SUSTAINABILITY OF EARTHEN CONSTRUCTION IN NORTH CYPRUS

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ABSTRACT

Sustainability depends on the maintenance of the natural world and natural resources. Built environment has the greatest impact on environment. Reducing energy consumption of construction and life cycle of the buildings will contribute to the sustainability. In this study, traditional structures of North Cyprus and their effective structures for environment protection have been analyzed. Traditional structures in Cyprus were built with natural materials such as stone and earth that creates healthy indoors, concerning the climatic conditions. Structures constructed with industrial materials no longer provide indoor comfort. Lots of energy is being used to provide indoor climate in today's buildings. A very large part of consumed energy in Cyprus is being used by residential sector. Earth is a natural building material made from sand, clay, and water. They may also be produced with some kind of fibrous or organic material (sticks, straw, dung) which is shaped into bricks using frames and dried in the sun. Earthen structures are extremely durable and account for some of the oldest extant buildings on the planet. Earth's strength and durability can be improved if needed. Dense forms of stabilized earthen construction have high thermal mass and able to store heat and provide long term energy savings for cooling in summer and heating in winter so, provide bioclimatic comfort for health with a suitable humidity and thereby balance indoor climate. Due to their high thermal comfort and being cultural characteristic properties of Cyprus, sustainability of Earthen structures are important. Earthen construction is not meeting with today's requirements because it has some disability such as low water resistance and low earthquake resistance. But these properties can be stabilized with gypsum. Revival of earthen construction will protect earthen architectural heritage.

Key words: Earthen construction, sustainability, indoor comfort

1. INTRODUCTION

Characterisation of earthen buildings involves definition of basic materials. Cultural and environmental conditions highlight the reuse of the earthen material today.

Nowadays the studies on earthen structure are among the most important subjects of sustainability that many researches are dealing with throughout the world. The rapid production of industrial materials is the threat for earthen constructions. In this study, earthen buildings around the world and Cyprus have been investigated. Labour, design and materials properties of earthen constructions have been defined. Advantages and disadvantages of earthen construction are also given in this study.

2. EARTHEN BUILDINGS IN HISTORY

Earthen building as an architectural technique has a very long history. Since towns were first built up, ten thousand years ago, Cyprus has used earth to build cities; residential buildings, palaces and temples. The earliest surviving remains had been found in the Güzelyurt. Earthen building has been used throughout all the world's ancient civilizations, from China to North Africa; from the eastern Mediterranean to America, in the mankind history [Ronald 2008] (Figures 1, 2, 3, 4). Taos Pueblo in New Mexico is the oldest inhabited settlement in USA since more than 1,000 years [Ronald 2008]. Earthen architecture has responded to the different climates with the knowledge, accumulated throughout the history.

Figure 1. USA, New Mexico – Taos Pueblo [Ronald 2008]

Figure 2. Egypt, New Gourna Mosque by Hassan Fathy [Ronald 2008]

Figure 3. Iran, Meiboud – Office of ICHO

Figure 4. Mosque of Djenne, Mali

3. NEW EARTHEN BUILDINGS AROUND THE WORLD

Earthen materials are commonly used all around the world; 33% of world population live in earthen structures [Ronald 2008]. Today's curriculum of higher education does not cover earthen construction subjects and cities have been concreted with concrete building materials. Since the building physics and building biology is in the curriculum, earthen structures are also increasing in demand. Intellectual people in European countries are aware of healthy living prefer to use earthen structures. In the USA huge residential buildings constructed with earthen material are the legend of prosperity. Institutes or individuals from Italy, Germany (Dachverbant), Austria (Architect Martin Rauch), France (CRATerre), Switzerland (SIA) are exercising different construction techniques and also trying to keep earthen construction in the foreground. In France around 15% of the population lives in earth-walled houses [Ronald 2008, Minke 2006].

4. EARTHEN BUILDINGS IN CYPRUS

In Neolithic period (10 000 B.C), settlement is found on the slopes to avoid the cold north winds of winter. Their door faces are to south. Walls were made of adobe and mud bricks and earth mixed with hay under the sun. Adobe is a natural building materials made from sand, clay, water and some kind of fibrous or organic material such as sticks and straws. Stones outside and adobe inside are sometimes laid on top of each other. Exterior and interior sides of walls are plastered with whitish earth [Salihoğlu 2008]. Buildings with courtyard system begin in the Bronze Age. These buildings consist of two rooms which have doors opening to the courtyard facing south. The foundation of the residence is composed of natural rock and block walls. Walls are made of adobe and their interior side is plastered with mixture of sand and lime [Salihoğlu 2008]. Rural houses built during the Ottoman's period were continued until the recent times. Wind is the main factor that effects on the planning of houses. Courtyards are surrounded with walls to create a calmer and cleaner environment [Salihoğlu 2008]. Roofs have little inclination and covered with earth. The roof exposed to sun and external atmospheric events is insulated against heat by using thick layers of earth. Inclined roofs have been designed to allow the rain waters to flow into gutters at the end of the roof. Room heights were 4 m. This height allowed warm air to move up inside the building meanwhile achieving natural climatization at the lower levels in the space. Courtyard will benefit from the morning sunlight while it is protected from the afternoon sun shine [Salihoğlu 2008]. There are mainly two types of Cyprus houses. One is countryside and the other is urban side. In countryside generally houses are single story however, in urban areas they are more integrated. Typical countryside example is shown in Figure 5.

Figure 5. Alker (gypsum stabilized earthen) building in Büyükkonuk, North Cyprus [Özbekoğlu 2008]

The Chamber of Turkish Cypriot Architects' Building is given as an example for earthen houses in Lefkoşa (Figure 6). The building is on Zahra Street facing Ledra Palas, on the Venetian walls in Arabahmet district, Nicosia. The 100 year old building which is a good example of typical Ottoman Turkish Civil Architecture was built as a two floor masonry building with the ground floor walls out of stone, first floor walls out of adobe, and interior walls out of wooden framework. Being a natural material, the gypsum plaster allows the adobe, stone, and wood to breathe and enables them to have a long life [Aktaç 2008].

Figure 6. Typical Cyprus earthen building
(The Chamber of Turkish Cypriot Architects' Building, Lefkoşa)

5. ADVANTAGES OF EARTHEN BUILDINGS

5.1 Embodied Energy

The embodied energy of a material refers to the energy used to extract, process and refine it before use in product manufacture. The most important factor in reducing the impact of embodied energy is designing long life, durable and adaptable buildings [Işık and Tülbentçi 2008]. Earthen structures use locally available materials and they typically have low embodied energy because transportation cost decreases. Earthen structures are completely recyclable with minimal resource

requirements. All over the world, the awareness of the embodied energy of materials and the global impacts of carbon dioxide emissions encourages the use of low-embodied energy materials. The use of earth for the built environment will continue to be a strong component in the future of humankind [Middendorf 2001].

5.2 Low Transportation Costs

Since earth exists all over the environment, there may be a very low cost for transportation of raw materials. It can be built by the homeowner. Environmental pollution will also be positively affected because lower transportation will cause lower energy consumption and environmental pollution [Middendorf 2001, Holtzhausen 2007].

5.3 Low Heat Transfer Value

Heat transfer is the movement or passing of heat from one point to another. Heat transfer value is the energy passed for unit time. This depends on the physical and chemical properties of materials. Denser materials have higher heat transfer. Light and porous materials cause low rate heat transfer. Heat transfer property of traditional earthen material provides indoor comfort. Since earthen walls exchange humidity they can be considered ideal for natural indoor comfort. Thermal comfort is experienced when the thermal processes within the human body are in balance i.e. when the body manages its thermal regulation with the minimum of effort and the heat dissipated from the body corresponds with the equilibrium loss of heat to the surrounding area [Neufert 2002]. Expected indoor temperature and-humidity should be 18-24^{0}C and 40-60%, respectively. For healthy living, there should not be too much temperature difference in indoors. Soil the best energy saving material stores thermal energy. After heating, walls give stored energy to the environment and balance the temperature. Because of its high isolation capacity, it protects the indoors from unwanted gain and loss. Therefore there will be no condensation on the surface of indoors. Lack of condensation prevents the wall from chemical and physical aging and there will not be any accumulation of micro-organisms [Middendorf 2001].

5.4 Thermal Comfort

Human thermal comfort is defined by ASHRAE (American Society of Heating, Refrigerating and Air-Conditioning Engineers) as the state of mind that expresses satisfaction with the surrounding environment [Ravikumar and Prakash 2001]. Thermal comfort is affected by heat conduction, convection, radiation, and evaporative heat loss [Ravikumar and Prakash 2001]. Thermal comfort is maintained when the heat generated by human metabolism is allowed to dissipate. Any heat gain or loss beyond this generates a discomfort. Lower heat transfer value of earthen walls provides temperature difference $\pm 2^0$C with outdoor temperature on the walls which does not create discomfort.

5.5 Renewable Material

Renewable is defined in Merriam-Webster as "capable of being replaced by natural, ecological cycles [Anne 2007]. A renewable material has economic and environmental value that can be replaced in the same amount. Soil is a renewable material for construction because it is a supply through the natural decomposition cycle or through composting and it is a non-toxic resource which can be readily recycled.

5.6 Low Fire Risk

The biggest threat of fire is to cause the collapse of building load bearing structures and result with harm to goods and human life. There are no flammable components in the earthen construction. Since fire turns earth into ceramic it increases its strength. Compared to other building materials, such as wood, earth houses feature efficient fire protection owing both to the use of concrete and the properties of the earth itself [Neufert 2002].

5.7 Workability

When the material has ability to be mixed, transported, poured, consolidated and finished easily and homogenously, it is classified as workable materials [Neufert 2002]. Earthen materials can be shaped by hand into attractively architectural forms: Because of its workability, rounded forms may be formed easily. It allows expression of personal creativity using traditional crafts and skills when produced by hand. Production by hand is labour intensive. For being workable, water amount should be high. Traditional production steps are shown in Figure 7 that also shows the labour intensive production.

Figure 7. Preparation of mud brick [Özbekoğlu 2008]

6. DISADVANTAGES OF EARTHEN BUILDINGS

Despite all the good qualities of traditional earthen constructions, the earth as construction material has some weaknesses. The disadvantages stated below are derived and mentioned from the experience of unstabilised earth construction.

6.1 Labour Intensive

Traditional earth building methods are extremely labour intensive. Adobe bricks are usually made by labour-intensive processes and adobe buildings require the hand placement of thousands of adobe bricks. Even with modern forms and pneumatic tampers, rammed earth construction also requires a considerable amount of labour [Minke 2006].

6.2 Design Limitations

Load bearing principles of earthen structures should be obtained from regulations and standards. General directorate of the earthquake disaster legislation (1997) defines some criteria on earthen structure design such as limitations of masonry structures, the wall height and wall width, window openings from the sides as a plan and window size depending on wall size. Earthen structures were excluded from the scope of earthquake regulations from this time beyond.

6.3 Durability

Durability is the quality of structures of continuing to be useful after an extended period of time and usage. Abrasion on earthen due to water affects its durability. Earthen materials gain its strength as drying. Therefore when it has contact with water it becomes more plastic and loses its strength.

6.4 Earthquake Response

Earthen structures are vulnerable to the effects of natural phenomena such as earthquakes, rain, and floods. Traditional earthen construction responds very poorly to earthquake ground shaking, suffering serious structural damage or collapse, and causing a dramatic loss of life and property. Seismic deficiencies of adobe construction are caused by due to their low strength. During strong earthquakes while 1/8 to 1/10 of the gravity acts as lateral forces on to the building, these structures develop high levels of seismic forces they are unable to resist, and therefore they fail abruptly [Blondet and Aguilar 2007]. Regulations are limitations in the earthquake resistance. Tensile strength of structures are so low that it can be ignored during earthquake. Earthen materials are ductile therefore they will have some plastic deformation under load before failure. Modern construction materials such as concrete, brick, aerated concrete are not ductile as much as earthen material. Earthen construction should be made according to earthquake safety standards [Yıldız and Gökdemir 2007]. It is a mistake to believe that earthen buildings are more sensitive to earthquakes than the other ones which are built with stones, bricks or concrete blocks. The important matter is always how well buildings are designed and built.

Traditional structures have been defined as old-fashioned. Earthen construction is not meeting with today's requirements because it has some disability such as low water resistance and low earthquake resistance. Earthen construction is labour intensive. Therefore the rapid production of industrial materials is a threat for earthen constructions. Water causes deterioration on earthen structures. Stabilization with gypsum and lime stabilization was used in Çatalhöyük in 9000 BC [Kafesçioğlu 1985]. Gypsum stabilization was developed since 1978 from Ruhi Kafesçioğlu at İstanbul Technical University [Kafesçioğlu 1985]. Buildings constructed with Alker since 1980 proved durability of earthen structures. This new composite material with lower shrinkage value is suitable to produce with the machines. In this manner, instead of labour intensive conventional production, new composite material has advantage for the construction sector.

7. CONCLUSION

Earth has been used as building material for thousands of years, and was discarded throughout the age of industrialization. In the last decay revival of earthen building techniques have been observed all over the world. The reason for this increase is the awareness in ecologically friendly construction and healthy houses. The growing dissatisfaction due to new buildings in the last century results from the increase of allergies and illness caused by indoor environment. Revitalization of earthen architecture in Cyprus can come true, if architects, constructors and craftsman had the knowledge and experience with the usage of earthen building products in new and historical buildings. Study on earth as construction materials and disseminate the knowledge can increase awareness and confidence on the technology. Gypsum stabilized soil has been determined for earthen construction revitalization. Gypsum stabilized soil, called Alker, has been studied in laboratory since 1978 and pilot buildings are in use since 1983. The advantages of alker are; low weight, low shrinkage, low heat transfer value, low energy consumption, less labour expenses and durability of the material. Characteristics of earthen construction in history and new earthen buildings around the world have been visualized to contribute to the awareness. Climate of Cyprus has been defined, as it has the greatest influence on to the architecture. Value of earthen building in Cyprus has been defined as: thermal indoor comfort in summer and winter seasons, indoor air quality, workability of the material, low embodied energy, easily available material, low fire risk, sound damping, etc. Most of the disadvantages, such as low durability, high labour demand, earthquake risk, low physical and mechanical properties are solved with the gypsum stabilization technology researches since 1978. Alker researches are summarised to be the base of the study.

REFERENCE

Aktaç, T., 2008. Restoration of Earthen Building on Zahra Street-Lefkoşa Kerpic08 Learning from earthen architecture in climate change International Conference, Cyprus International University

Anne, J., 2007. Sustainable sourcing of renewable materials, Reed Business information, Inc. V.44

Blondet, M. & Aguilar, R., 2007. Seismic Protection of Earthen Buildings. Conferencia Internacional En Ingeniera Sismica. Lima, V 22

Holtzhausen, H.J., 2007. Embodied Energy and its impact on Architectural Decisions, WIT Transactions on Ecology and the Environment 102 pp. 377–385.

http://folk.ntnu.no/fossumj/cpx/cardhouse2_e.html NTNU Norwegian University of Science and Technology

Işık, B. & Tülbentci, T., 2008. Sustainable housing in island conditions using Alker-Gypsum stabilized earth: A case study from Northern Cyprus, Building and Environment, Elsevier Volume 43, pp. 1426-1432

Kafesçioğlu, R., Toydemir, N., Özüekren, B. & Gürdal, E., 1980. Yapı malzemesi olarak kerpiç'in alçı ile stabilizasyonu Stabilizing earth with gypsum as a construction material), İstanbul, TUBITAK MAG505

Kafesçioğlu, R., Gürdal, E., 1985. Çağdaş Yapı Malzemesi Alker , Enerji ve Tabii Kaynaklar Bakanlığı Enerji Dairesi Başkanlığı, Shell, İstanbul

Kafesçioğlu, R. & Gürdal, E., 2003. Çağdaş yapı malzemesi-Alker-Alçılı Kerpiç.

Kafesçioğlu, R. & Işık, B., 2005. The Relevance of Earth Construction for the Contemporary World and Alker, Gypsum Stabilized Earth, Kerpic05 conference, ITU Süleyman Demirel Kültür Merkezi, Istanbul, 6-10 July

Middendorf, J., 2001. Properties and Methodology of Earth Structures, GSD 6400: Energy and Environment

Minke, G., 2006. Building with Earth: Design and Technology of a Sustainable Architecture, Birkhäuser Architecture Press

Neufert, P., 2002. Architect's Data, Blackwell publishing

Özbekoğlu, Ö. 2008. Revival of adobe for eco-turizm, Kerpic08, Learning from earthen architecture in climate change International Conference, Cyprus International University, Lefkoşa / Northern Cyprus

Ravikumar, P. & Prakash, D., 2001. Analysis of thermal comfort in an office room by varying the dimension of the windows on adjacent walls using CAD: A case study

Ronald, Rael., 2008. Earth Architecture, Princeton Architectural Press based on numerical simulation, Building Simulation, V.2 pp 187-196

Salihoğlu, T., 2008. Ekolojik Mimari ve Kerpiç Kerpic08, Learning from earthen architecture in climate change International Conference, Cyprus International University, Lefkoşa / Northern Cyprus

Yıldız, K. & Gökdemir, A., 2007. The Effect Of Ferrochrome Waste And Polypropilen Fiber Admixture On The Strength Of Adobe, SSN:1306-3111 e-Journal of New World Sciences Academy, Volume: 2, Number: 4 Article Number: A0037 Natural And Applied Sciences Civil Engineering