Küreken 2013: Designing a New Village with Rammed Earthen Construction in Eastern Anatolia

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ABSTRACT: The construction of a new dam around the city of Tunceli (existing in the Eastern Anatolian Region of Turkey) caused a necessary relocation of Küreken village which is located within the borders of Tunceli.
This study has been conceptualized on the idea to generate a functional master plan for the local settlement of Küreken village within its new borders on a new site. In these terms, first of all, this project is predicted to be an example for similar local settlements which shares similar climatic, architectural and conditional characteristics. Secondly, the study aims to offer a contemporary rammed earthen construction based on the analysis of the still existing village; its tradition, evolution within the last 30 years, its architectural and rural characteristics. In order to improve the new earthen construction technique against the earthquake loads, this study technically offers a new stabilization method called as *"Alker"*.

1 INTRODUCTION

Anatolia, a well-known land for earthen architecture, still shelters many local samples of traditional earthen houses. The Eastern Anatolia is one of the regions of Turkey where earthen heritages with their distinguishable regional characteristic could be found. Due to the increasing energy consumption of Turkey, particularly after the second half of the 20th century, a new energy investment program based on hydroelectricity has begun to threaten these vernacular heritages with the construction of enormous dams. As a recent example Tatar Dam constructed in Tunceli caused a similar condition which makes Küreken Village an important case for the project in order to create better conditions for a new village with its settlement and its architectural properties. In order to generate an appropriate project for the village, the characteristics of the old village have been studied in terms of its development, its architectural qualities and construction characteristics.

2 ANALYSIS OF THE OLD VILLAGE

Küreken, which is also known as Obuzbaşı, represents a typical Eastern Anatolian rural tradition.

2.1 Historical Evolution

In 70's, Küreken possessed a more different settlement structure than it has now (figure 1). The houses were built together with stall and barn so that a common roof could compose this compact living structure. This method of living was the most efficient one in this region, where the fuel energy resources were limited (only wood and dried cowpat).

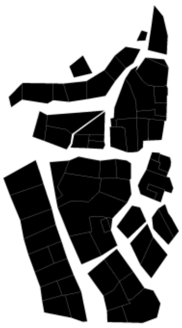

Figure 1.The Village in 70's

Figure 2.The Village in 2011

Moreover, the consanguinity and neighbourhood which are deeply structured within the community create a local atmosphere in which the social problems are dissolved. This social mechanism leads the local inhabitants to collaboration. Here, as in many eastern regions of Turkey, the closed relationships and rural lifestyle together form a compact rural settlement organization which forms the structure of Küreken.

The transformation from agricultural livelihood to an industrial based economy is the reason for dissolution of the compact life structure of Küreken, similar to many other eastern villages. An expanding industrial economy has escalated the commercial prosperity of the villagers. On the other hand this transformation proceeded with some consequences; the "new" and a lifestyle propagated by the media has particularly involved a radical change of moral conduct and the rural population has increasingly dwindled due to immigration in to the metropolis.

2.2 Architectural Character of the Old Village

At a typical village house (figure 3), spaces can be classified into 2 main zones according to their spatial characteristics:

– Cool zone: kitchen, store and bathroom
– Warm zone: bedrooms and living room

In the design of these houses, the following characteristics are observed: The houses are max two-storey high

– The kitchen and bathroom are located in the ground floor. Kitchen is a separate part which is simply organized and large in size.
– Storage is to see in ground floor, mostly separated from the house
– The toilette is generally separated from the house
– The guestroom and bedrooms are located on the first floor and a wide guestroom is mostly used for the guests
– The number of bedrooms is variable according to the number of the family members.

2.3 The Local Construction Method[1]

The village houses have been constructed with the following building techniques: The houses are constructed with two different types of adobe blocks; a 15x30x8 cm (kuzu) and 30x30x8 cm. (anaç).

– Both outer and inner walls are 66 cm with a 1 cm plaster overall and a 2 cm mortar.
– The foundation is constructed of natural stone blocks bounded with clay mortar and reaches to 1.5 m. height depending on location.
– A horizontal (ring) wooden beam is integrated to the walls at every 1 meter. Traditionally, poplar is preferred for its elasticity and excellent workability. Other tree types such as mulberry or elm tree are also widespread but structurally they are too stiff and breakable.
– The ground floor windows are commonly 50x50 cm. The functional reason is to keep this zone as cool as possible for dairy products and socially to ensure privacy.
– For the first floor, window openings are generally kept 80 x 60cm.
– The traditional whitewash is asbestos.
– Floors are constructed with 20 cm thick wooden beams and covered with rush mats and earth.
– The roofs were commonly flat in the past, but an additive gabled or hip roof has been preferred in last decade.

Figure 3. A housing group in Küreken

Figure 4. Construction detail of a ruin in Küreken

2.4 Evaluation of Traditional Methods:

– Adobe blocks are dried under direct the sun light which causes a high shrinkage.
– Stone block foundation does not provide a planar surface.
– Ring beams are not fastened sufficiently (figure 4)
– Annual renovation of the flat roof with 0,5-0,7 cm plaster causes a continuous increase in thickness reaching up to 50 cm. within the years.
– Insufficient level of detailing generates insulation problems on the ceiling.
– Renovation of the houses every 3-5 years due to damages arising at the façades
– Asbestos leads to a high cancer risk.

– The traditional 50 cm eave provides a shelter for birds, and causes damage on the roof.
– The typical size of ground floor windows is deficient for ventilation.
– Non-insulated glazing causes a high energy loss.
– The additional tin roof results with the overheating and an inconvenient reflection in summer.

3 PLANNING AND DESIGN BASED ON ANALYSIS

The project “Küreken 2013” uses the above explained pre-study as a starting point for generating both a planning concept for the village habitat, and for designing the houses. The design process is orientated with the following steps:

3.1 Planning new settlement:

In terms of efficient site utilization, the parcelling solution offered by the government for the new area has an arbitrary character. Vehicle and pedestrian axes are also problematic (figure 5). The old village settlement had a compact centre and an agricultural area around it. In comparison with this condition, the existing parcelling rejects this kind of rural structure which has been an efficient way of saving energy.

Starting from this point, this study aims to offer a better solution which will answer the needs and the problems of the area and its spaces in a better way. To this end, the existing official planning has been reinterpreted in the light of a pre-study of local data collection and offered an alternative to parcelization in order to regain the advantages of compact living. In this new proposal, the new settlement offers a south orientation in regard to the prevailing wind direction from southwest. Therefore, the house groups are oriented in the proper way that they can utilise the advantages of south-orientation and natural ventilation. The new rural planning also focuses on the natural expansion (figure 6).

3.2. Designing the Houses:

The new design strategy for the housing aims utilize the local data collection and to ensure an acceptable adaptation of vernacular values to the new social and constructional perspectives. In that sense, it is based on tradition while making use of the contemporary. For instance, similar to the typical architectural character, the proposal still respects the clear separation of private and open spaces (figure 7).
Secondly, the proposal offers a house type with characteristic of vernacular windows openings, while it offers a scaled and enlarged window type

Figure 5-6. The rural planning by government (on left) and the new rural planning based on pre-study (on right)

1- Entrance

2- Kitchen

3- Living room

4- Bedroom

5- Bedroom

6 -Guestroom

7- Fire place

8- Terrace

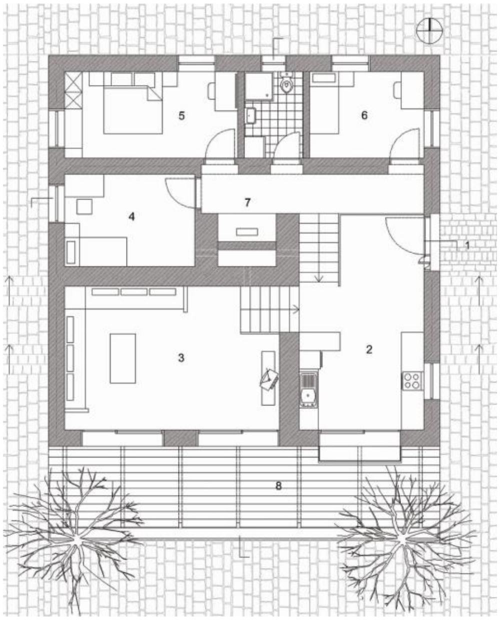

Figure 7. The new housing

for the south facades in order to utilize solar energy.

The weather of the site is cold and dry in winter; warm and dry in summer. The values of the last decade show a -2.7 °C average temperature in January. In the light of this data, the typical fireplace which is mostly situated in the kitchen is technically improved (with the integration of solar-heating panels and a warm-cold weather circulation compartment) and located in centre of the house.

Moreover, referring to the traditional flat roof on which the habitants can dry their products or use for other functions, the new design offers a terrace roof constructed with efficient insulation details, and without an eave.

Furthermore, the neighbourhood is preserved as a primary social structure, via common used areas and strong connection in between houses.

4 ALKER AND ITS PROPERTIES

In terms of construction, this study offers two innovations. The first is the replacement of stone block foundation with reinforced concrete foundation. The second is the material developed by Ruhi Kafesçioğlu after 1964, and announced in 1980 at ITU as "*Alker*" which is claimed to have better qualities than the adobe block.

Despite its traditional and common use as a building material, the adobe block has some disadvantages such as its less compressive strength, non durable character against erosion. For this reason, Alker is offered as a stabilisation method by this project in order to contribute the application of earthen materials. In 1980, at the laboratory of ITU Faculty of Architecture, under the leadership of Prof. Kafescioglu, promising results were obtained in the research project which was supported by TÜBİTAK.

"Construction earth, where its structural and chemical compositions have been modified by adding gypsum and lime, has been transformed into a new material with improved physical and mechanical properties, called Alker. The material consists of 8-10 % gypsum, 2.5-5 % lime and 15-20 % water (dry weight) which were added to construction earth with improved granulometric structure. Gypsum and lime are added to the mixture and it completes setting within 20 minutes, giving rigidity to the material which allows its shape to be kept and preventing clay shrinkage."[2]

4.1 Alker as a Building Material

Properties provided by the complementary activities of gypsum and lime during the formation of Alker can be summarized as follows: [3]

- Given mix ratios are by weight of dry earth under laboratory conditions. Converting these ratios into a volumetric scale at construction sites provides ease of application.
- As setting of gypsum completes in a short period of time, it provides a satisfactory rigidity the material.
- Curing and drying processes as well as production and laying areas for drying are not needed, which are important problems for all other similar materials.
- Due to the early setting time of gypsum, deformation and crack risk to the structure during the drying period is prevented.
- A new water insoluble chemical formation is created by adding 2.5-5 % lime and the product does not become dispersed as plain samples even though it stays in the water for a long period of time.
- The satisfactory rigidity created by gypsum in the first stage ensures shape stability of the blocks as the new formations continue developing in the structure.
- The production process is very easy and energy consumption in buildings made with this material is minimal.

4.2. Physical Test Results of Laboratory Research

In order to prove the result of the research project completed in 1980, the new laboratory methods were used by numerous tests at ITU, Faculty of Civil Engineering under the leading of Prof. Kafesçioğlu and Asst. Prof. Bekir Pekmezci in order to manifest the physical and mechanical properties of Alker. The results can be summarised as follows:

Four different series of specimens were produced: a plain earth mixture (PL), a 10% gypsum earth mixture (G10), a 10% gypsum 2.5% lime earth mixture (G10 L2.5) and a 10% gypsum 5% lime earth mixture (G10 L5).

Thermal Conductivity:

30x30x3 cm samples were used in the test. Tests were carried out in accordance with the ISO 8301 heat flow meter method. As a result of the tests, the coefficient of thermal conductivity in Plain, G10 L, G10 L2.5 and G10 L5 samples were 0.390 W/mK, 0.290 W/mK, 0.250 W/mK and 0.216 W/mK respectively. Samples with gypsum have lower heat conductivity values compared to those of plain earth. This value decreases when lime is added. This indicates that gypsum and lime make a contribution to heat insulation.

Capillary Absorption:

Capillary absorption was tested on 7 x 7 cm cross section samples. The results obtained are shown in figure 8. While the water rise rate is highest in the samples containing 10% gypsum and 5% lime, it is lowest in the plain and only gypsum samples. Although capillary absorption levels in the samples with gypsum-lime reached higher values, they had no erosion due to contact with water. The thin and continuous capillary network causes higher capillary suction. The structure formed by products of lime keeps the adobe buildings undamaged due to water.

Shrinkage:

Linear shrinkage measurements were done on 50x10x10 cm prismatic samples. Shrinkage measurements were carried out over 50 days. The samples were kept under laboratory conditions of 20±2 °C temperature and 65±5 % relative humidity. The relation between shrinkage and time is shown in figure 9.

Microstructure:

MIP test results of samples produced in laboratory and taken from experimental building II (figure 9) are presented in figure 13.

Total pore volume of samples containing 10% gypsum is lower than plain earth but greater than earth

Figure 8-9. Experimental I (left) and Experimental Building II (right)

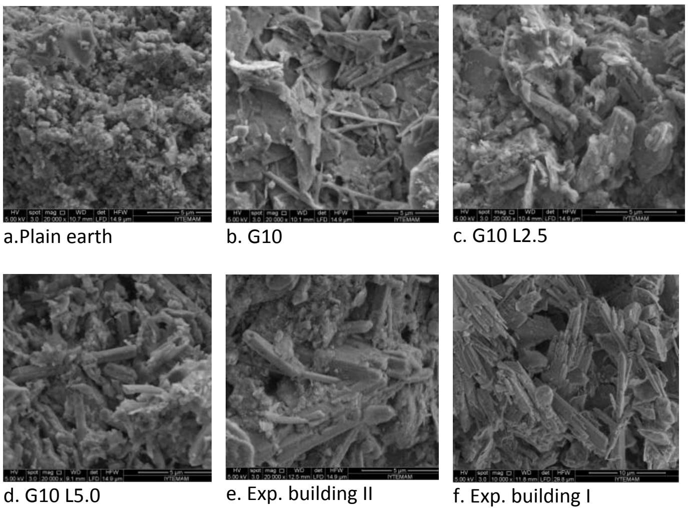

Figure 10. SEM Images

with gypsum-lime. This result is due to the filling of the pores by gypsum and lime products. The amount of mercury penetrated in plain samples is greater than that of samples with gypsum and lime. Samples with lime have lower pore volumes over all diameters tested. The experimental building exhibited the lowest pore volume among all the samples.

SEM images are shown in figure 10. Figure 10a presents plain earth and a loose structure that can easily be distinguished with individual particles physically bonded without observable binding products. Different structures in the samples with gypsum and lime can be easily distinguished in figure 10b to figure 10f. In figure 10b, needle like gypsum crystals are formed in plain earth with gypsum, forming a continuous web.The SEM images in figure 10c and 10d, show fewer calcite crystals formed on the gypsum web and earth. Figures 10e and 10f show a higher amount of calcite crystals formed and a denser structure in comparison to figure 10c and figure 10d.

Compressive Strength and Modulus of Elasticity:

Compressive strength and modulus of elasticity tests were carried out on 10 x 20 cm cylindrical samples (figure 14)

All series produced, except plain mix, exhibited parallel results during the first 7 days. Sample G10 with gypsum gained 0.37 MPa compressive strength at 0,5 hour, a significant part of its 7 day strength. Within the first hour, the compressive strength of the samples containing gypsum and gypsum with lime were satisfactory enough for the materials to be removed from the molds. According to 0,5 hour test results, the compressive strengths of the samples with lime and gypsum (G10 L2.5, and G10 L5) were lower than that of the sample with only 10% gypsum. After 7 days, an induction period for compressive strength gaining started. All the samples gained the most significant part of their compressive strengths after 7 days. At the end of 90 days of curing in air, compressive strengths of the mixtures varied between 2.4 and 2.9 MPa. While plain samples had the lowest strength at all ages, the samples with 10% gypsum showed the highest strength. Modulus of elasticity values of plain, G10, G10 L2.5 and G10 L5 samples were 880 MPa, 851 MPa, 831 MPa and 762 MPa respectively.

Shear Strength and Modulus of Rigidity:

Shear strength tests were done according to the ASTM E519-10 standard (figure 15) 50x50x20 cm block samples were used in the tests and loads were applied by a closed loop deformation controlled press with a capacity of 500 tons. A mold in 50 cm height was filled in three equal layers to produce the samples for shear strength test keeping inevitable joints in structure.

There is not a significant difference between the samples having different amounts of lime. Shear strength and modulus of rigidity of plain samples and samples with gypsum are very close to each other.

Calcite crystals, which were formed due to carbonation of lime and binding products formed as a result of the pozzolanic reaction, were shaped around and over the gypsum web and earth particles in mixtures having lime.

According to shrinkage measurement results, samples with both gypsum and lime exhibited the lowest shrinkage. The very low shrinkage amounts obtained can be attributed to needle like crystals formed which may resist compressive stresses due to shrinkage.

Although the highest compressive strength was obtained in samples including only gypsum, dramatic differences were not observed between samples with or without lime. But significant differences of shear strength were obtained in the samples with and without lime.

Microstructural experimental study shows that the amount of pores in samples with lime is less than that of plain earth and earth gypsum samples. Based on the principle that capillary water rises faster in narrower tubes, the capillary water absorption level increases in a short period of time in earth materials containing gypsum with lime due to the narrower capillary pores inside. MIP and SEM analysis results support this approach by lower pore volume values and a denser structure.

It is assumed that a reaction takes place between lime and silicious fine grains (Millogo et al., 2008).

This very slow but continuous chemical reaction creates a new water insoluble composition and the product formed as result; contribute to the development of increased mechanical performance and durability.

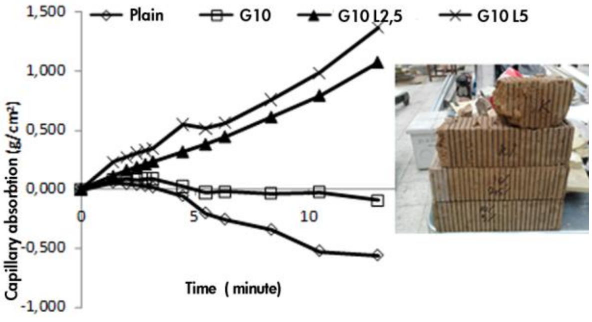

Figure 11. Capillary absorption

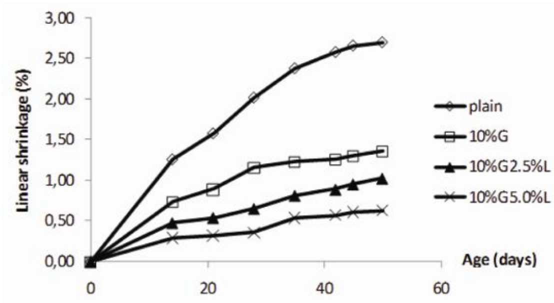

Figure 12. Shrinkage

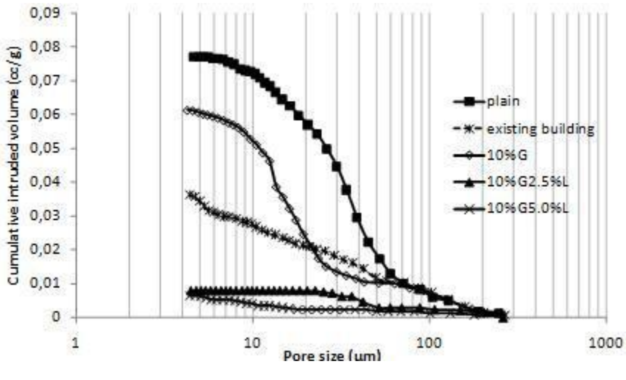

Figure 13. Mercury Intrusion Porosimetry.

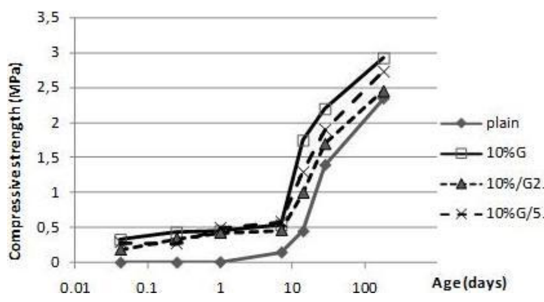

Figure 14. Compressive Strength.

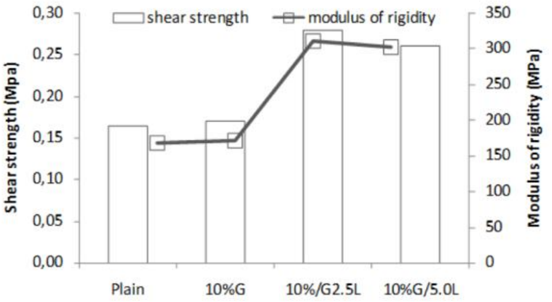

Figure 15. Shear Strength and Modulus of Rigidity.

5 CONCLUSION

In the last two decades, there started to occur many problems in the rural settlement activities because of various reasons such as the compulsory relocation of the existing villages because of construction of new dams on their site, and also re-immigration to the rural area. In this respect, this project can be considered as a pilot project showing how earth can be used as a correct and efficient material. Earthen buildings can be regarded as a solution to many of the problems in terms of settlement and planning.

While considering Küreken 2013 as a pilot project, this study aims to open up a wide perspective offering a general material technique based on earthen materials, so that the main themes mentioned in this study will encompass all the local regions where earthen construction techniques can be primarily used.

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7 NOTES

[1] Collection of local data (1-3) is done by author

[2] *TUBITAK MAK 505, Yapı malzemesi olarak kerpicin alçı ile stabilizasyonu*

[3] The informations from; "Pekmezci, B.Y., Kafescioglu, R., Agahzadeh E., 2012. *Improved performance of earth structures by lime and gypsum addition" has been summarized*