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RESEARCH ON THE POTENTIAL OF TRADITIONAL AND CONTEMPORARY FAMILY HOUSES WITH THE AIM TO CREATE A LOW-ENERGY HOUSE

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Abstract. *The strategy of the research paper is to conduct analysis of buildings for individual housing from the aspect of promotion of energetically efficient buildings construction. With that as a goal, all key aspects essential for design, such as government regulative necessary to comply with when constructing and reconstructing a building, climate conditions of the given area necessary in planning the strategy of construction, the record of existing housing stock as well as cultural identity through heritage of traditional buildings, were analysed. Through analysis of a traditional building, a reference model of the existing housing stock and hypothetical model- newly designed building, via software for analysis of energetic performances, the conclusions have been made and practical guidelines were given in the reconstruction of the existing and construction of new buildings based on tested scientific proofs. The work is focused on investigation and application of the elements of traditional architecture with a goal to improve energetic performances of new and existing buildings.*

Key words: *individual buildings, traditional buildings, energetically efficient buildings, traditional materials*

1. INTRODUCTION

More than 50% of energy in Serbia is spent in buildings and almost a half of pollution stems from the usage of the buildings. The housing sector includes about 38% of whole final energy consumption in RS in 2008. 70% of total energy consumption is spent in households and buildings. 56% of electricity is spent in households, with 62% of that on heating.[1]

To give its contribution in reducing CO2 emission, built environment requires specific policies- from accepting contemporary principles of construction all the way to adjusting existing construction fund to new goals.

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The houses in Serbia are built very conservatively, without thinking about the effects during the service of the building. Despite the raising awareness about the importance of energetic efficiency, the way of construction of individual housings has not been significantly changed. The buildings of existing housing stock represent great potential for energy savings through the process of reconstruction.

The central idea of this paper is to explore the potential of use of elements of traditional and modern building and based on newly designed individual housing building- a hypothetical model- to explore the potential of the usage of elements from the traditional architecture, in the sense of construction by the principles of bioclimatic architecture, which implies integration of the building in its natural and artificial environment. The primary aspect of such a concept is to improve energy performances, and the secondary to improve aesthetic quality, which implies construction complying with regional features and making of physical structures which participate in creating and maintaining the spirit of an area.

1.1. Research methods

A methodological procedure within creation of the research information base encompasses a method of in-the-field observation and an analysis of the substance of primary and secondary sources. The primary sources consist of the material collected during the site visit by direct contact with the building and the space organization; the technical documentation from the Belgrade City Institute for the Protection of Cultural Monuments, as well as the censuses of the Statistical Office of the Republic of Serbia. The secondary sources include the published works and articles on the researched area.

The second phase of the work includes analysis of parameters necessary for research as: climate conditions, legislation and standards to verify the methodology of the energy performance of buildings, as well as analysis by computer software to simulate and predict the behavior of buildings in different conditions. To this aim, the software that is used is PHPP7 (Passive House Planning Package 2007) for analyzing the energy performance of the buildings.

Key parameters of this software are: climate data, heated surface area of heat transfer coefficients of thermal elements of the building envelope, the surface of the thermal envelope in relation to the orientation, thermal mass of the building and the ventilation rate. Based on the software there has been calculated the value of the energy needed to heat and cool buildings, overheating frequency, and CO2 emissions.

Software Meteonorm 7 is used to enter climatological data that shows climate for locations by latitude and longitude, based on the average temperature from 2000 to 2009 as well as climatological data based on predictions of rising temperatures of IPCC scenario for future periods. Software Dynamic Thermal Properties Calculator 1.0 (designed by The Concrete Centre, London) was used for the calculation of the coefficient K of the thermal mass of the object.

2. THE ANALYSIS OF ENTRY PARAMETERS OF THE RESEARCH

2.1. Natural features

The climate of Serbia is moderate- continental. The average annual temperature of the air for the period from 1961- 1990 was 10.9 °C to 6.0 °C; the higher the altitude the lower the temperature. The absolute maximums of the temperature were measured in July and were from 37.1 to 42.3 °C in lower areas, and in mountainous areas from 27.6 to 34.0°C. In August, maximum temperatures measured were from 37.4 to 40.3 oC. Absolute minimum temperatures were noted in January from -30.7 to -21.0 °C in lower areas, and in mountainous areas from -35.6 to -20.6 °C.[1]

According to the report of IPCC (Intergovernmental Panel on Climate Change), warming of climate system is a fact, and the concentration of the gases with the effect of the greenhouse has been increased. Each of the last three decades has been successively warmer than the previous one since 1850.[2] According to the fifth report of IPCC, by applying wide range of measures, we can limit the growth of global average temperature to two degrees compared to pre-industrial level.

In Serbia, there was an increase in last century, so in last two decades 14 years with temperatures higher than normal were recorded, and the year 2000 was the warmest year in the last century. Serbia is a part of south-eastern sub region of Europe where higher increase is predicted than on the global level. That increase will move from 2,2 to 5,1ºC until the end of 21st century, especially during the summer months. Humidity of the air will decrease per year which will all lead to the increased risk from droughts.[2]

2.2. Government regulations, rule books, standards and strategies on energy efficiency of housing buildings

The main initiator of improvement of energy efficiency are: regulations, including national and international civil engineering regulations and standards, energy certificates for buildings and other incentives, including credit support, donations and subventions. Guidelines define mechanisms and principles of energy efficiency enforced by the members of EU and give a framework for making national regulations and standards. That way, international trends of energy efficiency are harmonized. International institutions set standards for energy efficiency in the sense of minimal requirements for buildings which are being introduced in national construction regulations. Besides the regulations, performances of buildings concerning energy efficiency go much further through many European standards.

Low energy buildings offer better energy performances, that is more than it is stipulated by national construction regulation. In Germany, a low energy house has a limitation in energy consumption for heating of 50 kWh/m2 annually. In Switzerland a low energy house must not use more than 42 kWh/m2 annually for heating. At the moment, in average low energy houses in those countries half of the given amounts is achieved; between 30 kWh/m2 and 20kWh/m2 annually.

[1] http://www.hidmet.gov.rs/ciril/meteorologija/klimatologija_srbije.php, used on 8th May 2015

[2] The fifth report is an overview of current state and scientific discoveries related to climate changes. It consists of the report from three work groups which you can see in Climate Change 2014 Synthesis Report Summary for Policymakers

Until the beginning of 2019, all new buildings in European countries will have to be with zero energy. That means that every building will have to produce its energy on the spot, whether it uses it or selling it to the network. Some countries have set their goals related to that: France - energy positive buildings until 2020, Germany - buildings that function without fossil fuels until 2020, Netherlands - energy neutral buildings until 2020, Norway - passive houses until 2017, Great Britain - zero CO2 buildings until 2016.[3]

Green buildings satisfy a number of criteria of environment protection, which implies increase of energy efficiency, but also decrease of water consumption, the use of materials related to influence on health and environment. At the same time they work on giving transparency between these systems of valuating buildings and recognizing needs for regional and national differences.

A passive house is a building in which the request for the heat is reduced via passive measures to a point where there is no need for conventional heating system. A house itself is not without heating system, but its size is significantly smaller.[4] For European passive houses the condition for heating is consumption of less than 15 kWh/m2 annually, but consumption of primary energy is less than <120 kWh/m2 annually for heating, hot water and households' need for electricity.

In Republic of Serbia, the first law to introduce the term energy efficiency of the buildings is The Law on planning and construction Official Gazette 72/2009, 81/2009 and 24/2015. By this law it is regulated that energy characteristics of high-rise buildings are confirmed by issuing a certificate of energy characteristics of a building, which is the necessary part of technical documentation enclosed with the request for a using permit.[5]

Based on Law and Rule book about energy efficiency Official Gazette 61/2011 the methodology for calculating energy class of the buildings is provided, as well as the list of standards to be applied in new buildings, fulfilling the condition from the manual 2002/91/ECEPBD.[6] According to the rule book on energy efficiency of the buildings, the table of the sums of sun eradiation and average monthly temperature of the air, based on which required energy for heating and cooling is calculated, has been given for Belgrade.[7] It is clear that different locations in Serbia can have very different climates, and in that sense it is necessary to provide for the architect all of the climate related data for all the locations. Energy classes for housing buildings are given through the levels from G to A+. For new buildings the minimum required is "C" class, and annual consumption for heating is ≤ 65 kWh/m2, and for the reconstructed buildings to be improved up by one class.[8]

3. Traditional Housing Architecture of Sumadija Region from Energy Aspect

Many authors have dealt with the analysis of construction heritage on the territory of Serbia and that research can be split into three groups. The first and the largest group was based on typology, analysis of dimensions and disposition of the rooms. The second group is made of researches dealing with dimensional characteristics and proportional legality of the traditional buildings. The third group, the one this work partly belongs to, is made of research related to research of energy characteristics of traditional buildings.

Development of traditional architecture is conditioned by natural and social factors. Natural factors influencing concept of construction are: climate, configuration of the ground, geological content of the ground and vegetation of the building location. Traditional architecture used natural resources for building, while climate and configuration of the ground influenced space disposition and constructive features of the house. Social factors which influenced the concept of construction were migration of the people, whether it was big transmigrations or transmigration of smaller groups, such as builders' groups.

In the examination of the influences which determined the construction of this region, the important role belongs to the builders who brought architecture of their birthplaces. Jovan Cvijic said that log cabins in Podrinski and Valjevo region were built by Osatians, while in other areas the peasants themselves were building them. Masons from the Nis and Pirot regions, since the beginning of 19th century, started to introduce a new kind of roofing - ceramida to north regions of Serbia.[9] Kojic talked about a group of builders who came to different parts of Serbia, among which the most famous "Masons Osatians, the name originated from region Osat in Bosnia, who were known by building log cabins." The second group of builders consists of masons from Pirot and surrounding places. The Pirot masons were known for replacing wooden chimneys with a brick-laid ones, and also for introducing more windows,[10] also they specialized in building houses with wooden frames filled with mud or bricks (bondrucar).[11]

Traditional buildings built before 1919 make 3,82% (calculated according to m2 of built space), and 6,05% (calculated according to total number of buildings) of total housing stock of Republic of Serbia. Out of that percentage there is 117 985 of detached family houses, which is total of 8 812 918 m2 of built space, which means they make 3,04 % (calculated according to m2 of built space), and 5,25% (calculated according to total number of buildings), of total housing stock of Republic of Serbia. For their heating 2 317 797 MWh/year is required, 3.55% of total required energy for heating of housing buildings in Serbia.[12]

3.1. Materials

The use of local materials is one of the most important characteristics of folk architecture and important part of regional diversities.[13] From Industrial revolution on the use of industrially standardized materials has been increasing, while traditional techniques and materials are fell out of use. Industrially produced materials require high energy consumption and have significant influences on the environment, while natural materials have a positive influence in the whole life cycle (Table 1).

The more the world standards for energy efficiency are improved, the less energy is needed in operation of buildings, so the energy consumption for material production becomes significant because it represents the larger part of total spent energy. Conventional buildings spend around 10-15 % of total spent energy in materials during the phase of work, which has recently been identified as an important phenomenon and something that will change nature of the debate and decision making about repeated use of buildings and energy efficiency in the following years.

Region such as Sumadija abounds with alluvial soil and clay, and in the past with forests. Initially, log cabins were built, and later on houses made of timber frame from vertically and horizontally laid timbers and columns with fixed sprits.

Table 1 Characteristics of materials from the aspect of impact on the environment[3]

Material	Embodied energy (MJ eq./m3)	Global Warming Potential (kg CO_2 eq./m3)
ranite	1300	26
imber	1058.88	57.7
ammed earth	942.5	37.7
raw	65	0.65
oncrete	1449.63	264
eel	182286	2035800
rick, perforated	4245	357
eramic tiles	22185	1167
oof tiles	5865	535.5
olystyrene XPS	3271.13	341.25

- The soil was used to fill the walls because of its multiple advantages and low coefficient of heat transfer (Table 2), it has a quality to influence the quality of air in a closed space, such as humidity, keeping it in the appropriate proportion for health (from 40 to 60%), contributing to the stability of inner microclimate.[14] Soil constructions enable an adequate measure for summer temperatures, via suitable soil mass.
- Adobe is made of clay soil, shredded hay and water. It has relatively high heat transfer, and its sound isolation is an advantage (Table 3). Enriched with fiber, adobe can be superior comparing to standard brick in decreasing large oscillations in temperature between summer and winter. Isolation capacity of adobe increases with the increase of porosity of the clay. [15] Buildings made with adobe can have large durability; there are hundred year's old examples of these kinds of buildings that exist even now. When Sumadija was abundant in forests, log cabins were built, and later, with lack of heavy wood, timber houses were built. The advantages of wooden construction are: it is easily regenerated, biodegradable and can be recycled, it requires a little processing used in construction and allows prefabrication which contributes to the decrease of construction waste. Wood has good characteristics: permeability, humidity regulation, appropriate warmth, easy process of treatment and installing. It has an ability to exchange air with the environment which permits cleaning and filtrating air. Wooden surfaces condition natural climate regulation of the inside space, and it is a material which can provide protection from radioactive radiation. [16]
- Ćeramida is a material produced from clay, at first by drying, and later by baking. Ćeramida was fitted on the roof slope from 1:3 and 1:4 because Ćeramida had not been tied to the laths.
- Rock represents one of the most interesting ecological building materials and as natural resource exists in different contents, structures and colors. Its application throughout the centuries has been very significant, and it still is one of the most

[3] Source: J. Fernandes, R. Mateus & L. Bragança, "The potential of vernacular materials to the sustainable building design", Vernacular Heritage and Earthen Architecture: Contributions for Sustainable Development – Correia, Carlos & Rocha (Eds) , Taylor & Francis Group, London, 2014, str. 625.

appreciated traditional materials. In traditional architecture of Sumadija it has been used to construct foundation walls and the basement walls.

- Brick was used in traditional architecture to fill the walls of timber construction, as well as for surfacing floors. The elements were formed from mixed clay mass which was imprinted in molds and dried in such a way to lose 20% of humidity. Dried elements were then fired in stoves on temperatures from 900-1000 °C.[17] Old dimensions of full brick were 30/14/6.5 cm.

Materials are of essential significance for the construction, but they also cause important influences on the environment, especially those whose production is of high energy intensity. Besides that, centered production of materials implies high energy operations for transport from the point of getting raw materials to the distribution of finished products.

Considering that traditional materials are closely related to local conditions and have significantly less influence on the environment, their use means the potential to decrease the influence during the life cycle of a building. The advantages for the environment regarding local materials are: no need for the transportation, less energy spent on production process and with that less emission of $CO2$; they are natural materials, often organic, restorable and biodegradable, with long life cycle and have low influence on the environment during the maintenance.

Table 2 Table of values of thermal conduction of traditional materials [4]

Type of (traditional) building material	straw bale	greasy loam and by- products	clay–straw mixture	wool	light loam	armour of loam-straw wattles
λ[W/mK]	0.067	0.688	0.18	0.038	0.344	0.344

Table 3 Table of values of thermal conduction of adobe[5]

Type of adobe	fired adobe	concrete brick	adobe with straw	adobe
λ[W/mK]	0.244	0.627	0.180	0.240

3.2. The design of a traditional house

Our ancestors had different expectations concerning heat and comfort of living in general. During the cold seasons they would change their way of life, behavior, adapting to the climate conditions. The solutions for heating comprised the hearthstone, and heating of only one room - house.

[4] R. Ana, "Traditional rural houses in Serbia – thermal performances and potential for energy retrofit" Arhitektonski fakultet univerziteta u Beogradu, http://www.biovernacular.ac.cy
and G. Steven and G. Richard, "Sustainable earth walls to meet the building regulations a School of Civil Engineering", University of Plymouth, Reynolds Building, Drake Circus, Plymouth PL4 8AA, UK, 2004, str.13.

[5] Source: J.D. Revuelta-Acosta, A. Garcia-Diaz, G.M. Soto-Zarazua, E. Rico-Garcia, "Adobe as a Sustainable material: A Thermal Performance", Division de Estudios de Posgrado, Facultad de Ingenieria, Universidad Autonoma de Queretaro CP, Queretaro Mexico, Journal of Applied Sciences 10(19):2211-2216, 2010, str. 2213.

Many builders of the heritage well knew how to use the potentials of a location. Traditional buildings often show many principles of passive modern design recognized in their location, orientation and overall design. If the location of the building was in hilly region, distinctive for Sumadija, the houses were laid in upper zone of slopes, oriented to South and Southeast. Energy wise this kind of positioning is a trusted measure in designing passive houses today. Since the building integrated in the nature, the construction and shaping the roof with largely overhung eaves, which had the function to protect from the precipitation in the winter season, and protection from the Sun in summer season. In housing buildings you can clearly see the connection between sloped terrain and horizontal and vertical plan. The drop of the terrain is always used for basement. Such an influence on number of floors in horizontal plan gives as a consequence porch or veranda. The windows of traditional family buildings are organized individually, they are wooden, mostly double with one layer of glass thus lowering infiltration. For two-part traditional buildings it was characteristic to place two opposite doors. This kind of placement was previously known in construction types of earlier date such as cabin logs, Osat houses and smokehouses. With some authors this kind of placement has a functional role, better communication with other objects in the yard. Aleksander Deroko gives us another explanation, where the opposite doors were, one small one big, placed in the wind direction and had a function of ventilation. [18]

While traditional buildings tend to have solid thermal mass, they often fail in exploiting this ability because the buildings are uninsulated and with lots of drought, and small percentage of transparent surfaces does not allow exposure of thermic mass to sun eradiation.

3.3 The analysis of energy performances of a building with traditional architecture

Since the subject of this work is application of the elements of traditional architecture in order to improve energy performances of the existing and new buildings, criterion for choosing the model is a building with best energy performances. The building which contains more complicated schemes and by abundance of elements illustrates traditional principles of construction in a best way. In that sense, house of family Zujevic in Nemenikuce, municipality of Sopot, was chosen as a relevant model; latitude 44.4 and longitude 20.6, altitude 177m (Fig 1). Office for heritage preservation of the city of Belgrade, lists this building in *culture site of immense significance* as a building that represents the most important exhibit of architecture of *Balkan style* in Belgrade region.

Fig. 1 Situation and the appearance of a traditional housing building

The house was built in 1837 and it measures 8.9 m x 7.0 m and with the balcony 2.3m wide. The building has four parts of 55,90 m2 net surface area and a basement of 29,0 m2 net surface area. The part of transparent surfaces in façade walls is 3,8%. The roof of the house is with four roof planes, and the roofing is Ćeramida. The attic space was not used for living, and in thermic sense it represented a good buffer zone between the outer space and heated space of the house, moderating temperature differences. The basement rooms were constructed with rock, plastered with a mixture of clay and hay. In winter season, the basement wall with high thermal mass with the plaster that has thermal insulation qualities, provides absorption of warmth during the day, and release of it during the night and heating the floor of the house. The filling of the walls on the first floor is a mixture of clay and hay in such a way that wooden laths would be nailed from both sides of the wooden construction, and the space between them would be filled with clay. The ceiling is wooden with a layer of clay and hay of 8 cm thick. The floor on the ground is made of brick placed over a layer of sand. The windows are wooden, double, casement with single glass panel, equipped with shutters and a grill. (Table 4).

The most dominant wind in Sopot is Northeast wind, so the house is placed with its shorter side perpendicularly to the wind and there are no windows on that façade. The balcony is placed on Southeast, and with deep eaves is protected from the summer sun, and allows entry of low sun eradiation in the winter. The ventilation of the building is conducted via the openings set opposite on longer sides and via open hearthstone. The winds from Southeast are present and fairly frequent during the whole year, with the intensity reaching 2,9 m/s compared to Northeast winds, so they are suitable for the ventilation.

Table 4 Coefficients of heat transfer for the elements of thermal envelope on traditional housing building

Outside wall	Floor on the ground	Attic towards the roof	Attic towards the basement	windows	doors
U=0,93 W/m2K	U=0,69 W/m2K	U=1,07 W/m2K	U=1,43 W/m2K	U=3,02 W/m2K	U=3,0 W/m2K

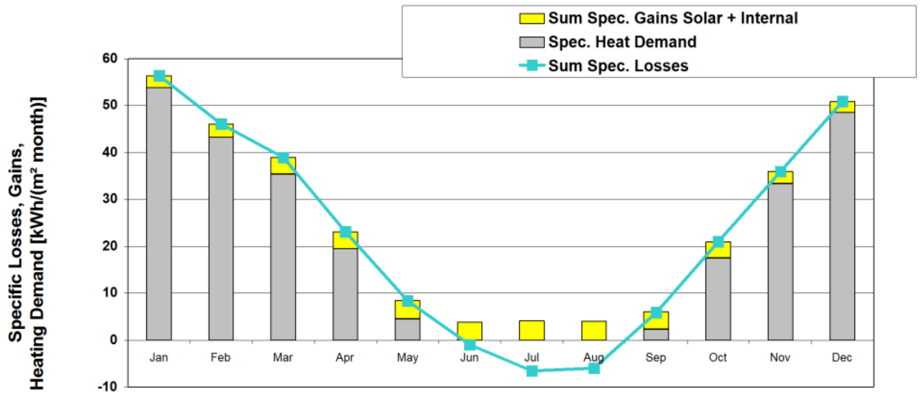

Fig. 2 Calculated heating demand, with PHPP 7, of a traditional housing building

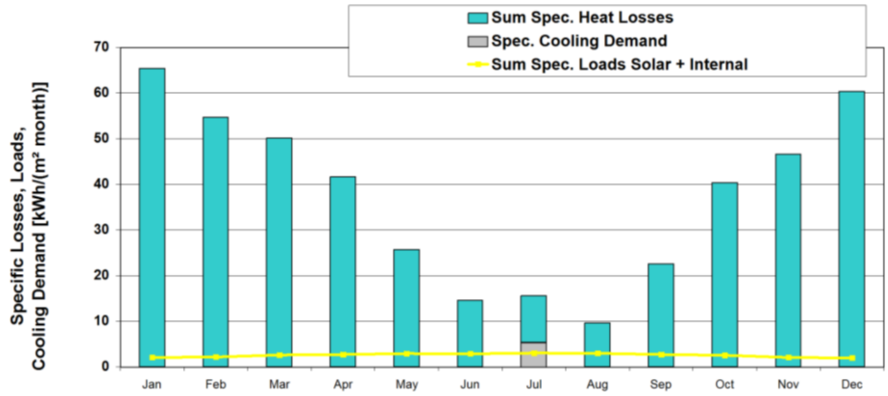

Fig. 3 Calculated cooling demand, with PHPP 7, of a traditional housing building

Traditional materials are different depending on the content of the soil. The content of the materials in the building itself also may vary, because we have a manual way of material production. One can say that calculating heat transfer of the elements of thermal envelope of the traditional houses is highly complex.

According to current standards, to achieve inside temperature of 20°C, the needed energy for this building is 254 KWh/m2 per year. That would represent G class according to Serbian Regulations (Table 5).

Table 5 Thermal performances of traditional housing building

The surface of the building m2	Energy required for heating KWh/m2a	Energy required for cooling KWh/m2a	Frequency of overheating	Thermal mass kJ/m²K
55,90	254	5	5% over 25°C	249

4. The Analysis of Modern Individual Housing Buildings from Energy Aspect

4.1. Housing stock of the Republic of Serbia

The housing stock of the Republic of Serbia is tracked through inventories according to which the largest number of apartments was built in the period from 1970-1980 (Table 6). During next ten years that trend is falling, to reach almost one fifth during the 90s. One family buildings make 87.35% of total housing stock in Serbia.[19]

Table 6 Table of representation of detached family houses according to the year of construction in Republic of Serbia[6]

< 1919	1919-1945	1946-1970	1971-1980	1981-1990	1991-2000	After 2000
1.73%	12.43%	32.47%	21.61%	15.19%	6.37%	3.60%

[6] Source: J.P. Milica, I. Darko, R. Ana, R. Aleksandar, Đ. Ljiljana, Ć.I. Nataša i N. Miloš, "Atlas of Family Housing in Serbia", Faculty of Architecture University of Belgrade, 2010, p.16.

The buildings of timber construction lingered longer in rural areas than in towns. Gradually timber construction disappeared completely, which lead to equalization of differences between the buildings in the villages and the towns in the 60s. In the 70s brick was replaced with hollow blocks made of clay, for the construction of the walls and the ceiling, and that way of building has been practiced since. In the buildings constructed in the 70s and the 80s, when the building permits were given on the basis of standard designs, unskillful adaptation to the location resulted in inefficient orientation.

The problem with the existing buildings is overheating, which is particularly accented in top floors. The summer temperatures which are considered acceptable are: above 25 ºC to 5% during the year and above 28 ºC, 1% of work year.[20]. Overheating requires necessary fitting of the air condition systems, which leads to an increase of total used energy and to increase of CO2 in times when there is an urgent need for its decrease. The energy demand for cooling living areas makes 6,4% of total electricity demand. In 1990-2000, there was a growth of 13%. In Europe, fitting of air conditions is fairly scarce, averagely about 0.2 per household, and that is 7 times more than it was in 1990. [21]

Some of the potentials of the housing buildings is that they are mostly detached, often in the centre of the lot, so it is possible to achieve some techniques of cross ventilation. Another of the advantages in less urban and rural areas is that there is no danger of pollution, noise and safety, so the windows can be freely opened. The researches show that the energy consumption decreases with increase of ventilation rate. The right way to use this effect is to increase ventilation rate when the outside temperature is lower than the inside temperature.

The buildings of the existing housing stock are constructed from materials with high thermal mass so there is a potential, which is currently unusable, because of the inappropriate insulation and insufficient exposure to the sun. Depending on orientation and the size of the windows in the building, the use of solar gains is improved in buildings with high thermal mass. Intelligent match of materials, heating, ventilation, solar shadow and night cooling, can additionally increase the use of thermal mass. According to the researches published in journal, the save of 2-15% in energy consumption can be achieved in the buildings of heavy category (materials with high thermal mass) comparing with equivalent buildings in light category (low thermal mass).[22]

Since the climate is heating during 21st century, it is predicted that daily variation will stay the same or it will have a mild increase, however the temperature range in which it occurs will gradually move up. However, the combination of thermal mass and night cooling will still be an efficient mean for the buildings to adjust to the effects of global warming. [23]

4.2. The analysis of energy performances of a modern housing building

The criterion the building was chosen as a referent model of a modern housing building is quantitative. The buildings constructed between 1971-1980 represent a group of the largest group of buildings in housing stock represented by 21,61%. The buildings constructed between 1981-1990 have similar characteristics as the buildings built in the 70s, mirrored in the use of materials, floors and shape. These two types of buildings are represented with 36,8% and show large consumption of energy for heating, over 300 KWh/m2 per year. The buildings often have floor system of GF+A or GF+1, two plane roofs, without porch, with narrow balconies 1,2 m deep.

House was built in 1972 in Mladenovac represents model of the houses built in the 70s and 80s. Its coordinates are: latitude 44,4, longitude 20,7 and altitude 150 m. The building is withdrawn from the regulation in about 3m and the entrance is oriented on Southwest. The building has 174,29 m^2 net area of heating area. (Fig 2).

Fig. 4 Situation and appearance of the housing building

The most dominant wind in Mladenovac is West, and the average speed is from 2.1 to 3 m/s. The house is with its gable side located perpendicularly to the wind. This position unfavorably influences energy performances both from aspect of cooling as well as from aspect of sunning. The west side is sunny in the winter season when it is needed but in the summer all surfaces of walls and windows are exposed to the direct sunlight. The ventilation of the building is performed via windows. Coefficients of heat transfer for the elements of thermal envelope are given in the table (Table 7). The facade walls and the ceiling are made of hollow blocks made of clay, the slab on the ground is reinforced concrete, and the finishing layer of the floors is parquetry and ceramic tiles. The building has no layers of thermal insulation.

Table 7 Coefficient of heat transfer for the elements of thermal envelope for elements of housing building, relevant model

Outer wall	Floor on the ground	ceiling	Slope roof	windows	doors
U=1.54 W/m2K	U=2.10 W/m2K	U=2.08 W/m2K	U=2.68 W/m2K	U=2.99-3.14 W/m2K	U=3,0 W/m2K

The energy required for heating is 330 KWh/m2 per year, which belongs to G class in Serbian regulations. The fuel is gas with boiler and radiators filled with water. The emission of CO2 when heating is 74,3 kg/m2 per year. For cooling the building needs 6 KWh/m2 per year, the frequency for overheating is 4% over 25 °C (Table 8).

Table 8 Thermal characteristics of a housing building, relevant model

Area of the building m2	Energy required for heating KWh/m2a	Energy required for cooling KWh/m2a	Frequency of overheating	Thermic mass kJ/m²K	Co2 em emission kg/m2a
174.29	330	6	4% over 25°C	450	74.3

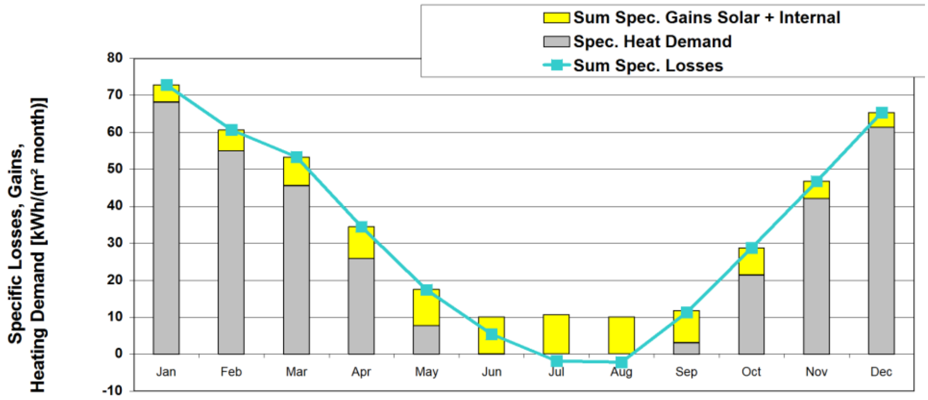

Fig. 5 Calculated heating demand, with PHPP 7, of a modern housing building

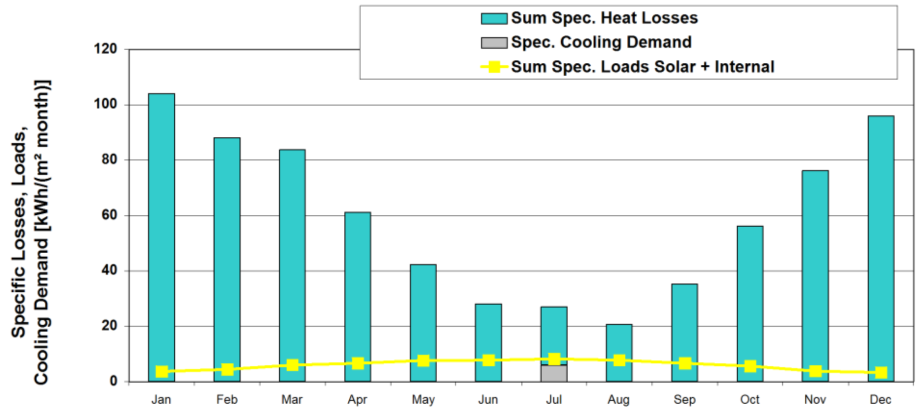

Fig. 6 Calculated cooling demand, with PHPP 7, of a modern housing building

5. Analysis of the Influence of Traditional Materials on Modern Housing Architecture from Energy Aspect

Acts of interpreting traditional one in modern architecture depends on the goal author wants to achieve. I. Maric states the ways of interpretation of traditional architecture based on the participation of all shaped elements, relations, constructions and materials.[24] The first group of interpretation ways consist of eclectic approach, and the second group of the approach referring to concepts of local, national culture which is intertwined to other cultures and it is called critical regionalism. In that group we differ ways of interpretation: partial influences, transposition and tradition as a criterion.

5.1. Analysis of energy performances of a hypothetical model

When we compare the traditional architecture building with a building constructed in the 70s we can conclude that by applying modern materials, after almost a century, we had not succeeded in making energy more efficient buildings, and that by using them we only unfavorably affected the environment pollution.

A hypothetical model represents an example made based on the analysis of all key elements influencing energy performances of the building, as well as based on urban parameters shown by the analysis of the existing housing stock as the most frequent ones (Fig 3).

The building has the dimensions of 11,30 x 11,90 m, in the variant of the floors of the building Gf + A, the useful area is 165,18 m2, and if under roof floor is not used for living, the useful area of the building is 113,63m2. Concerning energy efficiency the use of room under roof is a good measure, because the relation between smaller volume and bigger useful area of a building has been shown as dominant (Table 10).

Fig. 7 Situation and appearance of a hypothetical model

The porch which is enclosed by glass in the winter season, has been designed as a buffer zone in order to protect from the wind as well as a room which with its huge glass surfaces accumulates warm energy during the day. During the heating season the low angle of the sun can shine through the windows on the South facade, and the warmth is absorbed in thermal mass of the floors and walls. In the evenings, when the sun sets and the temperature drops, the flow of warmth is reverse and flows through back to the room. During the warm days, the space of the porch is open toward the outside so the overheating is avoided, and it seems as a widening of the life space. Solar control is most efficiently achieved by shutters and eaves.

In the windy conditions, cross ventilation can be performed in accordance with the conditions of the pressure on the building. The openings on the West and East sides are two parts windows, with a horizontal partition, so the upper, smaller part of the window can be opened and in such a way, to achieve the cross ventilation, with a higher zone of exhausting air. While in the night the bigger parts of the window can be opened, the lower zone will obtain night ventilation. In the variant of housing building with under roof floor, the night ventilation is achieved by vertical of the stairs which has a function of a chimney enabling extraction of the air into the summer, during the night.

In order to minimize heat losses, the high level of insulation is obtained for the elements of thermal envelope. In order to compare the building constructed under conventional and traditional materials the comparative descriptions of thermal layer are given (Table 11). The rate of infiltrations for well insulated buildings is 0,5 n [h-1].

Table 9 The layers of thermal envelope of a hypothetical model, Gf+0 with conventional and traditional materials

	Description of thermal envelope, conventional materials		Description of thermal envelope, traditional materials	
	Description of the layers	Coefficient of the heat transfer W/m2K	Description of the layers	Coefficient of the heat transfer W/m2K
Outside wall	Perlite mortar 3 cm Clay block 19 cm polystyrene 30 cm baumit 15 mm	U=0.174	mortar 3 cm adobe 12 cm hay 20 cm adobe 12 cm mortar 3 cm (mixture of clay and hay)	U=0.22
Floor on the ground	Ceramic tiles 8 mm Cement screed 4 cm AB plate 10 cm Breathable foil 1 mm Extruded polystyrene 14 cm Hydro insulation 4 mm Heaped dirt 10 cm	U=0.225	brick 12 cm sand 15 cm compacted soil, mixture of clay and hay 40 cm	U=0.28
ceiling	Perlite mortar 3 cm LMT ceiling 20 cm Breathable foil 1 mm Mineral wool 30 cm Breathable foil 1 mm	U=0.124	wool 30 cm wood 2,5 cm reed 5 cm mortar 3 cm	U=0.11
Windows/doors	Wooden frames glazed by double low emission glass filled with argon	U=1.12-1.16	Wooden frames glazed by double low emission glass filled with argon	U=1.12-1.16

The energy needed for the heating of a ground floor building is 27 KWh/m2 per year, and for cooling 1KWh/m2 per year. For the structure with floors Gf +A the energy needed for heating is 21 KWh/m2, and for cooling 2 KWh/m2 (Table 10). The designed fuel is gas, with boiler and the radiators filled with water. The building belongs to B class.

From the finished analysis it can be seen that traditional materials equally as conventional materials can meat high standards for low energy houses. According to the prediction of the temperature rise for 2050. the building constructed with conventional materials has shown a much greater leap in the frequency of overheating of 0%-8%.

Table 10 Thermal characteristics of a hypothetical model, designed with conventional and traditional materials

Area of the building m2	Energy required for heating KWh/m2a	Energy required for cooling KWh/m2a	Frequency of overheating	Thermal mass kJ/m²K	Co2 emission kg/m2a
Gf+A, conventional materials					
165.18	21	2	0% over 25°C	382/391	4.6
Gf+0, conventional materials					
113.63	27	1	0% over 25°C	474/517	6.0
Gf+0, traditional materials					
113.63	30	1	2% over 25°C	153/182	6.8
Gf+0, conventional materials, prediction for 2050					
113.63	15	3	8% over 25°C	474/517	3.4
Gf+0, traditional materials, prediction for 2050					
113.63	19	3	4% over 25°C	153/182	4.3

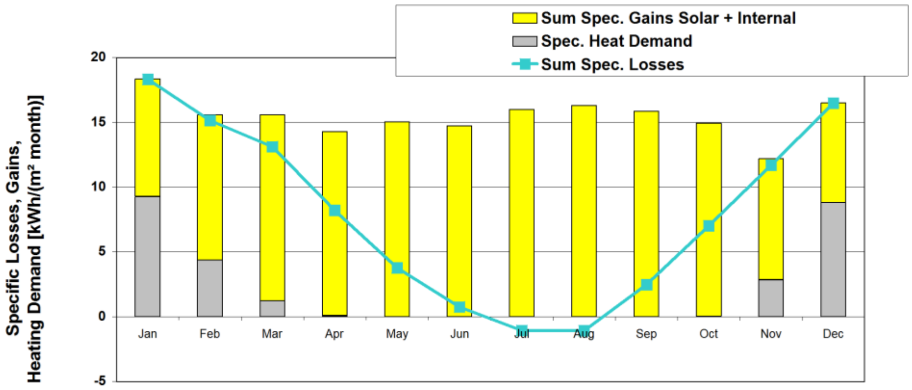

Fig. 8 Calculated heating demand, with PHPP 7, of a hypothetical model, Gf+0

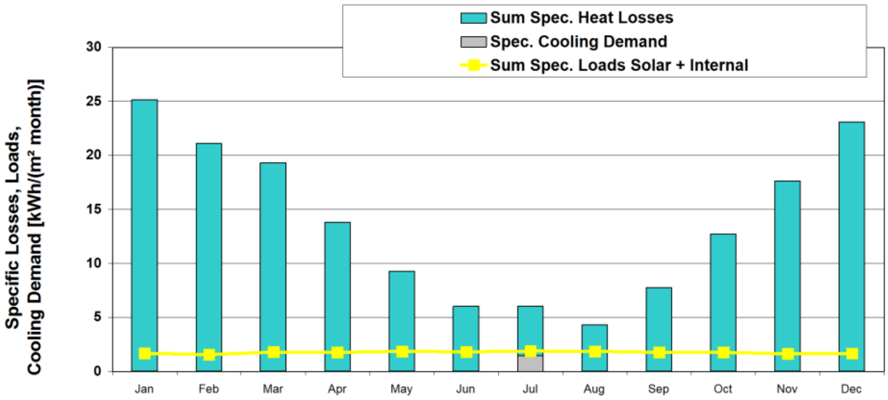

Fig. 9 Calculated cooling demand, with PHPP 7, of a hypothetical model, Gf+0

5. The Conclusion

The buildings of existing housing stock demand averagely around 300 KWh/m2 per year, per building energy for heating. Thus housing stock represents a huge potential for energy savings. Although the regulations in the field of energy efficiency have been introduced since 2012, the problem of great consumption of fuels has not been significantly improved. There are potentials which can be used with professional guidance in the reconstructions of the existing buildings. A lot of the barriers are related to inappropriate education of not only the tenants but also of the professionals from the field of civil engineering, as well as in accepted techniques of construction and living habits which are hard to change.

Recommendations for the reconstruction of existing residential buildings:

- wind protection,
  if there is no possibility of closing the openings on the facade that is exposed to the wind we can use vegetation with the aim of protection,
- orientation,
  small percentage of transparent surfaces is characteristic of the existing buildings; it is necessary to consider possibility of increasing the openings (e.g. converting the windows in the patio doors), especially in the south-oriented facades,
- insulation,
  out of all of the measures to improve the buildings, insulation proved to be the most important measure; wall and roof insulation has an especially large impact on reducing the energy required for heating,
- avoiding overheating,
  having in mind that existing buildings have a high thermal mass, it is necessary to put insulation on the outside of the thermal envelope so as to provide its effects in reducing the frequency of overheating and reduce the energy required for cooling, in order to use shading elements eaves, shutters and porches,
- ventilation,
  existing residential buildings have the potential to deliver good ventilation of the facilities, the presence of wind throughout the year, the temperature difference between day and night temperatures, the ratio of internal height and width of the object that is about 1:5, to use cross-ventilation, it is preferable for fresh air to enter at a lower elevation, but to outputs at a higher altitude, (for this effect double holes with horizontal division are suitable), in establishments that have internal staircase can be achieved by ventilation chimney effect, so it is above the staircase vertical incorporate an opening that opens, if necessary, along the windows on the ground floor,
- thermal mass,
  if it is necessary to improve the thermal mass consider balcony glazing so that the thermal mass is increased by introducing a reinforced concrete slab and part of the facade wall claddings in the heat, which reduces the risk against the heat, and increases the proportion of transparent surfaces.

The design of the housing buildings should be adjusted to the current and predicted climate conditions, so they can be energy efficient for a longer period. All the elements of passive design, thermal mass, representation of the transparent surfaces, orientation, the influence of the wind needs to be well balanced. Low coefficient of the heat transfer of the elements of thermal envelope do not always have to be a guaranty for energy efficient buildings.

The guidelines in reconstruction and construction of family housing buildings are:

- to include all potentials of location in the construction of the building, including orientation, winds, vegetation and available materials,
- to orient the buildings towards the South so the solar gains can be increased,
- to balance layers of insulation of the building, in excess of 30 cm increases the risk of overheating the building,
- to prevent the overheating by designing the buildings with balanced thermal mass, the relation between the thermal mass and the transparent surfaces so that they can meet the standards according to the predicted temperature rise,
- to provide ventilation which provides the quality of the air, which is necessary to avoid overheating, and in that sense to use night ventilation.

Traditional architecture is a mirror of many limitations of the location it belongs to, where the use of local materials and techniques of construction is one of the main characteristics. In folk architecture materials and building techniques have several advantages from the aspect of sustainability to be promoted: no need for transport, less energy spent in the production process and with that less $CO2$ emission, they are natural materials, often organic, reusable and biodegradable, with long life cycle and have low influence on the environment during the maintenance. Together with building techniques adjusted to them, they make the element which brings it to differentiation in the architectural style. As a contrast to that, the use of industrially produced materials leads to homogenization because of the same constructive approach, and so universal architecture is made which in many cases is out of the context of the location and dependent on energy and other resources.

One of the goals of this paper is promotion of the principle of construction of traditional buildings in order to build a low-energy house. A good source of information on the actual energy performance of the building could help tenants to make decisions during the construction of residential buildings. To this aim it is necessary to provide practical information and solutions to build energy-efficient houses with traditional materials through experimental research and monitoring of construction of such facilities.

Recommendations to promote the construction of family houses with traditional materials:

- ensure the availability of local production of components of materials to potential sites,
- educate stakeholders in the construction, through local workshops that specialize in a variety of traditional materials,
- inform and educate tenants through concrete guidelines, concepts and effects of the behavior of objects,
- provide accurate information about the real costs and benefits of the investment, including possible subsidies,
- provide an objective comparison with current practice and the acceptance of this type of facilities in the market.

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ISPITIVANJE POTENCIJALA TRADICIONALNOG I SAVREMENOG INDIVIDUALNOG STAMBENOG OBJEKTA U CILJU KREIRANJA NISKOENERGETSKE KUĆE

Strategija istraživačkog rada je da sprovede analizu individualnih stambenih objekata sa aspekta unapređenja izgradnje energetski efikasnih objekata. U tom cilju analizirani su svi ključni aspekti neophodni za projektovanje, kao što su zakonske regulative sa kojima je neophodno uskladiti izgradnju i rekonstrukciju objekata, klimatske uslove obrađivanog područja, koji su neophodni u planiranju strategija izgradnje, snimak postojećeg stambenog fonda kao i kulturni identitet kroz nasleđe tradicionalnih objekata. Kroz analizu tradicionalnog objekta, referentnog modela postojećeg stambenog fonda i hipotetičkog modela-novoprojektovanog objekta, putem softvera za analizu energetskih performansi, izvedeni su zaključci i date praktične smernice u rekonstrukciji postojećih i izgradnji novih objekata na osnovu proverenih naučnih dokaza. Rad se fokusira na ispitivanju i primeni elemenata tradicionalne arhitekture u cilju unapređenja energetskih performansi novih i postojećih objekata.

Ključne reči: *individualni stambeni objekti, tradicionalni stambeni objekti, energetski efikasni objekti, tradicionalni materijali*