EARTHQUAKE ENGINEERING TRENDS IN IRAN

By A.A. MOINFAR (*)

Iran is located in a seismic zone, but the antiseismic design of buildings on sound scientific principles here, is rather new, as we have not experienced in this country a major destructive earthquake from the time that earthquake resistant building practices have come into effect.

We have had and still have most of the time minor tremors in various part of the country, but these, together with the smaller semi-destructive quakes, occur mostly in sparesely populated regions where there are no important buildings, so that the authorities concerned have not realize the great importance of this vital problem.

There has been a sensible increase in the activities of the seismic zone in Iran during the past ten years, and those authorities are now seriously worried about what the future may have instore, for the Iranian people.

The earthquake of 1st September 1962 in the Ghazvin region caused extensive damage in an area covering more than 13,000 square kilometres, by demolishing more than 300 villages with some 12,000 casualties.

The epicenter of this earthquake was about 140 km west of Tehran: it shook the large city of Tehran with an intensity of grade V on the Modified Mercally Scale. Of course there was no damage in Tehran but the inhabitants realized that this large city of Tehran is situated in a highly seismic zone.

The construction of massive and high buildings in Tehran is increasing steadily; the population of the city is over 2,000,000. Therefore it is appaling to even think what a semi-destructive earthquake could do in Tehran.

Most of the constructions in Tehran are built in brick masonry in two or three stories, but recently many five or six-storied buildings have been built using the same method of construction, since we have no Building Code with provisions and regulations about the resistance of buildings against earthquake. Therefore we need complete supervision over the designs and execution of the buildings in Iran.

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Although brick itself is not an assismic material, yet
for economic reasons we have to use this material for ordina-
ry buildings. Thus we must make this type of buildings assis-
mic by certain reinforcements.

In this paper I shall first describe briefly the typical
brick buildings of Iran and the methods proposed for their
reinforcement against earthquake and finally describe the major
structure in Iran and the regulations proposed to make them
earthquake resistant.

A. Masonry buildings

Many years ago these types of structures were being built
for one or two-storied buildings and the thickness of their
walls was of course considerable, because steel was not being
used then and arched floors were mandatory. In order to absorb
lateral forces due to vertical load they had to make the walls
rather thick; at the same time they used lime and sand for the
mortar, and this mortar was getting stronger proportionally with
the length of time. Therefore the walls acted as a unit and
could resist some amount of lateral forces and there was less
danger than with the recent Masonry buildings in Iran.

Unfortunately in the recent brick buildings almost inva-
riably we have not considered the earthquake forces. By using
steel I-beams in the floors we need no thick walls in buildings
because there are no lateral forces due to floors. Recently
the height of the buildings increased, and five or six-storied
brick buildings without any reinforcement have been very usual
in Tehran and at the same time the strength of mortar has
become less because after the introductions of cement in the
field of the building materials lime was gradually discarded
whereas the use of cement instead of lime also did not become
popular due to its dearness. We can see many high brick
buildings in Tehran which employ either mortars of clay or
clay with a small amount of lime. It is evident that such
buildings cannot bear earthquake forces.

Thus I can say the introduction of cement and steel in
the field of building materials did not improve strength stan-
dards in ordinary buildings in Iran and in fact they probably
led to a reduction in design efficiency from the point of view
of earthquake resistance; in another word the use of steel
and cement tempted the constructor to go for higher buildings
and to be less careful with the design of the ordinary houses,
and that this resulted in an overall weaker construction.

The second consideration which I wish to mention here is
that in the existing masonry buildings there are no rigid con-
nections between walls and floors, and also the connections bet-

ween walls of different directions are weak. The usual method for floor construction is based upon installation of I-beams directly on the brick walls every 1 or 1.25 m, then to make the floor with 11 cm. thickness brick arches between two I-beams.

Sometimes when the vertical load is excessive, concrete bearing pads are installed under the beams for prevention of breakage of the bricks. It is evident that such a connection between floors and walls is not rigid. The deformation of walls in the time of earthquake due to cantilever moment is therefore inevitable. Occasionally reinforced concrete tie beams are installed around the walls under the beams and such a solution is adequate for making the different direction walls to act as a unit; thus this method will make the building relatively earthquake resistant but still connection between walls and floors is weak. We have therefore to study this connection between floor and wall and to understand that we need to make floors and walls as a unit. This is possible if we place the supports of I-beams directly into the reinforced concrete tie beams- However execution is rather difficult and especially is wasteful of expensive forming materials. As an alternate solution for rather rigid connection between I-beams and tie beams we can cast bearing plates to support I-beams in the reinforced concrete tie beam, then weld the I-beams to these bearing plates: (such bearing plates involve little extra cost as such pieces are always available from waste).

In the attached figures there are some proposed details for the connections between tie beams and walls; by using these details the rigidity of the connection will be adequately ensured.

The third consideration is the rigidity of floors containing I-beams and brick arches; we cannot call this type of floor rigid as the floor can be deformed and it is not able to transfer lateral forces to the different elements. However for several reasons as follows we use this kind of floor for ordinary buildings.

1. Execution is very simple and Iranian bricklayers and laborers are adapted and skillful in the construction of this type of floors.

2. Formwork in Iran is rather expensive and this type of floor does not require forming.

3. Although we have to import steel I-beams (as we import rods), in comparison with reinforced concrete the difference in cost is negligible; thus the cost of the material of reinforced concrete floor is much more than the cost of the material of this type of floors.

Being assured of the rigidity of brick floors, it is assumed that the provision of a reinforced concrete tie beam and a rigid connection between I beams and tie beam is adequate.

but it is practical to include some diagonal flat bars in the floor welded to the I-beams, to ensure complete rigidity.

The recommendations made for masonry buildings are as follows:

Limitation of height

1 - The brick buildings must be limited to three stories and in any case the height of these structures must not exceed 11 m above ground level; the mortar which will be used in these buildings is either cement and sand, or lime and sand of good quality.

2 - The concrete block buildings must be limited to two stories and in any case the height of these structures must not exceed 8 m above ground level; the mortar of these buildings will be of cement and sand.

3 - Coursed rubblestone masonry buildings must be limited to one story only and the height of these structures must not exceed 5 m above ground level; the mortar of these buildings should be of cement and sand.

4 - The maximum height of every story in the masonry buildings must not exceed 3.5 m, otherwise it is necessary to use a reinforced concrete tie beam in every 3 m height of the walls.

External and internal walls

5 - The amount of wall ratio including external and internal walls at any direction of the building must not be less than 20 centimeters per square meters. The wall ratio of any direction of every story will be calculated from the total lengths (in centimeters) of all the walls in that direction which are thicker than 20 centimeters divided to the area of that floor in square maters; and if the wall has opening, the equivalent length of wall can be calculated by using this equation,

$$1 = \frac{S - s}{h}$$

in which (1) is equivalent length, (S) is the surface of the wall, (s) is the surface of the opening and (h) is the height of the wall.

6 - Total area of openings in the external wall shall not be more than 1/3 of the surface of the wall, and total amount of spans of openings in the external walls shall not be more than 1/2 of the length of the wall.

The length of the walls is limited, and every wall must be

supported by other jonction walls, at least 8 m apart.

7 - The distance between the first opening in the external walls and the corner of the building shall not be less than 1 meter and the distance between two openings shall not be less than 1/6 of the total spans of those openings.

7 - The execution of the masonry buildings must be in a way that all layers will be coming up uniformly, without any notches and never "Hasht-Guir" (1) is to be used.

8 - The vertical joints of brick walls in ordinary buildings in Iran are usually without mortar, and thus the strength of the wall against lateral forces will be decreased. Therefore it is strongly recommended that all vertical joints be filled with mortar.

9 - The length of partition walls with a thickness of less than 20 cm should not be more than 3 m, otherwise it is necessary to use steel or reinforced concrete columns inside the partition walls. In any case the partition walls must be properly anchored to the main bearing walls by means of some pieces of flat or rod steel bars.

10 - It is necessary to install reinforced concrete tie beam over the foundation (under the masonry walls) and over the masonry walls (under the floors); these tie beams will make all the walls as one unit.

Floors

11 - Old type floorings which used to be constructed by installing round timbers on the walls and then were covered by straw mats and heavy clays must be discontinued.

12 - The usual style of constructing floors with steel I-beams and brick jack-arches with gypsum mortar for ordinary buildings can be allowed, if the constructor takes into consideration the reinforcement mentioned previously.

The supporting length of Steel I-beam on the wall must not be less than 25 cm, nor shorter than:

$$a = N + 10$$

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(1) "Hasht-Guir" is the usual work of the bricklayers in Iran for construction of brick walls; they willconstruct a certain wall in several parts, because of saving the Scaffoldings.Thus they will build a part of wall covered with notches in the end, then they will move the Scaffoldings for construction of new part, and the connection between these two parts is the notched section. It is clear the wall cannot be considered as a Unit.

in which "a" is the supporting length in cm and "N" is the height of steel I-beam in cm.

In the Ghazvin earthquake of 1st September 1962, there was a public bath in Buin-Zahra which was constructed relatively good, using brick with lime and sand mortar; this building was the only one which did not collapse completely, while all other buildings, more than 500, built of adobe were demolished.

The roof of this building was built of steel I-beams and jack arches set in gypsum mortar, some part of it had fallen and it was noticed that the supporting length of the steel beams of fallen part were too small, that is less than 15 cm.

B. Majors structures

The important buildings which we use for governmental or business offices in Iran are usually of four or five stories, but recently the buildings have increased beyond these heights.

These types of buildings are usually constructed of reinforced concrete or steel frames.

In the construction of steel or reinforced concrete buildings there has been no consideration of earthquake stresses, and as the buildings were not too heavy, calculations were only based up on vertical loads. Perhaps in checking four or five story buildings the dimensions which are calculated for vertical load are not too far off dimensions which we need to absorb earthquake forces, but the most danger is with recent buildings of a height of more than five or six stories. The moments due to earthquake forces especially in the lower floors at the connection of beams and columns are very high and the dimensions calculated for vertical loads usually are not adequate for such earthquake forces.

The regulations proposed for Earthquake Resistant Building in Iran are similar to other countries and I shall describe briefly in here:

Basic Building Materials

1 - The buildings which are higher than 11 m or more than 3 stories must be built by reinforced concrete or steel skeleton. These buildings shall be designed and constructed to resist stresses produced by Earthquake forces as the effect of a force applied horizontally at each floor. The force shall be assumed to come from any horizontal direction.

Buildings higher than 40 m in height shall have a complete moment resisting frame to resist at least 30 per cent of the earthquake force for the building as a whole.

Base shear

2 - The buildings must be designed to resist a minimum earthquake force calculated from this equation,

$$V = K.C.W.$$

in which (V) is the base shear, (K) depends upon the seismical map of Iran, (C) is the seismic coefficient which will be described later and (W) is the dead load of the building plus some live load to be described later.

Seismic coefficient

3 - For the buildings up to seven stories or less than 25 m , in height, the fixed seismic coefficient is proposed as follows:

If the buildings are built on allowable bearing soil of less than one Kg/cm2, the seismic coefficient should be C = 0.10 for ordinary buildings such as apartment houses, office buildings etc....; the seismic coefficient should be C = 0.125 for public buildings such as hospitals, schools, etc.

If the buildings are built on allowable bearing soil of more than one Kg/cm2, the seismic coefficient should be C = 0.08 for the ordinary buildings and C = 0.10 , for the public buildings.

4 - For the structures higher than 25 m, or the buildings more than seven stories the seismic coefficient should be determined with consideration to the fundamental period of the building; $C = \dfrac{0.025}{T}$ in which $T = 0.09 \dfrac{H}{\sqrt{D}}$, T is in second, H is the height of building in meter and D is the width of the building in the direction under consideration, in meter.

The value of "C" should not be less than 0.04 and not more than 0.10. In any case "C" must be more than $0.10 \dfrac{Ws}{Wt}$, in which (Ws) is the amount of (W) for the first 25 meters of the building above the ground, (Wt) is the total amount of (W) for the whole building.

Distribution of the lateral forces

5 - The distribution of earthquake forces in buildings more than three stories high will be in accordance with the American Code, Uniform Building Code, 1961 edition, that is $F_x = V \dfrac{W_x \, h_x}{\Sigma(Wh)}$ but for the buildings of less than three stories, the distribution of the Earthquake forces uniformly over the height of the building is permitted.

Seismic coefficient for the parts of the buildings

6 - The seismic coefficient for the parts or portions of the

buildings should be according to Uniform Building Code mentioned above.

Live load

7 - The live load of the buildings which must be considered in the calculation of the buildings against earthquake shall be determined as follows.

For the ordinary buildings such as apartment houses, Office Buildings etc. 60 Kg/m2 (while the live load for vertical calculation is assumed 200 kg/m2). For the stair, classroom, hospital etc. 180 Kg/m2 (while the live load for vertical calculation is assumed 350 Kg/m2).

For department stores, assembly hall with fixed seats, etc., 200 Kg/m2 (while the live load for vertical calculation is assumed 500 Kg/m2). For assembly halls with unfixed seats 280 Kg/m2 (while the live load for vertical calculation is assumed 700 Kg/m2).

Allowable unit stresses

8 - The extend of rupture stresses for any steel which will be used in the buildings shall not be less than 3,400 Kg/cm2; therefore we can assume the allowable stresses in the calculation of vertical load up to 1,400 Kg/cm2 for tension and compression, and 900 Kg/cm2 for shearing. If the rupture stresses of steel be more than 5,000 Kg/cm2 it will be permitted to assume that the extent of allowable stresses for calculation of buildings against vertical loads be of the same extent as the regulations of the producing countries.

Anyhow for calculation of buildings against earthquake forces we can assume allowable stresses to be 1/3 more than allowable stresses for vertical load calculation.

9 - The allowable stresses of ordinary concrete (with 300 Kg cement in a cubic meter for concrete) shall be as follows:

Sixty Kg/cm2 for vertical and 120 Kg/cm2 for lateral forces calculation, in the simple compression.

Fifty Kg/cm2 for vertical and 100 Kg/cm2 for lateral forces calculation, in the compression due to bending.

Special concrete is a concrete which will be made by giving special consideration with accurate granulometry of its aggregate.

The strength of this concrete must be tested, and the allowable stresses of it for compression must not be more than 1/3 of the strength of 28th day of its age; for the earthquake forces calculation the allowable stresses is 2/3 of 28th day of concrete age.
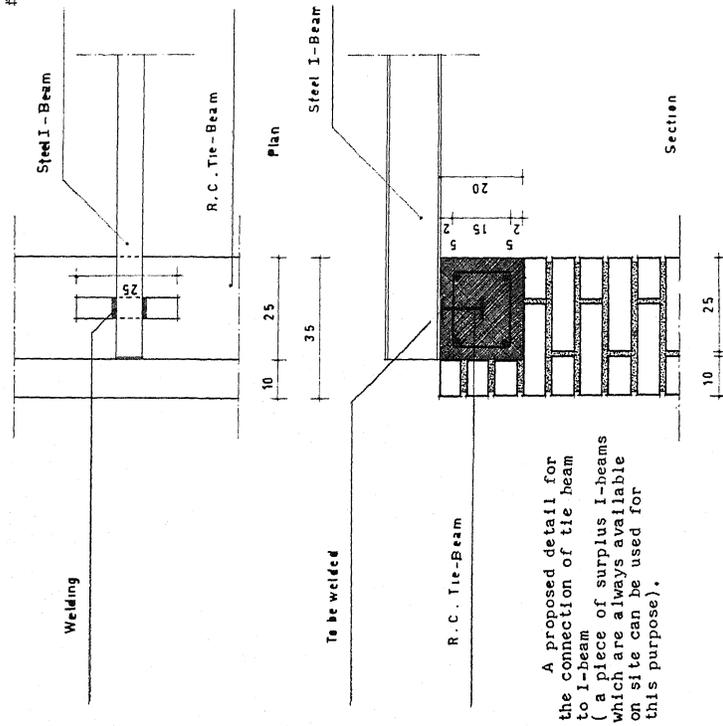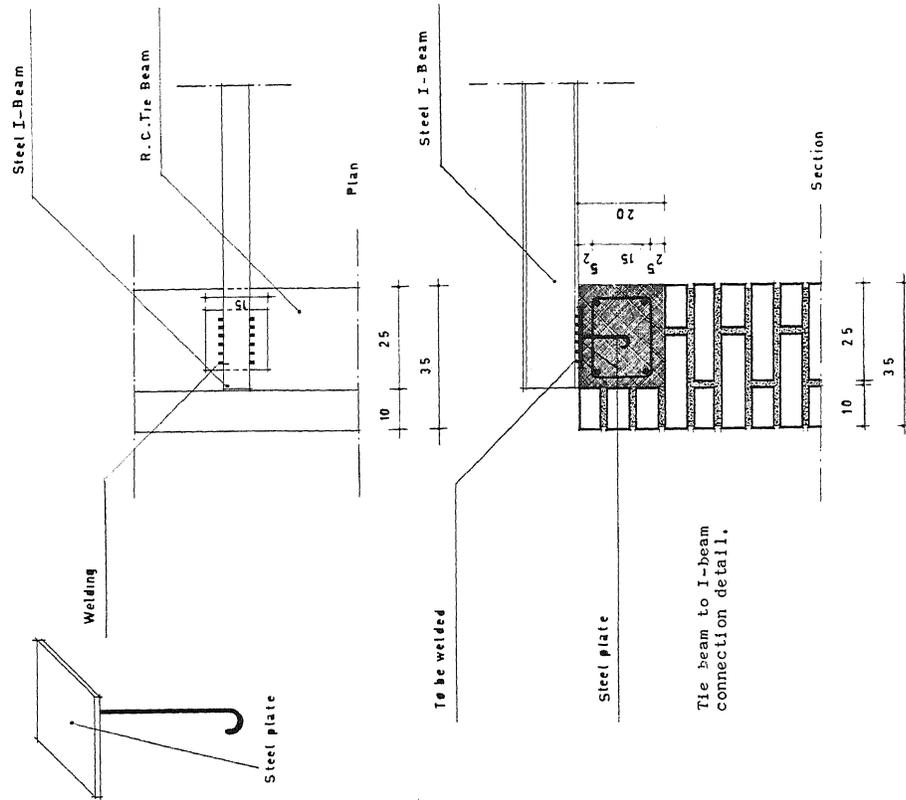
In any case the allowable stresses of compression of con-
crete shall not be more than 90 kg/cm2 for vertical loads, and
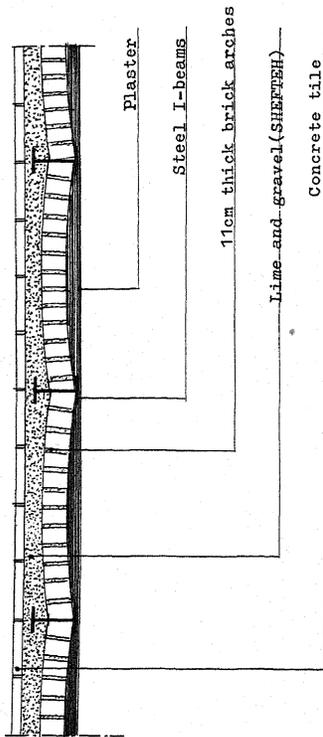180 for earthquake forces.

Acknowledgment

I wish to appreciate the consideration given by Professor
Behnia, Chief of the Technical Bureau of the Plan Organization
and Professor at the University of Tehran as well as Professor
Ambraseys of the Imperial College of Science, University of
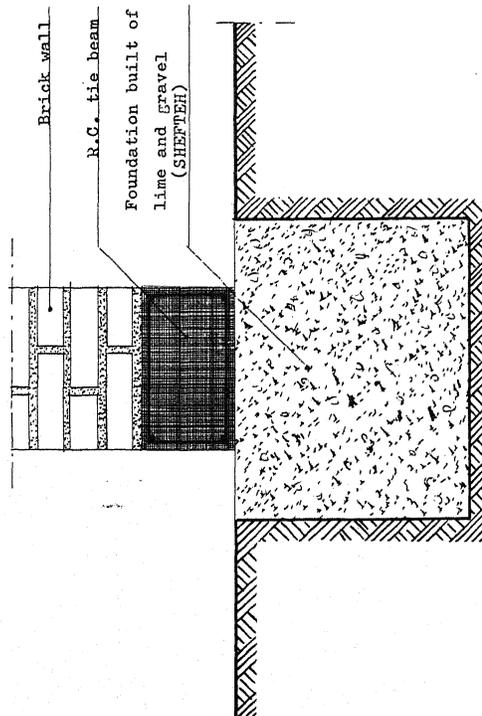London, for their encouragement given me in the preparation of
this paper.

References

1- Ambraseys N. (1962)"The Buyin-Zara (Iran)"earthquake of
            September 1962; in 3 volumes
            UNESCO Mission Report

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            ization of Iran No.(10)

6- Omate S., et al (1962) " A Preliminary report on Qazvin
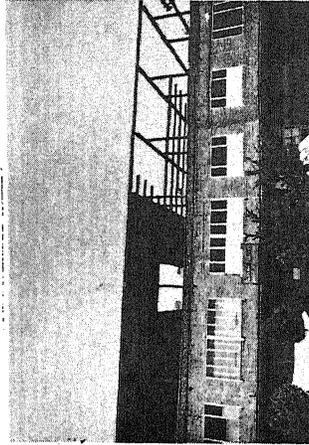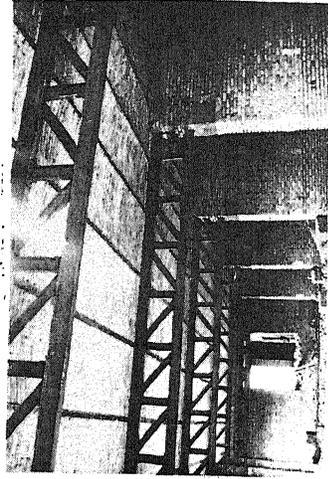   earthquake of September 1, 1962.

Steel I-Beam

R.C.Tie Beam

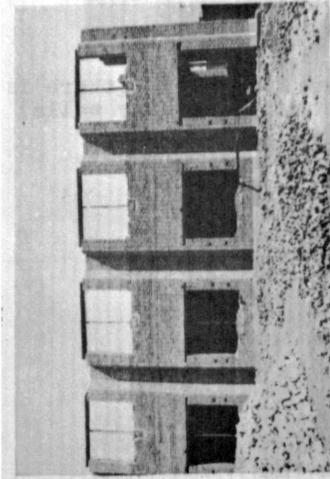Plan

Steel I-Beam

Section

20
2.5 15 2.5

25

35

10

15

Welding

Steel plate

To be welded

Steel plate

Tie beam to I-beam connection detail.

Steel I-Beam

R.C.Tie-Beam

Plan

Steel I-Beam

Section

20
5 15 2.5

25

35

10

25

Welding

To be welded

R.C.Tie-Beam

A proposed detail for the connection of tie beam to I-beam (a piece of surplus I-beams which are always available on site can be used for this purpose).
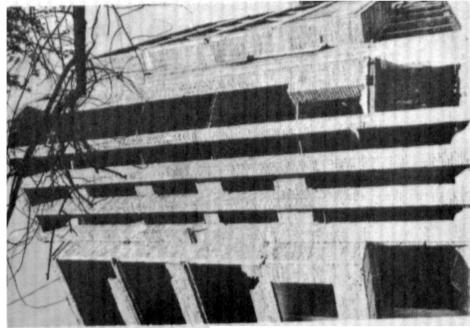
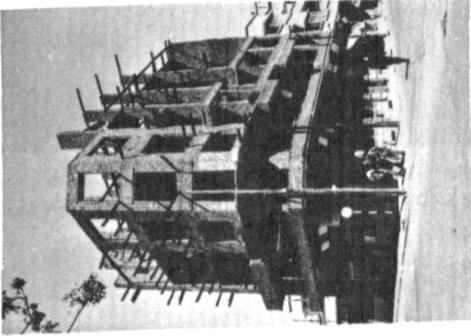The usual method of constructing floors with Steel I - beams and brick jack arches with gypsum mortar

Concrete bearing pads under the girders for prevention of breakage of bricks (but there is no rigid connection between the walls and floor)

Plaster

Steel I-beams

11cm thick brick arches

Lime and gravel (SHEFTEH)

Concrete tile

The usual method of constructing floors

Brick wall

R.C. tie beam

Foundation built of lime and gravel (SHEFTEH)

The usual foundations of ordinary buildings in Iran built of lime and gravels, called (SHEFTEH) , in which there is no consideration for solidity nor reinforcement against earthquake. Therefore the reinforced concrete tiebeam under the walls are necessary.

Six storied brick building under construction
(it is evident that such buildings cannot withstand
earthquake forces).

Stone building with no connection
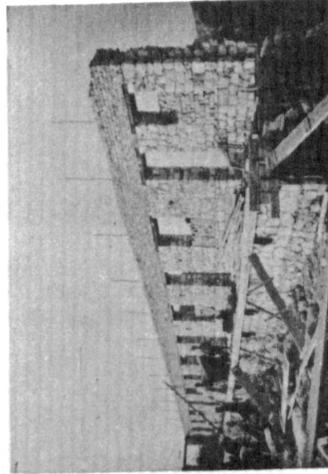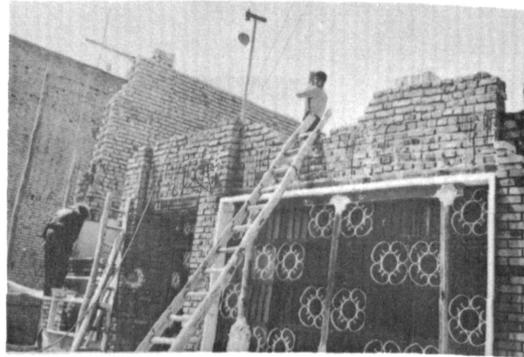between junction walls.

External brick walls with many disruptions
(such walls cannot act as a unit)

A typical brick building (there is no rigid con-
nection between floors and walls)

IV—425

Buin-Zahra dispensary after the earth-
quake of 1st September 1962; (brick
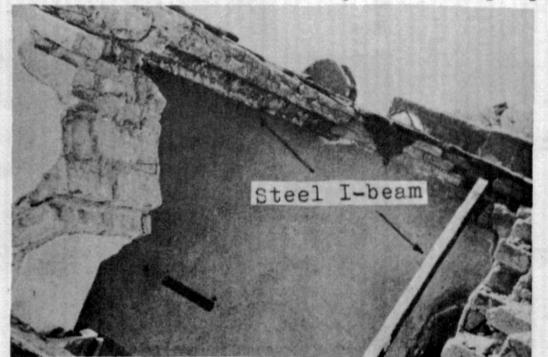building with I-beam and jack arches
roof)

Brick building with adopting "Hasht-Guir"

The same building from close

The same building from close (there is
no unity between perpendicular walls)

A part of the roof of the public bath
in Buin-Zahra which fell in earthquake
of 1st September 1962; (the supporting
length of steel I-beam of this fallen
part was too small, that is less than
15 cm.)

<u>E R R A T A</u>

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PAGE 421:   Para 9, Line 2 should read:

"<u>Fifty</u> kg/cm^2 for vertical and <u>100</u> kg/cm^2 for lateral
forces .... compression."

PAGE 421:   Para 9, Line 3 should read:

"<u>Sixty</u> kg/cm^2 for vertical and <u>120</u> kg/cm^2 for lateral
forces .... to bending."