB 45/80-55 quality requirements and typical values

Property	Unit	Requirement (MSZ 930)	Typical values	Method
Penetration at 25°C	0.1mm	45-80	47-60	EN 1426
Softening point	°C	≥ 55	58-62	EN 1427
Resistance to hardening				EN 12607-1
Change of mass	%	≤ 0.5	0.05 – 0.2	
Retained penetration	%	≥ 50	70 – 80	EN 1426
Increase in softening point	°C	≤ 8	3 – 5	EN 1427
Elastic recovery at 25 °C (*)	%	≥ 50	55 – 70	EN 13398
Fraass breaking point	°C	≤ -16	-18 - (-22)	EN 12593
Storage stability, difference in softening point (**)	°C	≤ 8	4 – 6	EN 13399, EN 1427
Flash point	°C	≥ 235	≥ 280	EN ISO 2592
Dynamic viscosity at 180 °C	mPas	≤ 500	300-450	EN 13302

(*) Stretching length is equal to 100mm
(**) Storage time at 180°C is 24 hours

Like the terminal blend rubber bitumen product, RMB is suitable for performance grading (PG) bitumen certifications. In Hungary, it is not required to carry out such tests, but the performance behaviour of RMB is also investigated. The performance grading qualification was done with temperature steps of 3°C starting at 58°C at high temperature and -12°C at low temperature. Table 2 summarizes temperature values where the characteristics of RMB binder reach the required minimum or maximum values. Based on performance grading evaluation RMB 45/80-55 can be classified as PG 76-28 binder. RMB meets the requirement at 76°C but fails at 79°C. Similarly, it meets the requirement at -18°C but fails at -21°C. (Temperature values presented in Table 2 were determined by logarithmic interpolation.)

Table 2 Performance-related characterization of RMB 45/80-55 used in this article

	Unit	Requirement	Temperature, °C	Method
Original binder				
Dynamic viscosity	mPas	≤ 3000	127	EN 13302
G*/sinδ	kPa	≥ 1.0	77.4	EN 14770
After Rolling Thin Film Oven Test (RTFOT)				
G*/sinδ	kPa	≥ 2.2	76.4	EN 14770
After Pressure Aging Vessel (PAV) test				EN 14769
G*·sinδ	kPa	≤ 5000	17.3	EN 14770
Stiffness	MPa	≤ 300	-18.2	EN 14771

4. Characteristics of Road Sections Constructed Using RMB

An RMB production plant was established in Hungary in 2012. Using its product, asphalt roads were constructed or rehabilitated over a total length of 150 km on some 110 road sections between 2012 and 2020. The market introduction of RMB in 2012 was preceded by important R&D activities, asphalt testing, and the construction of experimental road sections between 2004 and 2008. During this period, the temporary reconstruction of the existing Hungarian PMB production plant made RMB production possible. A total of five pilot production projects were carried out, and road sections were built at various locations of the Hungarian road network using the five RMB product batches. Positive lessons learned from these road construction projects were the basis to manufacture the RMB product subsequently put on the market in 2012.

During the period between 2004 and 2008, and later in the first years following the start of continuous production in 2012, RMB was exclusively used as a replacement for 50/70 bitumen in asphalt mixing. It was primarily used in the production of AC11 wearing courses and the rehabilitation of minor roads. As experience of use accumulated, more and more inspection results of road section became available over the years. In time, the quality control checks of the wearing courses replaced using RMB confirmed the results of the asphalt laboratory tests, showing that the quality parameters (bearing capacity, cold behaviour, fatigue characteristics, etc.) of asphalts containing RMB binder exceed the quality of asphalt roads constructed using 50/70 bitumen. Besides, favourable road construction experience was also needed for the road construction industry to start using RMB for the rehabilitation and even construction of major roads and motorways.

In 2014, the entire asphalt structure (AC32 base, AC22 wearing and AC11 binder course) of a new 4.2 km long bypass road section of the town of Villány in the southern part of Hungary was built using RMB. A total amount of 21 000 tons of asphalt was mixed for this road construction and 900 tons of RMB binder were used to produce it. The positive achievements gave new momentum to RMB use in road construction, and in the following year, RMB was used in the binder and wearing courses of a 2 km long, shared section of motorways M1 and M7 leading into and out of Budapest, the capital of Hungary. On this section, recycled asphalt was also used in a concentration of 15 wt%. The outcome again reinforced the positive image of RMB.

In the meantime, the product was used in several other minor or major road construction or rehabilitation projects, the method was adopted by a growing number of asphalt companies and road builders, and RMB application eventually became routine. The established routine and favourable technical results confirmed that besides replacing 50/70 bitumen, RMB can also achieve asphalt quality equal or superior to that produced using the polymer-modified bitumen PMB 25/55-65. This allowed RMB to be used instead of PMB 25/55-65 first in 2019 and then repeatedly in 2020 for the construction of new motorway sections. In 2019, all three asphalt layers (SMA 11 wearing, AC 22 binder, AC 32 base course) on a 2 km long section of motorway M25 were constructed using asphalt mixtures containing RMB. In 2020, RMB was also used for the construction of an expressway, a 5.6 km long section of the M76 motorway. Here a total of 1,400 tons of RMB was used to construct 2x2 lanes laying a base (AC32) and a binder course (AC22).

Of the more than 110 sections built so far, 32 experimental and 3 (conventionally composed) reference sections were field-tested on-site in 2019. This covered the visual characterization of pavement conditions and the classification of the macro roughness of

pavement surface. Also, the deflection of the pavement structure was characterized in 9 experimental and 2 reference sections.

Surface conditions (defects) and the sand patch type macro roughness of the pavement surface were characterized on the road sections with wearing courses built between 2012 and 2017 (i.e., 2-7 years old at the time of measurement) with rubber bitumen binder. Without access to the very small number of actual reference sections built, the registered condition marks of rubber-asphalt wear layers were compared to those of the standard trial sections monitored in Hungary yearly for almost 30 years (Road Management 2018) according to the following steps:

- classification of the experimental sections – small (max. 1500 unit vehicle/day), medium (1501-5000 unit vehicle/day), or large (min. 5001 unit vehicle/day) – into traffic categories, 5-stage assessment of the pavement condition of the experimental sections in 2019,
- determination of the annual average condition mark scores of the three traffic categories for various pavement ages,
- determination of the values corresponding to varying pavement ages of the surface integrity (defect) pavement performance models within the appropriate road section classes of the standard trial sections condition monitored since 1991 (Road Management 2018),
- comparison of the mean values of the corresponding rubber asphalt sections and the pavement performance model values of the trial sections with "conventional" composition (as an example, see Table 3),
- carrying out the same steps for the macro roughness of pavement surface after converting sand depths to 5-grade condition marks (Table 4),
- the reported condition notes for surface defects can be calculated by the algorithms of the Roadmaster keyboard defect collection device (e-ÚT 09.02.26 road technical specification), while for the macro roughness the values of sand depth can be calculated with the algorithms according to MSZ EN 13036-1: 2010,
- in Tables 3 and 4, the pavement performance model values are averages; Table 5 shows the mean, standard deviation, and relative standard deviation of the underlying data sets.

Table 3 Comparison of deterioration rates of medium traffic volume sections

Experimental sections		Reference sections		Difference
Age (year)	Mean grade	Age (year)	Mean grade	
7	3.0	7	3.6	-0.6
5	2.0	5	2.2	-0.2
4	1.9	4	1.9	-0.0
3	1.2	3	1.7	-0.5

In the other two traffic categories, the average surface texture rating of the rubber bituminous binder wearing courses determined by age group was again generally more favourable than the corresponding values of the standard sections chosen for reference, and only infrequently were they the same.

The average, macro roughness grades of the tested rubber-asphalt road sections by traffic category were in all cases better than the averages of the corresponding reference

sections. (The time series obtained after converting the macro texture values determined from the national public road network and monitored annually since then with a laser RST measuring car (e-ÚT 09.02.24) into 5-mark grades was chosen as the basis of comparison).

Table 4 Comparison of relevant macro roughness values of pavements

Traffic category	Experimental sections		Reference sections		Difference
	Age (year)	Mean grade	Age (year)	Mean grade	
Small	7	2.8	7	3.1	-0.3
	6	2.5	6	2.6	-0.1
Medium	7	3.0	7	3.8	-0.8
	5	2.7	5	3.7	-1.0
Heavy	5	3.5	5	3.7	-0.2
	4	2.7	4	3.4	-0.7

Table 5 Average, standard deviation, and relative standard deviation of data sets behind selected points of performance models

Point of performance model	Mean value	Standard deviation	Relative standard deviation
Surface defects, medium traffic, 7 years	3.6	0.36	0.10
Surface defects, medium traffic, 5 years	2.2	0.21	0.10
Surface defects, medium traffic, 4 years	1.9	0.10	0.05
Surface defects, medium traffic, 3 years	1.7	0.11	0.06
Macro roughness, small traffic, 7 years	3.1	0.40	0.13
Macro roughness, small traffic, 6 years	2.6	0.27	0.10
Macro roughness, medium traffic, 7 years	3.8	0.39	0.10
Macro roughness, medium traffic, 5 years	3.7	0.36	0.10
Macro roughness, heavy traffic, 5 years	3.7	0.29	0.08
Macro roughness, heavy traffic, 4 years	3.4	0.27	0.08

The dynamic falling weight bearing capacity (deflection) measurement performed with KUAB equipment on 3 experimental sections were compared - in pairs - with their neighbouring references (identical pavement structure but with traditional binder). The results obtained here have shown that the average deflections of the reference sections were on average by 10% higher.

5. Related Laboratory Asphalt Tests

The BUTE (Budapest University of Technology and Economics) Highway and Railway Department and the KTI Institute for Transport Sciences Non-Profit Ltd. have participated without interruption in the analyses of asphalt mix with rubber bitumen almost since the beginning of development work in 2008. As early as 2009, they tested rubber bitumen mixture according to earlier technical specifications with promising results. These earliest tests revealed it right away that the asphalt mixture with rubber bitumen had better asphalt mechanical characteristics than the asphalt mixture with traditional road bitumen (better fatigue resistance and plastic deformation); it was found that some of its features almost

reached or even outperformed the features of the polymer-modified bitumen (PMB) mixture. Over the last decade or so, we performed the particular asphalt mechanical tests on different asphalt mixtures applying three types of bitumen bonding. The key results obtained are highlighted below (Almássy et al. 2009).

This section summarizes the results of asphalt mechanical tests carried out over the past five years on asphalt specimens (test pieces) manufactured under laboratory conditions or on samples drilled on-site after several years of operation.

5.1. Applied bitumen types and results of conventional bitumen testing

In the tests, 50/70 paving grade bitumen, RMB 45/80-55 rubber modified bitumen, and PMB 25/55-65 modified bitumen by linear SBS elastomer were used as bituminous binders. These bitumen types are characterized by the quality parameters presented in Table 6.

Table 6 Results of conventional bitumen tests on different bitumen types (Tóth et al. 2016, Tóth et al. 2017, Gáspár et al. 2019)

Properties	Bitumen 50/70	RMB 45/80-55	PMB 25/55-65
Softening point, °C	50.2	62.0	78.0
Penetration, 0,1mm	55	47	32
Fraass breaking point, °C	-17	-21	-20

5.2. Asphalt mixtures used for testing

The following asphalt mixtures were used for laboratory testing between 2016 and 2019:

- AC 11 wearing course, with B50/70 conventional bitumen (as control mixture), with PMB 25/55-65 polymer modified bitumen (as control mixture), with RMB 45/80-55 rubber modified bitumen (rubber bitumen modified asphalt mixture) – testing year: 2016;
- AC 16 binder course (mI), with PMB 25/55-65 polymer modified bitumen (as control mixture), with RMB 45/80-55 rubber modified bitumen (rubber bitumen modified asphalt mixture) – testing year: 2017;
- AC 22 binder course (mI), with PMB 25/55-65 polymer modified bitumen (as control mixture), with RMB 45/80-55 rubber modified bitumen (rubber bitumen modified asphalt mixture) – testing year: 2017;
- SMA 11 wearing course (mI), with PMB 25/55-65 polymer modified bitumen (as control mixture), with RMB 45/80-55 rubber modified bitumen (rubber bitumen modified asphalt mixture) – testing year: 2017;
- SMA 11 wearing course, with PMB 25/55-65 polymer modified bitumen (as control mixture), with RMB45/80-55 rubber modified bitumen (rubber bitumen modified asphalt mixture) – testing year: 2019.

Table 7 presents the bituminous binder types applied and concentrations used for asphalt mixture production.

Table 7 Bitumen content of the tested asphalt mixtures. (Tóth et al. 2016, Tóth et al. 2017, Gáspár et al. 2019)

Name of the asphalt mixtures, (Testing year)	Bitumen content (m%)	Comments
AC 11 wearing course (2016)	5.1 %	
AC 16 binder course (mI) (2017)	4.5%	
AC 22 binder course (mI) (2017)	4.2 %	
SMA 11 wearing course (mI) (2017)	6.2%	0,5 % runoff inhibitor additive
SMA 11 wearing course (2019)	6.2%	

All mixtures are designed for high traffic resistance and their use is widespread both in Hungary and in many other European countries. Differences between traditional bitumen, polymer and rubber-modified binders have resulted in slightly different bulk density, voids free (maximum) bulk density and air voids per mixture types. The results of the air void content of asphalt mixtures with different bitumen binder type and identical aggregate structure and source are shown in Figure 2.

The asphalt mixtures prepared appear to meet the requirements of the new regulation, where the intended air void content may be 2.5-4.0% for SMA 11 (mI) mixtures, 2.5-4.5% for AC 11 wearing course mixtures and 3.0-5.0% for AC16 (mI) and AC22 (mI) mixtures. So, the difference in air void content is not significant, and does not play a decisive role in the test results presented below (see Fig. 2).

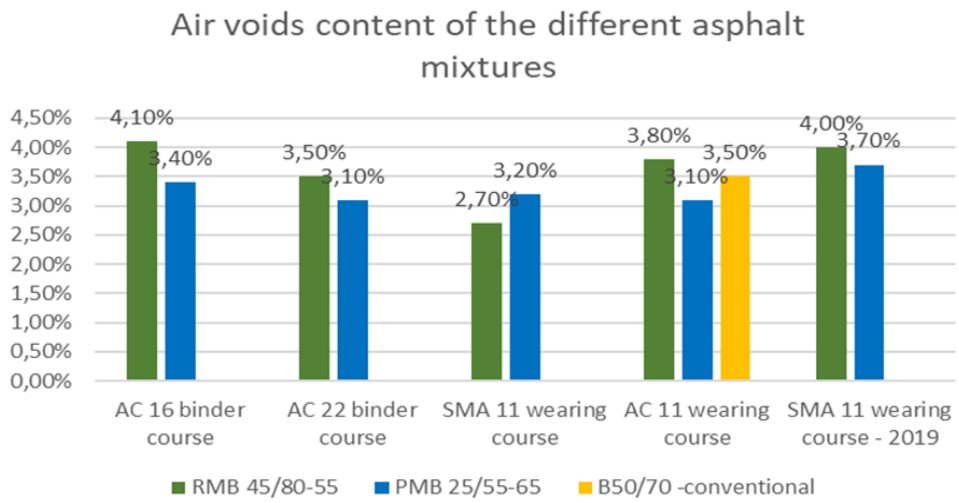

Fig. 2 Air void content of the asphalt mixtures with different binder types, otherwise identical mix volumetrics

Table 8 shows the particle size distribution of each mixture, which complies with the Hungarian technical specifications.

Table 8 Particle size distribution of mixtures used in the tests

Sieve size (mm)	Percentage passing (%)	Percentage passing (%)	Percentage passing (%)	Percentage passing (%)	Percentage passing (%)
	AC 11 wearing course (2016)	AC16 (mI) binder course (2017)	AC22 (mI) binder course (2017)	SMA11 (mI) wearing course (2017)	SMA 11 (mI) wearing course (2019)
31,5	100	100	100	100	100
22,4	100	100	97	100	100
16	100	99	73	100	100
11,2	98	69	52	94	95
8	71	58	46	55	56
5,6	56	46	40	43	46
4	46	37	33	36	36
2	36	26	21	24	26
1	24	18	16	18	19
0,5	18	16	15	15	16
0,25	14	12	11	14	14
0,125	11	10	10	12	12
0,063	8,0	8	7,9	10	10

5.3. Results of asphalt mechanical tests

In 2016 and 2017, in the laboratory of Budapest University of Technology and Economics, stiffness, wheel tracking and low temperature cracking tests using AC 11 wearing course, AC 16 binding course (mI), AC 22 binding course (mI) and SMA 11 wearing course (mI) with the application the above-mentioned bitumen binders were performed. (According to the Hungarian standard, the mI symbol refers to the use of a mixture of modified bitumen for intensive roads of highest traffic load category). In 2019, bending-fatigue tests were carried out to determine the SMA 11 wear-ing course fatigue life. In 2019, bending-fatigue tests were carried out to determine the SMA 11 wearing course fatigue life and stiffness values were measured in bored specimens that had been built in several years before.

5.3.1. Stiffness tests

The stiffness tests were performed at 20°C according to the EN 12697-27 standard (Bituminous mixtures – Test methods for hot mix asphalt – Part 26: Stiffness) on AC 11 wearing course asphalt mixtures. These test results show that asphalt mixtures containing RMB may achieve a higher stiffness value than asphalts mixed with conventional 50/70 bitumen, but do not reach the stiffness values of the asphalt mixtures containing a PMB binder (Fig. 3) (Tóth et al. 2016).

The results obtained for the bored specimens in IT-CY stiffness tests in 2019 showed that the stiffness values of RMB-mixtures were between 3000 and 4000 MPa, while the stiffness value of the reference sections with polymer-modified bitumen mixtures could reach 4446 and 5285 MPa stiffness. It follows that the stiffness of PMB binder mixtures was 30% higher than that of RMB's. In Figure 4, rubber bitumen mixture stiffness results are traced in green, whereas polymer modified mixtures stiffness results selected for reference are shown in blue (Fig 4).

The test involved an urban main road, Grassalkovich Street (built with the use of RMB-asphalt mixtures in 2014), and the road section on Road no. 7410 in Zalaegerszeg (built with RMB and PMB asphalt mixtures in 2012). Choosing Road no. 7410 in Zalaegerszeg was justified by the motivation that their RMB and PMB binder wearing courses were paved at the same time. The urban main road (Grassalkovich Street), built in 2014, was chosen because it carried the same traffic as Road no. 7410 in Zalaegerszeg. (Gáspár et al., 2019).

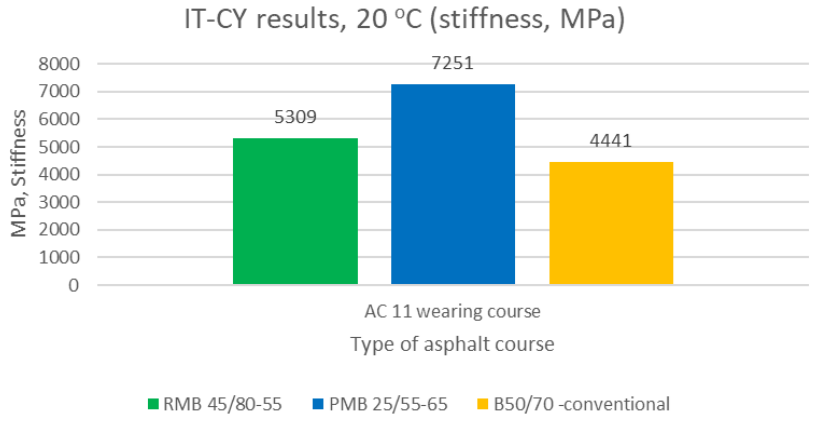

Fig 3. Results of the IT-CY test at 20°C. (Tóth et al. 2016)

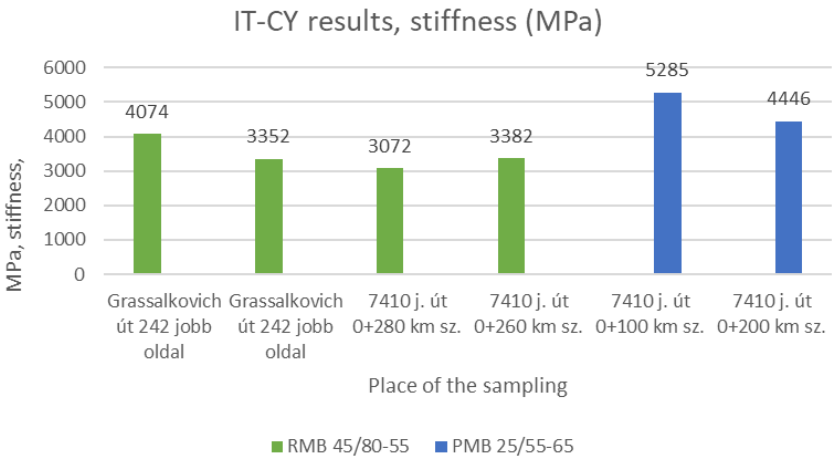

Fig. 4 RMB (green) and PMB asphalt mixture (blue) results for drilled specimens. (Gáspár et al. 2019)

5.3.2. Wheel tracking plastic deformation tests

The wheel tracking tests very well representing plastic deformation characteristics were performed according to the EN 12697-22 standard (procedure B, small specimen) at 60°C (EN 12697-22 2003). After the examination of practically all mixtures, it can be concluded

that wheel tracking test results show excellent plastic deformation characteristics for rubber bitumen modified mixtures since for them the wheel tracking depths obtained were much smaller than those for polymer modified or conventional B50/70 bitumen mixtures (Fig. 5) (Tóth et al. 2016, Tóth et al. 2017).

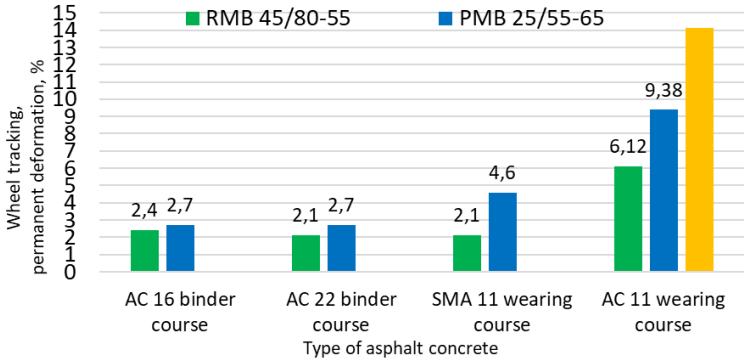

Fig. 5 Results of wheel tracking test (Tóth et al. 2016, Tóth et al. 2017)

5.3.3.. Low-temperature behaviour – resistance to cracking at low temperatures

With the excellent wheel tracking formation (rutting) properties of rubber bitumen mixtures in mind, it was normally expected that due to increased stiffness and plastic resistance, the low crack resistance of rubber bitumen mixtures would not be so outstanding. Nevertheless, for all asphalt mixtures tested, the cracking temperature of the mixture with rubber bitumen was the lowest, far outstripping the cracking temperature of mixtures made with polymer and conventional bitumen (Fig. 6). Low temperature crack resistance tests were carried out in compliance with technical standard EN 12697-46 (thermal stress restrained specimen test - TSRST test) (EN 12697-46 2012). It is important to note that the height and thickness of the test pieces were a non-standard 50 mm, and their length was 250 mm (Tóth et al. 2016, Tóth et al. 2017).

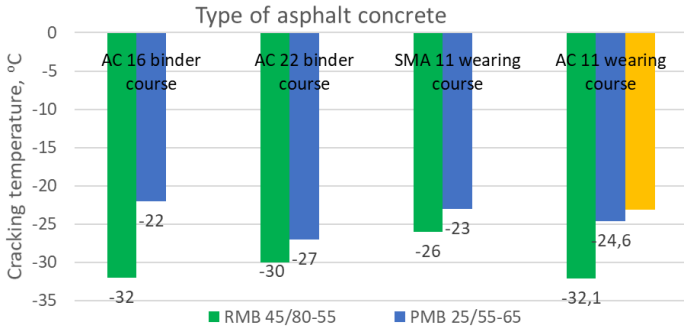

Fig. 5 Cracking temperature results for asphalt mixtures tested (Tóth et al. 2016, Tóth et al. 2017)

5.3.4. Fatigue resistance test

In the 2017 study, the fatigue resistance of asphalt mixtures AC 16 (mI) base, AC 22 binder (mI), and SMA 11 wearing (mI) was tested, while in the 2019 research SMA 11 wearing asphalt mixtures were tested (Fig. 7). In all cases, the tests were carried out at a test temperature of 20 °C and a frequency of 30 Hz, according to the relevant Hungarian road technical regulation (e-UT 05.02.11), in the analysis of test results the deformation value corresponding to the load repetition number of 10^6 was considered. In accordance with the standard EN 12697-24, the specimen geometry of fatigue resistance test is the following:

- SMA 11 wearing course: 5 cm high, 5 cm wide and 50 cm long,
- AC 16 binder course: 7 cm high, 7 cm wide and 50 cm long,
- AC 22 binder course: 7 cm high, 7 cm wide and 50 cm long.

Although the specification for the requirements of mixtures of asphalt paving (e-UT 05.02.11) does not contain a value to be achieved for the fatigue of stone mastic asphalt, the minimum values in the specification are 110 and 130 μstrain, respectively. Regarding the test results of fatigue resistance, it can be clearly stated that for all asphalt mixtures of different types, binder mixtures modified with rubber bitumen achieved better results and longer fatigue life than polymer-modified binder mixtures.

Compared to earlier fatigue tests carried out on other asphalt mixtures, it is observed that in 2019 the fatigue resistance of the rubber modified bitumen (RMB binder) SMA 11 wearing asphalt mixture turned out to be extremely high, namely 328 μstrain (Gáspár et al. 2019).

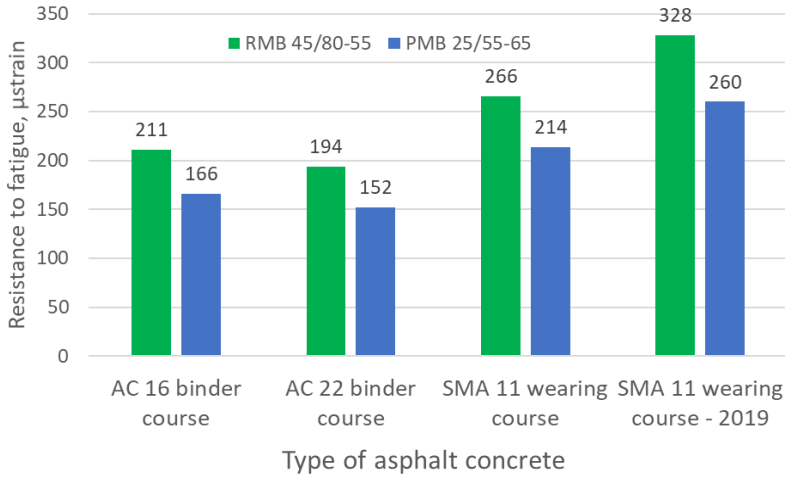

Fig. 7 Fatigue resistance of asphalt mixtures tested (Gáspár et al. 2019)

6. Pavement Structural Design

Using the principles of mechanical pavement structural design, it is possible to compare the material characteristics and behaviour of the various asphalt mixtures (Brown 2013, Cho et al. 2018, Cho et al. 2020). The performance of the different asphalt mixtures within the pavement structure can be detected in unit axis passes (pcs) or in the required asphalt

thickness (mm). To perform the calculations, a pavement structure model is needed, where the mechanical performance of each layer is given by its characteristic elasticity modulus (E), Poisson's ratio (μ), and layer thickness (h). In addition, the degree of inter-layer interaction should be recorded (Tóth et al. 2020).

When solving the design task, it is generally understood that these loads are known only in the axis of wheel load on the surface of the top layer, at critical locations, as these will be critical. In the case of asphalt mixtures, the fatigue criterion is that the horizontal (ε_t) strain arising in the bottom zone of the lowest asphalt layer is critical.

Complex and cumbersome calculations can be performed with structural design programs such as Shell BISAR or WESLEA (De Jong et al. 1979, Timm 2006). It was felt that the application of BISAR and WESLEA programs in the case of asphalt layers with non-conventional binders could have been used with due care. However, the aim of the model calculations in this case was to be able to demonstrate the extremely complex effect of different asphalt characteristics (especially their magnitude and direction) by quantifying them with some easily interpretable parameters. The obtained values of the model calculations are, of course, relative values, they cannot be generalized. It is reassuring, however, that the results of the calculations are in good agreement with the experience gained during experimental section monitoring, confirming them as if they were "validated". Of course, further research is needed to fully validate the model calculations for scientific purposes.

These software tools primarily determine stresses at any point in the model. For the calculation of specific deformations, it is assumed that the deformation is proportional to the stresses and thus the equations of Hooke's law adapted for the general spatial stress state apply. These equations can be used to calculate the specific deformation at any test point if the stress state of the point, plus the elastic modulus and Poisson's ratio of the layer are known. However, to understand the magnitude of specific deformations, one needs to know the fatigue behaviour of the material. Considering the appearance of fatigue cracks, the value of the ε_t (N) allowed limit strain corresponding to design traffic can be found from the Wöhler-curve of the material (Primusz et al. 2018).

The laboratory-defined parameters of the three asphalt mixtures included in the test are summarized in Table 9 (Primusz et al. 2020).

Table 9 Material parameters of asphalt mixtures

Mixture	Young's modulus [MPa]	Poisson's ratio [-]	ε_t (N) allowed strain [μs]
AC 22 binding course, B50/70	4 440	μ = 0.35	135
AC 22 binding course, PMB 25/55-65	7 250	μ = 0.35	152
AC 22 binding course, RMB 45/80-65	5 310	μ = 0.35	194

The performance of asphalt mixtures with different binders but with the same aggregate grading is presented in the pavement structure through the construction of a characteristic flexible pavement structure. It is common in all structures that the asphalt wearing course (4 cm and 4000 MPa) and the granular (FZKA) base layer (25 cm and 350 MPa) are made of the same material with identical thickness, assuming the same subgrade bearing capacity (50 MPa). (Marking FZKA means a continuously graded, unbound, crushed stone road base). The main difference between the three structures is introduced through the different material parameters of the asphalt binder course and the

upper base course (20 cm) according to Table 6. Full bond between asphalt layers and full slip between asphalt and granular layers are assumed. The most important details of the three pavement dimensioning options are shown in Table 10 and illustrated in Fig. 8.

Table 10 Flexible pavement structure dimensioning option with of FZKA lower base course

Layer	Thickness [mm]	Young's modulus [MPa]			Poisson's ratio [-]	Interlayer adhesion
Asphalt wearing course	40		4 000		0.35	Full bond
Asphalt binder course and upper base course together	200	B50/70 4 440	PMB 7 250	RMB 5 310	0.35	Full slip
FZKA base course	250		350		0.40	Full bond
Subgrade	infinite		50		0.45	

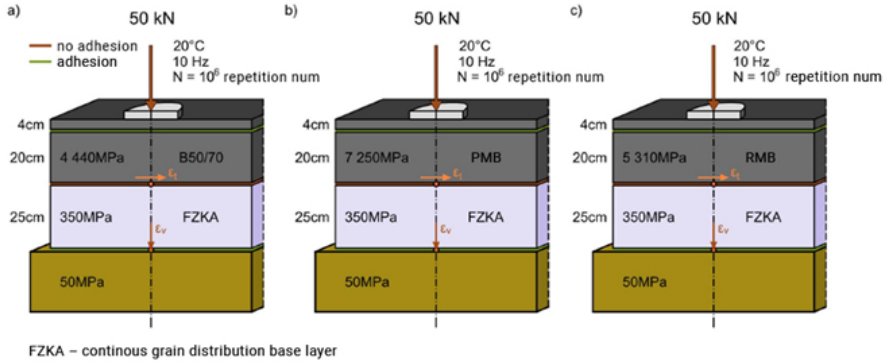

Fig. 8 Flexible pavement structure design options applied to the three test mixtures.

The standard and allowed strains of the structures characterized by the three mixtures are shown in Table 11.

Table 11 Standard strains (FZKA) in the bottom zone of asphalt binder course and of upper base course

Asphalt mixture	Standard strain, ε_t [μs]		Allowed strain, $\varepsilon_t(N)$ [μs]
	BISAR	WESLEA	
50/70	201,0	205.9	135
PMB 25/55-65	137,5	140.3	152
RMB 45/80-65	175,4	179.6	194

According to mechanical model calculations, the mixture containing the conventional 50/70 penetration grade bitumen DOES NOT COMPLY, while the bitumen modified with polymer or rubber does. To express the differences between mixtures more visually (in asphalt thickness), it is advisable to change the thickness of the lowest asphalt layer until the standard horizontal specific strain (ε_t) coincides with the allowed limit value $\varepsilon_t(N)$. Three equivalent structures are then produced for fatigue cracks. The calculations were carried out with BISAR software, the combined thickness of the equivalent structures with

asphalt binder course and the upper base course is shown in Table 12 and the dimensioning options are graphically introduced in Fig. 9.

Table 12 Need for asphalt thickness in three equivalent structures (FZKA)

Mixture	Standard ε_t [μs]	Allowed $\varepsilon_t(N)$ [μs]	Thickness [mm]	Difference [mm]
B50/70	134,0	135	265	+65 mm
PMB 25/55-65	153,2	152	185	-15 mm
RMB 45/80-65	194,5	194	185	-15 mm

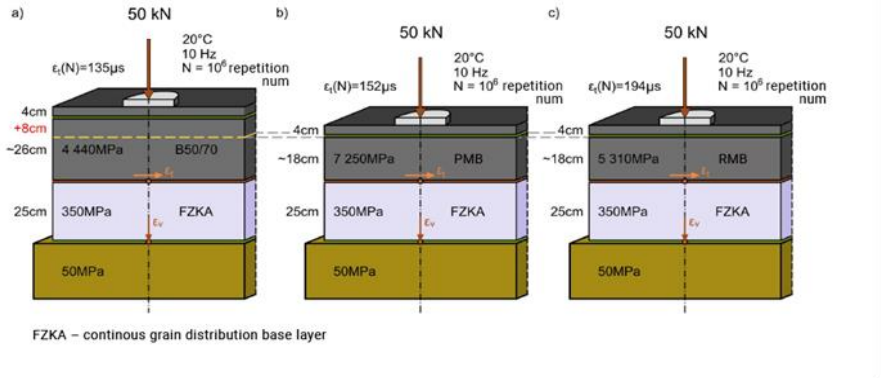

Fig. 9. The three equivalent flexible road structure models (FZKA)

For an asphalt mixture containing traditional performance grade bitumen, a 26.5 cm thick layer is required for a number of unit axle passes of 10^6, whereas for a mixture modified with polymer and rubber only an 18.5 cm thick layer is necessary resulting in practice in 8 cm asphalt saving. The calculation also demonstrates that the higher elastic modulus of the polymer-modified mixture is well compensated by the better fatigue properties of the rubber-modified mixture. The calculation presented for the granular (FZKA) lower base course was also repeated for the much stiffer lower base course of hydraulically bound stabilization (C_{Kt}). The layout of the structures is given in Table 13.

Table 13 Flexible pavement structure design option for C_{Kt} base course

Layer	Thickness [mm]	Young's modulus [MPa]			Poisson's ratio [-]	Interlayer adhesion
Asphalt wearing course	40		4 000		0,35	Full bond
Asphalt binder course and upper base course together	200	B50/70 4 440	PMB 7 250	Full slip 5 310	0,35	25% bond
C_{kt} base course	200		2 000		0,40	Full bond
Subgrade	infinite		50		0,45	

Design task has been solved again with BISAR and WESLEA programs, the standard and allowable strains of the three mixtures are shown in Table 14.

Table 14 Standard strains (C_{Kt}) in the bottom zone of asphalt binder course and of upper base course

Mixture	Standard strain, ε_t [μs]		Allowable strain, $\varepsilon_t(N)$ [μs]
	BISAR	WESLEA	
50/70	171.0	173.3	135
PMB 25/55-65	122.6	126.1	152
RMB 45/80-65	152.0	154.8	194

According to mechanical model calculations, even for the lower base course, $C_{kt,}$ only the conventional mixture containing 50/70 penetration, performance grade bitumen does not comply. To express the differences between mixtures more graphically (in asphalt thicknesses), the thickness of the lowest asphalt layer was changed until the standard horizontal specific strain coincided with the $\varepsilon_t(N)$ allowable limit. The required asphalt thicknesses of the asphalt mixtures included in the test are summarized in Table 15.

Table 15 Need for asphalt thickness of the three equivalent structures (C_{Kt})

Mixture	Standard ε_t [μs]	Allowable $\varepsilon_t(N)$ [μs]	Thickness [mm]	Difference [mm]
B50/70	135,4	135	245	+45 mm
PMB 25/55-65	150,2	152	165	-35 mm
RMB 45/80-65	195,8	194	150	-50 mm

Due to the stiffer hydraulically bound stabilization, the upper asphalt base course containing B50/70 performance grade bitumen requires only 4.5-5.0 cm of additional asphalt thickness in the case of 10^6 unit axle passes. The upper asphalt base courses with bitumen modified with polymer and rubber, in turn, result in significant asphalt savings. The interesting thing about the dimensioning case study is that for the stiffer lower base course, the difference between PMB and RMB mixtures can already be expressed in cm. The asphalt layer containing rubber-modified bitumen requires less asphalt thickness by 1.0-1.5 cm. In addition to the thinner asphalt top base course, this may also mean that the RMB mixture should be chosen when stiffer lower base layers are applied. This assumption can be confirmed unambiguously by future additional laboratory measurements and case study calculations. However, the results of modelling show that the mere fact that a mixture has a given, high or low stiffness and the magnitude of its fatigue resistance does not give a complete picture of the mixture, the conformity of the mixture can only be determined comprehensively when examined as a pavement structural layer (Primusz et al. 2020).

7. CONCLUSIONS

The RMB 45/80-55 binder presented in this article is a novel, rubber bitumen product type, which - as described here - is produced by the so-called modified wet process instead of the already familiar conventional wet processes. Due to its manufacturing technology and composition, RMB carries certain characteristics of both high viscosity rubber bitumen and terminal blend type rubber bitumen. During its development, the goal was precisely to eliminate or to reduce the disadvantages and to preserve the advantages of the latter. One of

the key quality parameters of the product is dynamic viscosity, the value of which allows RMB to be used in transport, unloading, pumping, asphalt production, and road construction the same way as polymer-modified bitumen types are. User appreciation over the past 8 years and construction experience gained from more than 110 constructed road sections have been favourable. Given this information, a comprehensive review of some of the roads built was carried out.

During the on-site pavement condition survey covering 35 road sections completed in 2019, the deterioration rates of pavement surface condition and macro roughness were better in the RMB sections than in the reference sections in all traffic categories. The pavement structure bearing capacity (deflection) values measured on sections at least 4 years old proved to be extremely favourable on all RMB sections examined. The promising research results confirmed the wide applicability of the RMB asphalt mixture. It can offer an economic, durable, and environmentally friendly solution for the construction of a wearing, a binder, or a base course in the national highway network, the municipally managed (local) road network, and in the case of paving areas.

Laboratory tests of different types of asphalt mixtures were carried out between 2016 and 2019 at the Budapest University of Technology and Economics. Traditional B50/70 bitumen was initially used as a reference binder; these results clearly showed that the parameters of each test of rubber bitumen mixtures were found to be superior to mixtures made with conventional performance grade bitumen. The results of subsequent asphalt mechanical tests showed that, for each type of asphalt selected, the rubber bitumen binder mixture produce better cold behaviour, fatigue resistance, and rutting resistance than the polymer-modified binder mixtures do. Laboratory mixtures and on-site bored samples had stiffness test results preferable than polymer modified binder mixtures do.

Simple modelling was used to test the structural layer behaviour of mixtures made with three different binders separately. Polymer modified bitumen (PMB 25/55-65), rubber modified bitumen (RMB 45/80-55), and performance grade bitumen (50/70) were studied. The model calculation demonstrated that the binder and asphalt mixture tests alone and the ratings based on them provide very limited information on their behaviour in pavement structures. Incorporation of a less stiff but outstandingly fatigue resistant mixture into an appropriate pavement structure layer may result in a significant – and quantifiable – increase in pavement lifespans or a reduction in thickness, while a layer with a stiffer but average fatigue resistant mixture may have a shorter life. These relationships remain hidden when worldwide standard pavement structures are applied; thus, their exposure is not possible by purely empirical means.

As a summary, the favourable behaviour of the asphalt layers with GmB binder could have been determined based on the concurrently favourable results of section monitoring and laboratory experiments. It is planned to increase the reliability of the statement with additional laboratory and field measurements planned soon.

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PERFORMANSE ASFALTNIH MEŠAVINA SA NOVIM TIPOM BITUMENA MODIFIKOVANOG GUMOM

Bitumen modifikovan gumom 45 / 80-55 (RMB 45 / 80-55) se u Mađarskoj koristi kao bitumensko vezivo za proizvodnju asfaltne mešavine od 2013. To je nova vrsta gumenog bitumena proizvedena po patentiranoj tehnologiji. U proteklih 8 godina korišćen je za izgradnju ili renoviranje više od 100 asfaltnih deonica. Prvobitno je RMB 45 / 80-55 korišćen za zamenu bitumena za asfaltiranje 50/70 u nekim projektima izgradnje puteva. Međutim, laboratorijski rezultati asfalta i iskustvo u izgradnji puteva pokazali su da njegov kvalitet može dostići i po nekim parametrima premašiti kvalitet asfaltnih mešavina proizvedenih s bitumenom modifikovanim polimerom 25/55-65 (PMB 25/55-65). Prvenstveno, njegova odlična otpornost na niske temperature i zamor su izvanredni, u tom pogledu; nadmašuje rezultate asfalta izrađenih s bitumenom modifikovanim polimerom. Njegova zadovoljavajuća otpornost na zamor kompenzuje manju krutost; stoga su i kod projektovanja gazne konstrukcije postignuti povoljni rezultati u odnosu na PMB. Uzimajući u obzir prednosti kod izgradnju puteva ove nove vrste gumenog bitumena, kao i podršku ekološki prihvatljivom recikliranju otpadnih guma i uklapanju u cirkularnu ekonomiju, realno se očekuje veće širenje RMB proizvoda u budućnosti.

Ključne reči: *gumeni bitumen, gumeni modifikovani bitumen,gumeni asfalt vezan bitumenom, laboratorijska mehanička ispitivanja asfalta, osmatranje deonice puta, ljuštenje habajućeg sloja*

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COMPLEXITY OF GEOTECHNICAL PROBLEMS IN THE PROCESS OF REVITALIZATION OF RESIDENTIAL BUILDINGS

UDC 728.025:624.13

Jelena Savić, Nikola Romić

University of Niš, Faculty of Civil Engineering and Architecture, Niš, Serbia

Abstract. *Revitalization of residential buildings is a process of renovation and improvement of the residential environment with the goal of providing users with a safe and healthy space in which to live. Through a series of necessary interventions and technical improvements, in the first phase of revitalization, the load-bearing structure, starting from the subgrade soil and foundations all the way to the top of the building, i.e. the roof structure, must be repaired and strengthened. The reinforced structure must guarantee the successful implementation of other planned phases of revitalization. The paper deals with geotechnical issues within which damages are registered, their causes are analyzed and measures for repairing the base soil and foundations are proposed. The problem is treated from the point of view of its complexity, the numerous causes of which are disscussed in the paper.*

Key words: *revitalization of residential buildings, damage, causes, remedial measures of the subsoil and foundations, geotechnical complexity*

1. INTRODUCTION

The most numerous buildings are buildings which are very often constructed on the ground different in terms of its geological composition, load-bearing capacity, sensitivity to changes in moisture content, oscillations of groundwater levels, as well as physical, mechanical and chemical changes. Many residential buildings were built at the beginning of the last century and earlier. Under the influence of various factors, they have lost their original value and significance over time, so they need to be renewed. In the period from the fifties to the middle of the sixties of the previous century, a large number of residential buildings were built according to the uniform designs without taking into account the geotechnical conditions

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Corresponding author: Jelena Savić
Faculty of Civil Engineering and Architecture, Aleksandra Medvedeva 14, 18106 Niš, Serbia
E-mail: jelena.savic@gaf.ni.ac.rs

of foundation building at the given location, so no exploration works were performed nor are there geotechnical investigations and reports.

Depending on the period of building, different construction systems, structural assemblies and materials were used, and very often these structures were extended or reconstructed. If we add the damage caused by non-maintenance, excessive subsidence, the impact of neighboring buildings, earthquakes and other sudden effects, then we can conclude how complex and extensive the process of their revitalization is, which basically aims to protect and preserve the housing stock. The first phase of revitalization is a constructive consideration, which results in a series of interventions and technical improvements on the structure of the building itself, in order to make it match the required load-bearing capacity and safety. Only a comprehensive and high-quality execution of the first phase can guarantee the successful implementation of the second phase of revitalization, which seeks to achieve a certain quality of housing.

In terms of structural considerations, according to the order and nature of things, geotechnical issues are in the first place, requiring an urgent analysis of the condition of the base and the condition of the foundation structure of the existing building. From the conducted geotechnical analyses, solutions should emerge that will enable safe, correct and cost-efficient solutions when repairing other parts of the structure.

2. GEOTECHNICAL ASPECT OF REVITALIZATION

Analyzing and solving the complete geotechnical issue in the process of revitalization of residential buildings can be divided into the following phases:

- Detecting building damage, registering and defining their character,
- Analysis of possible damage causes,
- Proposal of remedial measures of the foundations and the subsoil.

What makes the subsoil on which the buildings are built particularly problematic is that on the one hand it can be of poor quality, having insufficient load-bearing capacity and necessary stability, and on the other hand it is very susceptible to changes during construction and later during service. All this can cause damage to the foundation structure, on the walls, beams, columns, but also on the installations in the building.

2.1. Detecting building damage, registering and defining of their character

The process of assessing the condition of the building is approached according to a precisely determined methodological framework [1], which at the very beginning of a series of planned activities contains a visual inspection of the building and its surroundings (Fig. 1). An important task of this phase is the detection and registration of damage, which requires the use of necessary equipment and various accessories for non-destructive and destructive testing [1]. Conversations with building owners or tenants are especially useful, as they can provide information about the time of occurrence of the damage, the speed of their occurrence and the observed direct correlation with a specific cause.

Fig. 1 Detection and registering damage by the visual inspection of the building [2]

Cracks and fissures on the walls and other visible elements of the construction are most easily detected on the buildings. The most common causes of their occurrence are related to phenomena in the subsoil which can lead to more serious damage in the form of bulging walls, deformation of windows and doors, tearing and breakage of installations.

Fig. 2 Causes of damage of foundations and superstructure [1]

In order to predict the necessary repair works, it is convenient to categorize the damage according to their severity (from negligible to very severe) as proposed by Tomaževič [3]. Classification according to the basic parameters that define the nature of damage is also very useful, as shown in Table 1.

Table 1 Basic parameters of classification and nature of damage [4]

Basic parameters of classification	Nature of damage
Speed of occurrence	Gradual and sudden
Affected area and risk	Gradual and partial higher critical and lower
Manifestation	Visible-predictable, sudden, hidden
Cause and time of damage occurence	Damage due to the external or internal factors, damage during construction, damage during service
Elements on which they occur	Foundations, columns, slabs, beams, roof, insulation, cladding, installations

In many European countries, there is a number of classifications, as stated in [4] and [5], according to different parameters for a detailed assessment of damage to buildings. The goal is to provide sources of financing for the renovation of housing in old and damaged buildings, which is included in a number of legal measures and national development programs of these countries.

2.2. Analysis of possible damage causes

The causes of damage are very numerous, so, in order to conduct detailed analyses, they are also classified into certain categories. Those that arise from the nature of the building itself are internal factors, related to the local soil conditions on which the building was constructed and the type of structure implemented. Causes originating from the nature itself, intentional or unintentional human activity are external factors and they can be: long-term microbiological, physical or hygienic processes, natural random events - earthquakes, storms, weather effects, causes from the domain of human activity when using buildings or performing works in their surrounding.

As the effects of detrimental factors, as the cause of damage, often overlap, it is difficult to establish the predominant cause. Also, a special problem is damage whose causes are unknown. Therefore, more detailed examinations and analyses of experts of certain specialties are needed in the expert team that will have to find a balance between individual solutions and the existing technical regulations in reaching the final conclusions.

Since the paper deals with issues from the geotechnical aspect, the analysis of possible causes of damage to buildings will be related to the soil as their base and foundations as immediate supports.

In practice, the most common damage to buildings is related to the causes that originate from various phenomena in the soil, i.e. the base below and around their foundations. The soil is a three-phase system in its composition, composed of a solid, liquid and gaseous phase, so its compressibility and deformability under load become prominent [6]. The result of the resulting complex processes are displacements in the ground that lead to the settlement of buildings and their foundations. Differential settlement is especially harmful, as a result of which cracks can appear, their individual parts can separate, tilt, and even collapse. The degree of severity and the nature of the damage depend on the size and shape of the building foundation, number of storeys and the size of the resulting differential settlement (Fig. 3a).

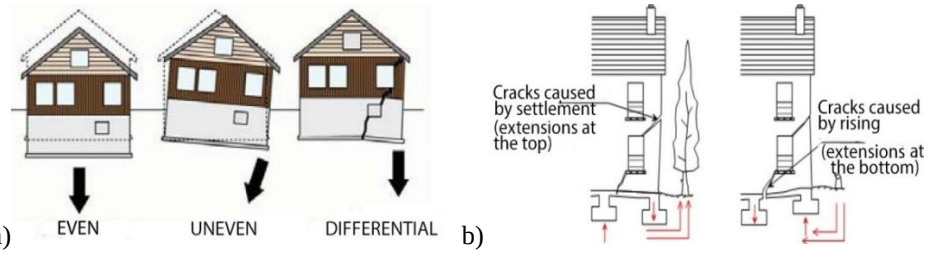


Fig. 3 a) General types of settlement of foundations and b) occurrence of cracks on the buildings [6]

One of the most common causes of changes in the soil that leads to settlement and serious damage is water. In coarse-grained soil, due to larger cavities and pores, water

moves and is squeezed out more rapidly and easily, so that under the load the settlement takes place quickly. In fine-grained materials, water moves and is squeezed out very slowly, so that the settlement process lasts long but the changes are considerable and usually larger than in coarse-grained soils. It is especially unfavorable if the building is located on clay soil that is prone to swelling and shrinkage due to the increase or decrease of moisture content. The absorption of moisture by the roots of trees can cause the sudden drying and shrinkage of the soil, which leads to a greater settlement in some places, and due to the difference in settlement also leads to damage of the foundation (Fig. 3b).

There are very unfavorable terrains in which the groundwater level can oscillate significantly over time, and in which the soil is sensitive to changes in moisture content. The oscillation of the groundwater level is characteristic for the areas with the change of rainy and dry seasons and for the areas where the groundwater level is related to the change of the water level of the neighboring rivers, lakes or wells. Alternating cycles of soil shrinkage during drying and swelling during wetting mean alternating settlement and rising of soil under the foundations of buildings, which results in severe damage in the form of characteristic cracks on both the foundations and the walls.

Water can escape from damaged plumbing and sewer installations or damaged gutters for a long time, as can be seen in Figure 2, and imperceptibly wet and wash away the soil, so that compromised parts of foundations and other parts of buildings begin to considerably settle and fail.

The occurrence of capillary rise from the ground through foundations and foundation walls, as seen in Figure 4, is detrimental for the building walls by damaging facade cladding, finish layers of walls and wood and metal elements.

Fig. 4 Capillary moisture, initiator and cause of damage occurring on the walls and foundations [7]

2.3. Proposal of remedial measures of foundations and subsoil

Nowadays, there is a large number of methods for interventions on the foundations themselves, the subsoil under and around the foundation, or a combination of both the subsoil and the foundations. The choice of an adequate method depends on several factors. The ground under the foundation must meet the required safety against failure and allow subsidence that will be within the permissible limits for the undisturbed and safe operation of the facility. Soil improvement methods achieve better bearing capacity and reduce soil subsidence. That is why these methods are called soil stabilization methods in the professional literature.

The *"Jet grouting"* method provides the option of strengthening the existing shallow foundations, whereby drilling is performed from the ground surface through the existing foundation footings, and the columns of stabilized material are formed just below the

foundation (Fig. 5). A water-cement mixture or a mixture of water, cement and bentonite is most often used as an injection mass. In the formed borehole, through a rotating drilling rod equipped with nozzles, the injection mass is inserted under great pressure, which breaks up the soil material and with intensive rotation forms a column that is a mixture of soil and binder - injection material. The obtained mass is characterized by high compressive strength and low water permeability.

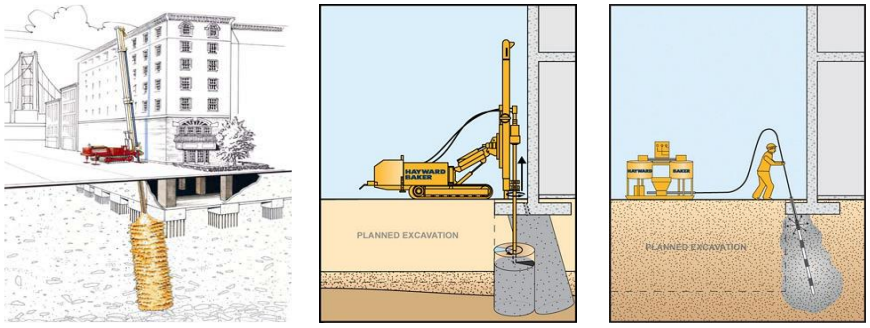


Fig. 0 Stabilization of soil under the existing foundations by jet grouting (Novkol) [1]

Deep injections is a method based on a similar procedure as the ***"Jet grouting"*** method. Namely, in the area where the settlement occurred, drilling directly through the foundations is used form a system of boreholes with a diameter of about 30 mm, a distance of 50-150 cm and a depth of up to 15 m. A special liquid resin is inserted into the boreholes, which soon after injection turns into a solid state and expands, increasing the volume up to 30 times. In this way, the soil is compacted and the foundation is pushed upwards, which is controlled by a laser.

The methods of strengthening the soil involve enlargment of the foundation base dimensions or foundation depth in order to reach the soil layers of higher bearing capacity. Strengthening of foundations solely with enlargment of the foundation base dimensions is performed if increasing the foundation depth is not possible. The additional lateral parts must be well connected with the existing footing, which is achieved by adding the necessary reinforcement (Fig. 6).

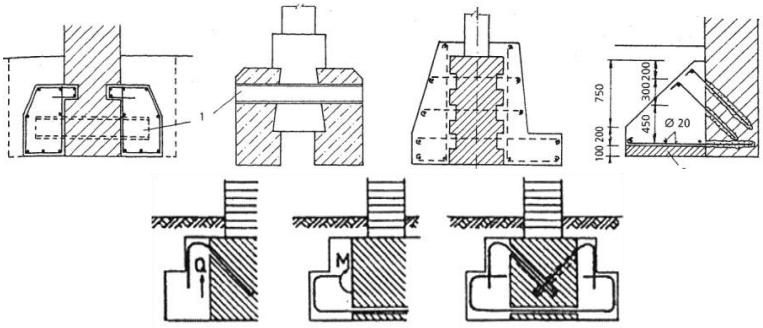


Fig. 6 Enlargment of the foundation base dimensions by casting lateral concrete parts on and connecting to the existing foundation footing with specially anchored reinforcmeent [5]

Excavation under the existing foundation for the purpose of concreting beneath the foundation is a very risky part of the entire procedure, as it may lead to increased settlement and damage to the whole structure. For that reason, the excavation and concreting beneath the existing foundations must be performed in sequences not wider than 1.5 m along the foundation length in an alternate order, until the foundation is constructed in full length.

If the strengthening of shallow foundations, due to the high soil compressibility and settlements, cannot be accomplished by increasing the foundation base dimensions, or by deepening the foundations or depth or by soil grouting, then the load can be transferred to the deeper layers of soil with a higher load-bearing capacity by using piles. When repairing and strengthening the foundations of existing buildings, several types of special piles are used, and these are the most common: "mega" piles, micro piles or root piles and prefabricated reinforced concrete piles. The micro piles were created on the basis of the request to repair the foundations of the existing buildings without shocks and vibrations, the eviction of the tenants, the excavation of the foundations and the construction of large construction sites around the building. Using a special drilling technique through the existing foundations of concrete, stone or brick, boreholes are made for micro piles into which firstly reinforcement and then very liquid concrete or cement mortar under pressure is inserted (Fig. 7). The pipe that was used to make the borehole is slowly pulled out during the making of the pile. In some types of piles, the metal pipe that was used for drilling, after reaching the desired depth, remains in the mass and serves as the reinforcement of the pile. Modern technologies of making these piles enable their diameter to range from 8 to 15 centimeters, and the length is usually up to 6 meters. Considerably greater depths can be reached by special drilling techniques which are presented in details in references [8] and [9].

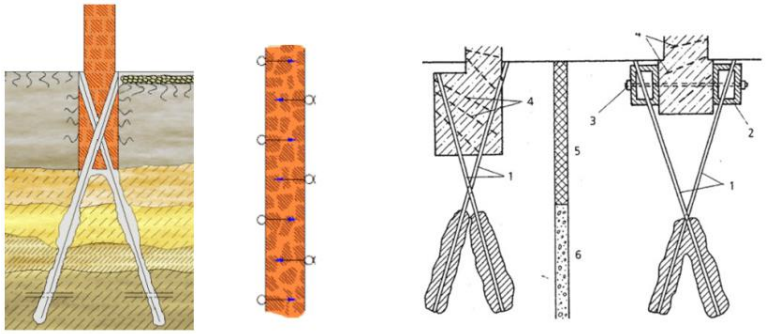
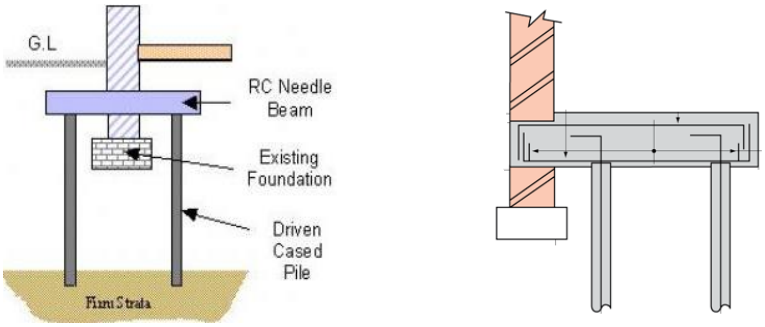


Fig. 7 Strengthening of foundations using micro-piles drilled through foundations [5], [10]

Some more modern approaches and technical solutions include a combination of piles and beams. One such solution, shown in Figure 8a, consists of a horizontal reinforced concrete beam, passed through the foundation wall perpendicular to its direction in which it lies. At the ends of the beam, there is a small pile of small diameter, which transfers the load of the structure to the deeper soil layers of a higher load bearing capacity. These structures, made of piles and beams, are placed at a distance of 1.5 m from each other. In case the access to the foundations is not possible from the inside of the building, or it is more complicated to build, both piles are placed on the same, external side (Fig. 8b).



a) beam passed through the foundation b) beam placed on the external side

Fig. 8 Strengthening of foundations by applying beams and piles [10]

Another variant solution comprises the application of a beam, which is cantilevered above the foundation and a pair of mini piles (Fig. 9). The cantilever beam can be reinforced concrete or I-section steel. The system is designed so that the piles that are closer to the inner side are loaded with compression, and the outer row of piles with tension [10]. After the installation of cantilever beams and mini piles, the entire surface along the wall is concreted, thus connecting all the elements into a continuous, single structure.

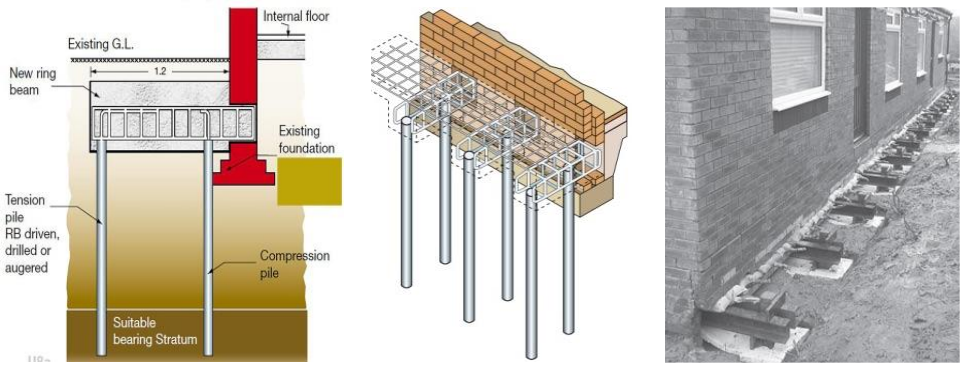


Fig. 9 Strengthening of piles using cantilever beams and pairs of piles [10]

3. MOST FREQUENT CAUSES OF COMPLEXITY OF GEOTECHNICAL ISSUES IN REVITALIZATION OF RESIDENTIAL BUILDINGS

Geotechnical issues, in general, occupy a very important place in the construction of buildings and include activities before the start of construction, during construction and during the service of building. The phase before the start of construction is planned for the implementation of geotechnical exploration works at the given location, on the basis of which the geotechnical conditions of the foundation should be defined. These include the layout and characteristics of the determined soil layers, the groundwater level and its possible oscillations, the bearing capacity of the soil for the proposed foundation depth

and the method of foundation. In this phase, other relevant data for the observed location are collected: geological, seismological, hydrogeological and data on possible underground structures, abandoned excavations and wells and underground installations. Based on all of the above, the choice of the type of foundation structure and the choice of soil excavation methods and securing the foundation pits are made.

When it comes to existing, old buildings, which are about to be revitalized, there is a number of aggravating circumstances that make the already complex geotechnical issues even more complex.

3.1. Lack of original design documentation

The lack of basic, original design documentation of the building, as well as of the study on geotechnical investigations and possible earlier repairs of the foundations is a major shortcoming in the case of revitalization of the observed buildings. The mentioned documentation has usually not been preserved through the decades-long period of time or geotechnical investigations has not been done at all. It often happens that there are some scarce data and results, but they are taken from the documentation of other important facilities in the immediate vicinity, which is inadmissible. Sometimes it is necessary to conduct some kind of "technical investigation", as stated in [11], in order to obtain documentation on previous geotechnical investigations or possible repairs of the foundations of the building. The results of these earlier studies would be invaluable for comparison with the results of the new investigations. This would make it easier to answer the question of what changes occurred in the soil, [1] and [8] and what could be the cause of the greatest damage to the building.

3.2. Problems related to performing new geotechnical investigations and determining the predominant causes of foundation damage

The carrying out of new geotechnical investigations is mandatory and must be very carefully planned and performed, bearing in mind several aggravating circumstances. Very limited space due to the proximity of neighboring buildings and their sensitivity and their condition, as well as the building being repaired, make this first phase of field work complex. There are cases where the adjacent building is immediately next to the one that is being repaired, so that side is completely inaccessible from the outside. Excavation of bore pits and drilling of boreholes must not cause additional settlement and compromise the stability of facilities in the immediate vicinity.

When it comes to determining the level of groundwater and its possible oscillations, no mistake must be made. The highest level of groundwater, due to the effect on the foundation structure, should be determined during the period of the greatest precipitation or the period of the greatest wetting of the subgrade soil for other reasons.

Due to the simultaneous action of several different, detrimental influences, which cause damage to the foundations and other parts of the building, it is difficult to single out the predominant influence. The solution is to form an expert team, which would consist of civil engineers, especially geotechnicians, geologists, hydrogeologists, hydrologists and others. Through a comprehensive review of the problem, additional investigations and consultation with building owners or tenants on possible changes and other important observations, the expert team should propose an appropriate solution.

3.3. The complexity of the issue related to the implementation of rehabilitation measures of foundations and subgrade soil

The most complex works in the construction of buildings are foundation works. Due to the variability and diversity of soil layers and the fact that the soil cannot be fully known in all parts, due to the presence of water and the proximity of neighboring structures, there are great risks in the construction phase and later in service. It is necessary to have extensive experience and practice as an important complement to the foundation engineering principles so as to address the issue of foundation construction, both during design and during construction phases [12]. Therefore, specialized companies and experts in the field of construction geotechnics must be hired to perform works on interventions in the foundation structure and the subsoil.

The most suitable way to strengthen the subsoil underneath and around the foundation is to grout the soil. Special equipment and grout are needed and works are carried out from the ground surface. Due to the impossibility of monitoring the movement of the grout mixture in the ground, damage to underground installations is possible. Careful preparation and professional execution of works is required.

Traditional methods of foundation strengthening, by increasing foundation base dimensions and depth, require larger excavations and carry a high risk both during construction and later in operation to cause subsequent settlement.

For a long time in our country and other developed countries, the use of Mega piles in foundation repairs has been widespread. Their construction was quite complex, but the load-bearing capacity of the foundation structure was significantly increased. However, long-term of soil suffosion from damaged water supply and sewerage pipes and the unresolved issue of atmospheric water drainage can lead to later settlement of Mega piles and rupture of their connection with the existing foundation structure, which requires its remediation. An example of one such situation where not all changes in the surrounding soil were observed in time is given in [11].

That is why the use of micro piles has found a wide application in the revitalization of residential buildings. There is much less risk, simpler execution of works and the possibility of resisting both vertical and horizontal loads.

4. CONCLUSION

The process of revitalization of old residential buildings, but also protected buildings of historical and cultural heritage, is in full swing today. The first thing that professional teams encounter is damage to almost all parts of the building. They must be carefully registered and analyzed in order to find their causes. The largest number of severe damages originates from the processes that took place in the ground below the building, especially causing damage to the foundation structure.

The paper emphasizes the importance of this geotechnical aspect of revitalization, within which, after a detailed analysis of the causes of damage, a proposal for measures to repair the foundation structure and the soil underneath and around the building is given. The causes of complexity and risks that accompany the solution of geotechnical problems are especially emphasized. The goal is for the rehabilitated subgrade soil and the foundation structure to be a reliable support for the rehabilitation of the superstructure and the new service of the building.

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SLOŽENOST GEOTEHNIČKE PROBLEMATIKE U PROCESU REVITALIZACIJE STAMBENIH ZGRADA

Revitalizacija stambenih zgrada je proces obnavljanja i unapređenja stambene sredine sa ciljem da korisnicima pruži siguran i zdrav prostor u kome će živeti. Nizom neophodnih intervencija i tehničkih unapređenja, u prvoj fazi revitalizacije, mora se sanirati i ojačati noseća konstrukcija, počevši od podloge i temelja pa sve do vrha objekta, odnosno krovne konstrukcije. Ojačana konstrukcija mora garantovati uspešno sprovođenje i ostalih predviđenih faza revitalizacije. U radu je tretirana geotehnička problematika u okviru koje se registruju oštećenja, analiziraju njihovi uzroci i predlažu mere sanacije podloge i temelja. Problematika je tretirana sa stanovišta njene složenosti čiji su brojni uzroci sagledani u ovom radu.

Ključne reči: *revitalizacija stambenih zgrada, oštećenja, uzroci, mere sanacije temelja i podloge, složenost geotehničke problematike.*

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Original Scientific Paper

ADVOCATING FOR GREEN BUILDING MINIMUM COMPLIANCE SYSTEM IN RWANDA: USING BRICKS TO ACHIEVE SUSTAINABILITY

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691.4(6)

Ilija Gubić[1*], Dheeraj Arrabothu[2], John Bugirimfura[3], Honex Laurel Hasabamagara[3] , Irenee Isingizwe[3], Azza Kagina[3], Afsana Karigirwa[3], Julie Mugema[3], Alleluia Mukiza[3], Robert Nishimwe[3], Willy Nshimiyimana[3], Armel Yuhi[3]

[1]Faculty of Architecture, University of Belgrade, Belgrade, Serbia
[2]Global Green Growth Institute, Kigali, Rwanda,
[3]School of Architecture and Built Environment, University of Rwanda, Kigali, Rwanda

Abstract. *Development countries in Africa will see 75% increase of its current building stock until 2060 due to the economic development, rapid urbanization and population growth. Rwanda's Third National Communication under the United Nations Framework Convention on Climate Change estimates that the carbon dioxide emissions from buildings will increase by 574% by 2050 in the business as usual scenario. The aim of this paper puts sustainable architecture and green buildings in a context of rapidly urbanizing Rwanda, showing five recently constructed brick buildings that exploit the culture while meeting the sustainability demands of the 21st century. Global sustainability agendas are advocating for the use of brick for its durability, quality, with environmental, economic, and social benefits for construction sector. This paper provides insights on the policies, such as the Green Building Minimum Compliance System, advocating for the use of brick as a sustainable construction material. Despite the rapid urbanization in Rwanda, the existing sustainable construction practices help in reducing carbon dioxide emissions, while this paper also documents results on social and economic perspectives for the community from construction sector.*

Key words: *green building, sustainable construction, sustainability, brick, green building policy, Rwanda*

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Corresponding author: Ilija Gubić, *PhD student
Faculty of Architecture, University of Belgrade, Belgrade, Serbia
E-mail: ilijagubic@yahoo.com

1. INTRODUCTION

There are no preserved built structures in Rwanda prior to 20th century, which is the period prior to the colonization, as Rwandans traditionally used perishable construction materials. After being appointed by Germany as an administrator in Rwanda, Richard Kandt started building the new capital, and his own house, which is the oldest built structure, from 1909, in Rwanda's capital Kigali [1,2]. After World War I, for decades during the Belgian colonization period, Kigali spatially grew from 40 ha in 1916 to 200 ha in 1958 [1]. There are numerous brick buildings from the colonization period that still remain today, including Maternity Clinic CHUK, Kigali Central Prison, Cloister of the Bernardine Sisters in Kigali; Group Scolaire, Our Lady of Wisdom Cathedral, and the post office in Huye [3,4], to name a few.

After its independence from Belgium in 1962, Rwanda continued to work on the infrastructure in Kigali and other today's secondary cities using brick. There are several examples of brick buildings in Rwanda from the period after gaining the independence, such as the 1980s extension of the Huye Campus of the University of Rwanda where brick is used and for buildings and for the pavement of public spaces. Another example includes the Ethnographic Museum in Huye built in the late 1980s.

During the genocide against the Tutsi in 1994, many of the heritage buildings were places in which crimes took place. Also, many of the buildings were destroyed. Only after the reconciliation process started with the new government, urbanization was triggered [5]. The urbanization process was followed by Vision 2020, Vision 2050, Economic Development and Poverty Reduction Strategy (I & II), National Strategy for Transformation (I), National Roadmap for Green Secondary Cities Development, master plans, and other new plans and policies related to green cities and green buildings [6,7].

In 2019, the Rwanda Housing Authority in collaboration with the Building Construction Authority of Singapore, the Global Green Growth Institute, the Rwanda Green Building Organization, and other stakeholders developed the Green Building Minimum Compliance System [8]. Designing a successful green building policy within the complex context of a government agency is difficult as multiple stakeholder perspectives are considered and aligned to meet the common vision and plan of action [9-12]. This system was approved by the Rwanda cabinet in April 2019 through a ministerial order determining the Urban Planning and Building Regulations and is an Annex-3 to the Rwanda Building Code 2019 [13]. Implementing the green building rating systems contribute to buildings' performance in environmental aspects, among others [14-16].

Implementing green buildings offers several environmental, economic, and social benefits to the construction industry, that includes prevention of global warming and climate change, minimizing carbon dioxide emissions and other pollutants, protecting the ecosystem, use of renewable natural resources, improving health, comfort, and well-being, alleviating poverty, improving economic growth, raising rental income, decreasing healthcare costs, and others [17-22]. The green building in Rwanda indicators address the basic green features any building should have, such as appropriate orientations for daylighting, natural ventilation, rainwater harvesting, efficient plumbing fixtures, low-impact refrigerants, greenery protection, paints not harmful to occupants, etc. These features can be applied to new Category 4 and 5 public buildings, such as health facilities, commercial buildings, educational buildings, cultural buildings, and others [8]. The Green Building Minimum Compliance System in Rwanda also promotes the use of bricks as energy-efficient building materials that reduces heat ingress into space by using advanced bonding techniques, such as the row-lock/rat-trap

bond, thereby reducing the need for air conditioning systems and providing thermal comfort for occupants [8,13].

Buildings contribute a quarter of global carbon emissions that arise from energy demand during construction and operation, and hence, considerable effort has gone to reduce energy consumption in buildings as it is responsible for a third of the world's consumption [23-24]. The Third National Communication Report on Climate Change of the Rwanda Ministry of Environment estimates that the carbon dioxide emissions from buildings will approximately increase by 574% by 2050 compared to 2012 levels in a business as usual scenario [13,25], although transition to green buildings comes with specific costs [26-30].

Thus, the Government of Rwanda and other stakeholders are pursuing sustainability in the building and construction sector by recommending the use of energy-efficient practices and sustainably produced local construction materials, such as brick. They also recommend the use of energy-efficient kilns and alternative raw materials for firing instead of firewood, thereby reducing carbon dioxide emissions and protecting the environment [8]. The Updated Nationally Determined Contribution of Republic of Rwanda 2020 identifies efficient brick production as one of the key mitigation pathways in the energy sector [31]. The use of locally-sourced raw materials for building material production, in this case bricks, by reducing dependence on conventional materials such as concrete and steel, potentially relieves pressure on the material supply chain, avoid increased construction costs while reducing transport-related greenhouse gases emissions and provides opportunities for local economic development [32].

The Made in Rwanda policy of 2017 by the Rwanda Ministry of Trade and Industry promotes the development of local construction materials, such as brick, in collaboration with the private sector, to reduce the trade deficit in construction materials [33]. The Assessing Rwanda's Affordable Housing Sector report by the Centre for Affordable Housing Finance in Africa has noted that bricks are part of Rwanda's top 10 building material exports [34]. This can be potentially owed to Rwanda's abundant clay deposits, which are of excellent quality. There is also a massive demand of the country's fast-growing cities for bricks [35].

The Promoting Climate Responsive Construction Material Production and Off-farm Employment in the Great Lakes Region (PROECCO) project of the Swiss Agency for Development and Cooperation (SDC) and implemented by SKAT Consulting Ltd has showcased many innovations ranging from low-carbon brick manufacturing to modern brick construction systems by promoting semi-industrial brick manufacturing, which consumes 20%–30% less energy in the production stage. This method uses biowaste, such as sawdust and coffee husk, for firing bricks. It also makes use of an innovative brick kiln technique that is modified to a local context. This technique can consume up to 75% less energy, thus significantly reducing carbon dioxide emissions compared with traditional brick manufacturing methods [35]. The PROECCO project has demonstrated that the brick walls built using the row-lock/rat-trap bond technique are 30% cheaper than conventional cement block walls and also help in insulation and thermal comfort. This lower cost of construction combined with modular designs results in affordable construction that embraces brick as a key construction material that can potentially meet the growing affordable housing needs in Rwanda [35].

The revised master plans for Kigali and newly developed for six secondary cities emphasize the inclusive nature of the participatory approach of developing polycentric cities with iconic cultural and traditional values. The revised Kigali City Master Plan Zoning Regulations mandate green building requirements by encouraging the use of local

construction materials, including bricks, and provide developers with incentives that permit certain additional gross floor area if a project demonstrates a sustainable building design technology and sustainable construction methods as per the Green Building Minimum Compliance System [36]. In addition, District Development Strategies 2018–2024 recommend cities and other settlements within the district to use brick and other sustainable construction materials.

The Government of Rwanda and stakeholders organized additional outreach events to promote the use of sustainable construction materials, especially brick, including "Urban Walk" [3, 4]. In addition, awareness and capacity building programs on Green Building Minimum Compliance System were organized for government officials, Rwanda Institute of Architects, Institution of Engineers Rwanda, and other professionals, where the usage of bricks and various green building strategies has been stressed [37,38].

2. MATERIALS AND METHODS

This chapter describes the research methods for the present study and the approach that was followed to fulfil the research objectives. In researching this paper, a combination of materials and methods was utilized.

1. The authors traced built heritage sites to better understand the cultural and traditional aspects of using bricks in Rwanda in its 20th century architecture, this was done through the "Urban Walk" event in Kigali and Huye in 2019. Outcomes of the event served authors to write an introduction of this paper.
2. A document review was utilized to understand the recent developments in the use of bricks globally and in Rwanda, especially with regard to the context of sustainable development and green building policies and practice. Relevant literature reviews of green building development were done using multiple databases like Web of Science and Scopus. While this activity informed research on global practices, it did not provide insights on country specific emerging patterns of the policy formulations and implementations related to green construction materials, especially bricks.
3. Original content and data from Rwanda that were used were prepared by the Government of Rwanda, the Global Green Growth Institute, SKAT Consulting Ltd., ENABEL, and other stakeholders. It supported Introduction of this research.
4. Descriptive case study research design was used. This research benefited from outcomes of following workshops and events:
    4.1. Two school years of a semester-long course "Architectural Theory" at the School of Architecture and Built Environment, in which the contemporary architecture in Rwanda was discussed and documented in 2018 and 2019. During this activity, the authors of this research also interviewed architects working for the Mass Design Group and ASA Studio to better understand their sustainable construction practices and the use of bricks in their flagship projects. Interviews were conducted with professional team members who were involved in the construction of each building. It was determined that the consultants who provide design and construction solutions utilizing green design standards would be better suited to assess the use of brick and other green building materials and discuss implementation of green building legislation. The interview questions were asked in person. The interview protocol consists of 10 questions that relate to the interviewee's personal information and about the green building they

designed or implemented within the studio. These questions were included to assess each respondent's role in the construction industry in Rwanda and, more specifically, it was used by authors to select buildings being studied in the chapter 3 of this paper. Outcomes also served to prepare results of this research.

4.2. Workshops organized as part of the various Green Building Minimum Compliance System dissemination programs conducted in 2019, 2020, and 2021, which targeted multiple building industry stakeholders and that authors of this research attended. It helped with understanding the policy in Rwanda and used to further assess buildings selected for this research.

5. In addition, the collected data for this research includes photographs of the buildings in Kigali and other cities from 2018, 2019, and 2020. Site visits were undertaken to obtain a greater understanding of the building and the key features that contributed to its green building aspects, that supported authors in the selection process and write the results for this research. Each case study building was visited by at least two authors.

3. RESULTS

As a building material, brick is very durable, user and maintenance friendly. Moreover, brick buildings are energy-efficient [39], highly resistant to compression, fires, and frost and can be reused and recycled. The production processes of bricks are environmentally acceptable, and the life cycle of brick structures is long. Bricks also do not require extensive maintenance [40].

Numerous public policies have been implemented globally and in the region in the last ten years to promote green building in the private sector [41,42] regardless of the implementation drivers [43-46]. The concept of green buildings and its definition is constantly updated as the construction industry develops [47,48]. This paper presents findings on five recently constructed buildings using brick in Rwanda, and they are in both urban and periurban areas. Some of these buildings were constructed before the Government published the Green Building Minimum Compliance System and before initiatives of SKAT Consulting Ltd.

To promote modern brick construction systems as a method of achieving affordable housing solutions and other policies on green construction materials and techniques, the selected and presented buildings show that by using bricks, these buildings fulfill their intended sustainability objectives, serve as inspirations for industry stakeholders to emulate contemporary architecture practices using locally made bricks, and contribute to the overall sustainability of Rwanda. The existing studies predominantly focus on the environmental aspect of green building [49] while this research in addition to the aspect of Rwanda's tropical climate, also discusses social sustainability of brick buildings, usually overlooked by researchers [50]. The green building research had been concentrated on the subject categories of engineering, environmental sciences & ecology, and construction & building technology, while knowledge gaps were detected in the areas of corporate social responsibility [51] that this article discusses. The results discuss buildings with various functions: culture, sport, health, housing, banking, and others.

3.1. I&M Bank Headquarters in Kigali

The new I&M Bank headquarter was built in Kigali, city center (Figure 1), and it was designed by a Kenyan company Planning Systems Services Ltd. Its main and unique character

is that bricks were used as the main construction material, for its facade. The building comprises two towers: a four-floor tower that is exclusive for bank activities and an eight-floor tower with offices for renting purposes. The towers are unified through a curling-like roofing structure. The eastern and western facades have 80% brick and 20% glass, thus optimizing on the window-to-wall ratio and reducing unwanted heat gains through windows. The building is ventilated through cross ventilation because it narrowly faces the axis of the most prevailing wind directions in Kigali: North-East and South-West. The Rwanda Green Building Minimum Compliance System encourages buildings to use sustainable construction materials such as fire-clay bricks, which are made by a local manufacturer. The project has used Ruliba (popularly known as Ruliba bricks), manufactured locally within Kigali, where coffee husk is the primary material used to burn the bricks in the industrial kiln. These bricks also have a low embodied carbon coefficient of 0.175 kgCO2e/kWh, which is lower than that of the bricks manufactured in the United Kingdom or elsewhere. Thus, overall, the use of bricks contributes to the sustainability of the building. Moreover, the use of bricks as a predominant building facade material that acts as a perforated screen wall on the eastern and western facades filters in the daylight also helps in reducing heat ingress into the building. Furthermore, the window installations on the building are concave, thus deflecting the direct heat from the sun on the building. Therefore, the building's brick and window design help light its interior without the need for the excessive use of air conditioning and artificial light systems. The building has a double skin with bricks in its exterior design and a glass facade in its interior design, thus considerably reducing the thermal transmittance (U-value) of the wall assembly. The Rwanda Green Building Minimum Compliance System 2019 encourages the design of an efficient building envelope for reducing energy consumption by following the envelope's measures related to the wall and roof assembly, hence, building presents a good example to construction industry stakeholders on how the sustainability can be achieved.

The roofing design is unique in Kigali. In addition to providing a different skyline to the city, it has environmentally-friendly features. The central portion of the roof is fairly transparent, allowing for natural light to pass into the central portion of the two tower blocks of the building. The roof is also overlaid with solar photovoltaic panels that help generate on-site electricity and reduce the dependence on grid-sourced electricity. The building was completed in 2020.

Fig. 1 I&M Bank HQ under construction © Ilija Gubić

3.2. Umubano Primary School in Kigali

Umubano Primary School is an educational facility that was designed by Mass Design Group to help support the educational programs in the Kabeza neighborhood in Kigali. A Partner In Education, with a mission of boosting education in Africa, got on board with Mass Design [52, 53] and completed the construction work in 2011 [54].

The school is located on a high slope terrain, and its design layout and circulation were directly inspired from the neighborhood, where the movement of people throughout the stepped agricultural land is similar to that on the designed walkways of the school [54]. The school comprises indoor classrooms, outdoor teaching areas, and playing areas for children, which are terraced, based on the surrounding landscape, and are all within five different levels of blocks. In the construction process of the school, local materials were used to minimize the transportation fees and support local markets, which helped in developing the region's economy, as employment opportunities were provided to the local people. The team used bricks and papyrus reeds in the construction, thus avoiding the use of imported materials, which are usually expensive and inappropriate. The design involves the application of natural lighting and ventilation to minimize energy consumption. For example, in each classroom, the walls are perforated to let in air and have vertical windows that transmit light. Also, the doors were made from papyrus reeds, which also allow light and air in the classrooms. The Green Building Minimum Compliance System 2019 encourages projects to maximize the use of passive design features, such as orientation, natural ventilation, and daylighting, to minimize heat gains, thus improving indoor thermal comfort and reducing energy consumption. The roof structure is made of Vierendeel trusses with two levels, resulting in clerestory lighting [54].

3.3. Women's Opportunity Center in Kayonza

The nonprofit organization Women for Women International got land to build an opportunity center in Rwanda and wanted a female architect to design it, choosing Sharon Davis. Sharon Davis Design is focusing on the social benefits, sustainability, and aesthetic sides of the design. Her best-known project in Rwanda is the Women's Opportunity Center, which received culture and brick awards. Focusing on collaborative design, sustainability, and public interest projects, the architect began her design by talking to the neighborhood's

Fig. 2 Women's Opportunity Center © Elizabeth Felicella

women who had misplaced family individuals or had been assaulted amid the 1994 genocide against the Tutsi. She aimed at designing a safe public space for women and girls. Rwandan women ultimately responded to her suggestion of designing the opportunity center to be like a village with a series of low-rise pavilions arranged in a circular pattern and classrooms at the heart of the site [55]. A farmers market, a community space, gardens, and guest lodgings would be arranged along with the outer edges of the circle. Women's Opportunity Center required a holistic perspective for meeting long-term social and economic demands that are related to the local Rwandan culture and available natural resources.

This project on a two-ha piece of land is described to be a series of human sale pavilions that are together to create a safe place and community for over 300 women. The buildings have round shapes, perforated brick walls, and hanging roofs, thus allowing passive cooling and natural ventilation.

3.4. Health Center in Rugerero

Health centers are few in the rural communities of Rwanda. However, people need easy access to them. In 2016, ASA studio was appointed to design the first health center in Rugerero, which was expected to serve up to 35,000 people from around the area. The building consists of one level, and it was built using local materials, such as fired bricks, stone foundations, metal roofing, and wood ceilings [56]. People were also involved in the design and construction of the project. Up to 50% of the builders were women who were hired from local communities. The layout was designed to provide easily accessible spaces with a strategic flow, and some basic considerations—such as the separation of the outpatients and inpatients—were applied to avoid contamination. Going deep into the plan, the programs were distributed in two blocks interconnected by a central corridor that is naturally lit using a skylight. Also, ventilation was achieved using the perforations on the walls and green patios. The use of these natural opportunities is the key for ASA studio to reduce power consumption. There is another block with spaces for nurses, isolation, and pregnant women. Between the two main blocks, there is a big central courtyard with natural views to enhance the healing process of patients. Rainwater is collected in an underground water tank and filtered using a water treatment plant. The built area is 3200 sqm on a 6000 sqm plot. Generally, the project is environmentally, economically, and socially sustainable.

Fig. 3 Health Center and public space in front of the building © ASA studio

3.5. Education Center in Nyanza

Rwanda has a vision of being a knowledge-based middle-income country as stated in the policies of Vision 2020, which is now Vision 2050. To achieve this goal, educational facilities are needed to train and educate the people. Different educational projects have been recently built using bricks. The Education Center is located on the road connecting Kigali and Huye (the Nyanza district, a southern province of Rwanda). The project was designed by the German architect Dominikus Stark Architekten and completed in 2010, and it is well known for its economic and architectural sustainability, as it uses local materials and involves the local community. The project comprises a 5500 sqm facility that is mainly composed of an administration office, classrooms, a language laboratory, a library, a kitchen, a dining room, an internet café, and a copy shop. The complex has no outward-facing windows as all the openings are oriented to a central courtyard, around which all the spaces are arranged, except for the internet café and copy shop, which face the outside of the complex and define the main entrance of the facility. The architectural approach aimed at arranging the spaces around the central courtyard to be training classrooms so as to also integrate the existing buildings into the new layout.

The upstream courtyards and brick column rows form the intermediate spaces between the central courtyard and the building, except for the dining hall, which can also act as a multipurpose hall. This hall is completely open to the courtyard by a glazed facade so that the courtyard can be an extension of the hall if needed. However, there is a row of wicker doors for protecting the interior from the hot sun, and the openings are high to allow air to circulate.

The complex was completely built by local builders using local materials, such as clay adobe bricks, steel, papyrus, and wicker. A simple ventilation concept was reached from the combination of these materials through the thermal storage capacity of the brick walls, resulting in a comfortable indoor relaxing climate, as well as natural ventilation from the wicker doors. Dominikus Stark Architekten used over half a million handmade bricks to build the education center's walls, floors, and columns. The choice of the main material was based on the material that is locally available and that can easily be made and installed without complex machines. Due to the manual firing processes that were used, the bricks had irregularities and different colors, giving the walls a different appearance due to their differences in terms of color and texture.

Fig. 4 Education Center in Nyanza © Florian Holzherr, Dominikus Stark Architekten

Thin papyrus sheets were used for the ceiling panels, and wicker works made from dried eucalyptus branches were used for dining doors and for the main gate of the facility, which were built by local basket makers. The other materials that were used were steel and corrugated metal sheets for the roofs and glasses for the windows, which were the only imported materials that were used in the project. The mono-pitched roof slope at the central courtyard is used to collect rainwater so that it can be used in cleaning activities and in irrigating the kitchen garden. Overall, the educational center built by Dominikus Stark Architekten used local materials and crafts with sophisticated designs to provide for the various needs of the local community.

4. CONCLUSIONS

Brick was very often used in the 20th century and currently in Rwanda as a building material. Nowadays, the brick production process is advanced with the use of industrial and semi-industrial kilns. The Government of Rwanda and its partners are supporting traditional brick manufacturers to upgrade their production facilities into semi-industrial facilities to improve the quality and supply of bricks along with reduction of their embodied carbon coefficient. The Government is also encouraging developers and investors to use "Made in Rwanda" construction materials such as brick in the construction of many types of buildings – that this paper is showcasing. Development stakeholders like SKAT Ltd. are working closely with the brick producers to upgrade their facilities, employ sustainable clay extraction methods, improve the working conditions of brick producers, produce low-carbon modern bricks, train masons on the modern brick construction systems such as row-lock bond, and max span slab systems to meet the growing demand for affordable construction in a sustainable manner. Examples of buildings in Rwanda that this paper presents, are examples of how construction section should engage communities.

The Rwanda Green Building Minimum Compliance System is also supporting the Government in its bid to promote green buildings by adopting sustainable construction practices along with increasing the operational efficiency of buildings to mitigate the emissions from the buildings sector thereby meeting the Nationally Determined Contributions (NDC) targets. The Government with support from partners is encouraging the implementation of Green Building Minimum Compliance System through awareness, outreach and capacity building programs to ensure the environment, economic and social benefits of green buildings tickle down along the construction value-chain. The five buildings discussed in this paper underline the importance of using locally manufactured materials in this case bricks that showcases the contemporary architecture of Rwanda combined with aesthetic designs that are functional yet relevant to the local climate context, and aided with passive designs as means to achieve sustainability. The usage of locally produced bricks also helps in the local economic development that has the potential to not just meet the growing construction material demand but also create decent off-farm employment opportunities for Rwandans as seen during the process of construction of buildings presented in this paper. The buildings demonstrate several green building principles that projects can adopt not just within the country but across the region to meet and potentially exceed the Rwanda Green Building Minimum Compliance System standard, at the same time create time-less contemporary architecture through bricks and ultimately contribute towards the triple bottom line of people, planet and prosperity.

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PRILOG PROUČAVANJU IMPLEMENTACIJE ZAKONSKIH OKVIRA U GRADITELJSTVU RUANDE: OPEKOM KA ODRŽIVOSTI

Zemlje u razvoju u Africi će povećati svoj sadašnji građevinski fond za 75% do 2060. godine zbog ekonomskog razvoja, brze urbanizacije i porasta broja stanovnika. Prema izveštaju o klimatskim promenama koje je Ruanda pripremila za Ujedinjene nacije, emisija ugljen-dioksida gradnje povećaće se za 574% do 2050. godine ukoliko se bude gradilo po sadašnjem scenariju. Ovim radom se održiva arhitektura analizira u kontekstu ubrzane urbanizacije Ruande i novih regulativa u graditeljstvu. Radom se prikazuju pet nedavno izgrađenih objekata od opeke koji svedoče o određenim kulturnim i istorijskim

aspektima gradnje u Ruandi, istovremeno ispunjavajući zahteve održivosti u novom milenijumu. Globalni programi održivosti zalažu se za upotrebu opeke radi njene izdržljivosti, kvaliteta, sa ekološkim, ekonomskim i društvenim prednostima za građevinski sektor. Ovaj rad pruža uvid u novije zakonske okvire koje je Ruanda postavila, a koji se zalažu za upotrebu opeke kao održivog građevinskog materijala. Uprkos ubzanoj urbanizaciji u Ruandi, postojeće održive građevinske prakse pomažu u smanjenju emisije ugljen-dioksida dokazujući društvene i ekonomske benefite građevinskog sektora za zajednice.

Ključne reči: *zelene zgrade, održiva izgradnja, održivost, opeka, regulativa, Ruanda*

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Original Scientific Paper

COHOUSING AND COLIVING - COMPARATIVE ANALYSIS OF TWO ALTERNATIVE HOUSING TYPOLOGIES BY REVIEWING CONTEMPORARY TRENDS

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Katarina Medar, Aleksandra Čurčić

Faculty of Civil Engineering and Architecture, University of Niš, Serbia

Abstract. *Throughout history, human interdependence has been manifested through various forms of housing typologies that imply some form of coexistence of unrelated persons. The two alternative housing typologies that are quite common in more developed countries today, cohousing and coliving, attract a lot of attention of both architects and scientists. Scholars are still actively dealing with determining the motives and the clear typological definition of these two typologies. Following a review of the basic characteristics through a historical overview and contemporary works of the two mentioned residential typologies, this paper presents a comparative analysis of their basic spatial and functional characteristics. The presented examples and characteristics can serve as a basis for further research, understanding and defining cohousing and coliving housing typologies.*

Key words: *cohousing, coliving, alternative housing typologies, collective housing, motives, characteristics*

1. INTRODUCTION

Dramatic demographic and economic changes that are constantly occurring in society globally, affect all aspects of life, in many ways the housing and its general perception, and consequently the housing structures themselves. The new world order influenced the discrepancy between the conventional way of living and modern (alternative) housing typologies. The conventional way of living was based on single-family houses designed for typical families from the 1950s, with a "bread-providing father and a full-time housewife", while the modern way of living is characterised by smaller households, women working outside the house, and a growing number of single parents, older people, and single people living alone. Modern households often face a crisis of child care, social isolation and a chronic

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Corresponding author: Katarina Medar
Faculty of Civil Engineering and Architecture, Aleksandra Medvedeva 14, 18106 Niš, Serbia
E-mail: katarinamedar@gmail.com

lack of time, in large part because people live in a community that no longer suits them, or can even be interpreted as unexciting. The increasingly mobile population has distanced many households from their extended families who have traditionally provided social and economic support. Things that people once took for granted, such as family, community and a sense of belonging must now be actively sought (McCamant & Durrett, 2011).

The demand for new housing typologies is increasing in the field of urban planning. In a way, this can be interpreted as a response to the modern paradox that in contrast to globalization and industrialization, there is a growing desire and need for security, social ties, and community (Castells, 1996).

Research has shown that in the Netherlands and the United Kingdom, young adults were found to be the most lonely generation, and around three-quarters of young adults consider this topic a taboo. This is a worrying fact, especially since research shows that loneliness and social isolation may represent a greater public health hazard than obesity. It can be concluded that the need for togetherness and belonging is closely related to mental health, a sense of security, and civic responsibility. By fostering social interaction and cultivating networks of support a 'sense of community' is enhanced and social capital is built (Chaskin & Joseph, 2010).

Most scholars agree that the built environment can play an important role in creating new ties between people and promoting social interaction. Certain characteristics of a neighbourhood or housing complexes are found to promote interactions and foster a sense of community. Thus, cities face the challenge of developing attractive, but compact urban housing areas that pay attention to a sense of community and human interaction (Hoppenbrouwer, 2019).

In this context, the re-development of an "alternative" housing typology - "collective housing" can be seen in many developed cities worldwide. This typology is quite general and can be further divided into cohousing, coliving, intentional communities, communes, etc. The main characteristic of this typology is that it focuses on sharing, togetherness, and collectivity (Tummers, 2016).

Traditional cohousing has high levels of user involvement in planning, construction, and management and is a resident-led scheme. More recently, another typology is in focus. Coliving has many similarities to cohousing but is developer-led. In part, coliving responds to the increasing demand for affordable, smaller urban dwellings (Hoppenbrouwer, 2019).

2. COHOUSING – CHARACTERISTICS AND RELEVANT EXAMPLES

2.1. Cohousing characteristics with historical review

Numerous definitions of the term cohousing (also referred to as co-housing) can be found in the literature, but all authors agree that cohousing implies the coexistence of a large number of households (15-40) in a community consisting of private homes and shared community space (McCamant & Durrett, 2011, Williams, 2005).

Defining characteristics of cohousing by most of the authors are:

- Co-developed, co-designed, and co-organized with the group. A genuine and authentic process of participation in creation and functioning;
- Extensive common facilities that supplement and facilitate everyday life. Common facilities are perceived as an extension of each household's own private house;

- Designed to facilitate interaction in the community (pedestrian-oriented and accessible for people with disabilities);
- Complete maintenance and guidance by tenants;
- No hierarchy in decision making;
- Balance between privacy and community;
- Safe environment for children with a high level of support;
- Mixed generation environment;
- Ecological design, with emphasized pedestrian communications and large open spaces.

Cohousing is a part of a common housing trend for which there is an increased interest. The physical layout of cohousing facilities consists of several private homes combined with shared spaces and facilities, which support togetherness and balance between privacy and community. "Danish cohousing remains the gold standard for cohousing communities around the world" (McCamant & Durrett, 2011). The “gold standard” qualifier can surely be debated, but it is inevitable that cohousing has developed (over the last five decades) into a widespread and well-established alternative to conventional housing in Denmark and that must be historically associated with this country.

The modern theory of cohousing originated in Denmark and is believed to have been fueled by the newspaper article "Children should have a hundred parents" by Bodil Graae. Guided by their needs and ideas, members of 50 families came together to create a suitable living environment for themselves. This group was divided into two groups that developed joint projects Sættedammen and Skraplanet, which are considered to be the oldest known modern cohousing communities (McCamant & Durrett, 2011).

The first modern cohousing creation is considered to be the community “Sættedammen”, built on the outskirts of Copenhagen, Denmark, in 1972. Members of 27 families hired architects Theo Bjerg and Palle Dyreborg to create a new type of housing that redefined the concept of neighbourhood, by combining the autonomy of private housing with the benefits of community living.

(a) (b)

Fig. 1 (a) Sættedammen ground floor plan and (b) Sættedammen central courtyard (source: https://www.arkitekturbilleder.dk/bygning/saettedammen)

The entire design process relied on the needs of pre-known tenants, which greatly influenced its appearance and functionality. The development comprises 27 individual units (4 different types of floor plans) that contain all the necessary facilities for the

complete and uninterrupted functioning of this residential household (Fig. 1 (a)). The housing units are arranged in two north-south oriented rows, with a common central courtyard in between. Housing units can be typologically classified as row houses. The houses themselves are built using a modular design, some one-storey and some two storey like stacked bricks (Fig. 1 (b)), allowing the interior walls to be moved around to suit the needs of the residents. All of them are accessed separately from the ground floor, and in addition to the entrance from the common central courtyard, each unit has access from the back, which increases the level of user privacy. Both rows have centrally inserted common areas (common houses).

Common areas consist of additional facilities (playrooms, workshop rooms, guest rooms, laundry, etc.), and facilities that are already located within the personal housing units (kitchen and dining room), larger and made for common use.

The parking area is located on the perimeter of the property. This allows for pedestrian areas around homes and incidental interactions between tenants. The common central yard is dominated by green areas, pedestrian paths, and other common use facilities.

2.2. Cohousing developments today

2.2.1. Marmelade Lane, 2018, Mole Architects, Cambridge, UK

Marmelade Lane is the Cambridge's first cohousing development, also referred to as K1. The project arose from City Councils' idea to directly support the emergence of alternative housing typologies and represents a viable approach nationally for solving the current lack of supply in the housing market.

Designing this cohousing community was a complex task, due to the large number of parties involved. City authorities, investors, designers, and future tenants actively participated in the creation of this cohousing complex. Homes are thus tailored to individual requirements without the risks or complexity of self-build, balancing personalization with the harmony of a visually cohesive architectural style.

This cohousing complex was planned for a mixed structure of tenants, families with small children, retired couples, and single households of different age groups, so the design requirements were wide. The development comprises 42 homes, a mix of two- to five-bedroom terraced houses and one- and two-bedroom apartments (Fig. 2(a)). Homes are arranged in terraces which front existing streets at the same time ensuring the development looks outwards as well as in. The terraces enclose the large shared garden with an open aspect to the south to maximize sunlight.

The residential buildings are set around a common green yard (Fig. 2(b)), and building with common facilities occupies one of the central places. Common facilities are designed to foster socialization, community spirit, and sustainable housing. They include large shared gardens with areas for growing food, playing, and socializing, as well as a flexible shared facility with a playroom, dining room, and kitchen for group dining, guest rooms, laundry room, etc. The communal facility is located on the peripheral part of the complex and consists of facilities needed for the maintenance of the entire neighbourhood.

(a) (b)

Fig. 2 (a) Marmelade lane ground floor plan and (b) Marmelade lane central courtyard (source: https://www.architecture.com/awards-and-competitions-landing-page/awards/riba-regional-awards/riba-east-award-winners/2019/marmalade-lane)

Parking is arranged on the perimeter of the complex, so the central space can be used for mutual activities of the tenants.

The entire project was done according to the highest standards of energy efficiency, passive systems were implemented using appropriate materials, and thus significantly reduced maintenance costs and increased quality of life.

2.2.2. Nanterre Co-Housing, 2015, MaO Architectes + Tectone, Nanterre, France

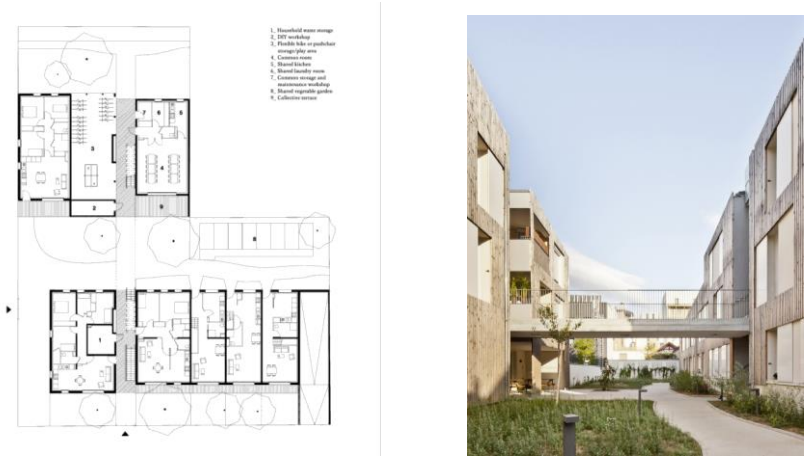
This cohousing community was created as a part of an experimental project for buyers of the first property in Nanterre, Paris, France. The site is located in the Paris suburban area, in a mixed use zone.

The project suggests a building height envelope from 2 storeys to 4 storeys to provide a soft transition between the two types of urbanization, imitating dynamic, but still harmonious environment.

The complex comprises two buildings connected by a footbridge for upper floor housing. Open shared space is placed between two main buildings. Nanterre Co-Housing open shared spaces include extensive shared gardens as the focal space of the community, with areas for growing food, socialising, and play. Common house consists of shared kitchen, a DIY workshop, and a large bike storage room.

The project comprises 15 housing units, with different floor plans (Fig. 3(a)), as the future tenants actively participated in the design process, as in the previous examples. All of them are accessed separately from the ground floor, or the footbridge floor. All the housing units are cross-through and benefit from considerable glazing. The location of the buildings facing mainly south, west, and east optimizes the passive solar gain.

The footbridge (Fig. 3(b)) is a place symbolizing the connection between the two buildings and residents. This footbridge is one of the strong features of the project since it overhangs the garden and the common room, enabling residents to interact in a very natural fashion.



(a) (b)

Fig. 3 (a) Nanterre Co-Housing ground floor plan and (b) Nanterre footbridge (source: https://www.archdaily.com/779035/nanterre-co-housing-mao-architectes-plus-tectone)

3. COLIVING – CHARACTERISTICS AND RELEVANT EXAMPLES

3.1. Coliving characteristics with historical review

Numerous definitions of the term coliving can be found in the literature. This term often overlaps with other forms of collective housing, primarily cohousing. Osborne defines coliving as a new housing typology, which is increasingly used and popularized, and whose main feature is housing in a rented space with spacious common areas and mostly smaller private spaces, fully equipped and managed by an independent administration (Osborne, 2018).

The term coliving refers to a form of coexistence in a living space, where the users are not members of the same family and voluntarily share the same living space, having the same or similar interests, intentions and the value system (Alfirević & Simonović Alfirević, 2020).

Coliving can be described as a group of smaller private units around shared space, in the same building. The equipment of private spaces is generally more modest since in most cases they are intended only for the function of sleeping, while other daily activities are planned in common space.

However, in comparison to other forms of collective housing, the motives influencing the formation of coliving communities are different. (Steding, 2019) Main motives can be described as following:

- Achieving affordable living by sharing the living space and the expenses;
- The possibility for users to socialise;
- Achieving more spacious living space and better content at a cheaper price;
- As a form of motivation for the elderly to contribute to the community, thus enjoying a long physical and mental activity;
- The possibility for users to participate and contribute to the community in accordance with their wishes or financial status, etc.

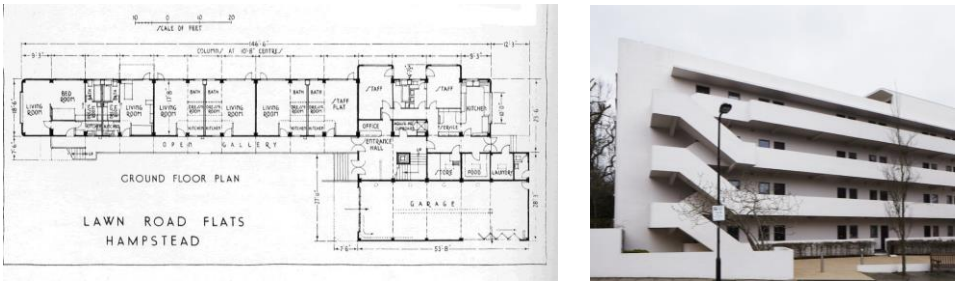
Coliving housing mostly attracts individuals with similar interests, often young professionals. This implies, among other things, shorter length of stay periods for residents in this type of housing facilities, which is a consequence of changes in people's interests and needs, which occur through different life cycles.

The authors agree that this modern form of housing is mainly related to areas with high degree of urbanization, as a response to the crisis of the housing market in large cities. (Osborne, 2018, Hoppenbrouwer, 2019)

Given the fact that the terms that define the forms of cohabitation are intertwined and often interpreted differently, the same happens with the interpretation of the first forms of coliving communities. Majority of the authors agree that the first coliving community is Isokon building (also referred to as “Lawn Road Flats”). Isokon was built between 1933-1934 in London and was designed by Canadian architect Wells Coates.

Isokon was designed as a form of shared living that moved beyond the nuclear family, heavily indebted to Le Corbusier’s ‘Vers une Architecture’. The development comprises 36 affordable apartments for young professionals that came fully furnished to encourage a minimalist lifestyle with a range of services available. Coates designed this as four storey block with two roof-top penthouses. The main elevation facing Lawn Road featured a cantilevered stairwell to the left (Fig. 4(b)), giving access to cantilevered balconies that are carried the full extent of the elevation. (Buss, 2012)

The main idea was to move all additional activities from the personal space and make them available to the tenants in the immediate vicinity. The building comprises distribution kitchen, restaurant, laundry, roof terrace, and spacious workrooms (Fig. 4(a)). The modernity of this project is also reflected in used materials, such as still and reinforced concrete, while the interior is mostly made of plywood.



(a) (b)

Fig. 4 (a) Isokon ground floor plan and (b) Isokon original staircases
(source: https://en.wikiarquitectura.com/building/the-lawn-road-flats-isokon-building)

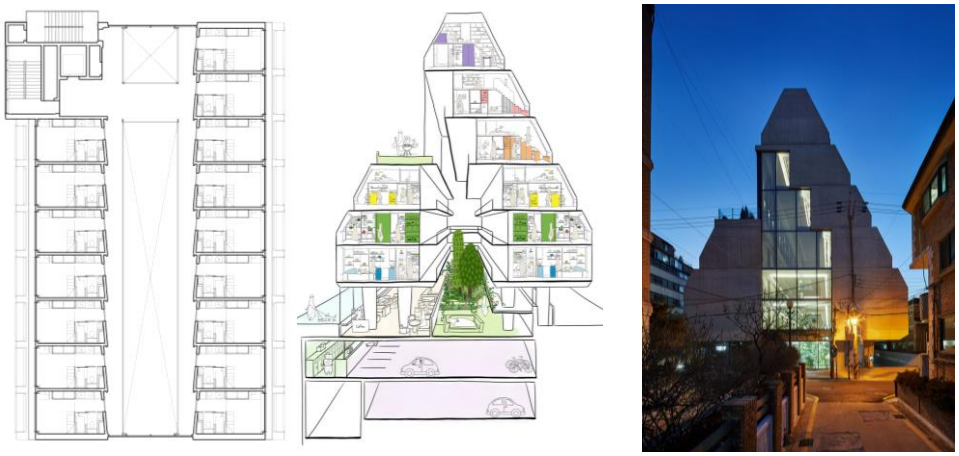
One cannot fail to mention the paradoxical nature of the functional concept of this facility, which is that the concept conceived as "affordable" at the same time implies that all life activities except sleeping and working are performed by a specialized service. Nevertheless, it was intended for the middle class, the working population, and was once home to great minds such as Walter Gropius, Marcel Breuer, and László Moholy-Nagy, architects and members of the Bauhaus movement, which further speaks to the architectural value of this work.

3.2. Coliving developments today

3.2.1. Treehouse Coliving Apartments, 2017, Bo-DAA, Gangnam-Gu, South Korea

This coliving complex is located in one of the central districts of Seoul, Gangnam, characterised by a high level of urbanization. Designed for single professionals and their animal companions, it is composed of micro-studios and micro-lofts.

In order to create spacious shared space for Treehouse, authors split the triangular concrete prism (Fig. 5 (c)), cutting through its centre with an atrium planted with large trees on the ground floor (Fig. 5 (b)).



(a) (b) (c)

Fig. 5 (a) TH 5th floor plan, (b) Perspective section, and (c) TH triangular concrete prism (source: https://www.dezeen.com/2019/08/12/treehouse-co-living-bo-daa-seoul-concrete)

The building comprises 72 units located on six floors. Treehouse's micro-apartments have different layouts on each floor, and housing units come in three different sizes. All units are designed with minimum dimensions, in the form of an open plan, and the areas of these three micro-apartments are: 16.5, 23, and 33m2.

Each residential unit is designed with a private bathroom, kitchenette, and small sleeping area, while all other facilities are shared and located in a common central atrium. Parking is arranged in the underground parking garage, as well as facilities for building maintenance. The green atrium takes on multiple functions, represents a gathering space, and allows access to all housing units. The ground floor of the central atrium consists of common kitchens, a laundry room, areas for pets, pantries, etc., while the first floor serves as coworking space. Stone flooring and benches in shared atrium aim to create a feeling of outdoor space. Details such as built-in modular storage and magnetic wall-paint have been designed to make personalisation of the spaces quick and easy, whilst door numbers are discreetly hidden to underline the impression of communal space.

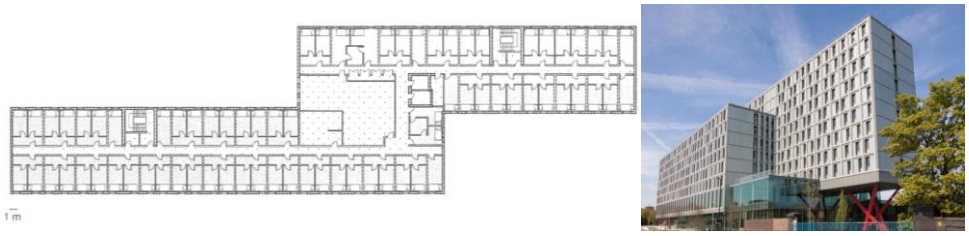
3.2.2. The Collective Old Oaks, 2016, PLP Architecture, London, UK

Young adults in London are faced with housing that is either expensive or inadequate. They are constantly being pushed out of urban centres, isolated, and marginalised. The designers, in cooperation with the start-up Collective, worked on developing a strategy for new and affordable ways of living for young professionals, based on high density, socialization, and togetherness.

The Collective Old Oaks is one of the most recognizable coliving typology project in Europe and currently the world's largest coliving building. The facility is located in the west part of London, in the Old Oaks neighbourhood, where significant measures of urban regeneration have been implemented in recent years. This hybrid facility connects residential and social spaces, where minimized living space is replaced by spacious and diverse shared facilities. It must be mentioned that the authors emphasize that this project is conceived as a "vertical" neighbourhood, and not as an isolated object.

The building consists of two slim tracts sliding across one another (Fig. 6(b)). Where the two volumes overlap, a central shared space was formed, which aims to enhance the possibilities for interaction between residents.

This 11-storey scheme comprises 323 residential units with 551 bedrooms, ground floor retail units, first floor co-working commercial space and common facilities for residents. All residents have access to these shared spaces, as supplementary to private space which includes only necessary amenities such as bedroom, bathroom and kitchenette.



(a) (b)

Fig. 6 (a) Old Oaks typical floor plan and (b) Old oaks sliding tracts
(source: http://www.plparchitecture.com/the-collective-old-oak.html)

Typical housing units are designed for one or two people. Most of the residential units are designed for two people and consist of a shared kitchenette and dining area in the entrance, and two bedrooms with private bathrooms. The units are designed with a great level of functionality and can easily be divided or merged with minimal interventions (Fig. 6(a)).

4. COHOUSING AND COLIVING - SIMILARITIES AND DIFFERENCES

As already mentioned in the paper, these two typologies of collective housing are often mixed and intertwined. Some authors interpret the term coliving as a modern substitute for cohousing, which can be justified by the fact that the coliving typology is more prevalent in the current circumstances, especially in more developed countries.

By reviewing relevant projects in the fields of cohousing and coliving, a comparative analysis of these two alternative housing typologies can be done.

To understand cohousing and coliving and their characteristics, similarities, and differences, one must primarily compare their initial motives.

The main motive for people seeking life in a cohousing community is socialization and a supportive community. Other relevant motives are mutual maintenance of complex, mutual child care, group performance of many regular daily activities such as dining, carpooling, free activities, etc.

The driving motive for people to enter a coliving community is usually the need for affordable urban dwelling, while socialization and strong neighbourhood comes second.

The physical appearance, location, functioning, etc. of the buildings of these two typologies are consequently different (following different motives behind them). This paper compares main characteristics of these two collective housing typologies (Table 1).

Table 1 Spreadsheet view of characteristics of cohousing and coliving

Categories	Cohousing	Coliving
1. Location	Suburban area	Urban area
2. Number of storeys	Low rise buildings	Multi-storey buildings
3. System of units grouping	Horizontal system of units grouping	Vertical system of units grouping
4. Connection to the ground	Direct connection	No connection
5. Green areas	Large, shared green areas	Usually no green areas
6. Involvement in design	Future tenants participate in the designing process	No involvement
7. Housing unit floor plan	By tenants needs	Typical unit
8. Housing unit equipment	By tenants	Already equipped
9. Private space	Single-family house features	Apartment features
10. Tenants structure	Usually diverse (different types of families, retired couples, single family households etc.)	Usually young adults (young professionals, millennials etc.)
11. Common facilities	Small number	Large number
12. Length of stay	Long-term	Temporary home
13. Management	By tenants	By specialized service

The comparative analyses of cohousing and coliving characteristics reveals the main distinctions between the two alternative housing typologies, which are sometimes mistaken in the literature.

5. CONCLUSION

Research into cohousing and coliving concepts can be described as a novel branch of researching housing architecture, and the number of scientific papers written on this topic in the past few decades is large (Alfirević & Simonović Alfirević, 2020).

There are many definitions of collective housing and its typologies. Since this topic is extremely interesting and according to many authors represents the future of housing, one

of the first steps must be understanding terminology and typology. The best way to do that is to observe both history and contemporary architecture worldwide.

By reviewing origins and representative contemporary works of cohousing typology one must conclude that this term implies living in an intentional community, driven by tenants' desire for socialization and supportive community in order of fulfilling basic individual needs.

By reviewing origins and representative contemporary works of coliving typology, it can be concluded that coliving implies a collective of young professionals, searching for affordable living in the city in troubled housing market.

By observing the characteristics of these two typologies, as given in Table 1., large differences between cohousing and coliving are determined.

Numerous examples of projects of these two categories designed worldwide, their names and architects thinking, shows that terminology is almost clear in practice work and that cohousing and coliving found their place in contemporary architecture practice.

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COHOUSING I *COLIVING* - KOMPARATIVNA ANALIZA DVEJU ALTERNATIVNIH STAMBENIH TIPOLOGIJA KROZ PREGLED SAVREMENIH TENDENCIJA

Međusobna zavisnost i benefiti koje donosi udruživanje su se kroz istoriju stalno ispoljavali kroz različite oblike stambenih tipologija koje podrazumevaju neki oblik suživota osoba koje nisu u srodstvu. Dve alternativne stambene tipologije koje su danas prilično zastupljene u razvijenijim zemljama, cohousing i coliving, privlače veliku pažnju kako arhitekata tako i naučnika. Teoretičari se još uvek aktivno bave motivima koji iza njih stoje i jasnim tipološkim određivanjem ovih dveju

tipologija. U radu je dat pregled osnovnih karakteristika kroz pregled prvih tvorevina i savremenih dela dveju navedenih stambenih tipologija i potom izvršena uporedna analiza njihovih osnovnih prostornih i funkcionalnih karakteristika. Prikazani primeri i izvedene karakteristike mogu da posluže kao osnov za dalje istraživanje, razumevanje i definisanje programa cohousing i coliving stambenih tipologija.

Ključne reči: *cohousing, coliving, alternativne stambene tipologije, motivi, karakteristike*

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Original Scientific Paper

METAPHYSICAL SETTINGS OF ARCHITECTURE ACCORDING TO THE THEO-ANTHROPOCENTRIC PARADIGM OF JUSTIN POPOVIC *

UDC 72:11

Slaven Stevanović

University of Novi Sad, Faculty of Technical Sciences, Novi Sad, Serbia

Abstract. *The basic truths of architecture have been forgotten. This paper searches for the solution in the knowledge of metaphysical settings of architecture. More precisely, the metaphysical aspects of ontology, gnoseology, axiology and methodology; which together represent the basic criteria of a scientific paradigm. The initial question must be gnoseological, i.e. - what is the raison d'être of architecture? The analysis leads to an assumption that without knowing the metaphysics of man there can be no knowledge of the metaphysics of architecture; that is, a conclusion can be drawn that the problem of metaphysic of man in architecture has not been posed. Therefore, man must be the main issue of architecture, as well as of this paper. Given that the problem of knowledge in general sense, and therefore of man, is also of theological and philosophical nature, in this paper, the problem of man is understood as a gnoseological choice; namely: the choice between man as man-god (man is the source of knowledge) and man as god-man (God is the source of knowledge). Respectively, there is a choice between historical antipodes, the paradigm of anthropo-theocentrism and the paradigm of theo-anthropocentrism. In this paper, I argue that the issue of god-man and the paradigm of Orthodox theo-anthropocentrism, as interpreted by Justin Popović, is potentially the most comprehensive solution to the problem of raison d'être of man, and architecture that he creates. Discussion and analysis have established that, in this pattern, man is seen as a holistic, spiritual and physical entity, whose primary need to be met and his raison d'être – is deification. Thereby, architecture of orthodox theo-anthropocentrism acquires not only a physical, but also a spiritual, and thus, a holistic dimension. It may represent a symbolic means (through sensory and primarily visual representation) of man's ascension to God. Theo-anthropocentric paradigm solves the metaphysical foundations and potentially forms more holistically organized architecture that meets the equally holistic, spiritual and physical, needs of man. Its material manifestation is determined by only one criterion – deification.*

Key words: *Architecture, Raison d'être, Man, Theo-anthropocentrism, East Orthodox Christian, Justin Popović*

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Corresponding author: Slaven Stevanović
University of Novi Sad, Faculty of Technical Sciences, Novi Sad, Serbia. E-mail: stevanovic.slaven@gmail.com
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1. INTRODUCTION

*„Nobody in this country teaches or encourages us to the **art of living**. We are looking at this art as a kind of debauchery, but we are hardly aware that its principles are **moderation**, **cleanliness**, and **overall respect for creation** – not to mention the **creation of the world**." Bernard Rudofsky (1964)*

A bit poetic and melancholy, yet devastatingly true, the words of Bernard Rudofsky actually outline and quite accurately represent the main idea of this paper. Ideological guidance that simultaneously represents both the motive and, in general, the larger problem of research. No matter this statement was rendered more than half a century ago and addressed the audience from a completely different continent, it is timeless and spaceless, and it is as current today as it was back then; maybe even more. So, in order to analyze the state of architectural culture today, we inevitably have to ask similar questions. Can we still say with certainty what architecture is? What values should architecture convey? What is its relation to man and the natural environment in which it emerges?

This unfinished set of seemingly quite simple questions, actually gravitates around a single central issue – the definition of architecture, its essence and its beginning; which is, in the broadest sense, the main initial problem in this paper. Still, if we operationalize and analyze Rudofsky's thought in a studious way, from a metaphysical standpoint, we will find that Rudofsky is actually talking about the beginning, or, more precisely, about philosophy or metaphysical problems of living; that is, the metaphysics of architecture – that is what is forgotten. In other words, the values that Rudofsky states (moderation, purity, compliance, creation) are parts of a larger (equally neglected) axiological system; a system which we cannot discuss if we do not set the metaphysical framework of the problem. In this particular case – the metaphysical framework of architecture. Thereby, it becomes clear that the search for a general definition in fact becomes a metaphysical quest for the essence (Greek: *ουσια*, Latin: *essentia*) of architecture. In addition, if we searched for the definition of architecture by analyzing and valorizing the known historical definitions, the result would be limited and conditioned by those definitions. Therefore, if the objective is to come to know the primordial definition, i.e. the ontological truth, then, logically, the quest for it has to be beyond generally known historical boundaries. The only way, therefore, is to replace the teacher of life with the teacher, and the mother, of all knowledge – philosophy. And also, to replace the scientific definition of architectural theory with the philosophical, metaphysical paradigm (strategy, or pattern).

Engaging in the discussion and analysis of metaphysical standpoints, every scientist is forced simultaneously to engage in a metaphysical *"paradigm war"* (Guba & Lincoln, 1994). During 20th century, there has been an abandonment of rigid materialistic standpoints of generally accepted positivism. The deterministic view that there is only one scientific truth has been abandoned (Groat, 2013; Ševšukić, 2006). Therefore, there is a variety of competing paradigms following various philosophical manifestos. However, this paper seeks the solution of the choice of scientific strategy beyond the boundaries of the aforementioned *"war"*. Whereas, even when the very paradigms are analyzed and verified from the metaphysical standpoint, and specifically from gnoseological perspective, a single general characteristic of great value can be perceived. Similar to what some authors, like Velimirović (2013b), Eliade (2003), Popović (1998), and Harari (2018) argue, in a gnoseological sense, all paradigms can be divided, or viewed from two antipodal angles: anthropocentric and theocentric. In other words, anthropocentrism includes all of those patterns whose gnoseological source is man. In contrast to that, theocentrism includes those patterns whose gnoseological source is God,

i.e. some or any transcendent being. This particular paper intends to solve the metaphysical problem of architecture through theocentric (god-centred) paradigm. The reason for that is simple and will be presented in more detail later. In short, we believe that theocentric holisticity is precisely the missing characteristic of anthropocentric paradigm in which contemporary architecture emerges. Since theocentrism is the common term for all theocentric strategies, this paper focuses more closely on the East Orthodox Christian, theocentric thought, respectively, the theo-anthropocentric (god-man-centred) paradigm. The reason lies in the analyzed belief that, the balance between the human and the divine, i.e. anthropocentric and theocentric has been most fully achieved in this particular thought. One of the world's most eminent representatives of Orthodox thought and this pattern, who intellectualized this thought within the wider theological-philosophical frame, is St. Justin Popović. The analysis and review of his work and thought represents the foundation of our study. Based on his research, we will try to build out independent and critical opinion about what this pattern represents, and how to use and transfer that knowledge into the context of architectural creativity.

In addition, it is important to emphasize that the main problem of anthropocentrism is relativization of theocentrism (Popović, 2009). Therefore, if we seek a solution to the problems of contemporary society, that is, architecture, relativization of theocentrism is what should be avoided. This paper will try to convey the theocentric thought in its fullness, without any narrowing or relativization of thought towards the spirit of the times (*zeitgeist*). Only external manifestos, not inner compositional-essential forces, can be adjusted to the spirit of the times. The disclosed is based on the belief that modern man, who strives to reconcile his metaphysical-existential status, does not need a variant of his own anthropocentric teaching. Current scientific trends (Alexander, 2002, 2018; Barrie & Bermudez, 2016; Carroll, 2017; Guba & Lincoln, 1994; Hoffman & Sandelands, 2004; Holmes & Lindsay, 2018; Pallasmaa, 2012; Purzycki et al., 2016; Salingaros, 2016b, 2016a; Sandelands, 2004; Zumthor, 2006) have confirmed the disclosed, but also show that contemporary man, a scientist, is striving to a transcendence of thought, because he knows and feels that it is the only way he can potentially reach a genuine socio-cultural, and hence an architectural progress. Each contrast leads to starting a new vicious circle, and thus re-mirroring mirrors in the mirror (Popović, 2009b).

Contemporary problems of architecture are primarily problems of value (axiological). That is logical, given that contemporary problems of society, and of man, respectively, are precisely of axiological nature. Therefore, the study of a paradigm whose (foremost axiological) influence is comprehensive, socially as well as culturally-productively, absolutely proves its legitimacy. We expect, through the potential transfer of theocentric, i.e. theo-anthropocentric, paradigm onto the corpus of architecture, mainly through axiological intervention, to really reach a deeply meaningful, holistically and metaphysically grounded architecture. The goal is clear and naturally complex, but, we believe, it is absolutely achievable.

2. Genesis of the Problem – from the Definition to the Paradigm of Architecture

> ***The problem of knowledge****, in essence, is a* ***religious-ethical problem****.*
> *St. Justin Popović (2016)*

Knowledge, therefore, has a theological and philosophical dimension. But knowledge is, in practical terms, also a general process that is carried out every day in almost every

moment of human life. Therefore, knowledge as a phenomenon or process logically exists within the architectural trends. You could say that, without the possibility of knowledge, man, the world, and thus architecture, would be doomed. So, knowledge is an essential, life-giving event; and as such, it should be approached with great caution and awe. Misunderstanding of the nature of knowledge and approach to it also logically leads to insufficiently accurate or completely wrong results. Therefore, the problem of gnoseology, which has always troubled mankind, is, and should be, the primary problem of every problem, including architectural. Relativisation of gnoseology is also relativisation of the approach to a problem, and thus represents disparagement of the whole problem.

Accordingly, the approach to the problem of definition lies in the forementioned quote of Popović. He directly refers to the gnoseology of knowledge as a central issue; but at the same time, he gives the answer – the solution is in the religious-ethical, theological-philosophical determination. With this approach, it is clear that the establishment of any definition of architecture in fact develops primarily into an exploration of its metaphysical constitutions. Specifically, the definition of gnoseological sources, as a starting point. It should be also emphasized that, in the already existing literature, the term *"gnoseology"* is usually being replaced by the term *"epistemology"* (Groat, 2013; Holmes & Lindsay, 2018; Lincoln & Guba, 1985); which represents yet another consequence of relativisation of the theocentric thought. However, the term *"gnoseology"* is wider than *"epistemology"*, as it allows a specific in-depth analysis, excursions into theology and transcendent knowledge, which is limited by epistemology. Therefore, considering that this term is more receptive for the nature and objectives of this paper, and guided by the thoughts of Popović, as well as other authors, like Kant (as opposed to Piaget, for example) this paper still retains the gnoseological terminology guideline.

Lev Shestov (2002) in his analysis also highlights the importance of gnoseological determination. His well-known thought: *"Gnoseology is the soul of philosophy (...) Tell me about your gnoseology and I'll tell you about your philosophy"* clearly confirms all of the above, but also paves the way for further research. Shestov practically points to the fact that the rest of metaphysical determination originates from the problem of gnoseology. So, the basic question of ontology, is a direct product of gnoseology itself; because, what else can determine what the truth is if not determination of the source of truth (Lincoln & Guba, 1985; Velimirović, 2013a; Popović, 2005b, 2016). However, what is most important is that gnoseology, and thus ontology, will determine the axiological values in the sequel; and all together, they will determine the methodology of approach (Guba & Lincoln, 1994). Finally, as Guba and Lincoln explained, all these metaphysical guidelines, in fact, make the basic settings for a scientific paradigm. In their popular paper from the late twentieth century (cited over 20,000 times!), which launched a revolution within methodology of approach to scientific research, they presented the revolutionary idea that paradigms can never be completely proven, and therefore, every strategy must be approached with a certain amount of faith. Because, it is belief or disbelief in some scientific strategy what makes determining relationship that practically valorizes the paradigm itself. This is truly a revolutionary assumption which, since it has been accepted by the scientific community, demystifies the rigid positivist approach to scientific research. At the same time, it clearly gives access to other proven scientific paradigms, such as constructivism, pragmatism, empiricism, idealism, structuralism, deconstructionism, etc. However, given that the selection of scientific strategy is a matter of faith (Guba & Lincoln, 1994), quite legitimately, we can propose testing the value of

theo-anthropocentric paradigm, as well. Without imposing it on anyone, but legitimately highlighting it as a potential solution and approach to scientific research.

Finally, why is all of this important for architecture? As already indicated, the choice of a paradigm, or metaphysical determination towards the problem of gnoseology, ontology, axiology, methodology, have the ability to give the final formulation of concrete architectural theories, i.e. consequently, definitions. Therefore, logically, not a single established definition, nor our relationship to architecture, can be determined without a clear metaphysical standpoint and the choice of a paradigm, which every architect uses to work and create. So, this is the necessary, although seemingly forgotten, beginning of architecture. Of course, all of this refers to those creators who still perceive architecture more as a demiurgy rather than a technical discipline. Bogdan Bogdanović was particularly inspired to write about an architect as a demiurge and the importance of this interpretation (Abramovic, 2007); although he was a somewhat controversial personality, it would be good to recall some of his important thoughts:

"The fact that, since Alberti till this day, no one has entirely exposed the ***internal form*** *of architecture does not indicate the inability of architects, but the masterful skill of demiurgy, embedded in every architectural inch, elbow, thumb or fingernail. It is an honorable task of true builders to painstakingly search for those* ***seals of the gift of the holy spirit****, although we all know they cannot be reached. "*

These poetic and true thoughts, however, contain a small problem that, in fact, potentially resolves the raised question of demiurgy. Negation (emphasized by the author) of the possibility of knowing the inner form, i.e. primal architectural force, or as we call it, its *raison d'être*, is a kind of negation of architecture itself. How can one be a true architectural creator if he do not believe it is possible to achieve and fulfill its *raison d'être*? We can certainly agree that it is almost a utopian endeavor, conditioned by countless feats; but we cannot negate the possibility itself. For, conditionality is more positive than negative, rather a possibility than impossibility, or it is at least of neutral determination; which is certainly encouraging, despite the improbability of the possibility itself. Perhaps the reason for the author's negation lies in the fact that while he uses big words like *"seal of the gift of the holy spirit"*, he uses lower case for the *"holy spirit"*; which is completely understandable, considering his communist ideological background. Using the aforementioned theological guidelines for him is obviously more of a literary act than actually a belief in it. This paper will, contrary to him, guided by the spirit of the Orthodox faith, truly try to believe that reaching the gift of the **H**oly **S**pirit is actually possible; and so is architecture as *"masterful skill of demiurgy"*. Finally, we believe that in this way, the metaphysical significance of the quest for the inner and hidden architectural paradigms, can be clearly seen.

3. *RAISON D'ÊTRE* OF ARCHITECTURE – MAN

"***Gnoseological problem*** *of knowledge dissolves into an ontological-ethical, and ultimately* ***comes down to the problem of the man's personality****." St. Justin (2016)*

The clear and concise thought of Justin Popović precisely defines and provides additional explanations why ontological beginnings of architectural thought in fact should be sought in philosophical, metaphysical considerations. Thus, practically every metaphysical problem, for example, the ontological, or ultimately gnoseological, is connected with man; and a man further with the surrounding space, natural or built. Yet, the disclosed can certainly be verified

and valorized by analyzing, for example, the basic questions which are usually posed when confronted with something unknown (Velimirović, 2013a; Dinulović, 2012):

Table 1 Basic questions towards the unknown

"What is it?"	The question of ontology
"Who is it from?"	The question of gnoseology
"What is it made from?"	The question of axiology
"How is it used?"	The question of methodology

In reflecting on the presented above, one can see that the knowledge of all these questions loses its value if we do not know *what to do with all this knowledge* – "***What is this knowledge for?!***" asks Nikolai Velimirović (2013c). Therefore, the main foremost-question, of all questions simply must be: *"**What is it for?**"* In other words, this is about (gnoseological) primordial question **reason of existence**, or perhaps using more inclusive French term – ***raison d'être***. So, we conclude, in the context of architecture, this foremost-question would be – what is the reason for the existence of architecture? Or, more subtly, what is the *raison d'être* of architecture? With this, we believe, we finally come to the core of the epicentral problematic question of both philosophy and architecture. Also, it must be stated that today, modern architecture simply does not know its reason for existence. Or, perhaps scientifically more precisely – modern architecture has relativized its *raison d'être*.

Table 2 Primordial question

"What is it for?" / "Reason for existence?" / "Raison d'être?"	The question of gnoseology

A good example of relativization and the evidence for the disclosed is the case of modernism. The theme of Le Corbusier and his idea is certainly special, very complex and interesting architectural-philosophical problem. But, the single detail that is important for us now is the fact that Charles-Édouard Jeanneret-Gris is one of the few architects who has actually asked the ontological question of architecture. Having said the historical thought that marked the past century: *"The problem of the house has not yet been stated"* Le Corbusier (1999) in fact suggests that the ontological problem of *architecture* is not stated. So, he was really on the way of solving the metaphysical origins of architecture. But today, more than a hundred years after the revolutionary manifesto, the question – whether the ontological problem of *a house* was in fact really a basic problem of architecture? – is justified. Also, have we, thanks to the evolving period of technological progress, modernized the house (and therefore architecture) in its essential basis, or only in its exterior? Is the problem of the house the problem of the exterior dimensions of the human body or the man has something more than just the body? Have we modernized the space of each house to meet the newly created progressive needs of consumerism, enjoyment, leisure, or men's needs are larger than that? Thus, by sublimating these rhetorical questions, having analyzed the above mentioned problems from today's perspective, it seems that the problem of architecture could not have been in solving the problem of *a house*, as Le Corbusier triumphantly highlighted. And especially not the house as an empty *"do-mi-no"* shell of *"household economics"* for progressive mechanized family and the same kind of man (Le Corbusier, 1999). This is, in

fact, a practical example of relativization of architectural reason for existence. Is it possible that the basic problem question of architecture is *"a house"*? But even if it is, from ontological and gnoseological standpoint, the problem has not been completely solved. Because, what is then the basic truth of *a house*? What is its reason for existence? On what metaphysical and physical foundations will we build that neglected truth of *a house*?

It may sound paradoxical, but sometimes only physics can help the understanding of metaphysics. Newton's third law defines the relationship of action and reaction; or, in more subtle interpretation, it can be said that, if the goal is to understand the reaction, one must first understand the action; or ultimately, the one who initiated the action. In other words, viewed both physically and metaphysically, the problem of *a house*, as a creation, could and should be, in fact, the problem of its creator – *man*. The intelligence which conceived, created the first thought, the idea, the need, the necessity, which in fact, in itself, *is* the very *beginning* of architecture. This *"man's mental, reflective, beginning of architecture"*, in fact, in other words, is the metaphysical problem, the purpose and goal of this paper. So, we are, finally, *forced* to express our opinion and conclusion that *man*, as the creator of the comprehensive (rational) architecture, is its sole and main *raison d'être*. The subject, instead of the object; man, not a house – is the epicentral source of the problem of architecture. Man was, is, and will remain the main subject of (rational) phenomenon called architecture.

For the sake of truth, it should be said that Le Corbusier (1956, 1999) indeed notes that the new architecture must build according to man's needs. However, when he talks about the problem of man he always refers to the man of progress. He never perceives man through his basic metaphysical meaning. And that is the general, initial problem of modern architecture. Because, as modern architecture is not a universal representative of architecture, so the modern man is not a representative of the universal type of man. Thus, it is clear that man should not be perceived against the spirit of the times, progress, or the like, but against the universal understanding, in a diachronic, timeless, metaphysical sense; as much as possible to us. And a redefinition of Le Corbusier's postulates is, therefore, essential here. Instead of thinking *"the problem of the **house** has not yet been stated"*, it should be said *"the problem of **man** has not yet been stated"* Or, in the context of this paper, more precisely: "*the problem of man today, on the epistemological-ontological-axiological-methodological level, has been neglected."* This is the beginning, and it is an undeniable foundation of any further understanding of the basic truths of architecture.

As much as it seems that the problem of metaphysics of man may go beyond the limits of architecture, it is the metaphysical foundations of *existence* of architecture that give the indisputable legitimacy to the study of man as the main problem of architectural activity. This relationship is inevitable, crucial and all-determining. **Without knowing man there can be no knowledge of architecture**, from the micro to the macro level, from the metaphysical all the way to the practical manifestation. And with this basic truth of demiurgy or architectural creation, we can only confirm the thought of St. Justin from the beginning of the chapter – gnoseological problem, or more precisely the *raison d'être*, must really be reduced to the problem of man's personality; this is the primary question that requires a solution.

3.1. *Raison d'être* of man – god-man

Identification of the problem of *"man",* as the basic question that solves the metaphysical foundations of architecture, practically opens a new architectural research field of incomprehensible proportions. Yet, to investigate *man* is an intention that must be

operationalized. In the context of this paper, that would mean to perceive the *raison d'être* of man. Or, more specifically, to answer the metaphysical questions of gnoseology, ontology, axiology and methodology of man. Accordingly, in order to solve a given problem, it is necessary to choose a research paradigm by which these human problems will be interpreted. According to aforementioned thought of Popović, that knowing a problem is a religious-ethical problem, we leave the choice of a research paradigm to this law. Thus, viewing different strategies through a kaleidoscope of multifaceted religious-ethical refractions, one can see the consequent regularity of differentiating these strategies into two all-determining groups. As indicated in Introduction, these are, on the one hand, anthropocentric (man-centric) paradigms, and, on the other, theocentric (God-centric) paradigms (Gustafson, 1981, 1994; Hoffman & Sandelands, 2004; Sandelands, 2004; Velimirović, 2013d; Eliade, 2003; Popović, 1998b; Harari, 2018). Thus, it is clear, through a prism or determinant, that knowledge is a theological-philosophical problem, the primordial relationship, the conflict between the two most famous historical antipodes (or at least seemingly antipodes): man and God, is practically revealed. Or, as Mircea Eliade (2003) puts it: the profane and the holy (man).

In other words, in the context of Christian understanding of the terminology of man, this relation can also be characterized as a relationship of man-god, that is, god-man. A closer analysis of these concepts and metaphysical definitions will be elaborated later, but for now it is important to note that this paper focuses on the subject of man as god-man. Contemporary literature, both philosophical and sociological, as well as architectural, is full of theoretical and philosophical considerations about the problem of man-god, i.e. anthropocentrism. In practical terms, architecture itself as we know it (since the 18th century) is absolutely man-centred. The aforementioned Le Corbusier and modernism are, of course, the proof of this. On the other hand, research on the topic of god-man and theocentrism is unjustifiably more than neglected. However, what is still encouraging is the fact that, since the last decades of the 20th century, there is also a growing tendency, in various scientific fields, towards the theme of transcendent human determination (Alexander, 2002, 2018; Barrie & Bermudez, 2016; Carroll, 2017; Guba & Lincoln, 1994; Hoffman & Sandelands, 2004; Holmes & Lindsay, 2018; Pallasmaa, 2012; Purzycki et al., 2016; Salingaros, 2016b, 2016a; Sandelands, 2004; Zumthor, 2006). Therefore, science is gradually turning to studies that combine religious and worldly problems in various ways. Thus, this paper, following current scientific trends, but also following its own scientific needs and evidence, which point to the theme of the transcendent, turns its focus to the topic of theocentrism. For, the only potential way to perceive the basic truth of man without being Le Corbizier's *"man of progress"*, that is, man-god, is through the antipodean East Christian Orthodox, holistic concept of man as god-man.

This turn towards man as god-man is based largely on the fact that in transcendent learning man is viewed as a holistic entity of mind, soul and body; which can never be expected from any non-transcendent anthropocentric teaching. It is simply the fundamental, ontological feature of this paradigm. In it, man will never be a holistic entity that exceeds the limits of the senses, i.e. physicality. Therefore, we share the belief that only in the holistic nature of the transcendent, god-manly, theocentric thought, which perceives man as a spiritual-physical being, has a potential solution to the raised question of architectural *raison d'être*. That is, precisely in man, as a spiritual-physical entity, we find the solution to the *physicality* of architecture, which is the central consequential problem of choosing man-god (anthropo-theocentrism) for the *raison d'être* of architecture. In the following, our goal is to give specific instructions through the analysis of theo-anthropocentric thought on how to transfer this thought to the level of architectural activity. Still, in order to succeed in this,

one must first analyze and comprehend the theo-anthropocentric thought itself in its general form, i.e. through Orthodox teaching of its metaphysical postulates.

4. The Concept of God-Man and Theo-Anthropocentrism According to Justin Popović

"We stand for god-man, because we stand for man." St. Justin Popović (2005a)

The thought of Justin Popović is always strong and deep, clear and extremely precise. Adherence to god-man, as he says, by no means implies a departure from man; on the contrary, the care for god-man is precisely the most consistent and complete care for man, respect for his integral and deepest personality.

While analyzing the personality of the god-man and the man-god, St. Justin, further on, strongly insists on the term *"personality"*, stating that in anthropo-theocentrism *"personality is impaired and destroyed; what remains is man – thing."* (Popović, 2009a). He based this on the analysis of the contemporary organization of society. The humanist man, having rejected the idea of God, and having put man in the first place (*homo mensura*), had to become an atheist; and with the help of relativization of all transcendent moral values, and for the sake of the most exalted – freedom, man becomes anarchist, as well. Giddens (1998) testifies to these thoughts of Popović, calling this period of modern development "*a century of industrialization of war"*. However, if man has become the absolute ruler and founder of values, then, according to Nietzsche (2012), he can also become *ubermensch* (overman), nihilist, man of absolute freedoms.

However, the idea of freedom that the described man so eagerly pursues has become the idea of slavery. For, instead of true freedom in controlling one's instincts, man, due to all of the above, but mostly due to relativization of transcendent moral values, becomes a slave, a captive of his own instincts and desires. This thirst for absolute freedom has in fact become a service to various *"gods"*. Instead of an atheist, man has become a polytheist; and that is through a devotional service to matter, to various idols of science, technology, culture, fashion, politics, and even architecture, and to all their products. So, we should be completely honest; instead of man mastering matter, matter has mastered man. We could even say, mastered in a completely literal sense. Man ceases to be a separate, free personality with his unique identity. The globalist idea is, after all, based precisely on the destruction of individual (thus unique) identities (Giddens, 1998). Man becomes an impersonal and *"soulless thing among soulless things"* (Popović, 2009a).

Accordingly, it is clear that the theme of personality that St. Justin emphasizes, becomes extremely important, both for man and for architecture, which is truly losing its face today (Pušić, 2009). Such a man, overman, or, in other words, god-man is therefore a depersonalized man also (Velimirović, 2013b; Popović, 1998c; Spengler, 2010). The only positive thing is that this problem was noticed by many, for example, at the 2014 Venice Architectural Biennale by Rem Kolhas (2014), among other things, it was dedicated to this very topic – the impersonality of architecture, society, man. Because if a person does not have an identity, neither does society, therefore neither does architecture. Therefore, the purpose of this paper becomes clearer; *"The one, who solves the problem* (of personality) *of man, has solved the problem* (of personality) *of society"* (Popović, 2009a), and thus the personality of architecture.

On the other hand, theo-anthropocentric paradigm, as mentioned above, is an absolute antipode to everything presented, including the attribute of personality. Most concisely formulated, philosophy, i.e. metaphysics of man as a god-man, ontologically relies on the personality of God-man Christ (Popović, 2009a). Thus, this must become the first and foremost, true antipode – **personalism**. In the place of the impersonal, anarchic, relativistic, physical man stands the Absolute, the hierarchical ruler, the spiritual-physical, divine personality of God-man Christ. But it is also important to comprehend that his principal position as God is not despotic, or in any way negatively absolutistic. On the contrary, by appearing among men, God, God-man Christ, calmly offers his divine personality to man. He offers, and does not impose. As St. Justin says, in the personality of God-man Christ *"the closest union of God with man is realized: neither God is underestimated at the expense of man, nor man at the expense of God."* Therefore, God offers man a perfect synthesis, *"not only God, not only man, but God-man."*

And this gives a practical opportunity to override any existing antipodes. **Man receives a call to deification from God himself, and, if the man's will desires it, the opportunity to truly become a deified man, a god-man, god by grace, that is, by the gift of Christ himself.** And this is a major and essential difference from anthropo-theocentrism; where man, by his own will, without the God's calling, and at the same time even overthrowing the true God, elevates himself to the level of some god. In theo-anthropocentrism, God bestows upon man the status of god, but again respecting the will of man, i.e. only if he wishes it and if he respects and accepts the conditions of his arrival to that new status. In other words, if man exerts himself in effort and life in the Church, fulfilling the prescribed axiological laws. Therefore, man as man-god, self-willed, guided by his own ego, becomes depersonalized; and man as a god-man, by God's gift with the consent of man, guided by divine love, is personified. Man, as a man-god, self-willed, guided by his own ego, *"worships"* his corporeality; and man as a god-man, by God's gift with man's permission, guided by divine love, is spiritually and corporally deified and transformed into the holistic entity of god-man.

Accordingly, it can be concluded that the basic reason for the existence of man as a god-man is transformation (gr. – *μεταμόρφωσις*), **deification** of both man and the entire nature and cultural social production; but not by man's arbitrariness, but by the calling, the grace, the gift of God himself. The only way to do this is through the methodology of god-man, i.e. the methods of **endeavor** and **holy life** in the Church according to its laws and Holy mysteries. That is, through the ascetic observance of axiological evangelical virtues and moral laws, both the innate **conscience**, the Old Testament **Decalogue**, and, most importantly, the New Testament moral law of **love**. More specifically, through endeavor in a large number of axiological values such as love, god-love (worship, philo-theos, gr. – *Φιλοθεος*), man-love (philanthropy, philos-anthropos, gr. – *φιλάνθρωπος)*, faith, hope, modesty, meekness, kindness, harmony, honor, honesty, respect, mercy, prayer, etc. By embarking on the path of the methodology of endeavor, one becomes a *"devotee of faith"* (Popović), and changes the axiological negatives within himself, i.e. the passions and sins, and thus, by the gift of God-man, he transforms himself and everything around him into god-man. With this he finally reaches, but also attests, the basic ontological truth of Orthodoxy and the theo-anthropocentric paradigm – **God-man** Christ. Shown in a form of table:

Table 3 The metaphysical features of theo-anthropocentrism

ontology of theo-anthropocentrism	**God-man**
gnoseology, the **raison d'être** of theo-anthropocentrism	**deification**
axiology of theo-anthropocentrism	moral laws: **conscience, decalogue, love**
methodology of theo-anthropocentrism	**a feat, a sacramental life**

5. Application of the Theo-Anthropocentric Paradigm on Architecture

Through evangelical (axiological) *virtues, not only man and humanity are transformed, but also the entire nature* (creation) *through them. St. Justin* (2009)

At the beginning of the discussion of the implications of the theo-anthropocentric thought on architecture and its practical manifestation, it is necessary to remember that this is actually a metaphysical antipode to the contemporary representation of architecture. It is not at all subject to *"standard"* (man-centric) perceptions of architecture; the established rules, criteria, concepts, and the like, of anthropocentric architecture are not applicable to the theo-anthropocentric architecture. Therefore, in order for it to be presented at all and to be understood, it is necessary to, at least for a moment, reject all widely held man-centric beliefs and rules about architecture. The reason is clear, and lies in the diametrical nature of paradigmatic metaphysical settings; which are, clearly, equally opposite, both at the level of organization of society and of architecture.

The solution of the theo-anthropocentric architectural cognition, as in the case of this paradigm in a general sense, begins with the main subject and creator – man. Since he is its main *raison d'être*, it is him who gives all the solutions and answers at the same time. So, since we are discussing man as god-man, we are also discussing a holistically understood man, or a spiritual-physical entity. And this makes the first, initial feature that plays a decisive role in the formation of the architectural manifestation of the theo-anthropocentric paradigm. This division into the spiritual and physical manifestation of man, in fact, also represents the division into the spiritual and physical *needs* of man, and thus, clear directions for the action of architectural production. Logically, from the point of view discussed, spiritual needs are the primary needs to be met. All others, including the existential ones, are dependent on the primary ones. Becoming a god by grace, therefore, is the landmark epicenter of needs. Their external, physical representation, while legitimate, is nevertheless secondary, indirect, and not crucial to the main *raison d'être* of man as god-man, i.e. deification.

It should be emphasized that the stated categorization of values does not in any way mean a complete neglect of physical needs. Such radicalization, while acceptable to the ascetic way of life, is very difficult to imagine in the context of modern lifestyle. Although this paradigm is a counterweight to the contemporary anthropo-theocentric pattern of life, it still cannot completely ignore the context of modern man and his needs. Instead, it aims to replace the absolutist rule of corporeality, or sensuality, with spiritual-corporeal synergy. Therefore, the goal of man who strives for god-man is to find an adequate measure, that is, to put his spiritual needs first, while simplifying, and not necessarily completely rejecting, the physical ones. So, putting one's needs in a balanced order, the cultural production of man, and therefore architecture, must strive for the same. The goal of theo-anthropocentric architecture should thus be to find the right balance between the two extremes; a balance that determines the

needs of the spirit and the needs of the body, and thus the way of its material representation. **The more modest these physical needs are, the simpler the architecture itself will be and closer to the primary spiritual need of deification. At the same time, its connection with the natural architecture in which it is created will become more harmonious, natural and less violently invasive.**

The only way in which man, and consequently architecture, can reach this balance is through the realization of ontological-gnoseological truths, and through practical application of axiological-methodological values of the known truth (Popović, 2009a) (see Table 3). Only by understanding and fully relying on the aforementioned can this architecture potentially be of help to man in the path of fulfilling his main *raison d'être* – the attainment of holiness, i.e. deification.

Of course, considering the limits of the paper itself, it is impossible to analyze all the ontological-gnoseological-axiological-methodological values and the ways of their practical application. This paper, in fact, merely sets out the beginnings of an analysis, the metaphysical foundations, of an extremely large and wide-ranging problem. However, in order to gain a general insight into the possibilities and potential ways of material representation of the theo-anthropocentric architecture, a brief overview of some of the features (modes of transmission) of the values mentioned within the architecture corpus will be given below. More specifically, by analyzing ways of interpretation of these values within individual examples and the limits of function, form, and construction of architecture.

5.1. The function follows the gnoseology of deification

The established metaphysical principles of god-manly, theo-anthropocentric logics are such that they represent the basis for the solution of any problem (Popović, 2005b). So, when we are discussing the practical embodiment of this idea in architecture, primacy and significance of the gnoseological question is the main starting point. More specifically, the gnoseological question of *reason for existence*, from which the clarification of ontology, axiology and methodology is derived, is the most important fact needed. Consequently, the basic architectural postulates of function, form and construction receive their characteristic order. In this case, *the function* must take the place of gnoseology. Because, only *function* can represent the *"source of architectural knowledge",* i.e. that stronghold that is primary and on which it is built, or from which it originates, all further form (axiology) and construction (methodology). Just as gnoseology (source) builds axiology and methodology (product), so does function (source) build form and construction (product). It can be put this way: axiology and methodology follow gnoseology, and form and construction follow function. Or, function follows gnoseology, and form and construction follow axiology and methodology. Finally, axiology of form and methodology of construction follow the gnoseology of function.

This order is, after all, more than logical, both in philosophy and thus in the very nature of creation, which in fact is metaphysics at work. Architect Louis Sullivan (1896), spending his childhood on the farm, daily studying the nature around him, inspired, he writes:

"Whether it be the sweeping eagle in his flight, or the open appleblossom, the toiling work-horse, the blithe swan, the branching oak, the winding stream at its base, the drifting clouds, over all the coursing nun, ***form ever follows function, and this is the law****. **Where function does not change*** (as the gnoseological source, N/A)***, form does not change.*** *The granite rocks, the everbrooding hills, remain for ages; the lightning lives, comes into shape, and dies, in a twinkling. It is* ***the pervading law of all things organic and inorganic, of all***

things physical and metaphysical, of all things human and all things superhuman, of all true manifestations of the head, of the heart, of the soul, that the life is recognizable in its expression, that form ever follows function. This is the law.*"*

In other words, and in a practical sense, for the architecture of Orthodox theo-anthropocentrism, *the way*, or *the appearance* of something, is not as important as is *the need* itself that is being built or satisfied, that is, *the function*. So, what is truly essential, ontologically-gnoseologically important, is what is necessary, but not what goes beyond that necessity. So, it is the essence, not the expression of the essence. But also, the very *way* of using that essence; *for what* is this essence, not *how* it is expressed. Or, by analogy, the soul is more significant than the body; or, the sense of the letter, than the sign itself; the function of a tool, than its form; the creator than the creation and so on. Accordingly, the functions of theo-anthropocentric architecture take on a special dimension. Not only is **function more important than its expressive form and construction**, but **all functions are subordinated to that primary need of man – deification**, his main *raison d'être*.

These are the two main characteristics of the function of theo-anthropocentric architecture; the second of which is the highest specificity related to the features of the function of anthropo-theocentric architecture. In practical terms, this can of course be manifested in different ways. One of these practical manifestations of the foregoing, and mainly the second characteristic, is that this architecture can in no way be limited to sacral function, as it might seem at first glance. Because, man, logically, does not live only within sacral buildings. His need for deification neither ceases, nor arises, nor is it related *only* to sacral function; it is ubiquitous at every moment of his existence, and thus in his every existential space. In a man who aspires to become god-man, there is no strict division between the profane and the sacred. Such a person sacralizes all the world around him with his life. Thus, every church, by its function and use, is sacred, and every Christian home, if it is so lived in, is sacred, i.e. suitable for deification of man. Therefore, it is extremely important to note that, as much as it instinctively refers to its application within sacral buildings, the theo-anthropocentric paradigm can by no means be restricted *only* to those spaces. On the contrary, it must be transferred to *every* architectural typology, every function that man uses in his life. If the architecture of anthropo-theocentrism does not know the typological limitations, therefore, the architecture of theo-anthropocentrism also cannot know any typological limitations; which is actually a very logical statement. This is, therefore, an extremely important all-encompassing fact, so far, through history, probably not set up or explored in this way, or at least not at that intellectual-scientific level.

Looking through history, there are not many examples of theo-anthropocentric architecture, and thus the functional determinations mentioned above; first of all, because, such architecture also requires a society whose development focus is on God and religion. However, one potentially relevant example would be the period of the Nemanjić dynasty in Serbia. The rulers then incorporated the Orthodox faith, thought, paradigm into the very ideological foundations of their rule (Debljović Ristić, 2013; Prodić, 2012). The main state-forming idea that built the Serbian empire at that time, and thus architecture, rested on the idea of merging the earthly and heavenly empires, for the sake of deification, salvation of both the rulers and the entire nation. This can also be seen in various examples, from Prince Rastko Nemanjić (Saint Sava) himself, who put this idea into action most consistently, to architectural examples of monastery complexes, rural settlements, individual dwellings and the like.

The most easily readable architectural feature is, the aforementioned typological subordination to that main function, the need of man – deification. The most readable example is that of monastery units where besides chapels and churches, various types of dining rooms, public kitchens, inns, orphanages for children and adults, hospitals, schools, workshops, and the like were also built. In doing so, virtually all of these functions were given a single sacral dimension; through axiological service to people (philanthropy), they served God (worship, philo-theos) and thus reached that sanctum of holiness (deification). So, the very choice of functions, thus typology, utilitarianism, purposefulness, goal and meaning of the buildings, was humane, philanthropic, so as to encourage spiritual growth.

Similar aspirations also prevailed in the interrelations of function – form – construction. There, as already stated, the function had the fundamental role. The emphasis in this relationship is on necessity, what is really needed; there was an architectural modesty that manifested itself both in function and in the form and construction of buildings of that time. There was one formative measure that did not go beyond the boundaries of luxury, comfort, ornamentality, an over-emphasis on sensuality, the banal aesthetics of the outside, and the like. Accordingly, one of the interesting details that rounds out this brief example of the Nemanjić dynasty and their view of society and architecture are the deeds of King Uroš. As we can read in his life (Popović, 1991), although he built it as a personal mausoleum, he used the Sopoćani monastery through his life a place of reception for foreign deputies. From this, it becomes clear that it was more important for him to invest in and emphasize the (functional) beauty of the Orthodox faith as a representation of the country, than to invest in and emphasize the (formative) beauty and luxury of his palace.

His example, in many respects, summarizes the essence of the theo-anthropocentric paradigm and theo-anthropocentric architecture and much could be written about it. However, as the famous Byzantologist Professor Ousterhout (1997), in summing up the Byzantine, that is, Orthodox culture of society and architecture, sums it up nicely: *"In a society where the physical and the spiritual intertwine, everyday life has never been a major concern. Salvation was obtained through good deeds, not large palaces."* In other words, he points to the fact that **salvation** (**deification**), through respect of axiological values, was the primary concern of the Byzantine, orthodox *"everyday life"*, and not how human palaces would be built or look. Referring also to the thoughts of the Byzantine politician and philosopher Theodore Methochites, he continues to state: *"It is not the exterior of buildings that is to be praised, but the display of compassion and philanthropy (mercy)."* That is, it was not the form of the structure that was so important, but the function that was always subordinate to that primary function of deification; and through various other subfunctions, or more precisely, axiological values, first the primary one – love, and through worship and philanthropy. It can be concluded that, if not conscious aid, then, architecture of theo-anthropocentrism must, at least, by no means be an obstacle to that absolute goal of holiness, that is, to the deification of man.

5.2. Form and construction as a visual aspect of deification

Form and construction could also be interpreted as a sensory, mostly **visual aspect** of function. Axiology and methodology as a visual aspect of gnoseology. Altogether, we could say that our quest, in architectural terms, is for *"the sensory, and first of all, the visual aspect of deification"* (Ivanovic, 2010). Although the ultimate goal is deification in a transcendent sense, where the very process of worship begins from the equally

transcendent God's calling, in the very practical context of the materialization of the formerly stated, the process begins from the material man and the surrounding material objects and spaces. Therefore, it is precisely these surrounding objects and spaces that potentially represent that sensory and visual aspect on the path of deification. And, it is important to point out, all objects and spaces from all existential levels; from hand to universe, as stated by Schulz (2000) in his *"existential spaces"*.

It is difficult, of course, to find direct references in the literature on how to reach the sensory or visual aspect of deification. Even with Justin Popovic, we could talk more about indirect instructions, and "readings" of Justin's thoughts, than about really direct allegations. However, Dionysius the Areopagite (according to translation: Prodić, 2012), one of the authors whom Popović mentions in his interpretations of the Orthodox thought, gave the problem of the visualization of deification a special doctrinal foundation. Interpreting the thoughts of Dionysius the Areopagite, Filip Ivanovic (2010) writes:

"Although the ultimate goal of ascension is a formless domain (God, deification – A/N), *this* ***journey begins with things that have form***. ***Image*** *and* ***vision*** *stimulate the mind in its flight. Thanks to the splendor of beauty, and the inclusion of the emotional-mental as well as the sensory, not just the mental* (spiritual – A/N) *field, an anagogical function is fulfilled: it becomes possible to ascend from a visible domain to an invisible, from a sensory to a spiritual experience; it becomes possible to experience God (...) being overflown with divine grace, and therefore, with salvation.* ***Symbolic language exceeds the power of discursive language****."*

So, a visual representation of form, space, or **images** is one of the more significant features of the deification process. For, humans themselves are sensory, and thus visual beings; in addition to mental, spiritual cognition, they possess that emotional ability of cognition through the senses. Therefore, in the context of ascension to God, and the process of deification, images, or in other words, *"symbols and signals"* (Ivanović, 2010, 2017; Velimirović, 2013e; Prodić, 2012) play a certain, significant role. Dionysius himself, in the following, explains exactly the above (according to: Ivanović, 2010):

"Our mind cannot otherwise ascend to the heights and contemplation of the heavenly orders except through peculiar material leaderships, that is, through the acceptance of visible reflections in an attempt to explain (understand) invisible beauties, to form non-material enlightenment through the light of material substances; (...) the whole order of visible beauties (ornaments), steadily indicates to the heavens (...). To make it even shorter: ***all actions appertaining to heavenly are given to us (because of our nature, most often) through symbols****."*

Accordingly, architecture itself, as well as, among other things, sensory and, first of all, visual activity, should be understood as a potential **symbolic means of man's ascension towards God.** Thus, architecture cannot be a goal for itself, nor should art exist for the sake of art (*l'art pour l'art*) (Arsić, 1976). On the contrary, the architecture of theo-anthropocentrism has a moral obligation, but more broadly ontological-gnoseological-axiological-methodological obligation, to provoke a certain aesthetic, anagogical feeling, experience, which would ascend spiritual-physical man to deified god-man. In short, the goal is to reach contemplation (understanding) of the *"divine aesthetics"* (as Dionysius puts it), through emotional symbols and signals. Similarly, Lidov (1998, 2006, 2012) writes in his *"hierotopies"*; however, it seems unnecessary, confining itself to experience within the boundaries of sacral spaces.

However, one should also know that this crucial aesthetic experience cannot be established without ethical conditionality (Arsić, 1976). Even the ancient Greeks always viewed aesthetics through ethics, that is, collectively as an axiological problem. The proof of this is even semantic in nature. The Greeks used the word *kalos* (*καλός*) meaning both *beautiful* and *good*. As refined observers of metaphysical and transcendent thought, they have found that *beautiful* is only that which is *good*, and *good* only that which is *beautiful*. In other words, aesthetic value is equal and dependent on ethical; and even vice versa. There is no difference between good and beautiful, morality and art, and thus morality and architecture. Even Plato valued the value of art according to its ethical influence; stating that the most important goal of art is to emphasize the value of virtue and to reject vice; which can be seen, for example, in his "*Ideal State*" (Arsić, 1976). This observation can in fact be subsumed as logical legality. That is to say, it is more than clear that given the diversity of ethical views, a work of art, of any kind, and therefore architectural, can potentially have different interpretations. For some, a certain kind of art can be beautiful, and for another, according to its ethical attitudes, it can even look disgusting; as, for example, in the case of Marcel Deschan's very extravagant, questionable, "*ready-made* art" (Bichkov, 2012).

Similarly, Christian thought does not separate one from another; like with most ancient (transcendent and metaphysical) thoughts, Christian teaching is the one that supplements, corrects, and presents in a more comprehensive and subtle, grounded way. So, from the Christian thought standpoint, or against the context of this paper – from the standpoint of Orthodox theo-anthropocentric paradigm, beautiful is what is good and thus, what elevates man's thoughts to God, allowing him to come to his ultimate goal, to fulfill his raison d'être, that is, holiness, or deification (Ivanovic, 2017; Arsić, 1976; Bichkov, 2010; Lazić, 2007, 2008). And as Professor Velimir Arsic (1976) puts it nicely, this value of ethics should permeate all Christian (theo-anthropocentric) creativity; therefore, the entire man's life, in all his segments and productions. And so, it should be concluded that in any religion or philosophy, this subordination of aesthetics to ethics is not as consistent and essential-constructive as in Christianity, and with emphasis, in Orthodox Christianity. And the reason is one – holiness, as the goal of man's life, which is ontologically-gnoseologically dependent on ethics and moral laws.

Therefore, according to aforementioned, it should be concluded that one of the most important goals of the architecture of theo-anthropocentrism is to find ways to transpose these ethical values into emotional, and first of all, visual, spatial aspect (Ivanovic, 2010). Here, too, specifically, according to the teaching of Orthodox thought, it is all about the ethical all-value of *love*, or, in other words, *love for God (worship)* and *love for man (philanthropy)*, which can be further developed into a multitude of other, auxiliary values, which make up the first two. These are values such as: *faith, hope, humility, meekness, kindness, modesty, honor, honesty, respect, mercy, patience, prayer,* etc. Therefore, the main goal is how to transfer all of the above, through a certain symbolic visualization, into a real-space domain, thus providing to man the adequate existential spaces to accompany him to his ultimate goal of deification.

Also, it is extremely important to note here that in laying down the principles of theo-anthropocentric architecture, we cannot in any way fall into concrete materialistic instructions. Giving any exact practical space design tips would mean limiting the unlimited. That is, the metaphysical nature of this paradigm is such that it does not allow for any restrictions and impositions (Popović, 2005b). Any more specific instructions would directly lead to the formation of a new style; which can by no means be the goal. The only practical criterion of

this paradigm is, in fact, of a metaphysical nature, and it is represented throughout this paper through various means. It is, of course, the all-criterion of deification. Therefore, it should be concluded that **every material intervention that contributes to deification**, or at least does not hinder it, **is allowed**. Thus, the *"spirit of the time" (zeitgeist)* as one of the values is certainly acceptable and even necessary; but again, only in the context of subordination of the *"spirit of the time"* to the criterion of holiness, not the opposite.

In particular, the example of modernism shows the aforementioned needlessness of any material limitations of philosophical settings. In addition to those generally known progressive values, there is also a significant metaphysical set that is unknown to everyone today, and advocated for by Le Corbusier (1956, 1999, 2008, 2013) in early modern thought. It is about values like identity, history, folklore, tradition, nature, spirit of the place, etc., which have never found their practical manifestation. The reason is precisely the unnecessary practical limitations embodied in the specific instructions regarding modern materials, technologies, systems, forms, production, forms of individual elements, etc.; which directly prevented the materialization of the mentioned.

According to this more than worthy historical example, but also to its very nature, the paradigm of architecture of theo-anthropocentrism must by no means fall into a similar trap. Its practical representation must remain at the level of metaphysical guidance. Any restriction, or specific instructions, such as those of Le Corbusier, would lead to an identical situation, a crisis in which we see the modernist, anthropo-theocentric, architectural thought. On the contrary, every architect, a demiurge, should have absolute freedom in expressing his creative thought. The only limitation is knowledge of the metaphysical settings of this paradigm, or, more specifically, the tendency to create different existential spaces that would, through different symbolic representations, convey the given metaphysical values in such a way, and with such aim, to provide man with adequate spatial conditions for his journey towards deification.

6. Concluding Remarks

Dura lex sed lex – the law is harsh, but it is the law

This world is based on laws. Many of which are made by different gnoseological legislators. As much as any law is strict, it is its secondary characteristic. More important than that is that the law *is, it exists*. Or that everything around us is, in fact, happening by some law. So, the presented practical paradigm is also a practical law which solves the aforementioned *"art of living",* mentioned at the beginning of this paper. Perhaps at some points it also sounds harsh, or rather utopian, and unreceptive to a modern man. Whatever attribute we use, resolving the basic ontological-gnoseological-axiological-methodological foundations of man and his life, that paradigm inevitably *is* the law. And as the law by which man's life takes place, historically and factually stable, should not and cannot be overlooked (Velimirović, 2013a).

As much as it carries a note of ideological beliefs, i.e. regardless of whether one believes in it, and consequently, in God or not, whether they recognize themselves as spiritual-physical beings, or just physical, science and thus architecture, is obliged to offer all of them a satisfaction of their specific needs. If modernism, or any other definition, a scientific strategy, can aim at the corporeality of man, his sensory needs, there is no legitimate reason for not forming a paradigm that would satisfy the spiritual-physical side of man (Hoffman &

Sandelands, 2004; Holmes & Lindsay, 2018). That is where the freedom of modern man lies. Therefore, the pursuit of this paper was constantly directed towards finding ways for architecture to meet the needs of that spiritual-physical man to whom the concept of the sacred, the sublime inner spiritual values still means something.

Thus, according to the presented analysis of the historically confirmed paradigm, we have revealed that the orthodox paradigm of theo-anthropocentrism is the law of living that firstly recognizes the *spiritual* element in man. Unlike anthropo-theocentric strategy that only focuses on the physical and sensory. This is perhaps the critical difference, or value, by which all other details of this paradigm are defined. Spiritual element offers the possibility of complete redefinition of man, society, cultural production, and thus architecture. By introducing the spiritual, man becomes a spiritual-physical being, the fullest holistic entity, whose needs go beyond physicality and sensuality. His most primary need is of spiritual nature, and that is the transformation into a new man, god-man, or deification (Popović, 1998a, 2009a). Similarly, the architecture for man as god-man must be guided by his primary need for holiness, but also by other physical-spiritual sub-needs, which are further specified by the metaphysical, ontological-gnoseological-ethical-aesthetic values of a given paradigm.

This architecture, therefore, should be a symbolic means of man's elevation to God; or, in the mildest interpretation, it should not be an obstacle on that way. In other words, **the goal of architecture of Orthodox theo-anthropocentrism must be to, by certain symbolic sensory, and primarily visual representation transpose the spiritual, metaphysical ontological-gnoseological and methodological-axiological values into different material spaces and objects; and thereby create adequate existential, material spaces and objects suitable to fulfill man's all-purpose of life – holiness, i.e. deification.** It should be clear that architecture, in the whole process of achieving the aim of deification, is of course, not an absolute necessity, but is potentially useful. Also, due to the nature of the paradigm itself, its material representation cannot be limited nor determined by any material advice. Its only shaping force is the given metaphysical postulate or all-criterion of deification. Or sublimely, **any material intervention that contributes to deification is allowed.**

Of course, all of the above are the starting, basic metaphysical postulates of theo-anthropocentric paradigm and its application in architecture. A complete typological classification, structuralisation of all the above-mentioned values, and their most important interpretations and transpositions to the level of architectural activity, is the most significant and key part which will follow in further research.

What may be added as an indication of the direction in which further research could go, is related to the practical manifestation of the given paradigm in architecture. Perhaps the easiest way this can be presented is on the example of planning the living area of a housing structure. It seems that today, modernist, or even neo-modernist, functional disposition scheme is not being questioned. Is the proposed segregation of space – for example, i.e. separation of the daily zone into subzones actually good? Should the living zone of a modern family cover a living room and living-bedrooms, study rooms, or should there only be only one central zone? Also, should the former function and importance of certain "forgotten" elements, such as the *fireplace* and *dining table* be reactivated (Karelin, 2019)?

Sitting by the fireplace, in the past, or at the dining table, later on, these elements had the function of gathering the family together, thus forming a unique living area. At the same time, they have contributed to the formation of a significant number of axiological values of this paradigm: the family was together most of the time; a feeling and reality of communion was being formed; feelings of closeness, love and harmony; interpersonal problems were

more easily solved; tolerance and calmness were being built; family members used to help each other; communication, intimacy, connection and trust were being developed; and the possibility for greater moral outbursts was lower (as they were all present) etc. Today, the central role of the fireplace and dining table has been replaced by television, computers, mobile phones, and habits and obligations, in general, of members of a modern family (Karelin, 2019); thereby directly forming several daily zones within a single housing structure. This also forms a set of axiological values, but this time, of the anthropo-theocentric paradigm. It is clear that there is a significant loss of time spent together with the rest of the family; members are becoming distant, they communicate less, they are not united; there is a lack of intimacy, love, harmony; potential problems are harder to solve; it is more difficult to build endurance, calmness; intimacy, connection and trust are reduced; loneliness and alienation arise, privacy leads to the possibility of major moral outbursts, etc.

Theo-anthropocentric paradigm would, logically, propose reaffirmation of these neglected elements, as very significant positive axiological catalysts of the above-mentioned axiological values. Of course, even though these elements are generally known and represented in a variety of architectural manifestations, in the context of the theo-anthropocentric paradigm, they get a completely different value and meaning. This in turn leads to the conclusion that all the architectural instructions, which this theo-anthropocentric paradigm suggests, make sense only if the man himself, or the family who live in these spaces establish their life, in general, on this paradigm. For all others, the aforementioned "architectural instructions" will have no special significance.

In addition, in further research, the analysis of specific case studies that potentially have some of the characteristics of this metaphysical paradigm should be carried out. Of course, a completely direct reflection of this strategy does not exist. Some of the closest examples are the periods of social development, when the focus of the society was on God, and thus the aforementioned periods of Serbia under Nemanjic rule or Tsarist Russia, Byzantium, and their architecture can be an interesting starting point. But if we look for examples out of Orthodox thought, i.e. social order structured according to Orthodoxy, then in general terms, potentially significant examples could be the vernacular creations of different nations. This "*traditional, anonymous, folk*" (Rudofski, 1976) architecture is a good example of merging man's spiritual and physical needs with natural architectonics. In this sense, it has perfectly found its place within the paradigm analyzed in this paper, given that it is, as interpreted by Rudofski, *humane, natural, calm,* ***manly, spiritual architecture***.

We should definitely not ignore some modern researchers and architects who have attempted to transpose the notion of the transcendent into the field of architectural activity, both in practice and in their theoretical papers. These include authors like Christopher Alexander (2002, 2018), Nikos Salingaros (2016a), Peter Zumthor (2010) but also a huge group of architects and scientists gathered around a scientific forum ACSF (Forum of architecture, culture and spirituality), led by Julio Bermudez and Thomas Barrie (2016, 2015). All of them have recognized the value of transcendent thought, that is, of man as a spiritual-physical entity whose needs in architecture go beyond mere physicality. Of course, their research does not gravitate toward Orthodox thought, but rather generally toward some vague metaphysical transcendence, but regardless, even as such, this thought is worthy of a general analysis.

In general terms, in addition to the aforementioned ones, there are many authors who associate architecture with society and man. It is precisely in their thoughts that this paper, although largely theological and philosophical, has found evident architectural justification.

Thus, for example, architect Bruno Zevi (1966) highlights the inevitable connection of architecture and society, by stating: "*space (...) is (...) a consequence of social reflection*." Or, even better, in Rossi (2008) we find: "*The city is a great show that in reality reflects the living conditions*." Gogol' claim is literary picturesque (1991): "*Architecture is human history written in stone*." However, maybe the famous Wright (by: Pfeiffer & Nordland, 1988) is the one who, against the context of our work, most closely and concisely concludes:

"I know that architecture is life; or at least, it is life itself taking form and therefore it is the truest record of life, as it was lived in the world yesterday, as it is lived today, or ever will live. So, architecture I know to be a Great Spirit."

So, it is clear, and we believe, justified, that the problem of architecture should be sought more deeply than its material, constructional foundations. The problem is in society and man's life in general; or, looking at the breadth and depth of theological and philosophical thought of Orthodox theo-anthropocentrism, we would like to make the conclusion with the words of Justin Popović (2009), *solving the problem of man* (in an essential, metaphysical sense) *resolves the problem of society*, and thus certainly, the problem of architecture.

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METAFIZIČKE POSTAVKE ARHITEKTURE PREMA TEANTROPOCENTRIČNOJ PARADIGMI JUSTINA POPOVIĆA

Osnovne istine arhitekture su danas zaboravljene. Ovaj rad rešenje traži u spoznaji metafizičkih postavki arhitekture. Bliže određeno, metafizičkih aspekata ontologije, gnoseologije, aksiologije i metodologije; što skupa predstavlja osnovne kriterijume jedne naučne paradigme. Polazno pitanje mora biti gnoseološko, odnosno – šta je to raison d'être arhitekture? Analizom se dolazi do pretpostavke da bez poznanja metafizike čoveka nema ni poznanja metafizike arhitekture, odnosno zaključuje se – problem metafizike čoveka u arhitekturi nije postavljen. S toga, čovek mora biti glavno pitanje i arhitekture i ovoga rada. S obzirom da problem saznanja u opštem smislu, pa time i čoveka, jeste i teološko-filosofske prirode, problem čoveka se u ovom radu shvata kao gnoseološki izbor; i to: između čoveka kao čovekoboga (čovek je izvor saznanja) i čoveka kao bogočoveka (Bog je izvor saznanja). Odnosno, nameće se izbor između istorijskih antipoda, paradigme antropoteocentrizma i teantropocentrizma. U ovom radu zastupam mišljenje da pitanje bogočoveka i paradigme pravoslavnog teantropocentrizma, u tumačenju Justina Popovića, jeste potencijalno najcelovitiji odgovor na postavljeni problem raison d'être čoveka, a samim tim i arhitekture koju on stvara. Raspravom i analizom je ustanovljeno da se u ovom obrascu čovek shvata kao holistički, duhovno-telesni entitet čija je primarna potreba koju treba zadovoljiti i njegov raison d'être – obogotvorenje. Time, arhitektura pravoslavnog teantropocentrizma dobija ne samo telesnu, već i najpre duhovnu, time holističku dimenziju; i može predstavljati simboličko sredstvo (kroz čulnu i vizuelnu reprezentaciju) uzdizanja čoveka ka Bogu. Teantropocentričnom paradigmom se rešavaju metafizičke osnove i potencijalno formira holistički ustrojenija arhitektura koja odgovara isto tako holističkim, duhovno-telesnim potrebama čoveka. Njena materijalna manifestacija je određena samo jednim svekriterijumom – obogotvorenja.

Ključne reči: *arhitektura, raison d'être, čovek, teantropocentrizam, istočno-pravoslavno hrišćanstvo, Justin Popović*

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DOMESTIC SPACE UTILISATION AND GENDER IDENTITY AMONG STAFF OF OSUN STATE UNIVERSITY, OSOGBO, NIGERIA

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Aderonke Olufumi Ajayi[1], Jayeoba Babatunde[2], Ayodeji Olusola Ajayi[2]

[1]Department of Architecture, Obafemi Awolowo University, Ile-Ife, Nigeria
[2]Department of Urban and Regional Planning, Osun State University,Osogbo, Nigeria

Abstract. *Gender identities are expressions of masculine or feminine natures and interpreted within socio-cultural contexts. In this study, gender identities, domestic space utilisation and gender roles among staff of Osun State University, Osogbo, Nigeria were identified and analysed. With the aid of pre-tested questionnaires, primary data were collected using multi-stage sampling technique from 222 out of 675 staff members of Osun State University Osogbo. Secondary data were obtained from the Academic Planning Unit of the University and Osun State Ministry of Lands and Physical Planning. Descriptive statistics such as frequency and percentage tables, cross tabulation, and Bem Androgyny Model were utilized for the analysis of data obtained. Findings on individual gender identities showed that 1.3% of the respondents were masculine, 36% were feminine while 62.7% of the respondents were androgynous. Majority of the males and females were androgynous however some males were feminine although no female was masculine. Remarkably, only 2.2% of the males were masculine. These findings further confirm that most individuals possess a combination of feminine and masculine traits known as androgyny, and that individuals' gender identities do not necessarily correspond with their biological sex. Results also showed that domestic space utilisation and domestic gender roles varied with individual gender identities rather than just gender (being male or female). The study concluded that gender identities are important to the concept of gender-integrated housing design. Therefore gender-responsive housing designed to equitably meet the needs of men and women should be encouraged.*

Key words: *Domestic space utilisation, gender identity, gender-integrated housing design, gender equity, Nigeria.*

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Corresponding author: Ayodeji Olusola Ajayi
Department of Urban and Regional Planning, Osun State University,Osogbo, Nigeria
E-mail: ayodeji.ajayi@uniosun.edu.ng

1. INTRODUCTION

Domestic space utilisation, gender roles and gender identity are important concepts to the study of gender. Gender roles are socially constructed norms and roles ascribed to males and females in line with their corresponding biological sex; these are communicated through social and cultural institutions [1,2,3]. Domestic work constitutes an important gender role within the household and is mostly consistently allocated to women; and even in some highly modernized societies where men are increasingly getting involved in domestic duties, still women mostly remain in charge of coordinating and organizing them [4]. Evidence shows that responsibility in the household strongly influences women's experience of urban infrastructure while it does not affect those of men [5]. This implies that as a result of gendered domestic responsibilities, the housing and neighbourhood concerns of women differ from those of men [6]. Gender identities are expressions of masculine and feminine natures [7].However, definitions of what is masculine and feminine vary with culture, from place to place and over time [8,9,10]. Similarly, some gender identities are not fixed (such as in androgynous people); rather they are constantly negotiated in interactions based on social and cultural institutions [11,12,13]. Gender identity refers to the degree by which people see themselves as masculine or feminine depending the society's definitions of what it means to be a man or woman, for instance being male or female may mean brave or emotional; and in response males will generally define themselves as masculine and females will define themselves as feminine. These self-definitions or self-meanings are formed in social situations beginning early in life as a result of interactions with important figures such as parents, teachers, peers and educators [14].

Individuals may consider their gender identity as deviating from the model set by the society that is, although they recognize themselves male or female they consider themselves as possessing traits contrary to the assumed stereotype; for example a female may think of herself as being rational and dominant rather than fitting into the stereotype of being expressive and submissive; this forms their gender identity and guides their behaviour. Furthermore, gender identities tend to be more important predictors of behaviour than gender (male or female). These indicate that domestic space utilisation, gender roles and gender identity constitute important aspects of the concept of gender and housing.

Studies have shown that men and women experience and interact with their housing differently [5,6,15,16,17,18]. Gender differences have mostly been the focus of these studies with gender similarities being rarely examined. Gender differences have been found to exist in various aspects of housing and the built environment such as spatial experience, transportation patterns, work opportunities, work-family balance, housing preferences and satisfaction, use of space and relations within space [5,19,20,21]. The structure of houses is directly influenced by gender differences, which in turn reinforces gender relations [6]. Gender differences also translate into gender-specific housing preferences in terms of type of housing, neighbourhood and community [16]. Likewise, gender differences have been found in housing satisfaction levels between female and male heads of households [22]. Furthermore, according to [23] there are gender differences in feelings of place attachment; women tend to have higher mean place attachment at home than men, likewise women tend to have a higher mean level of control when responses are standardized across all activities. Although studies on gender and housing are gradually increasing, some shortcomings have been observed in the existing literature. While there is a considerable amount of literature on gender differences, gender similarities are rarely examined [24]. Also, majority of the existing studies tend to examine gender as just the characteristic of being male or female

without considering individual gender identities. Meanwhile individuals vary in their gender identity regardless of biological sex; meaning that a female may possess masculine traits and a male may possess feminine traits. Furthermore, in spite of the fact that gender roles and domestic space utilisation are important to the whole concept of gender, domestic space utilisation are hardly considered in the studies on gender and housing, hence this study.

2. Literature Review

Conventionally, strong opposites in gender attributes of males and females form the basis for gender identity in which femininity is related with reproductive and unpaid housework, domestic sphere, body and emotions while masculinity is related to productive paid work, public sphere, mind and reasoning. The distinct roles and relations of men and women in a given culture, dictated by that culture's gender norms and values, give rise to gender differences. These gender norms, roles and relations also give rise to gender inequalities, that is, differences between men and women that systematically value one group often to the detriment of the other [3]. Although the gender division of labour varies from community to community, household work is mostly consistently allocated to women; and even in some highly modernized societies where men are increasingly getting involved in domestic duties, still women mostly remain in charge of coordinating and organizing them [4]. As a result of these gendered domestic responsibilities, the housing and neighbourhood concerns of women differ from those of men [6]. This is mostly as a result of the socio-cultural gendered division of labour which exists in varying degrees from place to place. According to the literature, individuals are socialized into these gendered domestic roles which are acquired early in life [20]. Consequently, individuals' needs and experiences many differ along the lines of these gender differentiated roles. However, it is worthy of note that gender cannot act in isolation in shaping needs and experiences, rather it interacts with other personal characteristics such as age, household structure and composition, marital status, stage in family cycle, level of income and level of education in influencing these needs and experiences [6,17,20].

Different domestic roles are carried out in different spaces, require different levels of support services and infrastructure, and shape specific patterns of activities in daily life; this implies that based on gender, individuals are likely to relate differently with the different spaces, features, services and infrastructure that make up housing. This is supported by findings of a study by [18] which asserts that when there are no significant differences in household income, householders are likely to value housing characteristics differently because of different social experiences and needs of men and women [18]. This implies that since compared to men, women often combine different activities daily such as an employment, caring for children and the elderly, cooking, cleaning and maintaining the home, this might translate into differing housing and neighbourhood needs, expectations and aspirations from those of men. Likewise, there is evidence that responsibility in the household strongly influences women's experience of urban infrastructure while it does not affect those of men [5]. For example, the absence of basic services such as good water supply means additional work and time spent in sourcing for it by women and young girls who are usually allocated the responsibility. Thus, it becomes clear that gender roles form an integral part of gender differentiated experience of housing.

Since the measuring of gender identity was developed by Lewis Terman and Catherine Cox Miles in 1936, various measures have been developed by different scholars; however the Personal Attributes Questionnaire (PAQ) developed by [25] and the Bem Sex-Role Inventory (BSRI) developed by Sandra Bem in 1974 have become the most widely used measures of gender identity.

While the BSRI is designed to measure dimensions of masculinity and femininity based on the concept of gender schematization (internalized traits of seeing things in gendered terms) , the PAQ is based on the concept of gender as being multifactorial i.e. the attributes distinguishing males and females are numerous unlike gender schematization which binds them all into one.

The PAQ comprises two scales: expressivity and instrumentality which measure the degree to which a person can be classified according to masculine or feminine adjectives. It is a 24 item self-report questionnaire in which people are asked to indicate the extent to which they can be characterized in terms of various adjectives. Thus, for example, a person responding to the questionnaire will be asked to indicate the extent to which they see themselves as independent: Not at all independent A.....B.....C.....D.....E Very independent [25].The BSRI is originally a 60-item index however short forms have been developed and adopted. The original BSRI included 60 dichotomous items divided into 3 subscales (Masculinity, Femininity, and Neutral) of 20 items each [26]. A personality characteristic was categorized as feminine if it was independently judged, using a 7-point scale, by both females and males to be significantly more desirable for women than for men and vice versa for masculine characteristics. In 1981, Bem used factor loading to develop a 30-item scale, with 10 items per subscale, validated independently by others [27]. Also, a 12 item Spanish version of the BSRI (BSRI-12) was validated by [28] and included the items: gentle, sympathetic, leadership abilities, acts as a leader, dominant, tender, warm, affectionate, strong personality, defend own beliefs, sensitive to other's need, and makes decision easily. This version demonstrated strong psychometric properties, in some cases better than the original 60 item BSRI [27,28].

A study of gender relations as they affect housing shows evidence of gender differences in the quality of space of the dominant users (usually the male head of households), size of space, hierarchy of space and the gender division of space. It also points out that women are mostly the victims of housing related health hazards such as accidents and diseases. It concluded that gender differentiation has a direct bearing on the structure of houses, which in turn reinforces gender relations [6]. Another study on gender related differences in housing preferences reveals that housing experience is indeed gendered in nature and these gender differences translate into gender-specific housing preferences in terms of type of housing, neighbourhood and community. Furthermore, the study shows that gender cannot be studied in isolation; rather it intersects other variables such as age, ethnicity, personal characteristics, residential history and household composition which account for remarkable diversity of housing preferences [6]. A study of gender differences in involvement in housing development found that more men than women were involved in housing development, most especially due to negative gender stereotyping of female house owners; and gender differentiated obstacles present in the mode of inheritance or purchase of land among other impeding factors like inadequate finance and knowledge [17]. Another study revealed gender differences in housing satisfaction levels between female and male heads of households [22]. A few similar studies have also been conducted in the Nigerian context. In a study of gender differences in the responses of students to their housing, findings revealed very strong differences between males and females in the use of domestic facilities, while

differences were barely observed in the use of non-domestic facilities. The study attributes these to the acquisition of and socialization into gendered domestic roles, which according to the literature seem to be acquired from an early age. However, there were also some gender differences which seem intrinsic and may be innate such as differences in satisfaction with crowding and design and furniture arrangement [20]. Likewise, [5] examined gender and urban infrastructural poverty in an African city: findings show significant relationship between urban infrastructural experience of both men and women and household income, level of education, household size and stage in family cycle. However, although household income and household size was most important for both genders, household responsibility was inclusively of great importance in the case of women only. Furthermore, occupation and responsibility in the household was only found in relation to the experience of women. In a similar study, the same author examined gender differences in the experience of housing, findings reveal gender differences in aspects of housing in which users were interested; and also, in the aspects of housing which were perceived to most affect their daily activities [15].

The foregoing shows that housing is not gender neutral. In fact, houses are a product of an array of socio-cultural factors which include gender; the design or spatial arrangement of a house is shaped by the socio-cultural force of power and gender relations and the nature of housing in turn differently affects the lives of men and women [6]. This implies that more research is needed in order to better understand the differences in needs, desires and responses of men and women in relation to their housing and its environment. Gender differences are displayed in domestic space through gendered spaces, objects and practices [29]. Therefore, in trying to understand gender differences in relation to housing attributes, it becomes necessary to study domestic gendered practices and gender differentiated roles.

3. METHODOLOGY

The Research Design

The study is empirical in nature and it utilized the quantitative approach of research, using a survey research design. The Osogbo Campus of Osun State University was randomly selected from the University Campuses. Data was obtained from both primary and secondary sources. The primary data was collected in the field from respondents while secondary data was obtained from journals, books, official records and statistics. The questionnaire was used in obtaining information from respondents.

Population, sample and sampling procedure

The study population is the staff of the university, broken down into Top level management, Middle level management, Senior and junior Academic staff, Senior non-teaching staff and Junior non- teaching staff [30].

Method of sampling

Multi-stage sampling technique was used in data collection. In the first stage, the study population was stratified into 7 cadres based on the organisational structure of the university, namely: principal officers, deans/ provosts/university administrators, heads of

departments and units, senior non-academic staff, junior non-academic staff, senior academic staff, and junior academic staff. At the second sampling stage, disproportionate sampling was used to survey respondents from each of the cadres; where nummber of staff in a cadre is below 100, the total number was surveyed, while 20% was surveyed from cadres having 100 or more staff. Preliminary investigation showed that there were 675 staff; all principal officers, deans/provosts/university administrators, heads of departments and senior academic staff were surveyed cumulating in 107 respondents, while 20% of senior non-academic staff, junior non-academic staff and junior academic staff were surveyed cumulating in 115 respondents. In total, 222 respondents were surveyed.

Instrumentation and Data Analysis

The data was collected using the pretested and validated questionnaire in 2018. Descriptive and inferential statistics were used for data analysis. In this study, gender identities were measured with the short-form of the BSRI [31]. As shown in Table 1, the masculine scale (8 items) includes characteristics that are perceived as men's characteristics (e.g., assertive, strong personality, and dominant). The feminine scale (8 items) includes characteristics that are perceived as women's characteristics (e.g., emotional, sympathetic, and understanding). The rest of the inventory (8 items) is composed of neutral items, which are

Table 1 BSRI Items showing the categories of items

Items
A. Neutral (androgynous)
1. Very Aggressive
2. Very Dominant
3. Very Excitable in A Major Crisis
4. Very Worldly
5. Highly Needful of Others Approval
6. Feelings Easily Hurt
7. Cries Very Easily
8. Very Strong Need for Security
B. Masculine
1. Very Independent
2. Very Active
3.Very Competitive
4.Can Make Decision Easily
5. Never Gives Up Easily
6.Very Self-Confident
7.Feels Very Superior
8.Stands Up Well Under Pressure
C. Feminine
1.Very Emotional
2. Able to Devote Self
3.Very Gentle
4.Very Helpful to Others
5.Very Aware of Feelings of Others
6.Very Understanding of Others
7.Very Warm in Relations with Others
8.Very Kind

Source: [7].

perceived neither as men's nor women's characteristics (e.g., very aggressive, very dominant and highly needful of others approval). Participants assessed how well each of the 24 personality characteristics describes themselves by using a 5-point scale (1 = very untrue of me, 5 = very true of me).

Generally, gender identity classification is done using participants' scores on the masculine and feminine scales. Common methods for classifying scores on the BSRI into gender identities are to split the sample using either the medians from Bem's original normative samples, the theoretical mean of the scale or the sample medians and Bem Androgyny Model. Whether dividing the scores by theoretical mean or median (sample or normative) the technique is the same [26,32,33,34].

The study applied the Bem Androgyny Model for construction of gender role or gender identity. After respondents complete the scale, they receive three scores: a masculinity score, a femininity score, and, an androgyny score. The masculinity score is determined by adding up all the scores on the masculine items and dividing by 8 to obtain the average rating on those items. The femininity score is likewise determined. Androgyny was determined by subtracting an individual's masculinity score from the femininity score. The gender identity of a respondent is determined by the value of androgyny score. If the value is 1.0 or greater, the respondent is feminine, -0,50 to +0.50 is androgynous while -1.0 or less is masculine. Therefore, scores closest to zero (whether positive or negative) indicate androgyny; as scores move farther away from zero in the plus direction greater femininity is indicated and as scores move farther away from zero in the minus direction, greater masculinity is indicated. Thus, sex-disaggregated data on their needs in relation to the housing attributes were obtained.

Domestic Gender Roles of respondents

In order to investigate the domestic space utilisation of the staff, respondents were asked to indicate the duties they perform at home and the frequency of these activities using a 5-point Likert scale. In the first instance, responses were disaggregated into male and female and later responses were disaggregated by gender identity. Some of the activities are cleaning inside the house, cooking, cleaning up after cooking, repairs around the house, laundry, fetching water, cutting grass, cleaning gutters, cleaning the surroundings and shopping for food. Others are caring for children, paying rent, paying school fees, paying other family bills and running errands for the family. The Likert scale was used to weigh the occurrence and frequency of these activities by attaching values of weight to different degrees of responses as shown below:

Everyday = 5
Often = 4
Sometimes = 3
Rarely = 2
Never = 1

A GRWV (Gender Role Weight Value) was obtained for each gender (male and female) by summing up the product of the total numbers of responses to each variable and the weight attached to each rating i.e. (a x 5) + (b x 4) + (c x 3) + (d x 2) + (e x 1). The mean used in the course of computation was also obtained by summing up the GRWV and dividing it with the total number of variables. The deviation (which was also used as gender role index) was also calculated, in order to establish the frequency of roles

carried out by respondents. From the calculation, a positive deviation indicates a high level of participation in these household tasks, and when the deviation is negative, it depicts a low level of participation.

Note:
NR (f) = Number of Respondents (questionnaire)
GRWV = Gender Roles Weight Value

$\overline{X}$ = Mean = $\sum$ GRWV /NR(f)

D = Deviation $\frac{\text{No. of variables}}{\text{(Gender Role Index)}}$ = GRWV /NR(f) - X

4. Results and Discussion.

Demographic characteristics of respondents

Information obtained shows that 52.3% of the respondents were male while 47.7% were female. Most of the surveyed participants were between 31-50 years (64.3%) with high level of literacy. The results revealed further that 2.9% of the respondents were Principal Officers, 5.8% Deans/Provost, and 10.5% were Heads of Department / Unit. Furthermore, 29.8% were Senior Academic Staff while 11.1% were Junior Academic Staff; likewise, 15.2% were Senior Non-Academic Staff while 24.6% were Junior Non-Academic Staff. Majority (63.4%) of the respondents were married, while 21.5% were single. The other categories constituted smaller proportions of the study population with 8.1% separated, 2.9% single parents, 2.3% widowed and 1.7% divorced. The respondents mostly fall into the married and single categories for both males and females alike. An equal number of males and females (4.1%) are separated, 1.7% of males and 0.6% of females are widowed while none of the males and 1.7% of females are divorced.

Gender Identity Classifications

Results of gender identity classifications are shown in Table 2. In general, 1.3% of the respondents were in the masculine group, 36% were feminine while 62.7% of the respondents were androgynous. In general, most individuals possess a mix of both masculine and feminine traits, known as androgyny. These results were similar to the findings of Bem's androgyny model in [32]. Further analysis showed that none of the female staff in the study had masculine gender identity, 43.9% were feminine and most of the females were androgynous (56.1%). Similarly, most of the male respondents were androgynous (68.9%) whereas 28.9% were feminine and interestingly, only 2.2% of the male respondents were masculine. These results show that individuals indeed vary in their gender identities regardless of biological sex; being male does not necessarily translate into being masculine, neither does being female necessarily translate into being feminine as some individuals possess a combination of both masculinity and femininity [14]. This implies that issues which are typically classified as feminine and therefore regarded as pertaining only to females may in actual sense apply to some men and vice versa; thus, generalizations based on stereotyped assumptions about gender would be in fact incorrect.

Table 2 Gender Identity across Biological Sexes

Gender Identity Group	Male (%)	Female (%)	Total (%)
Masculine	2	0	2 (1.3)
Feminine	26	36	62 (36.0)
Androgynous	62	46	108 (62.7)
Total	90 (52.3)	82 (47.7)	172 (100.0)

Domestic Space Utilisation in relation to Gender (male/female)

In this section, domestic gender roles refer to the domestic duties that males and females are expected to perform based on society's definition of what is masculine and feminine. As presented in Table 3, result of the analysis shows the gender roles of male and female staff of Osun State University. It was evident that the following household tasks, cleaning inside the house, cooking and cleaning up after cooking had the highest positive gender role index of 1.4 among the female category of staff whereas the index values were 0.2, 0.0 and 0.0 respectively for the male respondents. This implies that these tasks are mainly allocated to women and as such, women do these tasks very often. This reflects the domestication level of women in our society; regardless of their actual gender identity which in this case is mostly androgynous, the society has stereotyped them as such. This is also irrespective of their socio-economic characteristics such as level of education, employment cadre and level of income.

Table 3 Domestic gender roles of respondents.

	Domestic gender roles	Deviation (D)	
		Male	Female
i	Cleaning inside the house	0.2	1.4
ii	Cooking	0.0	1.4
iii	Cleaning up after cooking	0.0	1.4
iv	Repairs around the house	1.0	0.0
v	Laundry	0.1	0.8
vi	Fetching water	-0.3	0.3
vii	Cutting grass	-0.4	-1.1
viii	Cleaning gutters	-0.4	-0.7
ix	Cleaning the surroundings	0.1	0.0
x	Taking children to school	-0.2	0.2
xi	Picking children from school	-0.4	0.2
xii	Shopping for food	-0.1	0.7
xiii	Shopping for other domestic needs	-0.1	0.7
xiv	Caring for children	0.4	0.5
xv	Caring for the elderly	0.5	-0.4
xvi	Paying rent	0.1	0.3
xvii	Paying electricity bills	0.5	-0.3
xviii	Paying school fees	-0.1	-0.3
xix	Paying hospital bills	0.4	-0.5
xx	Paying other family bills	0.3	-0.2
xxi	Running errands for the family	0.3	0.2

Furthermore, responsibilities such as laundry (0.8) shopping for other domestic needs (0.7), caring for children (0.5), and picking children from school (0.2) were performed in a decreasing order as reported by the females in the study. Inferably, these are not as strictly allocated to women as the previously listed tasks. However, the task with the highest negative index for female was cutting grass (-1.1), followed by cleaning gutters (-0.7); both of which also had negative indices (-0.4) for males. This means that these tasks were rarely done by women in the study area, and although one would expect positive values for males; these findings indicate that even males rarely perform these tasks. It could be that housing situations warranting such activities are rare (e.g. the absence of green landscaping and open gutters) or that such tasks are contracted to cleaners. Meanwhile, repairs around the house (1.0) had the highest positive gender role index among the male respondents in the study area. This was followed by paying electricity bills (0.5), caring for children (0.4) running errands for the family (0.3) and cleaning inside the house (0.2). These findings indicate that the frequency at which males perform domestic tasks was lower compared to females. Results also indicate that cleaning gutters and picking children from school were rarely done by male respondents, these chores had the highest negative gender role index among the men (-0.4).

Information presented in Table 3 shows that there were similarities and differences between men and women in the type of domestic tasks which they perform and the frequency of occurrence. Cleaning inside the house, cooking, cleaning up after cooking, laundry, fetching water, taking children to school, picking children from school, shopping for food and shopping for other domestic needs were mainly done by women, while repairs around the house, cleaning the surrounding, caring for the elderly, paying electricity bills, paying hospital bills and paying other family bills were mainly done by men. However, both males and females were involved in cutting grass, cleaning gutters, caring for children, paying rent, paying school fees and running errands for the family. Certain housing attributes are required to facilitate the various domestic tasks which individuals undertake. Since domestic tasks tend to be gendered, it is expected that responses to the housing attributes associated with these domestic gender roles will also be gendered. This will be investigated and established further in the study.

Domestic Space Utilisation in relation to Gender Identity

Having established that 1.3% of the staff were masculine, 36% feminine while 62.7% were androgynous, further analysis revealed that 2.2% of male respondents were masculine, 28.9% were feminine while 68.9% were androgynous. On the other hand, none of the female respondents was masculine, 43.9% were feminine while 56.1% were androgynous (See Table 2). Respondents were grouped based on their respective gender identities as follows: Males-Masculine (MM), Males-Feminine (MF), Males-Androgynous (MA), Females-Feminine (FF) and Females-Androgynous (FA). The domestic gender roles and the frequency with which individuals performed them were then identified, and the mean value (X) and deviation from the mean (D) were computed. While a positive deviation value indicates high frequency of performing a given domestic task, a negative deviation value indicates low frequency.

Table 4 Summary of domestic gender roles by gender identity

SN.	Domestic Gender Roles	Deviation (D)				
		Males			Females	
		MM	MF	MA	FF	FA
i	Cleaning inside the house	1.8	0.5	-0.1	1.4	1.2
ii	Cooking	-0.2	0.5	-0.3	1.4	1.4
iii	Cleaning up after cooking	-0.2	0.4	-0.3	1.4	1.3
iv	Repairs around the house	0.8	0.4	0.3	-0.3	0.1
v	Laundry	-0.2	0.5	-0.1	0.9	0.7
vi	Fetching water	-0.2	-0.2	-0.5	0.0	0.4
vii	Cutting grass	-1.2	-0.6	-0.3	-1.4	-0.9
viii	Cleaning gutters	-2.2	-0.4	-0.4	-0.8	-0.8
ix	Cleaning the surroundings	-1.2	0.1	0.0	0.4	0.0
x	Taking children to school	-2.2	-0.5	-0.1	0.4	0.0
xi	Picking children from school	-2.2	-0.5	-0.3	0.3	-0.1
xii	Shopping for food	-0.2	0.2	-0.2	0.8	0.6
xiii	Shopping for other domestic needs	0.8	0.2	0.0	0.7	0.5
xiv	Caring for children	-2.2	0.3	0.4	1.0	0.3
xv	Caring for the elderly	-0.2	0.5	0.4	0.8	0.1
xvi	Paying rent	0.8	0.1	0.1	-0.5	-0.4
xvii	Paying electricity &water bills	0.8	0.1	0.6	-0.1	-0.1
xviii	Paying school fees	0.8	-0.1	0.6	-0.4	-0.2
xix	Paying hospital bills	0.8	-0.3	0.6	0.4	0.5
xx	Paying other family bills	-2.2	0.0	0.4	-0.3	-0.2
xxi	Running errands for the family	0.8	0.5	0.3	0.3	0.3

Key: Male-M = Male Masculine Male-A = Male-Androgynous
Male-F = Male-Feminine Female-A = Female-Androgynous Female-F = Female-Feminine

Table 4, provides clearer detail with respect to who performs what task. For instance, some domestic tasks appeared to be performed mainly by females when categorization was simply into male and female, however when further categorized by gender identity, it was found that males of certain genders also performed the tasks quite frequently. Various domestic gender roles were found to be performed with differing frequencies among the different gender categories. Generally, cleaning inside the house was found to be the most frequently performed domestic role by males and females alike with Male-Masculine, Female-Feminine and Female-Androgynous having deviation from the mean (D) of 1.8, 1.4 and 1.2 respectively; indicating that the task is in fact not strictly done by women. On the other hand, cleaning gutters and cutting grass were the least frequently done by both males and females across all gender identities (with deviation scores of MM = -2.2, FA= -0.8 and MM= -1.2, FF= -1.4 respectively)

Findings also show that among the males, males that are masculine took the lead in domestic tasks such as cleaning inside the house (D= 1.8), shopping for other needs, repairs around the house, paying of rent, electricity bills, school fees, hospital bills, and running errands (each with deviation scores of 0.8. On the other hand, they lagged behind in domestic roles such as cleaning gutters, taking children to school, picking children from school, caring for children, paying other bills (each with deviation scores of -2.2), cutting grass, cleaning surroundings (D= -1.2), cooking, cleaning up after cooking, laundry, and shopping for food (D= -0.2). Whereas, feminine males took the lead in roles such as cooking, laundry, caring for the elderly (D= 0.5 each), cleaning up after cooking

(D= 0.4), shopping for food (D= 0.2), cleaning the surroundings (D= 0.1) and cleaning gutters (D= -0.4). While they lagged behind in paying rent, electricity bills, school fees (D= 0.1) and paying hospital bills (D= -0.3).

Furthermore, androgynous males most frequently performed duties such as caring for children, paying other bills, taking children to school, picking children from school and cutting grass, (D= 0.4, 0.4, -0.1, -0.3 and -0.3 respectively); while they lagged behind in fetching water (D= -0.5), cleaning inside the house (D= -0.1), repairs around the house, running errands for the family (D= 0.3 each), caring for the elderly (D=0.4), shopping for other needs (D= 0). Evidence from the study shows that within the female gender group, feminine females had the highest frequency for performing the following roles: cleaning inside the house, cleaning up after cooking (D= 1.4 each), caring for children (D= 1), laundry (D=0.9), shopping for food, caring for the elderly (D=0.8 each), shopping for other needs (D=0.7), cleaning the surroundings, taking children to school (D=0.4 each), picking children from school (D=0.3) and paying rent (D= -0.5). However, they had the least frequency for paying hospital bill (D= 0.4), fetching water (D= 0), repairs around the house, paying other bills (D= -0.3 each), paying school fees (D= -0.4) and cutting grass (D= -1.4). Whereas androgynous females did the following tasks more frequently than other females: paying hospital bill (D=0.5), fetching water (D= 0.4), running errands (D=0.3), repairs around the house (D=0.1), paying school fees, paying other bills (D= -0.2 each) and cutting grass (D= -0.9); while they lagged behind other females in cleaning inside the house (D=1.2), cleaning up after cooking, laundry (D=0.7), shopping for other needs (D=0.5), caring for children (D=0.3), picking children from school, caring for the elderly (D=0.1 each), cleaning the surroundings, taking children to school (D=0 each), paying rent (D= -0.4) and shopping for food (D= -0.6).

It is worthy of note that while none of the females had masculine gender identity, those that were in the Female-Feminine and Female-Androgynous categories performed some tasks with equal frequency: cooking (D= 1.4), running errands for the family (D=0.3), paying electricity bill (D= -0.1) and cleaning gutters (D= -0.8).

In summary, although there were some domestic tasks which were mainly performed by men and others mainly by women, the results show that there were some deviations from the norm defined by society. Overlaps were found between men and women in the domestic space utilisation the frequency with which they perform these activities. This was as a result of the variations in individual gender identities whereby some males possessed feminine traits and some females possessed masculine traits. Striking similarities were found between some male and female gender categories in the type and frequency of undertaking some domestic gender roles. Only males having feminine gender identity behaved similar to all females in performing tasks such as cooking, cleaning up after cooking, shopping for food, paying school fees and laundry. Similarly, only females with androgynous gender identity behaved similar to all males in tasks such as repairs around the house and picking children from school. This implies that housing issues pertaining to domestic tasks which are generally viewed as feminine will in actuality concern some men depending on their specific gender identities and vice versa. This shows that beyond gender (i.e. being male or female), individual gender identities are important to the concept of domestic space utilisation.

5. CONCLUSION

Results of analysis of information on domestic gender roles of staff show that although some domestic tasks were mainly done by men and others by women, some typically masculine tasks were also performed by some females with similar frequency and vice versa based on variations in individual gender identities. For example, striking similarities in pattern were observed between males with feminine gender identity and the females in some types of domestic tasks (such as cooking, shopping for food and laundry) and the frequency of occurrence. Likewise, there were such similarities between females with androgynous gender identity and the males in some cases such as repairs around the house and picking children from school. These highlight the link between individual gender identities and the type and frequency of performing domestic tasks (domestic gender roles). Therefore, the role of gender in the frequency and type of domestic tasks that individuals perform exceeds mere classification into male and female; rather it encompasses variations in individual gender identities, the importance of which cannot be over emphasized. In the light of this, it is important to holistically consider both feminine and masculine needs for the purpose of adequately meeting diverse individual needs with regards to housing design.

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KORIŠĆENJE PROSTORA U DOMAĆINSTVU I RODNI IDENTITET KOD OSOBLJA DRŽAVNOG UNIVERZITETA OSUN U OSOGBU, NIGERIJA

Rodni identiteti su izrazi muške ili ženske prirode i tumačeni su unutar socio-kulturnog konteksta. U ovoj studiji identifikovani su i analizirani rodni identiteti, korištenje prostora u domaćinstvu i rodne uloge među osobljem Državnog univerziteta Osun, Osogbo, Nigerija. Uz pomoć prethodno testiranih upitnika, primarni podaci su prikupljeni korištenjem višestepene tehnike uzorkovanja od 222 od 675 članova osoblja Osun State University Osogbo. Sekundarni podaci dobijeni su od Jedinice za akademsko planiranje Univerziteta i Državnog Ministarstva za zemljište i prostorno uređenje Osun. Za analizu dobijenih podataka korišćene su deskriptivne statistike kao što su tabele učestalosti i procenta, unakrsna tabela i Bem androginski model. Nalazi o individualnom rodnom identitetu pokazuju da je 1,3% ispitanika muško, 36% žensko, dok je 62,7% ispitanika androgeno. Većina muškaraca i žena bili su androgini, međutim neki muškarci su bili ženstveni, iako nijedna žena nije bila muška. Zanimljivo je da je samo 2,2% muškaraca bilo muško. Ovi nalazi dalje potvrđuju da većina pojedinaca posjeduje kombinaciju ženskih i muških osobina poznatih kao androginost, te da rodni identiteti pojedinaca ne odgovaraju nužno njihovom biološkom spolu. Rezultati su također pokazali da korištenje domaćeg prostora i domaće rodne uloge variraju u zavisnosti od individualnog rodnog identiteta, a ne samo pola (muško ili žensko). Studija je zaključila da su rodni identiteti važni za koncept rodno integrisanog dizajna stanovanja. Stoga treba ohrabrivati rodno odgovorno stanovanje dizajnirano da ravnopravno zadovolji potrebe muškaraca i žena.

Ključne reči: *korišćenje prostora u domaćinstvu, rodni identite, rodno-integrisano projektovanje stanova, rodna ravnopravnost, Nigerija.*

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"KARAĐORĐEV DOM" IN RAČA: TAKING THE FIRST STEPS OF CULTURAL PROPERTY REHABILITATION PROCESS

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Elena Vasić Petrović

DEarhitektura Niš, Serbia

Abstract. *"Karađorđev dom" in Rača, a monumental building, protected as a cultural monument, whose construction was completed in 1933, after many years of use and several changes of purpose, has been abandoned since 2016 and is now awaiting its first renovation. The rehabilitation project, started on the initiative of the municipality of Raca, envisages numerous activities in order to prevent its further degradation and to reconsider the possibilities for its revival, adequate presentation and permanent protection. The paper presents the first concrete steps realized during 2020.*

Key words: *Karađorđe, Rača, rehabilitation, conservation.*

1. INTRODUCTION

"Karađorđev dom" in Rača was established in the period from 1929 to 1933, as a home for neglected children and orphans of the "Moravska banovina" authority. It is located in the area of the wider city center, on the corner of Queen Marija and Karađorđeva streets.

"Karađorđev dom" is enlisted as a monument of culture since 1988 (https://nasledje.gov.rs/index.cfm/spomenici/pregled_spomenika?spomenik_id=45181).

The building's base is rectangular, with protruding towers flanking all four corners. The front façade, whose projection dominates the main entrance part together with the monumental staircase and porch, was designed in the same manner (see Fig.1.).

Apart from its original purpose, it also served as an educational and school building for many years, and the last tenants were displaced persons from Kosovo and Metohija, after whose eviction it was left to decay.

"Karađorđev dom" and its courtyard are presently in a very poor condition, although it can be said that the period in which the general degradation occurred, after the last users

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Corresponding author: Elena Vasić-Petrović
DE arhitektura Niš, TC Kalča, I sprat, lok. CI-87, 18000 Niš Serbia
E-mail: elenavasic@gmail.com

left, had a much greater negative and almost devastating effect on the building itself, than all previous years of active existence.

In 2020 the local government of the Municipality of Rača initiated the rehabilitation project, supported by the Serbian government and the job has been assigned to "DEarhitektura" (https://dearhitektura.com/en/karadorde-mansion-conservation-and-restoration-works-raca/), a company based in Niš and to the author of this article as project team leader. The first step in project development was defined and executed in order to prevent further degradation of the building (Project for conservation and restoration works on the roof and all façades and for reconstruction of the lightning arrester system). Additional research and studies were completed at the same time to help defining the priorities and further rehabilitation processes that must be done concerning the cultural property and its surroundings (ICOMOS, 2003).

2. HISTORY OF THE BUILDING

"Karađorđev dom" was built in Šumadija in Rača in the immediate vicinity of the village of Viševac, where Karađorđe, the leader of the first Serbian uprising, was born. Although the idea of its establishment appeared immediately after the World War I, it will be realized much later. The building is compound of different architectural ideas and was erected under the supervision of several architects, given that the original designs from architect Dragiša Brašovan (A.Kadijević, 1989), have undergone changes during the time.

In 1932, „Karađorđev dom" already became a humanitarian educational institution with agricultural practice for homeless children of the Danube Banovina of the Kingdom of Yugoslavia, aged 6 to 16. It was ceremoniously opened and consecrated, a year later, on December 8, 1933, on the day St. Clement of Rila (J.Milovanović, 2016).

Fig. 1 "Karađorđev dom", a view from Karađorđeva street, the postcard from the period of construction, URL: http://slikeiprilike.com/tag/raca-kragujevacka/ (March 20, 2021)

Between 1941 and 1946, the building was out of order, and then started working as high school – Gymnasium, which was changed again in 1957 when Agricultural school was formed. From 1960 to 1997 the elementary school named "Karađorđe" used the premises of "Karađorđev dom" and after the building was left to decay (Ž. Andrejić, 2017). From 1999 to 2016 it was again "home", now for people from Kosovo and Metohija as they were refugees due to the armed conflict in this southern Serbian province.

3. REHABILITATION PROJECT

The Rehabilitation project has defined the first stage as the need for the reconstruction of the facade and the roof, replacement of carpentry and adaptation of the existing lighting installation, in order with the prepared project documentation, which will enable the first phase of renovation of the building, but also the improvement of the general condition of its immediate environment.

Detailed technical recording and analysis of all parts of the building and determination of its current condition, is shown through Study "A" - Report on the inspection of the building, as well as the need for additional analysis of materials, which is the subject of Study „B".

Also, in the final phase of drafting the project the topic of its development possibilities was covered in detail, through Study "C", which contains a proposal of the program of works that need to be performed in order to make the building the tourist amenity.

The design specifications of the investor envisage the development of a detailed 3d model of the building, which was completed in combination of geodetic measurements, photogrammetry and additional traditional technical recording *in-situ* (see Fig.2).

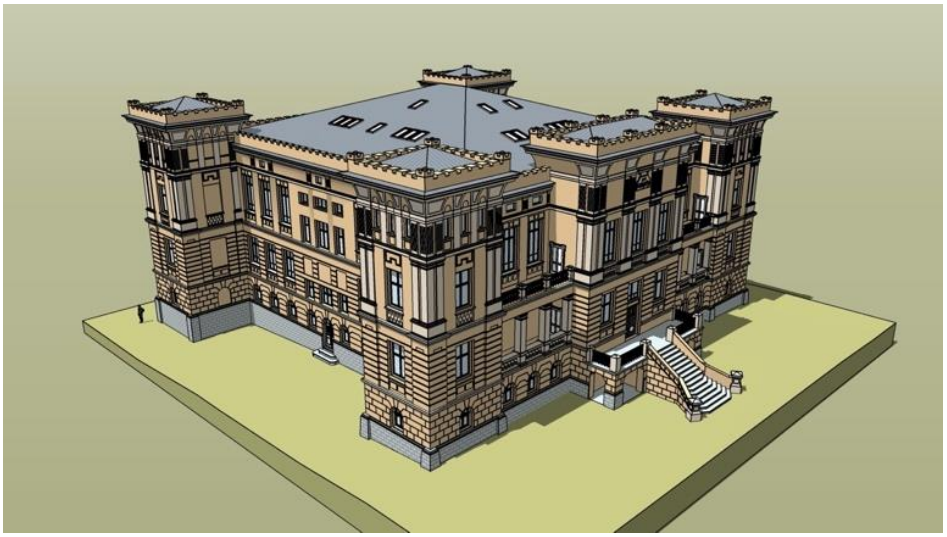

Fig. 2 "Karađorđev dom", 3D model, author: D.R.Vranić (December 2020)

4. Detail Description of the Building

"Karađorđev dom" is located at KP 332/1, KO Rača, which is positioned on the corner of Queen Marija and Karađorđeva streets and is owned by the municipality of Rača.

The subject cadastral parcel makes half of the block in which it is located and has a total area of 6,183.00 m2, while the building itself occupies 969.00 m2. The rest of the area, which is not under the building, is occupied by another recently added facility, which was built in the immediate vicinity of "Karađorđev dom" and another smaller building on the south side of the plot. These two mentioned buildings have no historical or architectural values, while the free areas have a very high potential for maximum utilization and activation, while retaining the basic characteristics - open park space, to which recreational areas and spaces for children to play and stay can be added, with proper and efficient organization and demarcation in accordance with the future purpose of the facility itself and its individual parts. Also, urban planning of certain parts, through paving and zoning, smaller or larger squares can be formed, for various purposes, which are missing generally in the surrounding urban space (E.V.Petrović, 2020c).

The courtyard can be accessed from both streets, through two gates, small one from the main street is pedestrian and a larger one is for vehicles. Sidewalks, access surfaces and plateaus are made of concrete. All other areas are grassed and contain high and medium greenery. The plot is fenced to the streets and the terrain is slightly sloping to the south.

The building is rectangular with the main entrance and monumental staircase, on the northwest façade (see Fig.3). The remaining façades also have entrances, so there is a total of four in the entire building and they are all at ground level (originally raised by 3 steps), except the main one, which is located on the balcony, which is a semi-level between the basement and ground floor.

Fig. 3 "Karađorđev dom", a view from Karađorđeva street (left), a view from the backyard (right), author: E.V.Petrović (November 2020)

The building contains a basement (partially illuminated by natural light), then a ground floor, first floor and attic space, which is not intended for use, but can be accessed by an auxiliary staircase, which extends through all floors, to the basement. Opposite to this staircase, which is positioned in the central part on the northwest side, there is the main staircase, which has no access to the attic space. All towers, as well as the protruding part above the main entrance, have another additional level, below their independent roof structures, which are accessed from the attic space. The main roof structure, above the central body, is four-pitched, made of wood and completely covered with metal panels.

The whole building, with its external appearance, is associated with the fortification, and contains elements of different architectural styles (Neoclassicism, Neo-renaissance, Eclecticism, Academism, etc.) (see Fig.3).

The facades of the building are characterized by strict symmetry, linearity and horizontal zoning, rhythmic repetition and arrangement of certain functional and decorative elements. The richness of decorative plastic is reflected in the multitude of applied geometric shapes and figures, which forms clearly differentiated zones between the cordon wreaths. The first, lower zone, is finished rustically, with large stone blocks and ends with a cordon wreath also of profiled stone elements, while all other higher zones are made with a flat finish in mortar and are painted in the same color, without emphasizing details. All the walls, except in the first zone, are built of solid brick.

By probing the facade surfaces and their detailed inspection, it was determined that the original color was "ocher" (visible in almost original form in the niches), while the entire northeast facade, as well as the associated towers, on all sides, were painted at some point in green color by "spraying", in the so-called *"hirofa"* method.

All facade carpentry is made of wood. All the windows were painted in oil paint in an "ivory" tone. All entrance doors are also wooden, with glazed fields in combination with decorative elements made of wrought iron and are painted in different shades of brown.

The building contains elements of electrical installations and lightning rods, which are visible on the facades.

The interior of the facility is largely neglected, and some parts have been adjusted to the purpose it had from 1999 to 2016, which is to accommodate displaced persons from Kosovo and Metohija.

On the entrance facade, to the right of the door, a memorial plaque with a relief and an inscription, made of bronze, was placed in 1998, dedicated to the anniversary of the breakthrough of the Salonika front.

The building has suffered and continues to suffer a very aggressive and negative effect from atmospheric water and moisture, primarily due to very poorly performed repair interventions on the roof, sheet metal cladding and damage to the gutters. Although based on older photographs, it can be seen that similar damage was present before, due to the characteristic problematic solution of collecting and distributing atmospheric water from the roof, behind the superstructures and penetrations towards the gutters, positioned on the facades. All façade planes, the roof construction, but also the interior of individual rooms, as well as the associated façade carpentry, are directly exposed to these negative influences.

Due to the complete absence of maintenance, great damage was inflicted on all other parts, which have a protruding position (entrance staircase, balcony, terraces), together with all its associated elements.

In addition to local destabilization and slight deformation of certain elements in the exterior of the building (entrance staircase, porch pillars, entrance stair railing, decorative elements of facade planes, attic cornice, etc.), weakened wooden elements of the roof structure and burning traces in the attic space of one of the towers, no other deformation or problems were noticed, which would indicate static destabilization. The inspection was carried out in all available parts of the building, outside and inside, including the roof planes. The basement rooms were not available for inspection. Of the visible, significant damage to the facade, it should be mentioned here that there is a larger crack on the northwest facade in the upper right corner, which extends from the attic zone, obliquely downwards, towards the corner tower (E.V.Petrović, 2020a).

5. Degradation Survey and Mapping and Proposed Technical Measures

The facades of "Karađorđev dom" in Rača are exposed to the negative influence of water and moisture. The key problem noticed during the detailed inspection of the building and all facade planes is the negative effect of atmospheric water.

Water penetration from the roof of the building: the most problematic are the gutters, collecting and draining water from the roof of the building. Namely, the gutter verticals were incorrectly constructed during the last reconstruction, and in the meantime, they suffered additional damage, so that the water flows directly to the walls of the building. There are practically no gutter horizontals on the building, and the elements that should take over the role of bays and horizontal drains do not exist in all places, where according to the rules, they should be. In addition to the above, all joints and penetrations through facade planes, as well as sheet metal cladding, are also problematic.

Penetration of water and moisture from the surrounding terrain: to a much lesser extent, but certainly not negligible, there is also the impact of water and moisture on the façades, like the stone plinth, stairs, and other associated elements in the area immediately above the ground. The connection between the existing sidewalks and the building is largely damaged, large cracks have been formed from which low, bushy and high vegetation grows. In some parts, the building itself was buried up to the level of the first step at the entrance doors, due to the construction of a concrete plateau, on the east side, or due to soil deposits, on the southwest and northwest side (E.V.Petrović, 2020a).

Fig. 4 "Karađorđev dom", main façade (northeast) deteoriation mapping, author: E.V.Petrović (November 2020)

Insufficient maintenance of protruding parts of the building and facades: due to the long-term absence of proper use, parts of the building that protrude in relation to the basic façade plane, as well as terraces and entrance balcony, suffer constant negative effects of water, frost, and other weather influences. The resulting damage progressively increases in the cycles of freezing and thawing of water, large temperature fluctuations etc. (see Fig.4).

The main entrance is positioned centrally and additionally protrudes in relation to the northeast façade and the central projection. It consists of a balcony, which is finished with a *"terrazzo"* lining, and along the perimeter with the profiled stone blocks. It is elevated in relation to the elevation of the terrain and is located on a kind of semi-level between it and the elevation of the ground floor of the building. Below the balcony there are laterally covered

open vestibules from which one enters the central closed part in the width of the staircase. The balcony railing consists of solid brick masonry pillars, between which is a wrought iron railing. The walls are made of solid brick and stone in the lower zone and are plastered on both sides in the brick part and treated in the same way as the rest of the facades in those zones. The staircase, also centrally placed, rests on solid brick walls. The stair treads are made of profiled stone blocks and are composed of segments (2 or 3 depending on the width). All masonry parts are in poor condition, certain parts need to be completely rebuilt. All mortar coatings must be removed and re-finished in the same manner as original. The "terrazzo" lining is in poor condition, so it also needs to be repaired. The wrought iron fence requires restoration, as do all the stone blocks (stair treads and balcony gutters).

The façade plinth in all parts of the building (Zone I), except the entrance staircase, is built in the same way, with stone blocks, with a profiled wreath at the top. The stone is of very high quality and rustically processed, and apart from surface damage and a few isolated cases of structural degradation, there are no major problems that need to be solved. Surface biodegradation (mosses, lichens, microorganisms, etc.) prevails, which developed due to the large amount of water flowing from the facade, as well as in the lower zones, where water comes from the ground. Also, graffiti can be seen on some parts. In this zone, there are stairs at the auxiliary entrances, also made of stone blocks, so beside all other planned work it is necessary to perform their conservation, restoration, stabilization, and replacement of the missing parts.

Zones of facade surfaces treated with mortar (II, III, IV): depending on the amount of water that flows through the facade and penetrates through the walls, different types of damage can be noticed on the facade surfaces. In principle, zone II has the least damage because it is the lowest and the least water from the roof, gutters, etc. reaches it. The amount of damage increases along with the increase in height. We distinguish two types of damage - *large*, which requires complete removal of all plaster coatings, occasional repair of the substrate and walls and re-execution of all elements according to the original and - *small*, which are mostly on the surface and require only removal of paint layers, repair of small damage, such as thin mesh cracks, followed by finishing and painting. Also, all cordon wreaths, protruding elements, such as windowsills, window openings and doors, are largely damaged and in most cases must be rebuilt completely according to the original elements. In addition, the replacement of facade joinery will require work on all elements that are in contact with it, because they will have to be dismantled and removed.

Attic zone of facade surfaces treated with mortar (V) have the greatest damage present. Most of the plaster surfaces have been washed away or degraded to such an extent that they must be completely removed and rebuilt. Also, surfaces and masonry parts require interventions in terms of repair and restoration.

In the area VI (superstructure) we distinguish two types of damage - mostly superficial plaster damages and structural, in combination with the previous one, where it is mandatory to rebuild parts or whole elements.

When it comes to facades, it should be said that all gutters and sheet metal edging are in poor condition and that they need to be completely replaced with new ones, also, it is necessary to adapt the existing lightning protection installation, because it is in poor condition. In addition, the remains of electrical installations should be removed, which are attached to the facade planes, because they are worn out and out of function (E.V. Petrović, 2020a).

Facade joinery consists of several types of windows and doors (entrance and balcony) and is all made of wood. In principle, all windows are in very poor condition and cannot be restored or repaired, so they need to be replaced. The wood material is rotten, many

parts and elements are missing. When it comes to doors, all entrances are in relatively good condition, when it comes to the structure and main parts, but they lack certain elements, they have added parts, they have undergone changes, so they will be preserved and restored, while the balcony will be replaced new.

Special attention is paid to the roof structure, where it is estimated that 100% of the roof planking, 80% of the rafters and 40% of the rest of the supporting structure must be replaced (see Fig.5). It is made entirely of wood and consists of a central part and independent roof structures in the towers and above the protruding front part of the building, so there are five in total. All roofs are hipped, covered with metal panels. Roof constructions and roof planes are positioned behind the superstructures, so that in general the construction of such roof created a potential problem for a period in which there is no continuous maintenance or as in this case for a period in which there is a complete absence.

This installation caused great damage to the façades and in some internal parts of the building, and the fact that the last reconstruction of the roof was somewhat clumsily and carelessly carried out contributed to a large part of the roof structure itself suffering damage (see Fig 5).

Fig. 5 "Karađorđev dom", interior of the attic (left), damage caused by inappropriate roof reconstruction (right) author: E.V.Petrović (November 2020)

Fig. 6 "Karađorđev dom", "*pull-off"* test results (test No4)-left, test results (test No1)-right, author: E.V.Petrović (November 2020)

6. MATERIAL TESTING

Based on a detailed analysis of all building structures of "Karađorđev dom" - current condition, mapping of negative impacts and types of damage, and implementation of testing and research procedures, which are documented and adequately transferred to technical - graphic, written and photo documentation, methodological approaches and types are defined, as well as conservation and restoration procedures and the need for additional testing of material.

Due to the great damage to the facades, both the plaster surfaces and the masonry structures themselves, we did the following:

- *"pull-off"* test on plastered surfaces, which is performed in situ: the main reason for this type of test is to determine the degree of damage to the plaster on certain parts of the façade, and to determine the surfaces on which the complete removal of the layers of material will be done, and
- testing of physical and mechanical characteristics of bricks (M.Muravljov, 2001), which was performed in laboratory conditions; all walls that have been exposed to water and moisture for many years, in addition to problems with the loss of surface material (mortar), have obvious problems with the effect of the same negative factors on the flushing of joints and binder which could affect the properties of brick itself, as the main building material; we have expected that based on the results of this test, we will be able to determine to what extent the brick could have been damaged in the mentioned processes and whether it requires some kind of intervention, in order to improve its properties.

The *"pull-off"* test is a method for determining the physical properties of a material on site and is generally used to show the degree of bonding of a particular material to the substrate and to determine its surface tensile strength. In our case, we examined the bonding of the plaster on the outside of the walls, to the brick base, of which the masonry structures themselves are made. The basic idea was to determine the condition of the plaster in different zones and in different positions, in order to define the conservation-restoration approach, with the aim of retaining the original materials as much as possible in case they are healthy and preserved. Testing was performed at 3 positions on the northeast façade and another 2 on the southeast façade, in zones II, III and IV.

The results of the tests showed that the mortar used for plastering of the façades was extremely durable. Only one, out of four test zones, was in bad condition and that the entire mortar layer must be removed there (see Fig.6).

Physical and mechanical characteristics of bricks are defined in this case by a method that includes *in-situ* sampling of materials and laboratory testing. Samples were taken from the place where the masonry structure was degraded to such an extent that no additional destruction was needed, but a destabilized piece of masonry structure (bricks connected in places with mortar) was simply removed by simple lifting and transport to the laboratory. Laboratory tests were performed at the Faculty of Civil Engineering and Architecture, University of Niš (E.V. Petrović, 2020b).

The results showed that the bricks are of satisfactory quality and that the planned works and interventions can be carried out.

6. CONCLUSION

There are three dominant factors that set the “Karađorđev dom” building apart from others and give it a special value:

1. A very strong connection with the character and life of Karađorđe (which is generally a feature of the wider area of Rača, including the place of his birth, which is in the immediate vicinity), and then with the royal dynasty of Karađorđević.

2. The nobility of Karađorđević family and Queen Maria, from whose fund the construction was done but also the selflessness of the Serbian people, who helped the building of a home for orphans after the Great War, although they were already bearing on their tormented shoulders all the weight and magnitude of the destruction that preceded the war years behind them.

3. Symbolism and monumentality of the architecture of the building itself, which was located almost a hundred years ago on the outskirts of a town in the heart of Serbia (E.V. Petrović, 2020c).

When we observe this facility in real time and space, it still has the same features, regardless of its current neglected condition, and therefore deserves a truly comprehensive and continuous care and constant presence of users and guardians.

"Karađorđev dom" currently has a total usable area of about 2,907.00 m2, and if you add a very attractive cover area, you can get a total area of about 3,876.00 m2, which provides many opportunities for different purposes. The building consists of very representative spaces on the ground floor and first floor, including large central halls and a ceremonial hall on the first floor, as well as spaces in the basement, which can also be activated and used in various ways.

Analyzed materials have shown that the bricks used to build the building have good characteristics, as well as that e.g., the existing load-bearing walls of the building can receive loads from the new floor structure between the first floor and the attic, in case the owners and users decide to activate this space.

The attic part of "Karađorđev dom" is the highest point in the area and by forming a gallery in this part, you can get an excellent lookout, which is another reason for its use.

Also, it is very important to note that the building has a total of 4 entrances, as well as one auxiliary - economic, below the main entrance staircase, as well as two staircases in the interior, one of which leads to the attic space. This means that the various functions of smart planning can be completely separated, and that even a variant in which a public-private partnership would take place can be quite a solid survivable model.

When intervening in the interior, especially in representative parts, special care should be taken to cancel all subsequent and harmful interventions and to return the premises to their original volume and appearance, while adjusting certain details to modern needs and new purpose (E.V. Petrović, 2020c).

By implementing the reconstruction Project and the ideas and results presented in the accompanying Studies, the Municipality of Rača will have a great chance to preserve their main public building and furthermore to present it to the public in the best light (EUROPEAN COMMISSION, 2018.).

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„KARAĐORĐEV DOM" U RAČI: PRVI KORACI U PROCESU REHABILITACIJE KULTURNOG DOBRA

„Karađorđev dom" u Rači, monumentalna građevina, zaštićena kao spomenik kulture, čija je izgradnja završena 1933. godine, nakon dugogodišnje upotrebe i više promena namena, napušten je od 2016. i sada čeka svoju prvu obnovu. Projekat rehabilitacije, započet na inicijativu opštine Rača, predviđa brojne aktivnosti u cilju sprečavanja njegovog daljeg probadanja i preispitivanja mogučnosti za njegovu ponovno oživljavanje, adekvatnu prezentaciju i trajnu zaštitu. U radu su prikazani prvi konkretni koraci realizovani u toku 2020. godine.

Ključne reči: *Karađorđe, Rača, rehabilitacija, konzervacija*

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