SEISMIC IMPROVEMENT OF TRADITIONAL EARTH BUILDINGS IN TURKEY

Lorenzo Jurina, Associate Professor / Politecnico di Milano, lorenzo.jurina@polimi.it

ABSTRACT

The analysis of current building methods still reveals a wide use of earth as basic material in some Turkish areas, even if this technique is decaying due to the social bias, that considers earth building poor and not enough modern if compared to brick or concrete building. Only a study of the potentiality of "adobe" traditional dwellings will allow for the maintenance and the enhancement of the existing ones and for a renewed possibility to put in practice the ancient skill of earth buildings.

Earth can be found everywhere and can be used as building material with good results, giving safe, comfortable and cheap houses. Some main defects, as the low resistance to water and the reduced ability to withstand seismic shocks, can be solved with simple technological stratagems. In this paper some traditional technological aspects of the building procedure by adobe are presented. In particular a number of methods on how to "stabilize" the base material with respect to water and some infrequently used but well-working ways of seismic improvement are shown.

Keywords: *adobe, ancient skill, seismic improvement, technological stratagems*

INTRODUCTORY REMARKS

Turkey is a country that has chiefly experienced, and still is experiencing, the situation of buildings with plain earth, and possesses some of the most ancient and great monuments of the past, maintaining such a technique even in the current situation.

The **ADOBE,** a term which is quite diffused at a universal level and what the English call *mud brick* or *sun dried brick*, stands for those blocks, or bricks, in plain earth, of rather large dimensions and sun dried. Their shape is given, mostly by hand, by means of suitable moulds in which a plastic mixture of clay, sand and straw is compressed into, and then traditionally installed.

Figure 1: adobe bricks during drying process

DETERIORATION AND REMEDIES

The widespread bias on the durability and on the resistance of buildings in earth often underestimates the extraordinary capacities of potential use which this material enjoys, above all when appropriate stratagems allow for its being *protected from water*.
These stratagems include:

- an adequate type of *foundations*, possibly uninterrupted, which effectively isolate the building from the ground
- the presence of a perimetric *drainage system*
- *protection against rainwater* guaranteed by an overhang of the roofing
- *structural compatibility* of the wall elements (in particular of covering masonry and plaster whose different stiffness and transpirable features have a negative influence on its durability)

Earth is a material which does not resist traction and which considerably cannot stand the effects of water. Several *stabilization methods* apt to improve the properties of earth will be illustrated in the following. These methods make earth capable of amazing performances in terms of resistance, waterproofing and durability.
Straw fibres, for example, preferably about 4/6 cm long, mixed with earth, have a basic role in *contrasting shrinkage* during the drying process and the consequent fissuring of the earth, especially in presence of an high percentage of clay. In the same way, the fibres limit the *excessive swelling* in case of humidity, bringing about an increase of *tensile strength.*
As from quantities of 4% in volume, a satisfactory outcome is achieved up to proportions of about 20-30 kg/m^3 which are quite frequent. Once this optimum percentage is exceeded, strength decreases.
It's worth to remember that a disorderly arrangement of the fibres inside the mixture creates a *tridimensional mesh* which turns out to be nothing else but brandering.
Their presence speeds up the drying process of the mass, right to its inner part, thanks to a humidity drainage outwards, favoured by the ducts of the fibres. Anyway, one has to take care about the absorption of water in case humidity is present. Among the advantages the increase of insulation characteristics, either thermic and acoustic.
Besides this, their application offers a special benefit in regard to seismic phenomena; the blocks become capable of absorbing major strain with a performance of plastic cracking, not fragile. The fibres-free blocks normally "crumble", whereas those with fibre brandering tend to maintain a certain unit under dynamic loads.
Inconvenient aspects of vegetable fibres are the risk of rotting because of long-term presence in humid surroundings, and their assailable feature on behalf of harmful.

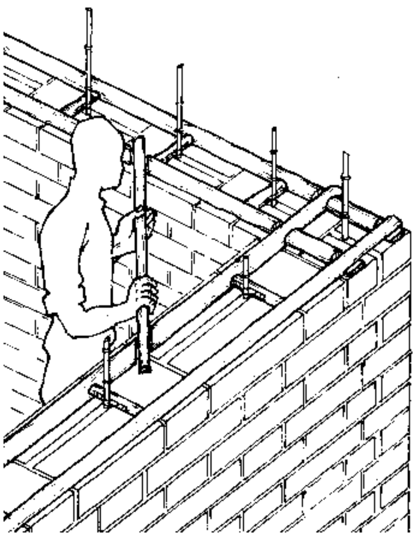

Figure 2: stabiliziation of adobe with straw fibers

Even **chemical stabilization** is resorted to in order to deal with the problems of the durability of the material.
A general rule recommends the use of *bitumen* for sandy earth, *cement* for medium or low plasticity muddy earth, *lime* for high cohesion clayey earth.
Practically all earth, and particularly the one with predominant sandy features, may be potentially stabilized with **cement**, on the condition that it does not contain an excessive quantity of organic substance or salts. Generally, the optimum percentages can vary between 7 and 8% of the volume, strongly increasing the strength of the material.
These are also many natural products of mineral, vegetable or animal origin, whose use has been handed down in time, linked, as it is, to learning and traditional methods.
However, most of them can guarantee a certain improvement with respect to water strength, thus slowing down their course of decay.
Among them, products of **mineral origin** are mainly used to rectify the granulometry of earth. Sandy fractions are added to modify excessively clayey mixtures, or viceversa. Special effects may be obtained by selecting specific earth such as *bentonite* – a clay with degreasing features – which expands if water is present, forming a waterproof barrier.
Also products of **animal origin** are usually devoted to the stabilizing of plaster and sheating.
Some of the traditional ones are solid animal dung, animal urine, fibres or animal hair, animal glue, oils and fats which may act as waterproofing agents.
Even products of **vegetable origin** can induce the same positive effects. Vegetable oils, wood ashes and polyphenol acids, derived from lignin, which form stable compounds, sap and latices are the principal.

Figure 3: beehive adobe buildings of Harran, south west Anatolia, Turkey. Harran was a major ancient city in Upper Mesopotamia whose site is near the modern village of Altinbasak, Turkey, 24 miles 44 kilometers southeast of Sanliurfa

EARTHQUAKE RESISTENT EARTH-BUILDING TECHNOLOGIES

Economy and the application of self-manufacturing of the *adobe* add on to the extremely widespread situation of this material. However, one of the main shortcomings which the material carries is the *scarse capability of resisting to earthquakes*, because of its low tensile strength.
In the past years, this has seen the development of a great deal of research which has brought up the suggestion of a *new earthquake-proof building technology*. Besides the quality of the material used, a basic role in the seismic strength of building lies with the undertaken building stratagems capable of guaranteeing the *total connecting* of all building parts and, hence, the capability of achieving an aggregate solution of the concerned structure. The following are a number of points which consider the best way to *"make adobe"* in a country prone to earthquakes.

<u>Preparation</u>
- First, *which earth?* Dark and agricultural earth is to be avoided since it contains an excessive amount of organic substances; in the same way, the mixture is not to contain stones, sullage, or vegetable residues.
The most adequate mixture carries about the following percentages: Sand: 55-75%, Silt: 0-28%, Clay: 15-18%. The earth is then to be sifted through a grid (with a 10 mm mesh) and then mixed with water (the proportions: 1/3 water, 2/3 earth).
- the mixture is then left to stand for at least a day or two;
- the mould is soaked in water before being used and subsequently sprinkled with sand to stop earth from clinging to its sides;
- once the block is ready, it is to be left to dry away from sunlight (in order to avoid fissures)

<u>Building datails</u>
- The foundations are to rest on solid land; it is thus necessary to carry out excavations until a stable land is reached and, anyhow, to a depth of at least 40 cm;
- the thickness of the excavations are to be at least 1½ times as much as the one of the wall;
- the foundations are to preferably be in plain concrete with considerably large stones. The following proportion is to be utilized: 1 part of cement, 4 of sand, 6 of pebbles/cobblestones and 10 of large stones, plus water. As an alternative, lime may be used instead of cement, or, as a last resource, large stones blended in with the earth itself. The thickness of the foundations has at least to double the one of the wall and the depth is to be more than 60 cm;
- in order to protect the base of the building structure against the erosive characteristics of rainwater (direct or bounced back), superfoundations, of the same type of the foundations, but with medium-sized stones, are to be carried out – with a minimum height of 25 cm.
- once the superfoundations have been realized, the upper surface is *scratched* with a nail in order to roughen the surface and, hence, to improve its grip with the upper layer of mortar;
- the mortar is to be of the same mixture utilized for the making up of *adobe*, and is likewise to stand for 1 or 2 days;
- in order to avoid a rapid drying of the mortar, it is advisable to wet adobe before laying
- joints are to be of 2 cm;
- the subsequent linking of the blocks and the masonry apparatus follow the customary rules of the structural work with a displacement of the vertical joints, controlling of the lining up of the wall, an arrangement of adequate lintels over the clefts – the only advice here is to erect a maximum of 1 metre of wall per day, in order to avoid buckling under its own weight;
- every 4 horizontal rows, *horizontal brandering* is arranged, utilizing rushes as from half of their thickness;
- the rushes are to be tightly fixed one to the other and to the *vertical brandering* rushes;
- at almost the top of the walls, it is basic to have every element come into play and to be sure of a perfect terminal connection of all the walls, placing an *upper connecting element*

which may be a wooden beam, concrete casting, an electrowelded mesh, to which, in turn, all the vertical terminations of the rushes of the masonry brandering are fixed;
- laying is carried on with a number of further rows of adobe which may also help to set the possible gradient of the roofing;
- the realization of the roof may be carried out with different technologies; in the case of a roof still based on the fundamental materials used, rushes and earth, connecting transversal beams are arranged between two facing walls at a distance of about 60 cm, and jutting out beyond the masonry line at another 60 cm (in order to guarantee a good protection of the latter). What is next placed, in a perpendicular direction, are the rushes, side by side and linked to one another by wooden strips, arranged above, which are nailed at an interval of so many rushes. Next comes a laying of 3 cm thick earth which is to be superimposed by a protecting element (roof tiles, corrugated sheet iron, terracotta tiles, etc. …);
- next to be carried out is the plastering of the wall which may be realized with a mixture, still of earth or of other substances, with greater waterproofing features. The mixture adheres better to the wall if a *nailed iron wire framework* – which acts as an anchoring element – is arranged beforehand. The plastering is to take place in two subsequent layers.

<u>General advices</u>
- The *symmetry* and the simple system of the building structure make up an excellent solution to guarantee a uniform performance of the structure itself, with no risk of bringing about dangerous torsional stress in case of earthquakes;
- the extension of a clear wall, in between two transversal walls, is not to be greater than 10 times its thickness. If greater lengths are needed, the wall is to be reinforced by means of an intermediate vertical buttress;
- the maximum height of the wall is not to be greater than 8 times its thickness;
- the breadth of a cleft is not to be greater than 1.20 m; the same measurement is to be made sure of as the distance between the cleft itself and the end of the wall; in such a way, the total of the cleft widths in the same wall is not to be greater than the proportion of 1/3 of the extension of the masonry itself;
- the supporting base of an isolated lintel is to be at least 50 cm;
- a fundamental aspect is the ultimate arranging of an upper connecting element (a *crowning beam*, or ‘correa’), and a minimum of 2 more rows of *adobe* to follow;
- in order to uniformly mete out the roof load, or the load of a floor, it is advisable to position a *distributing element* (a stone or a piece of wood) below the bearing point of a main lintel;
- the roof pitching is to be appropriately jutting out to shelter the walls from severe weather conditions.

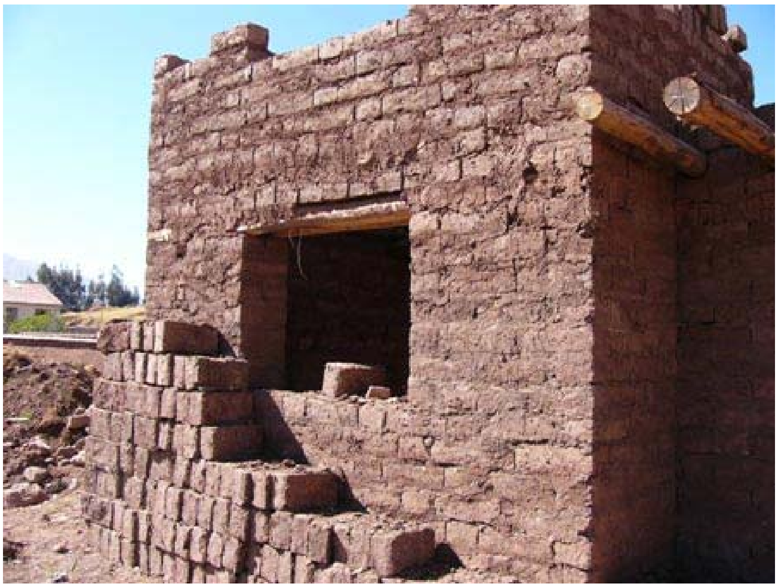

Figure 4: a traditional adobe building

CONCLUDING REMARKS

Earth has always been an effective and widespread building material made available by nature at all times. Man has been capable of wisely using it to his advantage, by way of ingenious shapes and enchanting architectural structures. Earth has won the interest of various cultures that have learnt to make good use of its appeal and versatility to create newer and more amazing structures.

Earth, as a material, has inexhaustible resources and pursues an inevitable and *alternating process of denial and repossession* on behalf of man who constanly forgets all about it only to discover its worth once again with a different attitude and with renewed interest.

The real solution of this seesaw behaviour lies, as always, in the very middle – without going to extremes: one is not to make a clean sweep of traditions for love of modernism, pursued at all costs, and not even to ossify oneself by adopting an uninspired and dogmatic recovery of the said traditions. In order to survive and be immortalized in times afar reasonably and effectively, one is to carry out the task of careful reappraisal of this architectural world – *particularly of the technological details it is characterized by* – in order to have it, by means of profound reinterpretation and modifications, adapt itself to the needs of present day society, sunk, as it is, in its unavoidable modernity. What lies ahead of us is a process split into phases. This process is sometimes against the general trend, yet, it is definitely unpredictable and somewhat challenging.

More details can be found on **www.jurina.it.**

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