付属資料Ⅳ　トルコ農村部の建築の地震時挙動

EARTHQUAKE BEHAVIOR OF RURAL BUILDINGS IN TURKEY

PREPARED BY
PROFESSOR DR. RIFAT YARAR
TECHNICAL UNIVIRSITY OF ISTANBUL
PROFESSOR OF CIVIL ENGINEERING
CHAIRMAN OF TURKISH NATIONAL COMMITTEE FOR EARTHQUAKE ENGINEERING

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INTRODUCTION

Turkey is one of the countries that frequently experience destructive earthquakes and the problem of vulnarability of Buildings and Dwellings in Rural Areas have became a very erucial problem. Losses of human lives specially in rural areas, have always been very high. Therefore, Turkish National Committee For Earthquake Engineering (TUNCEE) had initiated research programs and field investigations, in order to minimize the earthquake risk in Rural areas in Turkey.

The TUNCEE is an organization having a number of memberships including Earthquake Research Department of the Ministry,Universities, research centers, other public organizations and private engineering firms. The TUNCEE Carry out its researche programs under sixteen working groups covering all subjects of Engineering Seismology and Earthquake Engineering Two of these sixteen working groups entitled "W.G. on Rural Structures" and "W.G. on Masoury Structures" are responsible to performe studies related to different types of Rural Houses involving.

Mainly the different aspects of the problem and specially related to the behavior and the characteristics of Rural Buildings under Erathquake Forces.

In this paper the earthquake behaviour of rural buildings of various materials and structural systems will briefly be presented.

The behavior of rural buildings under consideration are mostly obtained from the work and observations conducted in Turkey by the members of working groups of TUNCEE mostly with the cooperation of Earthquake research department of the ministry, Istanbul Technical University Middle East University, and Boğaziçi University.

This paper summerises the results obtained these cooperative studies porformed during the last bifteen years.

Acknowledgement

I am greatly indebted to Mr. Oktay Ergünay, chairman of the Erathquake Research Department of Ministry, also, to Mr. Nejat Bayülke and Mr. Sinan Gençoğlu, both are head of the sections, from the same institution, for their valuable asistance during the preparation of this paper.

Rifat YARAR

1. SEISMISITY, SEISMIC HAZARD AND RISK IN TURKEY

1.1. NATURAL HAZARD

As a result of her orogenic system, geology, topography and climate, Turkey is exposed to various kinds of natural hazards causing substantial losses of life and property. With a land area of 776,000 km^2, a population of 51.000.000 and a rate of population increase of 2%,Turkey has to protect her national resources from the damages of natural hazards for their proper and adequate allocations towards the purposes of economic development.

The total number of houses damaged by the natural disasters in Turkey in the last 60 years is indicated in Table 1.1.

Table 1.1.
Number of Houses Damaged by Natural Disasters
in the Last 60 Years in Turkey

Type of Natural Disaster	Number of Houses Damaged	Percent of the Total Number
Earthquakes	333.935	% 65.4
Floods	78.047	% 15.3
Land Slides	54.930	% 10.3
Rock Falls	36.600	% 7.2
Storms, Rain, Hail	5.640	% 1.1
Avalanches	1.274	% 0.2
Total	510.426	% 100

1.2. EARTHQUAKE, AS THE MOST DAMAGING NATURAL HAZARD, IN TURKEY

We would like to explain briefly seismisity, seismic Hazard and seismic risk in Turkey. Noting that, especially after 1960's, the flood, landslide and rock fall hazards and the vulnerabilities are being decreased through the regulation of rivers and the land use planning, the earthqukes will be the natural disaster affecting Turkey in the future. As far as the natural disaster caused casualties and other economic losses are concerned earthquakes claim the uncomparably largest share amongst o ther natural disasters. Again the statistics of the last 60 years reveal that the average annual earthquake disaster related losses constitute about 0.8% of the total gross national product whereas all other natural disasters claim only 0.2 %. The natural disaster mitigation program in Turkey essentially means the mitigation of earthquake disaster.

Turkey lies within the Mediterranean sector of the Alpine-Himalayan orogenic system. The Alpine orogney is produced as a result of the compressional motion between Europe and Africa, whereas the Himalayan orogeny has resulted from the India-Asia collision. The main active facults, illustrated in Figure 1.1. are as follows:

o Nort Anatolian Fault (NAF) and the Anatolian Trough

The North Anatolian Fault is a morphologically distinct and seismically active right-lateral strike slip fault. It has a well developed surface expression for most of its length of 1000 km. The Anatolian Trough is the westward continuation of the northern strand of NAF.

o East Anatolian Fault (EAF)

The East Anatolian Fault is an active left-lateral strike-slip fault which extends from Antakya to Klarlıova, the eastern terminal of NAF. It is a fault zone which is about 2-3 km. wide, and links into the Dead Sea fault system.

o Western Turkey Graben Complex

This is an area of intense seismic activity which is related to the east-west trending graben complexes in the Aegean ragion.

Table 1.2 shows the large and the damaging earthquakes (Epicentral intensity I $\geqslant$ VIII) for the period 1925-1984, last 60 years.

Table 1.2.

List of Destructive Earthquake which Occurred last 60 years From 1925 to 1984 in Turkey

No.	Place	Date	Local time	Ms	I-MAX	Number of Heavy Damage	Number of Death	Death / Heavy Damage
1	Afyon-Dinar	1925. 8. 7	8h46m	5.8	IX	2043	3	0.001
2	İzimr-Torbalı	1928. 3.31	2h29m	7.0	IX	2000	50	0.025
3	Sivas-Suşehri	1929. 5.18	8h37m	6.1	VIII	1357	64	0.047
4	Denizli-Çivril	1933. 7.19	22h07m	5.7	VIII	200	20	0.100
5	Erdek	1935. 1. 4	18h20m	6.7	IX	600	5	0.008
6	Kırşehir	1938. 4.19	12h59m	6.7	IX	3860	149	0.039
7	İzmir-Dikili	1939. 9.22	2h36m	6.5	IX	1235	60	0.049
8	Erzincan	1939.12.26	1h57m	8.0	X-XI	116720	32962	0.282
9	Kayseri-Develi	1940. 2.20	-	6.7	VIII	530	37	0.070
10	Van-Erciş	1941. 9.10	23h53m	6.0	VIII	600	194	0.323
11	Bigadiç-Sındırgı	1942.11.15	19h01m	6.1	VIII	1262	7	0.006
12	Niksar-Erbaa	1942.12.20	16h03m	7.0	IX	32000	3000	0.094
13	Adapazarı-Hendek	1943. 6.20	17h32m	6.6	IX	2240	336	0.150
14	Tosya-Ladik	1943.11.26	0h20m	7.2	IX-X	25000	2824	0.113
15	Bolu-Gerede	1944. 2. 1	5h22m	7.4	IX-X	20865	3959	0.190
16	Gediz-Uşak	1944. 6.25	6h16m	6.2	VIII	3476	21	0.006
17	Ayvalık-Edremit	1944.10. 6	9h28m	7.0	IX	1158	27	0.023
18	Adana-Ceyhan	1945. 3.20	9h58m	6.0	VIII	650	10	0.015
19	Kadınhan-Ilgın	1946. 2.21	17h43m	5.6	VIII	509	2	0.004
20	Varto-Hınıs	1946. 5.31	5h12m	6.0	VIII	1986	839	0.422
21	Karaburun-İzmir	1949. 7.23	17h03m	7.0	IX	865	2	0.002
22	Karlıova	1949. 8.17	20h44m	6.7	IX	3000	450	0.150
23	Kurşunlu	1951. 8.13	20h33m	6.6	IX	3354	52	0.016
24	Hasankale	1952. 1. 3	8h03m	5.8	VIII	701	133	0.190
25	Yenice-Gönen	1953. 3.18	21h06m	7.4	IX	1750	265	0.151
26	Kurşunlu	1953. 9. 7	5h58m	6.4	VIII	230	2	0.009
27	Söke-Aydın	1955. 7.16	9h07m	7.0	IX	470	23	0.049
28	Eskişehir	1956. 2.20	22h31m	6.4	VIII	1440	1	0.001
29	Fethiye	1957. 4.25	4h25m	7.1	IX	3100	67	0.022
30	Bolu-Abant	1957. 5.26	8h33m	7.1	IX	4200	52	0.006
31	Köyceğiz	1959. 4.25	2h26m	6.0	VIII	775	0	0.000
32	Çınarcık	1963. 9.18	18h58m	5.9	VIII	230	1	0.004
33	Malatya	1964. 6.14	14h15m	6.0	VIII	678	8	0.012
34	Manyas	1964.10. 6	16h31m	7.0	IX	5398	23	0.004
35	Denizli-Honaz	1965. 6.13	22h01m	5.7	VIII	488	14	0.030
36	Varto	1966. 3. 7	3h16m	5.6	VIII	1100	14	0.013
37	Varto	1966. 8.19	14h22m	6.9	IX	20007	2394	0.120
38	Adapazarı	1967. 7.22	18h56m	7.2	IX	5569	89	0.016
39	Pülümür	1967. 7.26	20h53m	6.2	VIII	1282	97	0.076
40	Amasra-Bartın	1968. 9. 3	10h19m	6.5	VIII	2072	29	0.014
41	Alaşehir	1969. 3.28	3h48m	6.6	VIII	3702	41	0.011
42	Gediz	1970. 3.28	2302m	7.2	IX	9452	1086	0.115
43	Burdur	1971. 5.12	8h25m	6.2	VIII	1542	57	0.037
44	Bingöl	1971. 5.22	18h45m	6.7	VIII	5617	878	0.156
45	Lice	1975. 9. 6	12h20m	6.7	VIII	8149	2385	0.293
46	Çaldıran-Muradiye	1976.11.24	14h22m	7.2	IX	9232	3840	0.416
47	Erzurum-Kars	1983.10.30	7h13m	6.8	VIII	3241	1342	0.356
					TOTAL	315935	57914	

According to this Table, about 1.100 people are being killed and about 5600 buildings are being destroyed annually in Turkey.

Most of the loss of life, about 92 %, in the past earthquakes in Turkey has occured due to the collaps of buildings in rural areas constructed with local materials and workmanship, like stone, adobe and brick.
Although, rural buildings are used since ancient times, our sistematic knowledge on their earthquake behavior and performences are comparatively very recent.

Figure 1.2. provides the currently applicable offical seismic hazard zoning map of Turkey. As it is wellknown that, Turkey has frequently experienced devastating earthquakes. There is no need for a long discussion about significance of earthquake hazard and losses of lives.

On the basis of the currently applicable official seismic hazard zoning map of Turkey and the results of 1980 census, Table 1.3. shows the distribution of the population, land area, industrial centers and the hydraulic dams with respect to the different seismic hazard zones.

Table 1.3.

DDistribution of Population, Land Area, Industry and Hydraulic Dams
With Respect to the Seismic Hazard Zones

Earthquake zone	Population (Percent)	Surface area (Percent)	Big. Industrial Centers(percent)	Hydraulic dams (Percent)
First degree H.Z. I_o IX	22	14.8	24.7	10.4
Second degree H.Z. $I_o = VIII$	29	28.4	48.8	20.8
Third degree H.Z. $I_o = VII$	24	28.8	12.0	33.3
Fourt degree H.Z. $I_o = VI$	20	19.4	12.6	27.1
No hazard Zone $I_o \leq V$	5	8.6	1.7	8.4

Seismic hazard in Turkey as a whole can be illustrated by Figure 1.3. which plots the annual number of occurence of an earthquake of a given magnitude or higher within the entire territory of Turkey. The data base covers all the earthquakes of the last 70 years. Assuming a Poissonian behaviour of the data one can say that there exists 63 % probability of having one earthquake of magnitude 6.3 and above or ten earthquakes of magnitude 4.8 and above every year in Turkey. Similar probability levels are also valid for having a magnitude 7.3 and above earthquake in every 10 years. However, it should be noted that not all of the earthquakes take place in regions where potential damage in likely. For this reason the curve in Figure 1.4. indicating the annual number of occurences of an event of a given intensity level or above in whole Turkey is a better descriptor of the seismic hazard. Comparison of figure 1.3. and 1.4 indicates that only about 50 % of earthquakes in Turkey take place in areas that can cause damage.

Seismic vulnerability of the rural housing stock can be illustrated by Figure 1.5. This figure provides the percentage of heavily damaged dwellings in the adobe and stone mansonry, and wooden framed Turkish rural building stock for given levels of MSK intensities.

Seismic risk in the form of annual number of occurrences of the total number of heavily damaged or collapsed rural houses or of the percentage of the annual national budget spent for rural reconstruction is provided in Figure 1.6. Again assuming Poissonian behaviour of the data, there exists 63% probability of spending 0.07 % of the national budged per year or 1.4% of the national budged for every 10 years for rural post earthquake recontstruction purposes. Figure 1.7 provides the seismic risk in terms of the total annual number of lives lost in all Turkey. Similarly one can expect 63% probability of losing about 10 lives every year or about 800 lives every 5 years or about 8000 lives every 10 years in rural areas with adobe and stone masonry building stock due to earthquakes. As it can be seen the losses in areas wooden frame buildings are much lower.

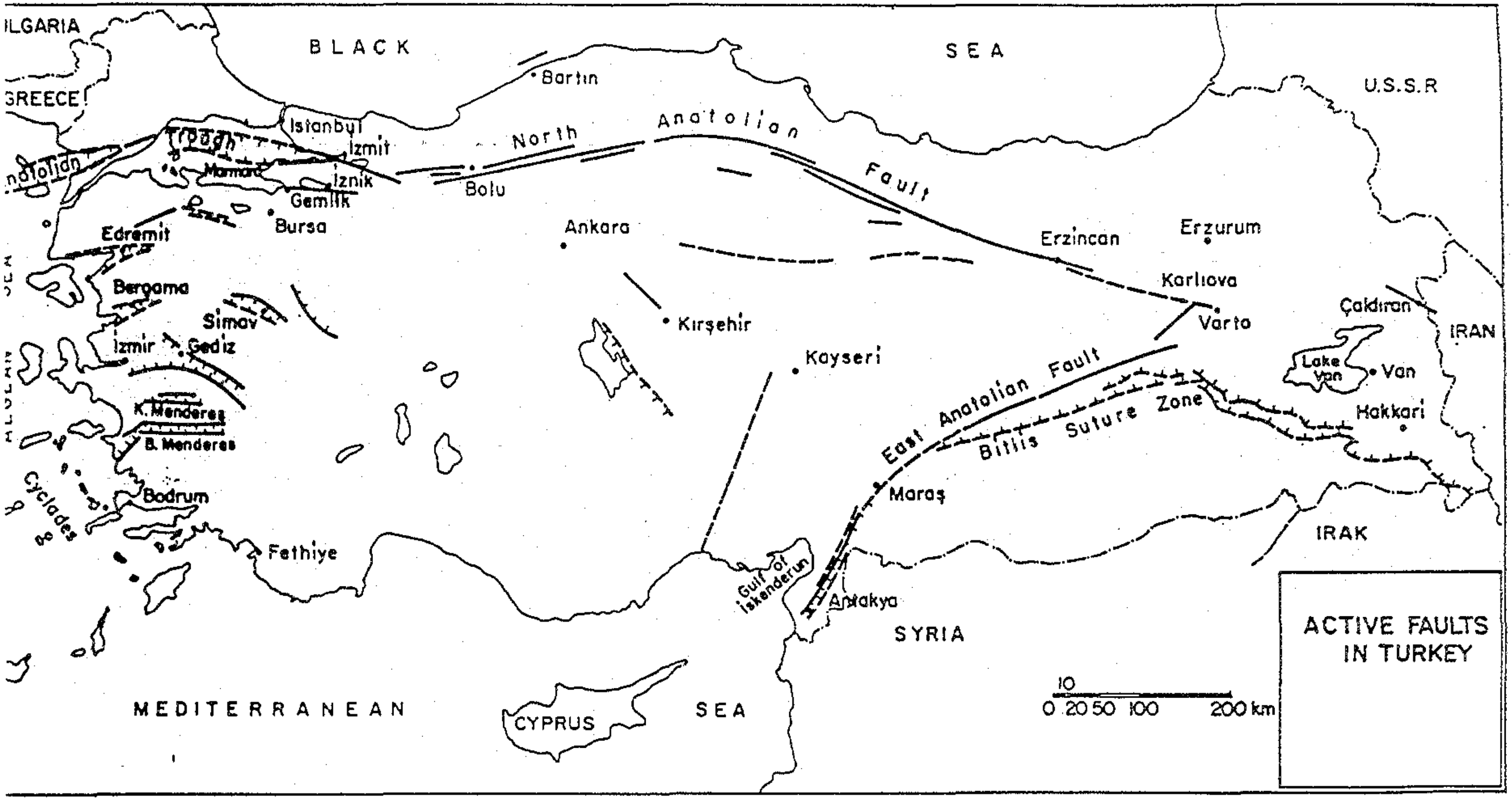


FIGURE 1.1. ACTIVE FAULTS IN TURKEY

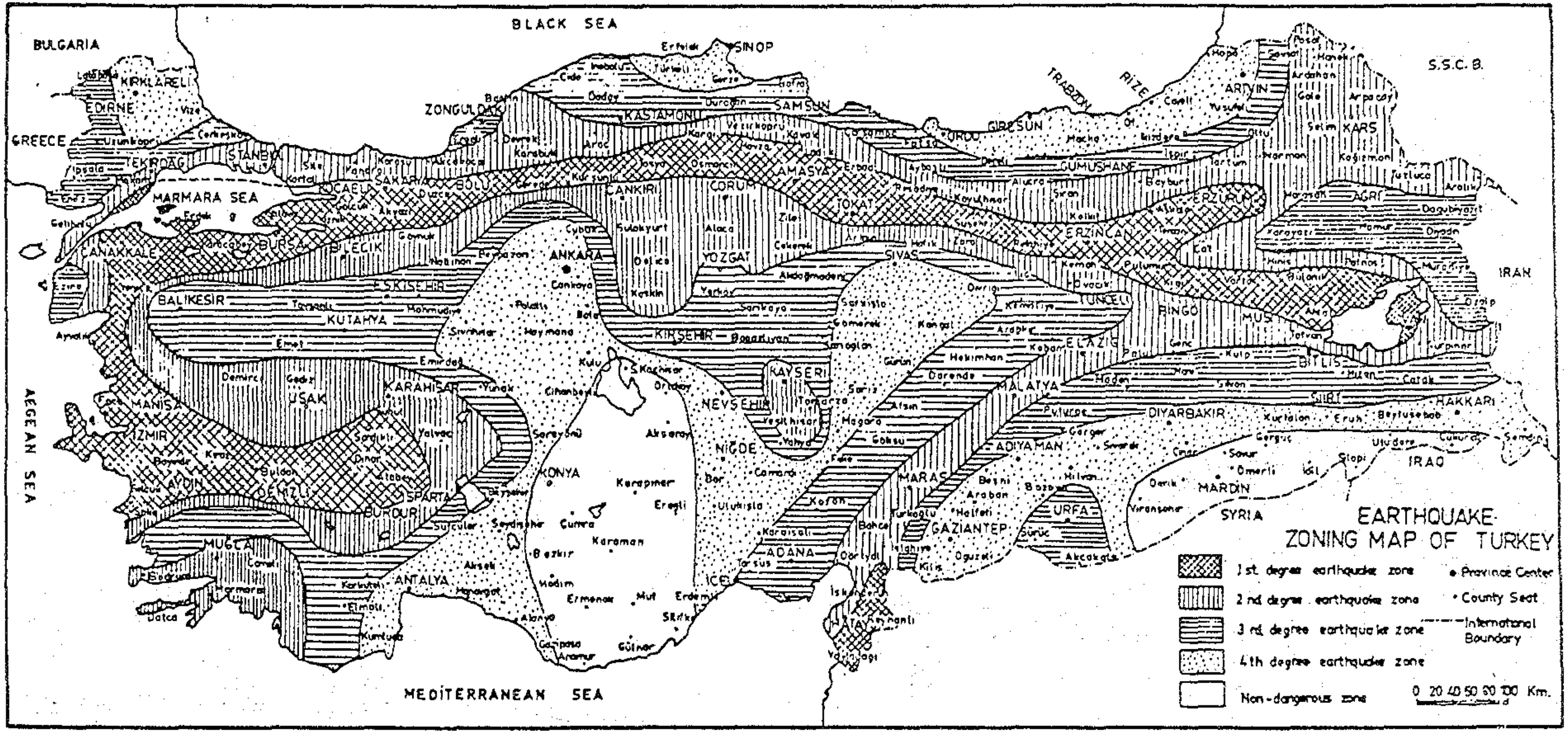


FIGURE 1.2. SEISMIC HAZARD ZONING

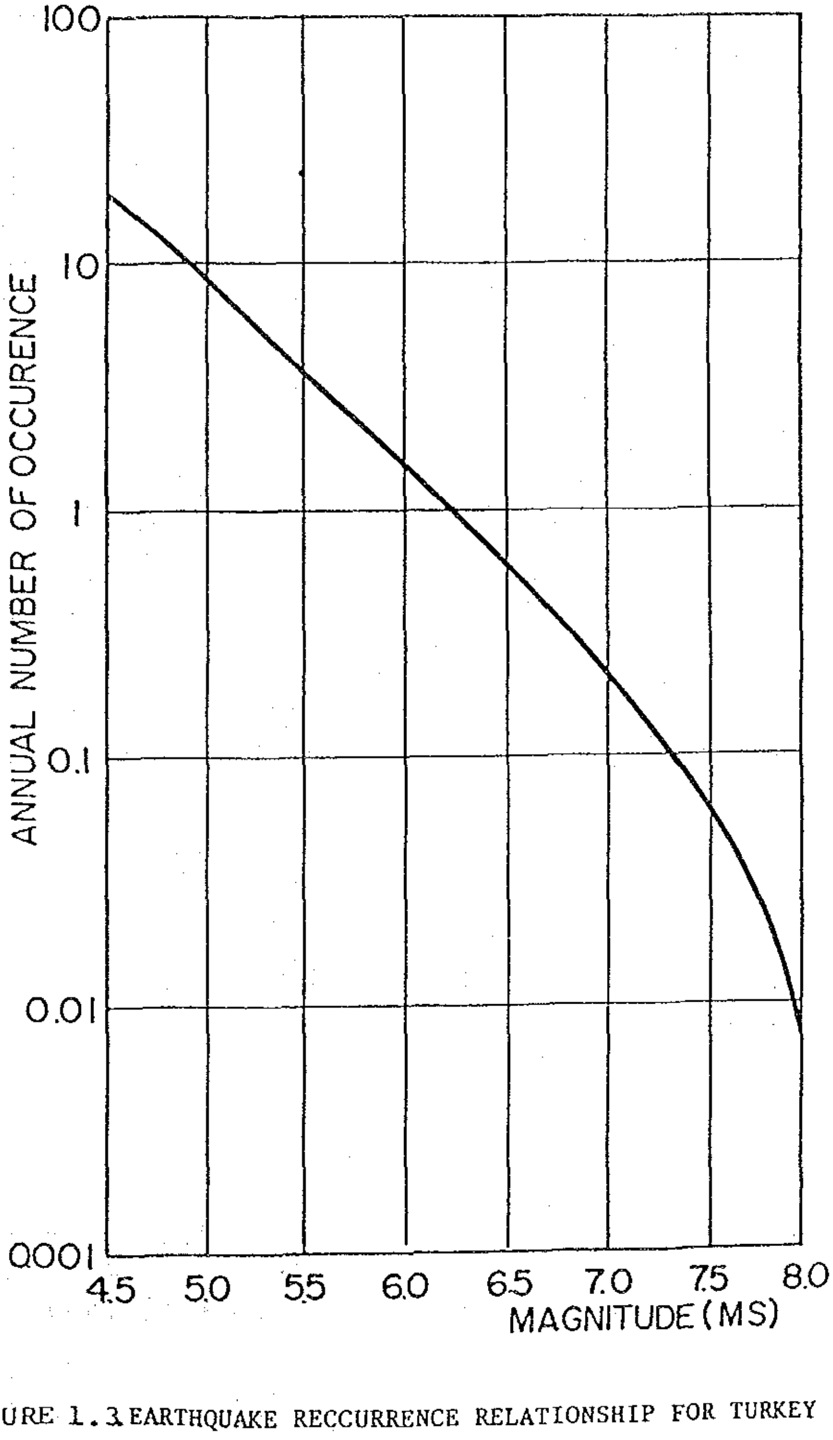


FIGURE 1.3 EARTHQUAKE RECCURRENCE RELATIONSHIP FOR TURKEY

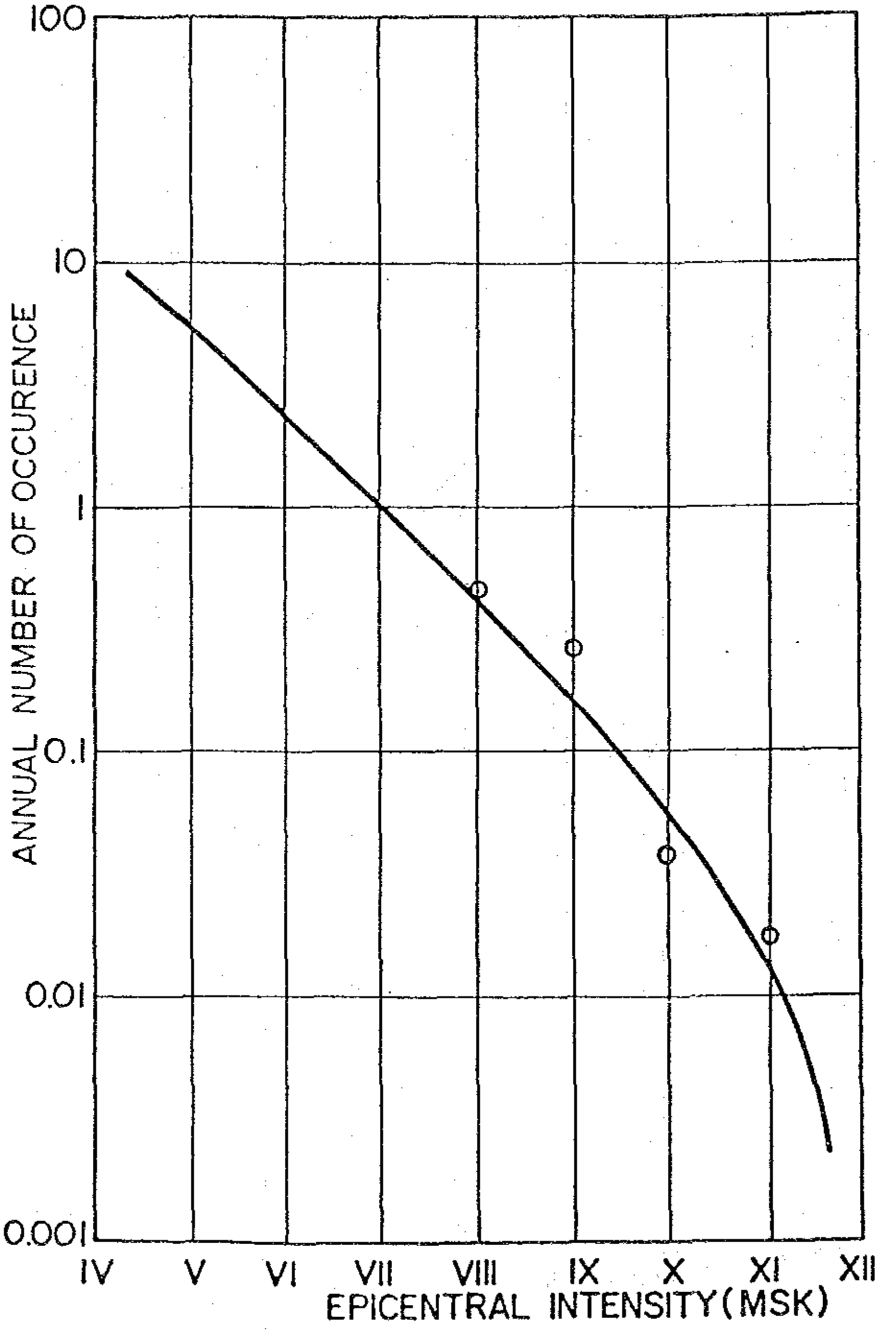
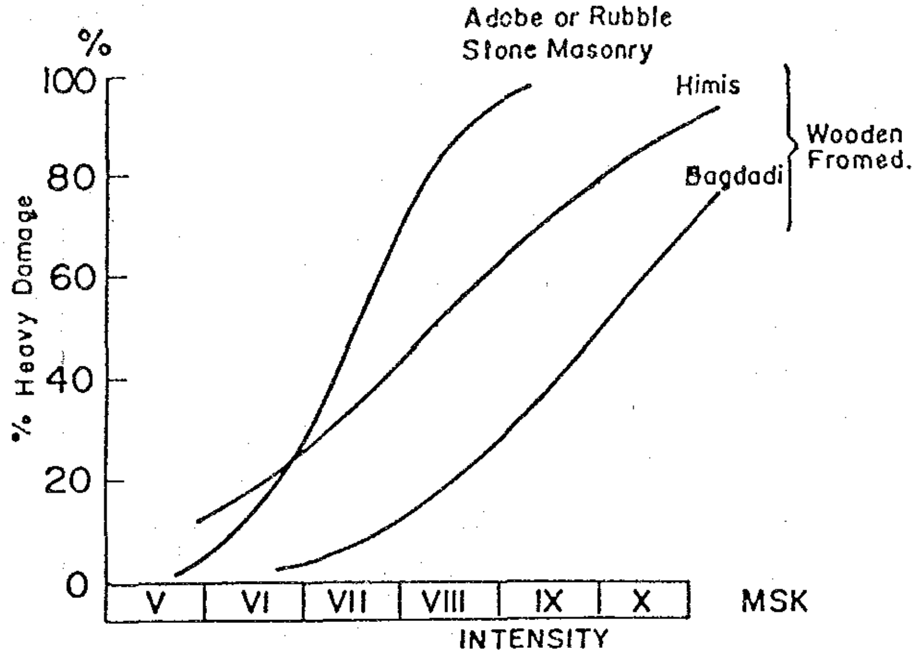


FIGURE.1.4.INTENSITY RECCURRENCE RELATIONSHIP FOR TURKEY



FIGIRE 1.5 SEISMIC VULNERABILITY OF THE TURKISH RURAL BUILDING STOCK

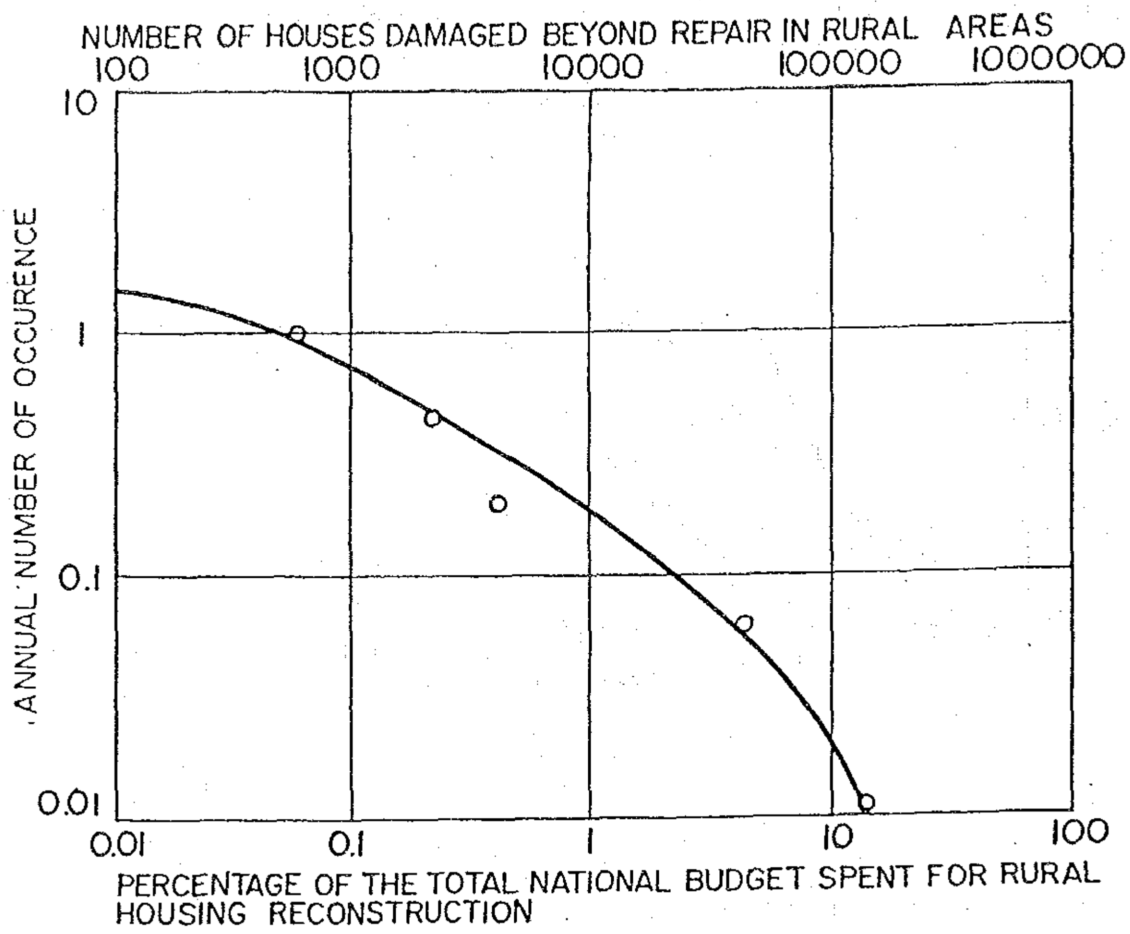


FIGURE 1.6. SEISMIC RISK FOR RURAL BUILDINGS IN TURKEY

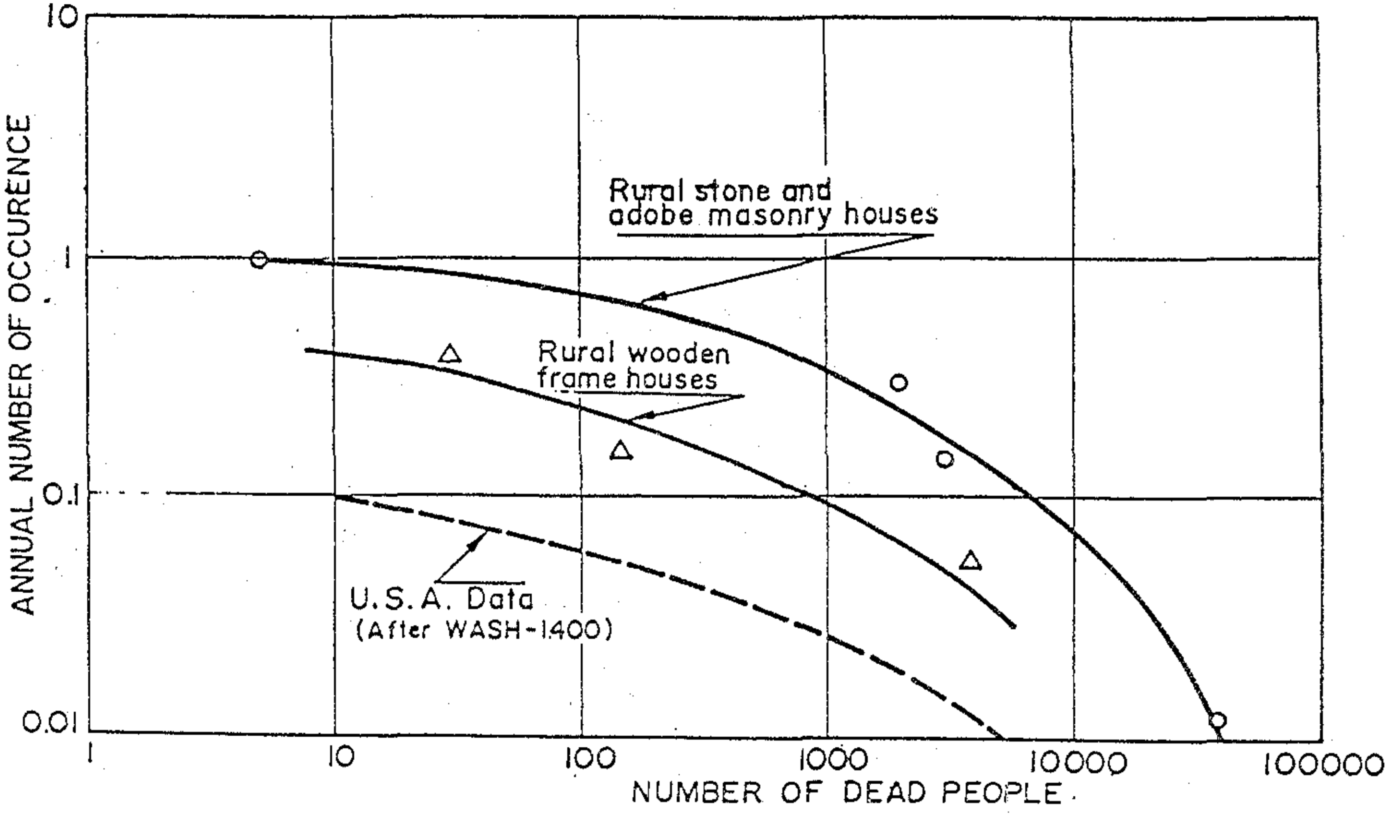


FIGURE 1.7. SEISMIC RISK FOR RURAL POPULATION

2. CLASIFICATION OF RURAL BUILDINGS IN TURKEY

2.1. METHODOLOGY

2.2. CHARACTERISTICS OF CLASSIFICATION

2.3. CLASSIFICATION OF RURAL DWELLINGS

2.4. FURTHER INFORMATIONS ON RURAL DWELLINGS AND BUILDING STOCK

2.5. ARCHITECTURAL LAYOUTS OF RURAL DWELLINGS

2. CLASSIFICATION OF RURAL BUILDINGS IN TURKEY

2.1. METHODOLOGY

a) Scope of the work

The Turkish National Committe for Earthquake Engineering since 1973 took the decision to investigate the problem of Earthquake resistant, low-cost rural housing which is structural and the social problem of development, which is also a problem of longstanding for many countries.

In other words, we must examine the existing knowledge relevant to the design, sitting and construction of earthquake resistant houses, including recent technological innovations applicable within the frame work of socio-economic and social requirements.

TTo obtain this special goal, first of all, it is necessary to evaluate the response of potential of the whole country againts earthquake damage, together with the state and Public Organisations.

To do so, we have to compile the data and research results as fellows:

a.1. Earthquake response of different types of houses, which comprises:
  a.1.1. Seismic activity of the country
  a.1.2. Rural dwelling types in the seismic regions
  a.1.3. Response of various types of houses to earthquakes.
a.2. The geography and geological structure of the country.
a.3. The state economy.
a.4. Demographic analysis.
a.5. Rural dwelling inventory.
a.6. The horizontal expansion and the increase in height of rural dwellings.
a.7. Infrastucture in rural areas.
a.8. Financial contribution of people to construction industry.
a.9. State policy on housing and the availibility of capital sources.
a.10.Manpower problem.

a.11. Construction technology and existing and new building materials.

a.12. Reaction of people to new construction materials

a.13. Housing industry.

a.14. The most favourable types of construction.

- a.14.1. Abode stabilization
- a.14.2. Bearing capacity of different types of lowcost rural dwellings built different construction materials.
  Against static and dynamic loadings (Earthquakes forces)

a.15. Code requirement and government control in construction.

Generaly speaking, whole these items concluded regarding the response;

1- Review in appropriate detail the history of the responses of different types of houses to earthquake disturbances.

2- Prepare a demographic analysis which shows:
How the people are moving, method of settlement, village and urban population ratios, regarding social behaviour.

3- Investigate the trends of living space expansion in housing and determine alternate criteria for expansion in horizontal or vertical directions.

4- And from the economic point of view:
Identify gross national product, growth patterns and state policy on hausing and availability of capital sources.

5- In view of the constructional materials, determine the availability and use of natural and artificial materials, its distribution in the country

were the detailed topics as being the parts of the main subject.

b) Method of investigation

In order to assess the technical procedure to reach the main result, it was necessary to progress on the following lines.

b.1. To determine the types of rural dwellings on a countrywide basis with their structural characteristics and building materials, including the site investigation and the labor sallaries etc.
We called this phase "Assessment of the Facts"

b.2. To classify the rural houses emphasizing their structural characteristics and the materials with regard to the response to earthquake disturbances.
We called this second phase "Classification".

b.3. To establish and describe the relation between the already-determined characteristics and the response potential of the rural dwellings considering the causes of damage during earthquake.
This phase called "Ethiology".

These three phases are necessary to assess the scientific knowledge.

As a last phase we must realize and design different prototeypes of rural houses regarding building materials and response characteristics. Also, this design realization must be extended to repair and streagthening of the existing houses.

In addition to these phases, to obtain a rapid and suitable result during Phase 3, we decided to divide the country into six (Seismo-Constructive) regions. (Map: 2.1). This was such that each region had approximately the following common characteristics:

1- Geological and geographical characteristics (Soilcondition, topgraphic figure, climate, and demographic characteristics, etc.)
2- Seismic activity
3- Building material possibilities.
4- Traditional or modern constructional systems and building industry.
5- Socio-Economic Structure.
(Economic possibilities, manpower, houses demand...).

2.2. CHARACTERISTICS OF CLASSIFICATION

Introduction

In general, one can propose, that the buildings in rural on urban areas built with local materials, local workmanship and tradition, and without any engineering input, can be classified as rural buildings the local materials generally are, earth(clay),stone and wood.However the other but permanant characteristic of rural houses is to be low-income houses.

However rural dwellings in Turkey are formed spontaneously, as a result of the combination of regional construction materials with the traditional structural methods.

Rural dwellings are also seen to exist in surrounding of the cities.

On the other hand, as the structures in the seismic regions are not specially designed to resist earthquake forces and no additional care is taken in their construction,therfor earthquake damages increase to larger amounts.

a. Factors Effecting the Formation of Rural Dwellings

a.1. Physical surrounding-Climate-Water resources-Vegation.

(i) The possibilities of obtaining constructional materials.

In the structures most of the time the primary constructional material existing on the nature (e.g. stone, timber) in forests, timber frames are frequently used. Adobe masonry systems are generally seen in regions where timber and stone suitable for construction cannot be found, but where water is available.

(ii) From the point of view of the shaping of rural dwellings:

The measurements taken against climatic conditions (sun, rain, snow, etc.) often influence the structural system as well as the shaping of architectural elements (windows, roofing, cantilevers, etc.).

a.2. The distance to cities and to the production centres of constructional material and transportations facilities:

The distance from the village to cities and the transportation facilities, influence the type and the quality of the constructional materials as well as the design and the constructional methods of the structures.

a.3. Socio-Economic Conditions

The socio-economic potential of the regional people, effects directly the possibility of using qualified workers and good quality materials.

a.4. Conformity With the Traditional Structural Discipline

One of the factors effecting the structural shaping of the rural dwellings is the "Traditional Turkish Structural Discipline". Structures built in accordance with this discipline have been observed to resist earthquake for years. On the contrary new buildings constructed with structural methods away from the traditional ones suffered much more damage during recent earthquakes.

2.3. CLASSIFICATION OF RURAL DWELLINGS

In view of their structural systems, and materials rural dwellings in Turkey can be divided into two main groups,

I. Block structures
II. Framed structures

I. Block Structures:

Structures in this group may also be studied in two sections

(A) Wood Block Structures:

The walls on wooden block structures are formed from timbers of 20-25 cm. of diameter, which are placed one on top of another and connected (nailed) at the corners.
This kind of structure has a wide application in the forest houses of Northern Anatolia (Bolu-Rize) and in the summer camping houses of the same region (Fig. 2.1a, Fig.2.1b).

(B) Masonry Structures:

Can be divided into five sub-groups.

B.1. Stone Masonry Structures:

This type of structures, in which the walls are made of stones, are generally constructed in the mountainous and rocky regions. Many structures of this type are seen in Eastren, South Western, South and South-Eastern Anatolia.

The walls are in general 40-50 cm. thick (sometimes 75 cm.) and the stones are held together with mortar. Only in the southwestern regions no mortar is used (dry wall). To increas the stability of the walls horizontal laths (wooden, metal or reinforced concrete) are placed with nearly one meter distonce.

Stone masonry structures can further be classified according to the kind and shape of the stones used. (Fig. 2.2.) As Rubble and shaped stones masonry depending on the mortar used may be considered as different types of masonry structures.

B.2. Adobe Masonry Structures

In general, adobe masonry structures are constructed in regions where timber, stone and other constructional materials cannot be obtained. It is unfortunately one of the most common structural systems used in rural regions of Turkey,and exist mainly the surroundings of Central and Eastern Anatolia.

This system also can further be classified as block adobe, poured in place and poured in place adobe strengthened with branches of trees or with other stabilizers. (Fig. 2.3).

B.3. Brick Masonry Structures.

In the rural regions near cities, bricks are used in the construction of walls. This structural system is mainly practiced in the surroundings of Marmara, in Northen, Nort-Eastern and other regions of Anatolia. Successful results are obtained when the ysytem is applied in accordance with

the traditional technology (Fig. 2.4)
(Fig. 2.5a) shows an example of traditional Turkish architecture using long wooden beams to realise eaves and balconies.
(Fig. 2.5b) illustrates iron anchorage detail of brick (or ston) massonry buildings, which makes the bearing walls earthquake resistant.

B.4. Other Block Systems.

This group is composed of the structures in which the walls are made from other materials than stone, adobe and brick. A few example are seen with concrete blocks and Ytong.

B.5. Mixed Systems.

Sometimes the above mentioned structural systems are used together. Some mixed systems are then obtained:

Stone and Brick
Adobe and Brick
Stone and Adobe

The practice of these mixed systems are emphasized by architectural considerations in the design of window and dooropenings, and by statical consideration in the construction of corners.

II. Framed Structures

Framet structures developed in rural regions can be divided into two groups according to the kind of the material used to construct the frame.

(C.) Timber Framed Structures,
(D.) Reinforced concrete or steel framed structures.

C- Timber framed structure is the common type of framed structures seen in Turkey. In different regions, different kinds of filling and covering materials are used. A classification can be made based on these differences:

C.1. Timber framed structures, with filled walles (Hımış)

(a) Filled with mud and branches of tress:

Branches of trees are knitted between the vertical elements of the frame, then plastered with mud, from both sides. This quite primitive type of structures are very common in the surroundings of streams and rivers (Fig. 2.6).

(b) Filled with adobe:

The spaces between the vertical elements of the frame are filled with adobe, this system has a wide application especially in the surrounding of forest villages in Western Anatolia. In Gediz and surroundings, 70 percent of the structures were of this type (Fig. 2.6).

(c) Filled with stone:

In the regions where stone is available, this type is as common as the preceding one. Mud can again be used as the binding material (Fig.2.7).

In the black sea region where the vertical elements of the frames are closer, square stones are used as filled material.

(d) Filled with brick:

This system in which the spaces between the vertical elements of the frame are filled with bricks, is especially practiced in Marmara region, Northern Anatolia, black sea region and partly in the Central Anatolia (near Ankara). As it is possible to construct multi story houses (max. 3 stories) with timber frames, the use of this system in two stories cantilevered (çıkmalı) houses has created a special style of construction (Fig. 2.8).

(e) Mixed Systems:

For several reasons, sometimes in some regions, the above mentioned systems are used together, to make up the mixed system.

C.2. Timber framed structures with empty (Hollow) walls.

(a) Walls covered with wood panels:

In this system commonly seen in forest villages, walls are covered from inside and outside with wood panels (called "Bedavra"), having cross sections of (2.5 - 3) x (15-20) cm. and length of 1,5-2 m. Many examples are met in Northern and Southern Anatolia (Fig. 2.10).

(b) Walls covered with lath and plaster, "Bağdadi" system:

This type of constructional system is widely used in the surroundings of Marmara and in the rural regions near to cities in the Aegean, Mediterranean and Black Sea.

In this system, strips of wood with small cross sections are nailed on the timber frame from interior and exterior and then plastered, forming finally a light and flexible structure.
This system is commonly practiced and developed in the traditional Turkish structural discipline (Fig. 2.9) shows the rural type of timber frame, building Called Bağdadi, and (Fig. 2.11) urban type timber frame building.

ii) Reinforced Concrete System:

Very few examples are seen in rural regions. Several applications exist according to different types of filling materials (Fig. 2.12)
The necessary but a few details about the construction of rural dwellings can be found in these figures.

2.4. FURTHER INFORMATIONS ON RURAL DWELLINGS AND BUILDING STOCK

In order to present a meaningful discussion on the subject of earthquake resistant behavior of rural buildings a clear and detailed definition of each classified types of rural buildings are warranted.

Regarding the principles of classification, which, has been based on the resistance to earthquake distrubances, block structures resist to external load by bearing walls (wood, adobe, stone and brick, etc.-) and the framed structures resist by frames itself. As an example adobe buildings means that the load bearing walls are constructed using adobe as material in this sense adobe dwellings are included in the general category of masonry structures.

In contrast timber frame structures where for example, adobe is used as infill material›will not be considered as adobe structure.

As may be observed from below given figures, the two structural systems are essentially distinct, and for this reason all aspects of structural behavior, including seismic, have profound differences.
And, again, the stone bearing wall type buildings behave as masoury (such as adobe, and brick,--) structure, which resist to earthquake forces by their walls, on the other hand the timber or reinforced concrete frame building with stone (or brick and adobe) infill walls behave as framed structures which resist to earthquake forces by frames regardless of the infill materials.

In (Figure-2.13) the classification scheme of low-cost rural dwellings in Turkey with respect to their structural systemes and construction materials can be shown.

In addition (Fig. 2-14) illustrates the geographical distribution of various types of rural buildings in Turkey.

This figure shows that, in easthern and southeasthern Turkey, stone and adobe masoury are the dominant rural building types, due to lack of economic means for substitute material and construction technology however in northern part, near the black sea in woodland area, different types of timber frame buildings are currently constructed.But in westhern and south westhern part of Turkey, timber frame with infill block walls (adobe, stone, brick, etc..) are frequently encountered.

Regarding the rural building inventory in Turkey, the numbers of different types of rural buildings can easily be calculated by the percentages given in (Fig-2-13). However approximately 50 % of the total building stock in Turkey can be considered as rural buildings to about 4.600.000.- units in 1984 estimates.

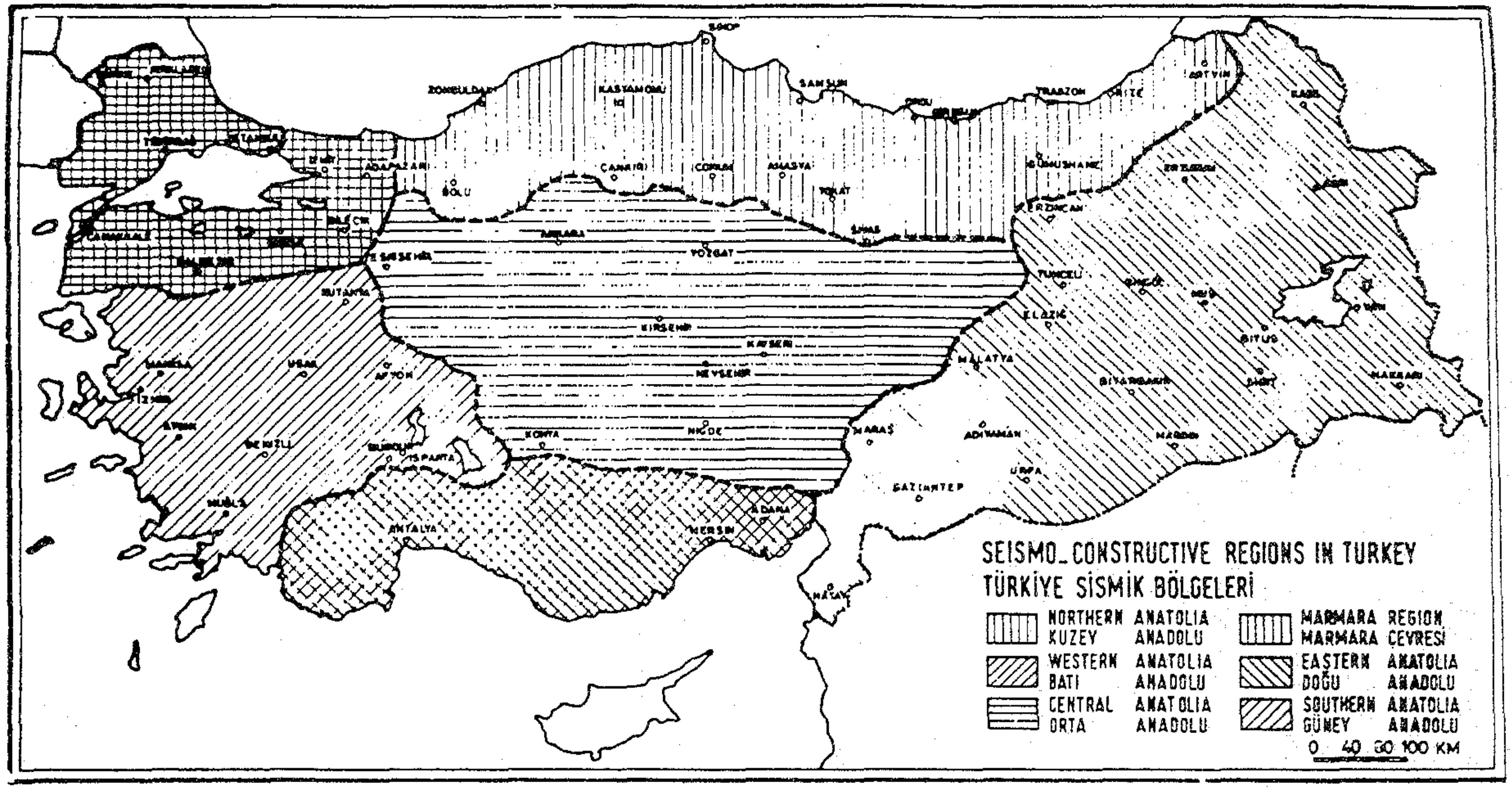
About 76 % (3.496.000) of all rural buildings are load bearing block structures and 18 % (828.000) are framed structures. About 98 % (3.426.000) of load bearing block structures are masoury, 32 % (1.100.000) are adobe, and 10 % (340.000) are brick, concrete block etc.-

2.5. ARCHITECTURAL LAYOUTS OF RURAL DWELLINGS

Architectural layouts of different types of rural buildings either masoury or framed type, have quite similar plans. Because it depends on the manner of living or sort of subsitances of the people in rural areas.

The sizes and the numbers of rooms and stories of rural building depend also on the social requirements of the families.

Several Figures appropiate to the livelihood of an animal breeding family are given. As an interesting example Figure (2.15) shows an architectural plan of a rural dwelling constructed, during the rehabilitation period, after Erzurum - Kars Earthquake of October 30-1983 in estarn zone of Turkey
This plan also shows, how the area (or number of rooms) of rural house subject to increase, due to the enlargement of the family and the number of animals following (Figure: 2.16) and (Figure: 2.17)illustrate two more layouts.


SEISMO_CONSTRUCTIVE REGIONS IN TURKEY
TÜRKİYE SİSMİK BÖLGELERİ
NORTHERN ANATOLIA
KUZEY ANADOLU
WESTERN ANATOLIA
BATI ANADOLU
CENTRAL ANATOLIA
ORTA ANADOLU
MARMARA REGION
MARMARA ÇEVRESİ
EASTERN ANATOLIA
DOĞU ANADOLU
SOUTHERN ANATOLIA
GÜNEY ANADOLU
0 40 80 100 KM
SİNOP
ZONGULDAK
KASTAMONU
SAMSUN
ORDU
TRABZON
RİZE
ARTVİN
KARS
ÇANAKKALE
TEKİRDAĞ
İSTANBUL
İZMİT
ADAPAZARI
BOLU
ÇANKIRI
ÇORUM
AMASYA
TOKAT
GÜMÜŞHANE
ERZURUM
ERZİNCAN
BİLECİK
BALIKESİR
ESKİŞEHİR
ANKARA
YOZGAT
SİVAS
KÜTAHYA
KIRŞEHİR
KAYSERİ
NEVŞEHİR
TUNCELİ
BİNGÖL
MUŞ
ELAZIĞ
VAN
BİTLİS
MANİSA
UŞAK
AFYON
İZMİR
AYDIN
DENİZLİ
BURDUR
ISPARTA
KONYA
NİĞDE
MALATYA
DİYARBAKIR
SİİRT
HAKKARİ
MARAŞ
ADIYAMAN
MARDİN
URFA
GAZİANTEP
MUĞLA
ANTALYA
MERSİN
ADANA
HATAY

MAP 2.1

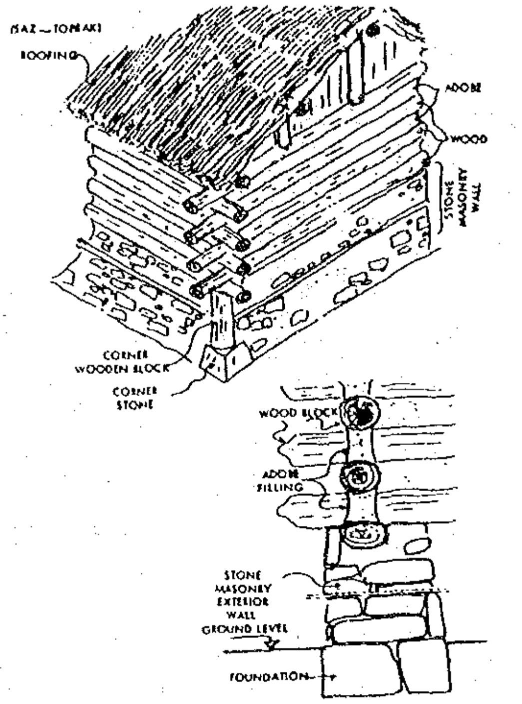


Fig. 2.1a. This figure shows very primitive wood block structure. Adobe is used to establish the wall. Bearing elements are the Block (massif) wood beams supporting on the corners.

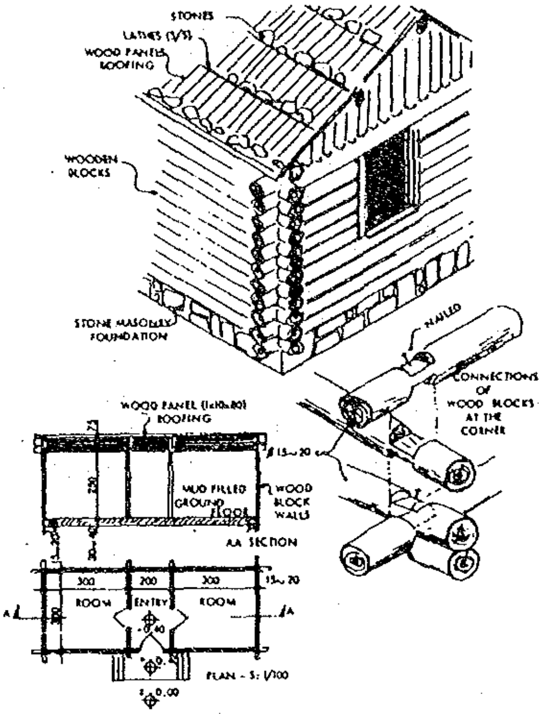


Fig. 2.1b. Shows clearly the construction methode of woode block masonry system.

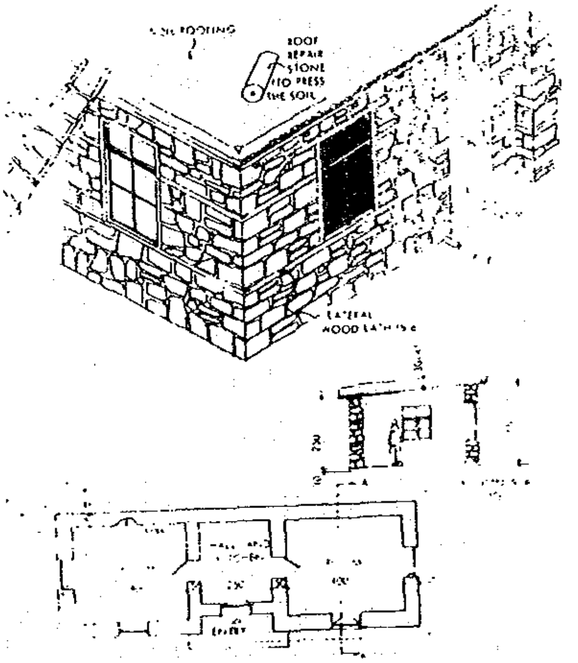


Fig. 2.2. This shows one interesting stone masonry structure and the construction methode. The roof is flat four bearing walls. Sometimes the lintels also continoue arround the walls connecting the window lintels the main constraints is to connecte the roof to the walls.

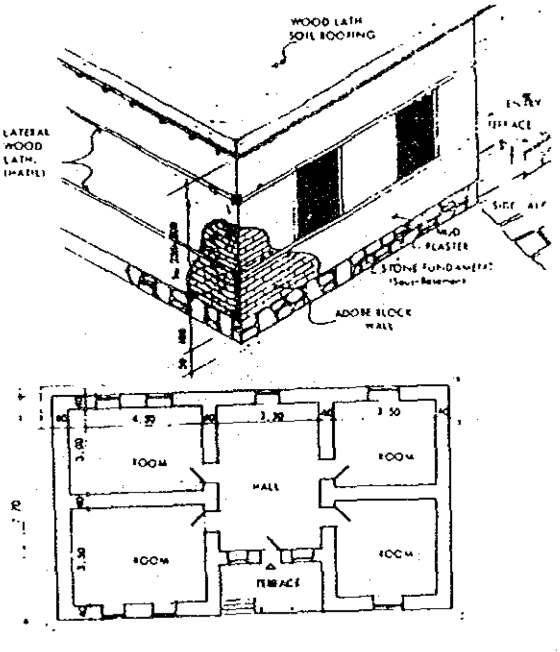


Fig. 2.3. Adobe-masonry system is shown; this building are build by adobe blocks. Generaly the number of Rooms increases according to the number of children of the family. The mud plaster prapared by yellow clay.

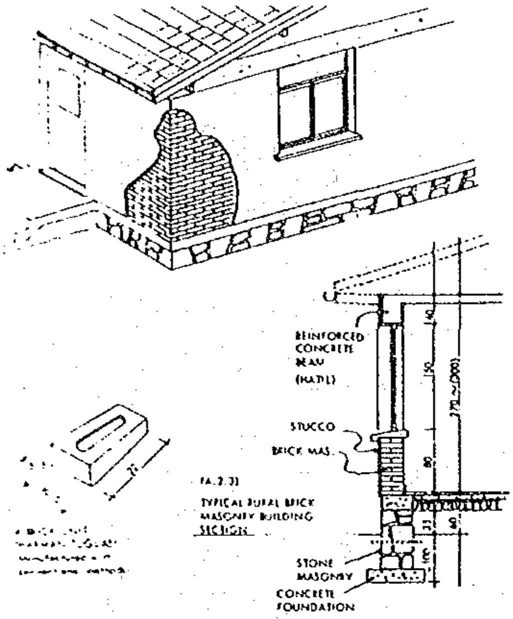


Fig. 2.4. Typical Brick masonry rural House. Brick units are manufactured with conventional methods. Generally the same tie-beams also used as the other masonry dwellings.

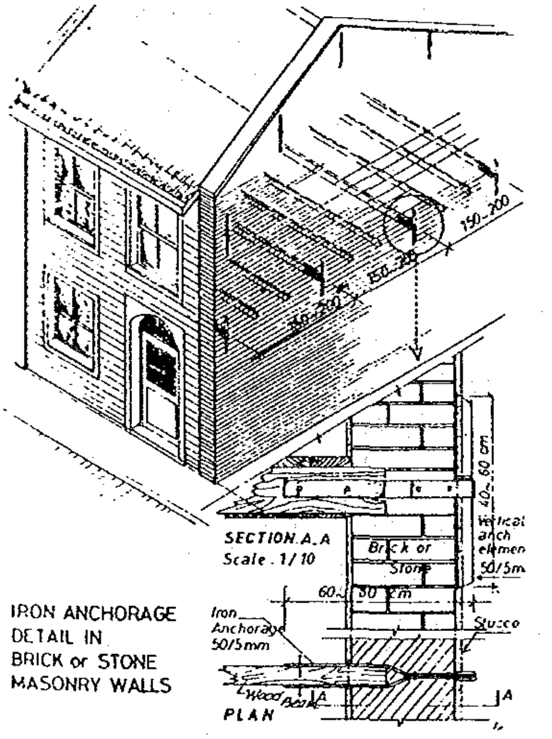


Fig. 2.5b. This figure shows traditional connection of side walls of a Brick or Stone masonry house. In rural areas floor and ceiling are wooden beams only woodjoists. In Rural region reinforced concrete floor system is not used. This traditional anchroge system gives more strength against horizontal forces.

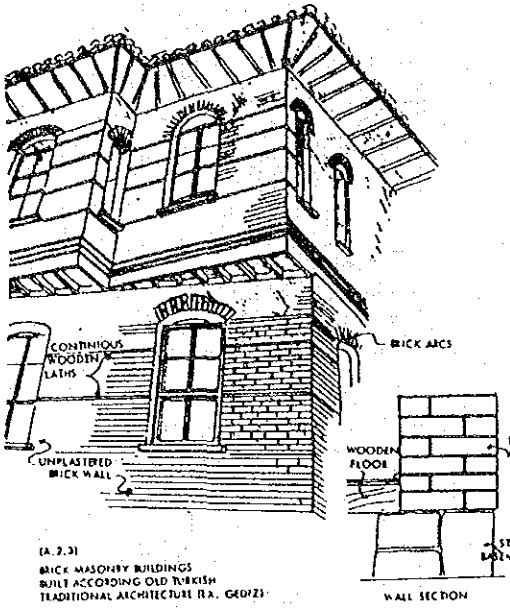


Fig. 2.5a. This figure shows an old type brick masonry structure as one of the example of traditional Turkish architecture. With very close wooden tie-beams in ceilling and roof wood beams are used. Upper part of windows long wooden beams realise the eaves.

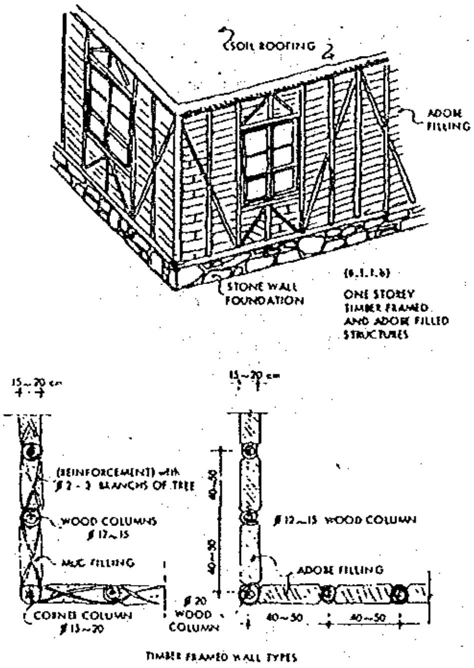


Fig. 2.6. This figure shows a Timber framed structure (Hımış) its walls filled by mud-adobe. Two different systems of wall construction is used first piled up by adobe block, and wood column wraped by thin tree branches. In second, Timber frome walls filled by mud-adobe.

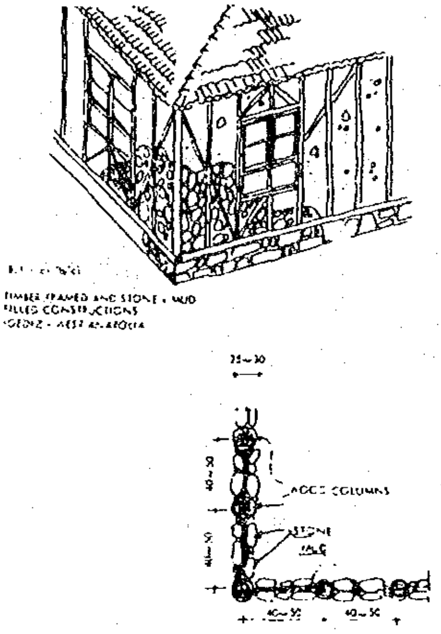


Fig. 2.7. The in fill material is stone and mud. Non enougb connection on bending between these two materials and columns exist. Only Timber frame system are strengthened by diagonals. During Earthquakes stones were poured out.

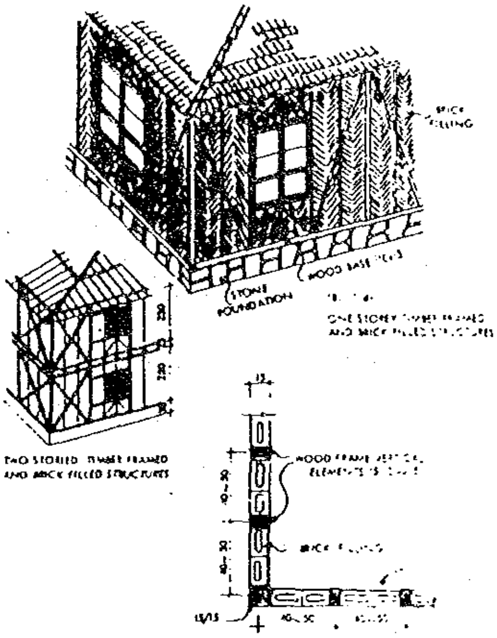


Fig. 2.8. In this figure a Timber framed brick filled rural house is shown. Due to the inclinations of the brick blocks, great shapes are produced in between so large amoun of mortar is being used.

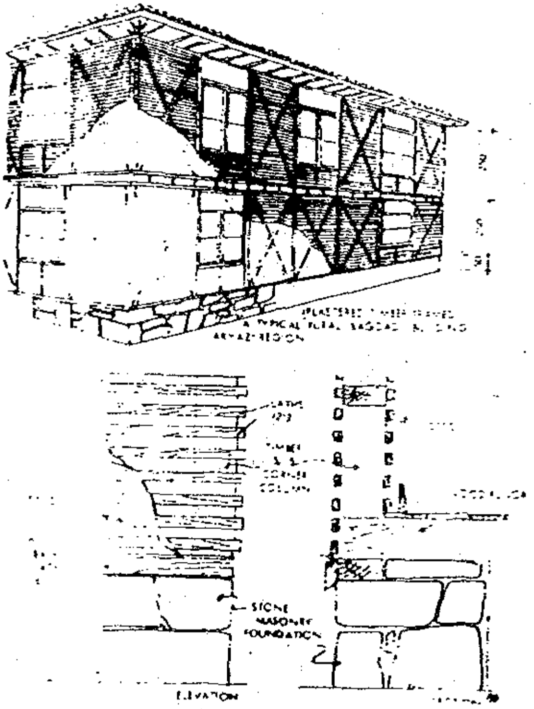


Fig. 2.9. This Timber framed ampty wall constructions are build according to the traditional system which-ever used in wealthy regions in Turkey.

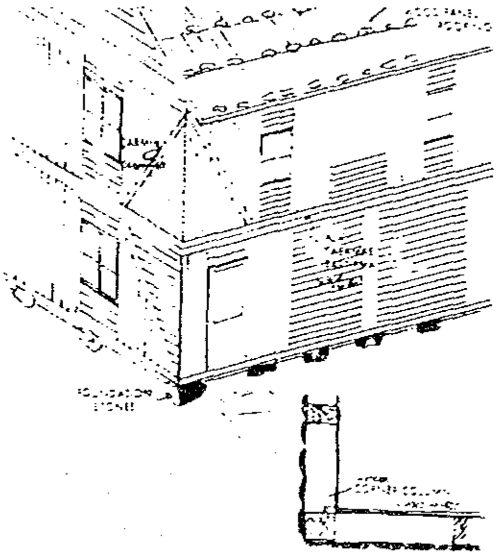


Fig. 2.10. This picture shows are of t interesting Turkish traditional Timber framed system which specially seen in Turkey in rural region or same region near the city. The all connections specially corners detailing carfully worked up. One more interesting featur is the type of foundation. The one or two stories buildings were placed on several isolated stones. Which allow t make side sway easily.

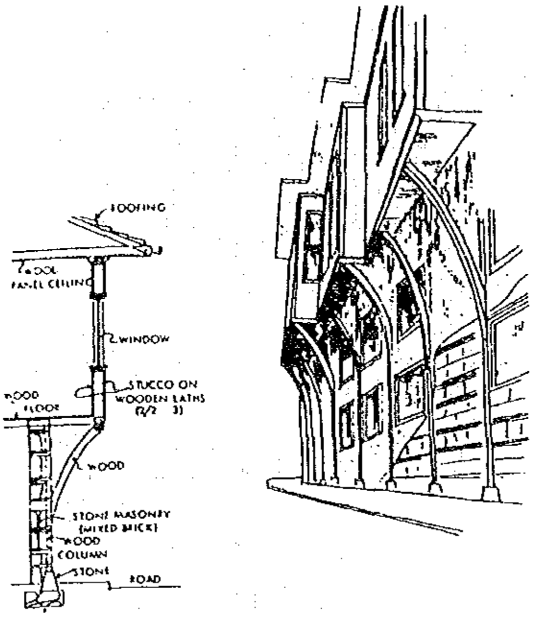


Fig. 2.11. This figure illustrate an interesting example of mixed. Timber framed, old Turkish,buildings (covered wooden laths and Plastered both sides) built as traditional architecture (Marmara Region).

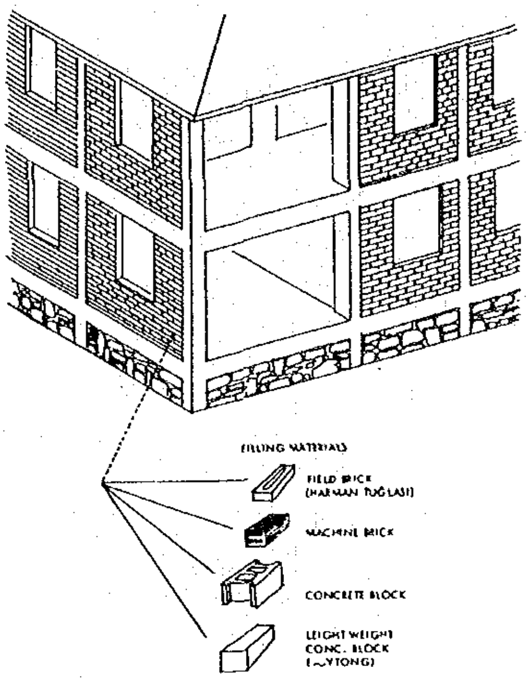


Fig. 2.12. A typical Reinforced concrete rural building. Different blocks are used as infill materials.

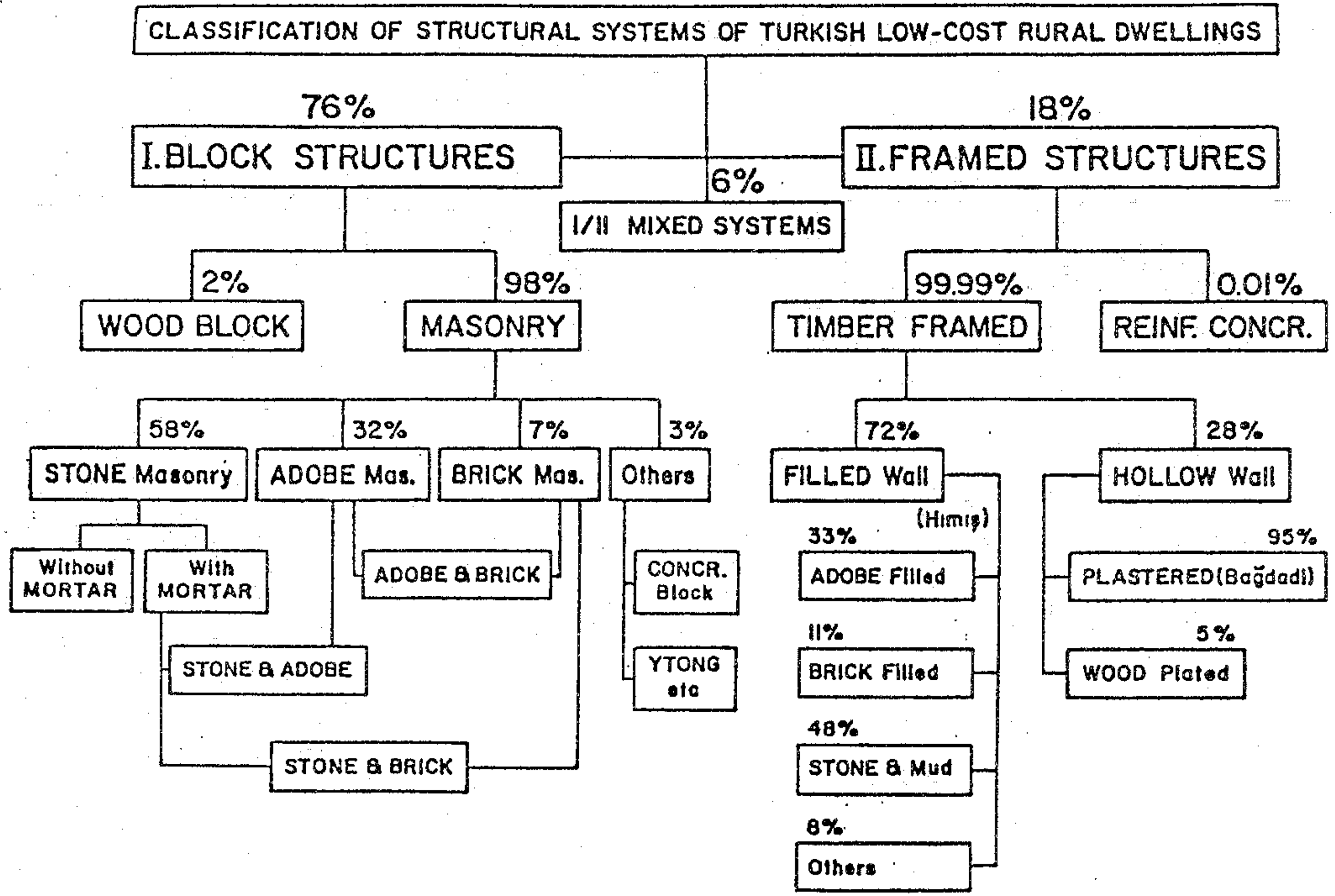


Figure.2.13. CLASSIFICATION OF STRUCTURAL SYSTEMS OF TURKISH LOW COST RURAL DWELLINGS

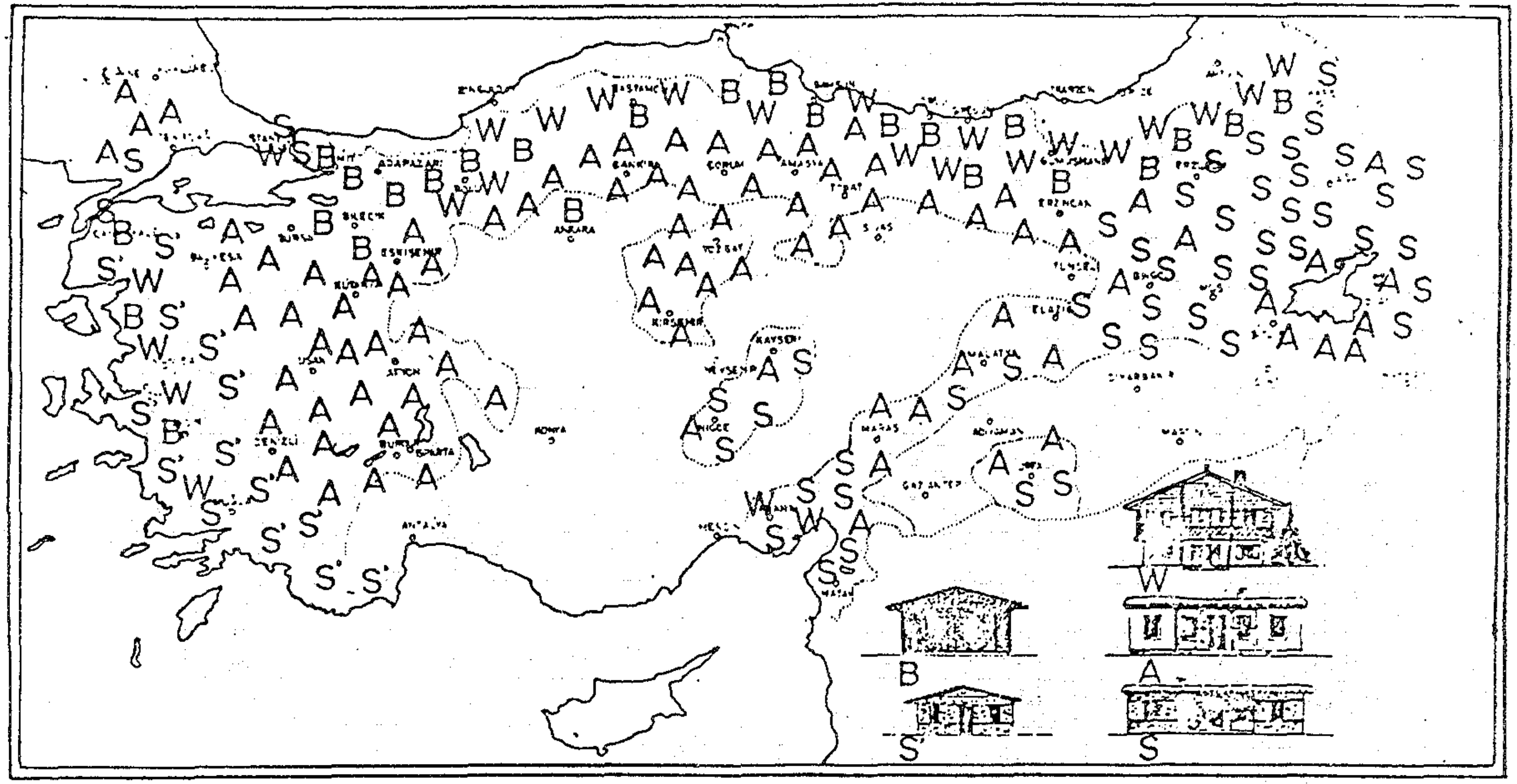


Fig. 2.14. Geographical distribution of rural Structures in Turkey
Adobe masonry
Wooden framed with brick infill
Stone masonry with earth roof
Stone masonry with timber roof
Wooden framed

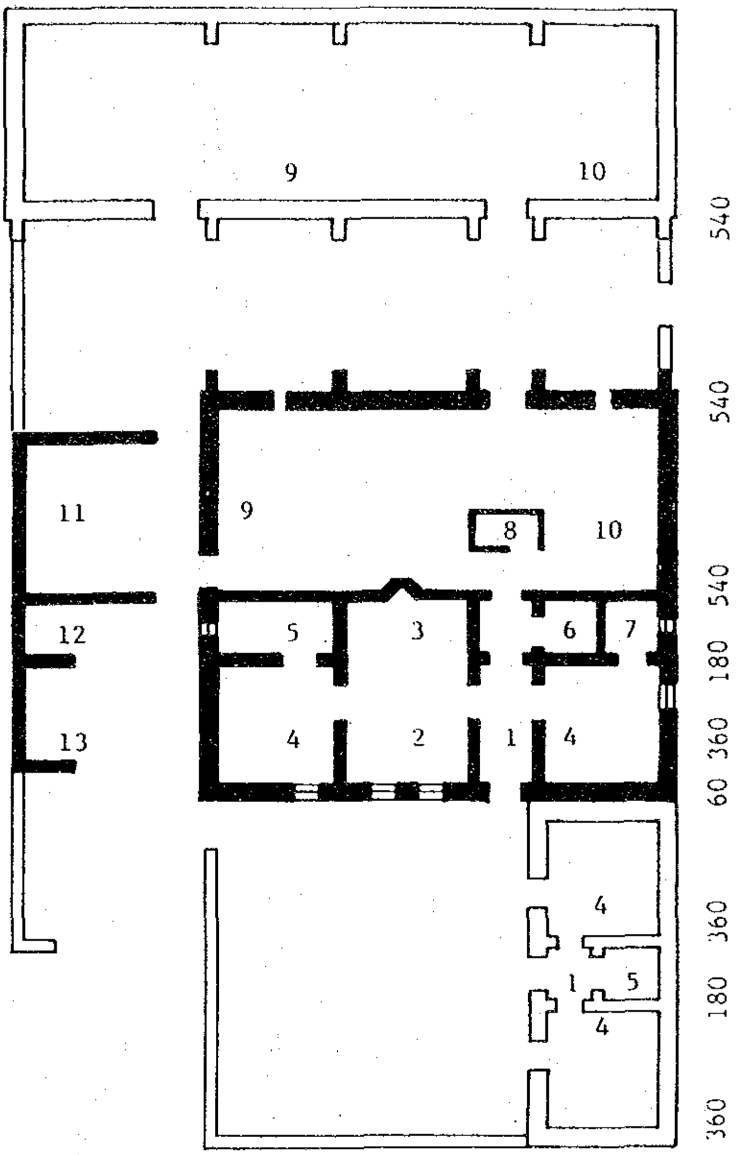


Fig. 2.15.

1	Giriş	Entrance
2	Gündüz odası	Living room
3	Mutfak	Kitchen
4	Oda	Room
5	Yüklük	Storage
6	Kiler	Pantry
7	Yıkanma	Bath
8	W.C.	W.C.
9	Ahır	Stable
10	Ağıl	Stable
11	Samanlık	Barn
12	Tezek	
13	Araç-Gereç	Tools-Equip
14	Tandır	Special kitchen

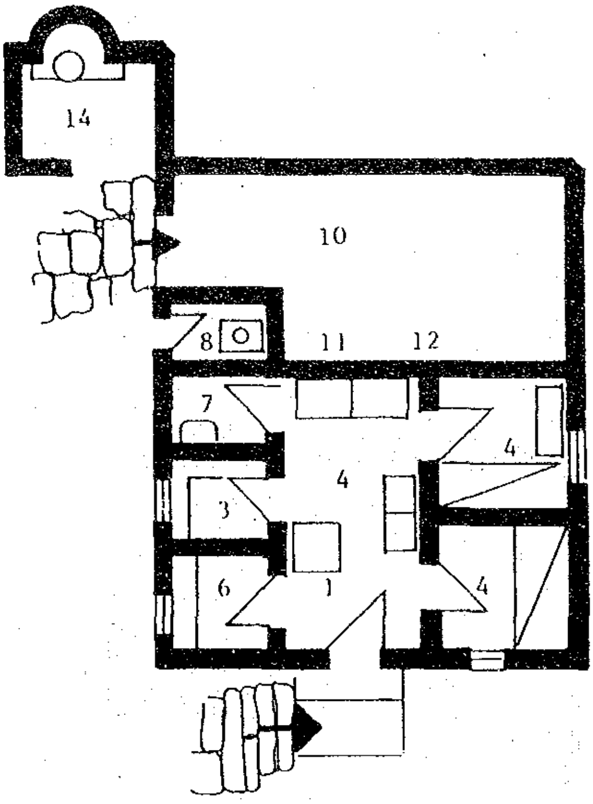


Fig. 2.16

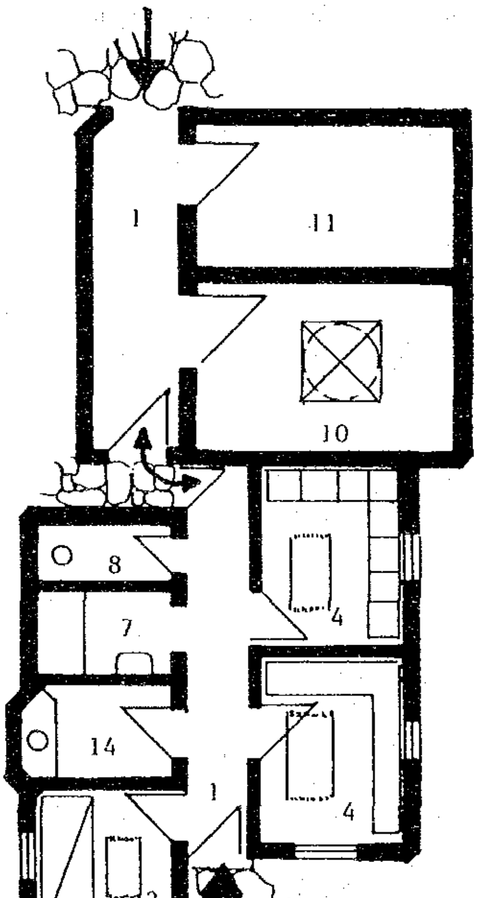


Fig. 2.17

3. CHARACTERISTICS OF RURAL BUILDINGS

3.1. CHARACTERISTICS OF ADOBE MASONRY BUILDINGS

3.2. CHARACTERISTICS OF STONE MASONRY BUILDINGS

3.3. CHARACTERISTICS OF BRICK MASONRY BUILDINGS

3.4. DYNAMIC CHARACTERISTICS OF MASONRY BUILDINGS

3.5. CHARACTERISTICS OF TIMBER FRAME BUILDINGS

3.1. CHARASTERISTICS OF ADOBE MASOURY BUILDINGS

a- Introduction

Earth is one of the oldest buildings materials known to man and will be with us for a long time to come. In Turkish archeological excavations mud-brick is encountered in strata from Neolithic to the 6 th century. The timber reinforcement of the adobe walls has been employed in earthquake prone areas at the time of the Neo-Hittite states dating back many millenniums and is still employed today in an essentially unchanged format.

In Turkey the most common application of earth as a building materiall is in the form of unburned clay bricks used in adobe construction. In very limited areas walls are built by molding of the clayey earth mortar in 0.8 to 1 meter thick continuous horizontal courses an ramming successively. Other application include the use of adobe block as infill material in wood frame structures.

As indicated above, 32% of the rural massonry structures are the adobe masonry. Thus, in Turkey, there are about 1.100.000 adobe rural buildings housing close to 6.000.000 people. The distribution of adobe buildings in the seismic hazard zones of Turkey are indicated in (Table 3.1).

Table 3.1.

Distribution of Adobe Buildings in Seismic Hazard Zones of Turkey.

Seismic Region	Number of Adobe Buildings	Percentage of Adobe Buildings
1. ($I_o \geqslant$ IX MSK)	270.000	24
2. ($I_o =$ VIII MSK)	150.000	14
3. ($I_o =$ VII MSK)	330.000	30
4. ($I_o =$ VI MSK)	230.000	21
5. ($I_o \leqslant$ V MSK)	120.000	11

b- Bearing Elements of Adobe Buildings

The characteristics of the bearing elements of a conventional Turkish adobe (Kerpiç, in Turkish) rural house will briefly be given is this item: Most traditional adobe houses are single story structures with a mudmortar stone masonry foundation and a heavy earth roof supported by unsawed logs.

Adobe wall foundations consist of 1.0 to 1.5 meters deep and 0.5 to 1.5 meters thick stone masonry walls usually built with the same mud mortar used for adobe block.

Adobe walls are built using the same clayey earth mixture as mortar in coursed ashlar bond with 2.5 to 3.0 centimeters thick joints. Wall thicknesses are: (1) 40 centimeters, using single "mother" units, (2) 60 to 70 centimeters, using "mother(x) and "cub(xx) units, and (3) 80 to 100 centimeters, building the inside and outside faces separately and filling inside with rubble. Wall heights rarely exceed 3.0 meters.

Especially in seismic regions the use of wooden tie-beams is common. Tie-beams are usually placed under and above the windows and under the roof. In areas of very low seismicity, such as southeastern Turkey, there are many adobe structures having to tie-beams (Figure 3.1).

In 60 percent of the total adobe building stock heavy flat earth roofs are utilized. The roof is usually supported by unsawed timber beams, or peeled tree trunks of about 10 to 20 centimeters in diameter, spaced at intervals varying from 30 to 60 centimeters. These beams rest on the tie beam at the top of the walls. The bearing length of the beams on the walls may sometimes be limited to 10 to 15 centimeters. On top of these beams a layer of wooden board of about 1.5 to 2.0 centimeters thick or a layer of thin branches of straw mat are placed. A 15 to 20 centimeters thick coat of clayey earth topped by a 3 to 5 centimeters thick impermeable fine clay layer constitutes the main roof insulation.

(x) Larg block units its dimension (25-30)x(30-40)(11-12) centimeters

(xx) Smaller block units its dimension (15-20)x(30-40)x(11-12) centimeters.

After the removal of the first snow a new layer of finer material is added to the roof and the whole roof is passed over by a cylindrical heavy stone (log) thereby thickening the earth roof layer ove the years to the unsafe limits, weighing up to 1.0 ton per square meter (Figure 3.2). The earthen terrace of the roof may have a surrounding stone cornice. In areas where timber is easily available and/or with post-earthquake experience the use of tiled or galvanized sheet metal covered timber roofs have become quite common. Plastering is usually applied to both faces of the wall 8 to 12 months after construction. A finer clayey earth mortar with more straw content is used. The final thin skin may either by clay or white wash (Figure 3.3).

Compared to the existing Turkish design specifications of adobe structures (Prof. M. Yorulmaz, 1981) the most common errors and deviations encountered in practice are as follows:

- Limited capacity and insufficient bearing area of roof beams on the walls.
- Increased thickness of the earth layer on the roof.
- Improperly tied walls at the corners.
- Non-existence or insufficiency of the horizontal tie-beams.
- Too many openings in the walls.
- Poor masonry practices.
- Poor water insulation.
- Poor quality adobe blocks.

In the near future, adobe construction will tent to continue as a craft rather than develop into an engineering practice that can accommodate rational design procedures. The relevant earthquake resistant design codes should attempt to synthesize the time proven practical construction procedures and sound engineering judgement into an applicable adobe construction guideline instead of prescribing the assessment and distribution of lateral seismic forces on adobe structures. Stasfactory performance of adobe structures have usually been witnessed when they were designed and constructed properly.

3.2. CHARACTERISTICS OF STONE MASSONRY BUILDINGS

a- Introduction

Although the stone masonry construction is used for buildings since ancient times, our knowledge on its seismic behaviour is comparatively very recent. The analysis of earthquake damage on such structures indicate deficiencies stemming from the construction practices and from its inherent brittle character. However, these observations also provide input for the assessment of appropriate measures to improve its seismic performance.

In Turkey, despite the extensive use of other construction materials and techniques, stone masonry represents a substantial section of the rural housing. These structures have the poorest earthquake resistance within the buildings stock and has been the main source of casualities after earthquakes.

b- Construction Practices For Rural Stone Masonry Buildings.

The rural stone masonry building construction in Turkey show wide differences depending on the degree of socio-economic development, climatic conditions, masonry and architectural traditions and quality of materials. However the following main types can be differentiated. These types are also being used in post - earthquake intensity assesments in Turkey since 1966.

1) Poor Quality Rural Stone Masonry Structures (Figure 3.4).

These structure encompass rubble or very poorly and randomly sized stone as building materials. The binding material is mostly mud. The wooden tie-beams (hatıl in Turkish) do not exist or if any are haphazardly located. Almost all of these structures are single storey and are simple restangular plan with small spans and openings. Wall thicknesses may reach to 80 cms depending on the climate. Walls are usually lived in two (inner and outher) skins with an infill of rubble. At its worst round and weathered stones from river beds are used without cutting. They are piled on top of each other using thick mud mortar. There are almost no binding stones to hold the two skins of the wall together and there are no wooden tie-beams. The roof construction is usually flat or slightly monopitched with around 30-50 cm earth on planks spanning across the unsawed tree trunks of about 10-20 cm in diameter used as joists with spacing between 30-60 cms. These joists rest directly on the top of the bearing walls, usually the facade and the rear walls. The bearing length of these joists on the walls may sometimes be limited down to 10 cms. After the removal of the first snow a new thin layer of earth is added to the roof and the whole roof is passed over by a heavy stone (log in Turkish) therby thickhening the earth roof.

These structures have the least resistance to ground shaking. The walls can easily collapse causing the fall of heavy roof thereby killing its occupants by trauma and suffocation the limits of damage, heavey damage or collapse are very close and cannot be easily identified. At intensity level of VI (MSK) damage to heavy-damage occurs and the intensity level of VII total collapse starts to take place. At the intensity level of VIII there is total destruction. The earthquake damage statistics in Turkey pertaining to such structures indicate that 30-40 people is killed for each 100 of such hevily-damage or collapsed houses.

2) Medium Quality Rural Stone Masonry Structures (Figures 3.5).

These are 1 or 2 storey buildings having simple rectangular plans with small spans and openings. Better qualities of masonry units and workmanship is used. Stones are shaped to make angular blocks to fit together in courses. Lime or cement-sand mortar is used. Especially in colder climate zones, the thick walls are laid in two seperate skins and the middle cavity is filled with rubble. However the two skins are usually tied together with transverse binding stones at regular intervals. These walls also encompass horizontal timber courses or tie-beams (hatıl, in Turkish) at the foundation, lintel and eaves levels of the exterior walls. These are usually continious around the corners. Flat and timber framed roofs with tile or tin sheet covering are in use depending on the climatic conditions and/or tradition. The connection of roof beams to the walls are accompolished through the wooden tie-beams. For two-storeyed structures the floors are made out of timber. The earthquake damage statistics in Turkey for such structures indicate that about 10-15 lives lost for each 100 of such heavily-damaged or collapsed houses.

3) Good Quality Rural Stone Masonry Structures (Figures 3.6).

The rural stone masonry houses constructed on the basis of earthquake code specifications and lost of the communal buildings in rural areas can be classified as good quality stone masonry structures. These structures usually have walls made out of cut and shaped rectangular stone blocks laid as stable units in proper courses and held in position with good quality cement mortar. Walls can be as thick as 1 m. Reinforced concrete tie (or ring) beams are placed at the foundation, lintel and roof levels tying the whole structure into one stable unit. These structures have suffered little damage consisting of some wall crackings or corner failures even in the epicentral area of large earthquakes in Turkey.

c) Construction Practices of Rubble Stone Masonry Dwellings

An interesting example about the poorest quality of load bearing wall construction has been observed during Erzurum-Kars earthquake October 30,1983.

In that earthquake suffering area, the reason of heavy distruction of dwellings were primarly due to the poor construction quality of the bearing walls. Entire buildings were build everywhere from local stones, and are laid as two skins of stonework with an infill of rubble as a wall % 60-80 cm. thickness (Figure 3.7). However many existing bearing walls of the dwellings were build with simple rubbles and using mud mortar. The masonry consists of small, weathered stones found lying nearby and were used without cutting.

This type of masouny is extremely vulnerable to ground tremors.

As it is wellknown that, on other important feature about the resistance of masounry buildings against earthquake are the behavior of wall-roof junctions. In most building of this area, very weak and interesting junctions can be shown in (Figure. 3.8 - 3.9 - 3.10).

3.3. CHARACTERISTICS OF BRICK MASONRY BUILDINGS

a. Introduction

As we know, the brick buildings are classified under the name of masonry or block structures. This type of buildings resist to external loads, including seismic, by bearing walls. Their walls are built with brick, used as materials.

This type of rural building construction widely used in the large cities or outskirts of these cities. There are also many public buildings such as school buildings, health centers etc... built by government out of brick, in rural areas.

b. Construction Practices of Brick Masonry Buildings

In general, the characteristics of brick masonry buildings can be considered as stone masounry depending that the floor systems in both types are the same.

In Turkey many of the brick masonry buildings have reinforced concrete columms, lintels and tie beams. However columns, and tie beams used,in the walls, are not designed to carry loads, but they are intended as elements which provide the integrity of the buildings.

This type of masonry buildings can be considered as a kind of reinforced masonry, insted of direct use of steel bars as reinforced material.

The reinforcement used in these tie beams and columns are at least four bars of ϕ 10 - ϕ 14 mm with ties of ϕ 6 - ϕ 8 mm bars at intervals of 25 - 40 cm. the cylinder strength of concrete used in this type of beams is around 100 kg/cm^2. The height or number of stories of brick buildings vary from two to five strories depending the earthquake zones. Two stories in first degree and five steries in danger free zones and minimum allowable wall thickness depends again on earthquake zones and height of the buildings.There are also many restrictions on the windov and door opening about their sizes, lacations. Total amount of openings, and the distance between two openings and also the distance between opening and the wall corner. These provisions can be considered as the requirements of Turkish code named "specifications for structures to be built in disaster areas" In general the brick masonry buildings has stone foundation, their walls are built from brick, and has timber roof trusses with reinforced concrete floor slabs and ceilings.

3.4. DYNAMIC CHARACTERISTICS OF MASONRY BUILDINGS

Dynamic characteristics of buildings can be consideret as their natural periods of vibration and damping ratios. These characteristics depend mainly on in plane dimensions and heights of the structures. However the vibrating loads with large amplitudes produce longer periods. In general natural periods of vibrations of masonry buildings are small, and vary approximately between 0.05 - 0.20 second. Considering the emprical formula given for reinforced concrete buildings, the period of vibration for masonry buildings may also be expressed with a similar type of formula, as:

$$T = 0.035\ N \text{ second}$$

and specially for brick masonry buildings, the expression

$$T \simeq 0.05\ N$$

can be used.(where N is the number of stories)However, natural periods of vibration for masonry building shows large variations.

The damping factor of a masonry building is very low (as 2-5 percent). This energy absorption characteristics of masonry buildings depend on period of vibration and the deformation (rigidity) or the stress level of bearing elements.

Damping characteristic and period of masonry building increase very significantly depending on the severity of damages, specially the formation of large cracks. As high as 300 percent increase in the period has been observed in a case of a masonry building damaged in Çaldıran Earthquake 1976.

3.5. CHARACTERISTICS OF TIMBER FRAME BUILDING

a- Introduction

The timber frame buildings and structures has been widely used in ancient times of Turkish history. During these days timber was frequently used as the basic construction material to built devellings and buildings, besides these the state and office buildings and mosques have been built as stone masonry.

In the city Istanbul the magnificient architectural design samples of timber buildings has abundently been used. The traditional construction techniques used in timber frame buildings were very successful. However, in contrast of the stone masonry, timber frame structures may adequately resist earthquake forces. But, susceptibility the fire after earthquake appears as an important deficiency.

b. Construction Practices of Timber Frame Building

b.1. Further Classification of timber frame building.

As have considered in the second section timber framed buildings has mainly been classified as filled wall (Hımış in Turkish) and Hollow (Empty) wall. Hımış, Filled wal type is a timber frame type with its wall filled up with adobe blocks, stone, bricks or concrete blocks. The framing may be formed from sawn timber or it may be of unsawn round tree trunks.

The second type of classified timber frame buildings plastered emply wall (Bağdadi in Turkish) are widely used in comparison with the wood plated type timber frame buildings. During the construction of Bağdadi type timber frame building the inner and outher faces of the basic frame are coverede with wooden lathes nailed to the framing system. The center-to-center distance between the lathes is about 5 cm. The inner space between the lathes my be empty (x). There is another type of timber frame not so frequently encountered in

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(x) Sometime filled up with adobe, brick, stone like Hımış, or with large size pebbles, pine cones or with pieces of tree trunks.

cities but more frequently in rural areas close to forests. This is called ÇİZEM, DİZEME or DOKU (in Turkish) In this type the wall framing consist of timber logs cut into two. The filler material of the walls is again timber. These three main types of timber frame buildings are shown in deail in (Figure 3.11).

b.2. Framing

In timber frame type of buildings the elements of the frame may be of various forms. Logs may be used without any treatment and even logs of crooked shape may be employed. Generally the quality of timber is not good in rural areas where as better quality of timber is used in cities. Timber is not dried in kilns and generally has a high water cantent. It dries naturally after it is placed in buildings and thus, large shrinkage cracks and weakening of nailed connections are very common. Pine wood is the most commont type used in building. Chemical treatment of timber against effects of fungi and insects is very rare. The vertical and diagonal elements of typical frames are 10 x 10 cm and 5 x 10 cm in cross section.

b.3. Foundations

The foundations of timber frame buildings are generally poor. If the ground water level is high, there is a need to protect the timber from moisture coming from the soil. In some buildings the timber framing rests on foundation stones. These are uncut large sized rubble stones gathered from the field. Buildings with this kind of foundation behaved very poorly during the 1944 and 1967 earthquakes which had occured on the North Anatolian Fault. Collapse of timber frame houses because of poor foundations should be expected more frequently in rural areas. Timber frame houses built in cities usually are 2 or 3 stories high and have continous foundation walls around. Their collapse during an earthquake due to foundation failure or due to poor connection to foundations seems less probable.

b.4. Exterior Finish

Protection of timber against environmental effects is required in order to increase the durability of timber frame houses. Most of the timber frame type of buildings have their exterior surfaces covered by a plaster of lime and sand mortar with some cement and on the whole, they appear as masonry buildings. The DİZEM type timber frame buildings do not have any protection on their surface. Formerly timber frame buildings built in larger cities such as Istanbul, Bursa, et. had their exterior covered with timber planks and paint. This was the tradition in late XIX and early XX centuries. The preference of a mortar cover is due to the fact that paint is more expensive and less durable as well as the fact that a layer of mortar provides some heat insulation as well.

c. Dynamic Characteristics of Timber Frame Building

During the field investigation made in 1981 in Bolu area the periods of vibration of several timber frame buildings were measured. They had square or nearly square plan shapes. Their story heights are around 3 meters. Plan areas do not vary greatly and they are about 100 m2 plus or minus 24 m2. Damping of one building was measured to be about 5-6 percent of the critical. Usually because of the nearly square shape of buildings the periods do not vary significantly about the two major axes of the buildings. The measured periods of vibration are given (Figure 3.12). The average period of two-story timber frame buildings is 0.354_0.051, while for three story buildings it is 0.382-0.039 seconds. There appears to be a noticeable increase in the average period with increase in story number. For parctical purposes, timber frame buildings of two and three stories can be considered having periods in the range of 0.3 to 0.4 seconds.

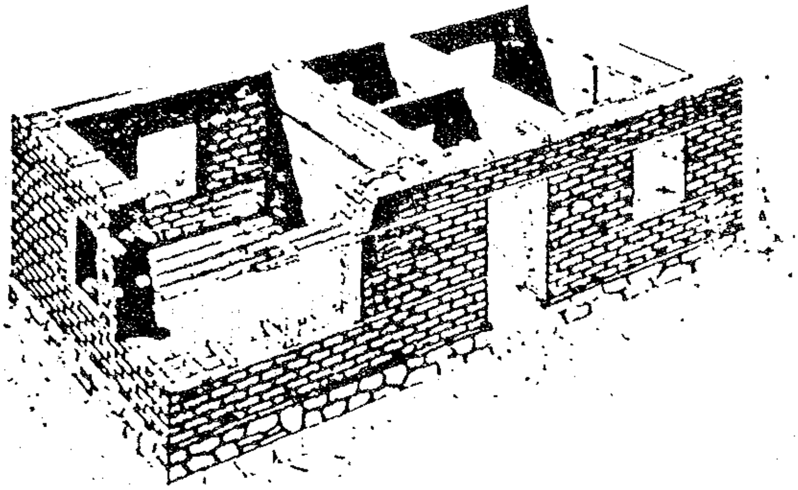


Figure: 3.1

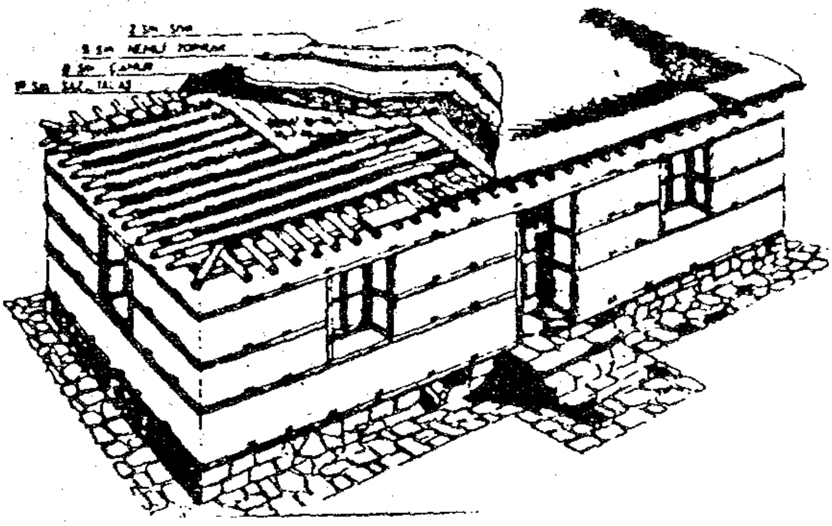


Figure: 3.2

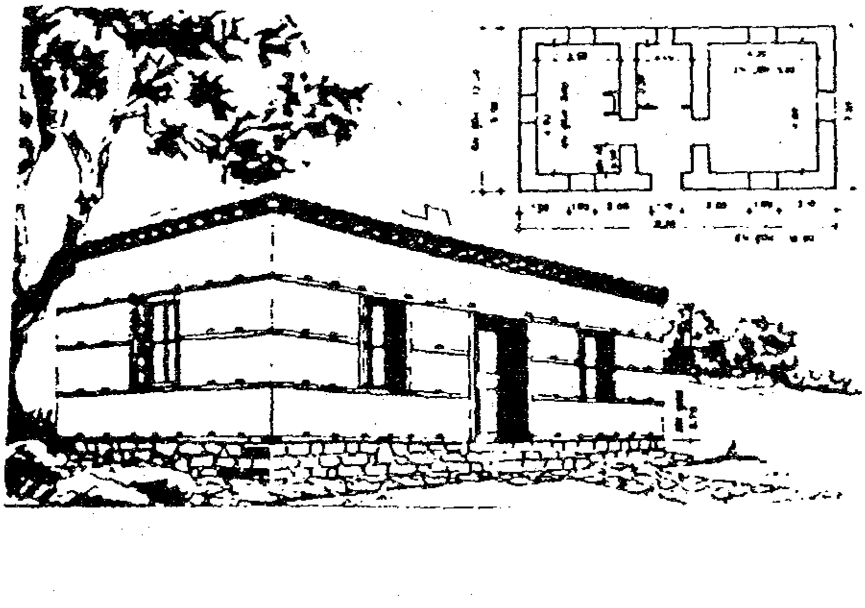
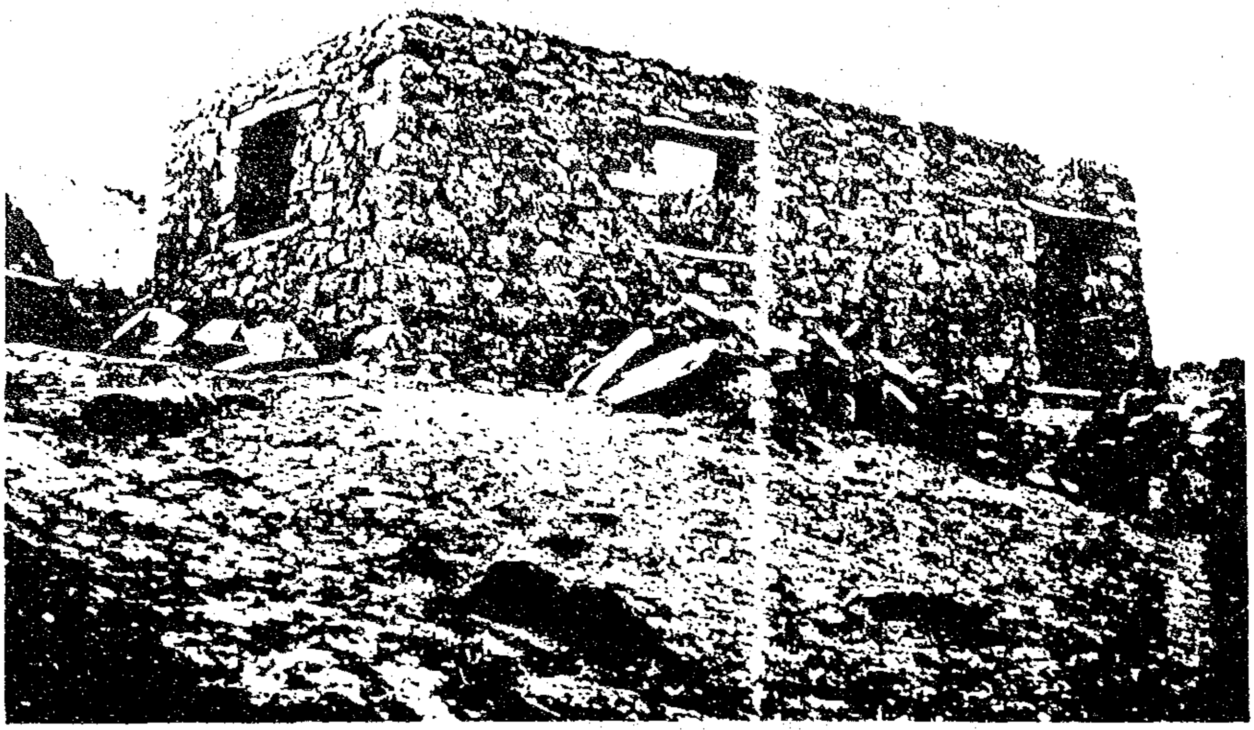


Figure: 3.3.



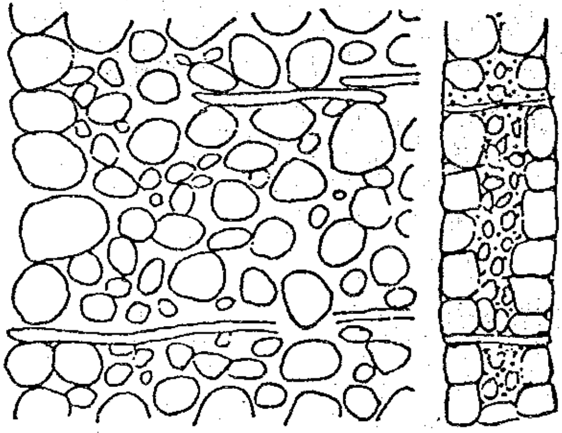


Figure: 3.4. A typical poor quality stone masonry building and the wall construction type.

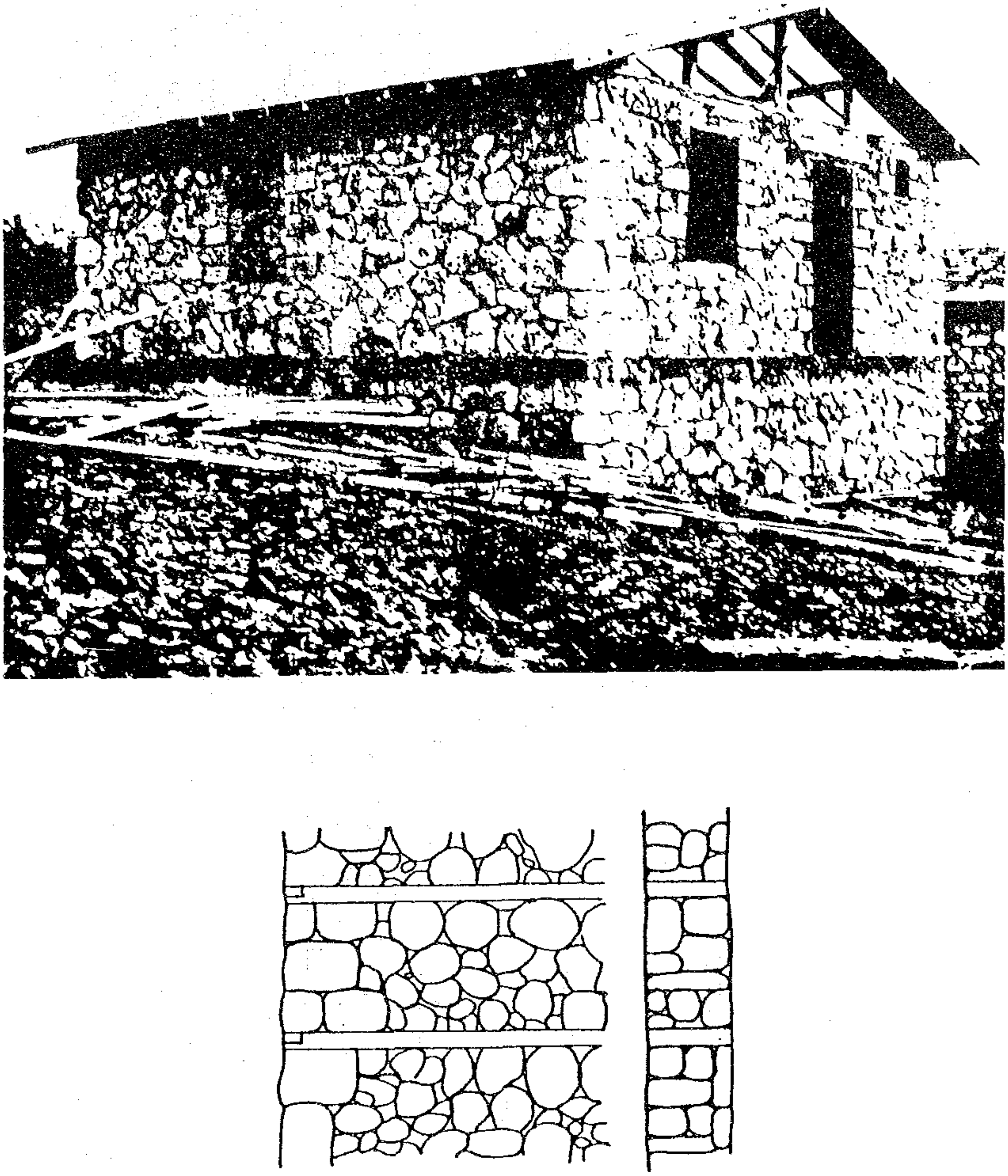
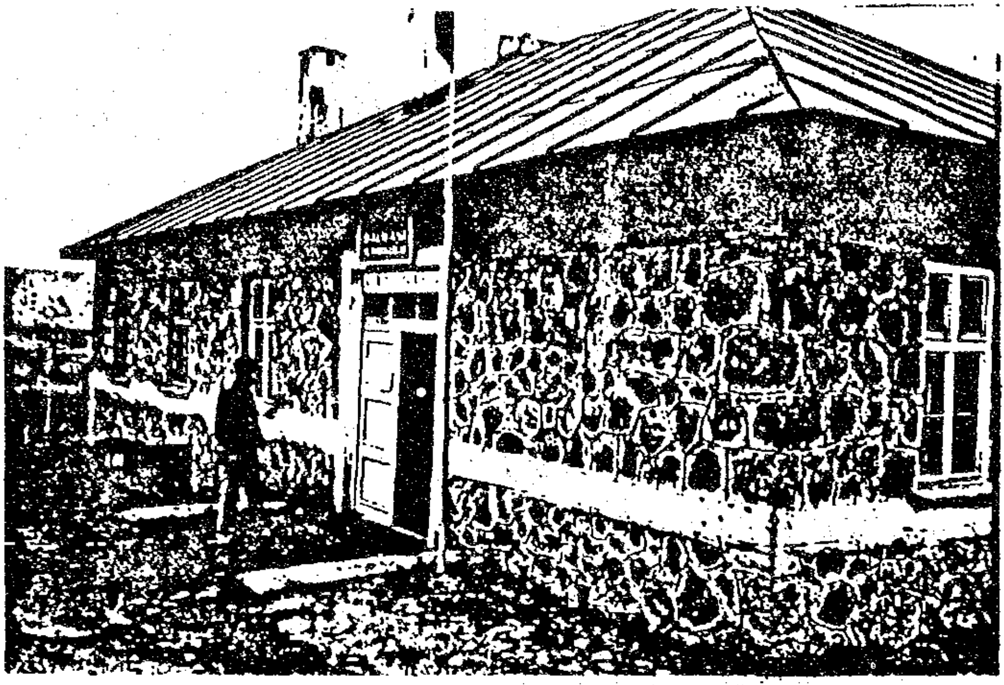


Figure: 3.5. A typical medium quality stone masonry building and the wall construction type.



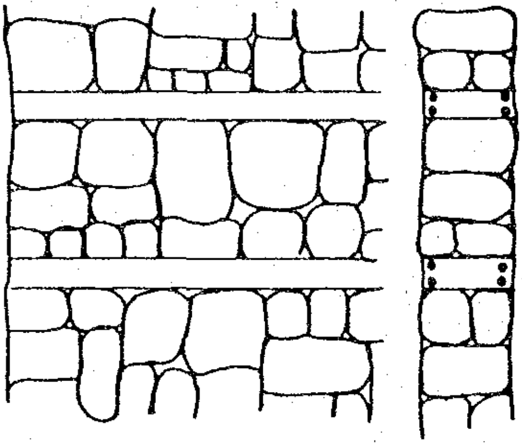
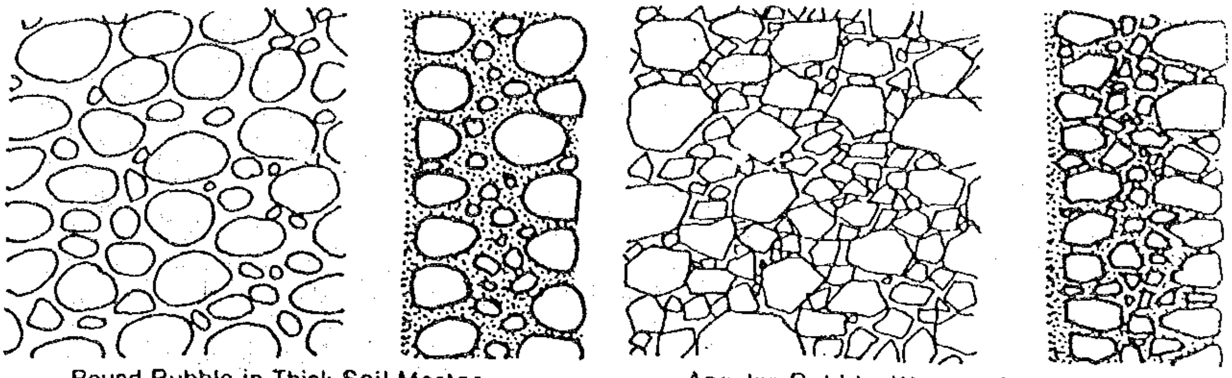


Figure: 3.6. A typical good quality stone masonry building and wall construction type



Round Rubble in Thick Soil Mortar

Angular Rubble Wedged Together

Figure: 3.7. Example of Rubble stone walls.

1. Small overhanging eaves parapet
2. Stonework pivots outwards
3. Tapering faces behind square external face, wedged into postion
4. Hidden beam bearing decaying
5. Softening roof soil allows timber eaves to pivot upwards
6. Parapet hollow channels water seepage into walls
7. Pivoting eaves causes cracks in soil roof
8. Poor bonding of new stone facade onto old wall core

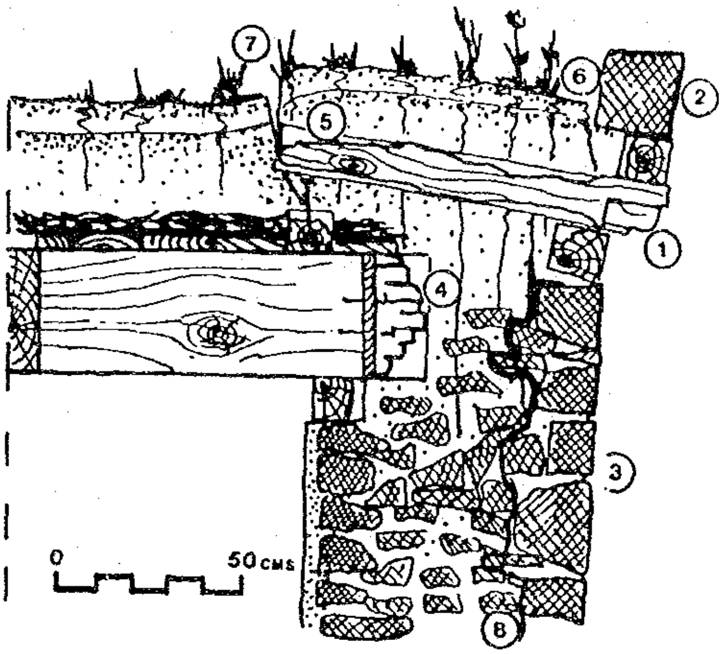
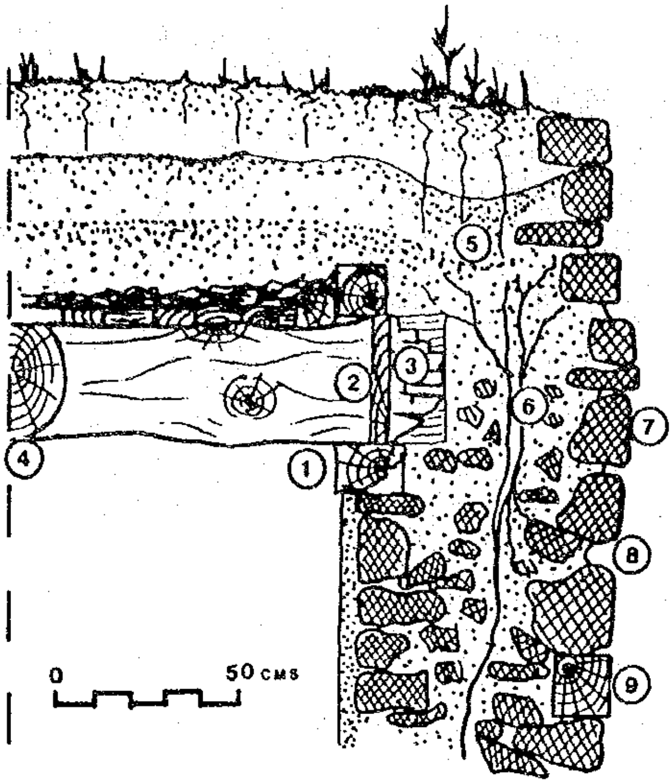
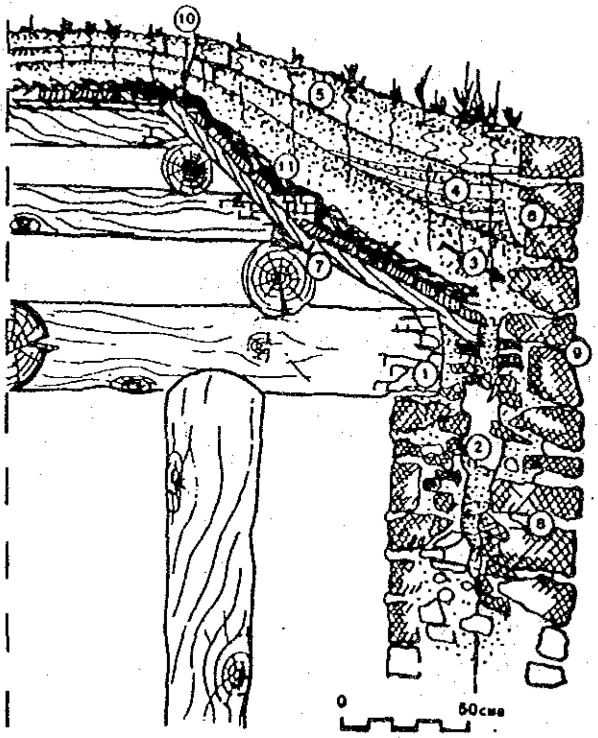


Figure: 3.8. Typical Traditional house with dressed-stone facade. Roof-wall junction.



1. Small wall plate often decayed
2. Infill panel stops ventilation
3. Decaying beam bearing
4. Sagging beams cause roof depression
5. Wall movements and water seepage break up roof fabric
6. Separation of wall skins and water seepage causes cracks and cavities.
7. Outward bulging wall
8. Soil mortar washed out by surface water
9. Hatil on outside of wall only

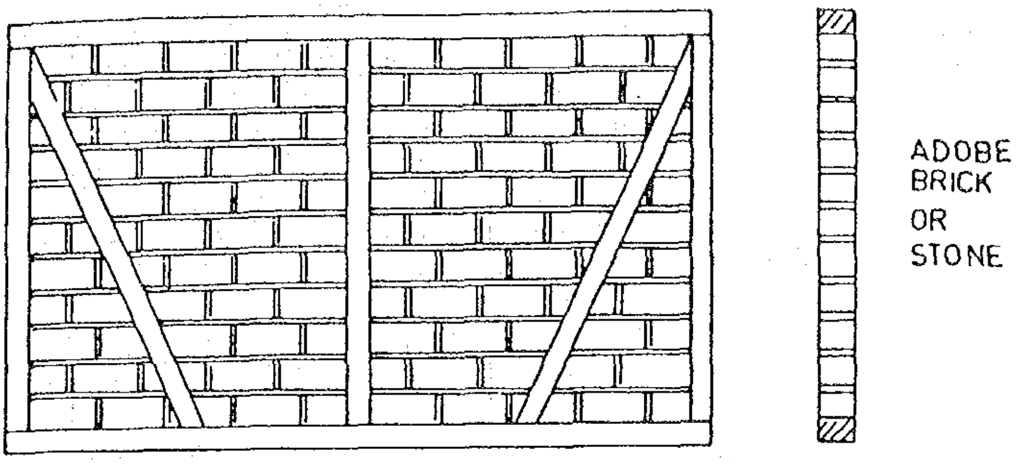
Figure: 3.9. Typical Traditional house. Roof-wall junction.



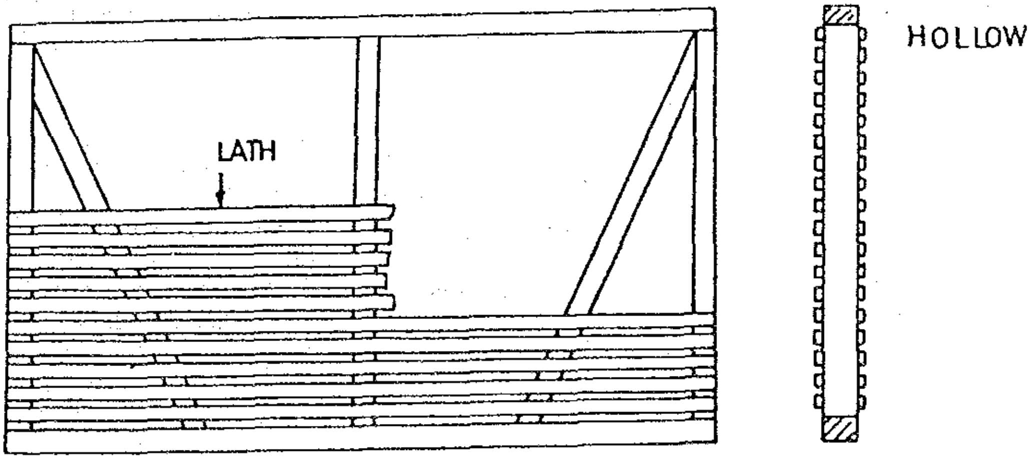
1. Timber decay from soil contact
2. Skin separation and water seepage
3. Lateral thrusting of roof soil
4. Additional soil layers from siltation
5. Grass root development binding the fabric
6. Additional facade stones poorly keyed back
7. Mortar washed out
8. Secondary joists not attached
9. Outward bowing wall
10. Cracks from soil creep
11. Decaying vegetation matting

Figure: 3.10. Typical Animal Shed construction, roof-wall junction

a) HIMIŞ TYPE



b) BAĞDADİ TYPE



c) DİZEME TYPE

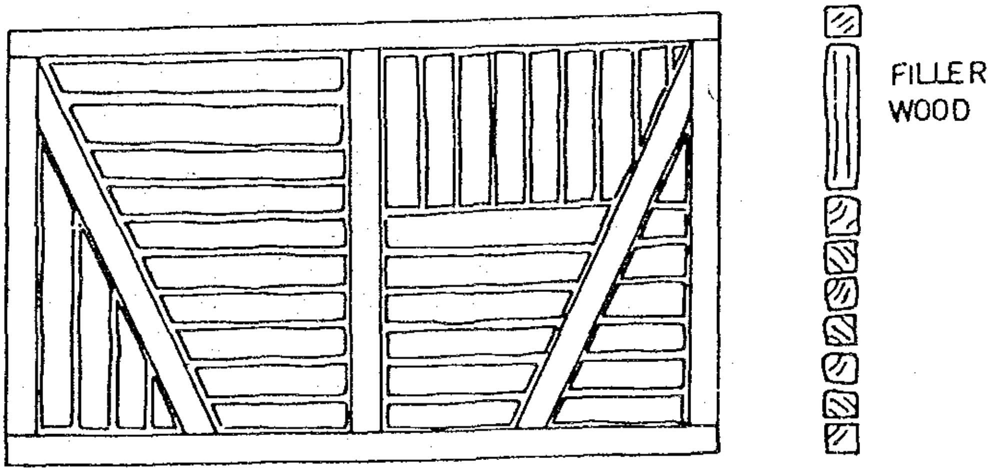


Figure:3.11. Types of timber frame

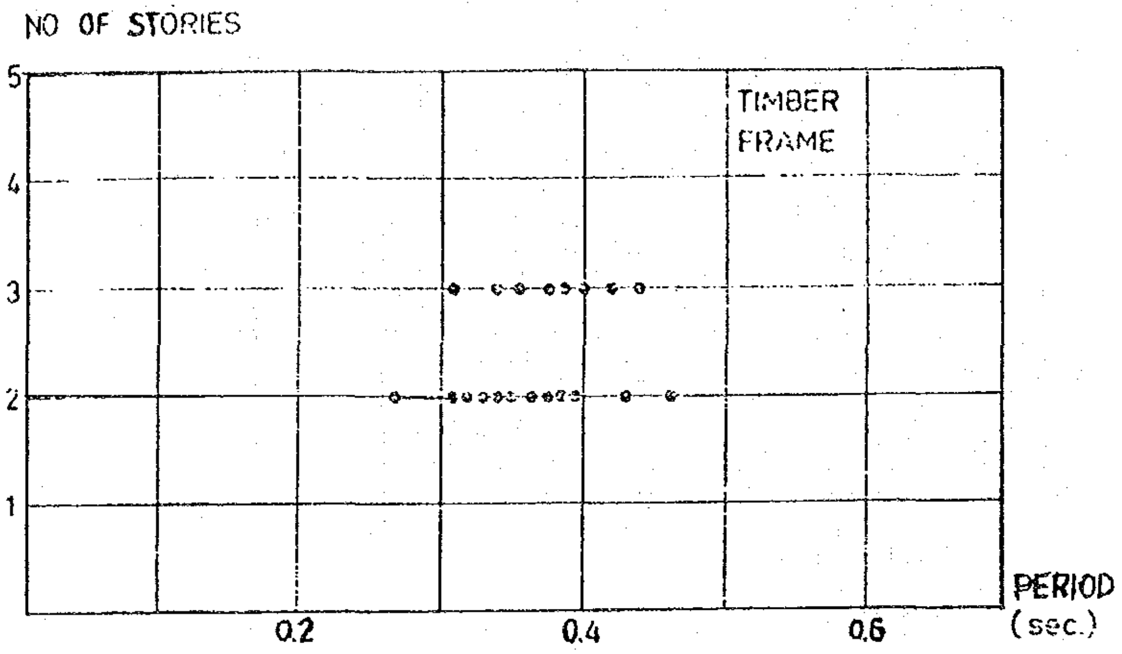


Figure: 3.12. Measured Periods of Timber Framed Buildings.

4. OBSERVED EARTHQUAKE DAMAGES AND PERFORMANCES OF RURAL BUILDINGS

4.1. STATISTICAL INVESTGATIONS

4.2. THE FACTORS AFFECTING THE EARTHQUAKE PERFORMANCES OF RURAL BUILDINGS AND THEIR DAMAGES

- 4.2.1. Adabo Masonry Buildings
- 4.2.2. Stone Masonry Buildings
- 4.2.3. Damage Characteristics Of Stone Masonry Buildings
- 4.2.4. Bric Masonry Buildings
- 4.2.5. Timber Frame Buildings
- 4.2.6. Damage Performances of Rural Buildings

4. OBSERVED EARTHQUAKE DAMAGES AND PERFORMANCES OF RURAL BUILDINGS

4.1. STATISTICAL INVESTIGATIONS

In general easthern part of Turkey has suffered mostly from destructive earthquakes. This area is also economically less developed, in comparison to the other earthquake prone areas of Turkey. The severe climatic conditions of the area and lack of financial capabilities, the people are forced to build their own houses with local earthen materials and stones (mostly unshaped rubble stone)

Damage statistics of rural structures pertaining to earthquakes since 1966 are indicated in (Table 4.1) The data is obtained from the official damage assesment reports of the Earthquake Research Division of the ministry. Only intensity areas of VII MSK and larger have been considered.

Table 4.1. Earthquake Damage Statistics of Rural Structures

August 19, 1966 Varto Earthquake (MS = 6.9, I_o = IX MSK)

T.S.	T.P	C.P.	M.D.P.	L.D.P.
Stone Masonry	85%	75%	20%	5%
Adobe Masonry	10%	50%	40%	10%
Other	5%	70%	25%	5%

July 22, 1967 Adapazarı Earthquake (MS=7.2, I_o = IX MSK)

T.S.	T.P.	C.P.	M.D.P.	L.D.P.
Wooden Frame	85%	55%	30%	15%
Adobe Masonry	5%	65%	20%	15%
Other	10%	20%	25%	55%

March 28,1970 Gediz Earthquake (MS= 7.3,I_o = IX MSK)

T.S.	T.P.	C.P.	M.D.P.	L.D.P.
Wooden Frame (Hımış)	40%	80%	18%	2%
Woodem Frame(Bağdadi)	50%	10%	40%	50%
Adobe Masonry	5%	30%	50%	20%
Other	5%	40%	35%	25%

May 12, 1971 Burdur Earthquake (MS= 6.2, I_o = VIII MSK)

T.S.	T.P.	C.P.	M.D.P.	L.D.P.
Stone Masonry	40%	55%	30%	15%
Adobe Masonry	50%	35%	35%	30%
Other	5%	40%	40%	20%

May 22, 1971 Burdur Earthquake (MS= 6.9, I_o = VIII MSK)

T.S.	T.P.	C.P.	M.D.P.	L.D.P.
Stone Masonry	80%	75%	20%	5%
Adobe Masonry	15%	40%	50%	10%
Other	5%	40%	45%	15%

September 6, 1975 Lice Earthquake (MS = 6.9, I_o = VIII MSK)

T.S.	T.P.	C.P.	M.D.P.	L.D.P.
Stone Masonry	85%	65%	30%	5%
Adobe Masonry	10%	50%	40%	10%
Other	5%	–	60%	40%

November 24, 1976 Çaldıran Earthquake (MS = 7.2, I_o = IX MSK)

T.S.	T.P.	C.P.	M.D.P.	L.D.P.
Stone Masonry	75%	75%	15%	10%
Adobe Masonry	20%	60%	30%	10%
Other	5%	25%	25%	50%

October 30, 1983 Erzurum Earthquake (MS = 7.1, I_o = VIII MSK)

T.S.	T.P.	C.P.	M.D.P.	L.D.P.
Stone Masonry	95%	50%	30%	20%
Adobe Masonry	2%	30%	40%	30%
Other	3	20%	30%	50%

Legend:
T.S.: Type of Sturcture
T.P. Percentage of the Type in $I \geqslant$ VII MSK area
C.P. Percentage of Heavily Damaged or Collapsed Structures
M.D.P. Percentage of Medium Damaged Structures
L.D.P. Percentage of lightly Damaged Structures.

These tables indicate that for site intensities of VIII MSK or greater about 45 percent of the adobe structures collapse or experinence heavy damage, 37 percent experience medium damage, and 18 percent experience light or no damage. The respective figures for stone masonry structures are 70,22, and 8 percent. Although the number of adobe and other structures involved in these earthquakes are quite limited and some of them have timber roofs one can say, in general, that the earthquake performance of the adobe structures exceed that of the stone masonry structures. It should be noted that a considerable percentage of stone masonry rural structures include rubblestones with mud mortar.

The casualty statistics also endorse this findings. Unpublished studies of the Earthquake Research Division of the Ministry of Publicworks and Resettlement indicate that, on the average, 11 lives are lost per 100 collapsed and/or heavily damaged adobe structures with flat earth roofs. The respective figure for stone masonry with mud mortar and flat earth roof is 26.

The official damage statistics have also been compiled by the Earthquake Research Division to indicate the damage of different rural structure clases in the meizoseismal area for different earthquake magnitudes. Two classes of rural structures are considered. The "Type A" rural structures encompass the adobe and mud-mortar stone masonry structures with heavy earth roofs and no tie-beams, whereas the "Type B" rural structures include stone masonry structures with lime or cement mortar and adobe structures both of them with thin earth or tiled timber roofs. Results are provided in Table (4.2)

The data indicated pertain to the structural damage statistics within approximately a 20 kilometer radius of the epicenter.

Table 4.2. Damage Statistics in the Epicentral Area of Earthquakes

M S	STRUCTURAL CLASSIFICATION	PERCENTAGE OF COLLAPSED STRUCTURES	PERCANTAGE OF STRUCTURES BEYOND REPAIR	PERCANTAGE OF STRUCTURES MEDIUM OR LIGHT DAMAGE
>	A	80	20	-
6.9	B	50	30	20
6.8	A	50	30	20
6.3	B	20	30	50
6.2.	A	20	30	40
5.7	B	5	15	80
5.6	A	10	20	70
4.9	B	-	10	90
	A	5	10	85
4.8	B	-	5	95

As may be seen from Table (4.2) the earthquake performance of adobe and stone masonry structures are mainly controlled by the weight of the roof and the presence of well constructed tie-beams.

4.2. THE FACTORS AFFECTING THE EARTHQUAKE PERFORMANCES OF RURAL BUILDINGS AND THEIR DEMAGES

4.2.1. Adabo Masonry Buildings

The following factors can be listed as follows:

- Limited bearing area of the roof beams subjected to heavy roof, loads creating bearing and shear failure of adobe walls underneath

- Insufficient connection of roof beams to the adobe walls. The roof cannot act as a rigid diaphragm and allows differential movement among walls leading to the collapse of the roof and/or walls. Out of plane walls behave like cantilever beams.

- Excessive wall openings leaving insufficient wall areas to resist lateral shear, leading to shear (diagonal tension) failures.

- Lack or improper construction of tie-beams and/or poor masonry practice of the corner connections of the walls causing separation of walls at the corners.

- Lack of structural symmetry either in plan or in the amount of openings.
- Dificient bedding of lintels above windows.
- Openings too close to the corners.
- Walls too high or too long between supports.

4.2.2. STONE MESONRY BUILDINGS

Stone masonry buildings, being an inherently rigid and brittle type of structure, does not exhibit a wide spectrum of modes and degrees of failure. The official damage classification guidelines of the Earthquake Research Division of the Ministry of Public Works and Settlement identify the following classes of damage for such structures.

- Light Damage: few and thin craks.
- Medium Damage: widespread cracking of walls that can effect the load carrying capacity of the structure.
- Heavy Damage : gaps in walls, failure of tie-beams, collapse of and/or walls.
- Total Collapse.

Earthquake damage statistics of rural stone masonry structures are provided in (Table 4.3). The data is compiled from the official damage assessment reports of the Earthquake Research Division of thi Ministry

Table 4.3. Earthquake Damage Statistics for Rural Stone Masonry Structures.

- Poor Quality Rural Stone Masonry Structures

Damage Classification	Intensity (MSK)				
	V	VI	VII	VIII	IX and Larger
Total Collapse	% 5	% 10	%15	%30	%75
Heavy Damage	%10	%20	%30	%40	%20
No or Repairable Damage	%85	%70	%55	%30	% 5

- Medium Quality Rural Stone Masonry Structures

Damage Classification	Itensity (MSK)				
	V	VI	VII	VIII	IX and Larger
Total Collapse	–	–	% 5	%10	%35
Heavy Damage	% 2	% 5	%20	%30	%45
No or Repairable Damage	%98	%95	%75	%60	%20

- Good Quality Rural Stone Masonry Structures (Satisfying Earthquake Code Requirements)

Damage Classification	Itensity (MSK)				
	V	VI	VII	VIII	IX and Larger
Total Collapse	–	–	–	% 2	%25
Heavy Damage	–	–	%10	%15	%50
No or Repairable Damage	%100	%100	%90	%83	%25

Apart from the poor stone masonry qualities, in general, the factors affecting the earthquake performance of rural stone masonry structures can be listed as follows:

- Disintegration of the whole structure due to very poor mortar quality.

- Insufficient connection of roof beams to the bearing walls. The roff cannot act as a rigid diaphragm and allows for differential movement and contilevered plate action among walls leading to the collapse of the walls and the roof.

- Idependently behaving double skinned bearing walls. The walls cannot act as one single unit since the inner and outer skins do not have any or enough tarnswerse connection. At the best the outer skin collapsed outwards due to plate action. At the worst whole wall and the roof collapses.

- Lack or improper construction of tie-beams. The in-plane behaviour of the walls does not have any ductility. The diagonal tension craks can start and grow very easily leading to seperation and collapse.

- Lack or improper construction of corner connections between joining walls. Walls behave independently with out-of-plane cantilever action leading to corner seperations and to eventual collapse.

- Excessive wall openings leaving insufficient wall areas to resist lateral shear and therby causing diagonal-tension type failures.

4.2.3. DAMAGE CHARACTERISTICS OF STONE MASONRY (RUBBLE STONE MASONRY) BUILDINGS

The rubble stone masonry can be considered as an example of poor quality of stone masouny, which has abundantly encountered in many villages of Horasan in Erzurum - Kars Earthquake October 30 1983.

In general the owner-built houses constructed with local unshaped rubble stone and traditional workmanship were the worst affected buildings type in the area.
The damage characteristics of a stone masonry, mostly rubble stone masonry, can be assessed trough four different phases.
The four phases of damage pattern of load bearing rubble stone masonry illustrated in (Figure 4.1).

This description of the damages of this type stone masonry houses has been adopted from coburn and Hughes (1984) paper. It is understood that the succesive damag patterne of stone masounry, generally, comprises well defined four progressive phases as:

a- Reactivation of existing weaknesses.
b- Structural seperation
c- Roof collapse
d- Disintegration

these phases and its details can clearly be observed in (Figure 4.1)

By examining the characteristic modes of failure, they have concluded that loss of strength is initiated by the reactivation of existing weaknesses in the wall construction possibly caused by earlier earthquakes; followed by the separation of the structure into separate components oscillating independently. Collapse of one or more wall elements or the failure of the bearing of the roof on its supporting walls then follows. In this process, the critical elements are:

a- The integrity of the wall construction
b- The wall-to-wall connections
c- The out-of-plane bending strength of the wall
d- The wall -to-roof connection

They have also stated that out-of-plane wall strength needs to be considered first in estimating and improving seismic resistance of stone masonry buildings.

4.2.4. BRICK MASONRY BUILDINGS

The brick masonry constructions can be considered as a subclassified item of masonry constructions, however, the damage patterne of brick masonry shows some differences frome the other masonry types. First of all a series of crack patterns can be observed clearly in comparison to the other masonry.

Brick masonry buildings start to have cracks in their walls at an MSK intensity of V-VI. If the intensity is higher, which may be due to earthquakes of longer duration, the cracks widen and the wall is weakened. The wall begins to loose its vertical load carrying capacity also. The X-shaped cracks due to lateral forces may be followed by vertically oriented cracks due to decreased vertical load carrying capacity of the wall. The occurence of vertical cracking following the deterioration of the brick wall by lateral earthquake forces is seen in buildings having walls with large door and/or window openings. In Figures-4.2 various crack formations depending on the shape, width and location of opennings are pesented. A relatively 'well' designed brick masonry building can withstand the Intensities of VIII-IX with serious and irreparable damage, but it will probably have to be demolished. The presence of tie beams and columns greatly improves the earthquake behaviour of brick masonry buildings. A 'well" designed brick masonry building should have openings whose total length is less than 40 percent of the total length of the buildings. The presence of sufficient amount of solid walls between two openings and between an opening and the corner of the building will also increase earthquake resistance of the building.

Over the years it wass learned through observations of earthquake damage that the presence of reinforced concrete slab or roof trusses of sufficient rigidity are very effective in tieing all the walls together and decrasing earthquake damage. Poorly connected walls cause damages in the walls as shown in Figure 4.3. Proper connection of walls at the corners are also important. In Figure 4.4. types of corner damage in masonry buildings are given.

4.2.5. TIMBER FRAME BUILDINGS

There are several factors which govern the earthquake performance of timber frame bulidings. It seems that age is the most important factor along with the connection details of the frame to the foundation. In Turkey the timber frame buildings are getting older. That is the percentage of timber frame buildings built within the last 10-20 years are very few compared to timber frame buildings of 40 or more years old.Even in forest areas of Turkey people are not built timber buildings as many as in the past.

In timber areas there is also high humidity which accelerates the deterioration of timber. The strength of connections in the frame is effected by the creep and shrinkage in timber. In addition, because the people in Turkey nowadays prefer to live in masonry and reinforced concrete apartment houses, the timber frame buildings which require good maintenance are not looked after properly. They are rather treated as buildings the majority of which will be replaced in the nex 10-20 years. An earthquake which may occur in the mean time may find many neglected timber frame buildings in cities formerly composed of timber frame houses. Another factor of damage which should be considered in case of an earthquake is fire. During the 1970 Gediz Earthquake a whole district of Gediz town was destroyed by fire, while the whole village of Akçaalan (population 2500) burnt down. In urban areas, like large cities Bursa and Kütahya nowadays there are still districts conposed of timber frame buildings and there may be few individual timber frame buildings in old districts converted to reinforced concrete and brick masonry buildings.

The timber frame buildings with brick and stone veneers are also common. Usually these surface walls fall down since they are not connected to the frames. The filler materials in the wall framing also fall down easilly. The nextstage of damage is the loosening of the connectinos and breaking up of some of the connections leading to the collapse. Since timber frame buildings are rather flexible, their lateral deflections during an earthquake may cause secondary moments and whole building may overturn. Single story timber houses without proper foundations may shift or rotate at their base or fall of their foundations and the framing may disintegrate.

It is observed that in earthquakes BAĞDADİ houses behave much better than HIMIŞ houses. Both types loose their surface mortar layer very early in the quake. But BAĞDADİ type is generally lighter and the numereous wooden lathes nailed on the framing provide considerably high damping and energy absorption to the structure.

4.2.6. DAMAGE PERFORMANCES OF RURAL BUILDINGS

As we may know that, the houses in rural areas of Turkey has already been classified in Part 2 as block structurs and frame structures; including timber frame houses as Bağdadi, Hımış and masonry houses, adobe block, brick, concrete blocks and stone used as materials; In Turkey the main and most effective factor that causes damage of rural houses is their roofing systems-masonry houses with reinforced concrete slabs and timber roof trusses always behaves better than flat earth roofs.

The type of morter used in stone masonry houses is also effective in preventing or limiting of damage. Regarding these characteristic and other important factors which are already mentioned, before, the rural houses can be classified as, well constructed and poorly constructed buildings.

The damage behavior of rural houses may be considered in two distinct groups which can roughly be proposed as: Timber frame buildings, brick buildings stone masonry buildings with cement and lime morter and with reinforced concrete slabs, both satisfying code requirements, Hımış buildings of well maintanied should be classified as well constructed rural buildings.

The rubble stone masonry buildings either with flat earth roofs or timber trusses brick buildings with timber floor and roofs, and alike, shoold be classified as "poorly constructed" buildings.
The damage ratio of these two types buildings are given in (Figure 4.5) and (Figure 4.6). Generally for the damage raito of timber frame buildings the curves given in(Figure 4.5)can be used.

But for brick masonry buildings curves given in Figure 4.5 and Figure 4.6 can be used; depending on the well made or poorly made brick masonry buildings.

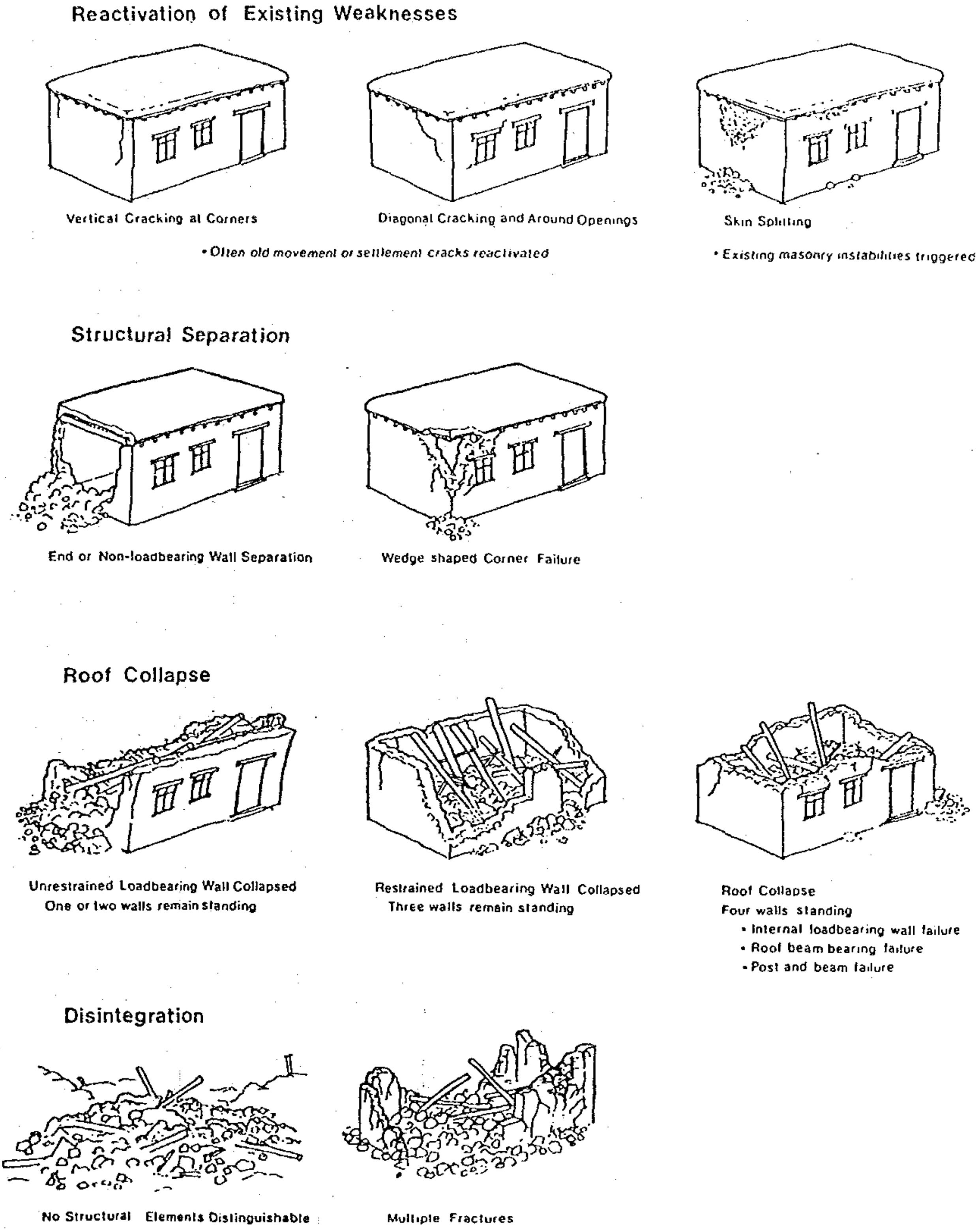
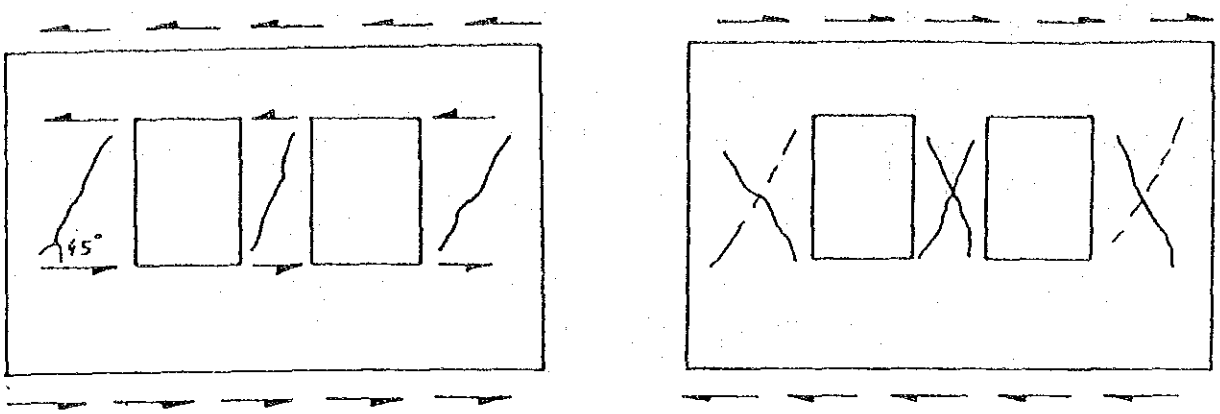


Figure 4.1. Damage characteristics of traditional houses.



(A) (B)

Diagonal Tension Cracking in Brick Walls

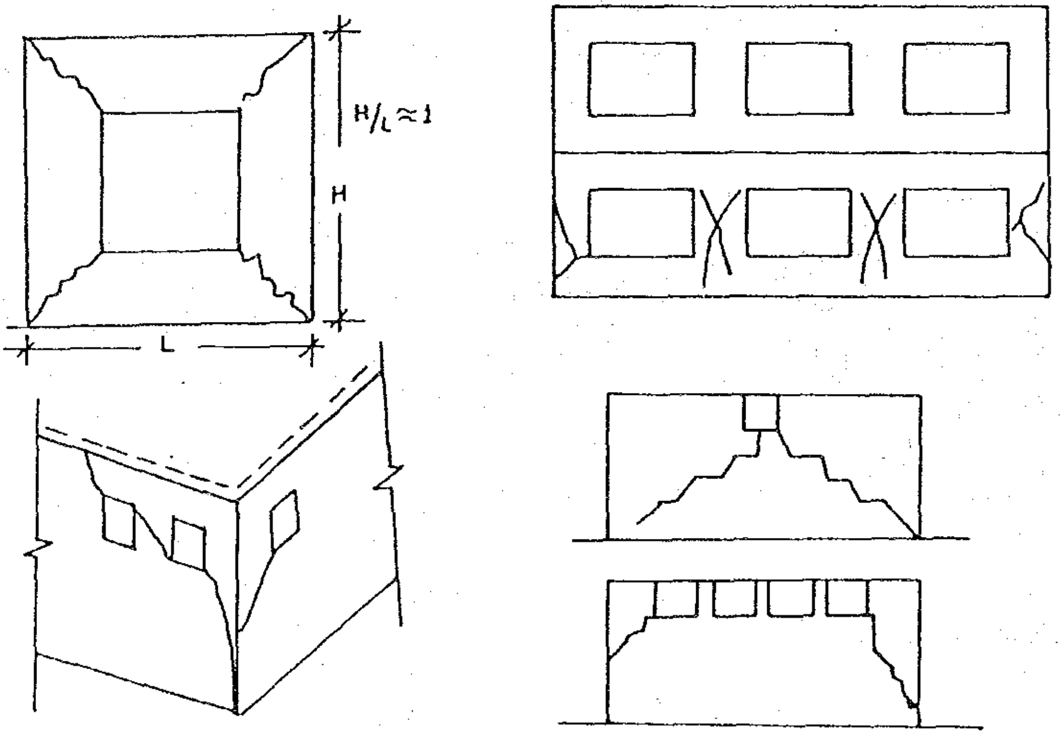
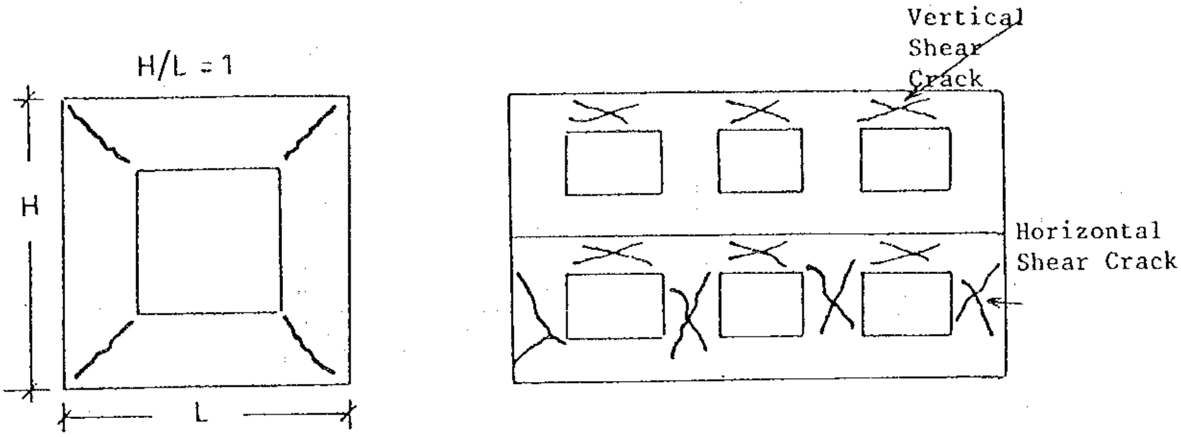
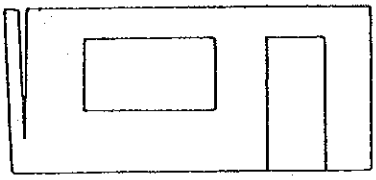


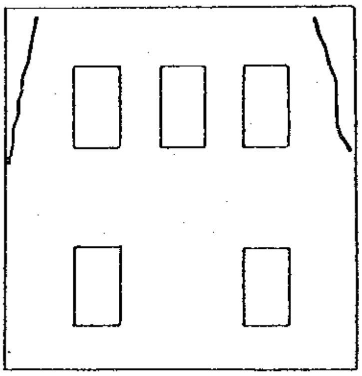
Figure 4.2. Vaious forms of earthquake crack formation in brick walls

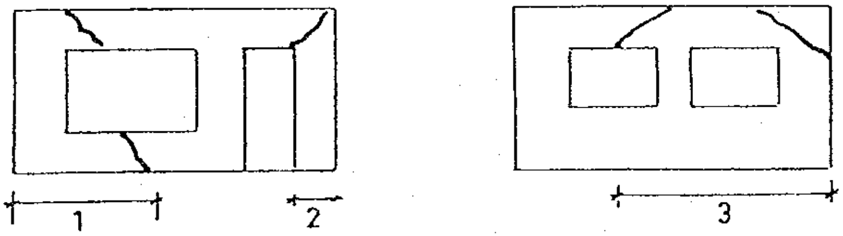


a) Shear Cracking in walls Due to Earthquakes



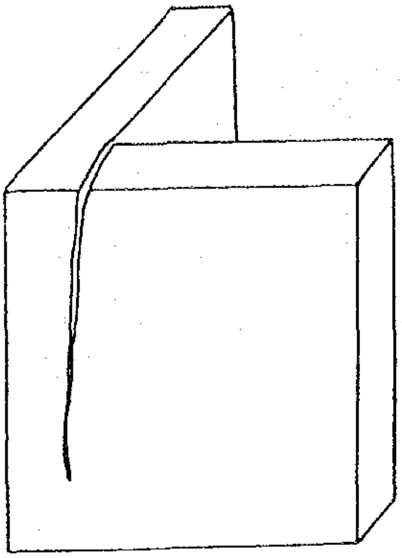
b) Cracking in walls with improper Connections



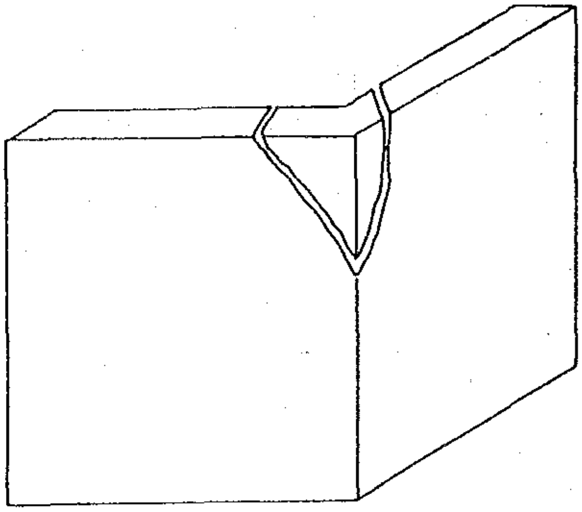


c) Settlement Cracks in Brick Masonry Buildings

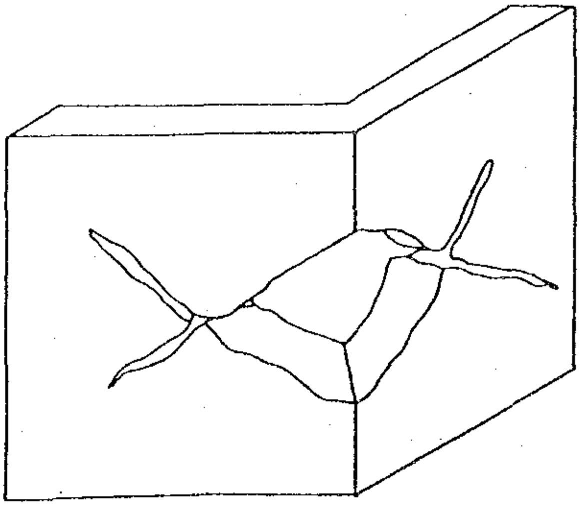
Figure: 4.3. Cracks in Brick masonry buildings.



a) Damage in a Poorly
Connected Corner
of a Brick Masonry
Building



b) Corner Damage in a
Masonry Building
Having a Flexible
Roof System



c) Corner Damage in a Brick
Masonry Building due to
Large Earthquake Forces

Figure 4.4. Corner damage types in brick masonry building

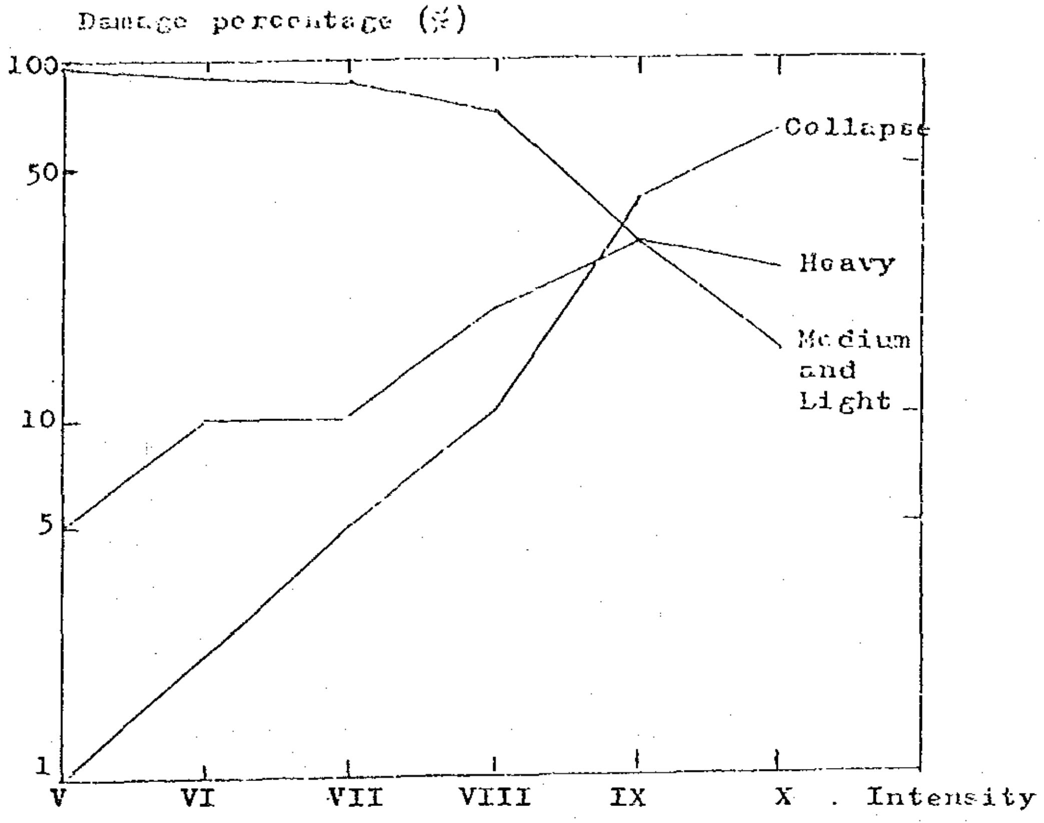


Figure 4.5. Damage Ratio for well constructed Rural Houses

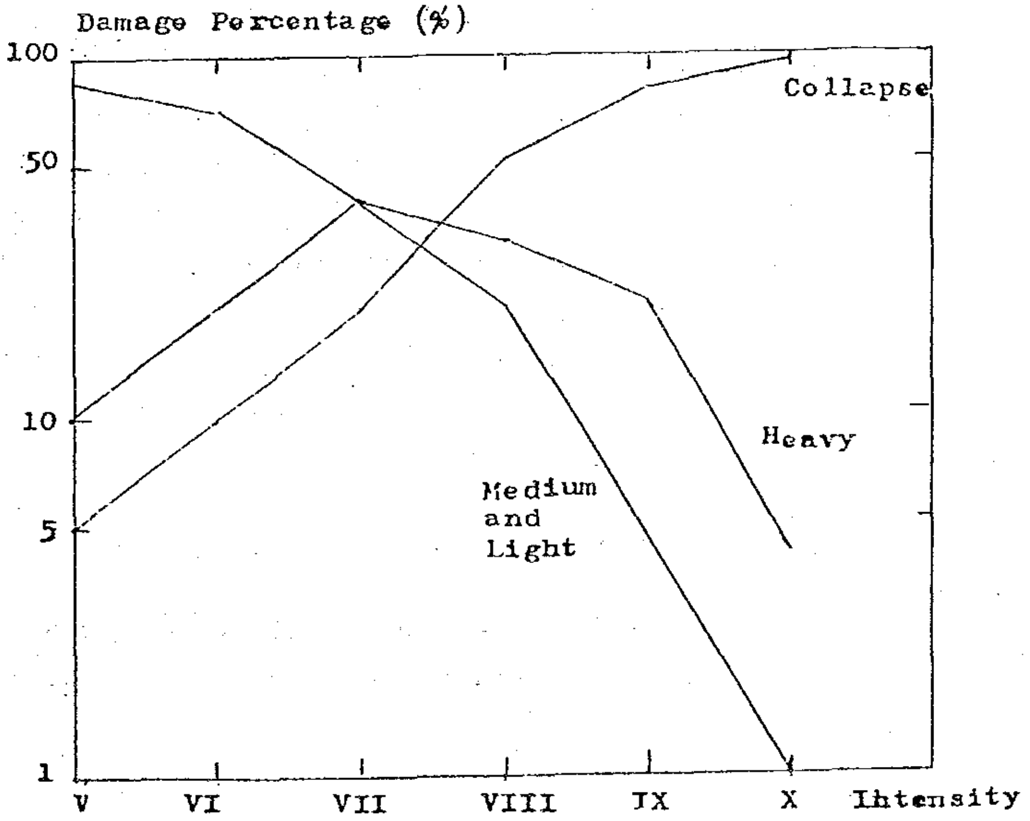


Figure 4.6. Damage Ratio for poorly constructed Houses

5. POST EARTHQUAKE REPAIR AND STRENGTHENING ESSENTIALS FOR RURAL BUILDINGS

5.1. GENERAL

The problem of a Post Earthquake Repair and Strengthening,initiates with the post earthquake evaluation of the seismic parameters of the region and the individual sites. In other words the site investigation is one of the primary task to start with.

The study of seismic parameters should include the expected maximum acceleration of bedrock for different return periods, amplification factors and to propose adequate time histories and average spectra for design of repaired structurs. As regard the structures itself and specially to identify the problems related to repair and strengthening of rural structures, like stone masonry buildings, their dynamic behavior and damage patterns during earthquakes should be carefully assessed. Furthermore, decision has to be made for the allowable degree of damage for a given expected acceleration of shaking. The economic value of a rural buildings can reasonably be represented by their construction cost.In other words, there are no secondary effects of the house failures such as associated with dams, factories, power plants, etc. For this reason the main function of the rural structure is to protect the life of the inhabitant. The object of repair and/or strengthening of such structures is then to prevent the collapse of the heavy roof which is the most frequent cause of loss of life. This may, in fact, be the first phase of strengthening and future improvements could include incorporation of other structural elements in design to increase the energy absorption capacity of such buildings. This would again involve public education programs to inform the builders about better utilization of other construction materials and techniques.

5.2. REPAIR AND STRENTHENING ESSENTIALS OF MASONRY RURAL BUILDINGS

Masonry structures are being considered as bearing wall systems, and earthquake damges can generally be traced to one on more of the following conditions:

i- Insufficient stiffness and strength of roof and flor diaphrams The absence of reinforced concrete tie beams or belts.

ii- Inadequate ties between the exterior walls and the floor and roof systems allowing the wall to fail perpendicular to its plane.

iii- Insufficient interlocking at wall intersections (particulary for stone masonry structures)

iv- Insufficient strength and instability of the walls.

Regarding the above given damage conditions a rational approach for strengthening or upgrading of masonry rural houses in Turkey should be considered as follows.

i- To improve the integrity of the wall construction (to prevent failure of individual stones or sections of a wall) independently of the whol wall.

ii- To increase the integrity of the wall-to-wall connections through realization of a well constructed tie-beams.

iii- To increase the out-of-plane bending strength of the walls,so that loads applied perpendicular to them can be transmitted to walls in the plane of these loads.

iv- To decrease the roof inertia load by decreasing its mass and generally reduce the buildings weight.

v- To attach the roof members securely to the top of the walls to prevent relative movement.

vi- In some compulsory cases, to avoid the sudden collapse of the roof trough utilisation of columns to support the roof.

Finally, it can briefly be added some new considerations to accomplish the design procedure to upgrade of a masonry buildings in order to give an example for rural structures or in other words for better understandin, stone masonry structures may be classified as box type structures where the primary lateral resistance against earthquakes is provided through the membrane action of the walls and the roof. Thus:

1. The out-of-plane walls should be able to resist their own inertia forces through flexural action as vertical elements.

2. The in-plane walls should be able to resist the lateral inertia forces developed at the entire roof and that from the top half of the out-of-plane walls through shear action as deep cantilever beams.

3. The roof structure must have sufficient strength and integrity to transmit the lateral inertia forces to the walls appropriately.

Although these conditions can be implemented during the construction phase the same does not hold true for strengthening of an already built one. The total cost of strengthening may even exceed that of newly constructed house, thus making it economically infeasible except for the restoration work for historic monuments.

In summary, for the Turkish case, all activities should be directed to the betterment of the roof structure and avoidance of its premature and birttle collapse during earthquakes for all rural structures within the primary seismic hazard regions. Once the lives are saved, the rest is the resettlement and reconstruction activities for which spesifically earmarked funds are officially available.

VI. EXPERIMENTS PERFORMED IN TURKEY ON RURAL BUILDINGS

Experimentation is probably the most prowerful research tool fon the study of the seismic behavior of rural buildings. This is due to the difficulty of developing analytical model for masonry structures.
A brief deseription were given below for information.

i) Experimental research for masonry structure has been initiated first in Technical University of Istanbul on full scale zelger type specimens and later on model shear walls. As a second series on 1/2 scale model shear walls. Strength, deformation behavior and failure processe under lateral-vertical load combinations were investigated. The effect of shape factor and boundary conditions was studied by using rectaugular, square T.-Type assemblage walls (Yorulmaz and Atan 1971).

ii) In addition to these series of tests, in ITU pure theoretical study has been already conducted. The purpose of this study was to define the relationship between the parameters of a wall opening (such as aspect ratio, position and area) and the rigidity with the strength of the wall and also between the reinforcement and the size of the openings.
The investigation is performed using computer program (Elas 75) and presented graphically for 148 cases which were obtained, by taking three length/height ratio for the wall, four area, twelve positions values and six length/height ratio for the openings. To compare these theoretical findings the fhoto elastic methods has been carried out on the same line. Several other theoretical researches using finite elements methods has been performed to adjust the experimental results. Several experiments on the behavior of individual masonry walls has also been carried out in Earthquake Research Devision of the Ministry Jointly with the middle east Technical University.

iii) Besides, new theories have been developed in the Middle East University in ANKARA, using the method of "System Identification". Experiments directed with this method have also contributed to research of dynamic behavior of masonry structures Mengi et al (1981) have performed testing of brick masonry walls on the shaking table for purposes of identifying dynamic parameters related to the system.

iv) Field testing can also be utilised as a tool for system identification. Field tests involving impact response measurements, ambiant vibration measurments and forced harmonic vibration studies have been performed in Turkey on many rural buildings. (Erdik and Tabban 1978, Ohta 1980, Bayülke 1980). However these experiments involve only small strain levels and can give information only for the elastic range.

v) Experimental research for masonry structure, using several block elements as concrete block or clay brick units, has been developed by Prof. Dr. P. Gülkan, 1979 in California at the EERC shaking table. These tests were conducted to assess the reinforcemend requirements our single story masonry houses.

vi) In recent years, several interesting experiments has been conducted under the cooperative research project entield "Seismic Risk Reduction For Eastern Turkey". This experiments are part of a joint research project between the Directorate of Earthquake Reserach Division of the Ministry of Public Works and Settlements, Middle East Technical University in Ankara, and the Martin centre for Architectural and Urban Studies at the University of Cambridge, in U.K.

Over the summer of 1983 a series of construction experiments were carried out in the grounds of the Earthquake Research Division of the Ministry. In May 1984 the relative strengths of the Construction experiments was tested by lateral loading to failure.

vi-1) Two series of full size tests has been considered. In the first series, to have the bending strength of the walls, a set of stone masonry walls were constructed and subjected to a static out - of - plane single loading.

Four walls were eventually built on the ground of Earthquake Research division of the ministry, and has been successfuly tested. (Fig.6.1).
The characteristies of these walls suitable to the construction type, surveyed in Eastorn area of Turkey, outlined briefly below:

Wall 1 A standard, unstrengthened, random ruble wall with mud mortar as built by large numbers of villagers in Eastern Turkey today.

Wall 2 A standard random rubble wall with mud mortar, reinforced vith horizontal timber hatils; a traditional strengthening method now largely fallen out of use.

Wall 3 A random rubble wall built to Turkish Standart 2510 "Design and Construction Methods for Masonry"; using cement mortar and reinforced with horizontal reinforced concrete beams. Mainly used for school and government construction in earthquake areas.

Wall 4 Cut and dressed stonework with cement mortar, used predominantly in mosques and ornamental community buildings.

However up to date one wall of each type was tested, the validity of the results quantitatively must be considered uncertain. Never theless, qualitatively, the results obtained are very useful, represents the reality. (Figure 6.2) Illustrate load deflection relationships.

vi-2) Second interesting, series of tests comprise, a set of complete building mock-ups, and using full-sized wall construction with different block elements are under operation These buildings were tested using sinusoidaly oscillating leteral acceleration on a shaking table.

Sinusoidal dynamic oscillation can usually, be excited by introducing an initial lateral displacement and then relasing. The general arrangement is given diagrammatically in (Figure 6.3).

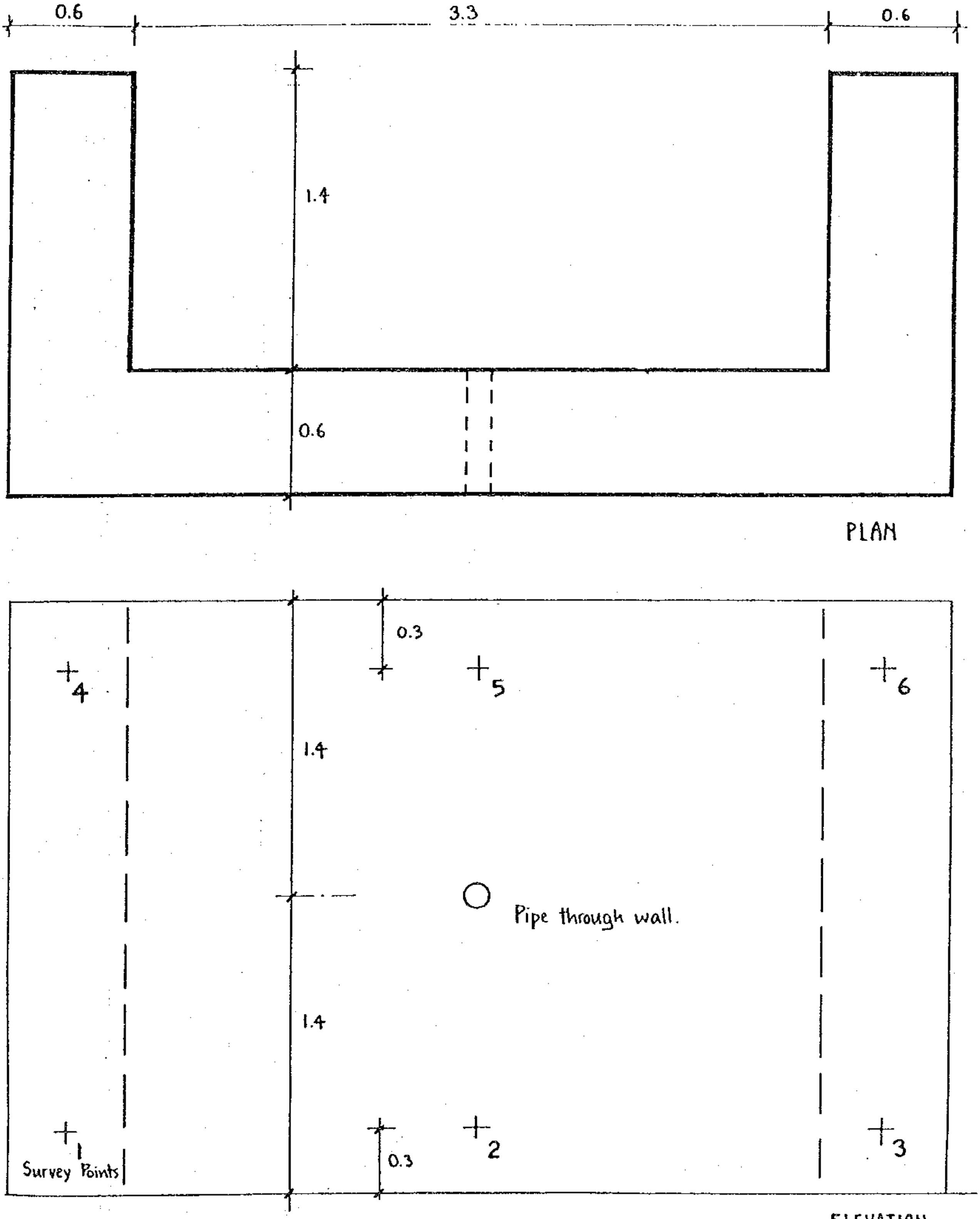


Figure 6.1. Test wall dimensions.

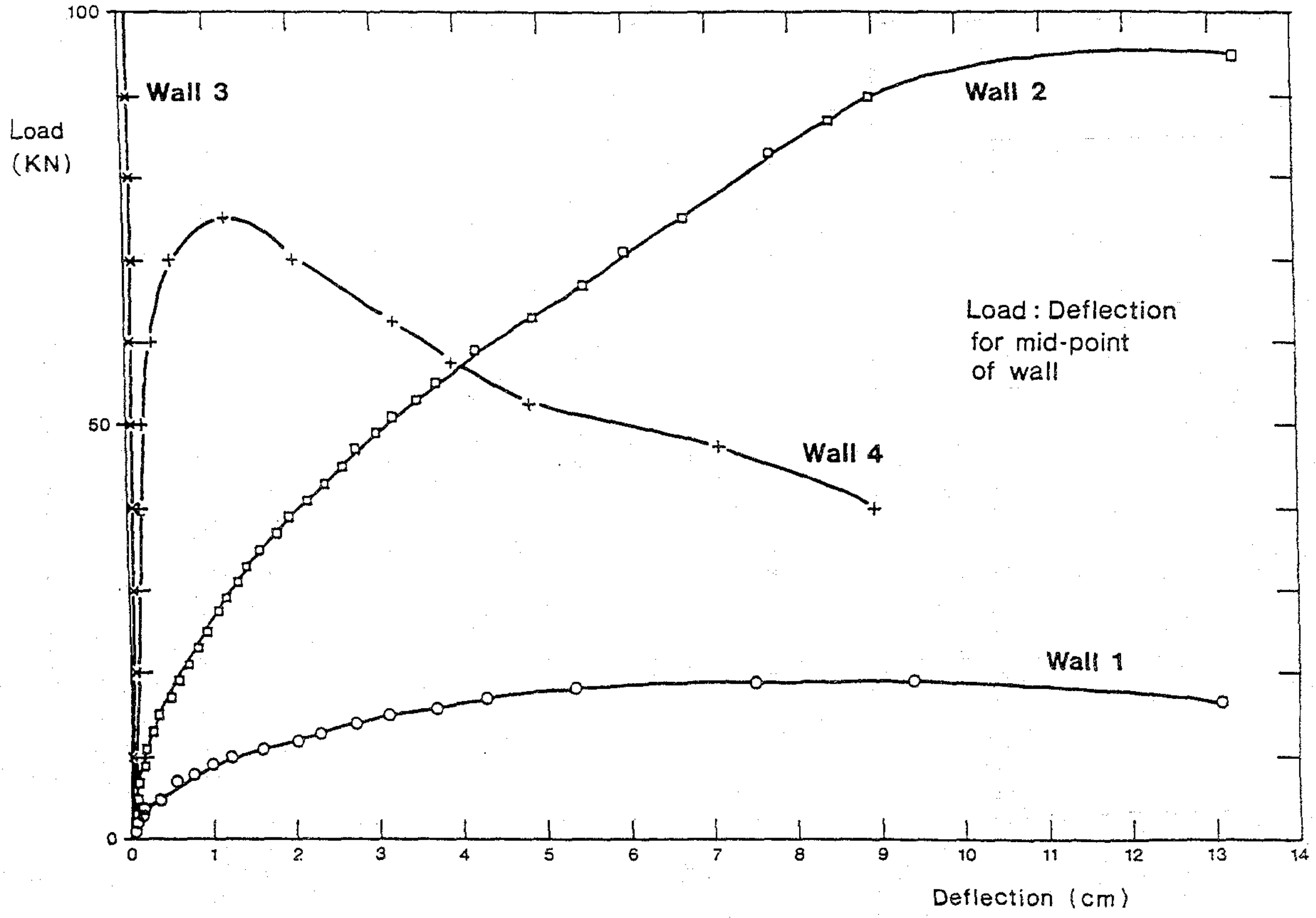


Figure 6.2. Load : Deflection curves for all walls.

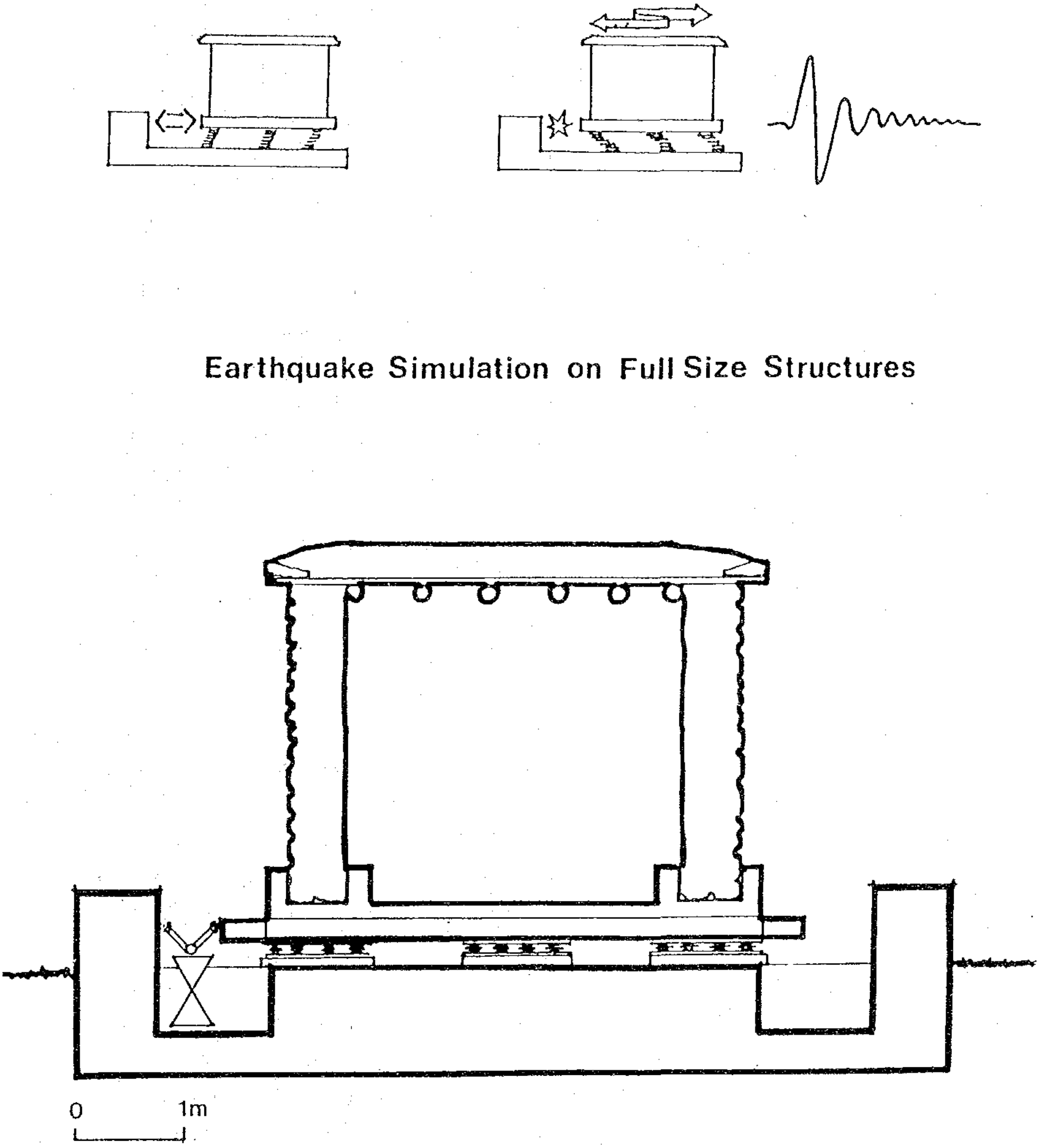


Figure 6.3. Diagramatic representation of the Ankara Shaking Table.

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付属資料Ｖ　トルコ農村部の住宅についての振動台実験報告

A SIMPLE SHAKING TABLE TESTS OF ONE STORY RURAL HOUSES IN TURKEY

EDITED BY
PROFESSOR DR. RIFAT YARAR
EMERITUS PROFESSOR OF TECHNICAL UNIVERSITY OF ISTANBUL
CHAIRMAN OF TURKISH NATIONAL COMMITTEE FOR EARTHQUAKE ENGINEERING

PAPER WRITTEN FOR DISCUSSION, IN THE MEETING OF WORKING GROUP V OF EUROPEAN ASSOCIATION FOR EARTHQUAKE ENGINEERING ON "CONTEMPORAY RURAL HOUSING IN SEISMIC AREAS" WHICH WILL BE HELD DURING THE 9TH ECEE, ORGANIZED BY USSR NATIONAL COMMILTEE FOR EARTHQUAKE ENGINEERING IN MOSCOW SEPTEMBER 11TH THROUGH SEPTEMBER 16TH 1990.

1990 - ISTANBUL

Contents

Foreword

This report was prepared to summarize the activities carried out by Earthquake Research Division of the Ministry of Public works and Settelment with the cooperation of Turkish National Committee using a simple shaking table vibrates by impulsive loadings, under the programme, "The behavior of Rural houses in Turkey" which is suitable to the subject of WG.5 on "Comtemporary Rural Housing in Seismic Areas" of EAEE.

This report originally includes the eleven tests conducted between 1986-1989. The two tests in Article VII, and VIII were not yet published. A more detailed explanation will be published under the programme of WG.5 with the cooperation of other country representatives.

I- Introduction

Since 1986 the year of the 8 th ECEE held in Lisbon, ten tests including the teste on repaired masoury build b. different block elements were carried out on the Simple Shaking Table established at the end of 1985 in the Earthquake Research Department of the Ministry of Public Works and Settlement, for the purpose to determine the behaviour of different tests on rural houses were performed using the following types of block elemants and mortars:

1- Two tests were made by hollow concrete block.

2- Three tests were made by rubble stone with mad mortar and heavy clay roof.

3- One test was performed with prefabricated house using the reinforced vertical light weight concrete panel elements.

4- Three tests were conducted on houses made of brick elements having vertical holes.

5- The test of Rural House with Adobe Block

6- The test of Repaired Brick Masoury House.

The Turkish National Committee, with the cooperation of the Earthquake Research Department will continue with the testing programme to investigate the behaviour of different types of rural houses in Turkey, subjected to dynamic loading under a reasonable long term programme.

This paper after a short definition of the simple shaking table summarizes the results of these tests. After these tests it is understood that houses built using concrete hollow blocks and adobe blocks build by mortar shows considerable strength in comparison to the elements without mortar and others.

In the rural houses built by walls using rubble stone and mud mortar, with ring beams and lintels shows important increase of strength againts dynamic loads. Even these lintels and ring beams under the roof made by simple wood or concrete. This precaution would prevent the casualties which have occured during the earthquakes mostly taken place in eastern part of Turkey.

The tests on prefabricated houses build with the reinforced light weight concrete panel elements demonstrated the importance of corner connections.

In the case of the tests carried out using brick elements with vertical holes the percentage of hole ratio and the use of mortar in the vertical and horizontal have provided considerable increase of strength.

It can be considered that using this simple shaking table we can evaluate and determine easily the necessary characteristics of different types of rural houses.

It is well known that the loads applied to the Structure by the ground motion, produce the inertia forces on the same structure under which the structure vibrates.

To determine the behaviour of a structure under earthquake loads generally real or simulated earthquake forces or ground motion, are used.

For this purpose a simple shaking table has been constructed in the Earthquake Research Division in Ankara, this table vibrates under impulsive loads, and can be considered as a kind of shaking table that would yield results for our purpose.

Different inertia forces, with different amplitudes, periods and different damping ratios can easily be produced. Inspite of the simplicity of the table the results have always shown very good similarities with the other results from classical shaking tables.

In the classical shaking tables a known earthquake ground motion, is applied. However for this table the given applied loads are produced by initial displacements.

It is well known that, to determine the behaviour of buildings, either from the characteristics of block elements or from the characteristics of walls, a great number of tests were required.

In this case, regarding the integrity of a building or structure. and because of the interactions of different elements and also existance of different phases, the real behaviour of a structure or building, should be determined based on tests conducted on the whole structure or a building.

The tests performed by this simple shaking table have yielded reasonable information for comparison among the useful characteristics of the different types of rural houses.

II. The Main Characteristics of the Shaking Table

Here we will give a short information about the characteristics of this Table (Figure - 1).

The Table oscillate freely after having one directional initial displacement given by special mechanism. These initial displacements may vary between 20-60 cm and the dominant period of the table varies between 0.15-0.30 sec.

The table is supported by rubber bearing pads as shown in Figure - 2.

To change and to increase the vibration periods of the table the number of bearing pads should be changed. Under this condition the capacity of the initial displacements increases. The weight of the table is 20.5 Ton when it is empty the table carries up to 50 ton additional weight.

In Figure 3, 4, 5 different views of the table and displacement mechanism have been shown. The accelerations of the table during tests were measured in three components by DR-100 (Sprengnether) and one component by Shinkoh acceleration devices .

Figure - 6 shows a typical acceleration record and Figure - 7 shows the maximum accelerations depending to the different weights of model houses and of different initial displacements.

III- The Tests Carried out on Houses Build with Perforated Concrete Blocks.

The dimensions of concrete blocks with holes, used in these tests are given in Figure - 8 and the plan of model house under consideration is shown in Figure - 9. The first house was build with the same block elements with its vertical holes filled by weak mortar with campressive stregth 13.6 kg/cm², and the second one was build without mortar.

Figure - 10 shows the damage patterns from four side views, of the model house having holes filled by mortar and Figure - 11 shows respectively the damage patterns of the house without mortar. The results have shown,that, evenif the hole of blocks infilled by very weak mortar, the damagability of the walls decreases considerably.
In other words, it can be considered that the walls with holes infilled by mortar would require larger dynamic loads to produce the same degree of damage. The shear stresses observed on the wall of the two model houses were given in Figure - 12. This shows that in the case of blocks with holes infilled by mortar, the shear stresses are initially doubled and increases rapidly with the displacement. In the other hand, since the strength of walls depends alone on the friction between block elements, the shear strength remains constant.

Finally we can conclude that, the houses supported by the bearing walls with concrete blocks with their verytical holes infilled by mortar con be used safely in earthquake prone areas.

IV- The tests of Rural Houses with Rubble Stone Walls

Three different rural house with thick mud roof, mud mortar and rubble stone walls were tested.

The plan of these three houses were same.
The main differences among these houses were the existence of lintels.

The first house had no lintels the other two houses had wooden or reinforced concrete lintels.

Figure - 13 and 14 show the plan and sections of the test houses under consideration.

Each model has been seperately oscillated three times by load produced through 20 m/m and 30 m/m and finally 45 m/m initial displacements and these displacements have been applied several times up to the complete distruction.

After each test, the out of plane permenant displacements of the models perpendicular to the direction of applied load, and also, the permenant displacements in the plane of the walls (load direction) were measured.

Having these measurements, the in plane unit shear deformations produced in the main load direction were calculated.

In Figure - 15, the mean values of permenant shear deformation in the plane of walls having door and windows were given.

The permenant shear deformation obtained, after 6 th loading, in the house without lintels, are almost the same in the houses with lintels after 8 th loading.

However between 8 th and 10 th loading very high accelerations were produce on the test houses.

In the Figure - 16, out of plane permenant displacements perpendicular to the loading direction, were given the first test house, without lintels, shows complete destruction after 5 and 6 th loadings and the wall made 5 cm out of plane permenant displacement.

While, number 2 house with reinforced concrete lintels, yielded 2.5 cm out of plane permenant displacements perpendicular to the oscillation direction and number 3 house with wooden lintels, yielded up to 3.5 - 5.5 cm out of plane permenant displacements, perpendicular to the oscillation directions, the walls did not collapse.

In Figure - 17, the final pasition of test houses with or without lintels were shown. As a final result the bearing rubble stone wall houses, with thick mud roof and mud mortar, but build with lintels, would gererally resist to earthquake loads without major collapse.

In addition it was observed, that the walls of houses with lintels, have shown higher resistances to greater acelerations and displacements, either inplane or out of plane, without complete destruction.

V- Test Results of Prefabricated Light - Weight Concrete Panel Structures

Exterior view of the test structure made of light-weight concrete (Ytong Panel) panels is given in Fig.18. The details of connections between roof to wall and panel to panel are shown in Fig.19.

However, panel to panel connection has been poorly designed purposely than the design proposed by manifacturer.

The damages occured in the test house, after having applied 10 cycles of loading is given in Figure.20-21. Seperation between the south wall panels is given in Figure-22. Nominal shear stresses for leight-weight panel are given in Figure.12.

The importance of corner connections of the panel structure is determined as a result of tests.

The energy dissipated due to the friction between panel elements is quite high therefore no shear cracks have been observed in panels. Although the existing shear in the panel is big enough.

It has been observed that, the seperations between the panel elements become max, 0.5 cm, when the initial displacement given to the shaking table increases to 5-6 cm .

In this case almost high level of accelerations were produced on the test houses.

As a result of this test it can be concluded that panel structures can resist to relatively high intensity earthquake if the corner connections are made as it is proposed by the manifacturer.

VI- Tests on Masonary Structures Made of Brick Blocks With Vertical Holes

The influence of the following three parameters on the shear strength of the structural brick block walls have been investigated by means of series of tests. These parameters are as follows; 1.Vertical hole ratio of brick blocks, 2.Strength of the mortar, 3.Vertical and horizontal usage of mortar in vents.

The important characteristics of the prototype structure used in this series of tests are given in the following list.

Brick dimensions (mm)	235x185x290	135x180x280	135x180x290
Unit weight of brick(t/m^3)	0.670	0.700	0.920
Hole ratio (%)	50	59.5	50
Comp.Strength of brick(kg/cm^2)	52	25	67
Com.Strength of mortar(kg/cm^2)	15	31	8
Pure tensile strength of mortar (kg/cm^2)	6.1	11	4.3
Weight of structure (ton)	9.5	7.6	11.2
Solid wall area in the vibration direction (m^2)	1.173	1.159	1.660
Total area of walls (m^2)	2.660	2.430	2.460
Height of the structure (m)	2.74	2.50	2.50
Wall thickness (cm)	20	19	20
Dimension of structure in the vibration direction (cm)	402	404	415
perpendicular to vib. dir. (cm)	388	355	356
Max.Nominal shear str.(kg/cm^2)	1.11	0.74	1.36
Unit declanation between walls in vibration direction	0.050	0.050	0.009
Strength ratio of mortar to brick	0.29	1.22	0.12
Ratio of shear stress to pure tensile strength of mortar	0.182	0.067	0.314

Hole patterns of the bricks used are given in Fig. 23. The plans of the prototype structures used in test number 1,2 and are given in Fig.24 and Fig.25 respectively. Nominal shear stresses in the walls due to the different initial displacements have been compared in the diagram given in Fig. 26.

The results achieved at the end of test can be summarized as follows (7).

1) Nominal shear stress increment about 30-90 % is obtained if mortars is used in horizontal vents.
2) The lower vertical hole ratio the higher sheor strength is obtained
3) The shear strength declines after the wall have cracked and have reached to more or less the level several times before total collapse of the wall
4) The lateral Load resistance of the cracked wall is simpliy due tothe friction beween the brick walls
5) The bricks used which are available in the market have 50 to 60 % hole ratio. In order to generalize the results obtained the lower hole ratios should be used.
6) Compressive and pure tensile strength of the mortar used in the test specimens are very low. Higher levels of compresive and pure tensile strength of the mortar should be used to find out the influence of the quality of the mortar on the shear strength of the walls 7) The rate of loss of ultimate shear strength becomes bigger if higher hole ratios are used in the bricks as it is shown in Fig.27.

VII- Results and Proposals

The shaking table set up at the Earthquake Research Department is very useful to test single story structures subjected to inertia like forces similar to the forces created during an earthquake. The structural behaviours obtained by means of labratory tests will be valid for the real earthquake effects. Because the mode of damages achieved at the end of tests based on initial displacements are similar to the damages observed during the real earthquakes. Although the vibration period of testing is oround 1 to 1.5 seconds many succesive vibrations ore given to the prototype to simulate a kind of strong motion record, 8-10 second long.

Experiments completed reveals the following results which are explanatory and may be used in practice; structures made of concrete hollow blocks can be used in seismic regions if their holes are filled by mortor; collapse can be prevented if simple lentils are used during the construction of rural houses made by masonary and mud mortar, the connection details of panel buildings is very important on the total resistance of the structure and big energy consumption is achieved betmeen the panels, the shear strength of a wall made of brick with vertical holes is highly dependant on the hole ratios, the higher hole ratios the lesser shear strength is obtained.

The behaviour of previously damaged structure are being investigated on the shaking table of the Department of Earthquake Research during these days in addition to the similar tests on adobe type structures.

VIII- The Test of Rural House Made of Adobe Block

An adobe block masonry house of 410 x 348 cm were tested on the impulse table and its behaviour were compared with the behaviour of a rubble stone mud mortar masonry and flat earth roof house tested three years ago on the same impulse table.

Over the years it had been observed in actual earthquakes that adobe masonry rural houses behaved setter than rubble stone masonry and these tests were also provided evidence supporting these observations. In the (Figure-29) the maximum observed impulse table accelerations and the corresponding permanent strains in the walls paralel to the direction of shaking of both adobe and rubble stone houses are given. The adobe test house were able to withstand higher accelerations and larger permanent strains as compared to rubble stone masonry.

In the rubble stone masonry test house the walls perpendicular to the table motion had collapsed outward after only a few number of loadings, while in the adobe block test house they did not collapsed at all Fig.30. The nominal shear strasses developed in the walls paralel to the direction of table motion reached levels slightly less than those observed in brick masonry test houses.

It appears that there are several factors which contribute positively to the relatively better behaviour of adobe masonry: 1- adobe masonry houses are lighter than rubble stone masonry: the test houses of nearly same dimensions had weights of 13 tons (adobe) and 46 tons (rubble stone) resulting in relatively lesser lateral forces being applied to adobe house, 2- the adobe blocks had almost full contact between each other thus both the adherence of mud mortar to adobe, both of same material, and the friction between adobe blocks contributed more to the shear strength of the walls, both of these two factors developed far better behaviour in adobe house under test conditions.

IX- The Test of Repaired Brick Masonry House

In this test a brick masonry house of plan dimenzions of 415 x 356 cm and 252 cm height which had been tested and partially damaged in a previous set of brick masonry house tests were repaired by two Ø 12 mm steel bars in the direction of shaking of the table at mid height of the walls crossing accross the cracks formed in the previous test, and tested to see the effectiveness of the repairing technic. The amount of reinforcing bars were kept at a minimum and the bars did not have any prestress. In order to see the effectiveness of the method of repair the test house was only 'repaired' not strengthened, to its pre-first test strength. In Figure-31 the nominal shear stresses measured in the first and second (after repair) tests are given. As can be seen from the figure the repairing technic brought the shear strength of the test house to its first test level; and after almost the same number and levels of impulsive loadings the repaired house returned to its post first test level of strength.

Another observation from the test is that the cracks from the first test widened below the level of the reinforcing bar, while those above the reinforcement level did not develope any new widening. The test indicated that repairing by bars crossing the former cracks, a kind of crackstiching, would be an effective strengthening method if cracks are crossed by more than one layer of reinforcing bars.

Acknowledgments: The editor of this report is indepted to Expert Engineer Mr.Nejat Bayülke from Earthquake Research Devision of the Ministry who is conductor of all these tests.

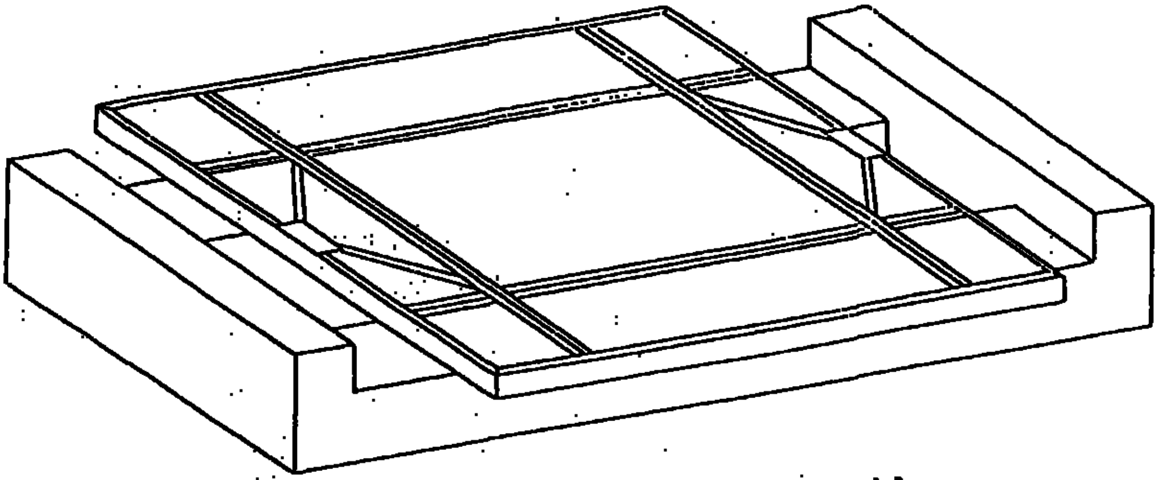


Figure 1. General view of shaking table

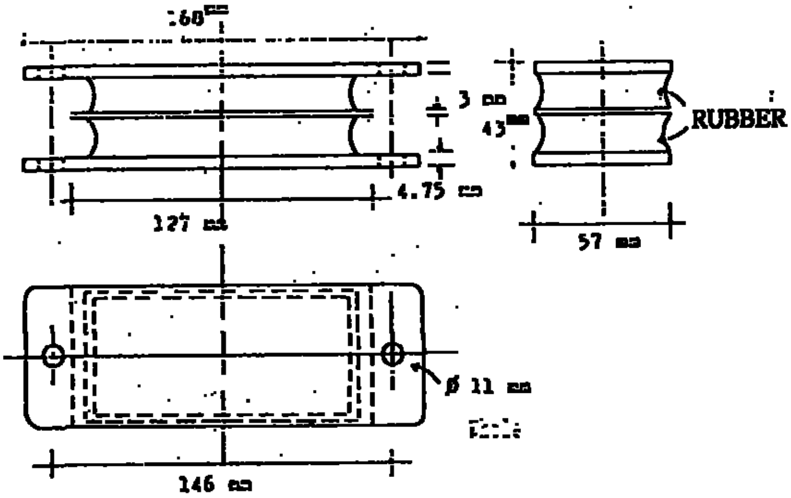


Figure 2. Supporting pads

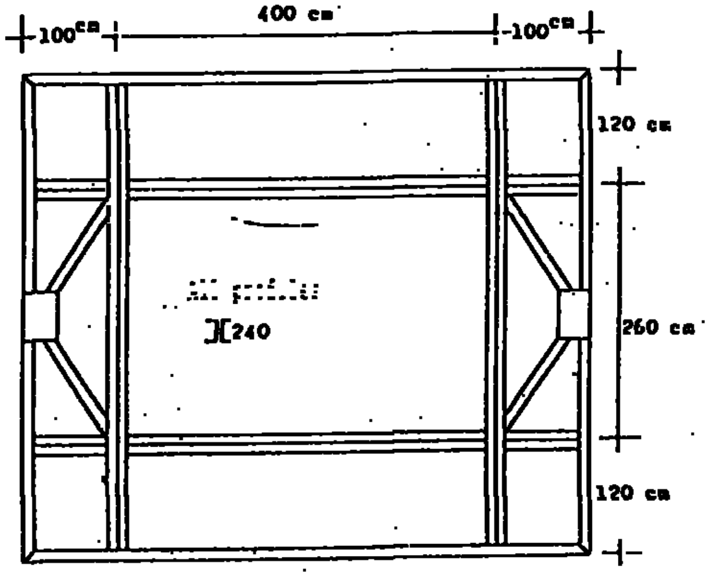


Figure 3. The dimensions of the steel section of the table

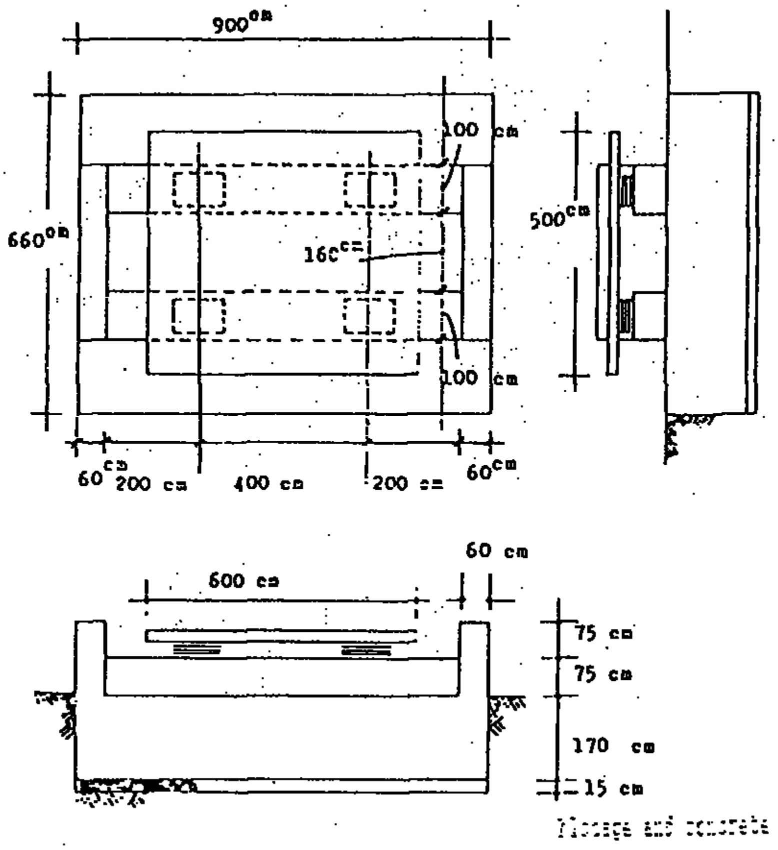


Figure 4. Different views of the table (side views and plan)

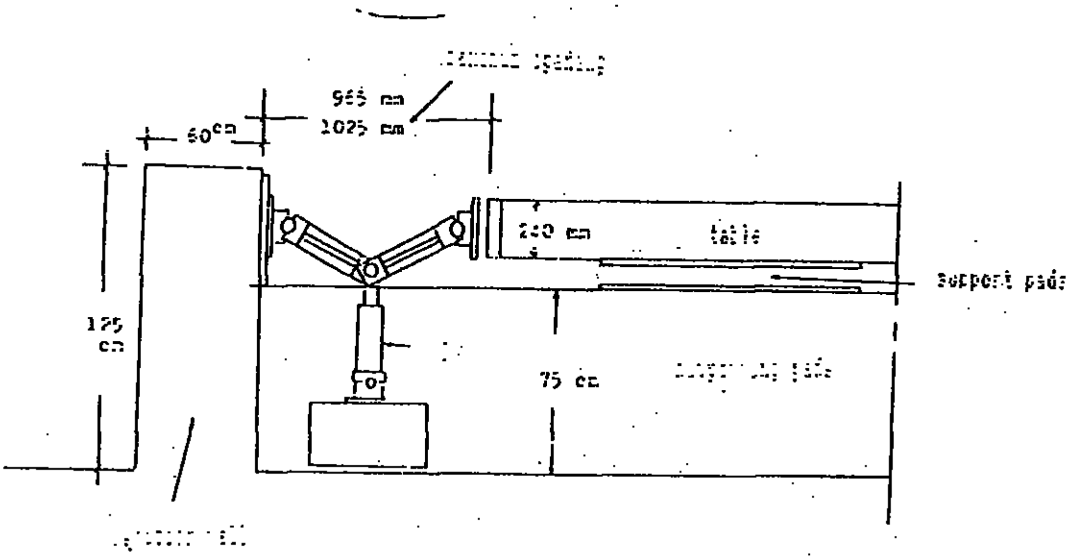


Figure 5. The movement mechanism of the table

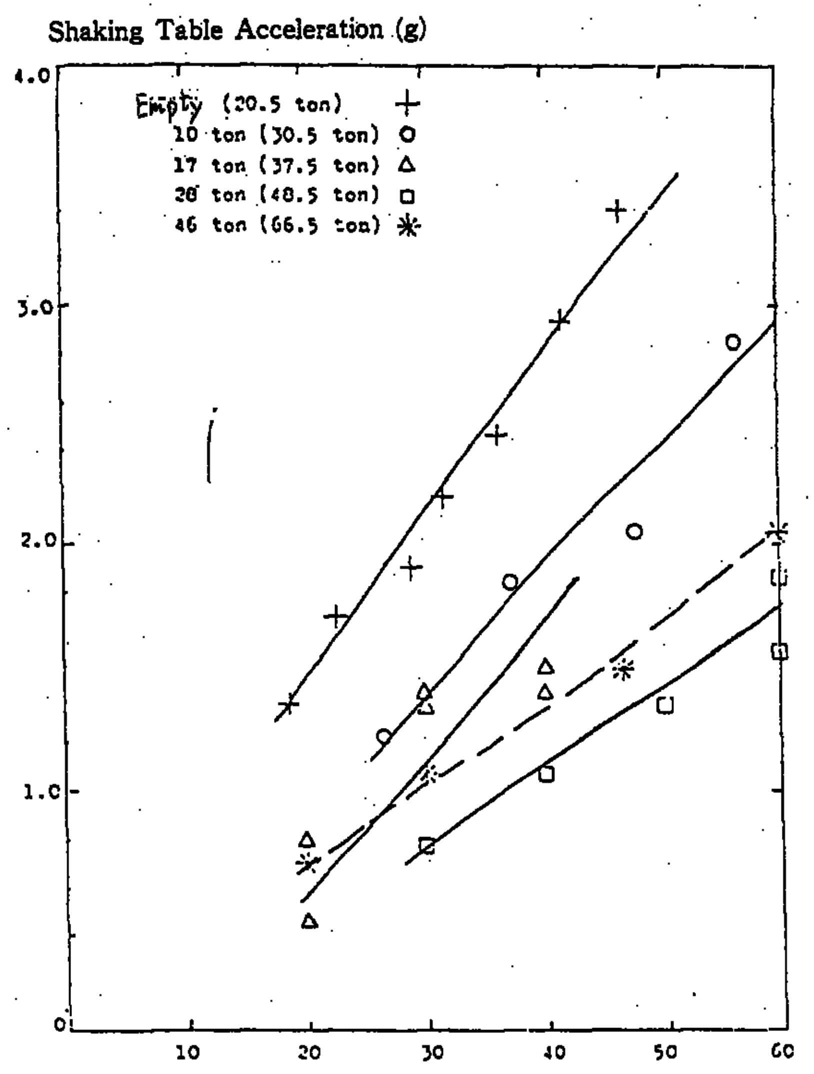


Figure 7. Relations between maximum accelerations, weight of the table and displacements

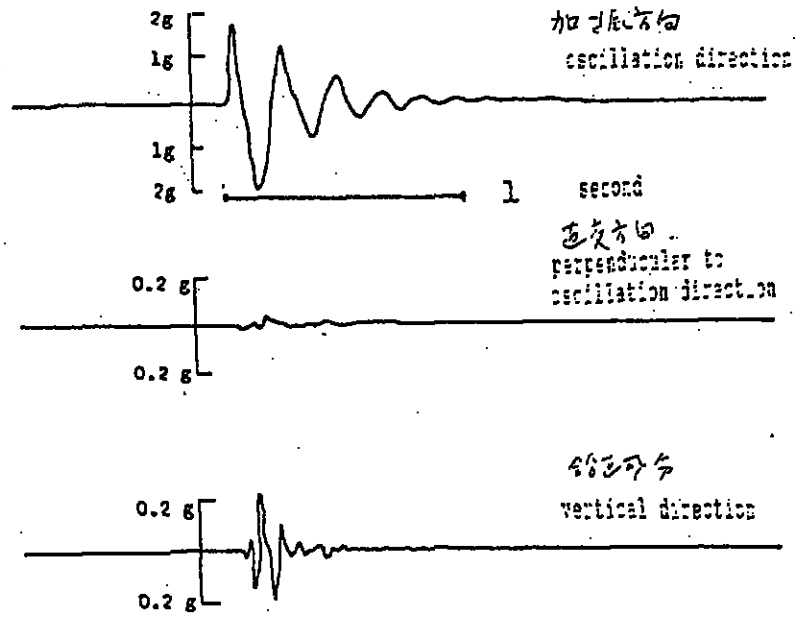


Figure 6. A typical acceleration record of the table

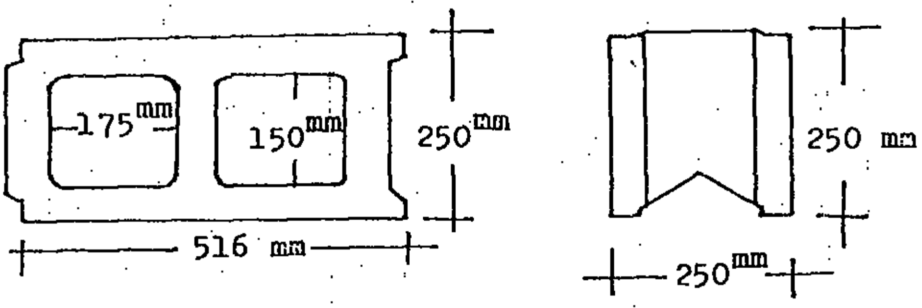


Figure 8. Dimensions of hollow concrete blooks

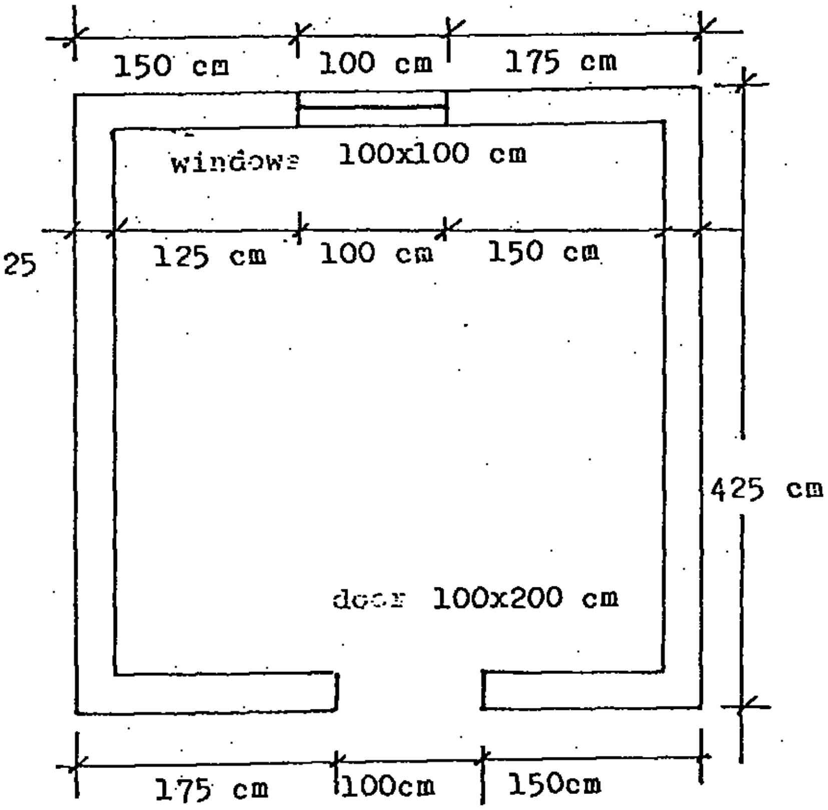
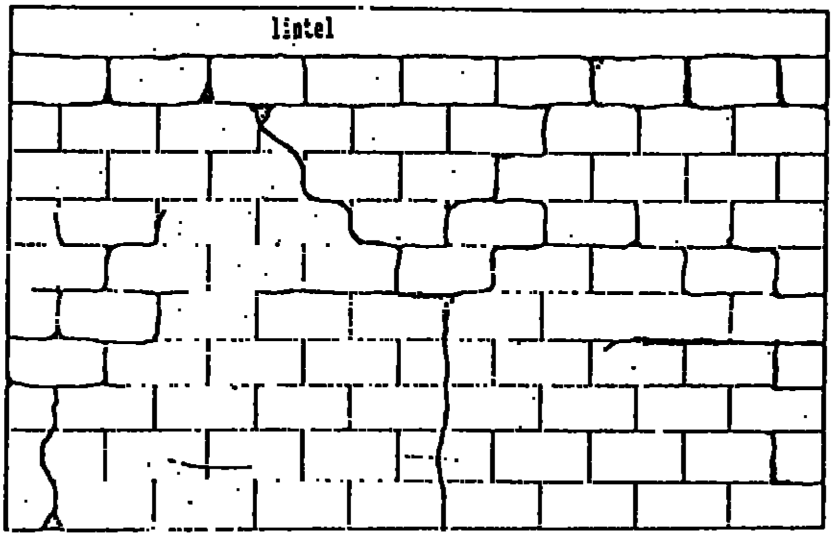
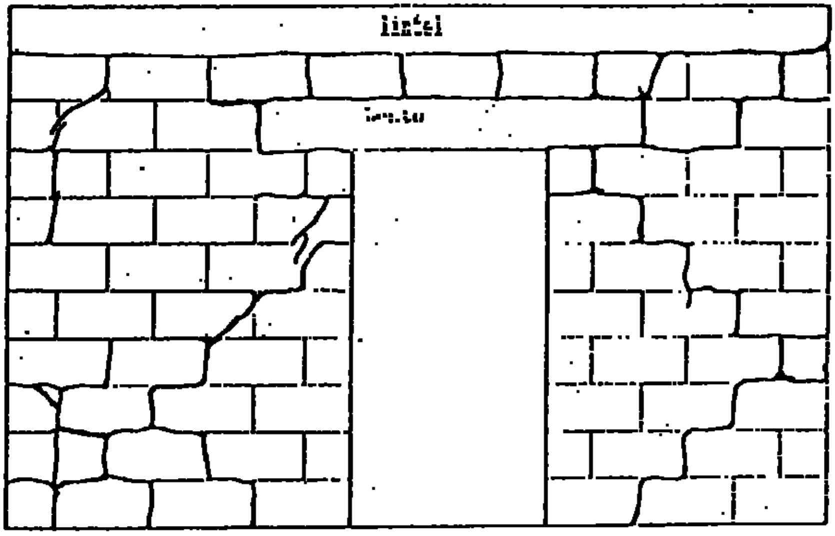


Figure 9. Dimensions of model house



Crack in East wall

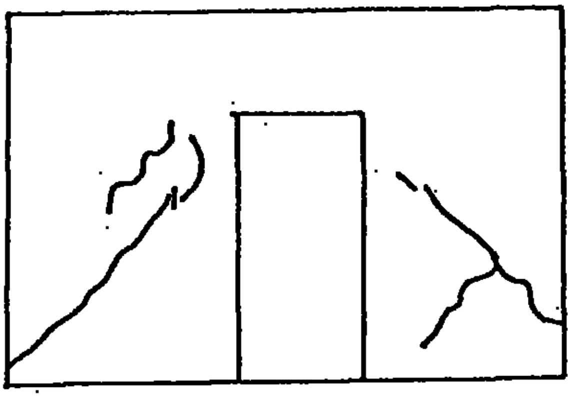


Crack in South wall

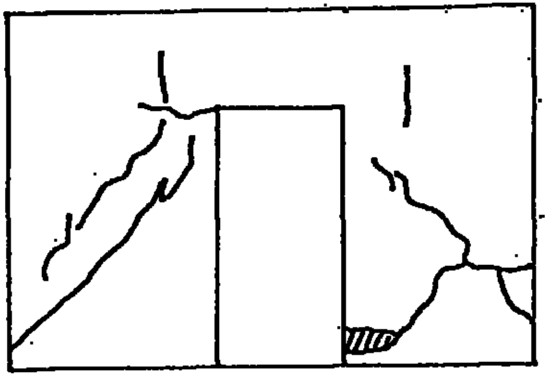
Figure 10. Cracks produced during the test in the house built of wall blocks infilled with mortar

13.6 kg/cm²

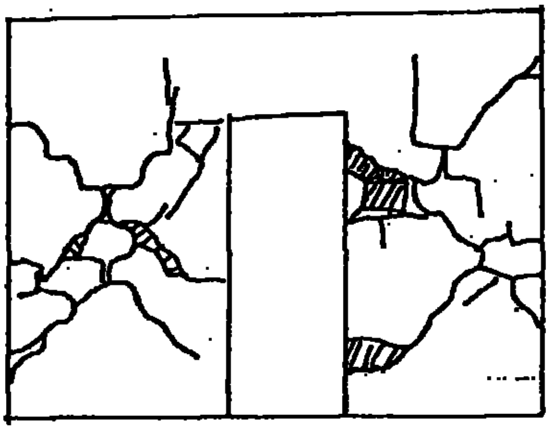
この程度のひびわれがあっても
"damageability" は減少する。



After first loading

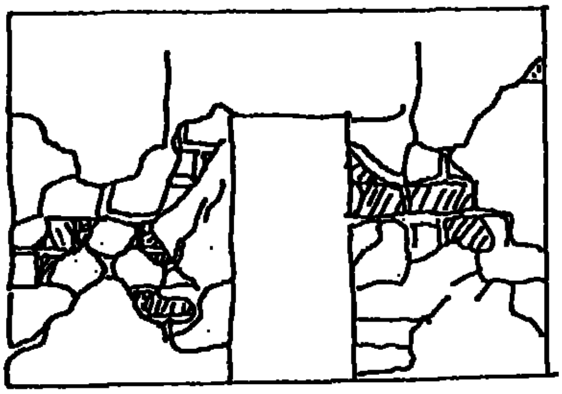


After second loading

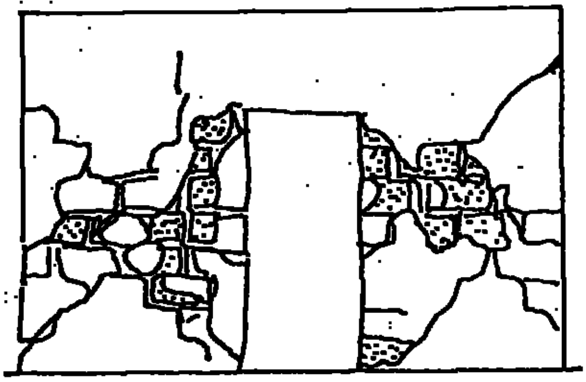


After third loading

Figure 11. Development of damage in the house without mortar filling



After fourth loading



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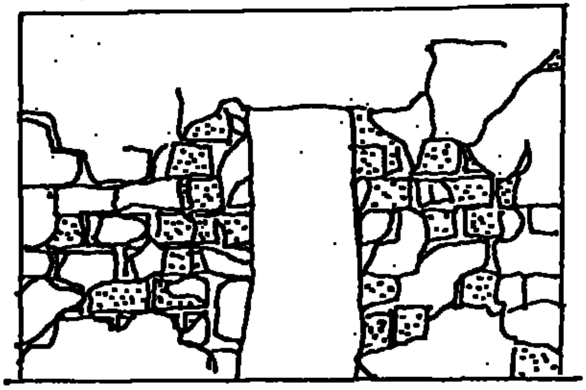


After sixth loading

Figure 11. Develoment of damagen the house
build of empty cell blocks

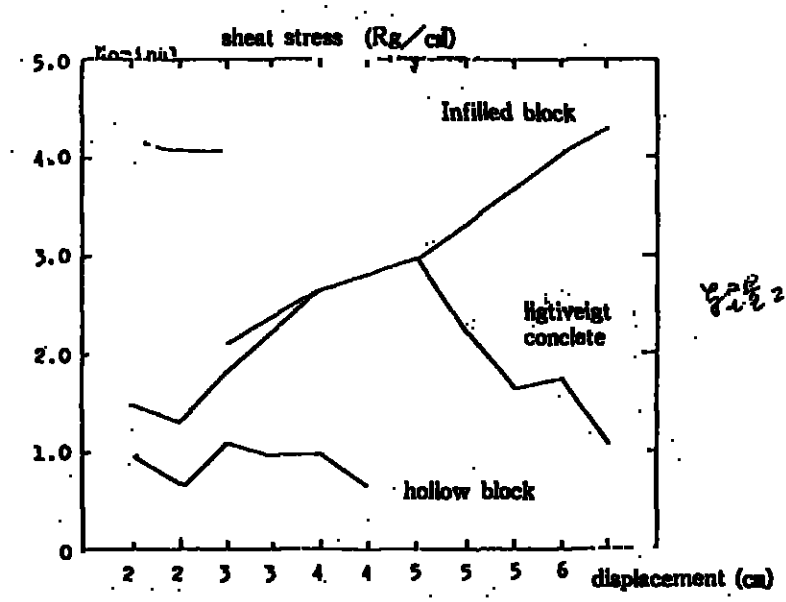


Figure 12. The shear stresses in the walls

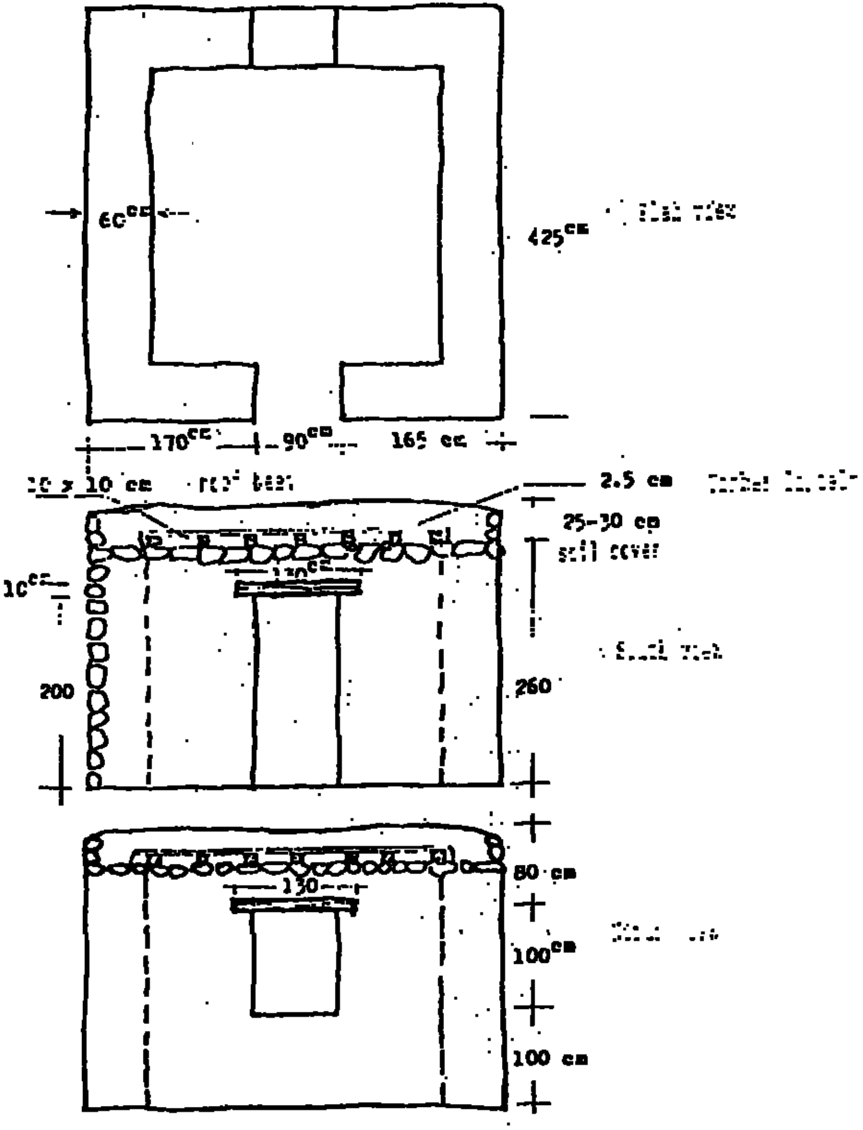


Figure 13. The plan and sections of the test houses without lintels

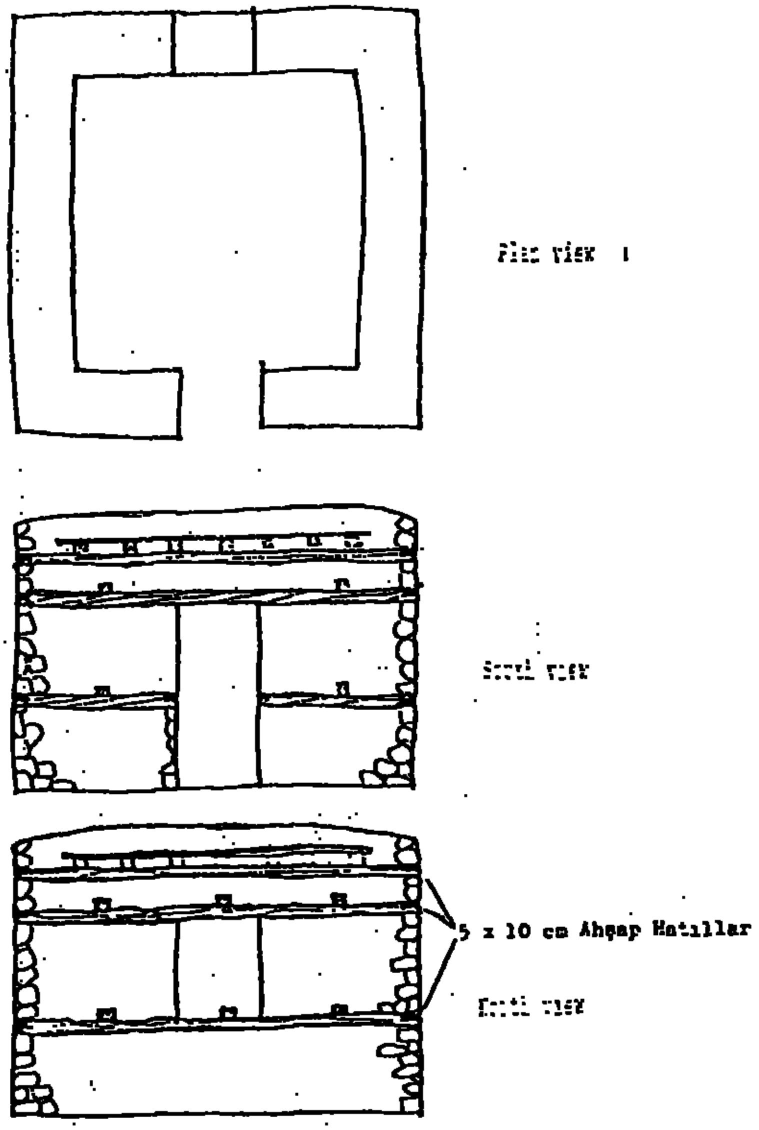


Figure 34. The plan and sections of the test houses with lintels

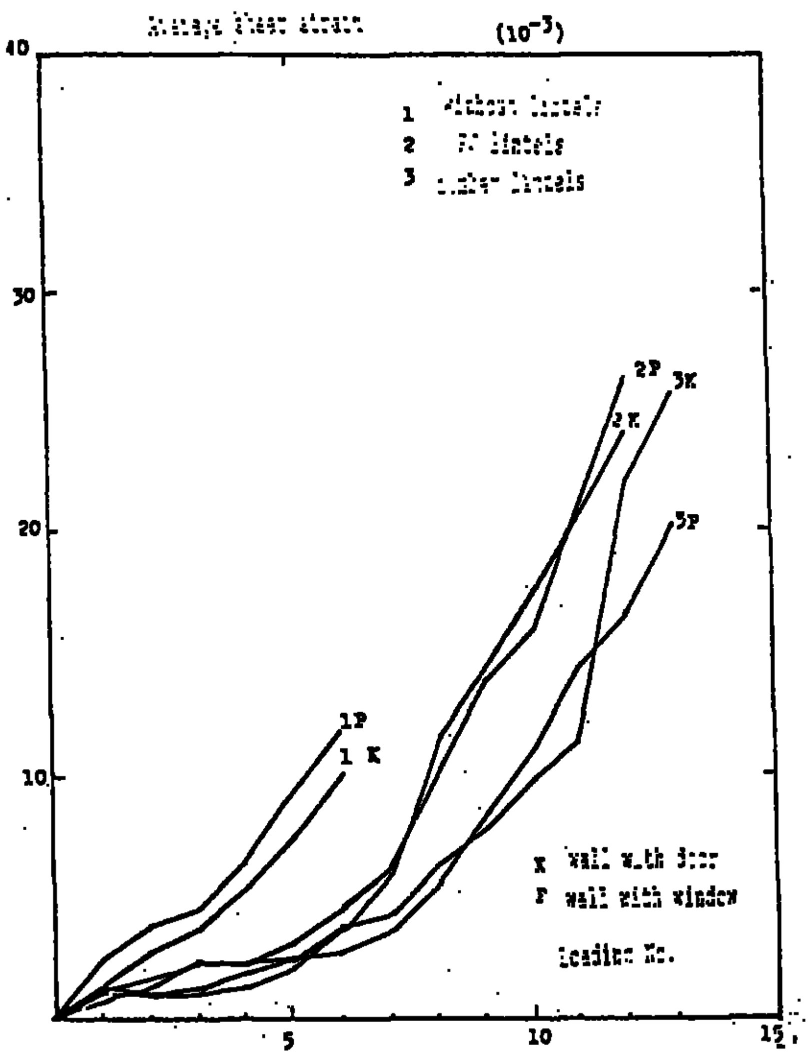


Figure 15. Permenant shear strain in the walls

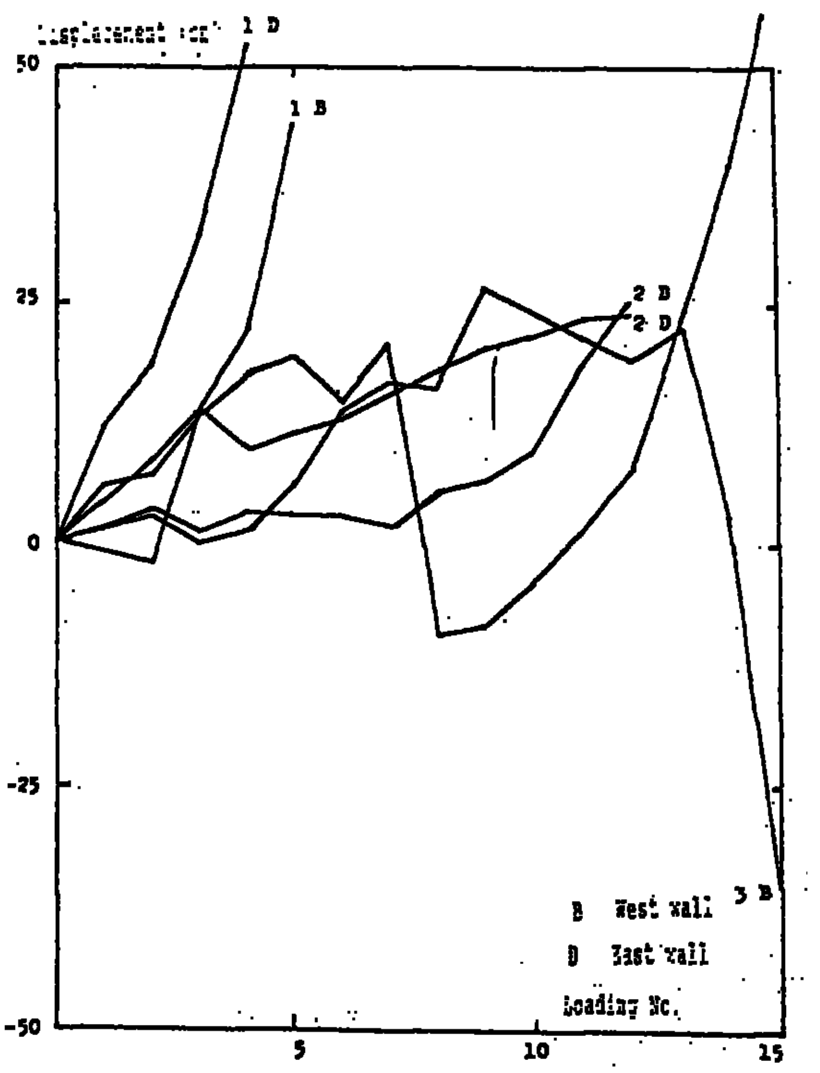


Figure 16. Permenant deformations perpendicular to the wal
for walls perpendicular to loading direction

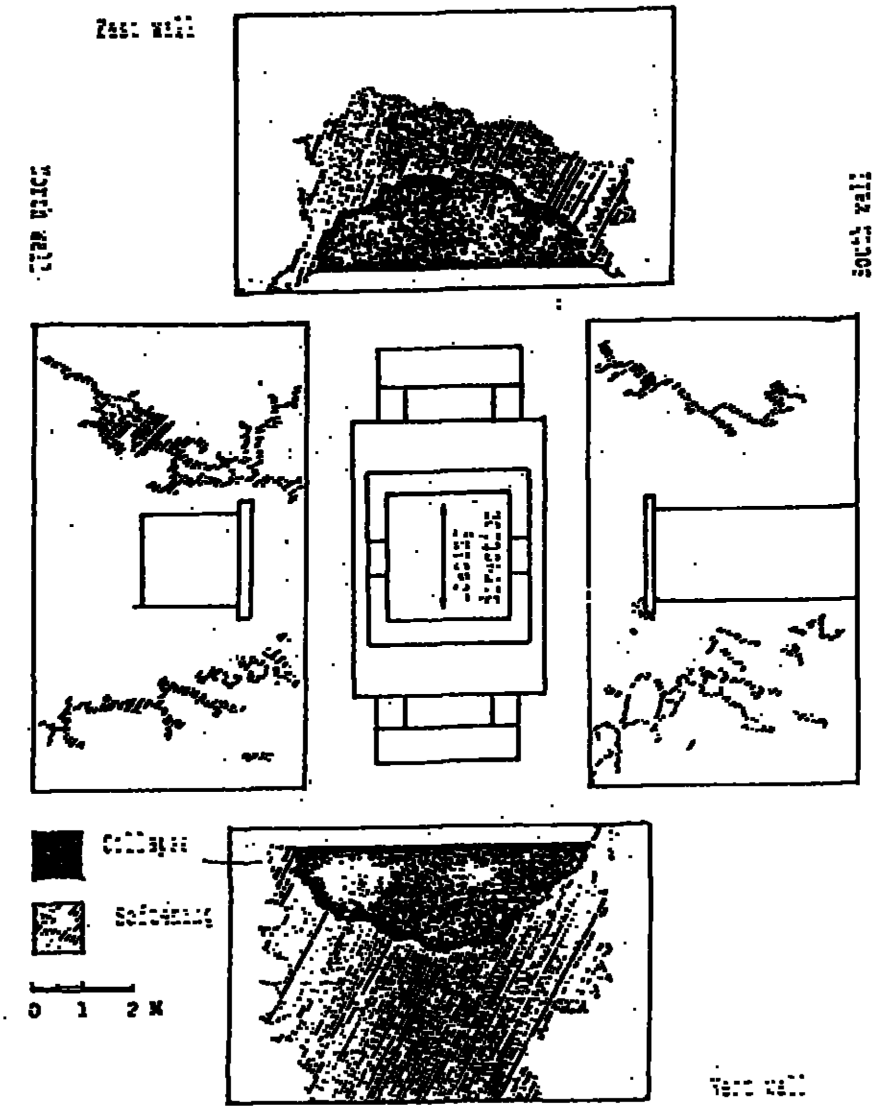


Figure 17a. Damage pattern for the house without lintels after 7th loading

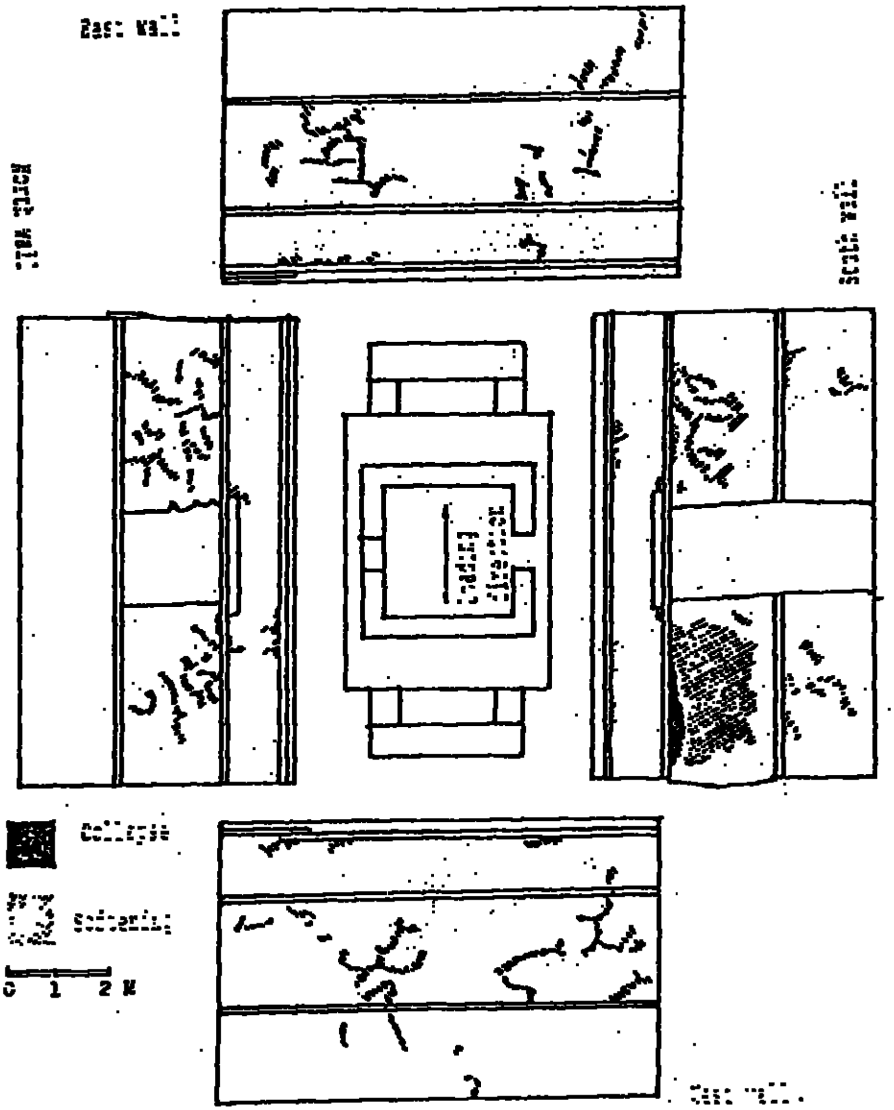


Figure 17b. Dammage pattern for the house with timber lintels after 12th loading

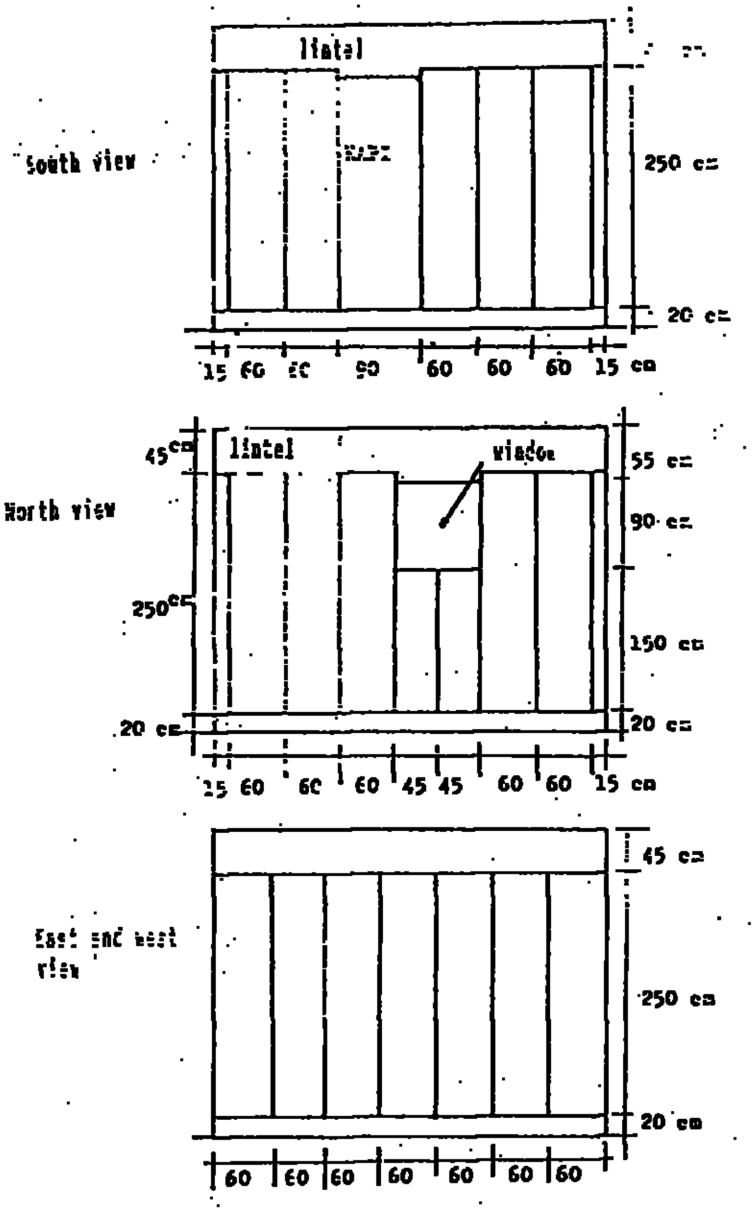
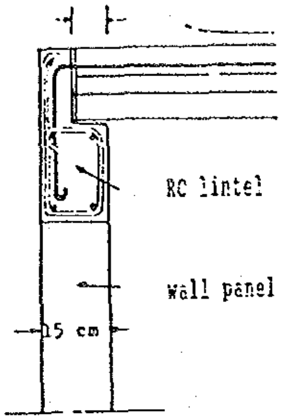
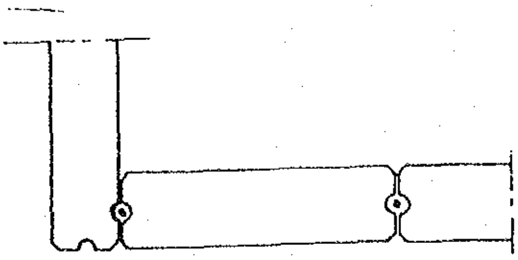


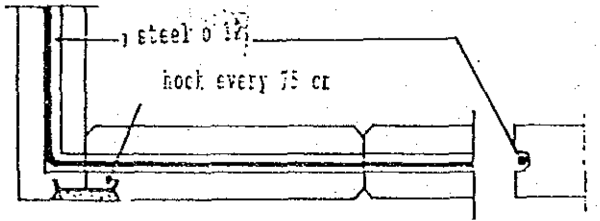
Figure 18. The side views of test house with panel walls





Panel to panel connection
(used)

Wall panel-ceiling plate
connection



corner connection
(proposed)

Figure 19. Connections details of houses with panel walls

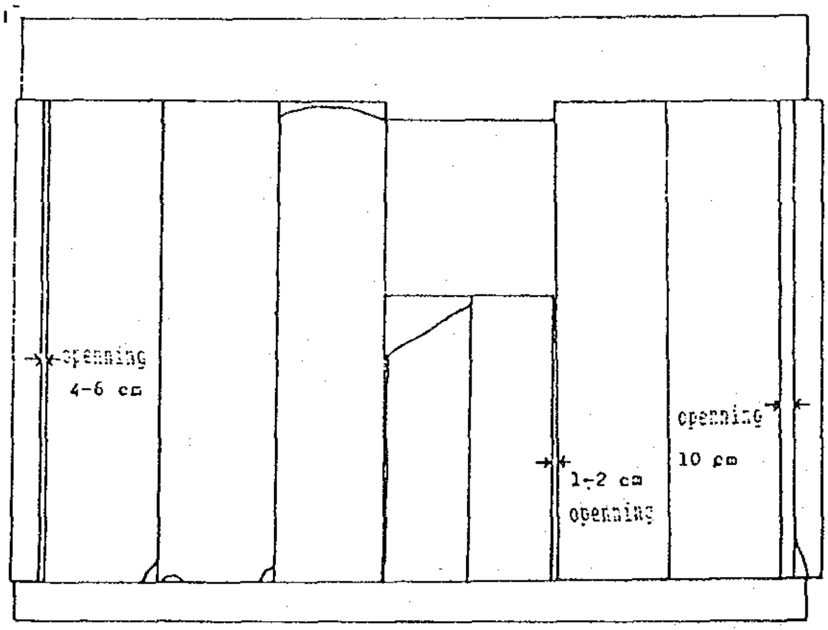
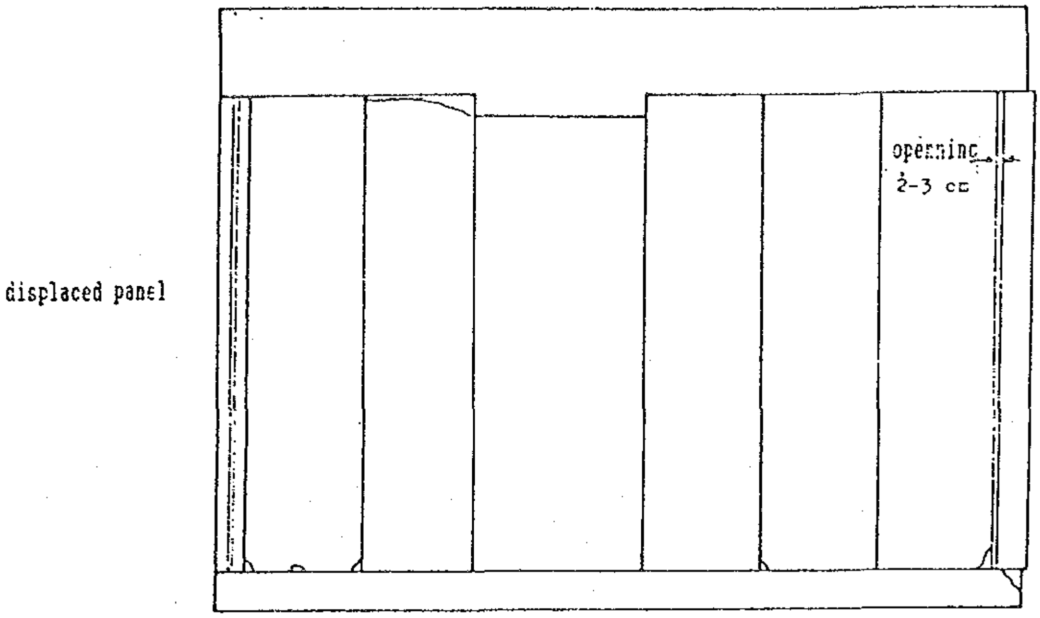
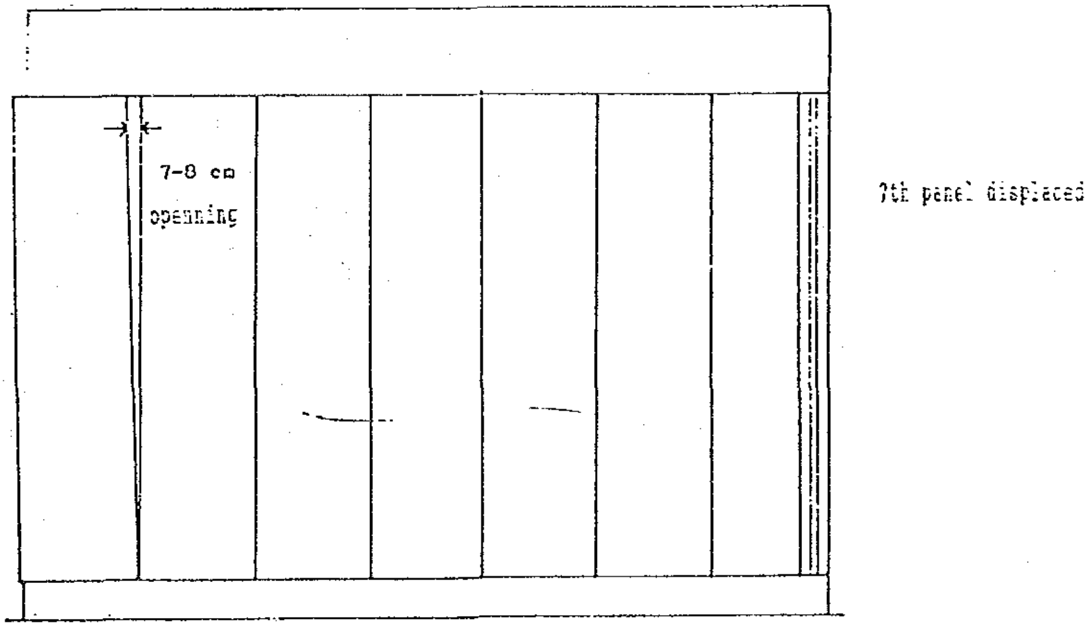


Figure 20. Damage to north wall



south wall



west wall

Figure 21. Damages to panel walls

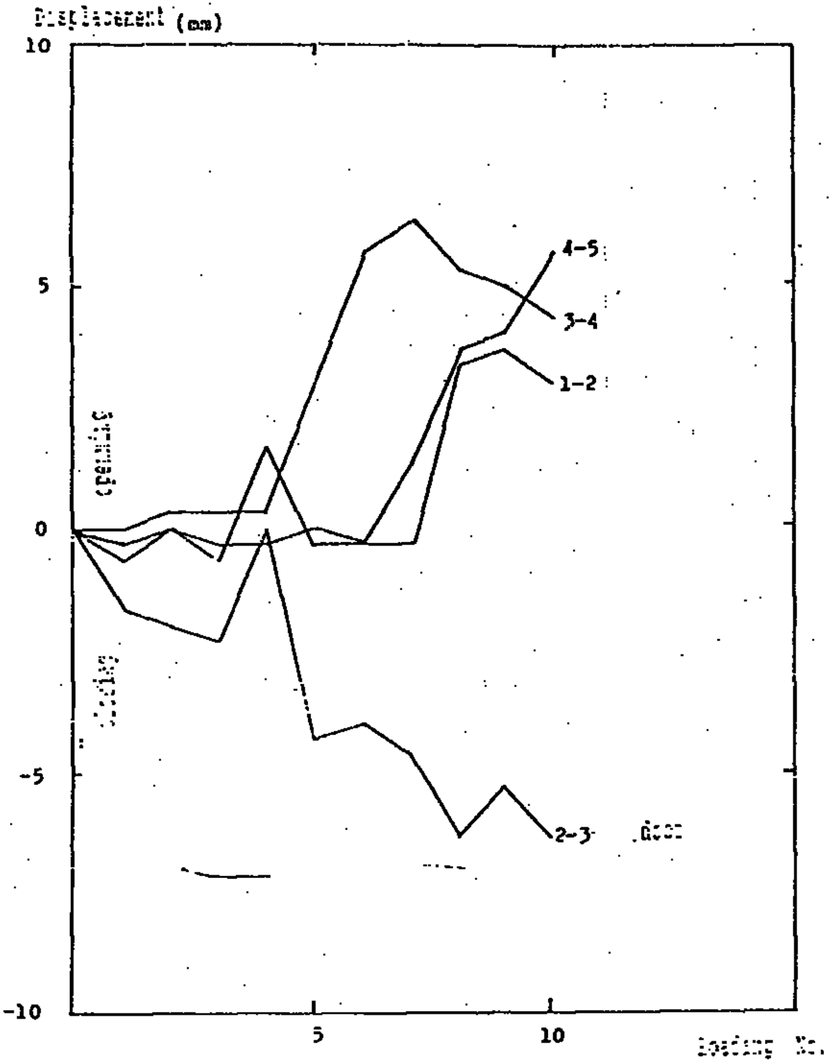


Figure 22. Seperation of south walls

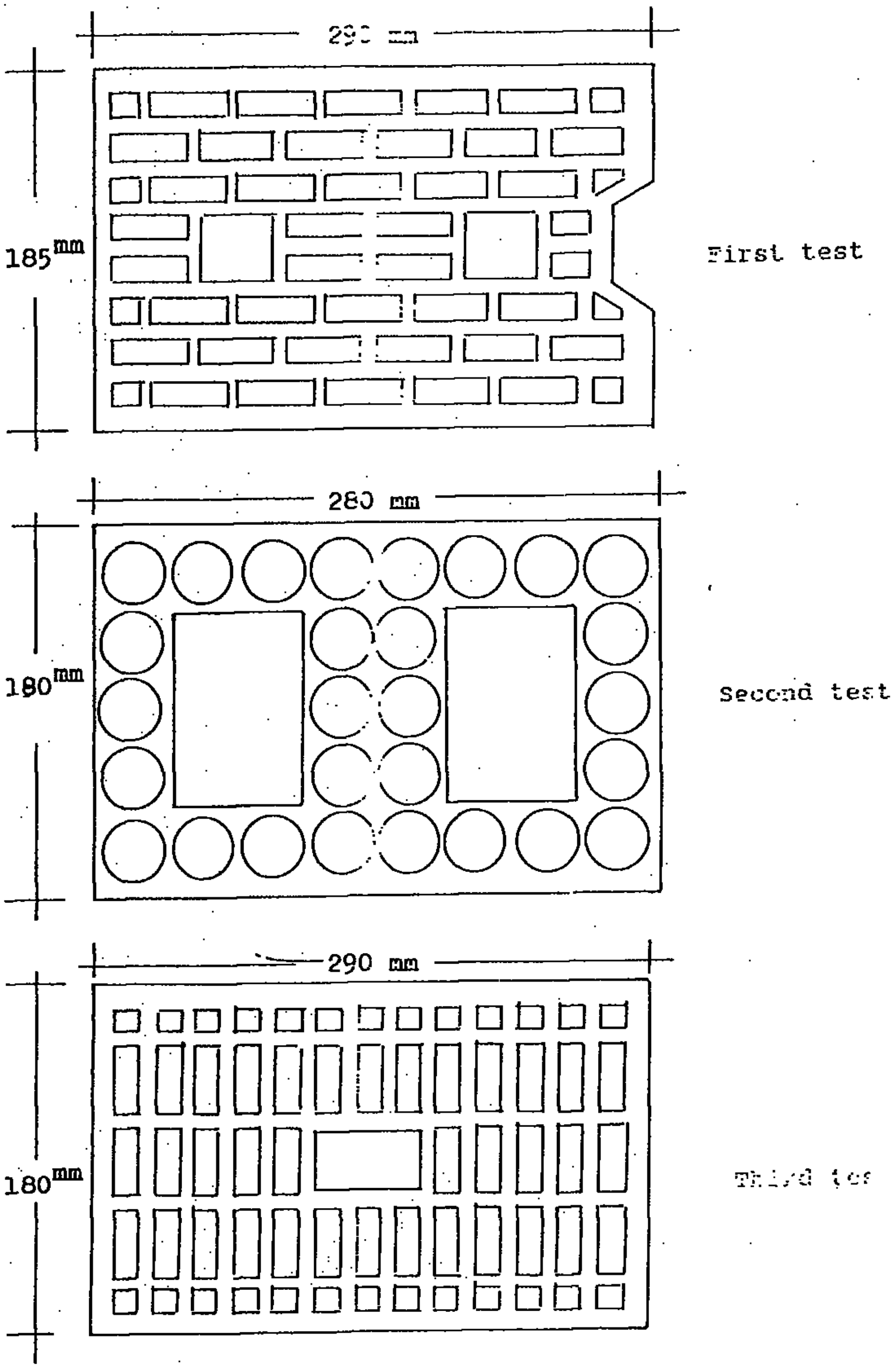


Figure 23. The shape of brick holes used in tests

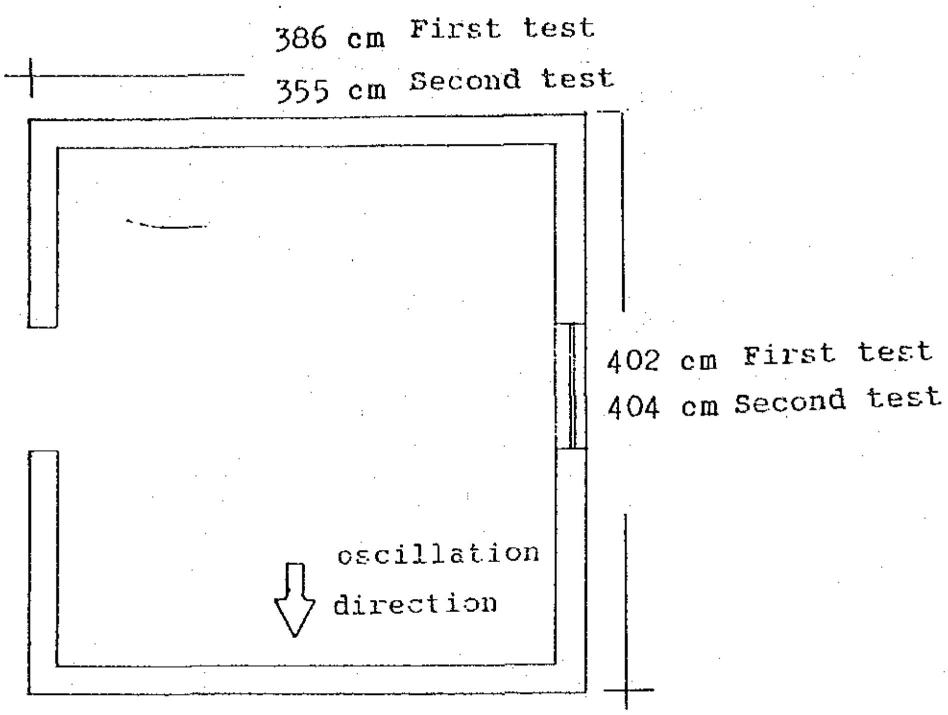


Figure 24. The plan of the first and second test houses

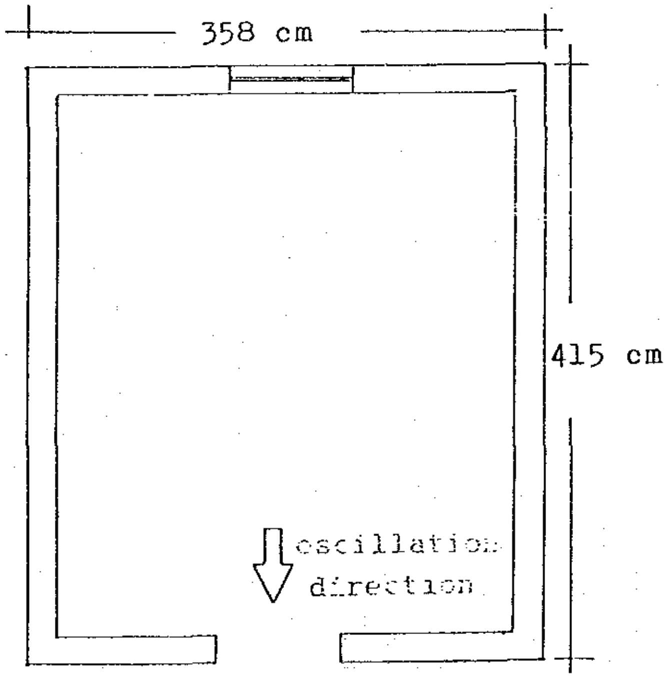


Figure 25. The plan of the third test house

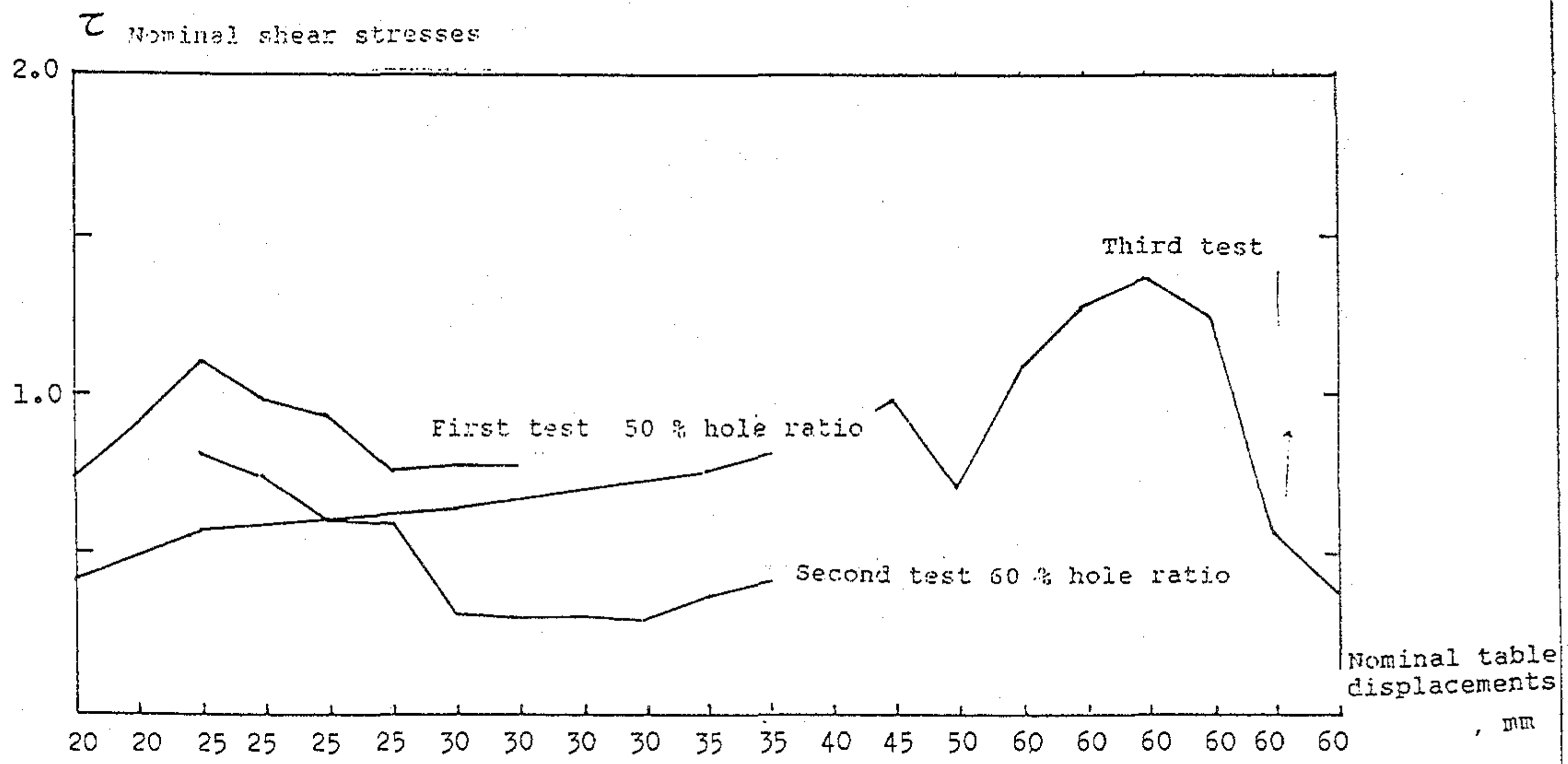


Figure 26. The nominal shear stresses produced in the wall

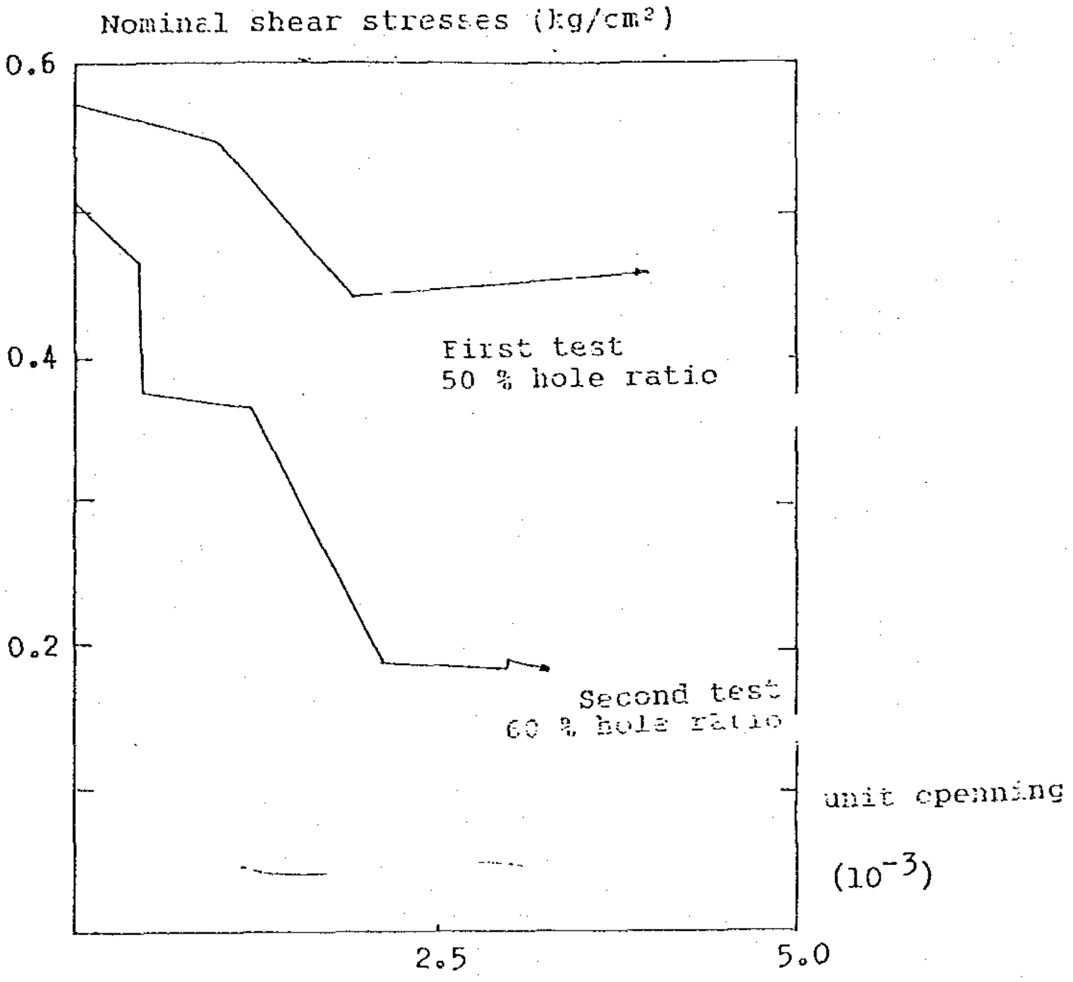
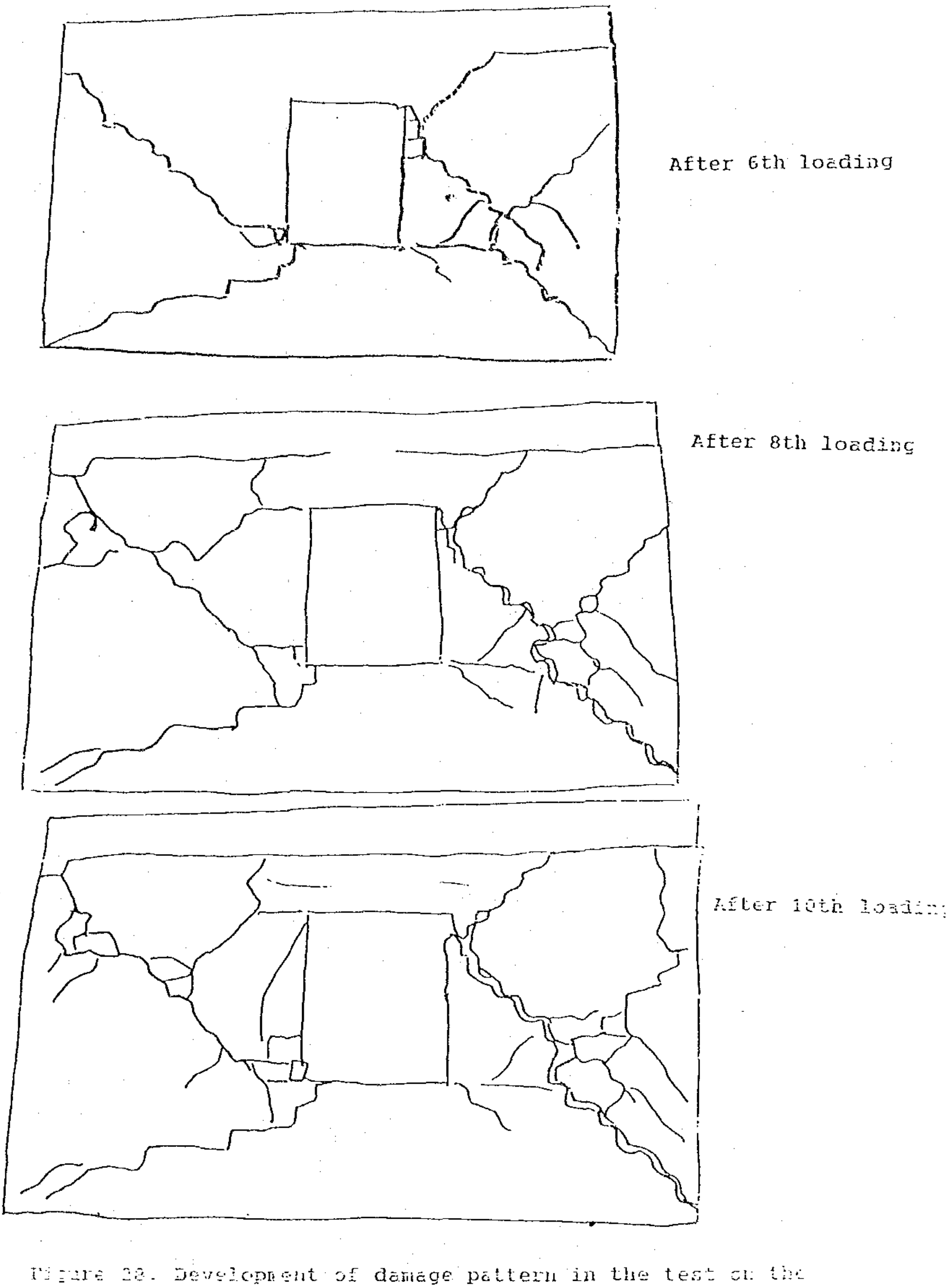


Figure 27. Shear stress and unit deformation variation in the rigth side walls of south face of the first and second test houses

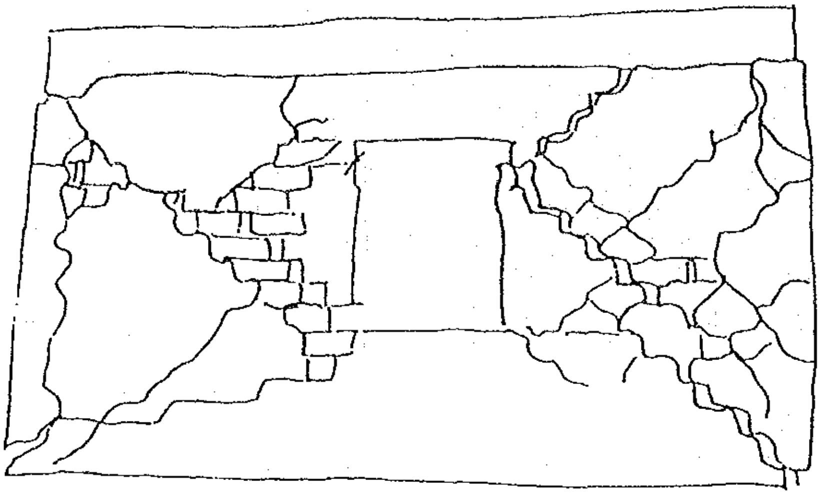


After 6th loading

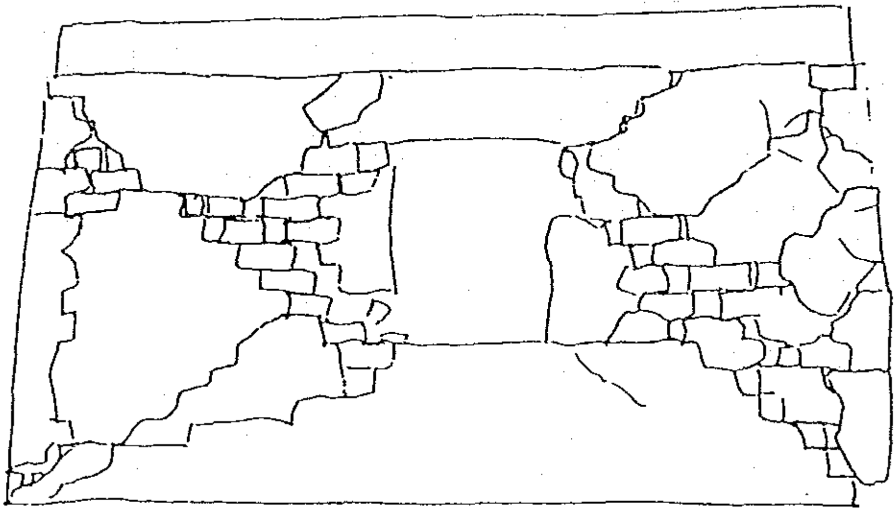
After 8th loading

After 10th loading

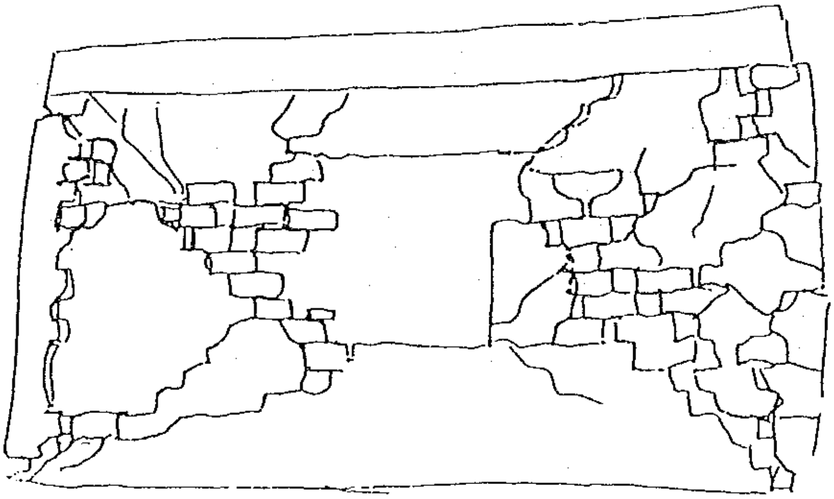
Figure 28. Development of damage pattern in the test on the masonary houses build by hollow brick blocks (second test)



After 12th loading



After 13th loading



After 14th loading

Figure 28. Development of damage pattern in the test on the masonary houses build by hollow brick blocks (second test)

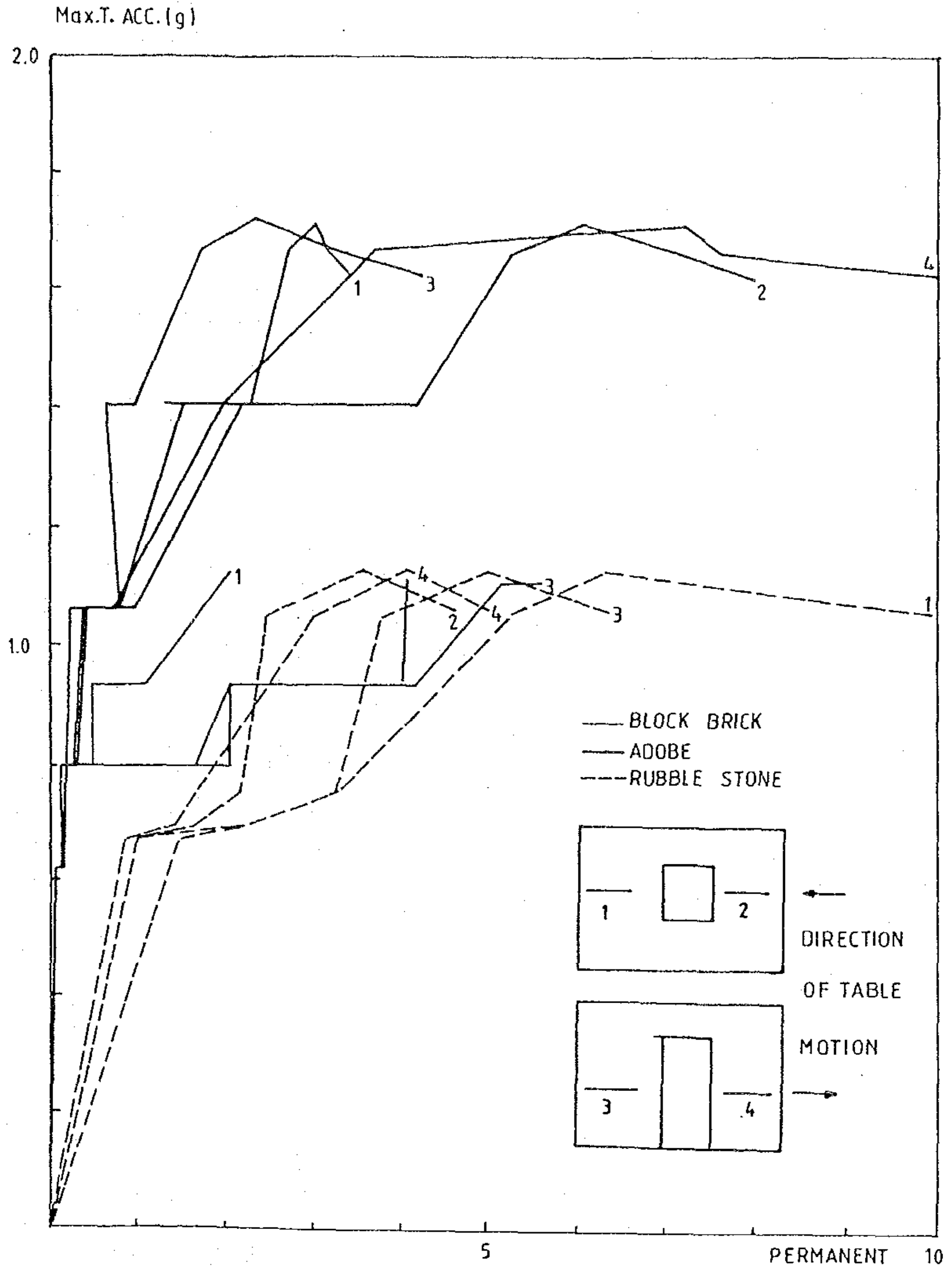


FIGURE: 29. BEHAVIOUR OF WALLS PARALEL TO THE DIRECTION OF MOTION IN ADOBE AND RUBBLE STONE MASONRY TEST HOUSES.

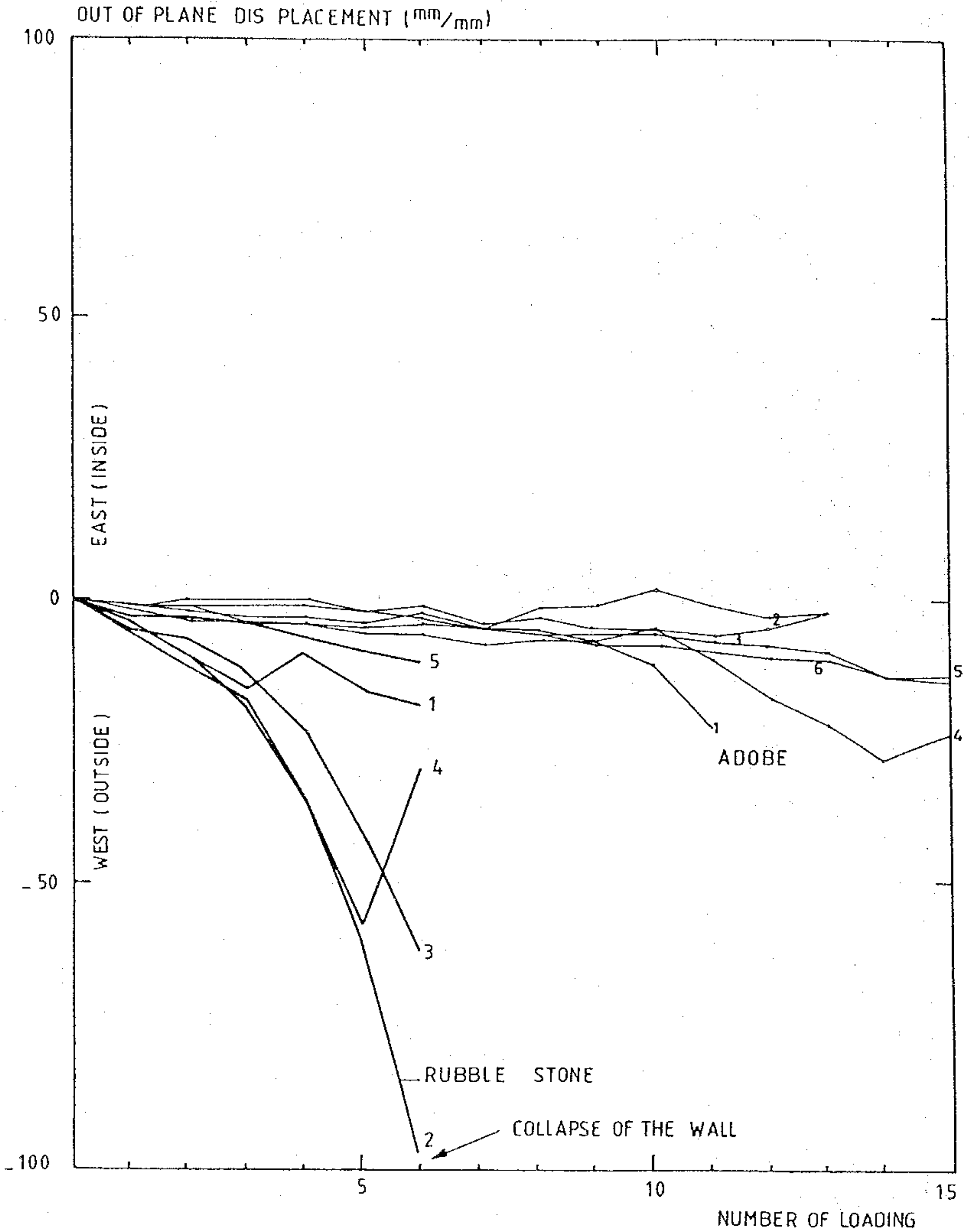


FIGURE: 30. OUT-OF-PLANE DEFORMATION OF THE WALLS PERPENDICULAR TO THE DIRECTION OF TABLE MOTION IN RUBBLE STONE AND ADOBE TEST HOUSES.

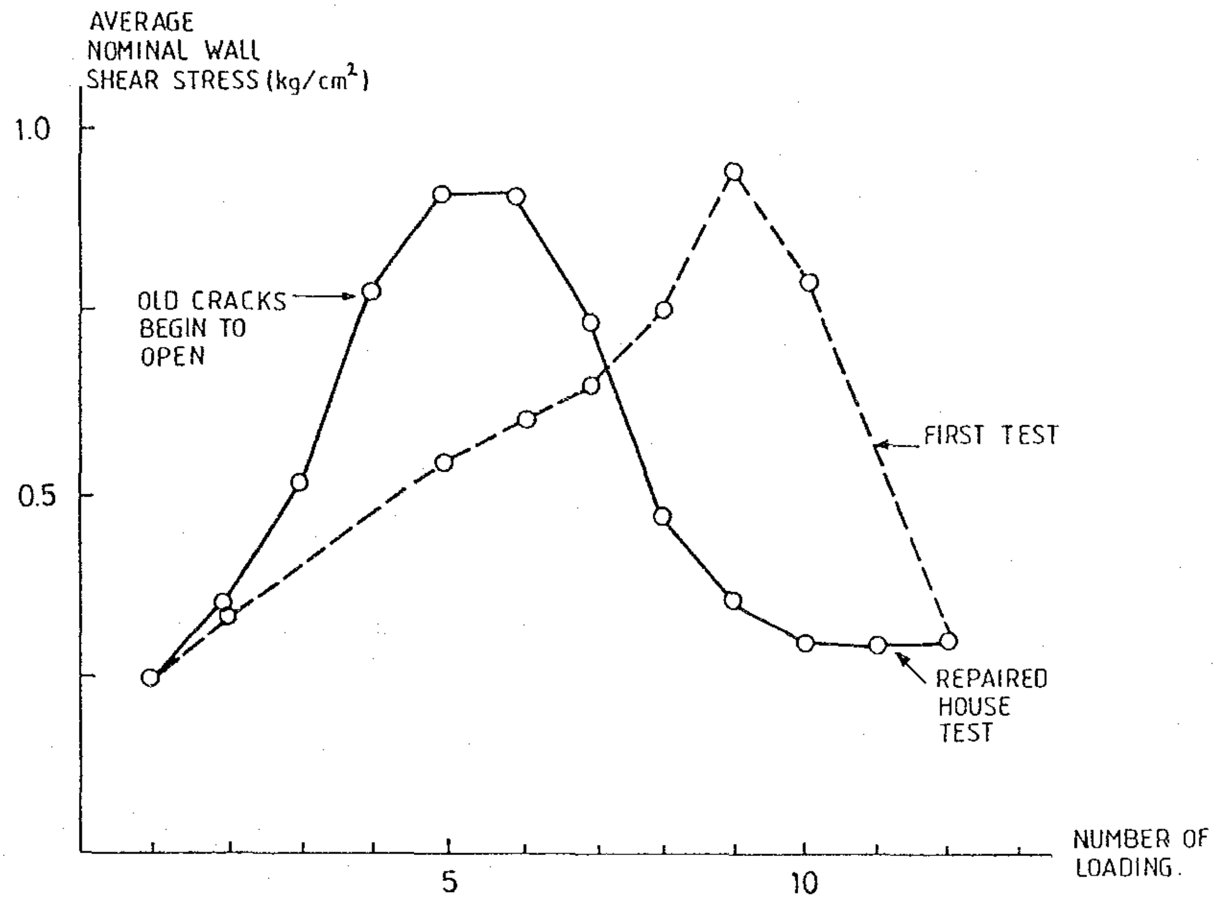


FIGURE:31. NOMINAL SHEAR STRESSES DEVELOPED IN THE ORIGINAL AND REPAIRED TEST HOUSES.