SPATIUM
No. 43, June 2020, pp. 44-51

UDC 728.6(495.6)
728.1(495.6)
Preliminary report - Short Communications
DOI: https://doi.org/10.2298/SPAT2043044D

CONTEMPORARY VARIANT OF A TRADITIONAL MACEDONIAN BONDRUCK HOUSE

Gjorgji Dimkov[1], Faculty of Architecture, University "Ss Cyril and Methodius", Skopje, Republic of North Macedonia

The traditional bondruck system for constructing single-family homes, which is one of the most important segments of Macedonian material culture and heritage, can create a path for developing and improving contemporary design and construction solutions for sustainable architecture in Macedonia. The classic variant of traditional bondruck has not been of a high enough standard over a long period of use, which was also the case even at the time when it was a popular building method. Some disadvantages of its classic variants such as: the lack of quality materials for external and internal processing, inconsistent stability due to technological defects in the wood, a low standard and level of physical performance, functional deficiencies etc., can be overcome with modern technological solutions, the use of new building materials, and the possibility of systematic planning in a market economy, combined with the realization that a higher standard of housing is needed today. Based on an analysis of traditional Macedonian bondruck, it is possible to make a contemporary version of this system with improved quality of performance, both of individual elements and of the whole system. This is demonstrated by the proposed solution of a reference house in the village of Bitushe, built with the traditional bondruck system.

***Key words*: contemporary, variant, traditional, Macedonian, bondruck house.**

INTRODUCTION

The task of this research is to explore the possibilities for enhancing bondruck systems that would introduce traditional construction concepts into modern building practice, with the aim of improving technical and energy performance and achieving adequate living comfort, as well as preserving the environment. This indicates that the topic is a contemporary one, and that scientific research can be put into practice.

Several scientific research methods have been used to design this study according to the nature of the problem and the field of research:

- Content analysis: research of reference literature, visiting and recording selected locations and measurements in the field, a case study;
- The historical method, which was used to obtain accurate knowledge of the course of particular social processes, taking into account the chronology of development, and the causal and consequential dependencies of the problems in question. The main instruments used in this method are published works and texts, projects and technical documentation;
- The comparative method, in order to establish a connection between the appearance of a general phenomenon in close or related fields, by constructing a positive or negative analogy; and
- Synthesis of the results.

After the synthesis and comparative analysis of the data collected and the results of the analyses, the basic principles and conclusions were established in the form of a reference model with satisfactory technical, energy and design performance.

TRADITIONAL ARCHITECTURAL CONSTRUCTIONS IN MACEDONIA

The architecture of houses built in the 18th and 19th centuries, scattered in the cities and villages of Macedonia, with its high-quality achievements in terms of function, construction and aesthetic design, reflected the socio-economic and political circumstances in the Ottoman period (Namičev and Namičeva, 2014).

The traditional house in Macedonia inherits its forms from the medieval house, the remains of which, due to the poor building materials used, have not been preserved to this day.

[1] Partizanski odredi 24, 1000 Skopje, Republic of North Macedonia
georgi_64@hotmail.com

In the so-called national architecture of Macedonia, we encounter extremely correct functional solutions, which can be said to be based entirely on modern principles. If we start with the construction of the house in relation to the insulation and the view of the landscape, and then consider the organization of the interior space and the ventilation of the rooms, with its windows placed in a row, we will see that the Macedonian master deeply penetrated and mastered the positive principles of spatial solutions with regard to the exterior, and even more the interior.

The shape of the buildings themselves, which have a ground floor and one or two floors, has a high aesthetic value in the architectural dismantling of the mass, with various architectural motifs. The relationship between the full wall surfaces and the openings, as well as their proportions, creates certain harmonious effects important for shaping the facades (Nikoloska, 2003).

Of particular interest is the actual construction of the Macedonian house. It is essentially functional, economical, standard, bold and often spiritually formed. Thus, the achievements of Macedonian national architecture can be said to represent, in most cases, a unity between function, construction and aesthetics, achieving a single harmony in the architectural expression.

The building traditions on the Macedonian territory were historically quite developed, from the late antique and early Byzantine achievements, and later throughout the Middle Ages. The numerous preserved monuments of sacral architecture are the best proof of the skill of the Macedonian masters in performing quite bold constructions. The building materials were primitive: stone, wood, lime and sand, and the technical means of construction were quite simple.

Having these conditions in mind, the ability and inventiveness of the Macedonian master is expressed in every house, and especially in the construction of larger houses and monastic complexes.

The completed works of the Macedonian masters abound with extraordinary construction solutions, both in the application of the material and its processing, as well as in the shaping of the forms. Without static calculations and based on experience, with great knowledge of the craft that was passed from generation to generation, the Macedonian master created a rational and at the same time unobtrusive construction, always with the function of individual units. Therefore, we can conclude that the function of the construction itself is clearly understood and consistently implemented, with cost effectiveness as a result of knowing the above principles.

The most common construction in traditional Macedonian houses is the bondruck system. It is a skeletal wooden structure consisting of horizontal and vertical wooden beams 14/14 or 16/16cm, fastened with brackets (Figure 1). Carved planks up to 1cm thick are nailed on the inside and outside of the wooden skeleton, onto which mortar is applied on both sides. The total thickness of such a wall is 18-20cm, and it is a combination of two canvases with a layer of air – the construction is quite light, with good insulating properties. This construction can be found on the upper floors of houses in Ohrid, Struga and other places (Figure 2). "In village houses, the space between the planks was filled with gravel, sand and mud" (Tomovski, 1959-61: 3).

Figure 1. Skeleton of a wooden bondruck system at a house in Ohrid (Source: Tomovski, 1959-61: 3)

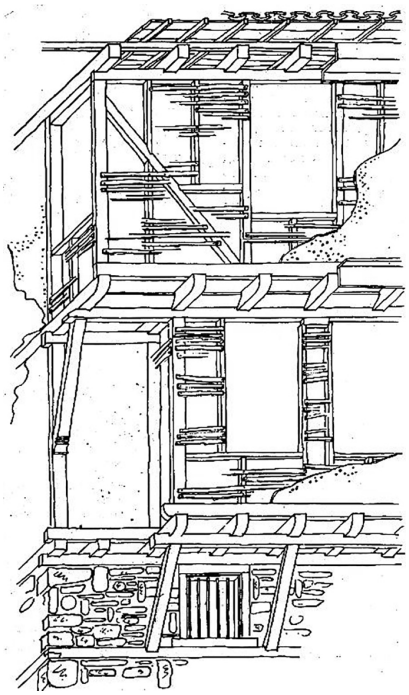


Figure 2. The bondruck construction was applied on the 1st and 2nd floor. The ground floor is masonry. The axonometric display of the constructive assembly shows the solution of the bondruck walls built in the Ohrid houses (Source: Tomovski, 1959-61: 4)

There is a strong south wind in Ohrid that tears the plaster from the facades. Therefore, often the walls are not plastered at all, but lined with a metal sheet as protection against the wind, so we can study these walls at all stages of their construction. The bondruck is almost American in style, filled with straw, then coated with a "shepher's" plank (Macedonian term) and plastered, or lined with an anti-wind sheet on the high ground floor made from a row of stone. On top of all of that is the roof, which is covered with shingles – to protect against the wind.

This type of construction was described by Grabrijan (1986: 145):

> "Isn't that a semi-dry construction? Only the clay between the stone and the plaster on the wooden planks of the "shepher" is wet, everything else was built dry. At the fishermen's houses in Ohrid, even the ground floor was built on wooden poles everything else was built dry and plastered. And when the metal sheet replaced the plaster, then it became a completely dry installation, built on completely modern principles and different from the brick construction".

In some places the bondruck construction is filled with "kerpich" (unbaked bricks). Of course, in these cases the construction is heavier in weight and the insulation is weaker. "Chopped straw, wood shavings, wood chips, dried corn leaves and other natural materials can be used for filling. This treatment of the wall contributes to its light weight" (Tomic *et al*., 1983: 67). In mountain villages, such as Galichnik and Tresonche, the console parts of the floor are usually lined on both sides with wooden planks that remain visible. In all of the above examples, the bondruck structure itself is not visible. There are also rare cases (in Galichnik), where the bondruck construction is visible from the outside, while the inside is covered with wooden planks.

Certain parts of the bondruck, such as the vertical and horizontal beams around the corners, around the windows and the visible wooden beams of the floor structures, parts where the plaster is poorly retained, are covered with wooden planks. The covers, therefore, have a purely functional role in which the Macedonian master shows his sincere attitude towards solving these seemingly small details. On the other hand, the covers and the aesthetic enrich the facade. With their dark patina, they contrast white and light-colored wall surfaces.

The bondruck construction allows the release of part of the floor or the whole floor, as well as the upper floors from the ground floor line. The cantilever overhang from the upper floors is due to a lack of building space and has a functional justification – it corrects the shape of the ground floor, which often follows the street line and has irregular shapes; it expands the rooms on the first floor, giving them more correct shapes, and it allows the installation of windows on both sides, which serve to look at one or the other side of the street. These cantilever overhangs are supported by consoles or brakes if they are larger or not in the direction of the floor beams.

The brakes are often visible, but can be also covered with wooden planks in various profiles, onto which mortar is applied. In addition to supporting the cantilevers, the brakes are also used to support other ejected parts, such as chimneys, stairs, eaves, etc.

Free-standing wooden pillars are load-bearing structural elements. If the wooden pillar is located on the ground floor, it is situated on a stone dug into the ground. At the top of the pillar is a wooden, usually profiled, capitula, through which there is a horizontal floor beam.

The foundations and ground floors of houses are usually masonry with stone between 50-80cm thick. Often the stone is also present in the upper floors, completely or partially, which is especially evident in houses in mountainous areas (Galichnik, Lazaropole, Tresonche, Krushevo, etc.). The stone walls are leveled and connected with wooden "santrach", a type of wooden cerclages at a distance of 80cm. Usually, stone walls are not plastered due to their resistance to weathering. Stone that is crushed or carved remains visible. Thus, a rustically treated ground floor looks heavier than the other floors, which is logical because those walls carry the structures above the ground floor. "For the construction of the ground-floor walls in village houses, unbaked bricks were often used, especially in houses with only one floor. Those walls are plastered and painted" (Tomovski, 1959-61: 85).

In general, the composition of bondruck walls and wooden profiles is very adaptable, improvised in situ, depending on the need and the size of the wood available, and then the size of the openings in the wall; there is no pre-determined method used to connect the wood – it is just cut and joined with nails, but never absolutely processed and flat. The trees are usually only cut into smaller profiles and are short in length. Even the wooden profiles (8/10cm) in the Ohrid houses are made according to the American bondruck system, at a distance of 40-60cm (Grabrijan, 1986).

Traditional Macedonian city and village houses both have a sloping roof. Since there is not too much snow, the roofs have only a slight slope, except in mountainous places, where they are steeper. They are covered with tiles, stone slabs or straw, depending on the construction site and the material available. In mountainous areas, houses are usually covered with stone slabs, and in settlements in the plains – with tiles. The Macedonian master was not always economical in the construction of the roof. On the contrary, the roof constructions abound with a lot of timber, due to the heavy roofing materials (such as in houses covered with stone slabs). The "chair" system is most commonly used, and the "pendant" is less common, usually in churches – basilicas. The roof structure itself is released from the plane of the walls, often up to 150cm or more, in the form of gutter-free eaves with visible wooden beams. Often, the eaves are covered with planks. Thus, the released eaves protect the facades, diverting rainwater away from the wall surfaces, which is a logical conclusion in the shape of the houses. Often, especially in city houses, the building ends with a rather protruding richly profiled wreath. The wreath is formed with a substructure. In some houses, the wreath also has a baroque shape. In city houses such as in Krushevo, Skopje and Bitola, the tympanum front is usually situated very centrally.

The floor constructions are made of wooden beams. In country houses, especially in the ground floor rooms, the ceiling beams are visible. Otherwise, the ceilings are usually covered with wooden planks with wooden moldings. The floors are also made of wooden planks or compacted clay (in country houses). In richer houses, there are carvings on the ceilings, which are examples of outstanding Macedonian woodcarving.

Stairs are always wooden, usually in patterns. In houses with a loggia (chardak), the stairs are situated in the porch (trem) and they lead to the loggia on the upper floor, from where the living rooms are accessed. In some monastery lodgings, the stairs are outside, on consoles, from the plane of the loggia. In this way, the vertical movement takes place freely, without taking up space from the porch or the loggia (Figure 3).

The structures and structural elements described are the most important ones, which are usually standard and appear in almost every Macedonian house.

Figure 3. The lodging in the monastery of St. Jovan Bigorski. The stairs are built out of the plane of the loggia (Source: Photo by the author)

> "The richness of the construction, the materials used and their processing, as well as the static regularities and the aesthetic created all demonstrate the inventiveness and capability of the Macedonian craftsman, who created with primitive materials and technical means using state-of-the-art building principles. Some structures of old houses serve as examples that can be applied in newly designed modern constructions" (Tomovski, 1959-61: 41).

PROPOSED SOLUTION FOR A CONTEMPORARY VARIANT OF A TRADITIONAL MACEDONIAN BONDRUCK HOUSE

An analysis of the construction of a traditional Macedonian bondruck house can be a starting point for forming a contemporary reference type variant as a proposal for modifying the traditional bondruck system and eliminating some of its shortcomings by applying contemporary technical solutions, which was one of the main tasks of this research. A contemporary reference-type variant was obtained by optimizing the energy performance of the basic structural elements, using contemporary materials that meet the requirements for thermal and sound insulation, design characteristics, safety of the structural system and construction technology, flexibility and energy savings.

For example, the exterior walls can be of much better quality, both in terms of the facade finishes and in relation to the intermediate layer and interior finish.

A. The final **exterior cladding** of the building can be achieved with a variety of contemporary materials that will allow the authentic appearance of traditional bondruck to be achieved: two-layer extension mortar made over a corrosion-resistant steel rabic mesh substrate or plastic mortar, waterproof plywood, ribs or corrugated sheets, etc.

B. The **Intermediate layer** with thermo-acoustic protection can be achieved with: an air gap of 3-5cm, positioned immediately after the coating material, which can be ventilated (in summer) or trapped as additional free thermal insulation (in winter). Then, better thermal-sound insulation can be achieved with: expanded polystyrene, lightweight special construction boards (heraclit), mineral, glass or stone wool 10-15cm thick as needed, reinforced with additional thermal insulation from the inside and outside side panels, hard-pressed 2cm thick polystyrene, hard-pressed mineral wool or polyurethane.

C. **The interior finishing** of the walls can be made of different building materials depending on the purpose of the partitioned rooms (gypsum board or wooden boards, panel boards, OSB boards, etc.), mounted on a wooden or metal substructure, between which the internal thermal isolation is positioned. This space between the metal subframe also allows the position for conducting electrical wiring cables, which in classic bondruck house are made on the outside of the partition wall, which are visible and therefore unprotected (one of the disadvantages of the traditional bondruck system).

All other architectural and design elements of the facade (vertical and horizontal cladding, window decorations, etc.) can be executed equally authentically with the classic variant, enhanced by new styling and design (Figures 4, 5 and 6).

Of course, this contemporary variant, over time, in accordance with experience and new needs, can continue to be a perfect solution for most of the key shortcomings of the traditional bondruck system. Certainly, one of the most serious shortcomings of traditional bondruck was the inability to provide sanitary facilities that were well protected from the effects of water and moisture. The waterproofing materials that we have today and the technical capabilities for their application mean that this problem is becoming banal, and even new, innovative solutions are possible.

The contemporary variant of the traditional bondruck system (Figure 7), designed using an adequate modular system or a completely free-developed architectural basis, makes the achievement of a new quality of architectural expression possible, both through the authentic application of traditional architectural forms and a completely new

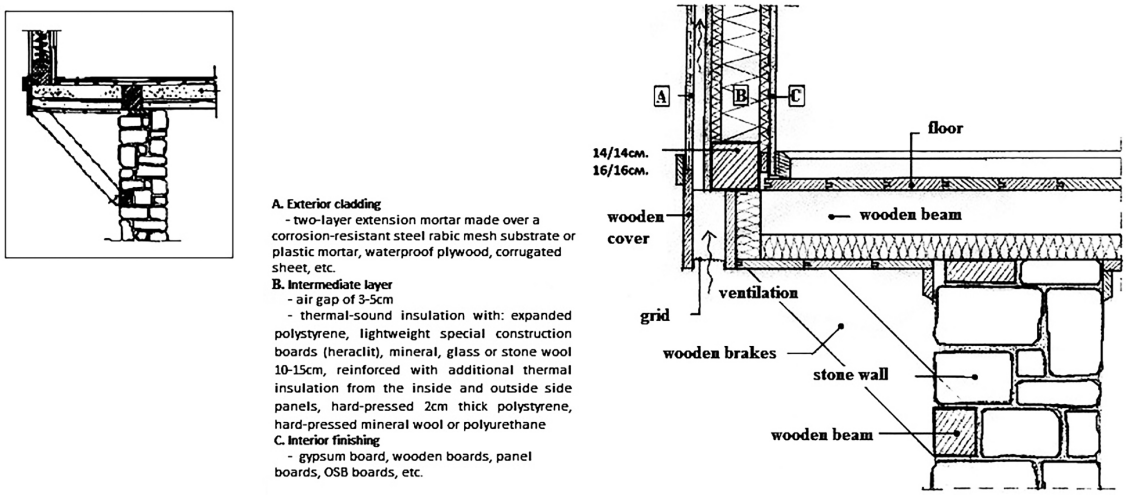


Figure 4. Contemporary variant (right) of a traditional bondruck system (left);
Cantilever formed by gradually releasing the beams from the floor structure supported by brakes
(Source: Drawings by the author)

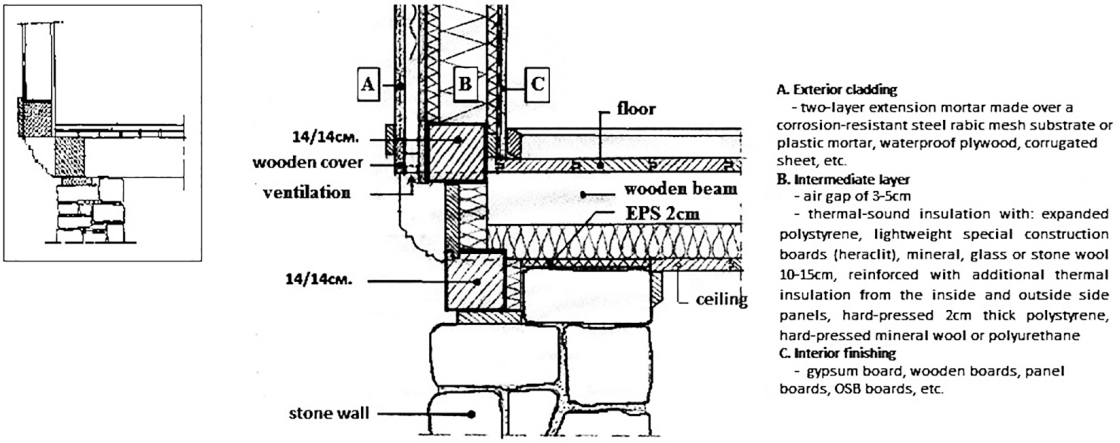


Figure 5. Contemporary variant (right) of a traditional bondruck system (left);
Detail of cantilever formed by a slight ejection of the profiled heads of the beams from the floor construction
(Source: Drawings by the author)

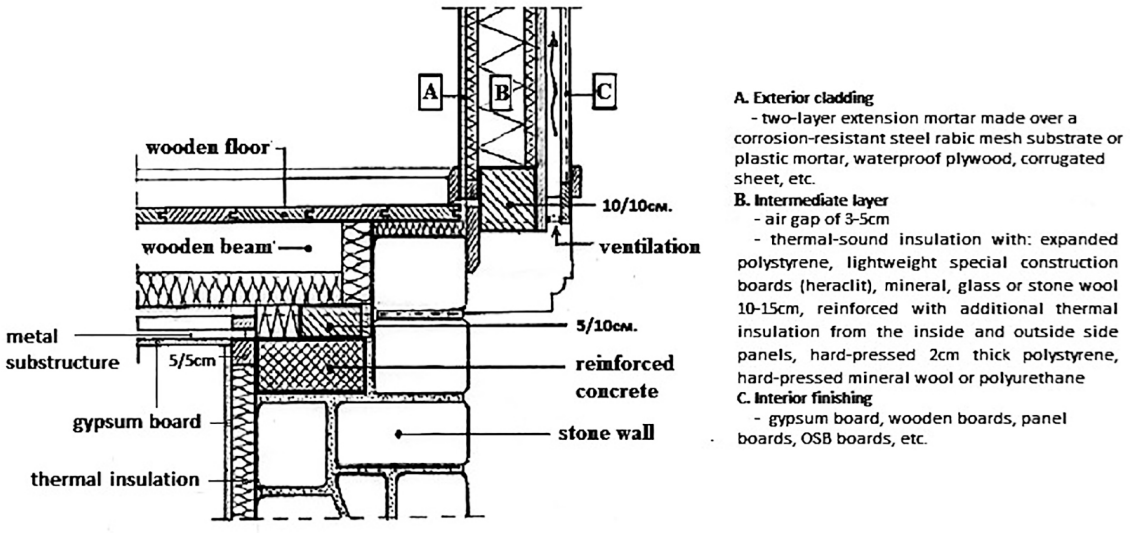


Figure 6. Contemporary variant of a traditional bondruck system;
Detail of a console released bondruck wall for a building with a basement or ground floor
(Source: Drawings by the author)

stylization and inventiveness in the design of the facade, to the extent that it may well follow the most recent tendencies in architecture.

This is demonstrated by the floor plans (and adequate details) of the reference example of a traditional bondruck system for an existing old house in the village of Bitushe (Figure 8). The building has three floors: the basement (with porch called "trem"), the ground floor (with hallway called "gjizentija" and cellar called "kled") and the upper floor (with the main living space called the "house" and two rooms called "odaja"). The stone wall of the basement and ground floor also extends upstairs in the area of contact with the neighboring building and the facade closure of the "house". Bondruck walls appear only in part of the facade closure of both rooms. One bondruck wall is in the line of the stone wall of the ground floor and the other is cantilevered (details in Figure 8).

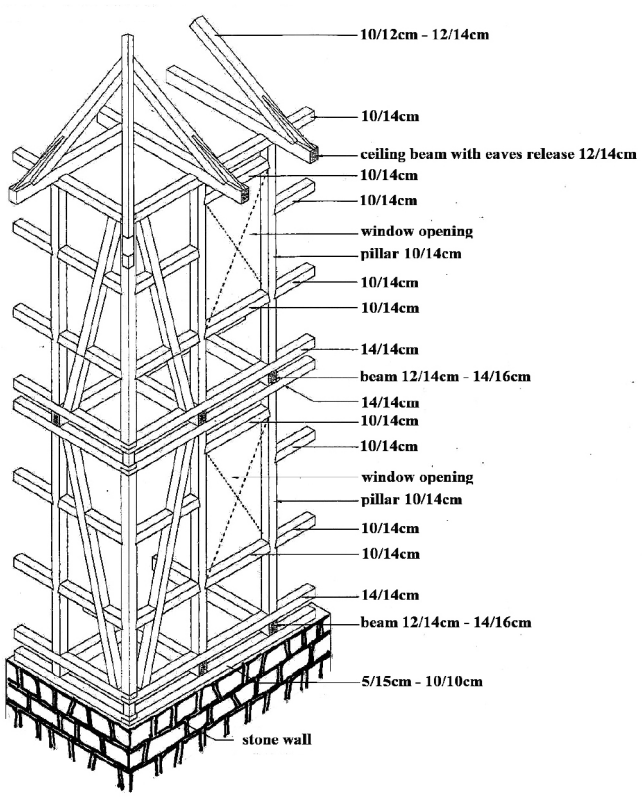


Figure 7. An axonometric display of the contemporary variant of the traditional bondruck system
(Source: Drawings by the author)

The following is the proposed solution for the same spatial concept in the contemporary version of the traditional bondruck system, shown in the floor plans (Figures 9a and 9b) and in the characteristic details of the floor plans (Figures 10a, 10b and 10c).

In order to preserve the authenticity of the traditional facade design, the stone walls of the ground floor, and the upper floor, it is proposed that the "sandwich" consists of: a facade cladding with stone 18-48cm thick, a 3.5cm concrete layer, thermal EPS insulation 5cm thick, a 12cm brick layer and lime-cement mortar of 1.5cm as the interior finish. Thus, the total thickness of the wall can vary from 40 to 70cm (as with the original, exclusively stone wall).

Figure 7 shows a variant solution with stone walls covered only on the inside with thermal EPS insulation 5cm thick and gypsum board 1.25cm on a frame of wooden slats 5/5cm.

Due to the reduction of the initial thickness of the stone wall (70cm) and to enable its load-bearing function, the new proposed solution requires the establishment of a skeletal system with reinforced concrete columns and beams in the position described in the floor plans (Figures 10a and 10b).

Variability in the dimensions and composition of the sandwich facade walls, traditionally built only in stone, as well as those built in the bondruck system, depends on the orientation of the wall, the climate zone in which the building is located, and the new purpose of its premises. In this way, better thermal protection can be achieved with the coefficient U=0.25-0.30 [W/(m^{2}K)].

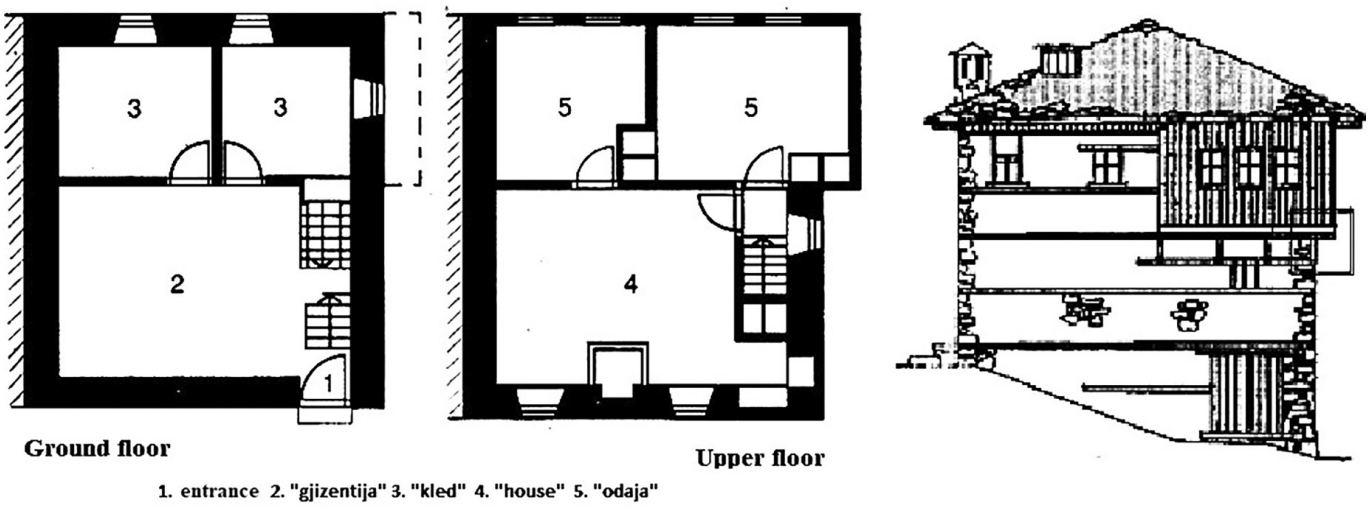


Figure 8. . Old house in Bitushe
(Source: Brezoski, 1993: 82)

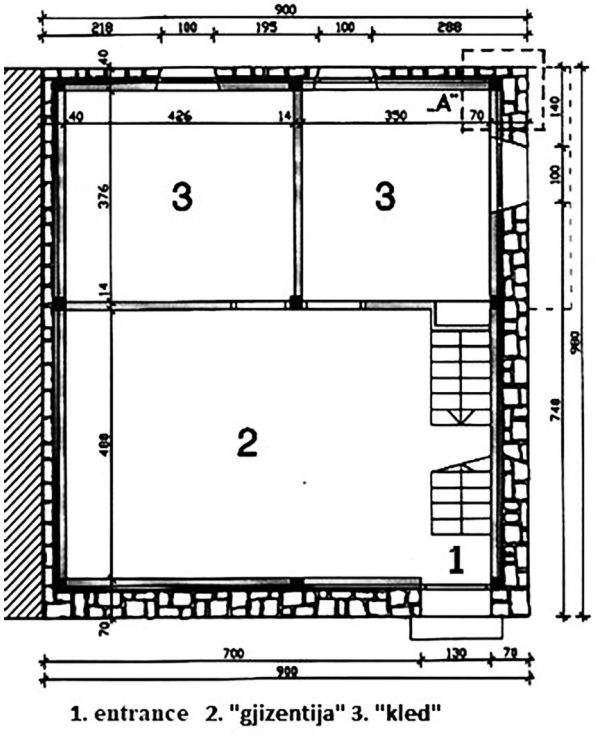


Figure 9a. Ground floor
(Source: Drawings by the author)

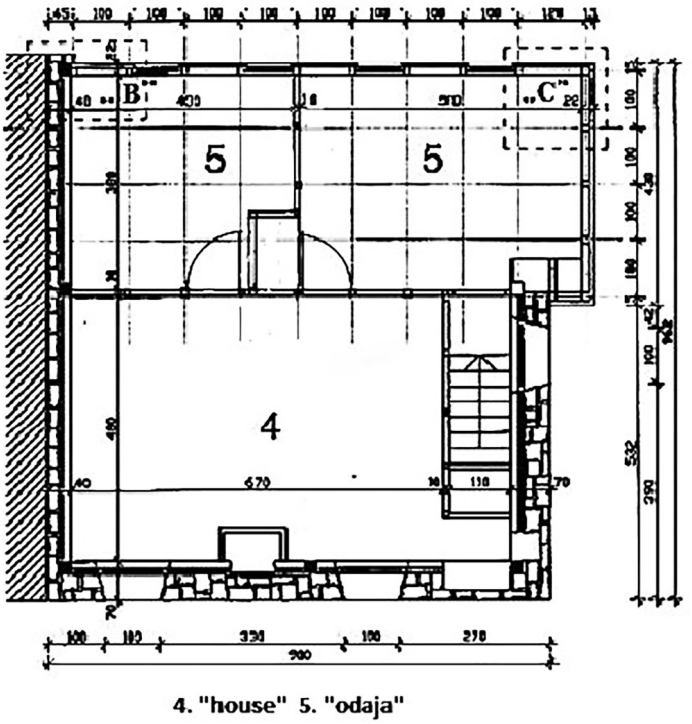
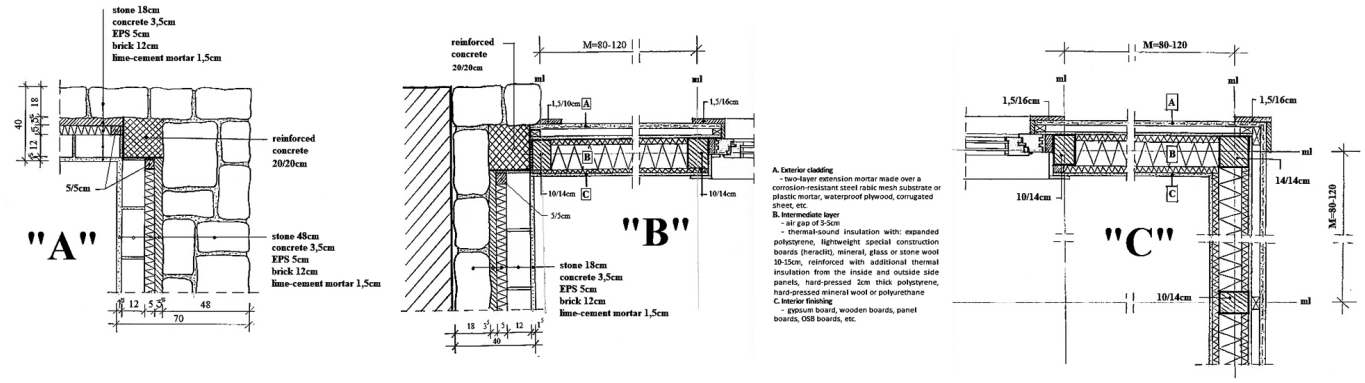


Figure 9b. Upper floor
(Source: Drawings by the author)



Figures 10a, 10b and 10c. Details of the joints of the facade walls ("sandwich" with finishing facade cladding of stone and the bondruck system)
(Source: Drawings by the author)

CONCLUSION

The analysis proves the values and advantages of bondruck systems, which can open the door to the true reaffirmation of this traditional architectural form through its further contemporary development, both in terms of using higher quality materials and applying modern processes to create a new architectural expression.

By applying quality processing methods and materials to the so-called "dry" installation process, as well as the use of sophisticated heating systems and infrastructure systems (installations), this architecture can greatly exceed the performance of current construction systems, especially in terms of construction time, cost-effectiveness during operation, energy savings, more comfortable conditions, bio-climate subordination and environmental balance.

This is in addition to their environmental friendliness, opportunities for easy recycling, replacement of most of the materials used, and flexibility if interventions are needed, even in the construction system. In addition to this, through the research and refinement of this construction system and on the basis of experiential knowledge during construction, this system can greatly exceed the performance of even contemporary bondruck systems that are applied today in the developed countries of the world.

The results of the analysis and proposed solutions confirm the basic task of this research: to formulate a proposal for a modified traditional bondruck system and a solution with contemporary materials that meet the requirements for thermal and sound insulation, as well as the safety of the construction system and construction technology, flexibility

and energy savings. This opens the door for the reaffirmation of this traditional architectural form by developing and applying a contemporary better quality variant.

REFERENCES

Brezoski, S. (1993). *Rekanska kuќa* (in Macedonian). Skopje: Bigoss.

Grabrian, D. (1986). *Makedonska kuќa - ili preod od stara orientalska vo sovremena evropska kuќa* (in Macedonian). Skopje: Misla.

Namičev, P., Namičeva, E. (2014). *Traditional city house in Northeastern Macedonia*. Skopje: Petar Namičev.

Nikoloska, M. (2003). *Gradskite kuќi od 19 vek vo Makedonija (prostorna organizacija)* (in Macedonian). Skopje: Republički zavod za zaštita na spomenicite na kulturata

Stojkov, T. (2006). *Practicum III – bondručni i lesno-montažni (BOLMO) sistemi, zbirka na rabotni crteži, detali i proekti, pp. 53* (in Macedonian).

Tomic, Lj., Pljakoski, D., Filipovski, Lj., Boskovski, V., Stoilova, M. (1983). *Erker i ograda vo arhitekturata* (in Macedonian). Skopje: Naša kniga.

Tomovski, K. (1959-61). Za konstrukciite vo narodnata arhitektura vo Makedonija (in Macedonian), *Zbornik na Tehničkiot fakultet – oddelen otpečatok. Skopje: Univerzitet vo Skopje, pp. 14.*

Received April 2020; accepted in revised form June 2020.