Re-Thinking Earthen Architecture for Sustainable Development, VAN Field Project

08 08 2022

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ABSTRACT

Earthen architecture is carrying knowledge from the history of mankind, as it is mostly used construction material. Living in earthen buildings is healthy. Indoor climate can be established with physical and mechanical property of earthen material. As a result, heating and cooling energy demand, up to the geographic living area, is minimized or not used.

Today, demand for adobe structure can be identify in three ways: health living, little money for energy usage, 0-energy usage for sustainable environment. With the rise of global population and epidemic effect in recent years demand for widespread settlement gained importance.

There is a need for re-thinking of earthen architecture: material durability, earthquake safety of loadbearing earthen walls, industrialized construction techniques. General usage of earthen material is for masonry or loadbearing structures. This study will summarize the findings on: *zero energy earthen buildings, *learning from earthen architecture heritage, *development strategy **on earthen** construction. With the field project in VAN province, the study will contribute for the demand on legal and administrative process using earthen architecture.

Keywords: Earthen Architecture, Zero Energy Buildings, Learning from Heritage, Development strategy, Collaboration

1 INTRODUCTION TO EARTHEN ARCHITECTURE

Architecture is carrying the knowledge from history and give definition for culture (Figure.1.1 and 1.2). Most of the world's population is living in earthen buildings (Figure.1.3 CRATerre). Half of the world population is living in earthen architecture.

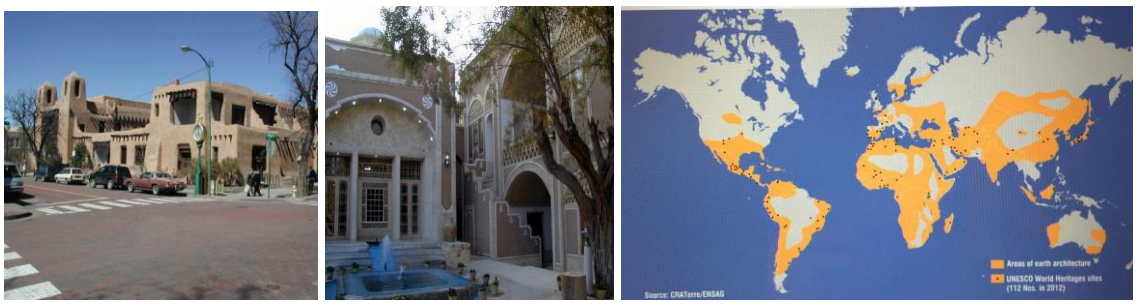

Figure.1. Earthen Architecture 1.1. Mexica and 1.2. Iran 1.3. Global Map of Earthen Architecture

2. WHY RE-THINKING EARTHEN ARCHITECTURE

Earthen architecture is creating "**healthy indoor**" environment with mechanical and physical property of earthen material. Therefore, earthen construction material is "**minimizing energy usage"** for indoor climate of the buildings and finally "**minimizes global pollution**".

2.1 Healthy indoor living with earthen Architecture

Indoor climate from buildings (Figure.3), constructed with earth is suitable for human health.
The fever of the human body is 36'degree (Figure.2). If the environment temperature is lower than 18'degree, energy loss of the body is high. The immune system of the person is risky. If the temperature around is higher than 24 degrees, the body cannot release the energy that the body is producing. In this position the immune system is risky again.

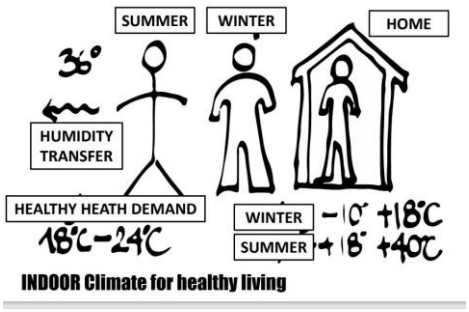

Figure.2 Healthy living temperature

Figure.3 Altınoluk, 1997, 280 m2 earthen house

2.2 Healthy Environment with Earthen Architecture

Global energy consumption of the buildings in the last century is extremely high, resulting with environmental pollution. Energy is consumed almost the same rate by the sectors 1.Industry, 2.Buildings 3.Transportation (Figure.4).
Earthen building consumes less energy because of the physical property of the earthen construction material [1]. For example earthen house 280 m2 in Altınoluk (Figure.3), constructed at 1997, is energy efficient. Since 25 years no energy is used for heating and cooling: So that we can use earthen material for "Zero-Energy buildings" in the climate change.

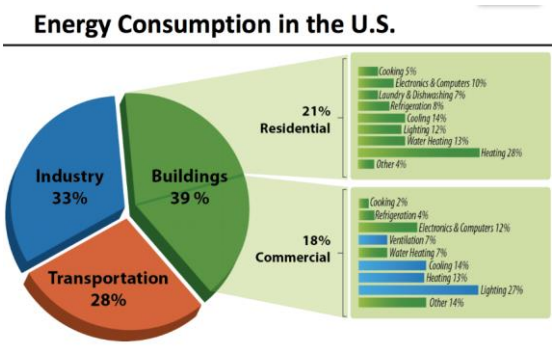

Figure.4 (eia-gov) Energy is consumed almost the same rate by the sectors

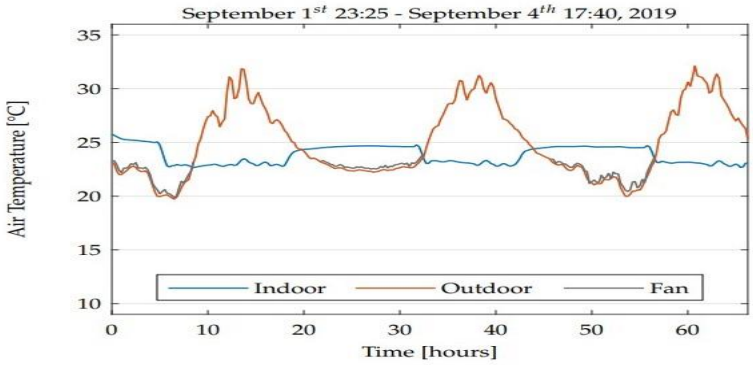

Figure.5. Murat Çakan + others [4] temperature: indoor +blue, outdoor +orange
Figure.6. Temperature test on the R&D Project Building TÜBİTAK 622, constructed at 1995 [1]

The research on the building TÜBİTAK 622, constructed at 1995 shows: the daily temperature from outdoor(orange) is not changing the indoor temperature (blue) in September (Figure.5 [4]). The earthen walls of the TUBİTAK 622 projects are designed 45cm according to the Istanbul climate (Figure.6).

4. EARTHEN ARCHITECTURE WITH DEVELOPMENT STRATEGY

Traditional Earthen Construction

As it is mentioned in (Figure 1.3) half of the world's population is living in earthen buildings with mostly similar construction technique. Soil with the content of 30-40 % clay will be mixed with water and straw in the preparation pool. Mixture will wait in the pool min 8-hours or more (Figure.7). In that period extract of straw dissolves in the water. Extract of straw in the earth mixture creates durability of earthen wall during rain and snow. When the mortar is ready earth blocks will be produced and dried on the field (Figure.8). Wall masonry will start if the block production number is enough (Figure.9). All the level of production and construction of traditional kerpiç-house (earthen house) is time taking and labor intensive. If homeowner does not carry the construction, earthen construction (kerpic ev) is expensive.

To enable using the economic and healthy earthen construction technics, research developed:
1. **Fast** durability techniques 2. **Fast** earthquake safety 3. **Fast** contemporary construction technics



Figure.7 Mortar preparation pool
Figure.8 Adobe production using the field
Figure.9 Adobe wall home, loadbearing wall system

4.1 Fast- durability techniques of earthen construction with gypsum and lime (Alker)

To get the durability with fast and short stabilizing process, 10%Gypsum is mixed to the earthen wall material [3]. While adding water to the mortar, hydration period of gypsum is about 4 minutes,

which is short for construction operations. Therefore, 5%lime is added to the earth and 10%gypsum mixture [3]. Hydration period with the water is about 20minutes, having enough time to finishing the construction process.
Clay content of the soil will be about 10-15%. "Clay+ Gypsum+ Lime" together will be about 30% binder in the mortar. During the new stabilization technique if clay content is more than 15%, demand for water will be high. If water content in the mixture is high, during drying of the material, shrinkage and finally cracks will occur. Table.1 shows the percentage of soil+ gypsum+ lime and water to receive earthen mortar. Table.2 shows mechanical and physical properties of stabilized earthen material (Alker).

Table.1 Percentage of stabilizing material -gypsum -lime – soil -water called ALKER [1]
Table.2 Mechanical+ physical properties of gypsum-lime stabilized earth (Alker) [1]

Ingredient	% by Weight	Practical Measures
Soil	100	2 full wheel barrow
Gypsum	10	4 shovel full
Lime	2	1 shovel full
Water	18-20	1 bucket full

Unit weight	1.6-1.7 kg/lt
Shrinkage	1.0-1.5%
Compressive strength	2.0-4.0 N/mm2
Shear strength	0.9-1.3 N/mm2
Water absorbtion	very low
Long term water exposure (except direct rainfall)	no erosion
Heat transfer value λ	0.4-0.5 kcal/mhC
Specific calorific	1.0 kJ/kgK

4.2 Fast- Developed Earthquake Safety: Learning from Heritage

Architecture heritage is mostly load bearing system, (Figure.13) using stone, brick, or adobe (earthen bricks). In some countries loadbearing system is not in the curriculum from civil engineers and architectural higher education. That is the reason, loadbearing buildings in the last century generally does not have earthquake safety. During the earthquake, lateral force damages the building after diagonal crack (Figure.10). Upper part of diagonal crack slides down and the building collapse.

Figure.10 Diagonal cracks, no earthquake precautions

The aim of the research is to manage the lateral force, created by earthquake, to avoid the diagonal crack in the wall. Load bearing wall must have **lateral energy dissipating surfaces** to avoid the diagonal cracks. Masonry wall of the **Heritage buildings** are mostly constructed with horizontal stone& brick layers. Learning from Heritage: As the strength of brick is lover then stone, the horizontal force of earthquake will be dissipated by the brick masonry (Figure.13) and there will be no diagonal crack. The loadbearing building with horizontal energy dissipating surface in the walls is safe during the earthquakes.

Figure.11 Shaking table test 2009, ANKARA, General Directorate of Disaster Affairs
Figure.12 Labor test at Istanbul Technical University, Civil Eng. Labor

Figure.13 Stone-Brick Loadbearing Wall; Learning from Architectural Heritage-

The earthen walls of the test building on the shaking table (Figure.11) in Ankara 2009, (General Directorate of Disaster Affairs) is constructed with horizontal energy dissipating layers, from ground to the top every 50cm. After 8-times earthquake test, the walls do not have diagonal cracks. There can be only horizontal cracks where the horizontal friction layers are. During the test, building is not destroyed.

Figure.12 shows the element after the Laboratory test. If horizontal crack occurs the next force from earthquake will not affect other wall sections.

4.3 Fast- contemporary earthen construction technics

Developing Construction Technology with Earthen Material at İTÜ (Istanbul Technical University), Since 1980 earthen material is subject for research to use earthen material for housing. As the rural and traditional earthen construction is time taking and labor intensive, industrialized earthen construction technology is developed and used. Table.1 gives the R&D list of earthen buildings, constructed as 1. Rammed, 2. Earthen block production for masonry, and 3. Shot-earth construction technology

4.3.1 Rammed Earth Construction:



Figure.14 Concrete mixer for mortar: 100kg earth, 10kg gypsum, 5kg lime and water
Figure.15 Ramming mixed mortar in to the wall-form with Compactor
Figure.16 TUBİTAK 662- research building -rammed into the form

Construction operation steps for rammed earth building are very fast:
material supply, construction equipment -supply, construction worker. If construction is by hand 4worker can ram 5m3 wall in a day. VAN headman-office (Figure.23&24): rammed earth building 6x6m2 (25m3) has been constructed in 3 days, If mixer (Figure.14) and compactor (Figure.15) is used wall construction is faster (Figure.16).

4.3.2 Earth-Block Production


Figure.17 Concrete paving stone machine, used for 60 000 earth block production
Figure.18 URFA- GAP four official residence, 400 m2, earth block construction at 2000

If the home owner is going to construct the building, 1. formwork for wall cannot be available or 2.expensive or 3.ramming needs some new knowledge. But mostly people know the masonry system. If there is support from government, that home owner get for a 3rooms building (like Figure.6). about 10 000 earthen blocks, they can make their houses. The earth block production is with **Concrete Paving Stone Machine** (Figure.17) which produces about 6000 pieces in a day.

In the city URFA, **GAP Regional Development Administration Office** is organizing the home supply FOR THE PEOPLE who are homeless after "Bilecik Dam" holds water.
Before starting the project with "**home supply for the homeless**", GAP organization finished a pre-project, residence for GAP employee, each home100 m2 x 4home (Figure.18). Two storied, earthen building has been constructed with 60 000 earth block, produced by **Concrete paving stone** machine. The building, construction at 2000 is still in use in URFA

4.3.3 Earth- Shotcrete


Figure.19 Dilekkaya. Shotcrete -earth construction
Figure.20 Dilekkaya home 2012, organization: Değirmenlik municipality

Early signs from Cyprus history, date back to 10 000 BC. Since the late Bronze Age (1650 BC) Cyprus had the commercial relations with Aegean World, Sicily, and from 1489Venetians used Cyprus as trade and fortified. From 1571to 1878, 300 years Cyprus was under Turkish rule. Just like the Mediterranean culture, architectural Heritage in Cyprus has earthen construction. Even people from Italy-Mediterranean region, went to USA-California for viticulture and wine culture, they used the Mediterranean earthen architecture. Today in Cyprus only **reinforced concrete** buildings are being built. For the indoor climate, air conditioner is in use. Cyprus buy the energy from overseas and it is expensive. "**Les energy usage**" in building sector must be the target.
R&D project keeps

1. **Learning earthen architecture from Mediterranean Heritage** and
2. **Re-Thinking earthen architecture**
   +durability, +earthquake safety, +fast earthen construction

If there is a need for FAST EARTHEN CONSTRUCTION: shotcrete machine produces earthen wall **7m3 in one hour** (Figure.19-20). In 8hours-daytime, with a small shotcrete machine (7m3 per hour= daily capacity) wall construction can be 56m3. In Cyprus-Dilekkaya (Figure.20) shot-earth building 7x7m was a R&D project from CIU (Research and Development project -Cyprus International University) , carried by Değirmenlik Municipality. PERİ Wall-Formwork supply was from EMEK inşaat. Shotcrete machine supply was from IŞIK AŞ. When earthen mortar is injected into the wall-form (Figure.19), the new wall construction can carry in a short time. The formwork pieces can be removed and can be installed in a new location.

5. VAN - FIELD PROJECT with new KERPIC CONSTRUCTION TECHNOLOGY

The periods of Van According to the archaeological research extend before the written history B.C. 5000-3000, until the beginning of Chalcolithic period. The Hurrions established the first state in this region. Then the state of Urartu with its capitol **Tusba** was established in 900 B.C.
Instead demolishing the architectural heritage,

1. **Learning earthen architecture from central Anatolia** and
2. **Re-Thinking earthen architecture in climate change**
   +durability, +earthquake safety, +fast earthen construction

The study is on VAN+ Tuşba province. Architectural Heritage is earthen load bearing wall system. Location of the city VAN is very east of Turkey. Continental climate prevails in Van. In a year 150days are under 0-degree. Following the historical background on indoor climate is important to use earthen architecture for **healthy indoor with low energy usage (Figure.5).**

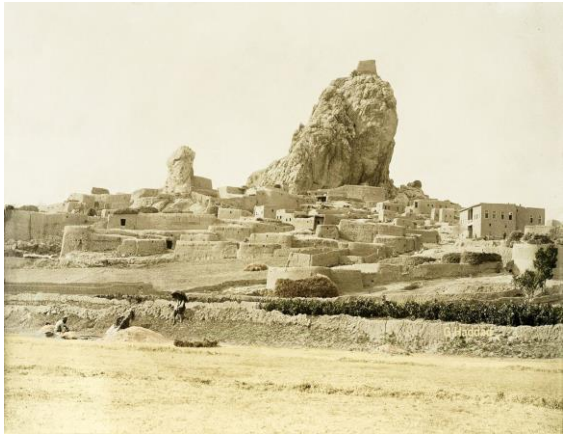
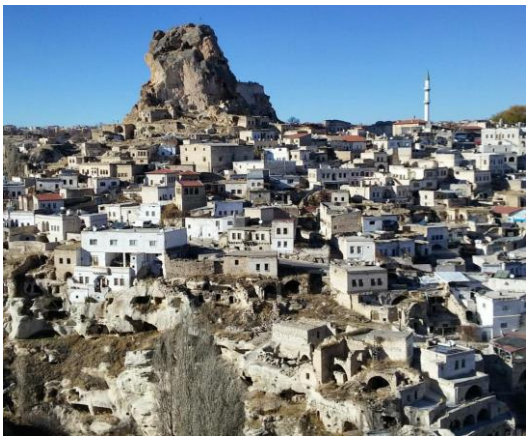

Figure.21 VAN 5000 BC archaeological location, 900 BC. Tuspa – earthen arch Heritage
Figure.22 Tuşba recently – concrete buildings


Figure.23 VAN Tuşba earthen architecture headman's office - in snow-time – no damage
Figure.24 VAN Tuşba earthen architecture headman's office – construction in 3 days

R&D building in VAN Tuşba as **Earthen Architecture Headman's** office was built in 2019.
People in VAN Tuşba, visiting **Headman's** office, will get the knowledge that:

-Today home-owner can build earthen construction
- indoor climate is healthy
- little energy for heating and cooling in a year

The building Tuşba, with 7x7 m is constructed in 3 days (Figure.24), with 5-workers and using mixer and compactor. Earthen Building is safe in winter and snow period (Figure.23).

6. COLLABORATION STRATEGY and CONCLUSION

- The Turkish **Earthquake Regulations** are clear that: load bearing structures is not permitted
- The Turkish **Earthquake Regulations** If the building is made in rammed earth (cement / gypsum stabilized) the structure will be frame structure.
- The study and research on earthen architecture will contribute for the demand on **legal and administrative process** using earthen architecture.
- The "**buildings permit"** will be engineered and in frame structure
- higher education must take the bearing wall system into **higher education curriculum**
- **governmental Authorities** have to learn from earthen architecture = energy savings,
- **governmental Authorities** have to learn from earthen architecture = Construction Industry

Collaboration is needed between : 1.governmental, 2.higher education, 3.local municipal administration, 4.local home builder etc. Table.1 shows list of R&D earth construction studies

Table. R&D project from B.IŞIK = fast and earthquake safe earthen technology

	Years	Location	Technic	Research + OWNER	R@D
1	1995	İTÜ Istanbul	rammed	TUBITAK 622	B.IŞIK
2	1997	ALTINOLUK	rammed	Okan Tütnar	B.IŞIK
3	2000	URFA	Earthen block	GAP İdaresi	B.IŞIK
4	2009	ANKARA	Shot-earth	Shaking Table Test	B.IŞIK
5	2011	VİRANŞEHİR	Rammed	Home Builder	B.IŞIK
6	2011	KIBRIS Dilekkaya	Shot-earth	Değirmenlik Municipality	B.IŞIK
7	2015	KÖYCEĞİZ	rammed	BKM film Plato	B.IŞIK
8	2015	URFA-GÖBEKLİTEPE	Rammed	Visiting Center	B.IŞIK
9	2019	VAN- Tuşba	Rammed	Office for local authority	B.IŞIK
10	2020	ERZİNCAN	Rammed	Palanga Goat Shelter	B.IŞIK

7 ACKNOWLEDGMENTS and THANKS to:
1.research participants 2.Gypsum Producers 3 IŞIK AŞ Company 4.PERİ Company

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