6. Thesis: the dosage of the filling material regulates *the piece density (ρ_t). The ρ_t is stochastically linearly proportional to the strength (σ) but it is inversely proportional to thermal insulation capacity (R). The piece density ρ_t can be optimised in the function of σ and R.*

7. Thesis: *the main aspect of choosing the qualification tests is to examine the disadvantageous mechanical parameters of the adobe such as:*

- *shrinkage*
- *strength („quasi" tensile and compressive strength)*
- *sensitivity to water.*
-

7.1. Thesis: *instead of the DIN 18952 complied binding strength test the „quasi" tensile strength test should be introduced. In case of cylindrical test, specimen made by dry technology the „quasi" tensile strength means the test of the compressive strength alongside the edges, and in case of the humid technology, it means respectively the test of the test specimen for bending strength.*

7.2. Thesis: *The notion 'water resistance and water softening' determining the relation of the construction materials to water cannot be applied in case of adobes. Instead of that we can propose to introduce the notion „sensitivity to water". The standard DIN 18952 for water sensitivity test should be taken over with a slight modification. The test should be made the same way by measuring the sludging time in case of both test specimens (cylindrical or prismatic).*

7.3. Thesis: *the shrinkage test should be made by measuring the length of the test specimen every day during one week with a tolerance of 0,1 mm. According to my examinations the shrinkage after one week can be considered as final value of the shrinkage.*

8. Thesis: *new consistency limits should be determined by taking into consideration the consistency limits in the soil mechanics and mortar technology in function of the adobe construction technology. These are the following:*

– earth humid (FN): consistency of the adobe mixed with **lower** water content belonging to ρ_{dmax} 95 %

– *slightly plastic (KK):* *consistency of the adobe mixed with a water content belonging to ρ_{dmax} 100 %*

– *plastic (K):* consistency of the adobe mixed with **upper** water content belonging to ρ_{dmax} 95 %

– *fluid(F):* *the consistency of the adobe mixed with the water content belonging to the dropping number n = 25 determined by the Casagrande test*

– *pourable (Ö):* *the consistency of the adobe mixed with the water content belonging to the dropping number n = 20 determined by the modified Casagrande test*

– *The FN consistency limit indicates the lower limit of the working in with dry technologies, the KK consistency means the optimal limit while the K consistency limit indicates the upper limit of the working in.*

– *The F consistency limit with humid technologies indicates the easiest working in, while (ö) means the limit of the formation ability.*

9. Thesis: *I propose to introduce the notion of the critical clay content (a_{krit}) The a_{krit} is the clay content of the adobe under which the shrinkage of the adobe is convergent and over which it is divergent. The convergence means that with a careful supplementary treatment the cracking of the adobe could be avoided. In case of divergence the adobe will be surely cracked.*

10. Thesis: *the limit water content (w_h) is the content of the mixing water under which the shrinkage of the adobe is convergent and over which it is divergent.*

The convergence means that with a careful supplementary treatment the cracking of the adobe could be avoided. In case of divergence the adobe will be surely cracked.

11. Thesis: *the fibre content of the load bearing adobe should be between 10-30 kg/m^3. It is not suitable to apply less than 10 kg/m^3 because the sensitivity of the adobe for cracking. The quantity over 30 kg/m^3 will no more effectively promote the tensile strength of the adobe, but it will significantly reduce its compressive strength.*

12. Thesis: *The maximum grain size (d_{max}) will very significantly influence the strength of the adobe. In case of a A $d_{max} > 4$ mm the compressive strength of the adobe will be significantly diminished. Mixing larger individual grains into the adobe – d > 4 mm– will also significantly reduce the compressive strength of the adobe.*

13. Thesis*: in case of adobe produced with dry technology, when during stabilisation processes besides its technological role the mixing water has also a chemical role in binding the lime, plaster or cement then it is not enough to apply the optimal mixing water(w_{opt}) for $\rho_{dmax.}$ This is namely not enough for the chemical binding but it extracts water from the w_{opt} assuring the maximum strength. So the stabilisation will have a negative effect.*

13.1.Thesis*: if we increase the quantity of the mixing water over the value (w_{opt}) needed to reach the ρ_{dmax} by the water quantity theoretically necessary for binding the stabilisation agents then the strength of the stabilized – with lime, plaster, cement - test specimen will nearly return to the strength of the non-stabilized adobes but the stabilization will still have no positive effect.*

13.2.Thesis*: on the basis of the above we can state that in case of dry construction technologies stabilization agents having water needs for chemical binding cannot be applied.*

13.3.Thesis*: in case of dry construction technologies only the stabilisation with polymers in fluid state is efficient. The fluid polymer has a plastification effect.*

14. Thesis*: the adobe produced with humid technology is produced with such a lot of surplus water related to the optimal water content (w_o)to be determined by the Proctor test, that can assure the water needs for the*

3. Thesis: *The range of the soils applicable for adobe construction can be determined by the triangle diagram indicating the proportion of the components and completed with one part of the range determined by Minke for burnt ceramics.*

4. Thesis: *The range of adobes suitable for construction can be determined by the following modification of the Fuller parabola*

$$a = 95\sqrt{\frac{D+5}{D}}$$

and by the rotation of the Fuller parabola with 180 degrees.

5. Thesis: *the material of the test specimen prepared for the test of the adobe should be of standard consistency in the interest of evaluation and comparativeness.*

5.1. Thesis: *the test specimen for the test of the adobe should be prepared according to the construction technology. In the function of this, two sorts of test specimen – dry or humid – should be prepared.*

5.2. Thesis: – *for the test of the adobe produced with dry technology the adobe can be considered as of standard consistency when mixed according to the Proctor test with a water content (w_{opt}) assuring a maximum body density (ρ_{dmax}).*

5.3. Thesis: *– for the test of the adobe produced with humid technology the adobe can be considered as of standard consistency when produced with a water content (w_{20}) belonging to the dropping No. n = 20, tested by the Casagrande test that indicates the formation limit.*

5.4. Thesis: *for the test of the adobe produced with humid technology the cone sinking and spreading test from the mortar technology can be also applied. The water content (w_{20}) belonging to the dropping number n = 20 with the Casagrande test is almost equal to the water content (w_{180}) assuring a cone sinking of 180 ± 10 mm and to the water content (w_{80}) assuring a 80 ± 10 mm cone sinking.*

University of Western Hungary

Theses for PhD dissertation

BUILDING WITH ADOBE AND WOODEN FRAME

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1. Introduction

In the spring of 2000 the River Tisza flooded large territories in her valley and the water washed away several villages. A considerable proportion of the damaged houses were made of adobe. At that time many people– among them also me – thought that it was not worth dealing with adobe as a construction material. And then my late professor's small monologue came into my mind:

- „One fault may happen, it is just a drop in the bucket,
- two can already make a trouble but,
- in case of three it is almost sure that they cause a big trouble,
- with four, down on your knees, you won't get away with it this time!"

Really, you must not make four mistakes, to build:

- on river flats
- without foundation, merely on rammed soil
- without waterproofing
- of material sensitive to water

These are four basic faults, which are well known for everybody, still committed. It is not the fault of the adobe, as it was applied on the wrong place and not professionally!

2. Raising the issue

In these days the development of society, science, engineering, industry, including construction industry and construction materials has accelerated, however this tendency has raised also some very serious problems, e.g. explosion of energy prices, pollution, crisis of big cities. In order to resolve these problems, three basic questions of our civilization should be examined:

- increase rate of the population of the Earth
- rate of use of the non-renewing energy sources
- increase rate of the territories that are no more capable for regeneration

We have to precisely analyse the whole production process (industry and agriculture) and then by focusing several things – that are namely obvious - we can set up four axioms in the possession of which we can go on thinking about our tasks.

a.) During production the human being manufactures the raw materials gained from the earth by the energy gained directly from the sun and gained indirectly from the earth to a “useful product”.

b.) Every product becomes a waste; this is only a question of time.

c.) Due to her size the Earth as raw material and as energy resource is limited.
d.) If the industrial technologies produce the „useful product” i.e. the „waste” with a higher speed than the regeneration or converting capacity of the Earth, then sooner or later we will live on a waste mountain.

If we want to avoid all that, we have to make these technologies and the products converted by them to be environment friendly. Besides that we spare with the raw materials and energy we have to reach **the simple and cheap re-usability**, and rehabilitation **of the end product**. Consequently we have to produce such industrial products where the re-use can be resolved economically at the level of the actual technology or it can be returned to nature without damages.

After having examined all the above I came to the adobe as a construction material that would meet the above criteria the best. This is a very primeval, natural local construction material still to be re-invented. We have to return to that material because of the disadvantages appearing time to time of the artificially produced construction materials, see the SBS (Sick Building Syndrome). Many people many times have already set up the advantages and disadvantages of the natural and artificial construction materials related to each other, using scientific, engineering, economic and emotional support. However nobody can unanimously answer the question which material is better. These are always the circumstances that decide what kind of construction material is the best, the most convenient. Besides the indisputable advantages like profitable, high comfort sense, energy-saving, possibility to use own work, etc.), adobe has disadvantageous characteristics and parameters, too (sensitivity to water and weather, low strength and sensitivity to shrinkage and dilation, variation of the soil used and the lack of the national regulations). The adobe has possibilities (houses, cottages, wine cellars, agricultural buildings: stables, cow-sheds, storing buildings), where under the given circumstances adobe is the most convenient construction material. Consequently its application would be optimal.

However today adobe as construction material and structural material has no physical, mechanical or chemical qualification numbers fixed in standards or technical specifications similar to the qualifications of the other well-known construction materials in Hungary, that could be taken into consideration during the design and implementation of the adobe as construction material. The lack of the regulations for the adobe considerably reduces and hinders the development of the adobe construction.

3. The aims and methodology of the research work

The most important aim of my research is to develop the qualification and test system for the adobe and by the assistance of this to define the characteristical qualification values of the adobe and in the knowledge of these to develop processes for reducing its disadvantageous characteristics (low strength, sensitivity to water, inclination to shrinkage).
In order to be able to choose the appropriate adobe for a given construction task and to produce the adobe from the available soils and then in order to be able to qualify and check this material, respectively during construction work, we have to set up the regulation system of the adobe still missing until today. We have to develop the qualification tests for the adobe, we have to determine the application possibilities of the different soils as construction material (as adobe), we have to collect the available experience and by the aid of this we have to determine the most important physical and mechanical characteristics of the adobe. Finally in the knowledge of these we have to update the processes for stabilizing the adobe.
I have strived to apply a complex method for reaching my aims. I tried to examine the topic together with the aspects appearing to the most important. Therefore I had to apply the partial fields of the geotechnical and construction material sciences connected to the topic.
In order to reach the above aims partly I leant to the following:
– The literature of adobe (some Hungarian literature, in the overwhelming majority of the cases German one);
– The literature of soil mechanics and of construction materials;
– The results of the laboratory tests;
– The memories of the unwritten traditions.
During my research work of more than seven years I collected the most important physical and mechanical characteristics of the adobe as well as the most important

Hungarian Electronic Journal of Sciences
http://heja.szif.hu/ARC/ARC-021227-A/arc021227a.pdf L

Conference papers in proceedings

1.The renaissance of the adobe (1996)
University of science Janus Pannonius
The third Conference about construction materials
Pécs 1996.szeptember 4-6. pp. 42-52.

Notes:	*number of publications in Hungarian:*	*7*
	Publications in English:	*1*
	Total number of the publications in the indicated topic:	*8*
	Read and revised (L):	*7*

List of the publications of the author appeared in other topics can be found on web site www.sze.hu/ep/arc , Total 13 pcs.

In Chapter 7 I make a proposition for executing the qualifying test system of the adobe in order to make possible that the adobe could be qualified and certified as the other well-known construction materials. The selected qualifying characteristics are: shrinkage, strength and sensitivity to water.

In Chapter 8 I discuss the optimisation possibilities of the qualifying characteristics of the adobe by the aide of the new investigation method. The primary aim is to produce a construction material with relative high strength, small shrinkage and low water sensitivity.

In Chapter 9 I examine the stabilization possibilities of the adobe with traditional binder materials (lime, plaster, cement), and with liquid polymers, respectively in the function of the construction technologies (dry or humid).

In Chapter 10 I summarize the aims of my research, theses and results.

6. Aims of my research work (theses)

The aim of my dissertation is to elaborate the task divided in the previous Section for 10 Chapters summarizing the experiences collected during the studies of the literature and from the results of the laboratory test of my own. The most important aims of my research are:

- *Elaboration of the qualifying test system of the adobe,*
- *The design of the technology resulting to reduce the disadvantageous characteristics of the adobe,*
- *Unification of the conditions for meeting these aims in the interest of comparativeness and evaluation.*
- *Partial completion of the Hungarian literature*

During the elaboration of the above tasks I formulated the following theses:

1. **Thesis:** *There are neither standards nor technical specifications in Hungary to regulate adobe as construction material or its tests. Therefore the unified qualification test process of the adobe should be set up.*

   Thesis: *the definition of the adobe: The cohesive soil mixed with filling material (chaff, pine-needle, shavings, etc.) and water and then used for construction purposes is called adobe mortar.* After having been dried it is called adobe.

   chemical binding of the stabilisation agents (lime, plaster, cement) above the water necessary to this technology.

14.1.Thesis*: the stabilisation of the adobe with cement until a content of 2-3 per cent will decrease the compressive strength of the adobe while between 5-10 per cent it will increase it. The upper limit is determined by the profitability.*

14.2.Thesis*: the stabilisation of the adobe with lime until a content of 2-3 per cent will decrease the compressive strength of the adobe, between 4-8 per cent it will increase it, while above 8 per cent it will again decrease the compressive strength of the adobe.*

14.3.Thesis*: the stabilisation of the adobe with plaster until a content of 2-3 per cent will decrease the compressive strength of the adobe, between 4-6 per cent it will increase it while between 7-10 per cent it will again decrease the compressive strength of the adobe.*
The stabilization with plaster is theoretically somewhat more efficient than the one with lime, however the very short binding time of the plaster requires a very quick and accurate work, that can be hardly kept even in laboratory conditions, therefore it is not proposed for the practice.

14.4.Thesis*: the stabilisation with polymers is effective with a volume of 1:2, 1:3 related to the mixing water. In case of humid technologies it may lead to uneconomic solutions. Consequently the stabilisation with polymers can be proposed only in case of dry technologies.*

6. Summary

Expected results of my dissertation:

- launching national regulations of the adobe as construction material
- elaboration of the qualification-test system of the adobe
- sampling, preparation
- production of adobe with standard consistency (in the function of the construction technology)
- forming test specimen (in the function of the standard consistency)
- execution of qualification tests (on the basis of the disadvantageous parameters of the adobe):
- strength (compressive and „quasi" tensile strength)
- deformation (ε_{zs}, ε_{duzz})

– sensitivity to water
– collection of literature for the most important physical and mechanical parameters of the adobe
– making some completions of the Hungarian literatures that is strongly incomplete

I see the possibility to use the above results in the promotion of the national adobe architecture that partly offers solutions for the serious environment, health and economic problems mentioned in Section 3 of this dissertation.

7. Publications in topic of adobe construction and adobe construction with wooden frame

Articles in Hungarian journals

1. The renaissance of the adobe (1998)
   "Magyar Építőipar" Hungarian Construction Industry No. 7-8. pp. 242-244. L
2. Qualification tests for adobe (1998)
   "Magyar Építőipar" Hungarian Construction Industry No 9-10 pp. 295-298. L
3. Construction methods and structural solutions with adobe (1998)
   "Magyar Építőipar" Hungarian Construction Industry No 11-12 pp. 348-350. L
4. Adobe construction methods and structure solutions with wooden frame (1999)
   "Magyar Építőipar" Hungarian Construction Industry No. 3-4 pp. 119-120. L
5. Cheap and environment friendly adobe architecture (1999)
   Construction Materials No. 99/1. pp. 6-13. L
6. Construction with natural local materials (2001)
   "Magyar Építőipar" Hungarian Construction Industry No.11-12 pp. 358-361. L

Journals in English

1. Examination of pressed adobe brick (2002)

adobe stabilization processes and methods. I set up the qualification tests for the adobe as construction material and I elaborated an updated stabilization process for increasing the strength and water resistance of the adobe.

4. The structure of the dissertation for reaching the targeted aims

The above tasks will be discussed in ten Chapters.

In Chapter 1 I draw the attention to the most severe mistakes made in the Hungarian practice of the adobe construction and later on I demonstrate the possibilities of the adobe construction by a local example.

In Chapter 2 I give a short historical review about this primeval construction material, about the adobe that is renewing in cycles time-to-time reviewing the contact of the humanity to adobe construction and its development in the last ten thousand years.

In Chapter 3 I describe the aim and actuality of the research, and the reasons of necessity for the perpetual return of the adobe as construction material. I analyse the advantages and disadvantages of the adobe as construction material.

In Chapter 4 I demonstrate the origin, components and structural construction of the soils underlining the cohesive soils suitable especially for adobe preparation. In the knowledge of theses I integrate the partial fields of soil mechanics applicable for adobe construction

In Chapter 5 I illustrate the characteristics of the fresh and solid adobe mortar. I integrate the experiences of the mortar technologies to be applicable and to be connected to the adobe construction.

In Chapter 6 I deal with the basic technological questions of adobe construction. Basically I divide the adobe construction technologies in two groups:
– First of all to technologies influencing the material quality (dry or humid, compacted or incompact)
– Secondly technologies affecting building construction process (monolith or pre-fabricated, traditional or updated).

In my dissertation I deal in details with the adobe prepared by technologies influencing the material quality.

The theory is as old as the adobe:

„Theoria sine praxi, est currus sine axi;
Praxis sine theoria, est currus sine via