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APPLICATION OF EARTH AND STRAW MIXTURES IN MODERN BUILDING

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SUMMARY:

Building with earth is widespread and still mostly based on traditional experiences. Increasing demands in energy consumption reduction during the construction and exploitation of buildings put more and more in the focus the good features of houses built with earth. Testing of earth mixtures with other natural materials showed that it can get even a quality of bricks, which indicates the lack of appropriate standards for this type of construction.

Testing are performed with mixes of earth and straw intended for rammed earth and adobe construction. This method of preparation and construction applies in alternate construction with straw bales and it is also used in the construction of prefabricated panels with wooden frame filled with a mixture earth and straw where it is possible to build prefabricated structures or as a filling of wall screens in skeletal structural system of larger dimensions and number of floors.

Laboratory tests have shown that the mechanical and thermal properties of this material fulfilled the high demands for the construction of modern buildings. Based on the presented results it can proceed the development and testing of structural elements for that kind of building.

Also, based on results, in the article the authors presented possibilities of architectural design of various building possibilities of objects, as practical examples of prefabrication applied in some countries.

Key words: *earth, mixture, straw, rammed earth, structure*

INTRODUCTION

Building with earth is widespread and still largely based on traditional experiences. . Increasing demands in energy consumption reduction during the construction and exploitation of buildings put more and more in the focus the good features of houses built with earth Testing of earth mixtures with other natural materials showed that it can get even a quality of bricks, which indicates the lack of appropriate standards for this type of construction [1]. More precisely preparing and placing of the mixture will help to set the missing standards for this type of construction [2].

In addition to the previous tests of mixtures for rammed earth structures and adobe building [3], in this study the tests were conducted with a mixture of earth and straw [4]. This way of preparation and construction is applied in alternative construction of straw bales but more and more is used in the construction of prefabricated panels with wooden frame, filled with a mixture of earth and straw, where it is possible to build prefabricated structures or to use the mixture as an infill of wall screens in skeletal structural system of larger dimensions and the number of floors.

Laboratory tests have shown that the mechanical and thermal properties of this material fulfilled the high demands for the construction of modern buildings. Based on the presented results it can precede the development and testing of structural elements for that kind of building. The advantages of this type of construction is in accessibility of local materials (immediate surroundings around the construction site), easy to process with simple tools, less possibility of thermal bridges thanks to the fully filled 1 layer massive walls.

Thermal comfort of a house made of earth allows to meet high standards for energy efficiency performances.

PREPARATION OF THE MIXTURES

Preparation of samples started with sinking of the straw in water for 20 minutes, then it drained and mixed with the clay, and additional water enough to achieve a uniform mass - Figure 1 (left). Then the molds were filled with a mixture and compacted as in Figure 1(right) it is showed. The molds were then placed for drying.



Figure 1. Mixing and filling in the molds

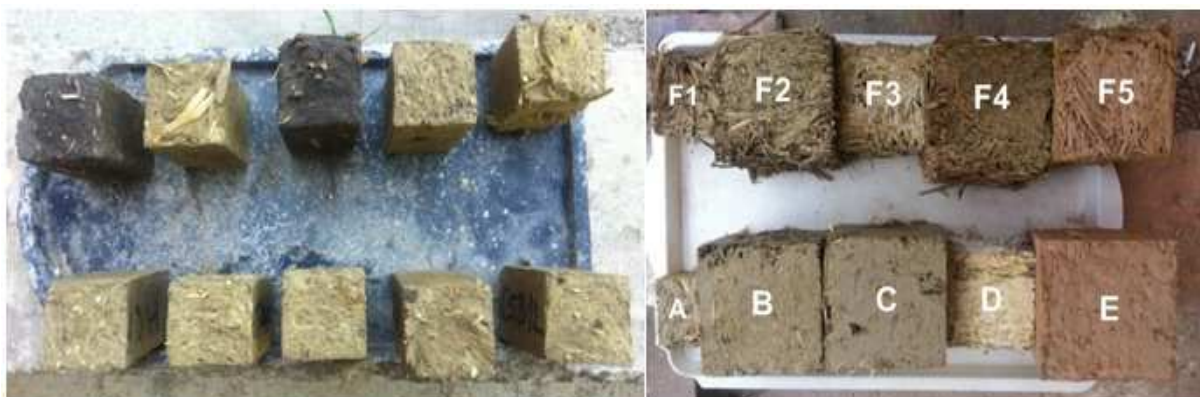


Figure 2. Causes after drying

Table 1. shows the test mixture proportions of clayey earth with straw (Figure 2.), based on which further developed could be make with these materials of excellent thermal insulation characteristics .

Table 1. The mix proportions

Labels	Composition	quantity (g)	Note
A	Clayey earth, straw, water	1 liter, 1 liter, 150 ml	straw was not soaked in water
B	Clayey earth, straw, water	1 liter, 2 liter, 150 ml	straw was not soaked in water
C	Clayey earth, straw, lime	0,5 liter, 2 liter, 0,5 liter	
D	Clayey earth, straw, ground ceramics	0,5 liter, 2 liter, 0,5 liter	
E	Straw, lime, ground ceramics	2 liter, 0,5 liter, 0,5 liter	
F1	Clayey earth, straw, water	2 liter, 1 liter, 50 ml	
F2	Clayey earth, straw, water	4 liter, 1 liter, 50 ml	
F3	Clayey earth, straw, water	6 liter, 1 liter, 50 ml	
F4	Clayey earth, straw, water	3 liter, 1 liter, 50 ml	

Mixtures labeled A, B, C, D and E have relatively lower strength (at sample D is to even negligible), as shown in Table 2. They can be used as a kind of thermal insulation plaster on any kind of solid walls (rammed earth, adobe or fired brick). During the casting of these samples into molds a smaller force is applied in order to result the lower compaction - similar as it would be in plasters on the wall. Mixtures labeled as F1, F2, F3 and F4 were cast into the molds in 3 layers with a compaction force of 5 kN. These mixtures are intended for the construction of rammed earth or abobe.

Table 2. Results of testing

Labels	fc [MPa]	γ [kg/m ³]	λ [W/mK]	Cp[10 ⁶ J/m ³ K]
A	0.473	832	0.114	0.383
B	0.730	1083	0.322	0.911
C	0.511	1292	0.318	0.943
D	0	665	0.105	0.398
E	0.284	1048	0.22	0.915
F1	2.083	965	0.208	0.381
F2	4.137	1263	0.346	0.894
F3	4.137	913	0.205	0.771
F4	2.298	1189	0.288	0.555

All samples were cured at a temperature of 20 ° C to 25 ° C at a relative humidity of 40 to 60%, 6 months, as it was necessary to ensure that their thermal characteristics are stabilized. On a cube form samples with edge length of 15 cm were first measured the coefficient of thermal conductivity - λ and the heat capacity Cp and subsequently, their density γ and compressive strength fc. These results proved that it is possible to achieve a very low coefficient of thermal conductivity with acceptable strength (sample A), but also it is possible to achieve a good compaction with a relatively high strength (for samples F1, F2, F3 and F4) - suitable for rammed earth wall structures, with a good thermal insulation and accumulation characteristics, required for creating a pleasant microclimate inside the building during warm summer days.

As on the basis of these results - F1, F2, F3 and F4, can be seen, one-layer insulating infill made with clay and straw could provide similar characteristics in terms of thermal requirements, as a three-layer

Ecococon panels. Mixtures with labels A, B, C, D and E could be used for a further improvement of HVAC properties, primarily on the walls made with earthen materials.

POSSIBLE APPLICATION OF TESTED MATERIALS

Possibilities for the application of this kind of construction are multiple and range from individual prefabricated houses to multi-storey buildings. In this way, the possible application can be divided into the following categories:

Individual straw bale construction, the method of construction, resulting from a traditional manual construction where, thanks to the use of mechanization in agriculture bale of straw blocks appear as suitable for construction, in Figure 3.



Figure 3. The house built by Lehel Horvat, Serbia

Precast panels, the next logical step in the development of traditional materials in a modern building and adapting modern technologies of construction. This is the development of modular panels with a wooden framed structure, where it is possible to build smaller buildings up to two floors, in Figure 4, [4,5,6].



Figure 4. Ecococon panels

This method of preparation of the panel allows the semi-industrial way of production and opens up a wide range of possibilities for architectural design, Figure 5.

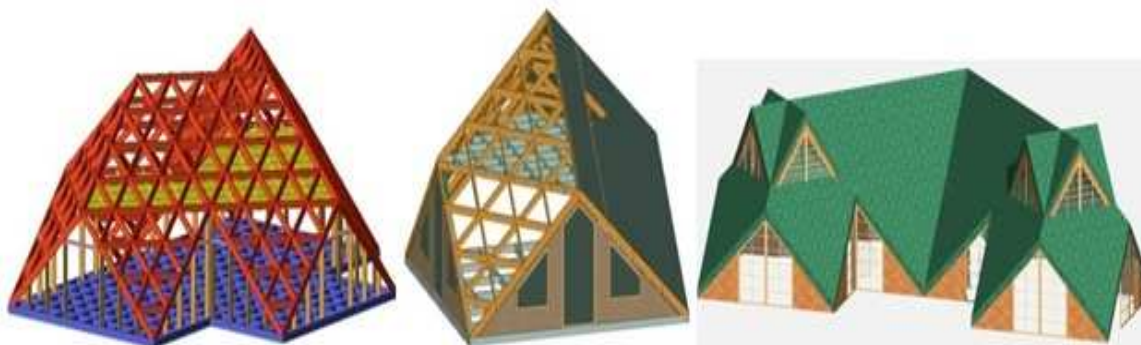


Figure 5. More options for developing different forms of objects (by I. Hegediš in 2015)

Use in multi-storey buildings, a reinforced concrete skeleton and metal buildings systems of larger size and number of floors (residential, commercial and industrial) are ideal forms for application of infill screens like prefabricated wall panels [7,8]. Their production shall be placed depending on the transport routes of basic materials (wood, straw, clay) and can be executed in specialized factories or at the construction site. This is due to the simple technological procedures, small machine engagement and flexibility.

CONCLUSION

Accessibility of raw materials in the immediate environment, simple technology, validated mechanical and thermal characteristics of building with straw and clay confirms the absolute justification to carry out further investigation of all aspects of the application. Laboratory tests contribute to the experiential knowledge to standardize and introduce as a technical standard in construction.

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