TURKISH STANDARDS AND CODES ON ADOBE AND ADOBE CONSTRUCTIONS

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ABSTRACT Standards on adobe, cement treated adobe blocks, adobe buildings and their construction methods are presented.

Adobe buildings section of Turkish Earthquake Code is also presented and compared with the above mentioned standards; the conformability of Standards and the Code is discussed by taking into consideration the ideas which were effected the preparation of these regulations.

1. Introduction

In Turkey adobe buildings, though decreasing sharply in number in cities, they are still widespread in rural areas and hold a percentage of approximately 20 %, of all buildings which have been built as masonry structures. Apart being used structurally, adobe blocks are also used as a filling material for timber framed constructions. (1)

Adobe is most popular, particularly in the regions where farming is the main occupation. Climate is another factor effecting to its usage, e.g., regions with land climate seem more favourable for this material.

People living in rural areas who have to build their own houses, stables and straw ricks prefer adobe for the following reasons :

a. Raw material of adobe, i.e. clayey earth, is available nearly everywhere and in most cases free of charge,
b. They have a wrong impression that these houses could be built without feeling necessity for some technical knowledge or advice,
c. Workmanship is simple,
d. These houses provide high degree of thermal and noise insulation,
e. Farmers could build their houses by utilizing their seasonally available free time.

On the other hand, in some cases, adobe houses have some significant disadvantages. These buildings are vulnerable to water. Adobe blocks may lose most of their strength and shape when they confront with water. Another disadvantage is their undesirable behaviour under seismic effects, particularly in cases where necessary provisions had not been taken into consideration during the building phase.

Several investigations were carried out to improve the

adobe blocks as a building material and to establish a set of rules for designing adobe buildings and their construction methods.

Turkish Standards Institute and Ministry of Reconstruction and Resettlement to achieve the above mentioned objectives issued three standards and a code respectively, under the following titles :

a.1. Cement treated adobe bricks, (2)
  2. Adobe blocks and production methods, (3)
on adobe as a building material,
b.1. A specific section in Turkish earthquake resistant building design code related with adobe buildings, (4)
  2. Adobe buildings and construction methods, (5)
on adobe buildings.

The purpose of this paper is to introduce, discuss and compare the contents of the standards and the code mentioned above.

Initially, rules of standard and/or code will be presented, then the applications made by people who are unaware of these rules and build according to their traditional methods.

2. Adobe Blocks

2.1. Dimensions :

Standard defines two groups of adobe blocks each having two types :

		Dimensions (cm)	Volume (dm3)	Weight (kp)	
Group I	a.	12x19x40	9.12	10-12	(cub)
	b.	12x30x40	14.40	15-25	(mother)
Group II	a.	12x18x30	6.48	7-11	(cub)
	b.	12x25x30	9.00	10-15	(mother)

Dimensional tolerances are ±5 %.

Surveys indicate that 12 cm depth is a very popular dimension. However, 10 - 11 cm depths are also encountered. Width x length dimensions differ for the cub blocks (15 to 20) x (30 to 40) cm,

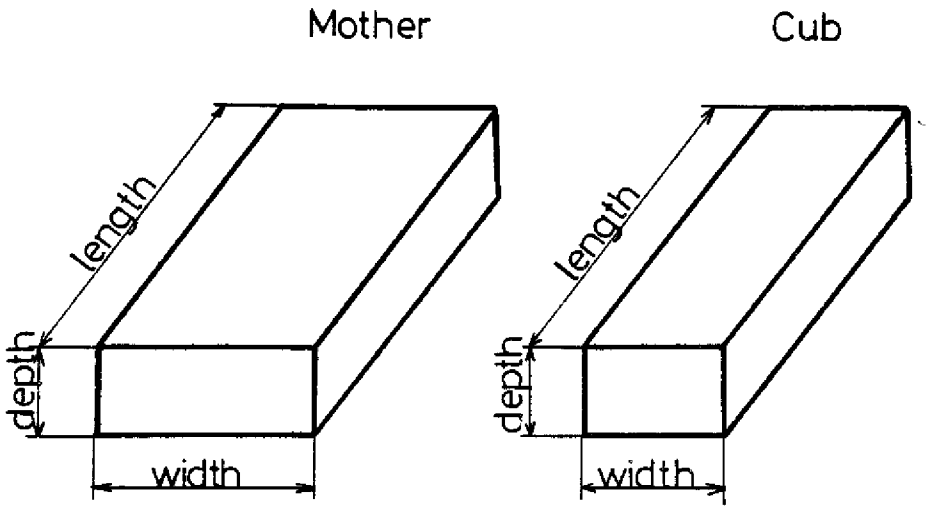


FIG. 1
Adobe block dimensions

for mother blocks (27 to 30) x (30 to 40) cm. (6).

This shows that standard aimed to obtain an average value of usual dimensions and generalize it as a rule.

2.2. Compressive Strength :

Standardly, compressive strength of adobe blocks should have a minimum of 8 kp/cm2, and the average of three specimens tested should be 10 kp/cm2 at minimum.

Compression tests on specimens sampled through 62 localities have given an average value of 9.55 kp/cm2 for compressive strength, 3.12 kp/cm2 for standard deviation. (6). This shows that standard values are viable and can be realized with little effort.

2.3. Water resistance :

When they are tested, as described in the standard, it is expected that the blocks should not disintegrate before 45 minutes.

2.4. Materials for adobe blocks :

Standard describes the raw materials of adobe blocks as follows :

Adobe blocks are made of clayey earth. The most suitable earth for this purpose should have 30 - 40 % of clay. 40 % of earth should go through 0.063 mm sieve. It should not contain

stones bigger than 3 cm. If earth contain more clay than it is recommended, then sand, crushed brick or stone, slag is advised to be added. Hay, which is used as an additive, should be dry, not-rotten and their fibre lengths should be 10 - 12 cm. Mixing water should be clean.

In practice, earth usually obtained from excavated earth at building site or in the neighbourhood, however, in some cases special pits provide earth for adobe construction. Roots, gravel and in most cases hay are additives used in practice, though in some regions additives are not used at all.

2.5. Preparation of materials :

Standard describes the production method as follows : A pit is excavated 3-5 m in diameter and one meter in depth and an amount of earth, which will be treated in one day is deposited into it. 500 lt water and additives are added for each m3 of earth and they are mixed and pressed thoroughly. Depending on the clay ratio within the earth, for each m3 of earth, hay is added with the following amounts :

20 % clayey earth	5 - 7 kp
35 % clayey earth	7 - 10 kp
50 % clayey earth	10 - 15 kp
70 % clayey earth	15 - 20 kp

This mixture left at rest for 12 hours.

In case earth has a high clay ratio, 70 - 340 lt sand,stone or brick crushings or slag should also be added for each m3 of earth.

In practice, however much more hay is added as compared to specified amounts in the standard.

2.6. Methods and tools for adobe block production :

Standard also describes specifications of the field where the blocks would be produced, tools would be used and gives drawings of some of them. It explains in detail how mixture should be cast into moulds, cured and dried.

These procedures and tools are in fact adopted from the real

life applications throughout the country. However, standard puts them forward in a systematic manner and emphasizes the important points.

2.7. Tests on adobe blocks :

Standard describes the tests which should be done on raw material and the adobe blocks and explains the preparation of test specimens, test procedures and how the test results should be interpreted. These tests are on the determination of :

a. Tension and compression strength, shrinkage, softening properties of the mud material,
b. Dimensional accuracy, compression strength and water absorption properties of adobe blocks.

It is inconceivable for a villager, who builds his own house to carry out these tests. Therefore, the purposes of defining these tests, as I understand, to help government offices responsible for building habitations at rural areas by standardizing the tests and to provide common basis for different laboratories working on adobe constructions.

2.8. Works on improving the qualities of adobe blocks :

Several researchers have been working to improve the properties of adobe blocks. Cement treated adobe blocks with their established standard are some of results of these works.

2.8.1. Treating with cement :

Standard gives the dimensions of cement treated adobe blocks as :

7x11.5x24 cm
11x11.5x24 cm
11x17.3x36.5 cm
11x23 x36.5 cm

These dimensions are, confusingly, not in line with the dimensions of the standard of adobe blocks.

28 days average compressive strength of these blocks should be :

for 5% (in weight) cement/earth ratio 10 kp/cm2
for 7% (in weight) cement/earth ratio 16 kp/cm2
for 10% (in weight) cement/earth ratio 21 kp/cm2

Their density should be 1.70 - 1.95 kp/dm3. Dimensional tolerances are 5%.

Then, preparing of the earth-cement mixture and casting into moulds are explained.

Finally, tests for dimensional accuracy, density and compression strength are described.

Tests carried out by researchers have shown that applying pressure on the mixture causes increase on the compressive strength of the cement treated blocks. (7). With 5% and 10% cement contents compressive strengths are increased to 20 and 35 kp/cm2 respectively. After water absorption and freeze-thaw tests these strengths are only decreased by 10 - 15%.

2.8.2. Treating with gypsum or other stabilizers :

Since Turkey has big deposits of gypsum, gypsum treating of adobe blocks is also investigated with successful results. 10 - 15 % gypsum addition to earth has increased compressive strength of gypsum treated blocks to 40 - 50 kp/cm2. (8, 9, 10).

3. Adobe Buildings

Under this title standard and the earthquake code are presented and compared.

3.1. Materials :

Adobe blocks should conform to their standards. Stone and timber should conform usual building standards and material specifications. Mortar is the same material which is used to produce adobe blocks. Apart from conventional roof covers, timber planks, reed, hay, clay and earth are mentioned as roofing materials.

In Turkey the most common roof cover for adobe buildings is clayey earth or clay. (11)

Earthquake code refers to the above standard in materials respect.

3.2. Number of storeys :

Standard mentions one and two storey buildings.

Earthquake code gives permission only single storey adobe houses, with at most, a stone walled basement. As 95 % of population of Turkey lives in earthquake zones, that means nearly all adobe constructions in Turkey should required to be single storey buildings.

3.3. Foundations :

Standard gives a minimum of 70 cm for the foundation depth with a provision that it may change depending on the soil conditions.

Earthquake code increases this depth to 80 cm and below to the freezing level of the site.

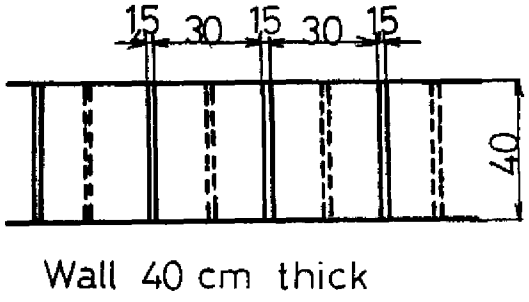
For the width of foundations, standard gives 50 cm for single storey, 60 cm for double storey buildings and instructs to revise these widths for poor soil conditions. Earthquake code also gives 50 cm width and calls for the stone foundation wall to raise at least 50 cm above ground and specifies the mortar qualities for stone foundation walls. These matters have been explained in the standard in more detail. Furthermore, specific information is given on the arrangement of steps of foundation levels at the sloping building sites. Earthquake code calls for 60 cm stone wall for basement walls.

Surveys made on 76 localities have shown that average foundation depth is 76 cm and standard deviation is 34 cm. (12). The height of the foundation wall above the ground level is found to be 74 cm as an average through 58 localities with a standard deviation of 40 cm. As these results indicate, the applications differ in a large range.

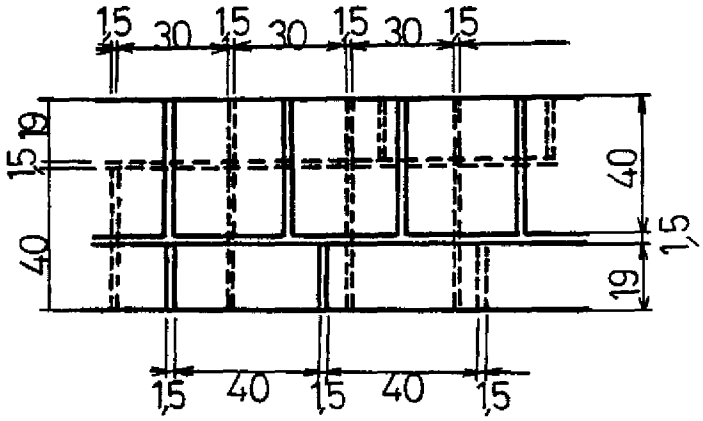
3.4. Walls :

3.4.1. Wall thicknesses :

Standard instructs wall thicknesses 40 cm for single storey buildings and upper storey of two storey buildings. Wall thicknesses of the lower storey of two storey buildings should be 50 cm.

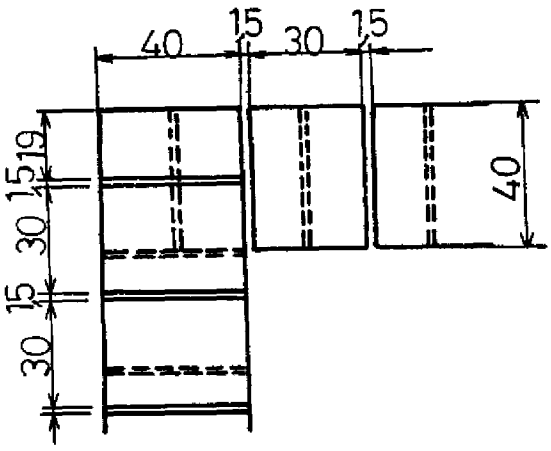


Wall 40 cm thick

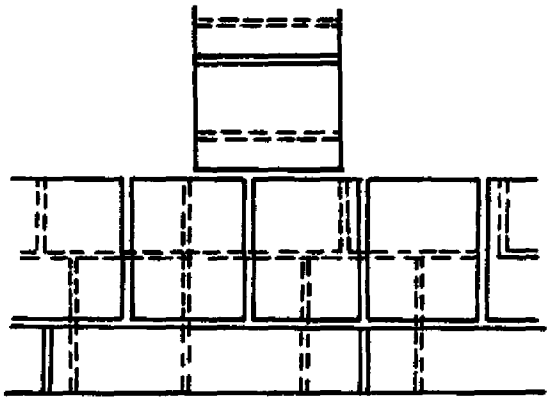


Wall 60 cm thick

All dimensions are in cm



Wall corner 40 cm thick



Wall corner 60 cm thick

FIG. 2

Wall thicknesses

Earthquake code assumes the length of adobe block 30 cm, which differs from standard's block dimensions and instructs 45 cm wall thickness for external walls and 30 cm wall thickness for internal walls.

Standard allows 18 cm wall thickness for non-structural walls.

Measurements made on 82 localities give an average wall thickness of 57 cm for external walls with a standard deviation of 10 cm. (12). For internal walls 63 measurements were made and average thickness is found as 50 cm with a 13 cm standard deviation.

The wall thicknesses given both in standard and earthquake code are smaller than the applications in practice. Apparently, the standard and the code assume blocks which were produced properly according to their own standards. As a matter of fact, the maximum compression stress is calculated as 2.18 kp/cm2 for a single storey adobe house which is designed against seismic effects. (13). This value, compared with the compressive strength of, 10 kp/cm2, given in the standard, represent an ample safety factor of 4.6.

3.4.2. Wall heights :

Standard has given maximum wall heigths as :

for 40 cm thickness 2.50 m ,

for 50 cm thickness 3.00 m ,

for 60 cm thickness 3.50 m .

Earthquake code restricts this height to 2.70 m for all cases.

Then standard gives information on constructing of the wall. On the other hand earthquake code instructs buildings to be rectangular in plan and symmetrical in both directions.

3.4.3. Free longitudinal length of walls :

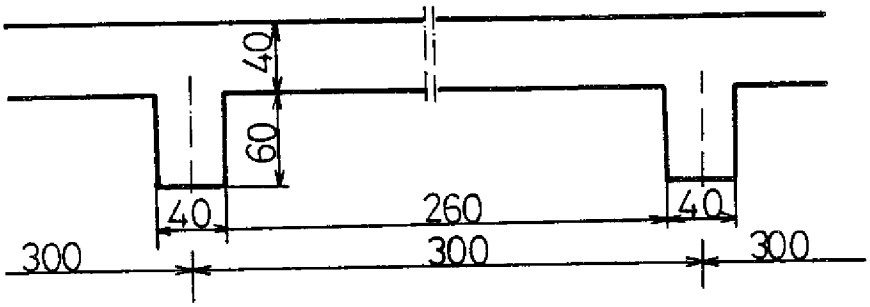


FIG. 3

Wall with additional props

Standard fixes the free space between the transverse walls at 4.00 m maximum. This distance may be increased to 6.00 m at independent stables and straw ricks.

Earthquake code gives this distance as 4.50 m between the axis of transverse walls, which conforms with standard's value.

3.4.4. Wall openings :

Earthquake code gives more detail on this subject and standard differs slightly from the code.

Minimum distance between the building corner and the opening should be 1.00 m and the opening should be at least 50 cm from the crossing point of walls. Maximum dimensions for doors are, 1.00x2.10 m , for windows are 0.90x1.40 m. Wall portions between openings should be minimum 60 cm ; if this distance is shorter, then two 10x10 cm timber posts should be provided on both sides of the opening and these posts should be connected to tie beams and/or lintels.

These limitations on openings could provide a good thermal insulation and enough load carrying capacity to absorb the lateral forces due to earthquake action.

Insulation against humidity should be provied under all adobe walls.

3.5. Chimneys :

Chimneys should be so arranged that they should not coincide with the cross-section of structural walls. Preferably they should not made of adobe blocks. Cross-sections of chimney space should be minimum Ø 15 cm or 15x15 cm.

3.6. Tie-beams :

Both standard and code call for 4 tie-beams. They should be provided above foundation, under window, above window, and under roof, levels.

3.6.1. Timber tie-beams :

Standard gives the cross-sections of tie-beams as 5x10 cm or Ø 8 cm, code 10x10 cm. Both call for twin tie-beams at above

said 4 levels on both surfaces of the wall. They should be tied with each other horizontally at every 1.00 m according to standard and every 0.50 m according to code with cross tie-beams.

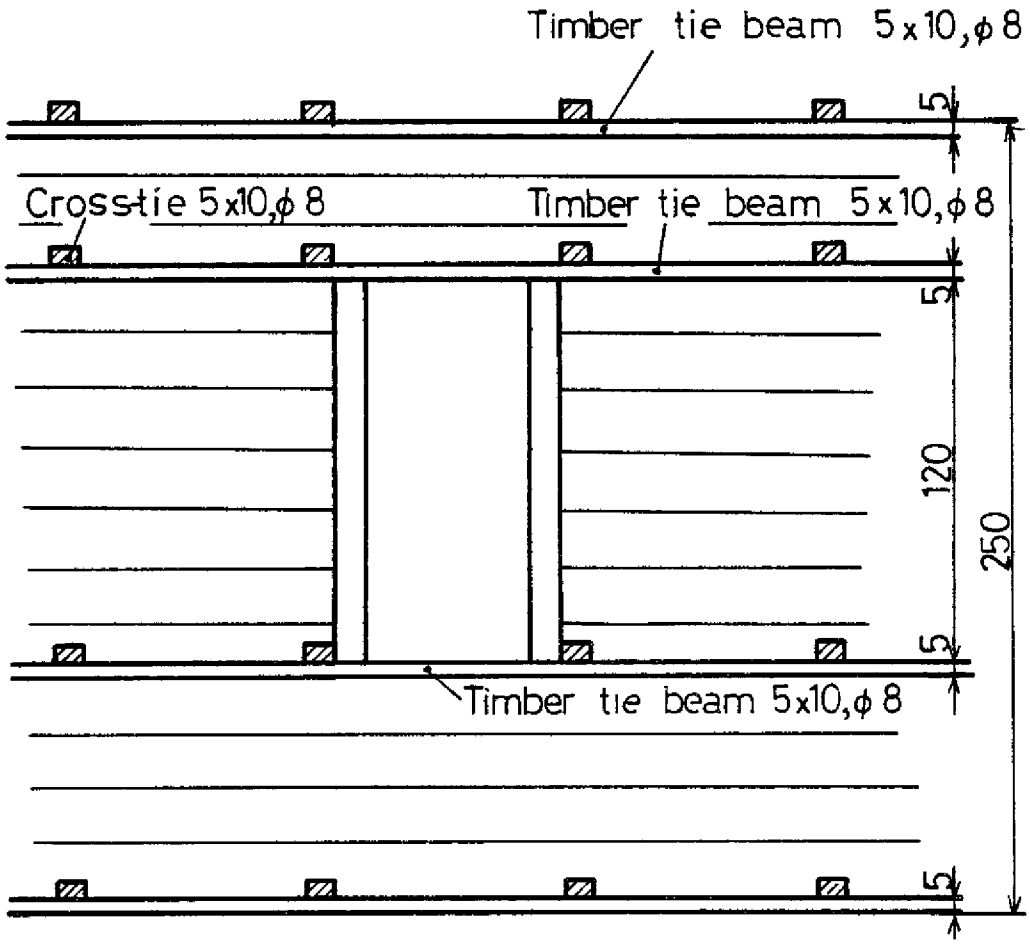


FIG. 4
Timber tie-beams

3.6.2. Reinforced concrete tie-beams :

These ties should have the width of the wall, a depth of 15 cm and 4 times Ø 10 mm bars reinforcement. Standard calls for stirrups at 40 cm, code at 25 cm. In both cases diameter of bars is 6 mm.

Standard also gives information on the construction of these tie-beams of which importance in earthquake behaviour of buildings is undisputable.

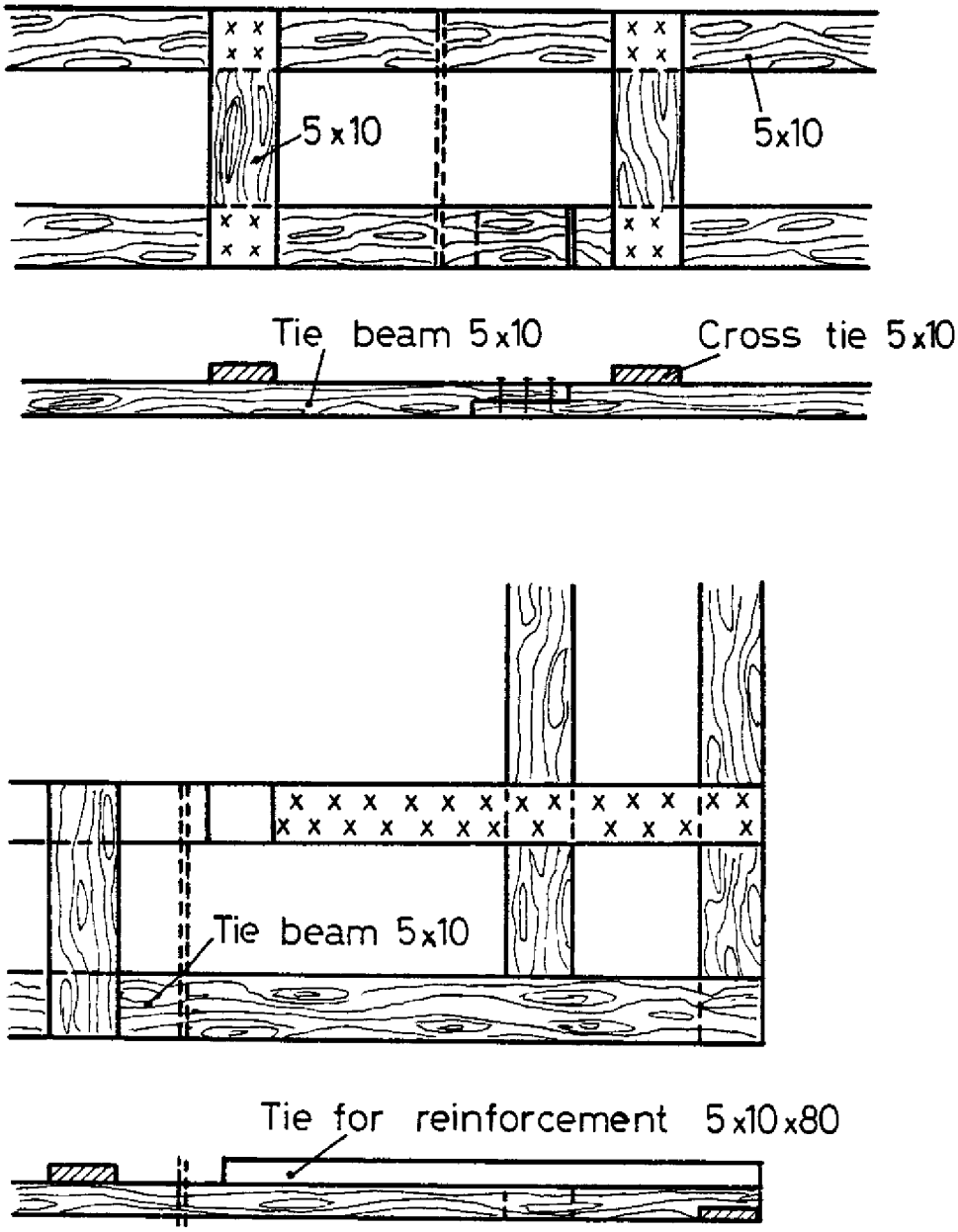
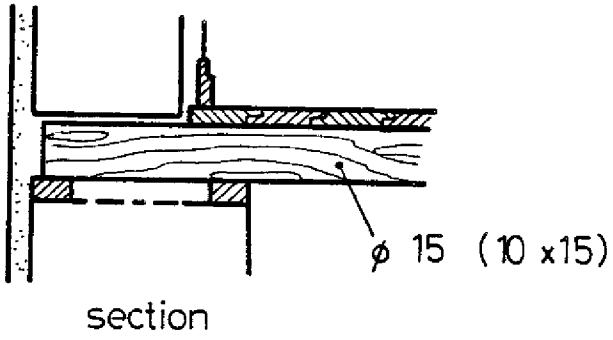


FIG. 5
Timber tie-beams

22 of 86 buildings taken under survey have no tie-beams at all. 19 buildings have one, 15 buildings have two, 29 buildings have three and only one building has four tie-beams. This shows that builders of traditional houses in rural areas do not give due importance to these ties.

3.7. Floors :

Earthquake code offers little information on floors as it assumes the buildings to have single storey.



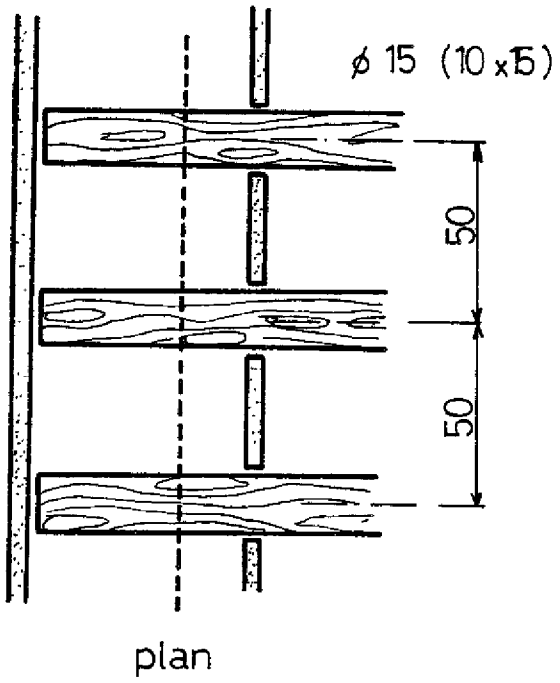


FIG. 6
Floor detail

Standard recommends beams at 50 cm from center to center for floors and at 40 cm from center to center for roofs. Their cross-sections should be ϕ 15 cm or 10x15 cm. The maximum span for these beams is 4.00 m. This shows conformity with free wall length.

3.8. Roofs :

Earthquake code calls for a roof as light as possible and 50 cm eaves out of the building. Earth covered roof is prohibited in Earthquake Zone I and II and it is only permitted in Earthquake Zone III and IV, provided that, the earth cover is not thicker than 15 cm. Standard also emphasizes on light roofs, gives constructional details for several types of roofs and roofings, including earth.

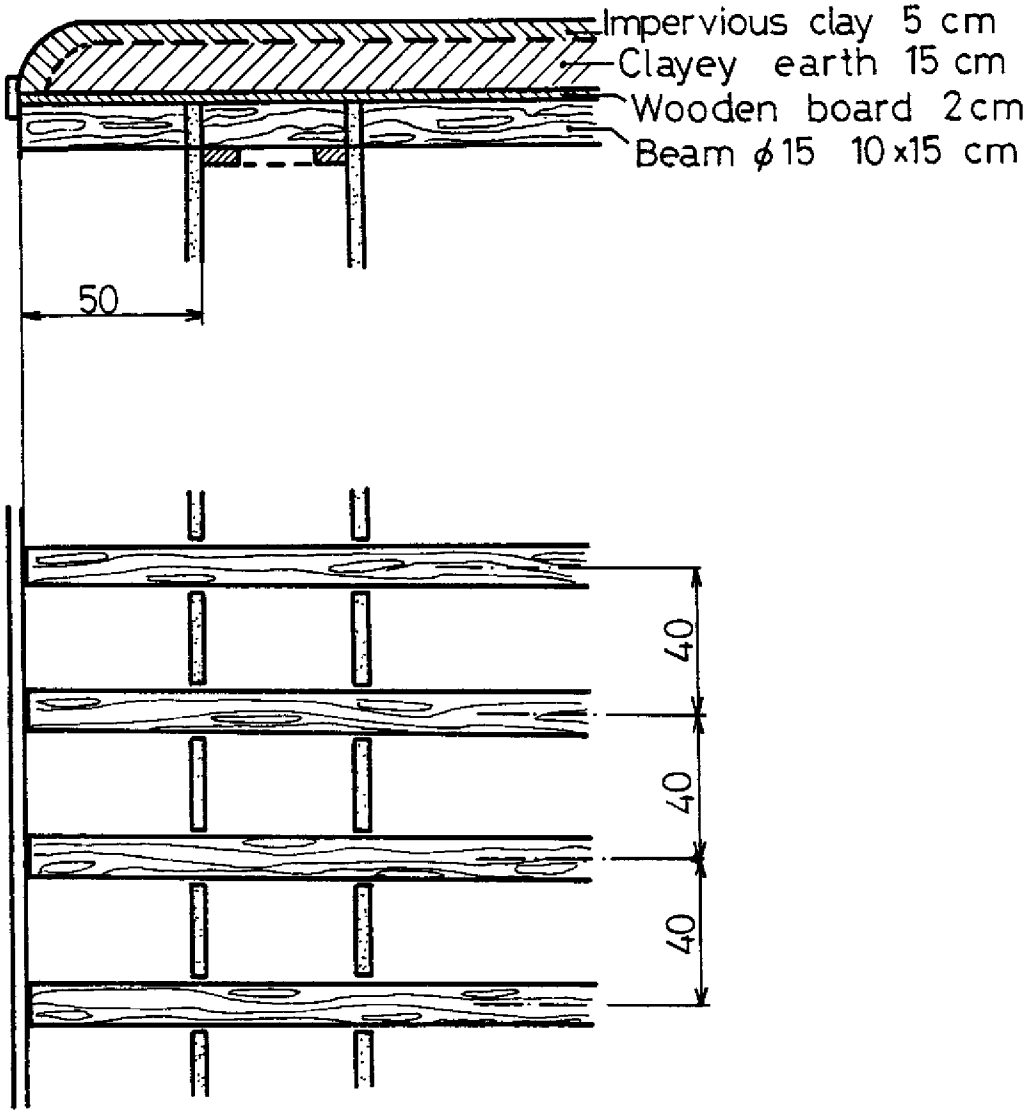


FIG. 7
Roof detail

46 out of 86 buildings which were investigated have earth covered roofs. The average thickness of the earth is 25 cm and its standard deviation is 11 cm.

Some of the recent earthquakes in Turkey though their magnitudes were moderate, regretfully resulted in with high numbers of casualties. One of the main reasons of failures of these rural houses is their heavy roofs which cause big inertia forces at roof levels which in turn cause the failure of the walls and the collapse of the heavy roof over the inhabitants to crush them like a press. This is the most important disadvantage of adobe buildings, which are indispensable to villagers as long as they are cheap to build and provide good insulation.

3.9. Other building elements :

Standard puts forward some rules and recommedations for doors, windows and plastering. Earthquake code does not mention about these aspects as it assumes these elements non-structural.

4. Conclusions

Earthquake code which essentially aims to limit even prohibit the adobe buildings in earthquake zones brought forward discouragingly strict rules and limitations for this type of buildings.

On the other hand, standard assumes that this type of construction will continue and therefore gives detailed information on their building techniques to improve their design.

In Turkey, adobe constructions are well described both by standards and earthquake code. The buildings which will conform with the rules of these documents are expected to have an acceptable behaviour under earthquake forces. However, it is a reality that the large percentage of adobe construction builders do not conform to these documents and this situation could not be taken under control.

As a last word, we hope that the earthquakes be few and apart and if they occur our buildings would resist them so that the people would not perish and suffer.

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