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Wood as the Main Building Material in the Construction and Materialization of the Bosnian Chardaklija House

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Abstract
Wood is one of the natural materials with which man first began to build. From the Neolithic Age (4500-2000 BC) to the Late Iron Age (around 1000 BC), man built individual houses and entire settlements of wood, over water (soynice). Access bridges, pylons for the foundation of objects in water bodies (rivers, lakes, seas) and the entire structure were built of wood. In some historical periods (the colonization of North America, for example) wood was the key building material for fast and relatively cheap construction, from individual buildings, family estates (ranches), bridges to entire cities. By designing laminated wood, wood becomes a 'modern' material with completely new properties (especially high structural properties) that can be compared to the properties of reinforced concrete and steel. In addition, wood remains a 'natural material' that never ends up as waste that would burden the natural environment.

Keywords: Wood, Natural environment, Bosnian chardaklija house

1. Introduction

About 4 billion hectares, or about 31% of the world's land area, is covered by forests. The sustainable management of this forest estate is critical for the World Bank for several reasons. First, forests are home and food for millions of people, including some of the world's poorest. Second, the results of deforestation in difficult local and global conditions are damaging to the environment. Third, controlled/sustainable commercial exploitation of forest products could contribute to economic growth. However, the characteristics of forests make sustainable management challenging. The positive externalities of forests are uncertain, diffuse and difficult to access. Deforestation outweighs the benefits of conservation or sustainable management [1]. Bosnia and Herzegovina is the country with the largest share of forests and the greatest diversity of forest species in the Western Balkans. Due to their natural and diverse structure, as well as significant natural regeneration, they represent a key resource for the further development of the economy and society. Forests and forest lands in Bosnia and Herzegovina cover an area of 3,231,500 ha, of which 1,652,400 ha are tall forests and 1,252,200 ha are pine forests [2]. The other part includes bushes, bare and other forest land. These data point to the fact that about 63% of the territory of Bosnia and Herzegovina is covered with forest and forest land, with values that are among the highest in Europe, of which about 20% of forests are privately owned, or 80% are state owned. Forests are characterized by a great variety of types, because the country itself is geographically well positioned in terms of different climatic influences, from coastal Mediterranean forests to mountain forests in central Bosnia and Herzegovina (Mediterranean, sub-Mediterranean and moderately continental climate zones) and has over a hundred species of trees. The main tree species are fir, spruce, white and black pine, beech, various types of oak, and in a smaller number there are species of noble deciduous trees, such as maple, elm, ash, and fruit trees (cherry, apple, pear). Forests in the mountainous parts of Bosnia and Herzegovina are characterized by the relative preservation of forest ecosystems, their naturalness, which represents a comparative advantage of Bosnia and Herzegovina. Forest stands of the rainforest type are also represented, which are separated and protected as well as the protection category according to the IUCN categorization, among which is the largest and most diverse rainforest reserve in Perućica. Since architecture is the 'framework of life' created by man, it is directly based on the environment (natural and social), on the one hand, and man - a huge system of needs, on the other. The fact of the enormous wealth of forests in Bosnia and Herzegovina cannot be omitted from the consideration of architecture [3]. The topic of this paper

The topic of this paper explicitly considers the role of wood in the construction and materialization of one of the most important programs of vernacular architecture – the Bosnian čardaklija house.

2. Wood as a building material

In architecture, wood is used to create the basic structure of a building (vertical, horizontal and inclined supports), to make opening elements, to materialize the final layer of all surfaces (floors, ceilings, walls, roofs), to make built-in and movable furniture, to make various artificial materials based on wood... Such a wide application is the result of the good properties of wood: high strength (in relation to volume weight), low thermal conductivity (λ, from 0.14 to 0.21 W/mK, while λ of stone is from 2.30 to 3.50 W/mK, brick from 0.47 to 0.76 W/mK, for example), frost resistance, resistance to chemical influences, easy workability [4]... However, wood also has its weaknesses that are the result of its organic nature: susceptibility to rotting, hygroscopicity, anisotropic structure, flammability... Considering the degree of technological processing, wood is used in construction in three basic forms: Ordinary wood obtained by mechanical processing of wood; in this form, the products retain all the authentic properties of natural wood, Wood products created in slightly more complex technological processes in which individual properties of wood are used extremely rationally (veneers, plywood, panel boards, laminated wood...), Wood-based products obtained by complex physical-chemical technological processes; here, wood waste is actually used (sawdust, shavings, bark...) where, in combination with a specific binder (organic or mineral), very high-quality materials with specific properties are created (durisol, heraclite, chipboard, hardboard)...). All of the above wood products are obtained from wood from nature. Of the three basic parts of wood in nature (root, trunk, crown), wood is mainly used for construction purposes. In the case of deciduous trees, however, the tree in a technical-constructive sense is usually not usable in its entire height, but only the trunk (the part of the tree from contact with the ground to the first major branch). In conifers, however, the entire tree is usable for technical and construction purposes, from the point of contact with the ground to a diameter of 7 cm without bark. The quality of a wooden structure mainly depends on the geometric characteristics of the tree (trunk). With regard to its use in construction, the following hardwoods are the most important: oak, beech, ash, walnut, maple, acacia and poplar [4]. The most important of the physical properties of wood are: humidity, shrinkage and swelling, volume and specific mass, and thermotechnical properties. The humidity of wood is a consequence of the presence of water (bound or free) in its mass. Free water is found in tubular cells (capillaries) and between fiber cells, while bound water is constitutionally present in the chemical composition of wood, and to a lesser extent also physically present, in the form of sticky water around fibers and tubes. Free water can be removed from its mass by the process of drying wood. We cannot remove chemical and bound water in this way. After cutting wood, in the process of natural drying, water evaporates, first from the edges of the mass, and then successively from its interior. We distinguish two areas of wood moisture: hygroscopic and capillary. The hygroscopic moisture of wood is lower than the saturation point of the fibers, and is determined by the physically bound (adhesion) of water in the wood. Its presence in the wood mass is a function of the temperature and relative humidity of the environment. The specific weight is practically independent of the type of wood and is about 1560 kg/m3. The volumetric weight differs from one type of wood to another. Since wood, as a building material, originates from a living organism, it is obvious that its volumetric weight will depend on the climate and the character of the soil on which the tree grew. Also, the volumetric weight directly depends on the moisture content of the wood. The technical properties of wood are a direct consequence of its structure, chemical composition and moisture content. For example, the coefficient of thermal conductivity (λ) in the direction of the fibers is about twice as high as the value perpendicular to the fibers. (For pine wood this ratio is $\lambda_l : \lambda_r = 0.35 : 0.17$ W/mK) [4]. As the moisture content of the wood increases, its coefficient λ also increases. An increase in moisture content of 1% corresponds to an increase in the value of the coefficient λ of about 1.25%. Similar to the coefficient λ, the coefficient of thermal expansion αi varies depending on the direction of observation. For the temperature interval from -50 ºC to +50 ºC, the value of this coefficient is as follows: parallel to the fibers α_i = 03 to 0.6 mm/m/100 ºC, radially to the fibers α_i = 03 to 0.6 mm /m/100 ºC and tangentially to the fibers α_i = 03 to 0.6 mm/m/100 ºC [4]. Some architectural programs (residential architecture, for example) are the most famous and valuable examples of traditional architecture in Bosnia and Herzegovina [4,5,6,7,8,9,10, 11,12,13,14,15,16,17,18,19,20,21].

3. Wood as the main building material in the construction and materialization of the Bosnian chardaklija house

The Bosnian chardaklija house is one of those achievements of non-native architecture that, with its spatial organization, materialization and external appearance, most vividly reflects the nature of the Bosnian and Herzegovinian man, the nature of his family and the general view of the world. This house is not just a building. It is the materialized history of a man and his family, at the same time as contemporary as a museum that, with its content, bears witness to the past and predicts the future. In the range of overall architectural programs of folk architecture in Bosnia and Herzegovina, the Bosnian chardaklija house stands out because its disposition at the moment of its original construction perceives the future, sometimes four generations of human generations following one another. It is a building designed in the way a living organism functions, and by that very nature it is an example of understanding flexibility in architecture and a precursor to the modern understanding of bioclimatic, or sustainable, architecture. The Bosnian chardaklija house is, above all, a house for rich people in the countryside. On the one hand, it is firmly rooted in the tradition of folk architecture, but it also has elements of a town house as a transitional form from purely folk architecture to a town house design that shows the influence of other, often geographically distant cultures and designs. The most developed form of the Bosnian čardaklija house was created in the region of the Zvijezda and Konjuh mountains, or in the municipalities of Vares, Ilijas and Olovo. We also encounter particularly rich designs in Travnik and in the vicinity of Zenica and Kakanj. In addition, the most developed form of the Bosnian čardaklija house implies: a rich development of the vertical construction plan (basement, ground floor, first floor and čardaks in the roof volume); symmetry of the design along the central vertical plane of symmetry; an open space ('dimluk') from the hearth on the ground floor to the badž and komina (wooden shutters) in the roof shell; the arrangement of divanhans at the floor level (one on each half of the house, in relation to the vertical plane of symmetry); a high level of spatial-organizational and functional flexibility (which allows for parallel living of one, two, four and even six families). At the same time, the level of housing comfort decreases with the number of families

living in one house at the same time. There is a large number of house solutions, between the above to the most modest one whose basic feature is the existence of a ground floor and an upper floor. On the other hand, there is a range of solutions according to the scheme of the vertical plan of a ground floor plus an upper floor (with or without a basement), without a chimney, with or without a vertical axis of symmetry (Figures 1, 2). These are those solutions that are close to the solutions of the original house of wealthy people who, primarily, live and work in the city. And while the most developed form of the Bosnian chardaklija house is designed in a way that follows the development of a family, from one to as many as six, houses that follow the solutions of the original house of the city lord are inherited, adapted and change their appearance in accordance with changes in the social environment and people with new needs. In this way, man, by himself and with his house, preserves the family code and memory of the place (genius loci), as time-tested software that guarantees the continuity of existence. The uniqueness of the natural environment in Bosnia and Herzegovina, the uniqueness of the appearance of Bosnian and Herzegovinian towns, villages, people and the Bosnian čardaklija house environment. The most developed form of the Bosnian chardaklija house, like a living organism, is born, lasts with internal (from the outside invisible) metamorphoses and finally dies. The building material of this house, as a rule, is used to build a new house (in the same location), in the conditions of the new social environment and has been noticed and presented to the professional public by travel writers, from the East and the West [6].

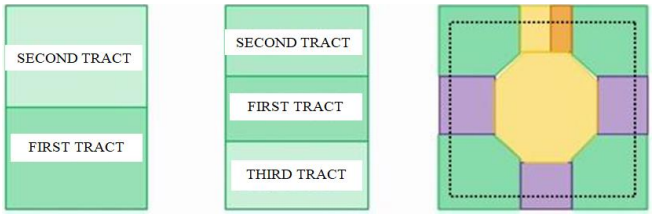


Fig 1: Basic schemes of the horizontal plan of the Bosnian chardaklija house
Source: Author (Drawing, 2016)

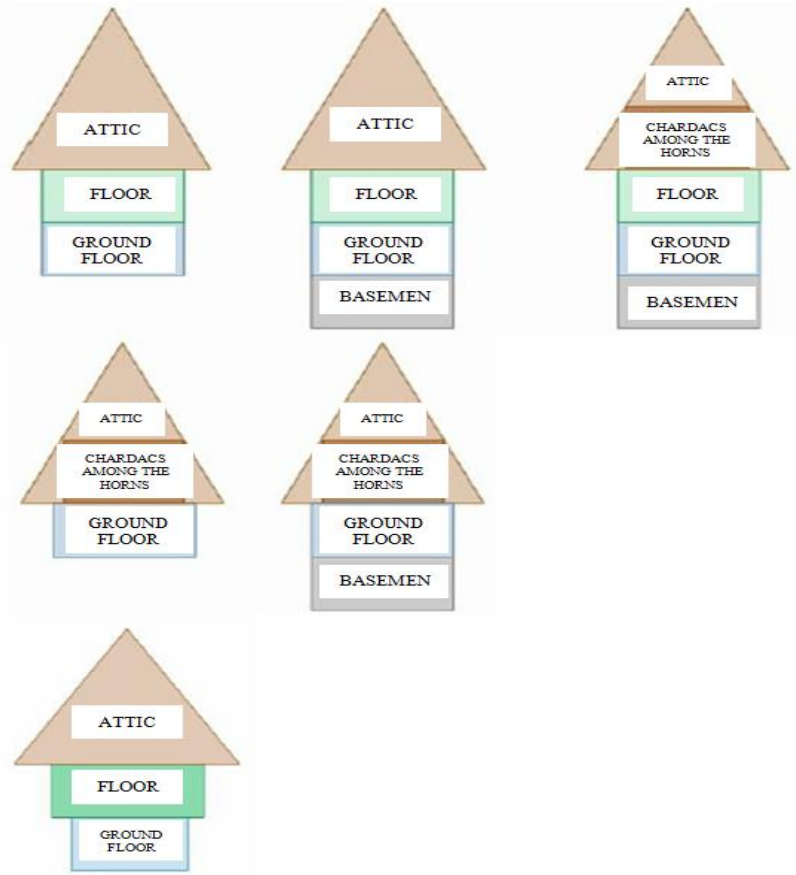


Fig 2: Basic schemes of the vertical plan of the Bosnian chardaklija house
Source: Author (Drawing, 2016)

4. Construction and materialization of the Bosnian chardaklija house

The functional-spatial requirements expressed through the disposition of the horizontal and vertical plan, as well as the overall physiognomy of the Bosnian chardaklija house, are closely related to its constructive structure and materialization. The space of the house, in fact, cannot even be viewed outside of its construction and materialization, since the definition of all the elements of the house takes place in a single, simultaneous process (Figure 3). The common property of the wide range of solutions of the Bosnian chardaklija house is its symbiosis with the natural environment, including the materials from which it was built. In this way, the universal requirements dictated by the social environment and the more or less similar status of man in the house, through adaptation to the natural environment (which is quite colorful in Bosnia and Herzegovina), the house takes on different appearances.

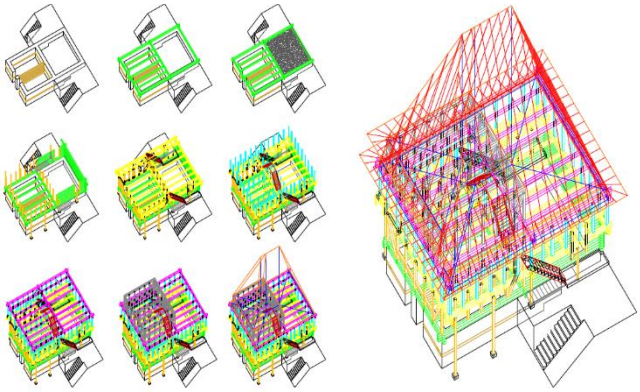


Fig 3: Generating the spatial-constructive assembly of the Bosnian chardaklija house
Source: Author (Drawing, 2016)

Horizontal plan of the house – vertical elements of the structure. The Bosnian chardaklija house was built on terrain of varying slopes, from ideally flat to extremely steep. Sometimes this was the choice of its builder, and sometimes it was imposed by the general position of the settlement in the natural environment. In the case of construction on flat terrain, a floor buried in the ground (cellar) was not built, but, as a rule, a ground floor and a basement. In the case of construction on slightly sloping terrain (which was most often the builder's choice), one floor (basement, storeroom) was built half-buried in the ground, then the ground floor, partly on the ground and partly above the basement floor, and the first floor, in a wide range of solutions discussed in the previous chapter. When building on extremely steep terrain, the vertical plan was developed similarly to construction on slightly sloping terrain, with the exception that the terrain conditions were used in such a way that the entrances to each floor could be arranged directly from the terrain. Sometimes the street elevation was at the level of the roof eaves (Figures 4, 5). In all cases, the foundations of the spatial structure of the house were made of stone. Sometimes the foundations were extremely reduced, to individual stones, on which the foundation beams (foundations) were laid, and on them the complete structure of the house (Figure 6). Other times, the foundation stones were lined up next to each other, in a more or less continuous sequence, and the foundation beam and the structure of the house were placed on them (Figures 7, 8, 9).

Image 4: Left: Korkut family house in Travnik. Layout. Right: Bugilovic family house in Gornja Tuzla
Source: Author (Drawing, 2016)

Image 5: Krslak's House 01. View of the house from the southwest (approach to the house)
Source: Author (August 24, 2016)

Fig 6: Individual foundation stones support the foundation beams and the entire structure of the house. The Abazovic family house in Donja Koprivna near Cazin
Source: Author (July 25, 2016)

Fig 7: The Camdzic family house in Puracic near Lukavac - wooden foundation beam placed on a series of foundation stones
Source: Author (August 5, 2016)

In most cases, stone foundations were part of the structure of the basement (or ground floor) walls, of varying thickness, masonry methods and fineness of stone processing. In natural environments that were lacking in stone and houses were built with a basement, stone was used to build the foundations and walls facing the ground, while the rest of the basement walls were made in a wooden skeleton system ('bondruk') with adobe infill. In some cases, the basement walls were completely made of wood, including those in contact with the ground (Figures 13,14). It is interesting that each village had its own quarry where stone was exploited ('extracted stone for the house'), then a place where clay was dug for making adobe, a place where sand was taken...

Fig 8: The Smajlovic family house in Cehaje near Srebrenik - wooden foundation beam placed on a series of foundation stones
Source: Author (July 4, 2016)

Fig 9: The Ejubovic family house in the Poljice village near Lukavac - wooden foundation beam placed on a row of foundation stones.
Source: Author (July 4, 2016)

Ground floor. Depending on the complex of inputs that encompass the concepts of natural and social environment and the concept of man (as discussed in this book), the construction of the ground floor in a Bosnian chardaklija house is done in various ways: all walls, external and internal, are made of stone (Figure 10); the external walls are made of stone and the internal walls are made of wood or a wooden frame with a filling of adobe or wickerwork with compacted clay (to which straw and chaff shavings are added), (Figure 11); all walls, both external and internal, are made of horizontally placed wooden logs, stacked vertically (Figures 12,13,14); the wall frame is made of wood, and the filling is made of wooden inlays ('ukobica'), (Figure 15); the wall

frame is made of wood, and the filling is made of adobe or wickerwork with compacted clay (to which straw and chaff shavings are added), (Figure 16); various combinations of all the above solutions (Figures 17,18).

Fig 10: The houses in the Gorani village near Konjic - construction of the building: combined solution of the materialization of the walls
Source: Author (August 4, 2016)

Fig 11: The houses in the Gorani village near Konjic - construction of the building: combined solution of the materialization of the walls
Source: Author (August 4, 2016)

Fig 12: The house in the Visnjici village near Vares - building construction: ground floor walls made of hewn wooden logs
Source: Author (September 25, 2016)

Fig 13: The house of the Ahmic family in the Brizdje village near Zepce - wooden basement walls in contact with the ground
Source: Author (July 18, 2016)

Fig 14: The Camdzic family house in Puracic near Lukavac - construction of the building: external walls of the ground floor (and basement) made of wooden logs
Source: Author (August 4, 2016)

Fig 15: The house in the Dastansko village near Vares - structure of the building: basement walls made of stone and wooden 'ukobica', ground floor walls made of hewn wooden logs
Source: Author (September 25, 2016)

Fig 16: The Cekic family house in the Poljak neighborhood, Sanski Most: exterior walls of the ground floor made of wooden planks; massive wooden columns support the main wooden ceiling beam, which is supported on the column via a 'saddle'
Source: Author (July 22, 2016)

Fig 17: The Korajlic family house in Hrvatinovici near Tesanj - construction of the building: ground floor walls made of finely worked stone
Source: Author (July 27, 2016)

Fig 18: The Lekic and Mirkic families house in Przici near Vares - construction of the building: the exterior walls of the ground floor are made of wooden logs (and some of the wooden frame with a wooden frame)
Source: Author (September 25, 2016)

Floor. Since the first floor is a second floor, its construction and materialization on the Bosnian čardaklia house show the rationality of the builder. The walls of the floor are light, most often made of a wooden skeleton with filling. The filling is adobe, wooden wattle with a charge of clay (with the addition of 'ukobica'), hand-made bricks (in recent times also industrial bricks), sawdust, straw and chaff), wooden stakes. In the conditions of the natural environment, where there is an abundance of stone, the walls of the floor are also made of stone, while the walls of the doksat or divanhan are never made of stone, but in a light construction made of wood with one of the fillings (Figure 19). In some areas in Bosnia and Herzegovina, the contrast between heavy stone walls and light cantilever structures made of wood is particularly emphasized (Figure 10). In the houses of wealthier owners, the design of the floor was the most suitable opportunity to express social and property status. The first floor was designed with a cantilevered opening into free space, beyond the contour of the ground floor, on one, two, three or all four sides of the house. It was insisted that the first floor have a large number of windows (compositionally arranged), whitewashed exterior surfaces, and an aesthetically emphasized transition from the ground floor with a surface of finely finished wooden planks (Figures 5,17). Sometimes the wooden beams of the interfloor construction themselves, with their dense row of ends, represent a sufficiently strong accent that emphasizes the floor level. Sometimes the wooden beams of the interfloor construction from the ground floor to the first floor are omitted (10- 30 cm) beyond the outer surface of the outer wall, thus emphasizing the floor (Figure 19, left). Aware of the beauty of the view that the structural assembly of the building, the wooden skeleton with the infill, leaves on the outside observer, the craftsman and the owner of the house leave the outer surfaces of the outer walls unplastered.

Fig 19: Left: the Smajic family house in the Starposle village near Kakanj - spatial-constructive structure of the building. The first floor is left to one side of the house. Right: Houses in the Brnjic village near Kakanj - the conceptualization and materialization of the walls clearly reflects their role in the constructive part of the building

Source: Author (May 28, 2016)

Vertical plan of the house – horizontal elements of the structure. The verticality of the spatial-constructive and functional-utilitarian structure is one of the fundamental characteristics of the Bosnian chardaklija house. There is no doubt that all the functional requirements of the house could have been solved at the level of a single horizontal plan (which is a characteristic of the houses of some peoples, in other geographical areas). Solving the functions along the vertical of space is demanding since new material-functional boundaries are introduced in its definition (interstorey structures), as well as structures that should ensure the communication of people and things along the vertical (staircases). The conception of the house through three horizontal levels (basement, ground floor and first floor) provides more possibilities for shaping the space, or the nuances of the functions that will be realized according to the performance of each horizontal level. Regardless of the fact that the Bosnian chardaklija house is, as a rule, a house of rural and suburban areas, its verticality expresses the human need for quality views as well as the desire to introduce rich natural lighting into the rooms of the house. The verticality of the house also enhances its natural ventilation, which is a very important function of a living space at all times of the year, especially in summer. The verticality of the Bosnian chardaklija house sends a clear message to the space about the property and social status of its owner.

Inter-storey construction. Since in a Bosnian chardaklija house, there are usually three basic horizontal levels (basement, ground floor and first floor), and a roof, defining the boundaries between them is a serious task, both from a structural aspect and from the aspect of ensuring the comfort of the space in terms of the requirements of architectural physics (thermal and acoustic requirements and requirements for water vapor diffusion). There are four basic solutions for inter-storey construction, each of which is based on the use of wood as a structural material (Figure 20). The simplest solution for inter-storey construction has wooden beams whose cross-section and their spacing are determined by the span and the expected horizontal load. In classic solutions for a Bosnian chardaklija house, beams and floors are necessarily hewn, since in this way the tree ring lines are followed and the beam has a perfectly smooth outer surface, which ensures its better durability than if it were made by sawing. Wooden floors are sometimes extremely thick (7-9 cm). The contact edges of the floors are profiled ('sipil'), into which thin battens are inserted when the floors are placed on the beams. This is a simple but well-designed solution for sealing the joints between the floors (Figure 21). This type of interfloor construction is usually built between the basement and the first floor. In houses with a livestock barn on the ground floor, a layer of compacted clay with straw and chaff shavings is added to the floors, and new flooring is placed on top of this layer. This 'supplemented' solution to the interfloor construction is designed to prevent the passage of vapors from the barn into the living space.

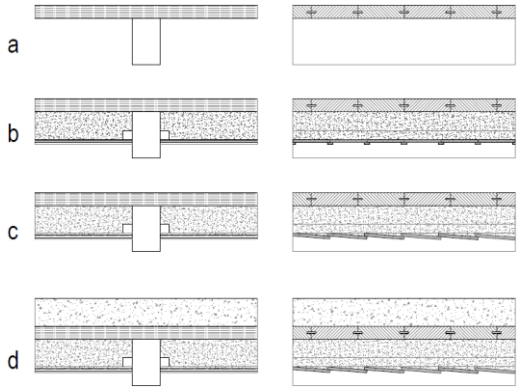


Fig 20: Construction and materialization of the inter-storey construction

Source: Author (Drawing, 2016)

Fig 21: The Colak family house in the Brnjic village near Kakanj. The hewn wooden floors are about 7 cm thick

Source: Author (28 May 2016)

When conceptualizing and materializing the inter-storey construction between the ground floor and the first floor, acoustic insulation is placed at the height of the wooden beams, which is most often made of compacted clay with straw and chaff shavings. Sometimes, river sand or blast furnace slag is placed as acoustic insulation). As a supporting base for the layer of compacted clay, a wooden covering is made, the visible surface of which (the ceiling) can be finally finished ('shishe') or plastered (Figures 20,21). Wooden slats ('sipke') or reed mesh are arranged as the support for the plaster. If the ceiling is made with a final wooden covering, then it is given visual attention from an aesthetic aspect (Figure 22). In some houses, the final finishing of the ceiling combines the solution of a plastered surface and wooden covering (Figure 23). In the inter-storey construction between the first floor and the attic, a layer of compacted soil (sand or slag) is added to the concept of the inter-storey construction from the ground floor to the first floor on wooden floors. This is done for several reasons: improving the thermal insulation of the inter-storey construction, both for the winter and summer periods, and ensuring fire protection of the inter-storey construction (Figure 25). In addition to the above-mentioned solutions for the inter-storey construction, in the Bosnian chardaklija house one can also find solutions for an extremely stable inter-storey construction made of a stone vault whose convex side is leveled with pieces of stone and soil. We encounter such solutions when the house is literally built into the rock, when its owner has good financial opportunities resulting from his social position (Figure 24).

Fig 22: Left: Ejubovic family house in the Poljice village near Lukavac. Ceiling in the large room, ground floor. Right: Hamidovic family house in Dzafici near Kalesija. The surface treatment of the space is tailored to the human body. All elements are both new and old at the same time. It is a solution with universal and timeless values
Source: Author (June 4, 2016; August 5, 2016)

Fig 23: Musafirhana in Fojnica. Ceiling in the chardak in the southwestern part of the first floor
Source: Author (July 29, 2016)

Fig 24: Krslak's house 01 in Jajce. A stone vault as a inter-storey construction between ground floor and first floor
Source: Author (July 21, 2016)

Fig 25: Left: the Korajlić family house in Hrvatinovici near Tesanj - roof construction. Right: The Pozderac family house in Cazin. Inter-storey construction, floor-attic and roof construction
Source: Author (July 27, 2016; July 25, 2016)

Staircase. Given the fact that emphasizing verticality is one of the most important characteristics of the Bosnian chardaklija house, the role of the staircase, as a structure that ensures the connection of the horizontal plans of the house, is extremely important. The placement of the staircase in the space of the house is always guided by the principle of achieving its functionality and the spatial functionality of the house as a whole. In doing so, the opportunity is never missed to give the staircase additional importance and meaning, which are in the sphere of philosophy, psychology and aesthetics. In most cases, the staircase in the Bosnian čardaklija house is placed in such a way that it is quickly noticeable when considering the architectural physiognomy of the house. In classic chardaklija solutions, the staircase is placed next to the main body of the house, on its longer side, so that the staircase is directly next to the main entrance to the house (on the ground floor), and the exit from the staircase is in the middle of the side of the floor plan. In addition, the arrangement of the staircase results in the construction of an entrance porch on the ground floor level and a divanhana on the first floor level. In wealthier chardaklija houses, two staircases are built, one on each of the opposite long sides of the house. The porch on the ground floor and the divanhana on the first floor, both elements made of wood, contrast with the white color of the walls of the main body of the house, and this is the most striking image of the čardakli by which it is remembered. In some solutions of the house, the staircase is placed inside its main body, right next to the main entrance to the house. Here, the staircase is not visible from the outside, but the divanhana, often emphasized with doksati, reveals its presence. In variant solutions of this concept of situating the staircase in the house, the staircase is accessed from the space of the 'house', or the living room. Sometimes the staircase is placed inside the main living room space, the 'house'. This is a rational solution since the warm air from the space of the 'house' permanently rises through the open space of the staircase, to the divanhana on the first floor, making these spaces truly 'warm'. In these solutions, the staircase itself can be of a standard design or reduced to the form of a ladder, which can be moved if necessary (Figures 25, 27, left).

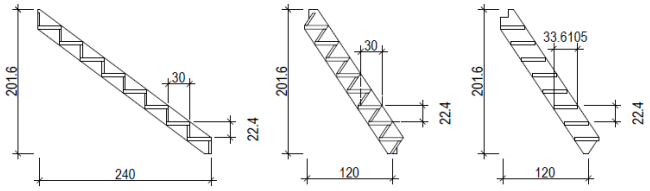


Fig 26: Rationalizing the staircase
Source: Author (Drawing, 2016)

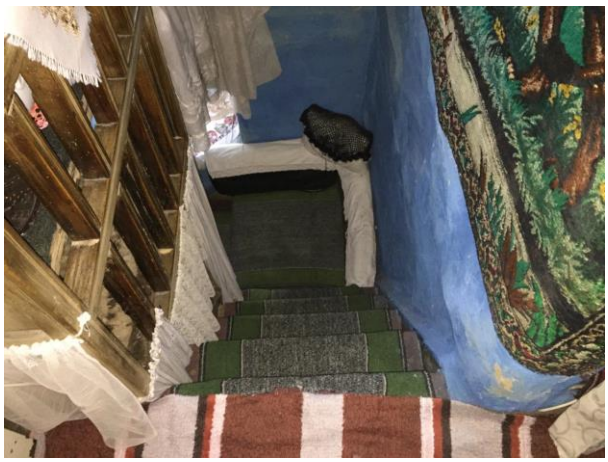


Fig 27: Left: The Zekotic family house in Voljevac near Gornji Vakuf (The staircase support was already used earlier). Wooden staircase construction: tread profiling recessed into the main support. Right: Bugilovic family house in Gornja Tuzla. Wooden staircase (basamaci) and divanhana oriented towards the street
Source: Author (August 3, 2016; July 9, 2016)

In wealthier houses, the staircase is particularly emphasized, as its form flows with the arrangement of the space on the ground floor and first floor, where the staircase starts and ends (Figure 5). In the Bosnian chardaklija house, a single-legged wooden staircase ('basamaci') was most often made. This staircase was made as a prefabricated building and brought to the site. The construction of this kind of staircase consisted of two side supports, planks (with a cross section of 5 x 25 cm to 10 x 30 cm) between which treads were inserted. At the same time, treads had both tread and front surface or only tread surface (Figures 26, 27). The width of the staircase was from 60 to 100 cm, and the number of steps was from eight to thirteen. It is interesting how the staircases were

made with the same tread width and height, but with different final dimensions. In wealthier houses, where the clear heights of the space (especially the ground floor) were greater, a two-flight staircase was built, with a floor plan in the shape of the letter "L" (a staircase on an "L"). In rare cases (mainly during some reconstructions of the original building), a There were also double-flight staircases. These staircases took up more space at their base, but were more comfortable (Figure 4, right, Figure 27, right).

Roof. Next to the entrance porch with a staircase and a divanhana, a high voluminous roof with wooden shingles as a covering, is one of the most important characteristics of the Bosnian čardaklija house (Figures 4,28,29,30). There were several reasons for building such a roof: climatic conditions. Most of Bosnia and Herzegovina is covered by climates with a lot of precipitation, especially snow. The high, steep roof was supposed to ensure fast and efficient drainage, or snow removal, so that the wooden covering would dry quickly and absorb some of the smoke components (tar) that make it resistant to rot and insects. In cases where the roof is the roof is made of stone slabs, the height of the roof is small, so that the stone slabs can stand, and so that the impact of the wind on the roof is less; functional requirements. In the culture of housing whose spatial framework is the Bosnian house čardaklija, dried meat and smoked dairy products are extremely important in human nutrition, throughout the year. The voluminous roof provides the necessary space for drying and smoking meat, with the possibility of its constant supervision from the main living room - the 'house' (Figures 29,30); requirements of architectural physics. The high voluminous roof in the overall In the spatial-functional structure of the house, it functions as an extremely important 'buffer zone' (protective zone), with the possibility of manually regulating the ventilation intensity of the air that is affected by its volume. The huge air volume, with reduced ventilation intensity, functions as thermal insulation in the winter, while in the summer, when the ventilation intensity can be increased, the air flow functions as a fan that cools the main body of the building. The ventilation intensity is regulated by opening and closing the shutter in the roof. husks using a long stick, from the space of the 'house' (Figure 4). This 'thermo-regulating effect' of the attic space is complemented by a layer of compacted earth (slag or sand) in the floor-attic interfloor construction. In addition to the thermal insulation effect, the huge attic space It enhances the process of vapor diffusion through the floor-to-ceiling interfloor construction in such a way that it is practically impossible for condensation to occur in any part of the interfloor construction. Its eventual occurrence in the roof covering (on the inside or outside) is in any case outside the boundaries of the main body of the house. In terms of construction and materialization concept, the voluminous roof of the Bosnian čardaklija house is at the same time extremely simple and sophisticated. Its simplicity is reflected in the fact that all its elements are made of wood (beams, rafters, cross-beams, laths, shingles), which is prepared by an officially uneducated, but extremely skilled and talented folk craftsman, a 'dundjer'. The only elements that are not made of wood are iron nails, namely forged nails (in the early years of Bosnian čardaklia construction), which could also be made by village blacksmiths. An almost regular, unique, constructive solution of the roof is 'with rafters and cross-beams (pajanta)', where one or two cross-beams are possible between the rafters, according to the height of the roof (Figure 4). Roof solutions like 'chairs', upright or sloping, single, double or triple (Figure 25, left) are rarer. The sophistication of the roof of the Bosnian čardaklija house is reflected in the fact that it is made of linear elements (sticks), and that in the constructive structure of the house it functions as an extremely light and rigid shell, that is, a spatial structure. The roof of a Bosnian chardaklija house is reminiscent of the construction of a basket or a beehive, where the main linear elements (horns and ridges) are interconnected by battens, and all the elements together by wooden shingles. In addition, the technology of using the building (with permanent fumigation) its elements) provides permanent and effective protection against the harmful effects of weather and insects.

Fig 28: The Vrhovcic family house in Matijevici Street, Vares. Roof: design, construction, materialization
Source: Author (January 16, 2016)

Fig 29: The Zekotic family house in Voljevac near Gornji Vakuf. 'Ring-shaped' roof
Source: Author (August 3, 2016)

Fig 30: The Dusper family house in Kraljeva Sutjeska. Roof of the 'rafter with a crossbeam' type. Chimney with a strap for regulating ventilation
Source: Author (July 29, 2016)

Opening elements. Opening elements are those places within the boundaries of an architecturally defined space where it is included (excluded) from the environment. These are extremely important points where a 'great change' occurs between two environments, and as such they are extremely complex, with many levels of meaning. From their design, materialization, position within the boundaries of the architectural space, number, (...), one can 'predict' the content within the architectural space, judge the owner of the house, judge the artistic talent and technical skills of specific performers - folk craftsmen...

Doors. Three groups of doors can be seen in a Bosnian chardaklija house: the basement door (storeroom), the main entrance door, and the door inside the architectural space. In the classic solutions of a Bosnian čardaklija house, all doors, both those on the outer walls and those inside the house, are made of wood. Moreover, the doors on this type of house are identical throughout Bosnia and Herzegovina. Differences appear in the designs of doors in more recent times (since the mid-20th century), where their creators were educated craftsmen-masters, who, through the design of the door, wanted to show their uniqueness on the market. The door at the entrance to the basement is massive and rustic, mostly single-leaf. Regardless of the material from which the basement wall is made, the door has a frame, a door frame made of massive, more or less finely processed wooden logs, and a leaf made of hewn boards about 5 cm thick. The planks on the door leaf are connected to each other on the inside with two or three bars, and sometimes with a crossbar connecting the bars (Figure 31). The hinges on the door are made of wrought iron, and are usually placed so that the door leaf cannot be removed. The dimensions of the door are 'on a human scale', sometimes such that a person has to bend over when passing through them (80 x 120 cm). In wealthier houses, a more or less pronounced wooden arch is made on the door frame, which also emphasizes the door (Figure 31, center and right).

Fig 31: Left: house in the Brnjic village near Kakanj - entrance door to the storeroom. Middle: the Hamidovic family house in Dzafici near Kalesuje - entrance door to the storeroom. Right: the Kovacevic family house in Vrazici near Celici - entrance door to the storeroom
Source: Author (28 May 2016; 5 August 2016; 19 July 2016)

The entrance door to the ground floor ('house') is similar in every way to the door at the entrance to the basement (cellar,

storeroom), except that the dimensions of their frame are larger. The solutions for entrance doors with an arch are very common, from its indication (the arched cut of the lintel), to the careful design with a visibly emphasized need for 'beauty' (Figures 32, left, 33,34,35,36, left). In the classic solutions of the Bosnian chardaklija house, double-wing doors are rarely found (Figure 32, right, 33,34, left). However, in more recent implementations, double-wing doors are made, partly due to the need to bring in and take out larger-sized equipment.

Fig 32: Left: Popržanović family house in Maglaj (Stari Grad/Old Town) - entrance door to the storeroom. Right: Alagić family house in Cazin
Source: Author (July 18, 2016; July 25, 2016)

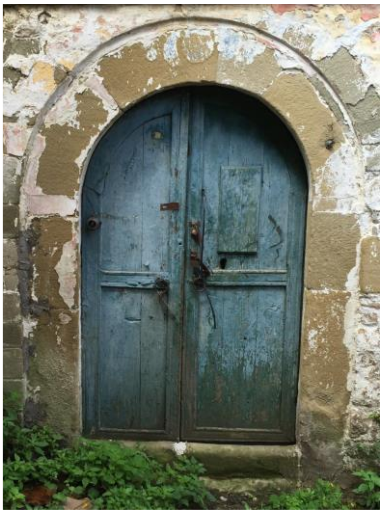


Fig 33: Left: the Uzeirbegovic family house in Maglaj - false door. Right: Poprzanovic family house in Maglaj (Stari Grad/Old Town) - front door.
Source: Author (July 18, 2016; July 18, 2016)

Fig 34: Left: Pozderac family house in Cazin - entrance door to the ground floor. Right: Bugilovic family house in Gornja Tuzla - entrance door to the ground floor
Source: Author (July 25, 2016; July 9, 2016)

Fig 35: The Smajic family house in the Starposle village near Kakanj - entrance door to the ground floor
Source: Author (28 May 2016)

Fig 36: Left: the Kasumovic family house in Vrnograc - false door to the ground floor. Right: Comor family house in Lukomir on Bjelasnica - entrance door to the ground floor
Source: Author (July 25, 2016; July 18, 2016)

In the design of the interior doors of the Bosnian chardaklija house, we encounter a wide range of different solutions. Regardless of the fact that the doors are made by hand, the level of technical wood processing is astonishingly high, so that the doors, beyond their primary utilitarian purpose, become true artistic creations in themselves (Figures 37-42). Particularly noteworthy are the cases of wealthy houses where each door is unique, different from the others, which gave each room (or the person who lived in it) an identity, and the owner of the house the image of a person who deeply thinks about the dimensions of the architectural space (Figures 38,39). In the classic solutions of the Bosnian čardaklija house, paint is not used as a finishing touch to any architectural element, but each material stands out with its natural color, an expression in itself. Hence, doors that have been exposed to smoke from an open fireplace for a long period of time, which has given them the color of honey, are particularly impressive (Figures 37,38,39). The peculiarity of the door on the Bosnian chardaklia house is reflected in the original design of the handles as well as the mechanisms for their 'locking' and 'safety assurance' (Figure 41). With the newer versions of the doors, their typification is noticeable, which is the result of the training of their craftsmen. Here too, however, one can see the craftsmen's effort to show their individuality on some ('their') details in the design of (typed) doors.

Fig 37: The Zumra Dzider's house in the Crnoc village near Kakanj - war on the chardak
Source: Author (28 May 2016)

Fig 38: Doors to rooms (oriented towards the 'house') in the Dusper family house in Kraljeva Sutjeska
Source: Author (July 29, 2016)

Fig 39: Doors on the porches in the Dusper family house in Kraljeva Sutjeska
Source: Author (July 29, 2016)

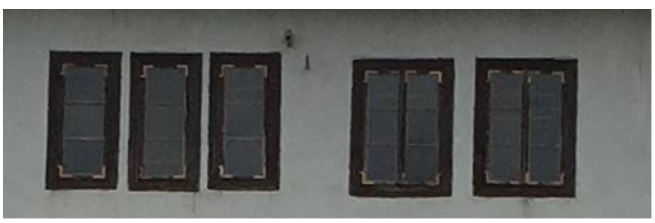
Fig 40: The Zaimovic family house in Gornji Zovik near Brcko. Doors on the chardaks and in the kitchen area ('mutvak')
Source: Author (July 19, 2016)

Fig 41: The Zaimovic family house in Gornji Zovik near Brcko. Doors on the chardaks
(northwestern part of the first floor)
Source: Author (July 19, 2016)

Fig 42: The Bugilovic family house in Gornja Tuzla. Superb craftsmanship in making the doors on the čardaks
Source: Author (July 9, 2016)

Windows. In Bosnian chardaklija houses, we encounter a wide range of different window design solutions. In general, the design of windows corresponds to the purpose of the room in which they are installed. Similar to door design, window design solutions are the same throughout Bosnia and Herzegovina, with some regional specificities. The most common solution is a double-leaf, single window with three panes on each pane. The dimensions of such windows range from 60 x 80 cm to 100 x 130 cm. Smaller windows are made as double-leaf, single-leaf, with two panes on each pane (Figure 43). Single-leaf window solutions (with one pane) are also encountered. Under the influence of Western European architecture that came with the Austro-Hungarian administration (1878-1918), three-leaf windows, or double-leaf windows with a third pane opening around a horizontal axis ('ventus window'), are often installed in Bosnian chardaklija houses. This solution was particularly widespread in western and northern Bosnia and Herzegovina, and meant the acceptance of a new culture based on 'science, technology, progress' (Figure 45).

Fig 43: Archaic window solutions. Houses in Lukomir
Source: Author (22 May 2016)



Windows on the Pozderac family house in Cazin

Fig 44: Different window designs
Source: Author (July 25, 2016)

Since the mid-20th century, solutions for triple-wing windows have been encountered, as well as solutions for

double windows. Very interesting examples of houses where an effort was made to avoid uniformity in window design are shown, so windows of the same size (sometimes different sizes) were made with different 'graphics' of the window panes. Solutions for windows on thick walls are particularly interesting. Sometimes the rectangular profile of the window was ensured by rectangular perforation of the wall with wooden beams in the lintel of the opening (Figures 46,47,48). Sometimes the perforation was made into a vault, sometimes a segment of a dome with the addition of a beam-lintel in the part where the window is installed. Solutions where the perforation in the wall follows a more complex profile, a semicircular, segmental or curly arch, are rare.

Fig 45: The House in Vrnogracki kriz at Velika Kladusa. Three-leaf windows, one wing of which is 'na ventus'
Source: Author (July 25, 2016)

Outside Inside

Fig 46: The house in Cuhovici near Konjic - window on a thick wall
Source: Author (August 13, 2016)

Fig 47: Left: the Pozderac family house in Cazin - windows in thick walls. Right: Musafirhane in Fojnica - window in thick wall of ground floor
Source: Author (July 25, 2016; August 1, 2016)

Fig 48: Left: Krslak's House 01 in Jajce - window in the thick wall of the ground floor. Right: Krslak's House 02 in Jajce - window in the thick wall of the ground floor
Source: Aurhor (July 21, 2016; August 24, 2016)

Surface treatment. In the Bosnian chardaklija house, natural materials, by themselves, give each element of the building a sincere expression, consistent with the complex of properties that each material possesses, from physical-mechanical to aesthetic-expressive. Paint is rarely used as a coating in any element of the building, to create a 'more beautiful impression' than the one left by the material in its natural expression.

Interior surface treatment of the house. The main construction materials used in the Bosnian chardaklija house are: stone, wood and earth (as adobe, filling in the walls of a wooden frame and wickerwork and in inter-storey structures). These are elementary materials that we find in nature, so their application in creating the spatial-constructive structure of the house has an extremely strong aesthetic-psychological effect that establishes a direct and intimate relationship between the observer from the outside and the house. And the materials that man obtains through a certain intervention on natural materials (lime, brick, tile, ceramic 'pots' for lining brick ovens...) are not very 'distant' from their natural sources, so they also seem intimate, tailored to man. All the interior surfaces of the Bosnian chardaklija house, walls, floors and ceilings, can be made of only one of the mentioned natural materials, but, for the most part, combinations of materials are used in accordance with their properties and place of application in the spatial structure of the building and their availability in nature. The use of stone alone in the design of all surfaces is rare, but it is extremely interesting and convincing. In the treatment of the interior surfaces of the Bosnian čardaklija house, stone is found on the walls and floors. In the context of the contents of the room, its place in the materialization is extremely appropriate, convincing and aesthetically refined (Figure 49). It could be said that wood is the material that determines the Bosnian chardaklija house's so recognizable architectural physiognomy. In the treatment of interior surfaces, wood is most often used in the treatment of floors, ceilings and the creation of opening elements. Its aesthetic properties are enhanced in cases where surfaces and elements are exposed to smoke over a long period of use of the building (Figures 49-52). Moreover, smoking is the most effective way of protecting wood from the effects of weathering and insects, and a very gentle form of its care. In some cases, individual parts of the wooden surfaces are superficially treated with lime milk, as protection against the harmful effects of moisture from condensation (in the place of thermal bridges), (Figure 51, right). Since the 1950s, examples of coating wooden surfaces with oil paint in various shades can be seen, which (especially for opening elements) is an effective protection against weathering and insects (Figure 53). Coating the wood with paint (or glaze) comes after the house has ceased to be used in the traditional way, with an open hearth.

The earth in the surface treatment, completely visible in its natural state, is encountered in the treatment of the floors of the 'house'. As the fillings of the wooden skeleton are made of adobe and wickerwork with compacted earth, they are rarely left visible in the interior, since they are plastered (with earth plaster) and whitewashed. On some wall surfaces, lime deposits about 1 cm thick are possible. The primary treatment of floor surfaces (stone, earth, wood) is supplemented by rugs of varying levels of value: furs of domestic animals, coarse cloth made of goat hair, woven strips of wool or linen ('struke', 'zatke', 'trulje'), more modest rugs made by joining wool strips ('ponjave'), more or less expensive wool rugs ('Bosnian rugs'), and expensive rugs originating in some of the countries of the Isokas (Figures 54,55).

Fig 49: Stone wall (towards the ground) and wooden ceiling (impregnated with smoke) in the Smajic family house in the Starposle village near Kakanj
Source: Author (28 May 2016)

Fig 50: The Zaimovic family house in Gornji Zovik at Brcko - wood in surface treatment in the interior
Source: Author (July 19, 2016)

Fig 51: Left: the Zumra Dzider's house in the Crnoc village near Kakanj - wooden ceiling in natural color. Right: the Cukas family house in Cuhovici near Konjic - painted parts of the wooden ceiling (in the thermal bridge area)
Source: Author (July 19, 2016; August 13, 2016)

Fig 52: The Tresnjo family house in Cuhovici near Konjic - natural wood color in the smoke-impregnated wooden ceiling
Source: Author (August 13, 2016)

Fig 53: The Kovacevic family house in Vrazici near Celic - wooden ceiling in natural color and painted with green oil paint
Source: Author (July 19, 2016)

Fig 54: The luxury of floor mats. The Zaimovic family house in Gornji Zovik near Brcko
Source: Author (July 19, 2016)

Fig 55: Detail of the floor in the Dusper family house in Kraljeva Sutjeska
Source: Author (July 29, 2016)

Treatment of the surfaces of the house in the exterior. Similar to the interior, in the exterior we most often encounter materials in their natural expression: stone, wood and earth. In the case of the classic solutions of the Bosnian chardaklija house, stone is encountered in the construction of the basement walls and the walls that enclose the space facing the enclosed area (Figure 56, left). If the stone is easily available in the natural environment, all walls, from the basement to the first floor, exterior and interior, are made of it (Figures 10, 11). Floor coverings and roofing are made of stone. The level of treatment of stone surfaces in the exterior is different, from completely untreated stone to extremely fine and especially decorated treatment. The level of treatment of stone surfaces always depends on the possibilities of the owner of the house, less often than the natural properties of the stone itself. It is interesting that in some areas the outer surfaces of the stone are whitewashed. Such cases always speak of the cultural and psychological profile of the house owners, who in this way emphasize orderliness in their living environment (Figure 56, right). In some parts of Bosnia and Herzegovina, examples of chardaklija houses can be found in which both the construction and the materialization are expressed in the most visible way, without even the slightest means of covering them. Such cases are aesthetically very striking, regardless of the fact that in terms of architectural physics they are not very effective. Contrast is one of the most important ways of expressing in composing the architectural physiognomy of the Bosnian čardaklija house. Stone, as a heavy material that bears pressure and is resistant to weathering, is used to build the foundations and basements that support the entire structure of the house, in contrast with white walls on the ground floor and first floor, the lightness of which is further emphasized by the perforations of (once numerous) windows. The whitewashed walls of the ground floor and first floor volumes contrast with the dark color of the wood from which the divanhana is made. The dark color of the wooden logs contrasts with the white surfaces of the

painted walls The dark volume of the roof with its shingle covering contrasts with the white volume of the main body of the house (Figure 56, right).

Fig 56: Left: the Krslak's house 02 in Jajce - contrast of stone (in the lower floors) and light, white volume of the first floor. Right: the Vrhovcic family house in Vares - contrast of dark, natural wood color and white painted wall surfaces of the ground floor and first floor
Source: Author (August 24, 2016; April 16, 2016)

Fig 57: Left: The Camdzic family house in Puracic near Lukavac - contrast of the dark, natural color of the wood and the white painted surfaces of the walls of the ground floor and first floor. Right: the Ejubovic family house in the Poljice village near Lukavac - visible structure of the building
Source: Author (August 5, 2016; July 4, 2016)

Conclusion

This paper presents wood as a building material, its properties, products and application in traditional architecture – the Bosnian chardaklija house. Man began to build his dwellings and settlements from wood since the Neolithic Age (4500-2000 BC). He also used wood to build various utilitarian objects (bridges, cattle sheds, hay drying sheds, granaries, for example). By devising a technological process for the production of laminated wood (both in the form of linear beams and in the form of surface elements), wood became a construction material almost as important as reinforced concrete and steel. The production of thermal insulation from wood sawdust and the production of cladding (hard-pressed laminates, veneer panels and bakelite cores) expanded the use of wood in architecture. In addition, wood remains a 'natural material' that never ends up as waste that would burden the natural environment. The fact is that forests (wood) are one of the greatest natural resources of Bosnia and Herzegovina. This work shows how one of the most important architectural programs, the house/home, was created in the synergy of the natural and social environment, on the one hand, and man, on the other.

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