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RETHINKING OF THE VERNACULAR ADOBE ARCHITECTURE REHABILITATION

Ákos Nemcsics[1], Antal Ürmös [2] and György Gröller [3]

[1]Research Group for Materials and Environmental Science, Óbuda University, Budapest, Hungary
akos.nemcsics@uni-obuda.hu
[2]Research Group for Materials and Environmental Science, Óbuda University, Budapest, Hungary
antal.urmos@uni-obuda.hu
[3]Research Group for Materials and Environmental Science, Óbuda University, Budapest, Hungary
groller.gyorgy@uni-obuda.hu

Abstract: *In recent work, heat-technical modeling, life cycle assessment, and rehabilitation of the vernacular adobe wall house is discussed. Our topic choice is based on the fact that a significant part of the Hungarian rural housing stock consist of adobe-walled buildings. The adobe wall construction is especially perfect for the seasonal climatic equalizing, which property has increasing ecological importance due to the effect of growing global warming up. Largely, these adobe-walled houses are part of our cultural heritage, therefore they are worth to preserving. Finally, their constructional conservation, energetical rehabilitation and also maintenance problems are briefly described..*

Keywords: *adobe house, heat technical modelling, life cycle assesment, cultural heritage, rehabilitation*.

1. INTRODUCTION

The folk architecture is an exemplar for the ecological architecture in the viewpoints of applied structure and material, too [1]. Optimized structure and material use of these houses have evolved over many centuries. These ecologically optimized solutions can be found in the vernacular architecture remained to us. The vernacular architecture is typically architecture of the villages. Worldwide, but especially in Europe, the composition of building stock is drastically changed during the 20th century. Due to growing comfort demands, the traditional buildings were demolished and modern ones built instead of them. By the pulling down of the traditional vernacular houses, our cultural heritage has brooked important damage. In economically poorer areas, this building stock transformation is slower process. In these financially disadvantaged areas, a significant number of traditional buildings have been preserved. With the help of the novel high-tech technology, these old vernacular houses can be rehabilitated to achieve the new comfort claim.

Very important feature of the folk architecture is that it adapts to its natural, geological and climatic environment (Fig. 1.). This architecture applies local building materials like: earth, stone, wood etc. [1]. Here the choice of the building material is ecological, because they do not need additional production energy [2, 3]. Taking into consideration of the local climate, in the hills or in the colder area, the wood construction is usual. In one hand, the wood as raw material is given by the forest, on the other hand, the wooden wall has high thermal insulation. In the area of hot and dry climate, large mass constructions and large specific heat-coefficient materials are suitable. In such areas, the houses were built from earth and stone. In the rainy countryside, the high picked roof is subservient. In dry areas, a flat roof is advisable for collecting precipitation.

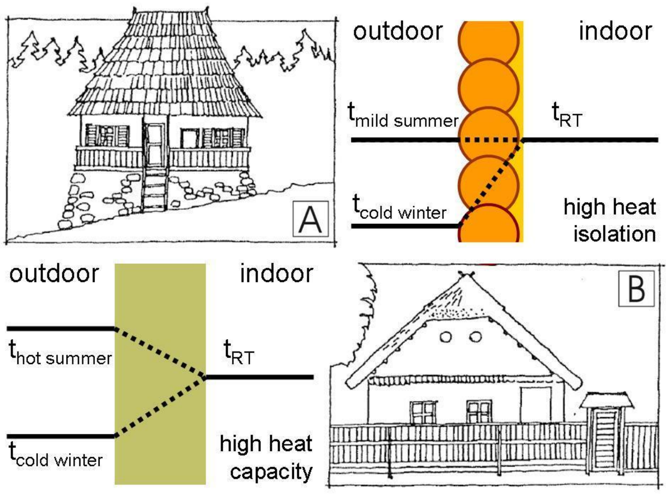

Figure 1. The folk architecture accommodate to the environment (morphology, climate etc.) (A) Hungarian vernacular house in mountainous district (Csík region) and (B) in lowland (Alföld region) (Source: [1])

Due to the economic reason mentioned above, important vernacular architecture has remained in the Carpathian Basin as a cultural heritage. It should be emphasized that these old folk buildings have not been replaced by new houses only for purely economic reasons. Unfortunately, among the residents, the old house symbolizes poverty, so the honor of these old houses is not right. In the Hungarian low land, the specific climate is extreme: the summer time is hot and the winter time is cold. Therefore a large mass and large specific heat-coefficient walling is appropriate. So here, traditional houses have adobe walling (Fig. 2) [2, 4].

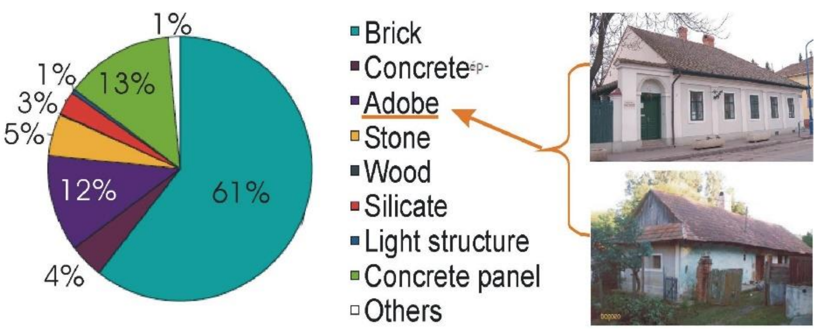

Figure 2. Recent building stock in Hungary according the building material. notable amounts (12%) of the building are still from adobe especially in low land. (Source: [4])

In fact, in Hungary, more than ten percent of the building stock is adobe-walled, the majority of them represent cultural heritage, which could also be declared a monument. (Fig. 3.) [5].

Figure 3. Houses by adobe walling from north part of Hungarian low land. (A) a family house, (B) a reformed church (Tákos). (Source: photographed by author Á. N..)

2. CLIMATICAL AND CONSTRUCTIONAL ASPESTS

The technology of the building from adobe and from earth is very old. More thousands years old adobe walling and building residuals have survived to posterity. Under dry condition, the adobe walling is very strong and durable structure. The biggest enemy of this structure is the moisture, which loses its stability when exposed to water. Therefore it is important to protect it from the rain and from the ground water. As example, the more thousands years old building conservation, the Limestone Mosaic Church in the Mesopotamian town Uruk in have to mention [3].

The adobe wall house has healthy indoor climate. Not only its thermal equalizer property is excellent, but its humidity balance ability as well. The reason of the cheap, local raw material, and outstanding building physical properties, the adobe-architecture is back in fashion again. In Europe, mainly residential houses build from adobe. In Africa, and in South-Asia, the adobe wall public buildings (such as church, schools etc.) are also not rare. The adobe walling technology is various, depending on the area [7-9].

The sliding frame technology is a possible solution. The walling from brick shaped adobe elements, dried on sunshine, is an other solution. The flickered - plastered structure among the twig frame is one of the older method. In Hungarian folk architecture, all of these three common technologies were popular. Recently, the first two solutions are used again. The cooker and oven constructions from the adobe were also very popular. Firstly, the frame of the oven or cooker was built from thin curved twigs as stiffening structure. Afterwards, the flickered adobe-clay to the wood frame, during the first heating burned out and the clay changed into the tile material.

The adobe wall architecture is fit for the Hungarian low land climate because, it is necessary to store large amount of heat. Because of the global warming up, the summers are getting hotter. The heat storage capability of newly built hollow brick and lightweight constructed houses are low. Therefore, there is plenty of air conditioning equipments in the newly build houses. The good thermal isolated lightweight constructed houses are suitable in the cold northern and mountain areas, where the summer air temperature not exceed the 20-25 ^{o}C. The Hungarian low land climate in the past 25-30 years changed a lot. It is more and more common, that the summer is warmer than 35 °C. While earlier, warmer than 30 °C was an extraordinary case and considered very-very hot.

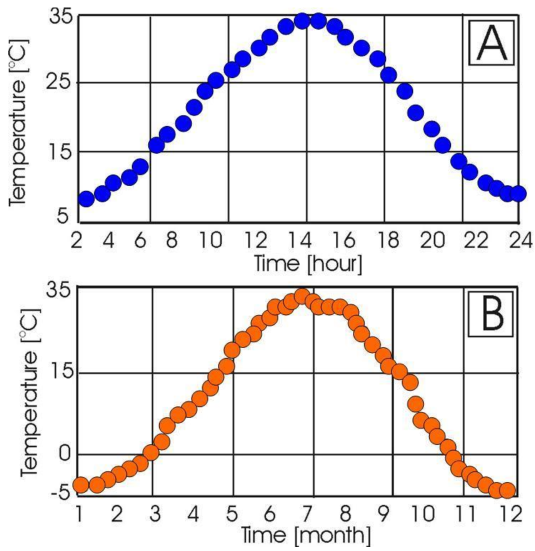

Figure 4. The temperature change versus time for different periods. (Source: [6])

The locals are not adapted to the recent warmed up climate, so they often use air conditioning equipments. Unfortunately, these instruments neither operated by solar cell, but by network current from power station, which causes positive feedback, as regards CO_2 emission and global warming up [4, 10]. In our investigations, we taken into account the average of our many years of solar radiation access and heat measurements. The annual temperature changes (i.e. excitation) can be well approximated by sine function. The temperature waving shows a good correlation with the fluctuation of sun radiation (Fig. 4.) [6, 11].

3. HEAT TECHNICAL CONCEPT

In the engineering practice, the thermal sizing of buildings and building structures refers to a steady state. Here, a simple resistive electrical circuit is used for the description, where the walls or walling structures and their junctions are represented by a resistances connected in series. The difference in external internal temperature corresponds to the voltage. The temperature profile, formed along the cross-section of the wall can be investigated as voltage drop on resistors. A necessary parameter for the calculation is the heat transfer coefficient (α), and the thermal conductivity (λ), which parameters can be found in the literature [12], [13]. The stationary model mentioned above does not correctly describe all of thermal behaviors. For example, we did not consider the heat-storage capability. So, it is necessary to extend with the slowly-changing anstationary case. Let we see a simple homogenous wall structure, like the adobe wall is. As we seen in the previous chapter, in the examined climate, the thermal profile gives a good approximation of sinus function, which is in the terminology of the electro technical description, means harmonic excitation. In our case, the heat-capacity of air, which is bound the wall is much lower than the wall structure, so in first approximation, we can neglect the calculation of the heat transfer coefficient (α). So the electrical equivalent circuit of the wall construction consists a resistance (d/λ) and an impedance (A/cm), which are parallel connected each other, where d is the wall thickness, A is the normalized area, c is specific heat capacitance, m is the normalized mass of the walling [6].

Let's do an examination with typical data [14-17]. Depending on the adobe composition and the moisture content, the data (ρ, c, λ) are scattered, so we took their mean values. We took a 50 cm thick adobe wall, which is common in the Hungarian folk architecture. Where this wall is not complete isolated from ground. Therefore the moisture content of the wall is variable. So we became the building physics parameters the following values: The wall density is ρ = 1500 - 2000 kg/m^3, the heat-capacitance is c = 1.2 – 3 kJ/kgK, the heat conduction is λ = 0.52 - 0.64 W/mK. The amplitude and phase characteristics are shown in the (Fig. 5.). (The phase and amplitude characteristics can be derived from the s_{11} "reflexion" parameter [18].)

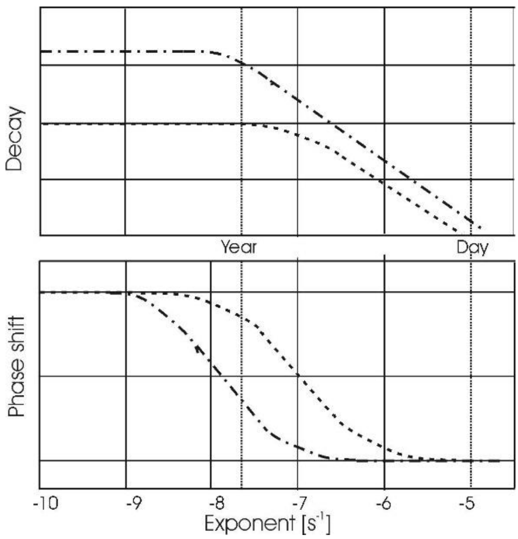

Figure 5. Plot of the decay and phase shift for different building materials. Dotted-dashed and dashed lines represent the above based adobe and a brick wall structures, respectively. (Source: [4 6])

Nowadays, in Hungary, the 38 cm thick brick wall is the most common walling structure. Because of the comparison, investigate our data for this wall type, which details is ρ = 1700 kg/m^3, c = 0.88 kJ/kgK, λ = 0.72 W/(mK). On the figure, vertical lines indicate the values, corresponding the day and year. It is readable from the figure, that the heat balance of the adobe wall is larger than the brick walling in regard to one year. The thermo-technical operation of the adobe walling shows not only phase shift but also hysteretic behavior. The stored heat and its detailed calculation described elsewhere [6].

4. COMPARATIVE LIFE CYCLE ASSESMENT

Let's compare the adobe walling buildings and the brick houses from the viewpoint of lifecycle, and their impacts on the environment. We mentioned above, that the adobe wall building needs only winter heating. In summer, its inner climate is very comfortable. In newly built houses, lower winter heating may be required because of its better thermal insulation. But during the summer time, the interior of the building often overheats.

Against the summer warming, many use air conditioning. So the adobe wall house energetically is not unfavorable [4]. The pulling down of the adobe wall building and the construction of the new one need also energy (Fig. 6.). Furthermore, the adobe wall building represent not rarely cultural heritage. Hereinafter we show, how we can take it more comfortable [19]. One of the most important things is waterproofing. There are several people involved in making adobe houses comfortable [20-23].

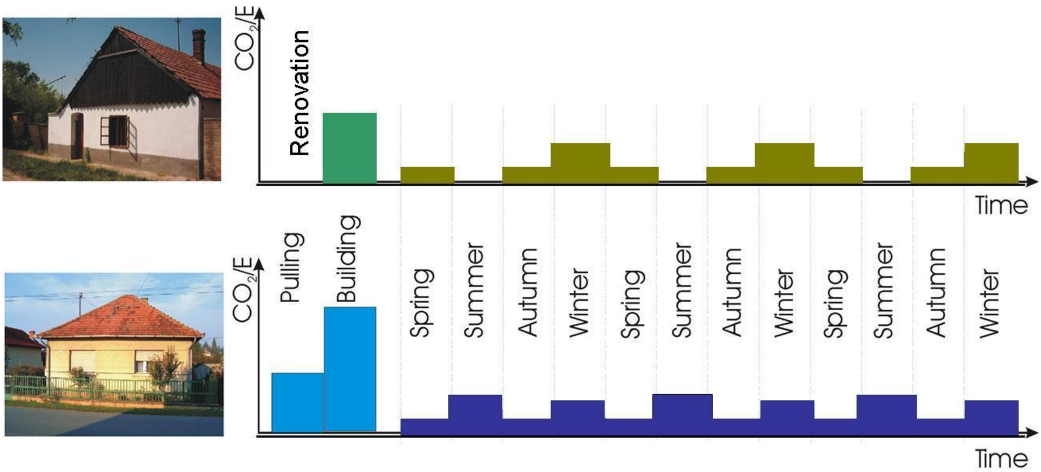

Figure 6. Comparison of the life cycle for an original adobe wall house and a brick wall house substituted the original building

In the following in the frame of life cycle assessment, the adobe wall house and the brick house in the view point of annual CO_2 emission are compared. For the valuable comparison of the houses, they have the same (75 m^2) floor area and the same (North-South) orientation. For the calculations, the walling properties are the same as used in the former caption. The walling thickness in the case of adobe and brick are 50 cm and 38 cm, respectively. The building structures were made in the usual size with usual material choice. The relevant literature gives the usual structure for both adobe [24] and brick buildings [25]. The building engineering equipments has been designed to meet today's average needs, which is similar for both building types except for air conditioning. This latter is unnecessary at the adobe building. In this way, our calculation are suitable for trend comparison.

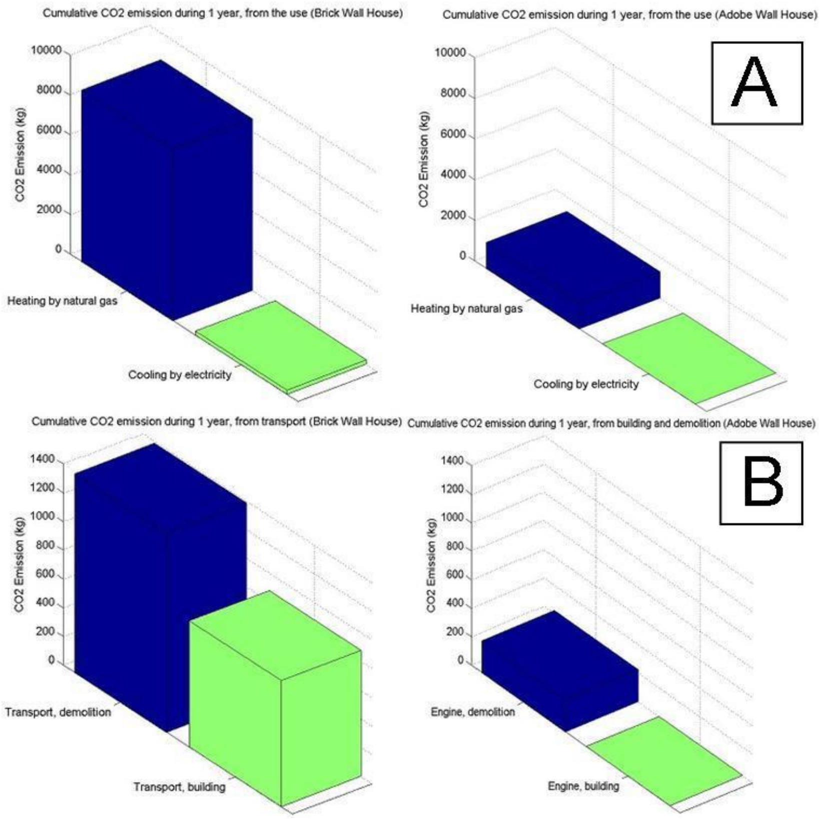

Figure 7. (A) The annual CO_2 emission of the brick house and the adobe wall house; (B) The CO_2 emission of the brick house and the adobe wall house during the building and demolition processes. (Source: Produced with the help of LCA program Gabi)

In the Figure 7/A the annual CO_2 emission of the brick house and the adobe wall house are shown. In this figure, the blue column represents the CO_2 emission from the heat, and the green column represents the CO_2 emission from the cooling. In both cases the same condensation boiler was chosen. The fuel is natural gas. The figure shows, that the annual heating CO_2 emission of the brick house is larger compared with the adobe wall house emission. In case of the brick wall house, a split air conditioning equipment is equipped. The annual cooling CO_2 emission of the brick house is an extra pollution. In the diagram, it can be seen that the annual CO_2 emission of the adobe wall house are smaller, than the brick house. This is due to the bigger walling thickness and the larger heat capacity of the adobe walling, whereupon it cool down and heat up more slowly, than the brick walled building.

In the Fig 7/B., CO_2 emission of the brick house and the adobe wall house are shown during the building (blue columns) and the demolition (green columns).
These two values are different, because in the case of demolition, the dust of the undercoat is also transported elsewhere. In the case of the adobe wall, in the building process the adobe wall is constructed usually by manual force, by the cradling method, using local raw materials (clay, straw).

The reason of this, that during the heating period (spring, autumn and winter), the brick house always need heating, because the walls are relative thin and their heat capacitance is small, so the building cools rapidly. Because of the same reasons, in summer time, the brick wall building also heat up rapidly. It should be noted, that only the rooms have air conditioning equipment. In contrary, in the case of adobe wall building, air conditioning equipment is not necessary. In winter time only, an auxiliary heating is necessary. It should be emphasized again that these calculations are for qualitative comparison only.

5. STRUCTURAL AND ENERGETICAL REHABILITATION OF THE OLD ADOBE HOUSE

In a regrettable manner, in Hungary, among the population of the country, the poverty and the underdevelopment are associated to the adobe walling houses. Therefore, if they can do, they demolish the adobe wall house and build a brick house instead of this. Among the educated population, the construction from adobe clay is spreading again. The university or college educated people are environmentally conscious and they looking for the healthier and more environmentally friendly solutions. Nowadays, already appear publications related to adobe clay architecture, but this is always very few, for the change the point of view.

Figure 8, 9. Two renovation processes of the adobe house. Upper part: strengthening of the of the walling: (A) splitting (B) connection of the cable-rope to the screw (C) The streched cable-rope in inside (D) The screw with underlay in outside. Lower part: Strengthening of the surfaca: (A) the moulding surface in outside (B) the wire mesh mounted on the wall (C) rough-casting (D) polished plastering in inside. (Source: Experimental work by the author Á.N.)

As mentioned before, the adobe walling must be protected against the water (the rain, splashed water and the ground water). The one of the most important thing, that the roof structure and the coverage of the house must be perfect. We can protect ourselves by surface cover, against the splashed water. There are many kind of water insulation exist, against the ground water (pressed metal plate into the wall, chemical material to the drill hole etc.).

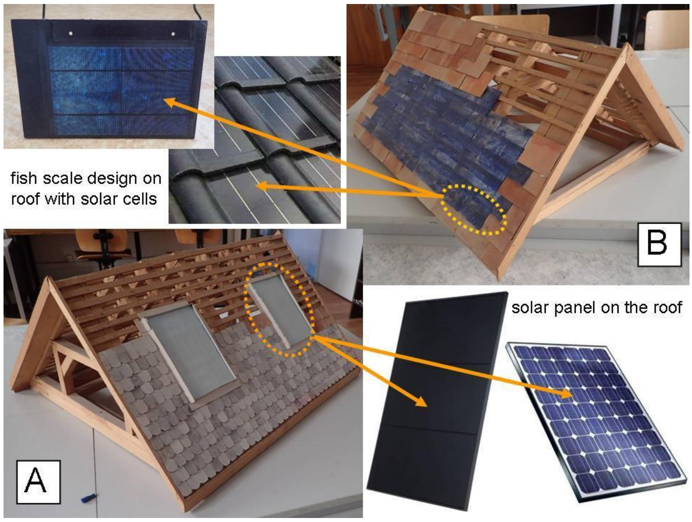

Figure 9 (A) fish scale designed solar cover (B) panel designed cover (The illustrative board model was built by Gergely Nemcsics)

In many cases, we have to renew neglected buildings. Because of the injured roof and continuous rain can be happen, that the wall cracks. Above all, it needs to eliminate the reasons of these cracks. The next step is, that these cracks cannot open further, it need contracts the wall, by wire rope. The surface of the adobe wall is friable, it not keep the painting and the plaster. We can help on this, that on the surface we fix a thin wire mesh with big nails and we plaster thin in a traditional manner (Fig. 8.). The renovated adobe wall building is not only power saving and healthy (for example humid balancing), but it emits very calming mood, because of its traditional formation.

In many cases, there is a situation, to make the viewpoints of the environmental protection, energetic or monument protection consistent. Often there is a dilemma that should be stacked to the old, but outdated solution (from the energetic point of view) or the novel solution, which is not fit from the aesthetical point of view. Should we choose high-tech or low-tech? Because of technical development, this dilemma seems to be solved. In case of the protection against moisture and wall insulation, there are many solutions, which are not inconsistent the monument protection or aesthetical viewpoints.

From the energetical point of view, primary the solar cells come into play. The reasons are its lifetime very long and aesthetical fitting is to be also solvable. There is two main methods to install solar cells to the high picked roof. One of them is the solar cell, which appearance is similar to the window laying in the plane of the roof. The other is the lamella-type or fish scale designed covering. In this case the solar cell is laminated into the roofing slate or roofing tile. The color of the surface can be modified by surface layer. Currently, among the product in the commerce there are many choices. So the lamella-type solar cell is one possible solution of the energetical favorable monument renovation [26].

CONCLUSIONS

In this work, we showed that in Hungarian low land, the adobe clay architecture corresponds to the climate, which is proved by vernacular architecture. We showed that the adobe clay houses preserve both from the viewpoint of either energetically advantageous or preservation of the cultural heritage. Furthermore we showed some possibility, for the improvement of the status of the adobe building.

The present work contains three main conclusions. Firstly, the transient electro-technical model shows, that the thick adobe walling is appropriate for the seasonal heat balance. Secondly, the result of the life cycle assessment presents, that the preservation and renovation of the old adobe wall buildings is more ecological solution, than their breakdown, and instead of they building of new brick wall houses. This conclusion is proved with the consideration of long term building maintenance as well. Thirdly, the suggested solutions of the building rehabilitation are confirmed by many year experiences.

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