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THE ENDURANCE OF EARTHS AS BUILDING MATERIAL -AND THE DISCREET BUT CONTINUOUS CHARM OF ADOBE

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An Overview

The use of earth as building material in our time is linked with several considerations. There seem to be two periods of enlivened interest, one in the 1930's extending to the early 1950's, and the second in the latter part of 1970's. As things stand, such interest in the material brings mainly the conclusion that its chemistry and mechanics should be studied extensively, especially since the soil constitution varies greatly from one place to another.

To start with, earth as building material appears to be one of the few alternatives in low-cost housing. In some of the industrialised countries, in a period starting before the 1930's and extending into the 1950's there has been more experimentation with the material than with housing projects based on it. In the rest of the world, especially in Asia and South America, experimentation with earth-built housing itself has been more in spurts than in continuous programs ever since 1945. Such projects are likely to use a mixture of ancient and new techniques and analyses, but equally likely to abandon the vernacular design existing in the particular districts.

These housing programs have remained in the experimental stage, except for squatters' settlements in certain countries. In the squatter settlements, however, next to nothing is being done with respect to new methods concerning the resistivity of the material. Furthermore, because of the fast rate of building in our time, and because of the conditions imposed upon the squatters, even the standards of the past are not likely to be reached or observed.

Earth is used mainly in the walls of a building. Since the costs of walls do not often exceed a quarter of the total costs of building, earth material's contribution to lower costs becomes problematic. As a result proponents may cite an overall cost reduction of ten to fifteen percent, an amount too low to

constitute an alternative in many circumstances. Labour costs are not considered lower but higher in certain types of earth buildings, especially pisé (in other words, rammed earth).

In this context the advantage of using earth seems to be reduced to areas where alternative materials are not to be found, or would be costly[1]. In experimental situations under the guidance of able and committed people good results and lower costs may also be reached[2].

A second source of interest in earth material derives from the appreciation of vernacular building, and a dedication to its preservation. Since low-cost programs have addressed themselves to traditional building techniques only too seldom, and therefore are more likely to stifle than to develop such techniques, here we observe one of the inner conflicts of purpose which exist in the study of earths as building material. An appreciation of vernacular may often connote an interest in its present livelihood and in the sustenance of the manner of construction.

On the other hand, simply the preservation of existing and rather monumental or otherwise historic earthen buildings or relics is now becoming one of the major considerations in the interest toward the material. The emphasis in conservation and restoration has shifted considerably over the last decade from individual buildings to neighbourhoods and to textures on settlement scale. In our estimation earthen buildings, or other types of construction which use earth, are to become the major field of concern under the new emphasis since it is especially in earthen construction that district characteristics are pre-eminent. It goes without saying that restoration may sometimes afford approaches costlier than in the construction of housing projects. Therefore the goals and the methods to be adopted for either purpose will differ, even if this only means slight adjustments to the treatment of the earth. The same difference will apply to present-day construction of vernacular, in which new chemicals may be helpful to the continuation of tradition.

There is a liveliness and movement to the surfaces of earthen buildings[3] and nearly a tactile beauty to their protective coatings. Such qualities seem to have been obtained effortlessly in the "vernacular" styles and in the historic buildings to be preserved. On the other hand these qualities are ranked as quite secondary by the designers of contemporary housing and by the engineers who inspect earthquake damage. In the latter approach earth as building material appears as something to be discarded, or at best to be tolerated in cases either where there are no other choices or where earthen construction seems to be adopted by squatters.

We think that earthen construction has produced the most varied and exciting forms of building in the world, on steep hillsides and in the flat plains, in the case of free-standing buildings and in the uninterrupted continuity of texture in villages or large cities (such as Kano, Nigeria). The ambiance created may not only be the result of the manipulation of space by the builders, but may also directly derive from the earth as building material.

1. In some of the easternmost parts of Turkey adobe is still preferred as building material. It is considered best for winter conditions, and "even cheaper" than cement "*briket*".

Houses here have adobe bearing walls, wooden posts, round section wooden beams, flat mud roof, and at times adobe plaster coating on vertical surfaces. The jugdment that traditional housing *is particularly vulnerable to earthquake* is found "a preconception largely".

From the Report "Çaldıran Depremi" by C.TÜRKSOY and K.KILIÇLI, February 1979, METU, unpublished.

2. F.AFSHAR, Salseleh Development Project in Iran, in the seminar *proceedings Toward an Architecture in the Spirit of Islam* (held at Gouvieux, France, 1978).

3. The ICOMOS Statement for Yazd :

Fig.1. Yukari Ulupinar, Turkey. (Photographs accompanying the article were taken in 1978. The buildings are of recent construction. In these and many other villages earthen construction is ongoing. Modalities continue. Variations or mutations from tradition are part of the practice.)

EARTH AND WATER, EARTH AND EARTHQUAKE

While interest in earth may range from conservation of buildings to provision of new housing or to division and use of space, the earth's chemical reaction with water in the walls will in all cases constitute the primary concern. This in turn will immediately focus on clay and colloid content in the earth sample.

On the other hand, the viability of earth as building material in the near future depends to a great extent on its resistance to earthquakes, since its acceptability is most seriously questioned in this respect. Unesco missions to the earthquake areas of central or eastern Iran roundly condemn earthen construction, and so do turkish civil engineers on visits to eastern Turkey. Opinion on the matter is divided, however. Construction in unbaked mud bricks, or earth in general, is commended for its resistance to earthquakes by archaeologists and architects working on buildings aged thousands of years and situated in earthquake areas[4]. The Californian interest in rammed earth or adobe several decades ago equally produced a number of statements on the earthquake resistance of earthen buildings.

4. The ICOMOS Statement for Yazd I

On the Peruvian Andes, village churches have survived a great number of earthquakes since 1572[5]. Conversely however, in Huaca Garagay in the same country the overall conditions for the preservation of adobe are so uniquely excellent (virtually no rain, no capillarity, no salinity, very low relative humidity and very low thermal variation) that the causes of deterioration in the buildings, the last phase of construction being assigned to probably 1000 B.C., are attributed to earthquakes. Let us add, that these Chavín style temples had no foundations[6]. This may account for the possible failures during earthquakes.

5. C.Obregoso in Yazd II

6. G.Chiari and R.Ravirez in Yazd II. The Chavín culture is the earliest highly developed in pre-Inca Peru, 900-200 BC.

In sum, the viability of earth as building material will depend on earthquake engineering, on the manipulation of water

infiltration, on new chemical compounds and molecular research and on the renewal of workmanship. Earthen walls may under certain circumstances be economically and practically preferable to concrete, more so than in the case of stone and other materials used in traditional "provincial" styles. As for the viability of historic earthen structures in the centres of cities, a question to be raised more for Iran than perhaps any other country, -such matters need be studied in terms of land rents and land speculation rather than in terms of mud bricks.

Before we go on to the historical and geographical extent of the use of earth as building material, and to other questions of detail, a few more general remarks will be to the point.

We think that the case for adobe, and for earthen bricks, is widely stated in the literature[7]: this literature promises much for adobe and not necessarily as a secondary, but primary building material. But the need for further inquiry becomes apparent in each experiment. On the other hand this inquiry has been developing only slowly over the last decades. The reason is rather obvious to us. Earth does not have the backing, the funding and the sponsors that cement and steel have. It is lack of extensive experimentation which is at the base of the continuing controversies and inconsistent findings in the field of earthen bricks and earthen walls. Such experimentation will have to be still more extensive because surface treatment and internal consistency in earthen walls generate purposes which may be at odds with each other, from restoration to new construction.

Another major difficulty is that people from various professions who come closest to obtain significant information on earthen construction have very little interest in the subject. At the present it is possible to document the great historical and geographical extent of earthen buildings from photographs and not from written documentation. The texts which accompany these photographs very seldom explicitly mention the building material if it is earth. Agreed that steel and stone show themselves explicitly on photographs, but mud does not.

7. Many of the arguments may be considered specious, however. There is also a good deal of divergence in findings and conclusions.

Terminology

In this article we use the terms "earth" "earths" and "earthern (building) material" to cover all the varieties. "Adobe" will refer to construction made with earths of high clay content and with what is sometimes called the *wet* method, the reason being that higher clay content in practice leads to kneading and moulding with more water. On account of the reversibility in clays, that is to say the propensity to re-absorb water after being dried out, adobe is not recommended nor very often practiced in areas outside the arid zones.

"Sun-dried brick", "unburnt brick", "unbaked brick", "unfired brick", "puddled earth", "mud wall" and "mud brick" are employed by many authors as equivalent to adobe, even though one senses that certain writers intend a larger classification by the use of these terms.

"Wattle and daub" or "mud and wattle" refer to practices where the load-carrying frame is of timber or branches of trees; perhaps because of minor or major differences the term "wattle and daub" is not applied to similar practices in countries other than United Kingdom, where the term "half-timber" embraces earth as well as other masonry fillers. "Mud and wattle" seems to be preferred by english-speaking authors for huts in certain parts of Africa, often in surprisingly rainy areas. In this type of construction mud serves as filler and as a screen in visual terms (in addition to its function of atmospheric and thermal insulation).

In *pisé*, or "rammed earth", the clay content and the humidity of the earth are lower. The "ramming" refers to the practice of tamping the earth inside shuttering, or "forms". Roughly for two decades from the 1930's much *pisé* experimentation was made in continuous horizontal courses rammed successively, -thus this method could be thought to be monolithic. However, in many laboratory experiments mixtures with lower clay content were tested in brick form. Furthermore, even with lower clay content, bricks offer the advantage of separate drying, and depending on the viewpoint, more leisurely labour. Consequently pisé may now be thought in terms of bricks. At the present the distinction is stated in terms of "pressurized" bricks, for which simple machines have been developed after the 1950's, and non-pressurized bricks, which will very often be of the originally wet mud type.

Adobe versus Pisé

It will not be an exaggeration to say that restoration workers emphasize surface treatment of earthen walls. On the other hand research for new construction tends to focus on stabilisation for the entire depth of the wall. The only two stabilisers used by a large number of experimenters are cement and bitumen. In the 1950's prevalent opinion exhibited more hope for the drier pisé method in reaching good stability. If in the 1970's our interest is concentrated on restoration and on the sculptural qualities of traditional building in most parts of the world, it will be adobe for the centre of attention.

It seems that the above terms are not used consistently in the literature. As one consequence we do not find agreement on the extent and origin of pisé in the world. Some authors propose that pisé originates from the wetter climate of Europe, -if so it is fitting to think that this being a European and thus presumably a more advanced method, it was proposed for universal application in the 1950's. Nevertheless the experimentation in industrialised countries was intended for local use, and very often with the purpose extending the use of earth into rainier climes.

Other writers use the term "pisé" in a wider geographical context.

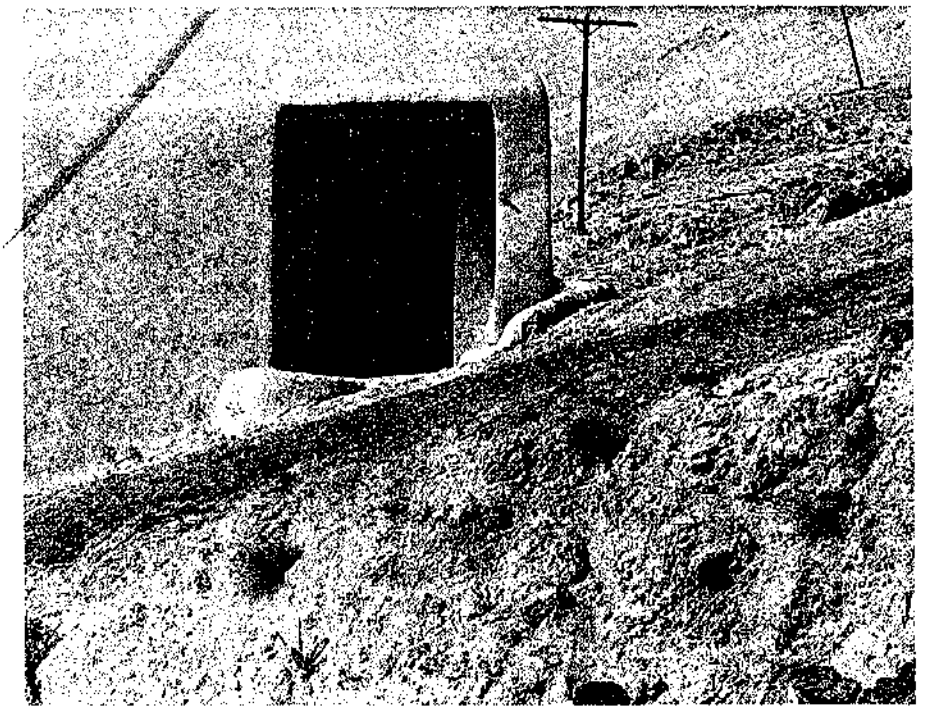

Fig.2. Yukarı Ulupınar, Turkey.

THE RANGE OF ADOBE

It may be questionable to use the term "adobe" universally. Here it is adopted for purposes of brevity. The only contrasting term available is "pisé". First, a clear demarcation between the two may not be universally possible. Second, it is after all true that earthen construction is more particular to a drier climate, the province of adobe. In the future it may be more fruitful to distinguish among the particular compositions of adobe. We expect the variety to be great, -the chemical response to various earths should also possess the requisite variety.

South America and southwestern United States have attracted much attention in the documentation and study of adobe. Irak and Iran however, are the major countries for the study of earthen construction in the opinion of many. In the plateaus of Iran the climate is propitious for the maintenance of adobe structures, while structural problems arise not from earthen walls but from the roofs covering such walls[8].

In Irak thousands of years ago earth was the most plentiful building material and was used in unbaked form. Irak and Iran both, while using unbaked earth extensively, have generated building forms such as the arch, the vault, and the dome which today we do not necessarily associate with adobe. These may be thought of as the contributions of adobe to the classical building technique[9]. In these countries the sun-dried brick led to the development of baked brick, in contrast to the neighbouring countries in the west and east, -Turkey and the Indian subcontinent where baked brick is not conspicuous.

8. In the plateau villages houses are covered with earthen domes or vaults. Annual maintenance involves additional layers of thatching and mud. After a period the roof becomes too heavy, and is a main cause of failure in earthquakes.

The same progressive loading of the roof is found in eastern Turkey (19 percent of rural housing in adobe) where there's more rain than in central Anatolia (42 percent of rural housing in adobe). In this case the roofs are flat.

Since there seem to be two sources for the above statistics, it is not clear to me whether the above percentages were obtained on a sampling basis or otherwise.

9. In some contrast to wood framing techniques, which in many countries were reproduced in stone structures. The forms generated by adobe were later developed more suitably for stone, and steel.

For adobe in bloom we must look to the African savannah however, especially in what is called the Western Sudan. From Mali in the west to northern Cameroon in the east the most joyful architecture of the world is built in adobe. Some areas in this zone have lateritic soils, as may be expected in regions with comparatively hot and humid or Mediterranean climates[10]. Laterite is only one of the major types of soils which appear in buildings. Other areas in the zone are drier throughout the year.

In the savannah of Western Sudan there are fewer large scale earthen buildings in comparison to southwestern Asia or to the Americas. Furthermore earthen buildings are likely to be limited to a single story[11], this perhaps being due to social practices, and even to social structure, rather than to engineering and climatic considerations.

In this region the cylindrical mud hut with a conical thatched roof may be taken as the prototype. At the present cone-forms survive in the shape of entire dwellings, as for instance in the area around Pouss (Masa tribe: Cameroon). The coming of the square house to this region is attributed to the influence of Islam[12]. Round and square are often endemically separated but may come together, as in the Bandiagara escarpment or the city of Kano (there may be separate purposes attached to each form). Separate huts are connected, in many areas, into compounds by means of continuous walls[13].

The square house brought with it a flat mud roof[14]. The outward thrust of this comparatively heavier roof required buttressing in many cases, thus not only bringing to mind the Great Mosque of al-Qayrawān (Tunisia) but pointing to the "spires" of the mosque at Mopti (Mali). The "Jenne" style, in the same country, is without buttresses[15]

Baked brick may have been introduced to this savannah region in the 14th Century but it has not displaced adobe. In contrast to the *bad-gir*[16] dominated townscape of Yazd, and to the stark silhouettes of Dezfūl (Khūzestān, southwestern Iran) and some pueblos in southwestern United States, and even starker sparse landscapes of the Himalayan adobe, but more in the same spirit with the voluptuous curves above the elongated covered bazaars of larger cities in the Iranian plateau (Kāshān, Mashhad, Kermān and Esfahān, in an arbitrary order of sensuousness), the Sudanese savannah handles its earth shelter with mirth, willful choice and seems to press the external layers of mud caressingly into place[17]. The structure of the shelter is produced in the same process. Among the known building materials, this could only be done with adobe.

We are not only interested in the maintenance and restoration of existing buildings, but also in the future of a particular manner of shaping the daily townscape in minute spaces with specific "uses" and in the regulation of access and view with continuous walls and discontinuous heights.

The "tapering pinnacles" may be reduced to only symbolic smaller forms, as in Daura (Katsina province, northern Nigeria), this time not load-carrying. In Daura large strong monochromes and large reliefs are splashed on to the external surfaces. In

10. Laterite derives from particular varieties of parent rock and is a result of leaching. An alternation of long wet and dry seasons lead to complete oxidisation of organic material in the surface. The downward seeping water is then neutral. Alkaline materials and silica are removed. Iron (and aluminum) oxides remain. Laterites may often have a reddish colour. Laterite hardens on exposure.

In constantly dry climates water does not seep down, thus leaching does not take place, producing soils other than laterite.

The savannah climate is given as consisting of a short summer rainy season and a dry winter.

11. Presumably with exceptions at Jenne, Timbuktu, and other places.

12. If passage from round forms to square is assessed as progress from primitive to more advanced, such being the case for many 19th Century travelers and *much of contemporary anthropological* social science, this appraisal itself points to quite primitive sensibility.

13. This is one kind of the temporal or spatial continuities suggested in the title of this article.

It is clear that descriptions of the nature found in the present text should be *profusely illustrated. Since, however,* we do not possess original prints, we miss this chance of bringing together the scattered illustrations of Western Sudan.

We think that visual material on earthen construction in the world should be brought together in a single collection at a scale much larger than available at the present.

14. Over wooden beams. Also found in Turkey, and if we can trust photographic evidence, in Yemen, Morocco, Tibet and other places.

15. J.R.Richter writing on Ghana, in Yazd II. With respect to the Sudanese type Richter says "crenellated buttresses", "tapering pinnacles projecting above the parapet".

16. Vertical wind catchers

17. Often we have a tendency to call this sculpture. It may be more suitable to express oneself as in this sentence, if the main tradition of sculpting is thought to be carving. The process here is different, at times even opposite.

Zaria and other Hausa settlements finer arabesques cover the whole of wall surfaces. Hausa decoration was once applied in the interior of houses, only in more recent times has it been used on the exterior[18].

18. Encyclopedia Britannica, 1:260 (1974). Frank Willett on Visual Arts, in article "Arts of African Peoples".

In Dogon shrines symbolic forms may project as horizontal, vertical or grid ribs, this also recalling Tunisia. In northern Ghana, in the Grunshi compounds form-giving may transcend the structure either for figurative representations or for the contiguity of unadorned space shapes.

Highlight India

India's long history in adobe is even less well-known. In the settlement of the floodplains of the Indus river, more familiar to us through Mohenjo-Daro and Harappa, northern expansion led to the founding of Kalibangan around the middle of the third millenium. In this site most of the domestic arhitecture was in mud brick (the site is some three hundred kilometers west-north-west of Delhi). There were differences between this settlement and the others in the proportions of fired brick versus sun-dried brick used in construction[19].

19. I am not informed on the temporal comparison of the earliest fired brick in Mesopotamia and in the Indus plains, and neither on any diffusion from one to the other.

Lothal, in present-day Gujarat and on a one-time estuary near the head of the Gulf of Cambay, had its houses on "massive platforms of mud bricks and mud"[20], under difficult conditions, -such as four flood destructions in its 850 years of continuity, sea salt, and as observed at the present summer gales and 70 to 100 cm of rain per year.

20. R.Sengupta in Yazd II

Thousands of years later, some of the larger scale earthen housing projects in the world were undertaken in East Punjab, not very far from Kalibangan.

Again today, a few hundred kilometers east from here and five hundred north of Delhi, Leh the capital of Ladakh has a preponderance of earthen buildings, it would seem. Once more we are in an arid zone, this land very high in the western Himalayas receiving minimal precipitation. The *gompa* (monastery) settlements on steep hillsides would seem to have either adobe structures or adobe coatings[21]. There are defensive earthen walls in highland Tibet (in Gyantse for example). In these regions adobe and stone seem to be used alternatively or in conjunction. This in turn suggests that earth is not used solelyin the absence of other building materials. The huge Potala in Lhasa would have its topmost five stories built in unbaked earthen material[22]. In the rainier areas of the eastern Himalayas photographic evidence suggests thick mud walls with thatched roofs.

21. As usual sources are not explicit about adobe.

22. Unattested sources in my 1952 work on this subject.

In 1567 Akbar in his struggles with the leading Rajput house, attacked the reputedly impregnable fortress at Chitor with a snakelike device, intricate to describe or visualise, which was called "sabat" and wide enough for ten horsemen abreast, it is said, -"with side walls of rubble and mud which could resist cannon balls"[23]. This is one of the highest commendations we know of the strength of earthen construction.

23. B.GASCOIGNE, *The Great Moghuls*, New York: Harper and Row, 1971, p.91.

More Extent and Variety

There are two regions where tall buildings (six to nine stories) are erected with large scale reliance on adobe. One is again in Africa, in Morocco, where tall towers appear to rely on adobe bricks and adobe coating. Precision on this point and on the possible use of stones is, as usual for adobe, lacking[24] Towns such as Ouarzazate, or Ait Hadidou settlements, are in the Atlas Mountains where nomadic and settled lifestyles intermingle, with higher altitudes and southern exposures receiving little rain. In the second region (Yemen) adobe more often serves together with stone and as material for binding, coating, flooring and roofing.

24. An extensive study of Moroccan adobe is not published.

Egyptian rural structures are often built of mud bricks, houses being in continuous rows in the Delta. In the Valley itself it seemed that mud was more often used in the case of houses within gardens, and among them were some which resembled in shape the pylons of the large temples. The traditional architecture of Kharga oasis (al Wahat al Khārija) includes overall shapes which are similar to some in northeastern Central Anatolian plateau, but also has "sculptural" tendencies comparable to certain parts in the Sudanese savannah and to the village of Balaban in Cappadocia. In other words, as examples show, the diffusion of construction methods is likely to be insignificant in the case of adobe: while there are major differences between neighbouring districts, there are similarities across continents.

In celebrated but nearly abandoned Harran (Turkey, near the Syrian border) half-baked bricks co-exist with adobe used as binder, as partial coating and as floor.

Remains from the Past

The use of sun-dried brick is traced back to the 6th millenium BC in Iran[25] and in Mesopotamia[26] Information available at the present suggests that there has been no unidirectional development in earthen construction and that techniques and methods may succeed each other at different periods in a given region. There seems to be no point in an analysis or explanation in terms of historical sequence.

The Icomos Statement of 1972 sets the adobe problem in two categories[27]: on the one hand there are the countries where stone is not plentiful (Hungary, Ghana, Rumania, Chile are cited[28]), on the other the archaeological sites. In Central Asiatic sites, for instance, coursed brick alternates with layers of mud. It is tempting to speculate that this method of construction should exist in a much greater number of cases than documented. This is especially important since the "sculptural" tendencies found in many parts of the world and the sloping walls (Nile Valley, Tibet) may point to mud layers rather than to mud bricks[29]. This question is very much neglected. The Icomos Statement makes clear that even within Mesopotamia there is great variation in the composition of

25. P.Varjavand in Yazd II

26. Encyclopedia Britannica, 3:162 (1974). On the Anatolian plateau the "neolithic" villages of Hacilar and Çatalhöyük contained mainly mudbrick houses. The earliest dates assigned to these villages vary from 6700 to 7000 B.C., these being considerably older than the quoted dates on Iran and Mesopotamia. If dates for settled life will be extended further back in the Nile Valley and Southeast Asia, in the case of Nile Valley the dates for adobe may be equally extended back.

27. Prepared for Yazd I

28. In Hungary windmills going to several stories

29. The sloping walls in Irak are to be associated with the sizes of buildings. In the Urartu masonry of Toprakkale sloping walls are thought to be a measure against earthquakes.

bricks and the technique adopted for laying them. It is comforting to see that the field of restoration has learned to emphasize this but contemporary laboratory and engineering concern tends towards standardisation of analysis. Since standardisation does not exist in the chemistry and physics of the soils, the mechanical conclusions do not agree on detail and on the crucial matters. It is possible that useful knowledge may be obtained not from the repetition of existing laboratory methods, but from those addressed to the historical examples, some of which we are listing at this point.

The Ziggurat at Aqarquf (Dur-Kurigalzu, the capital of the Kassites founded in the 15th or 14th Century BC) attains 46 m of height on one of its sides, and the height of its base is 14 m, the citadel being founded on a layer of gypsum "spread first with sand and soil". Each side has seven recesses and six buttresses over a distance slightly more than 72 m. Every six or seven "rows" of clay bricks are followed by continuous reed mats. The large structure has "weeping holes" for internal horizontal drainage. The citadel was originally plastered with clay[30].

Another author also maintains, that in Iran for instance unbaked brick has never been left exposed, but his statement seems to be limited to the brick[31], thus not excluding adobe plaster. In the Achaemenid period adobe was used as filler between two slabs of stone, and therefore never in reach of climatic elements. In the Sassanid period the earthen fortresses and city walls were covered with Kah-Ghel[32] (straw-earth) or plaster with lime. There are thick mud walls of the Period IV city at Hasanlu in southern Azerbaijan. These walls were burnt during an attack around 800 BC. "As a result the walls frequently offer a hard baked surface - and a plain mud-plaster coat appears to offer sufficient extra protection"[33]. The author picks up the suggestion derivable from this and thinks that safe and economic ways should be found for firing the exposed walls of mud-brick buildings for preservation. There seems to have been no response to this idea during the several years which have elapsed since then. Serious restoration is naturally concerned with original colour and original texture as well. It is perhaps our contemporary builders who should take up the suggestion.

In Turkish archaelogical excavations mud-brick is encountered in strata from the Neolithic to "the 6th Century".[34] These layers first suggest that there has been little or no change in the material to our days. In the way adobe is prepared in holes dug in the ground combustion ash, cullets and potsherds[35], and debris of all provenance would "by themselves" get mixed in with the dough. Cullets(?) and potsherds from "l'Age de Bronze Ancien" were found in the mud bricks of the Phrygian levels. It is thought that these admixtures provide extra 'solidity' and adhesion for the mud brick.

Brick length, width and thickness varies enormously within a particular site, from level to level, and from one district to another. The size may also be affected by regional construction practices, and by the use of wood or stone in the building. There is no information on clay content versus sand, which has come to be the central issue in our time.

30. A.al Jumaili in Yazd II.

G.Torraca, in a résumé and analysis for the meeting, maintains that the Ziggurat was never plastered but covered with baked bricks, and speaks of a 4 m thick lining all around the structure.

Equally, he speaks of palm leaves rather than reed mats, and recommends the leaves for their "tying" action, and for good distribution of "charges".

31. R.Kassai in Yazd I

32. This word is variously transliterated by Iranian authors.

33. D.Stronach in Yazd I. The same effect is also found in Troy. We feel that this method of firing would have little effect on architectural decisions at the time of building, not only in the case of restoration (if this is at all to be approved), but also in the continuation of present day vernacular. On the other hand fired single brick and unbaked brick result in architectural traditions quite alien to each other. For people who are convinced that adobe in comparison to fired brick is only a poor man's choice in *all* climates let us make clear that the availability and cost of either have not even been precisely compared for the past, nor for the present.

34. R.Temizer in Yazd II. In anticipation of the discussions of earthquakes and of the use of wood in adobe, and conjointly with respect to the references to half-timber, let us call attention to S.LLOYD, *Early Highland Peoples of Anatolia*, London: Thames and Hudson, 1967. Parallel between Troy II g and Jacobean London with respect to half-timber (p.36), half-timber in monumental gateways in Malatya (p.102), timber reinforcement of mud-brick in areas possibly subject to earthquakes at the time of neo-Hittite srates, and lack of same in presumably earthquake-free areas (pp.99-100).

35. "tessons" in the french text. I am not certain that cullets are intended by the author. Let us add that earliest glass is traced to the middle of the 3rd millenium. This matter may be important as regards adobe adhesion to glass.

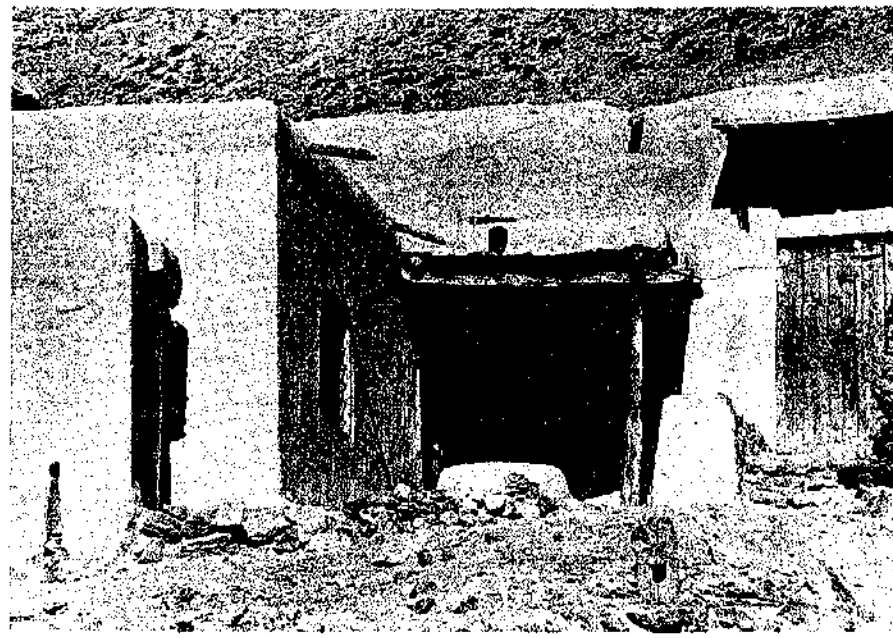

Fig.3. Yukarı Ulupınar, Turkey.

On the other hand there may be little difference in size between the bricks of the Neolithic and for example those of Troy, Boğazköy and so on. The author adds that brick size is affected by the dimensions of the hand (and foot) rather than by the fixed standards which may be imposed by builders on considerations of construction.

Stone walls are found to be better preserved as compared to adobe walls, -we should add, when stone walls are not used as quarries in later ages. In many sites stone appears in the foundations under adobe walls during the Late Neolithic. However the foundations may be without stone in later ages, as in Beycesultan (Late Chalcolithic) for instance.

In certain other sites wood is laid horizontally on the stone foundation, and is coated together with the surmounting mud brick wall. There were wooden columns as well, placed vertically in the wall at given intervals, these being sometimes replaced by stone at corners.

The structural qualities of such practices may have been tested over the centuries, but in adobe the consequent knowledge does not seem to have been transmitted. At the present, we would think, the advantage and disadvantages are not ascertained either unless we put full faith into semi-empirical building by-laws and official posters intended for rural areas, such as in South America and Turkey.

It is clear that the use of wooden beams and columns in the above instance is tied to purposes and principles different from those in wattle-and-daub.

On the other hand the above instances constitute another reminder that adobe construction cannot be studied only in terms of mud. In new construction there are chemical agents to be mixed with the mud, but also other building materials to

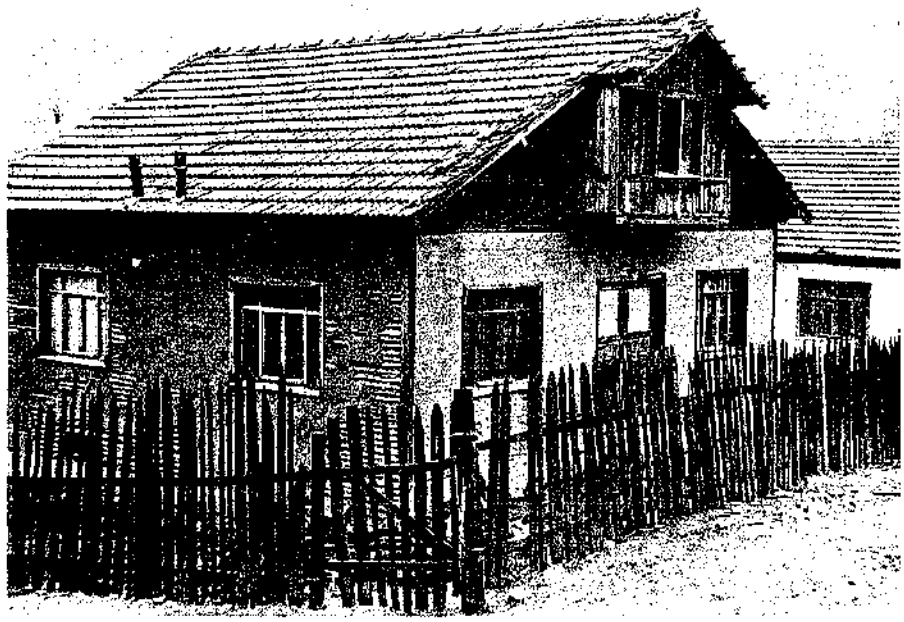

Fig.4. Akyokuş kavağı, Mudurnu valley, Turkey. Adobe used as protective surfacing material. (In the reconstruction of this village after the 1967 earthquake, the method of aided self-help allowed certain variations between buildings. The filler material in the walls is stone for some buildings, adobe for others.)

be used in conjunction. In restoration and "urban design" we must appreciate much more, not only the structural differences between adobe and adobe-and-stone and adobe-with-wood, but that textural continuity in townscape, divisions of space, perceptive appreciation of the neighbourhood and affective response differ from a town all in adobe to adobe as filler and coating within wood frames.

The Ziggurat of Ur is thought to be built of sun-dried brick (4th millenium BC). The steps were replaced by burnt brick circa 1500 BC. The largest known ziggurat was built in Iran at Dur Untashi (Choga Zambil) in the 13th Century BC. The adobe in this ziggurat has become a matter of economics in conservation[36].

36. P.Varjavand in Yazd II

Earthen buildings in Ghazne (Afghanistan) have also been included in a conservation program, such as the Palace of Masud III and the Buddhist Temple area, Tappeh Sardar,[37] -the city of Ghazne being the home of Ghaznavid art which influenced the stone architecture of Seljukids and that of the "Mughals" in India. The only goal in these cases is the consolidation of remaining structures, the conservationists being sensitive about keeping intact the legibility of past sequences and about wall connections and building phases.

37. D.Faccena in Yazd I

This is only one example to the variety and nuance of purposes in the application of conservation principles to individual buildings. The different approaches may not at times be mainly concerned with the soil, but at other times will have to focus on the composition of the soil and on the chemical treatment of it.

The "troncopyramidal" *huacas* in the Andean zone, the palace at Sayri Tupác, ancient structures in Cúzco, and the "intact" remains at Trujillo[38], and thousands of kilometers to the north, the grid-forming remains at Casas Grandes (Chihuahua)[39] are representatives of the extensive tradition of adobe in the Americas.

38. C.Obregoso in Yazd II. We assume that the author speaks of adobe at all points. There is reference to walls 50 m high.

39. Probably founded circa 1050 AD, burned around 1340. I have no information on the age of the walls.

In Africa, in Egypt and to a lesser extent in Turkey dovecotes of adobe structure provide the richest variety of building forms. Hannibal crossing from Africa to Europe, built earthen (rammed ?) watch towers in Spain, which were still in use two hundred and fifty years after his time. The Governor's Palace, built in 1609, is in use as a state museum in Santa Fe, New Mexico.

Europe and Climate

In mid-twentieth century there were some one hundred earthen (rammed ?) houses in Denmark. One of these in Odense was believed to be between three and four hundred years old. On the Normandy peninsula earth (rammed ?) walls were erected in Neolithic times (certain sources designate European examples as "rammed": this may be not a specific designation).

The use of earth in building diffuses from the arid belt to the humid in Ghana. There is change in its use in the transition from arid central Africa to the lakes area of the Great Rift Valley, while further south the Zulu kraals are laid out in the same spirit as earthen compounds to the north. Intrusions to the humid belts are likely to be found in contiguity with the arid zone. In Europe however, if we exclude the "tens of thousands"[40] of wattle-and-daub buildings in the United Kingdom and the similar elsewhere earthen building does not seem to have been prevalent over the last thousand years and more. If it is true that Europe progressively abandoned earthen building, the change is more attributable to climatic trends than to technological or social bases.

40. J.Warren in Yazd II

The Celtic castle in Heuneburg (Würtemberg) may be attributed to the late Hallstatt period[41]. A mud-brick wall extends more than 250 meters. "Towers project from the wall to a distance of 9 meters", the wall being 3 m thick. The bricks are covered with thin plaster, which seems to have been renewed each year. ".. the climate was already very damp by this time".

This wall is said to be the only one in existence north of the Alps. In the following period quite different techniques were used and mud-brick was abandoned north of this line for several centuries. Then, Romans preferred to use mud-bricks for buildings of minor importance in the German provinces. In the Middle Ages and after, "we have nothing of this kind in our architecture. The reason why is, however, another story".[41]

41. W.Bornheim-Schilling in Yazd I

CONTEMPORARY RENEWAL OF INTEREST IN RAMMED EARTH

In the first half of twentieth century there has been an involvement with earthen construction in countries where the climate is predominantly damp (except in peripheries), either the industry being advanced or family income being rather high, -some of these countries were the Soviet Union, Australia, the United Kingdom, the United States, and presumably Germany. This situation suggests at first that countries less dependent on earthen construction were undertaking research with respect

to it, and that more dependent countries were not. The larger of these countries, however, have arid zones which also happen to be on the economic periphery. Furthermore, studies were concerned with extensions to wet zones.

In our knowledge the greatest effort was in the United States. It appears that a housing shortage coupled with higher buildings costs after 1918 prompted some of these efforts. In the following Depression decade there was an intensification, and a concern with rural areas. In the war years after that there were shortages of building materials and skilled labour. Despite several programs and projects, housing implementation and laboratory research were inconclusive, but by this time the cumulated knowledge was nearly impressive.

If we should trust hearsay information at the time, when the newly set Israeli state moved into settlements abandoned by Palestinian Arabs, it found adobe buildings and adopted them. The newcomers were surprised when two years later these "buildings crashed on the heads of occupants"[42]. The buildings were supposed to be whitewashed annually and the newcomers did not know. One reliable information is, however, that there was a United Nations Technical Assistance program for earthen construction in Israel, initiated in 1951-1952. Rammed earth was in vogue, and thus became the main constituent. This program was also abortive, but a short review of the proposed state of the art at the time will put into relief many aspects of earthen construction.

42. I relay this type of information only because it is suggestive with respect to the tradition of adobe.

In the method of rammed earth the sand content was higher and the clay content lower, this decreasing the susceptibility of a wall to rain and to water in general. The clay colloid particles are much smaller than sand particles, thus their much greater total surface within the soil compounds results in an equally great capacity to adsorb water. Losses of water and dessication produce smaller or larger cracks. These cracks play a role in the re-absorption of water, and have detrimental effects on the structural qualities of a wall. In the sandier soils, preferred in rammed earth, water content in the moulding and tamping stage is lower, furthermore dessication does not produce detrimental cracks. This is, in non-technical terms, the gist of the problem of earthen construction.

Rammed earth construction, however, introduces several elements extrinsic to the tradition of adobe. First, the shuttering used in ramming precludes both the size and the plastic moulding of various types of buildings in several continents. Adobe has been the material of traditional vernaculars, therefore rammed earth will bring just as many unfamiliar elements to many regions as non-earth materials may. The shuttering immediately leads to two proposals or speculations which may be designated as half-way industrial: large-scale housing construction would reduce the cost of shuttering through repetitive use, and, tamping being the heavier task, compressors may be introduced. This last item would equally point to large scale construction.

At times therefore, rammed earth appears not an improvement over traditional earth construction methods, but a distant second choice to concrete, and perhaps to other materials. Stabilisation of adobe, though not yet as promising, should be the main goal for research.

Rammed earth, sandier up to certain limits, therefore offers compressive strength and stability in itself, and appears more suitable for further stabilisation with chemicals used until the present. Otherwise agreement over the best soil mix and the best stabilisers is not to be found in the literature of the last six decades, and the terminology used is not comparable within itself.

The Agricultural Experiment Station of the South Dakota State College initiated several of the inquiries. The specific gravity and the density of soil increases with higher sand content. This conclusion we assume is obtained with good and consistent ramming. Density studies do not seem to have attracted sufficient attention after the 1940's when the above finding was reported. A more important aspect, perhaps, of density is that the failure of adobe with respect to water or earthquake in many rural areas may be simply due to entirely insufficient compaction, therefore density.

On the other hand, what are called "heavier" soils with higher clay content[43] showed greater strength than sandier soils[44]. The lighter soils increased more in strength than the heavier, but at the end of two years there still was difference between the two.

The heat insulation properties of earthen walls are often commended. Experimenters at South Dakota also found that thick rammed earth construction provided "more favorable insulation values than the more common types of construction". South Dakota found .18 to .22 specific heat for a rammed earth sample. On the other hand thermal conductivity figures from studies in various places do not agree.

In addition to cracking, another crucial property in earth construction is the optimal moisture for various soils at the stage of moulding or ramming. In this respect also, there seems to be only general agreement as between experiments[45]: optimal moisture varies in inverse proportion to the amount of sand. Many experimenters treat sandier soils with moisture down to 4 percent or somewhat less, while others may reach up to 7 or even 10 percent. This is the dry method. In the wet method used with clays moisture content may reach 18 percent or more, while some experimenters hold it to 6 percent. This variation is probably one of the many factors, along with stabilisation or the lack of it, with the great variety of soils, with the varying physical units of measurement, with the set-up of the experiment and others, which preclude agreement between conclusions.

The higher optimal moisture content of clay leads directly back to the question of cracking: as long as the moisture was sufficient to bond the particles, shrinkage and therefore cracking varied directly with the amount of moisture at the time of moulding (or ramming).

In what we have termed adobe the clay content may vary from 50 percent to 80. Among the many materials which may be added to clayey soils straw and bitumen have attracted most attention.

Straw is found in adobe walls throughout the world. It is also used in wattle-and-daub. It has been reported in adobe walls of the Neolithic. There are mainly two properties ascribed to straw: it is a binder, it is said (therefore contributing to

43. Thus seemingly at odds with the above paragraph. The term "heavy" here comes from agronomy and not mechanics, and therefore is not a good example for internal inconsistencies found in the terminology associated with earthen construction.

44. This conclusion seems to be directly contradicted by Alkan (1972), in whose experiment a soil with 66 percent sand content (very close to the ratio recommended for rammed earth) has much greater compressive strength. The experiments of Alkan differ however by including stabilisation factors (in addition to reversibility and immersion in water).

45. Even if quantitative inputs and outputs are not in agreement at all.

stability as well as compressive strength), and presumably through capillarity it is thought to contribute to faster and more even drying in the wet method. Other opinions, however, not in the minority, range from "harmless" to "positively detrimental to compressive strength".

Cement may be used as stabiliser with clayey soils. On the other hand practical considerations on construction site favour the use of bitumen. Bitumen increases compressive strength less than cement does, this being a negligible difference. In one experiment, bituminous emulsion was found to increase the compressive strength of moulded bricks, but to decrease that of pressed bricks[46].

46. Alkan (1972)

More optimistic builders point out that adobe can receive the finishes and coatings used on other materials. The important ones are plasters and "thin skins".

Plastering may very well be from the same material as the monolithic wall or the brick, if climate and other factors permit. In new construction plastering may include more stabilisers than the wall. In restoration work, sensitivity towards the original building may often preclude this. In new construction plasters may receive a final coat of thin painting.

A thin skin may be whitewash, or hopefully in our time, a new chemical. In the latter case thin skins constitute the third crucial area of research, both for new construction and for restoration work. While in new construction stability may be attempted for the entire depth of the wall, often surface protection will solve the problem of stability. In restoration work many prefer thinner protective coatings since the impermeability of thicker coating, while desirable for resistance against external agents, creates a graver problem through the accumulation of water behind the coating in the wall.

In rammed earth,[47] especially with regard to monolithic walls, the salient points are the following. The earth will be laid in courses not more than ten centimeters deep. Otherwise the ramming of the earth will be uneven. The edges should slope so that different horizontal layers in the wall could groove into each other. The same precaution should be taken at corners. Interior partition walls cannot be treated in this manner and create special design difficulties[48].

47. I will not go into the many construction details, which are to be found in the references. There is less necessity for agreement over contruction details than on the constitution and chemical treatment of the soils. Foundations and footings may prove more important than other details.

48. In Iğdır (eastern Turkey) a massive monolithic adobe wall, not properly indented into a second perpendicular wall, in oscillation during the 1963 earthquake crashed along its length into the second wall, causing total failure of the building.

The literature on rammed earth ranges in advice from no coating to overprotection. It is said that rammed earth being highly stable, there would be no need for finishing or plastering in the manner of adobe, especially in dry climates. On the other hand eaves are proposed to protect the exterior wall surfaces from rain, and also are a number of coatings which may even be spread on wire mesh and nailed to the earth wall. The latter overprotective approach is explicitly or implicitly intended for damp climates.

While clay serves as binder, in the stabilisation of rammed earth it is not the soil with less clay, but one with more clay and less sand which requires the larger proportion of cement.

In short, clay is the binder but also the "cracker" in the soil. Therefore contemporary study and practice have pointed toward higher sand content, 30 percent clay to 70 percent sand representing empirical wisdom. But this is not the adobe of regions where earthen buildings predominate. It seems equally that the more stable material has not been used extensively in recent construction.

CAUSES OF FAILURE IN EARTHEN BUILDINGS

The causes of failure may be grouped under several headings. In the case of structural or mechanical causes there may be readier agreement on the remedies, while there is great variety in opinions, findings and compounds as regards the chemical interaction of mud, water and polymers.

On the other hand structural studies of adobe in spite of apparent consensus, are not advanced enough to result in clear cut remedies. Advancement may come compellingly from the side of earthquake engineering since it is estimated that a majority of the losses of life during earthquakes are caused by the failure of adobe. The response to this situation until the present has been in the direction of the abandonment of earthen construction. At this writting, it seems that more and more people are acknowledging the difficulty of changing the building material in rural areas. There are a few signs that there will be more research on the structural properties of adobe.

At the same time, it is difficult to assign the strength and consistency of a wall separately to chemical bond and to behaviour under compression. In consequence, there are conflicting evaluations. On the one hand, the study of the mechanical properties of a brick, such as compressive and flexural strength, are found to be "as important or more important" than an investigation into the details of its composition[49]. That a mud brick is "far more delicate" than the structure of which it is a part[50] may be considered a thought parallel to the above, but for us another orientation (not elaborated in the source).

49. G.Torraca in Yazd II

50. G.Gullini in Yazd II

In restoration work the new protective chemicals are found to be of doubtful value[51], while they may also change the nature, texture, consistency and even colour of the adobe, in contrast to the principal tenets of conservation. The same author prefers still to count on the future promise of new chemicals, as we do here. It is reported that coating and impregnation of a wall do "not serve the purpose"[52] of conservation. "Other means" are then sought, but the proposed "optimal solution" consisting of a mixture of mud, cement and sand is, in our opinion, still within a chemical context. At this point it should be made clear that the present inconclusiveness of chemical research is not to be attributed to the absence of universal solutions, but to the lack of satisfaction in the case studies. At any rate, attempts to find a single chemical or "step-process" has often proved disastrous[53].

51. P.Varjavand in Yazd II

52. R.Sengupta in Yazd II

53. G.S.Cattanach in Yazd II

The chemical causes of failure should be viewed in the above context: that there are not satisfactory results yet, but that chemical research will be pursued, and perhaps will be in the vanguard.

The action of water soluble sulphates contributes both to the internal breakdown of the mud-brick and to the erosion in walls caused by rain water[54]. Soluble salts cause deterioration in Lothal and Iran[55]. Capillary rise from the ground[55] may initiate some of the chemical actions. As a result of physico-chemical "aging" adobe may become pulverulent[56]. In a mechanism compared to the partial dissolution of calcite -migration-deposition and recrystallisation in stone, certain clay minerals contribute to decay in adobe[57].

54. R.Munnikendam in Yazd I

55. G.Torraca in Yazd II

56. M.Siroux in Yazd I

The same author recommends against the use of adobe from local ruins for purposes of repair. He considers it "terra morte".

57. S.Z.Lewin and A.E.Charola in Yazd II

The chemical interventions in adobe do not seem to be intended as specific counter-measures to the chemical causes of failure mentioned above, but addressed to the overall stability of the wall. The reason is likely that chemical failure is neither the single causes nor entirely separable from other processes, but there is no elucidation in the literature on this point.

Structural failures may result from posterior additions to the particular building, from other transformations and from clumsy juxtaposition of constructional units, -the penetration of water from openings, joints and cracks being another cause[58].

58. M.Siroux in Yazd I

Foundations may be made from the same adobe used in the building, at shallow depth (India, Iran, Ghana and many other places)[59]. In the history of Western Asia the large adobe structures were placed on platforms, which later gave way to the practice of direct wall foundations[60]. Foundations may be important causes for structural failure as regards capillary rise and earthquakes. This is the principal reason why a system of drainage ditches encircling the urban districts is proposed as the major protection measure for the towns of Iran[61]. There are stone foundations in the history of adobe, but this subject is especially treated by the rammed earth literature of the 1930's and 1940's, stone foundations being strongly recommended to project ten to thirty or even sixty cm above ground according to climate.

59. G.Torraca in Yazd II

60. G.Gullini in Yazd II

61. R.Kassai in Yazd I

Brick disposition in the wall is an important element in wall strength[62], and untested or undeveloped dispositions may cause structural failure.

62. G.Torraca in Yazd II

There are specific "weak points" in the structures[63]: parts of the structure next to or near the foundations, parts situated on slopes, the exterior surfaces, interstices and corners.

63. Y.Daneshdoust in Yazd I

In wattle and daub the movement of mud filling within the wooden frame may lead to structural deterioration, but most structural problems in this type of construction may be traced to wood itself[64].

64. J.Warren in Yazd II

Among the mechanical agents affecting either the surface of the structure or the structure itself we may list the wind, which is an important agent of deterioration in Western Asia and Peru, and snow, the weight of which is a potential cause of failure when coupled with an earthquake and a mud-on-wooden-beams roof already overburdened with extra layers of thatching and soil.

Internal condensation of water may lead to structural failure through swelling and shrinkage cycles, since even in the arid zone we may find daily fluctuations of more than sixty percent in relative humidity[65]. Surface condensation on "north" -facing walls in early hours of the morning may be worth investigating[66].

65. R.Munnikendam in Yazd I

66. G.Torraca in Yazd II

Microbiological growth on the surfaces of adobe buildings and biological effects in general are reported from the more humid region of Ghana[67].

Considering the above list of causes, one tends to find the major antagonist of adobe, that is to say rain, somewhat innocent by itself. Adobe is found from very arid regions to those with 1000 mm of rain or more. Regions of Europe, the non-adobe continent, with a precipitaition in excess of that figure are only Norway, Yugoslavia, the Alps (much of it in the form of snow) and the borders of the Irish Sea. There may also be unreported earthen walls in rainier climates such as those of central Africa and eastern Himalayas.

67. J.R.Richter in Yazd II

EARTHQUAKE FAILURE

There are many comments, but few studies, on the performance of adobe in earthquakes. Some of these comments have already been listed in the appropriate sections.

Indeed, many adobe towns have been leveled, but we may consider adobe more resistant than burnt brick in this respect because, its mortar being of the same material it has more homogeneity[68]. The problem of flat heavy roofs, mentioned a few times before, should be considered as incidental and not intrinsic to adobe.

The adobe dome is especially encountered in Iran. Domes on urban bazaars, as it would appear are almost always built over stone masonry, while in rural areas they are entirely of adobe. In Nimbluk valley, easternmost Iran, adobe failure was investigated in terms of distances from earthquake fault and of proximity to lurch fractures[69]. Nearly all roofs were either domes or barrel vaults, exhibiting much destruction in correlation with distances and especially with the nature of surface soils.

In the sub-region timber is scarce. Kiln brick construction was introduced after the earthquake: we have quoted above the opinion of an architect from Iran on mud brick as compared with burnt brick. Under the circumstances, fired brick and other materials still have to justify themselves in future earthquakes, and an advanced engineering study of adobe domes and vaults remains to be initiated and completed[70].

In the most recent earthquake in eastern Turkey (Van and Muradiye and Çaldıran) an adobe village on the fault line was not harmed, and concrete structures much farther away failed. The physical and social factors in these failures are not well known around the world.

68. R.Kassai in Yazd I

69. J.S.TCHALENKO and N.N.AMBRASEYS, Earthquake Destruction of Adobe Villages in Iran, *Annali di Geofisica* XXVI, *2-3*, 1973, pp.357-389.

On the other hand the failure of mud and wattle huts in the Uganda earthquake of 1966 is assigned to the following weaknesses: walls are improperly tied at the corners, there are no bracing elements, plant bindings become brittle with age, the inner walls are not tied to the roof, there are too many doors in the walls, the vertical poles are weakened by termites. From the UNESCO Earthquake Reconnaissance Mission Report on Uganda, July 1966, by I.S.Loupekine.

70. In Z.B.GREGORIAN, Shell Membrane Theory Applied to Masonry Domes, *Art and Architecture, Iran, 15-16*, pp.164 to 155 in reverse order, attention is called to the perpetual goal of reaching pure compression forces without bending. In domes the "hoop force" is compressive from the top of the dome down to a particular plane. From that plane to the base of the dome it becomes tensile. In order to prevent cracks in domes either a tension or a compression ring is required around the periphery at the base of the dome, depending on the angle at which the dome meets the substructure. The symmetry of domes aliminates shear forces.

In Cain, Afshar and Norton (1975) the *inverted catenary* curve in section of the adobe vaults in Western Asia, especially Iran, is pointed out for not creating either bending or tension stresses.

TREATMENT OF ADOBE IN RESTORATION

If we leave strictly structural considerations aside, we are faced with various manipulations of adobe in place and the fresh soil which may be added to it. We may then be concerned with repair or maintenance with the soil to be added, with engineering or secondary structural measures such as drainage or capping, or with the treatment of adobe in place with synthetic polymers.

The investigations concerned with rammed earth, or with stabilisation in general had focused on additives such as cement, bitumen, lime, straw and so forth. In our knowledge experimentation with synthetic polymers is scant with respect to new construction and more aboundant for the purposes of restoration and conservation.

Repair with the same material as the adobe in place is understandably favoured by restoration workers, especially in western Asia: in this way the original qualities of the building will be conserved or restored[71]. In Ghana however, this is found uneconomic[72]. Economic considerations aside, in what appears to be a dominant inclination among the more sensitive restoration workers, we may use parent soil in "sacrificial protection"[73]: if historical buildings are protected with strong impermeable coatings, these being not only the polymers already mentioned but cement plaster and others as well, there may be "total erosion" of the original structure behind the coating so that we may prefer to protect with soil softer than the adobe in place. The softer material will weather away easily but keep the structure intact until renewal with the same softer earth.

Annual maintenance, structural repairs and drainage within and around buildings are perhaps the most important measures, and will be eleborated according to local conditions. Among the additives used or proposed in new construction there is locust bean pod juice in Ghana[74], and fibres of aquatic plants (Lorix) and Anzarut resin in Iran[75]. Various concentrations of lime, alone or in mixture, have been used in many continents either as coating or as stabiliser internally.

In restoration work impregnation with synthetic polymers has not been satisfactory yet, and impregnation with materials like lime are naturally out of question. In such work attention always comes back to surface treatment. In this respect lime is found acceptable in the interior of a building, but undesirable in the exterior because it is water-insoluble, once again leading to the oft-mentioned trouble of water accumulation and seepage within the wall.[76]

Synthetic polymers have been used on surfaces in preference to the treatment of the depth of wall. Dilute solutions of hard and soft methacrylic polymers have shown significant penetration and waterproofing at Hasanlu Tepe[77]. It is thought that acrylic emulsions strengthen the brick and surfacing against weathering due to precipitation and cyclical freezing. On the same site experiments are conducted with toluene polymer solutions, emulsion-based mud plaster and sun-dried brick.

Ethyl silicate base is found useful on vertical surfaces only[78]. PVA emulsions are found to ameliorate stress distribution when used in penetration, but undesirable as coating[79]. A variety of epoxy resins and diluents have been studied[80]. Delcroix divides chemical treatments into external, structural and textural[81].

THE PLACE OF CHEMISTRY AND PHYSICS IN THE STUDY OF ADOBE

In the literature concerning synthetic polymers for the treatment of adobe explicit statements to the effect that inquiry should be centred on the properties of the basic

71. We have already mentioned the caution against reworking the adobe found in ruins.

72. J.R.Richter in Yazd II

73. G.Torraca in Yazd II

74. J.R.Richter in Yazd II

75. Y.Daneshdoust in Yazd I

77. V.Pigott and D.Butterbaugh in Yazd II

78. G.Torraca in Yazd II

79. J.Warren in Yazd II

80. R.Munnikendam in Yazd I
In this article there is a long list of chemicals.

81. G.Delcroix in Yazd II.
The external treatments must be adapted to circumstances. In structural treatments rigid or semi-rigid polyurethane foams may be used, or cement-based foams, or lost elements may be replaced by clay-cement grouting. In textural treatments: the softening point of mud varies in proportion with the fixation of penetrating water by hygroscopic salts. Products which alter the behaviour of clay by fixation on the silicate matrix do not cause swelling or softening even at saturation point.

material, that is to say clay and colloids, are hard to come by. Such properties of clay minerals, in their capacity of fillers and colloids, have been more extensively studied for the paper, paint, rubber and oil industries. In comparison to purer states of clay, clay in loam and in adobe appears to be much more complicated for study. As a result, the polymer experiments do not include separate references to the size of soil particles, be it sand or clay, or the more unstable middle-size particles (silt).

Clay minerals have been studied by X-Ray diffraction in the last few decades, for industrial purposes. Infrared spectral data are also available. Such concerns have been late to appear in adobe study. Lewin and Charola inform us that X-Ray diffraction as well as petrographic identification have now come to adobe study, and that much may be expected from Scanning Electron Microscopy.

Delcroix, "owing to the important role of the clay phasis" examines adobe in terms of "cohesive soil mechanics" (*physical*: granulometry, range of liquidity, plasticity and shrinkage, apparent specific density, porosity; *mechanical*: direct and indirect measurement of cohesion, and of internal friction angles; *chemical*: calcareous content)[82].

82. The experiments are performed at the Soletanche Laboratory at Montereau in France, under the direction of J.Granier.

It would seem to us that laboratory work *of this kind would not necessarily* result in making soil treatment out of bounds for low-cost housing.

It may also be helpful to note that the literature on adobe construction and conservation does not treat the following matters:

That clay minerals contain water in several ways (in pores, in adsorption, in hydroxyls).

That adsorbed water has a structure different from liquid water.

That the rate of loss of hydroxyls may *be sudden or gradual according* to the kind of clay.

That different clay minerals develop in humid or desertic areas, with the clays of arid regions tending toward imperviousness, greater water holding capacity, and higher silica content.

That while mixed layers of various clays tend to be as stable as the layers from a single type, this may not hold true for a variety of mixtures per locality, which situation may actually be at the bottom of disagreements.

THE TISSUE OF SETTLEMENTS

There are mainly two reasons why we should be concerned with adobe. The first is that there will be a large volume of earthen construction in the rural areas of the world. Such construction is also increasingly seen in large cities in the form of squatter settlements.

The second reason is that adobe practice until the present has produced settlement forms and textures particular to itself. These tissues may be analyzed as associated with adobe, but they may also be abstracted from it for certain purposes. Most of the adobe villages and towns are in less polluted districts. These settlements offer more deliberate pace in living and more awareness of the elements. The information on the extent to which these settlements were appreciated by their builders is little, and when it exists it is mostly supplied by outsiders. It may very well be that larger cities have helped to develop more response to townscape and landscape, but this response is so dulled in larger cities at the present that attention turns outward.

Adobe preference may still be a matter of costs in many sub-regions, and this may be weighed not only in terms of inputs but also in that other building materials are items of commerce while earth is not.

The polyvalence of adobe as building material, and its malleability have favoured numerous "crafty" solutions in conception and design, and a variety of roof covers which are often unknown in architecture of 'the stiff'[83]

One is tempted to say that this material which lacks resistance to bending after being incorporated into a structure, nonetheless expresses flexure in its somewhat frozen shape.

83. M.Siroux in Yazd I

We have translated "astuces" by 'crafty solutions'

Fig.5. Yukarı Ulupınar, Turkey.

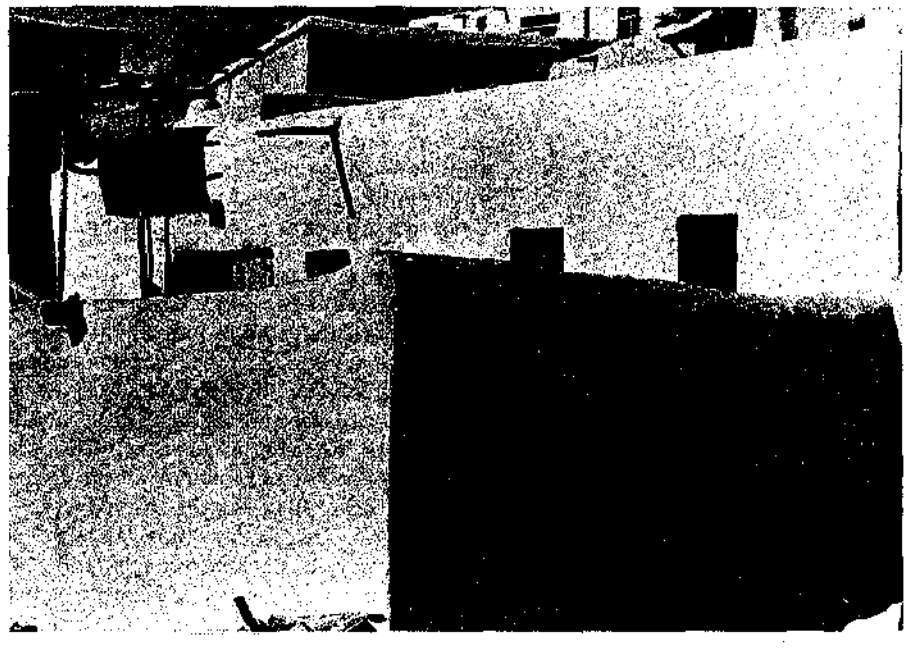

Fig.6. Yukarı Ulupınar, Turkey.

The roundness of adobe structures in Africa has been previously mentioned. Such an ethos is repeated in the smoothed edges of rectangular structures. Furthermore adobe, in its southern journey toward rainier districts in Ghana, changes from sharp buttresses and delineated articulation into irregularly and casually moulded rounder forms[84]. Richter observes, also, that maximum compressive strength in mud buildings is attained when the building is circular in form.

84. J.R.Richter in Yazd II

Wood enters adobe construction much more often than realised, in the form of beams, load-bearing frames, wood work, and even as spokes to stand on in order to help repair and maintenance. We may have neglected structural analyses of adobe when it is

itself load-bearing perhaps because we equated it with stone masonry. In the case where wood constitutes the frame stress distributions would be different. A study of this type has never been undertaken.

It is with these elements that the tissue of an adobe settlement is formed. In this tissue adobe is not a "non-rectangular" principle necessarily. It is rectangular most often, but softly. It does however, nearly possess a "no-coordinates" principle , where space arrangement is defined on the spot and not referred to larger grids. There are no imposed rectangles and no meted-out parcelling. It is possible to tamper with the dictates of larger shapes and to place courtyards and spaces nearly wherever and as you like it.

In this capacity the settlement tissue is at odds with the dominant settlement layout in our time, which is directly derived from both halves of the 19th Century. Town planning in 19th Century was concerned with urban therapy, larger units and advance planning. Larger buildings were not only the result of speculation, density and commerce, but were included in the programs of utopian socialism. The conception of larger buildings was derived equally from Europe as it was a few centuries earlier: radially positioned and thus needing and possessing much space around the building just as a statue would.

Urban therapy programs were pretended to cope with the undesirable dictates of the rent-gradient in the cities. Instead these programs took over the logic of rent-gradient.

In the framework of radially arranged space and the rent-gradient, advance planning degenerated into simplistic geometrical mapping and transformed into waste of space. This formalism actually was a reversion to the ancient principles of planning used in colonial outposts, military camps, some royal preserves, royal incursions into city centres, and in the geometry of mandalas and geomancy.

In the tissue of adobe, it is not possible to see canyon streets. In spite of the material, there is more terrace living, on the roofs. The settlements are open to the sky. There is no wholesale form-giving, and no exact repetition, there is also no conspicuous flouting of similarities. Rather than technology, these may be the reflections of social practices, and provide opportunity to reflect on practices which pass as more advanced. This is the point at which the principles of the tissue may be abstracted from adobe.

In Turkey, we have a tendency to consider vernacular architecture near the centres of cities as under serious threat from renewal or land-rents. Kassai finds that adobe construction in Iran is subject to more "erosion" in the case where the particular building is "isolated" from the urban network, and especially when it is located outside cities.[85]

85. R.Kassai in Yazd I

The immediate deduction is that the singular accomplishments of the past, abandoned at the present, would continue to survive if new functions were found for them and if people actually lived in them. Let us point out however, that the principle proposed in the 1960's (to the effect that a building simply restored is a museum and one with new inhabitants is a living

thing) was an easy formulation and a sentimentalist exaggeration. Since renewal of function often ends up in a restaurant or night-club, such treatment of adobe and other buildings continuing from the past may be an abuse of both the building and the potential gay customers.

This remark applies both to the isolated buildings, and to the more recent interest of R. Kassai in the revitalisation of urban centres[86].

86. in Yazd II

To conclude with scattered recent examples, the Housing Ministry of Greece has issued in 1978 a traveling exhibition on the revival of vernacular, and a publication, which I have difficulty in transcribing, let alone understanding. It seems that *adobe* was used in many instances. This approach owes worldwide much to the work of Hassan Fathy and to the recent conservation emphasis on vernacular. As one who was once concerned with *rammed* earth I appreciate much the more recent emphases.

The poorer man may get into mud (construction) for obvious reasons, and the rich in order to have a sculpted house, but the mid-ground projects do not seem to benefit from either approach[87].

87. P.G. McHenry in Yazd I

The earthquake in Lice (eastern Turkey) took place only a few years ago. "Permanent" shelter was built immediately. It is definitely unsatisfactory. It has been hardly acceptable as temporary shelter. It has now to be replaced. Residents want reinforced concrete frame buildings. Aware that satisfactory results will not be obtained in these housing projects designed and administered from too for away, I ask "what about the local traditional style?". Even the best ashlar masonry has failed badly in the earthquake. And then adobe? "We liked our adobe houses much. They were much more spacious than these new shelters. But we don't want such houses any more. They were too dark inside, and we used to feel a bit dusty in them". If these are the problems of adobe houses, they should be solved easily[88].

88. Adobe has more cheerful associations. The reconstructed Indo-european root *dheigh* means "to knead clay". In the old Avestan language of a region not too far from Lice this root is transformed into *daēza*, meaning wall ("originally made from clay or mud bricks"). This leads to "paradise", by way of Greek. The walled-in garden in the arid landscape of western Asia, especially Iran, is at the origin of the notion of paradise.

From *dheigh*, we also have bread kneader/mistress of household: "lady", and result of kneading/shape: "figure".

The word "adobe" comes from another language family. *Al-tōba*, Attōba: "the brick" in Arabic.

(all information in this note derived from American Heritage Dictionary, 1969).

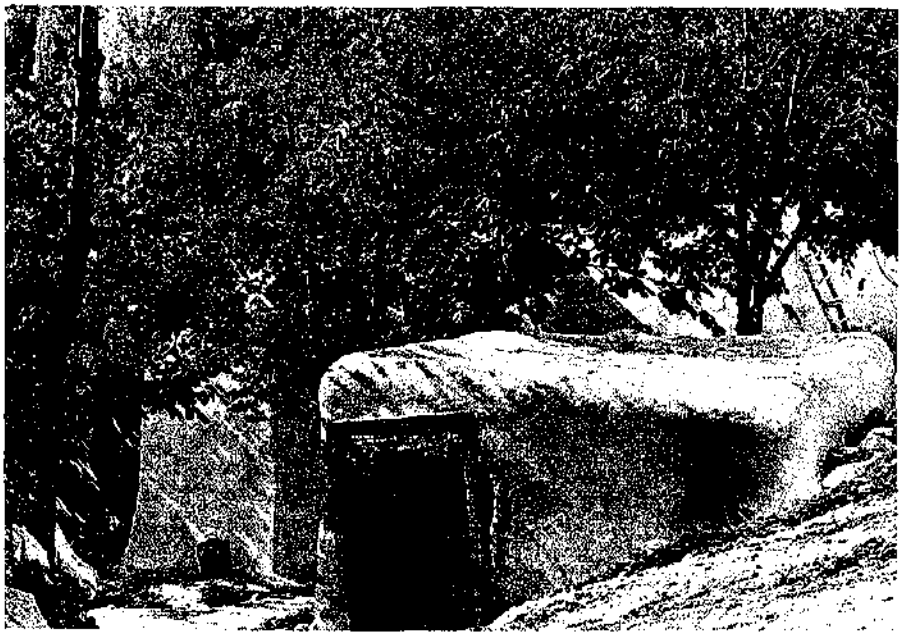

Fig.7. Yukarı Ulupınar, Turkey.

YAPILARDA KERPİÇİN DAYANIKLILIĞI VE YARARLARI

ÖZET

Açıklama

Kerpiç Afrika'da Batı Sudan bölgesinde ve İran yaylalarında egemen yapı türüdür, Irak, Indus ovası, Meksika ve Peru büyük bölgelerinin eski tarihinde büyük yapılarda kullanılmıştır. Eski dönemlerde Kuzey Çin ve Ukrayna'da bile yaygın yapı türü sayılabilir. Bugün birçok ülkede yapı tarzı olarak canlılığını korumaktadır. Hindistan'da çağdaş büyük konut topluluklarında kerpiçin önemli yeri vardır.

Gerek kerpiçin en eski örnekleri gerek günümüzdeki yaygınlığı açısından Anadolu'nun bu ülkeler arasında bile seçkin bir yeri var. Buna karşılık, dilimizde kerpiç konusunu bugünkü yaygın sorunlar ve türler açısından tartabilmek için yeterli terim yok. Türkiye dış ülkelere açılma kararını kesin veren birkaç ülke arasında bulunmasına rağmen en kapalı toplumlardan biri olarak kalmıştır. Gelecekte dilimize kerpiç ile ilgili yeni terimlerin girmesi gerekecektir. "Kerpiç" teriminin kendisini dar veya geniş anlamda mı kullanmak gerekir kestiremiyorum. "Kerpiç" bazı kimselerce toprak malzeme için, belki bir çoğunluk tarafından ise pişmemiş tuğla anlamında kullanılmaktadır. Ayrıca kerpiç çok killi ve diğer ülkelerde "yaş" denilen yöntemle şekillendirilen toprağı anımsatmaktadır. Böylece daha kumlu ve "kuru" yöntemle şekillenen topraklar için geçerli olduğu belli değildir. Bununla beraber ülkemizde bu anlamda da kullanıldı.

Bu özette "kerpiç" terimi geçecek, fakat daha geniş çerçeve gereken yerlerde "toprak" terimi kullanılacaktır.

Toprak yapılar bugün de dünyada çok yaygın. Kır ve köylerdeki yapı türlerinin değiştirilmesi gereği olmadığı artık birçok kimse tarafından anlaşılmakta. Bu durumda topraktan yapıların üstünde çalışmak ve elde bulunanları korumak gerekiyor.

Toprak yapıların ucuzluğu ve dayanıklılığı açıkça belirlenmiş değil, fakat ileri sürülüyor. Belirleme yapıldığında toprak yapıların yalnız başka çıkar yol olmadığı durumlarda değil, daha yaygın koşullarda yararlı olduğu ortaya çıkabilecektir.

Sanayileşmiş ülkelerin bir kesiminde 1930'larla 1950'ler arasında toprak yapılara ilgi gösterildi. Bu dönem içinde çabalar malzemeyi killi kerpiçten uzaklaştırmak, ve kumlu toprakların kalıplar içinde sıkıştırılması yöntemini (pisé veya *rammed earth*) geliştirmek üstünde yoğunlaştı. Son on yıl içinde toprak yapılara duyulan ilgi ise dünyada çeşitli yörelerin yapılarını ve yapı geleneklerini korumak amacına bağlıdır. Bunun sonucu ilgi tekrar killi kerpiçe yönelmiştir.

Kerpiç yapı sorunları su ile kil ilişkileri üstünde odaklanmaktadır. Kerpiç yapıların statik ve dinamik'i üzerinde incelemeler gelişmemiştir. Dünya üstünde deprem zararlarının yarıdan fazlası kerpiç yapılara bağlandığından, önümüzdeki yıllarda bu incelemelerin gelişmesi beklenebilir.

Kerpiç Batı Sudan'da çember duvarlı ve çalı örtülü ufak yapılardan başlayarak büyük bir çeşitliliğe ve zenginliğe ulaşmıştır. Yapılar bugün de çoğunlukla tek katlıdır. Belki Müslümanlıkla beraber dört köşeli yapılar bölgeye girmiş ve

beraberinde toprak kaplı düz damları da getirmiştir. Düz damların daha büyük ağırlığı birçok Afrika ülkesinde dayanak duvarları ve payandalar gerektirmiştir.

Ateş tuğlasının Batı Sudan'a 14nc. yüzyılda girdiğini kabul edersek, bu yapı malzemesi altı yüz yıldır kerpiçin önemini azaltmamıştır. Kerpiç, İran'la beraber Batı Sudan'da, kullanılan yöntemin tersine "yontu" saydığımız yapı düzenlerine ulaşmıştır.

Yemen bölgesi ve Fas'ta kerpiç ile çok yüksek yapılar meydana getirilebilmektedir. Eski dönemlerde Peru'da çok yüksek duvarlar, Irak ve İran'da dolgu büyük yığınlar (ziggurat) yapılmıştır.

Eski dönemlerle ilgili bilgilerin ağırlığı yazıda İran, Irak ve Anadolu'ya verilmiş, günümüzdeki Anadolu'nun çeşitli yöreleri içinde Ulupınar köyleri, Balaban, Harran, Lice, Muradiye, orta yayla ve Mudurnu'ya kısa göndermeler yapılmıştır.

Kerpiç yapılarda çeşitli dayanıksızlıkların giderilmesi bundan sonraki çalışma gündemidir. Dayanıksızlığa yol açan süreç ve unsurlar arasında kükürt tuzu ve diğer tuzlar eriyikleri, suyun temellerden yukarı tırmanması, temellerin yeterli olmaması, kerpiç "tuğla" döşeme yanlışları, toprağın az sıkıştırılmış ve gevşek olması, rüzgâr, kar yığılması ve nemin duvar içi yoğunlaşması vardır. Yapıların dayanıksız bölüm ve yerleri temel ve üstü, dış yüzeyler, köşeler, aralıklar ve eğimli yerlerde bulunan duvarlardır.

Koruma için kullanılan yapay polymer'lerden şimdiye kadar kesin sonuç alınamamıştır.

Duvarlardaki kurumuş ve gevşek kerpiç yaş yöntemle yapıldığında esnek ve yuğurulmuş bir görüntü vermektedir. Geçmişte ortaya çıkan kasaba dokuları bugünkü kentlerin tersine "koordinat"sız, "parselasyon"suz, esnek tasarımlı, havaya açık, tekrarsız, yer kaybı azdır. Bu kasabalar toprak "rant", kümelenmelerine ve beceriksiz "öngörü" planlarına bağımlı olmadan ortaya çıkmıştır.

Bazı gözlem ve sonuçlar:

Bir taraftan kerpiçin iç yapısı, diğer taraftan duvarların statik ve dinamik'ini incelemek gerekir. Bununla beraber bu iki çeşit araştırmayı birbirinden kesin ayırt etmek kolay değildir.

Kerpiç yapı tekniklerinde komşu bölgeler arasında farklar, uzak bölgelerde ise benzerlikler vardır. Bu, kerpiçin tür yayılmaları ile değil yöreler içinde geliştiği izlenimini vermektedir. Ülkeler içinde de kerpiçte tek yönlü bir gelişme gözükmemekte, çeşitli yöntemler zaman içinde birbirinin yerine geçmektedir. Kerpiçin tabakalarla döşenmesi ile tuğla şekline dönüştürülmesi arasındaki ilişkiler ve karşıtlıklar yeterli derecede incelenmemiştir. Arizona, Batı Sudan, İran, Eskişehir ve Kayseri bölgelerindeki kerpiç yapıları kerpiç tuğla geleneği içinde düşünmek zordur. Arizona ve New Mexico'da son dört yüz yılın yapılarında İspanyollarca getirilmiş bir tuğla düzeni eski düzenin yerine geçmiş sayılmaktadır.

Toprak yapıların statik ve dinamik'i taşla beraber tutulmuş, böylece ayrıntılı bir inceleme görmemiştir. Ahşapla beraber kullanılışında çeşitli sistem farkları iyi bilinmekten çok

uzaktır. Bu konuya girildiğinde en ilginç örnekler Anadolu ve İngiltere'den çıkabilir.

Toprağın çeşitleri şimdiye kadar yapıldığından çok daha fazla inceleme gerektirir. Ayrıca, suyun gözeneklerdeki, hydroxyl halindeki ve kil parçacıklarına yapışmış durumdaki davranış farkları ele alınmamaktadır.

Yazd II belgeleri için Ayşıl Tükel Yavuz'a teşekkür ederim.

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G.GULLINI / G.TORRACA: Rapport Général

Note: There is a separate statement by ICOMOS. The two following texts are in persian and not translated into other languages:

A.A.SARFARAZ: the Oldest Mud-brick Monuments in Dāmqān

M.SAIDI: Effects of Earthquakes on Mud-brick Monuments

YAZD II : Second International Symposium on the Conservation of Monuments in Mud-Brick, Yazd (Iran) 1976.

(The following are the papers submitted to the symposium. They are not edited for printing, and some of them are untitled.)

G.S.CATTANACH: Conservation of Adobe in the Southwestern United States

G.CHIARI: Adobe in Peru

G.CHIARI and R.RAVINEZ: Huaca Garagay (Peru)

Y.DANESHDOUST: La Sauvegarde et la Réanimation de la Ville de Tabas

G.DELCROIX: Characterisation and Conservation of Unfired Earth as a Building Material

G.GULLINI: untitled

A.al JUMAILI: Restoration of the Ziggurat of Aqarquf

R.KASSAI: Réanimation des Agglomérations en "Brique Crue"

S.Z.LEWIN and A.E.CHAROLA: Conservation of Archaeological Stone and Unbaked Brick in Iran

C.OBREGOSO: L'Adobe dans la Zone Andine

V.PIGOTT and D. BUTTERBAUGH: Field Tests of Hasanlu Tepe

J.R.RICHTER: Conservation of Buildings in Unburnt Brick (Ghana)

R.SENGUPTA: Preservation of Proto-historic Mud Brick Ruins at Lothal in India

R.TEMİZER: untitled

G.TORRACA: Analysis of some answers to the Second Questionnaire on Mud-Brick Preservation

P.VARJAVAND: Le Revêtement des Monuments en Brique Crue et en Terre: un apport à leur Conservation

J. WARREN: Conservation of Wattle and Daub Structures