A SURVEY OF BUILDING DAMAGE DURING THE EL-ASNAM, ALGERIA EARTHQUAKE OF OCTOBER 10, 1980

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SUMMARY

A large number of buildings of modern as well as old construction in and around the town of El-Asnam, Algeria sustained catastrophic damage due to the earthquake of October 10, 1980 and this was followed by numbers of casualties. It was observed in the field inspection that careful attention for the effects of severe ground motions was not paid to those buildings in both the design and construction. This paper describes the observed performance of engineered buildings, mostly of reinforced concrete, and following discussions related to the seismic design and construction.

INTRODUCTION

A destructive earthquake occurred on October 10, 1980 near the town of El-Asnam which had a population of 125,000 and was 180 km west of the capital city of Algeria [1-3] (Figs.1 and 2). The earthquake measured a Magnitude of 7.3 and was followed by surface faulting (Fig.2). The town experienced the MM intensity between IX and X. Although no record of the main shock was obtained, an aftershock of a Magnitude 5.8 recorded the ground acceleration of 31% gravity [3]. A great number of buildings of modern as well as old construction in and around the town sustained catastrophic damage during the earthquake and this lead to the death toll about 2,500.

Seven weeks after the earthquake two reconnaissance teams, organized by the Japanese Government and the Architectural Institute of Japan, respectively, were sent to the affected area to make investigations of the effects of the earthquake. The first author of this paper participated the former team while the other joined the latter team of practical engineers. Field investigations of the latter team were made for one week, often jointly with some members of another team, focusing on the performance of engineered buildings. The investigations included the elastic wave prospecting and microtremor measurement of the ground (Fig.3) as well as inspection of buildings [1]. This paper describes the observed performance of buildings and discussions of the seismic design and construction of buildings in the area.

BEHAVIOR OF BUILDINGS

According to the survey of about 6,500 buildings in El-Asnam and its vicinity, which was made soon after the earthquake by the Organisme de

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Controle Technique de la Construction (CTC)[3], most buildings, say 75% or more the total number, were those of unengineered masonry structure. The other buildings, up to 6 stories tall, normally consisted of concrete frames with masonry infill. Some use of concrete shear walls was noticed in recent construction. Light industrial buildings generally used steel framing. The damage assessment made by the CTC indicated that a quarter of 5,000 or more buildings in El-Asnam were severely damaged or collapsed while one third the buildings experienced only minor damage. The other 42% needed further investigation before reoccupation or condemnation.

Where configuration was poor or walls were inadequately braced by across wall, substantial damage and collapse was common in unengineered masonry buildings (Photo 1). The shear failure of short columns was observed (Photo 2). Note that spandrel walls of masonry as well as concrete are capable of restraining the deformation of columns. A significant change in story stiffness resulted in excessive displacement and consequent collapse of columns in a soft story (Photo 3). In case of 3-story apartment buildings in Photo 4, their structure had a crawl space at their base for sanitation, which was about 1 meter high. As no structural wall was provided at the space, short columns of small dimension (25 cm square) had to carry entire lateral loading, thus, the failure at that level and the drop of entire building were not surprising. No damage to steel frames was noticed (Photo 5). Buildings with masonry infills in good configuration or concrete walls behaved very well. In a 3-story apartment building in Photo 6, concrete walls absorbed a sufficient amount of energy with moderate damage to protect concrete frames. No damage was observed in a 3-story dwelling which had exterior infill walls with small and regular penetration and the numerous interior walls (Photo 8).

It appeared that the soil condition was generally good and there was no strong relation between the building damage and soil. The measured shear wave velocity in the surface soil at the building area (sites 1 to 3 in Fig.3) was 210-260 m/sec, while the predominant period of the groud at the site 2 was about 0.2 sec. Although obtained data was very limited, it did not indicate any sign of special condition of the soil, such as soft soil, which must be carefully taken into consideration in the design.

PERFORMANCE OF SOME PARTICULAR BUILDINGS

Several buildings were inspected in detail measuring the dimension and the site condition. A 6-story mill factcry building shown in Photo 9(a) was rather old and was separated into four blocks by seismic joints having narrow space about 3 cm (Fig.4). The observed damage to structure was 1) compression failure of columns, 2) shear failure of beam-to-column joints and 3) pounding between adjacent blocks (Photos 9(b) to (d)). The damage dominated at the upper stories from the third of the block B where the number of columns was significantly reduced (Fig.4). Apparently, the narrow space of the seismic joints resulted in the pounding. It was supposed that the top story of the block D was lost due to the pounding (Photo 9(a)). Presumably, the absence of shear reinforcement in the beam-to-column joint would have extended the cracks up to failure. Although its ultimate strength was approximated, based on the column dimension, to be much less than 0.2 in terms of the shear coefficient as indicated in Fig.5, its long fundamental period and the existence of basement would have avoided catastrophic damage.

A group of identical 2-story dwellings of reinforced concrete was under construction on a hillside at the site 2 in Fig.3, and they were near the completion. It was interesting that a half or more the buildings were pancaked (Photo 10), while many of the other buildings were standing without any significant damage to structures. As the more collapse of buildings was found at the farer side from the hill, as indicated in Fig.6, it was suspected that the subsoil conditions accounted for the difference in their behavior. The approximated ultimate strength of a building, based on the column dimension and reinforcement, was slightly higher than 0.2 in terms of the shear coefficient.

DISCUSSIONS

A large number of engineered buildings were heavily damaged or totally collapsed due to the earthquake. The inspection of those buildings indicated that careful attention for the effects of severe ground motions was not paid in both the design and construction. Main causes of their bad behavior would have been 1) inadequate architectural design which includes soft stories, short columns and irregularlity in plan and elevation, 2) inadequate structural design and detailing which include the lack of appropriate lateral resistance, heavy floor system, poor confinement of concrete in columns and beam-to-column connections, and inadequately provided seismic joints, and 3) poor material of concrete and quality control.

The slenderness of columns and heavy floor system would have been resulted in high shear and axial stresses in columns. This apparently lead, together with poor confinement of concrete, to the brittle failure of columns. While there were encouraging observations of buildings which survived the earthquake. Wall-frame structures of concrete behaved in good manners. In case infill was of subsequence and building had regular configuration, damage was limited. These suggested that the use of structural walls was effective against severe earthquake and it would have been possible to significantly reduce the damage and number of casualties without any significant increase in cost. It will be emphasized that hollow masonry infills in traditional construction in this country can be used as structural walls when they are provided with appropriate reinforcement and are reinforced with concrete frames. The seismic behavior of such walls, however, have not been well understood, therefore, further studies will be necessary to establish design guidelines.

Practically no new lessons were learned from the performance of buildings during this earthquake. The observed performance of this time, however, reaffirmed that essentially the design should be done according to the basic principles governing seismic-resistant design and that proper seismic resistant construction practice should be used.

The seismic performance of a reinforced concrete building is strongly affected by many factors such as the level of shear and axial stresses in columns, the amount and configuration of structural walls and the distribution of stiffness throughout stories. It is, therefore, essential to check these factors in the design by certain procedures to understand the performance of the building. From the view point of practice, simple procedures will be desirable. In Japanese engineers' practice, it is regulated to check by simple procedures 1) average axial stress of columns, 2) length of walls per unit floor area, 3) eccentricity in each story and 4) stiffness ratio between

adjacent stories, when detailed analysis of the building is not conducted. Border values for the procedures are given based on the experience of previous earthquakes.

New Algerian seismic regulations have been proposed in 1981 [4]. The regulations have been well organized and refined based on the knowledge gained analyzing the effects of this earthquake as well as on suggestions given by foreign experts including the first author. It is expected that the regulations will lead to significant reduction of building damage and casualties when they are enforced and appropriately practiced.

Rehabilitation of the damaged buildings will be major problem. For repair and strengthening of concrete structures, existing construction techniques will be available. Damaged parts in a building will be repaired by mortar or epoxy injection, or by replacing concrete. The addition of concrete walls will significantly increase the strength of a building while jacketting existing columns with concrete and reinforcement will improve the ductility. Hollow masonry infill will also improve the strength of a building. Furthermore it will be a strengthening as well to change the adverse configuration of walls. According to authors' estimation for the previously described mill factory building and 2-story dwellings, their strengths can be increased up to the level of over two times the strengths before the earthquake when concrete walls are appropriately provided along with repair.

ACKNOWLEDGEMENT

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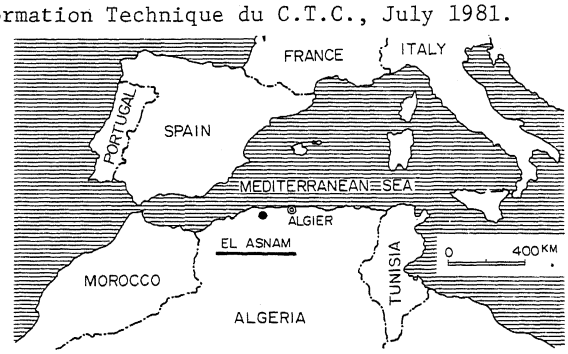
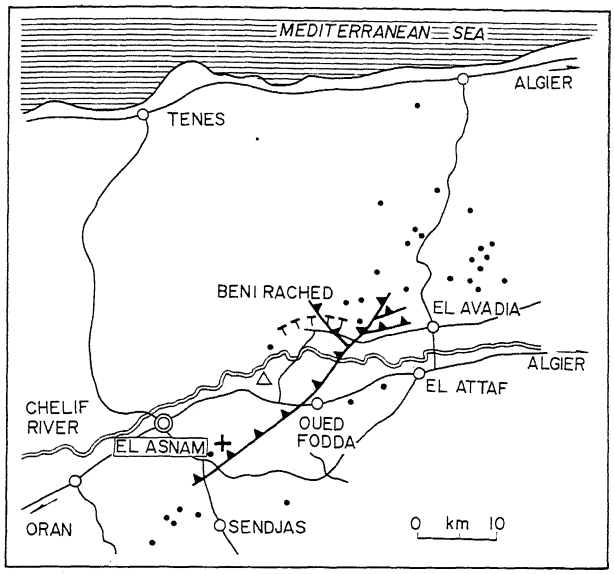


Fig.1 Location of El-Asnam, Algeria



The El-Asnam,
Algeria Earthquake

Date : October 10, 1980

Time : 13:25:23 (local time)

Latitude : N 36,143

Longitude : E 1,413

Magnitude : 7.3

+ Epicenter

Surface Faulting (1980)

Surface Faulting (1954)

• Aftershocks

Fig.2 The Earthquake and El-Asnam Area

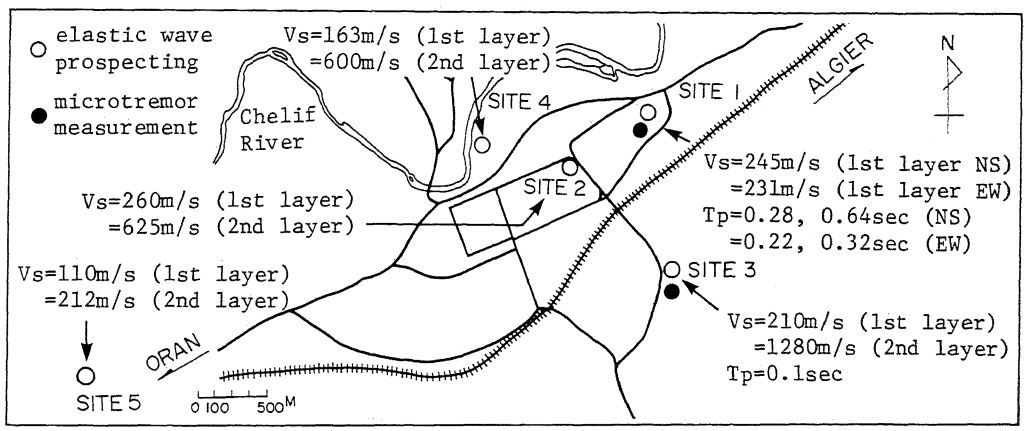


Fig.3 Field Measurement in and aroud the Town of El-Asnam [1]

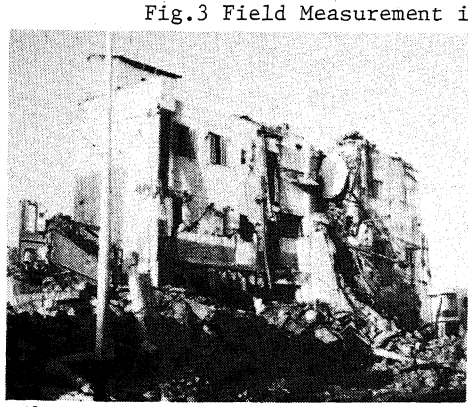


Photo 1 Damage to Masonry Building

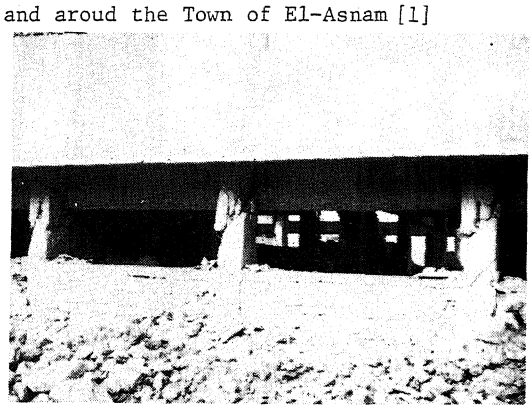


Photo 2 Damage to Short Columns

Photo 3 Collapse of Soft Story

Photo 4 Collapse of Columns at the Crawl Space for Sanitation

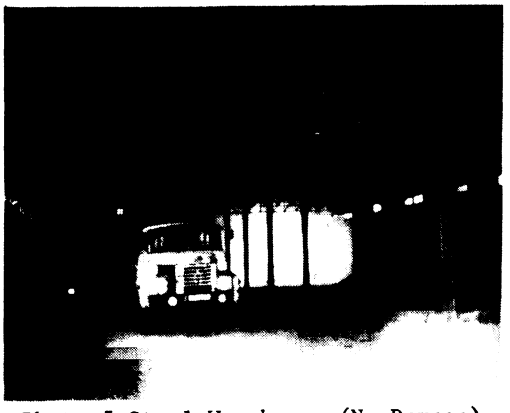


Photo 5 Steel Warehouse (No Damage)

Photo 6 Wall-Frame Structure (Moderate Damage)

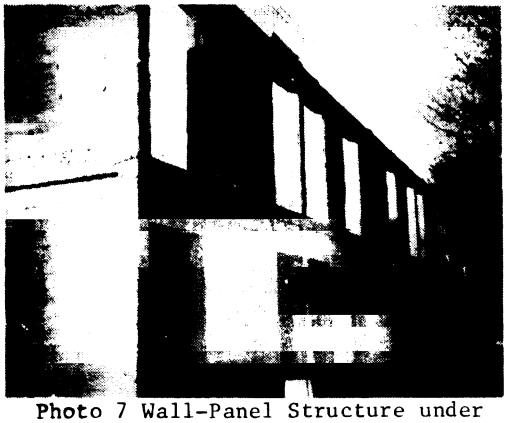


Photo 7 Wall-Panel Structure under Construction (No Damage)

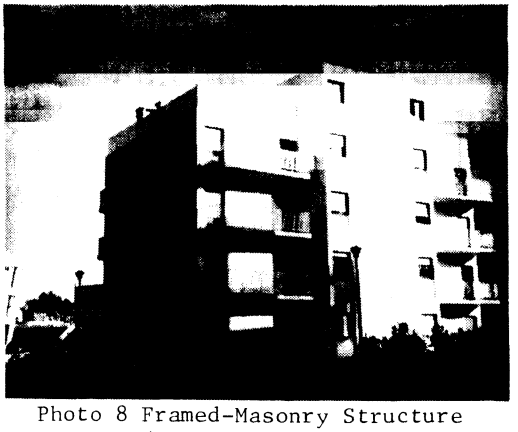
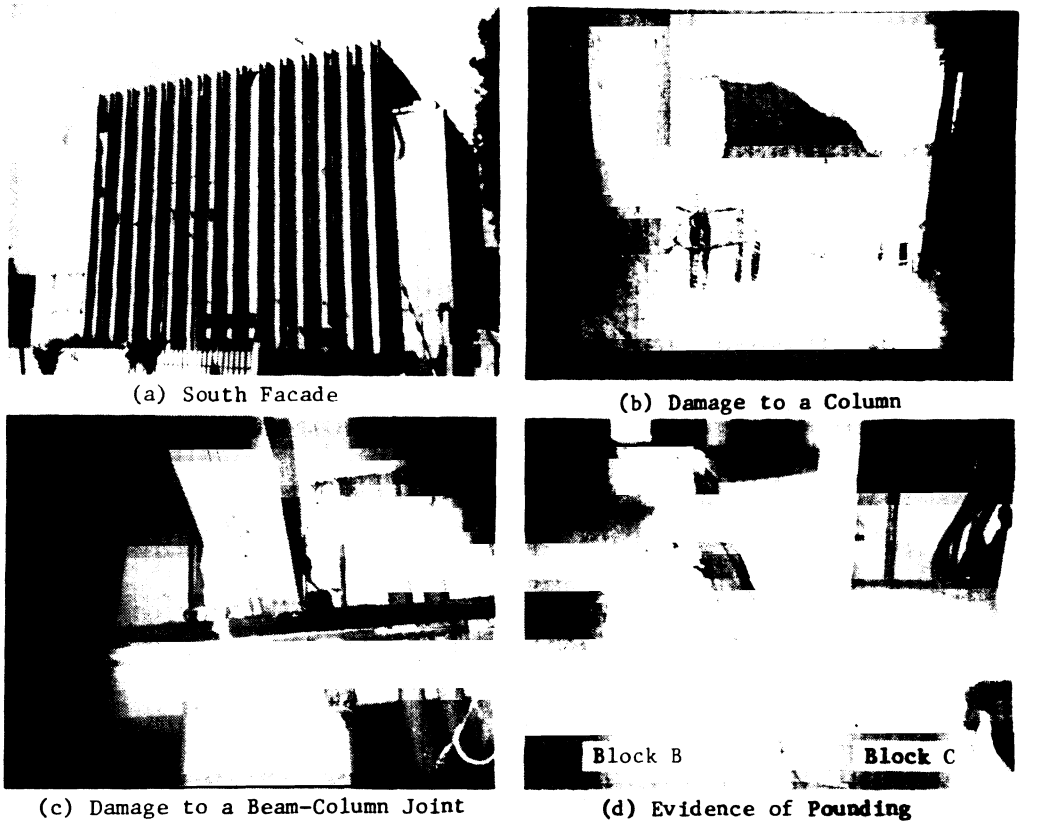


Photo 8 Framed-Masonry Structure (Minor Damage)



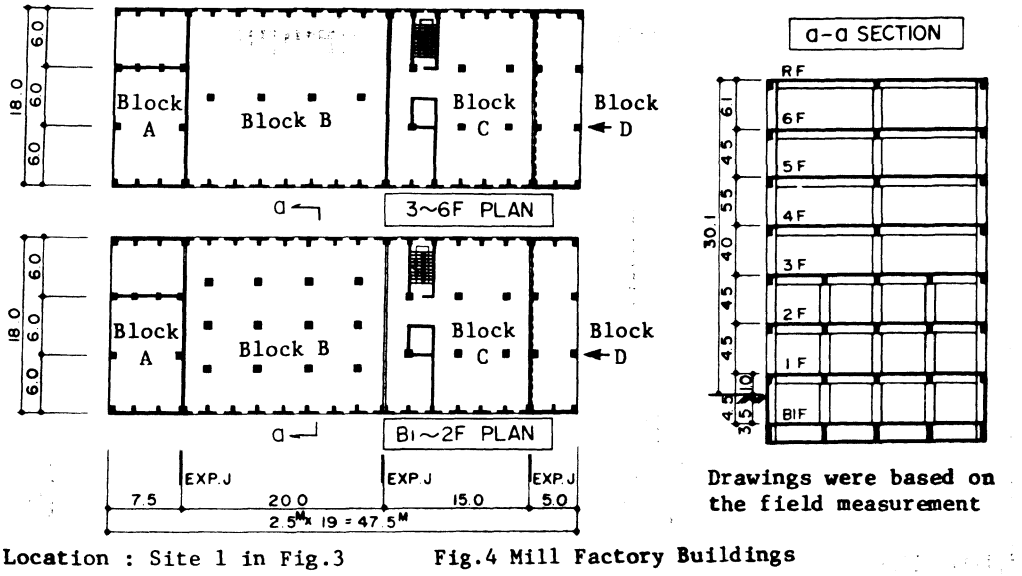
(a) South Facade

(b) Damage to a Column

(c) Damage to a Beam-Column Joint

(d) Evidence of **Pounding**

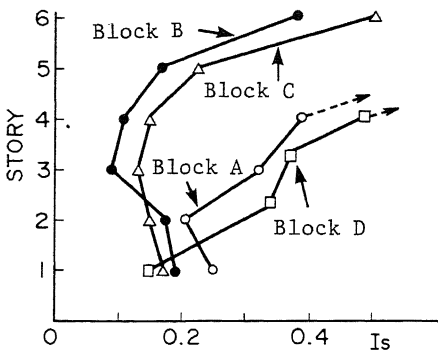
Photo 9 Mill Factory Buildings



Drawings were based on the field measurement

Location : Site 1 in Fig.3

Fig.4 Mill Factory Buildings



Ultimate Strength (Shear Coefficient)

- Assumed ultimate shear stress
  Column : $\tau u = 7 Kg/cm^2$
  R/C wall : $\tau u = 10 Kg/cm^2$
- Measured fundamental period of Block B building
  Longitudinal direction 1.1sec
  Transverse direction 1.1sec
- Measured predominant period of the ground
  0.28, 0.64sec (NS)
  0.22, 0.72sec (EW)

Fig.5 Approximated Ultimate Strength of Mill Factory Building (Longitudinal Direction)

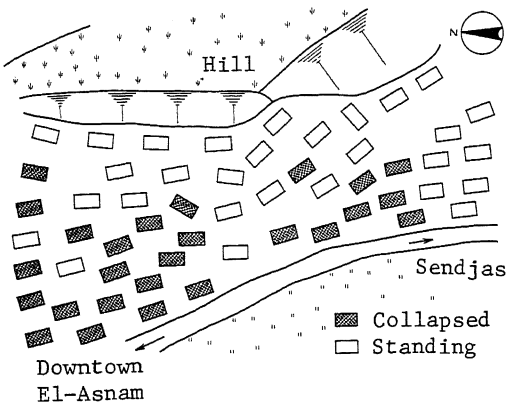


Fig.6 Location of 2-Story R/C Dwellings

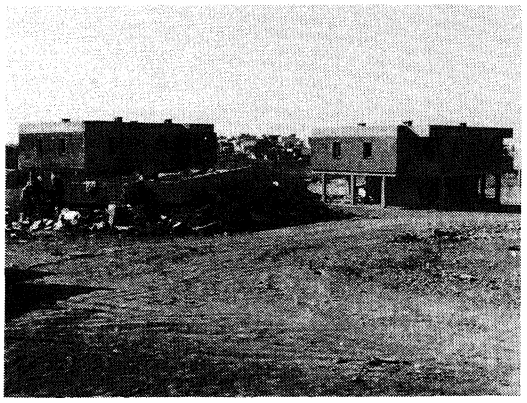


Photo 10 2-Story R/C Dwellings

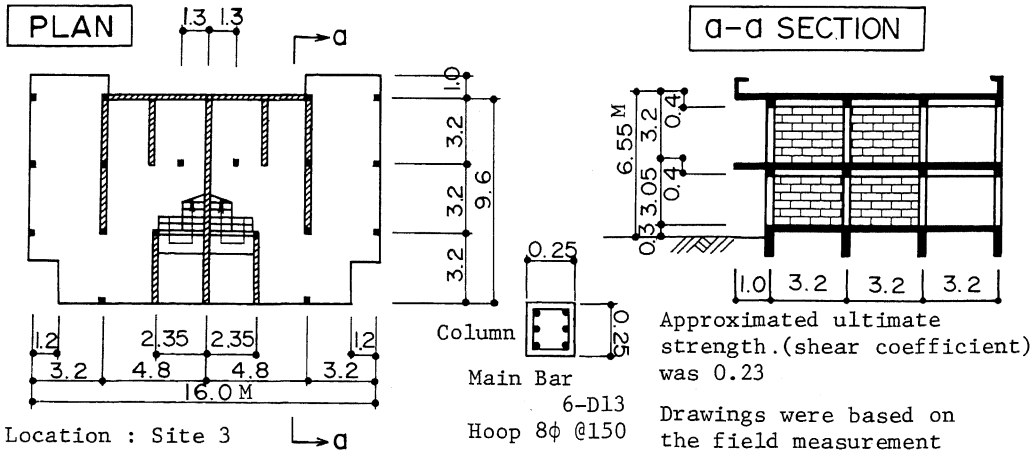


Fig.7 2-Story R/C Dwelling