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SYNOPSIS On the 12th of October, 1992 an earthquake of 5.7 moment magnitude hit Dahshour (Egypt) and the surrounding area. The characteristics of the building stock exposed to this earthquake is firstly presented in the paper. Then, the Dahshour earthquake is discussed in terms of the lessons that can be learned by engineers. The paper presents a short description of the geotechnical effects and the observed patterns of damage of the existing building categories and monuments. Finally, a list of the most important conclusions is introduced.

INTRODUCTION

On the 12th of October, 1992 an earthquake of 5.7 moment magnitude hit Dahshour and the surrounding area. It caused considerable shaking in Cairo, the heavily populated capital of Egypt, leading to hundreds of life loss and thousands of injured and homeless. This earthquake led also to the collapse of several buildings and the damage of thousands. This earthquake was felt all over Egypt and caused considerable damage also in El-Fayoum and Giza provinces.

POPULATION STATISTICS OF GREATER CAIRO

The Capital of Egypt Cairo is a heavily populated City. It has a population of about 10 million persons (approximately 1 in 5 of the Egyptian population) and a total number of buildings of more than 580,000 buildings. Greater Cairo is defined as the District of Cairo, Giza City and the City of Shopra El Khaima. Table 1 presents the population of Grater Cairo in the period 1947–1986. This population is expected to reach about 17,000,000 by the year 2000.

Table 1 Population Statistics of Greater Cairo in the Period 1947-1986

Date	Population	Increase	% Growth Rate/Year
1947	2,333,901		
1960	3,994,413	1,660,512	5.47
1966	5,189,829	1,195,416	5.00
1976	7,450,380	2,260,551	4.36
1986	9,753,860	2,303,480	3.10

CHARACTERISTICS OF THE BUILDING STOCK

The building stock exposed to the 1992 Dahshour earthquake covers a very wide range of structural systems, materials, age and design concepts. Also, the long history of Egypt and Cairo is reflected in the large number of historical monuments in the city, ranging from the Great Pyramids to Coptic and Islamic buildings. Some comments on the characteristics of structures in Greater Cairo and the surrounding area are given bellow.

Description of the Building Stock

Building stock in Egypt is classified according to the structural system into six categories as summarised in Table 2.

Table 2 Structural Systems of Building Stock in Egypt

Code No	Structural System
1	Reinforced concrete slab-beam-column structures
2	Prefabricated
3	Bearing walls and reinforced concrete slabs
4	Bearing walls and other slab types
5	Adobe
6	Others

Engineering supervision of buildings in Egypt was not properly enforced. Therefore, quite a high percentage of the building stock was executed without adequate engineering supervision. It is worth noting that the vast majority of the engineered buildings are designed without considering seismic loading and constructed without providing adequate ductile detailing for joints and elements.

Building Statistics

The number of buildings in Greater Cairo classified according to their structural system are presented in Table 3.

Table 3 Distribution of Buildings in Greater Cairo according to Structural System

City	Structural System Code*						Total
	1	2	3	4	5	6	
Greater Cairo	189827	2471	240090	114007	17345	18882	582622
Percentage	32.6	0.4	41.2	19.6	3.0	3.2	100 %

* Review Table 2

Most buildings of the 4th category are old buildings which were built before 1950 and have two to five stories. Buildings consisting of bearing walls and reinforced concrete slabs were built in most cases without engineering supervision and consisted of three to six stories.

The distribution of building stock in Greater Cairo according to the year of construction is illustrated in Table 4. Table 5 presents the distribution according to the number of stories.

Table 4 Distribution of Buildings in Greater Cairo according to Construction Year

City	Construction Time-Band					
	-1940	40–49	50–59	60–69	70–79	80–86
Greater Cairo	78654	41366	54184	102541	159638	146239
Percentage	13.5	7.1	9.3	17.6	27.4	25.1

Table 5 Distribution of Buildings in Greater Cairo according to No of Stories

No. of Stories	Cairo	Giza	Shopra	Total of Greater Cairo	Percentage
1	105549	32735	15029	153313	26.3
2	85889	39292	14993	140174	24.0
3	78005	29395	10062	117462	20.2
4	62895	23479	5737	92111	15.8
5	32110	12528	2328	46966	8.1
6	15937	4836	652	21425	3.7
7+	8582	2496	93	11171	1.9

EARTHQUAKE SOURCE PARAMETERS

The preliminary source parameters of the Dahshour earthquake, 1992 as reported by the National Research Institute of Astronomy and Geophysics, Helwan Institute (NRIAG) and the United States of Geological Survey (USGS) are presented as follows :

NRIAG :

Origin Time	=	12 October 1992, 13 : 09 LT
M_D	=	5.3
Location	=	29.775° N, 31.082° E
Depth	=	30 km

USGS :

Origin Time	=	12 October 1992, 13 : 09 LT
M_B	=	5.9
Location	=	29.826° N, 31.228° E
Depth	=	30 km

Where M_D and M_B are the duration and body wave magnitudes respectively.

The surface wave and body wave magnitudes and the Modified Mercalli Intensity based on the National Earthquake Information Centre (NEIC) are as follows:

Surface wave magnitude (M_S)	=	5.2
Body wave magnitude (M_B)	=	5.9
Intensity distribution in Cairo on soft soil	=	VII
Intensity distribution in Cairo on good soil	=	V

The Modified Mercalli Intensity (MMI) distribution presented by the Ain Shams Geophysical Research Team [1] and by Thenhaus, et al. [3], are presented in Figs 1 and 2, respectively.

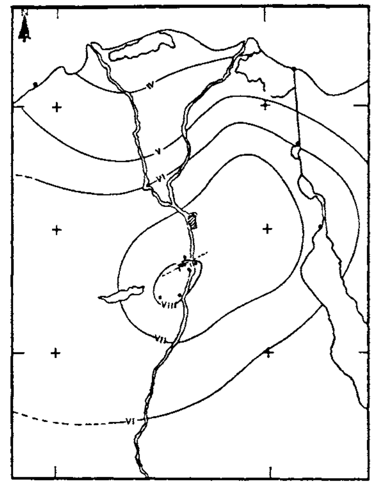

Fig 1 (MMI) Distribution Presented by the Ain Shams Geophysical Research Team [1]

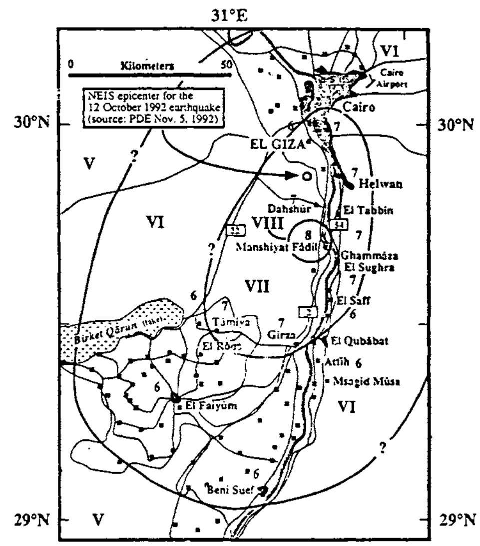

Fig 2 (MMI) Distribution Presented by Thenhaus, et al [3]

GEOTECHNICAL EFFECTS

The Dahshour earthquake of 12th of October 1992 is not an exception of many other earthquakes in the effect of soil condition on the damage level detected by buildings. It was noticeable that buildings founded on soft soil were more severely damaged than similar buildings on firm soil.

Soil liquefaction is another geotechnical effect that was observed in the highest intensity zone in the villages of Manshiyat Fadil, Al-Ayat, Kom Awshime, El-Beleda, Al-Akwam and Al-Ghammaza Al-Kobra.

Soil liquefaction was the reason of the observed settlement in the Cairo-Bani Swef road. This settlement took place at El-Atff and was as much as 1.75 m.

Large sand boil craters were developed in Bedsa village, which is about two km away from the settlement position of Cairo-Bani Swef road.

Sand boils were also observed in several locations in areas of distance as far as 20 km from the earthquake epicentre.

EFFECT ON BUILDINGS

Performance and damage description of buildings in the affected area are discussed in the present section.

Engineered Buildings

Excluding the collapse of the 14-story reinforced concrete residential building in Heliopolis, Cairo and the 4-story reinforced concrete school building in El-Ayat City, the performance of the engineered buildings was reasonable compared to similar earthquakes. Description of the main features of damage to engineered buildings and the frequently observed defects is presented hereafter.

The 14-story building which collapsed had a construction license for 7 stories only, where the other 7 stories were accumulated illegally. This building has collapsed a few seconds after the beginning of the earthquake leading to the death of 71 persons. The investigation of this building has attributed the collapse to the very poor construction and small section dimensions. It was reported that the strength of the foundation and structural elements were not sufficient to carry the licensed 7 stories safely.

The second engineered building which collapsed during this earthquake is one of several reinforced concrete buildings consisting Nasser Technical Secondary School in El-Ayat City, about 10 km from the earthquake epicentre in Dahshour. It was a four story reinforced concrete skeletal structure and was built in three stages started in 1984. This building had a stair case located in its western side. The ground story was left open as a shed while the above three stories were stiffened by the presence of infill panels. Large windows were located in the outer walls of the building to provide ventilation and lighting.

This building has completely collapsed during the earthquake. It was observed that the S-E corner of the fourth floor was moved by about 6.0 m to the North and about 2.0 m to the East. It was also noticeable that the third and fourth floors rotated about the stair case by about 5 and 12 degrees, respectively. Stirrups spaced up to 60.0 cm were observed in both beams and columns. It was also noticed that the cold joints between the columns and beams at the top and bottom of the column were smooth, leading to a very weak lateral shear resistance of the columns at these locations, Fig 3.

An interesting case is the damage of a mosque in Kom Awshime village, about 15 km from the epicentre. This mosque, as most of such structures, consists of a one story building and a minaret of about 2.5x2.5 m in plan and 15 m in height. The minaret is located in a corner of the mosque. The two portions are separated by a structural joint. These portions have complete different dynamic characteristics. The main building is a rigid short-period structure ($T \approx 0.1$ sec.) while the minaret is a very flexible long-period structure ($T \approx 1.0$ sec.). The damage detected and its causes can be explained as follows :

- The presence of the minaret at a corner increased the torsional movements.
- The lateral forces in additional to the torsionally-induced forces led to the failure of columns farthest from the centre of rotation.
- The flexibility of the minaret caused excessive deformations which led to the damage of the non-ductile columns at the minaret top.
- Pounding between the minaret and the mosque caused their separation and led to damage at the inadequate structural joint.

Fig 3 Widely Spaced Stirrups and Smooth Cold Joints

The contribution of pounding in increasing the destructive effect of earthquakes was evident in this earthquake. This is illustrated in Fig 4 which shows the damage due to pounding detected in a school in El-Roddah city. Similar cases were observed in El-Ayat, El-Fayoum and Greater Cairo.

Fig 4 Separation of Buildings and Column Damage Due to Pounding

Short column effect was also common in this earthquake, specially in schools where large windows are located in the outer walls to provide ventilation and lighting. Fig 5 presents an example of short column failure as observed in several schools in El-Roddah, El-Ayat and Tameiah Cities.

Fig 5 Shear Failure of a Short Column Arising due to the Existence of Large Windows.

The collapse of parapets was one of the observed failure patterns. Many cases of injuries and fatalities occurred due to this mode of failure. Fig 6 shows the collapse of the parapets of a school building in Tameiah City. Most of the parapet was damaged during the earthquake while the rest was demolished later on.

Fig 6 Failure of Parapets due to the Absence of Lateral Support

The effect of inconsistent stiffness of the main axis of buildings was noticed. The concentration of deformation in the flexible direction of a building in Cairo that led to permanent deformation and tilting of the building was reported.

As previously mentioned, no seismic provisions were used in Egypt to provide ductile reinforcement detailing. Despite this fact, there is no evidence that reinforcement detailing significantly contributed to the damage of buildings except in Nasser School building which completely collapsed in this event, Fig 3.

Diagonal cracks due to shear was the most common non-structural damage pattern observed in this earthquake. Many of the buildings in the affected provinces have suffered this damage pattern. This is attributed to the excessive deformation of these buildings and the inadequate separation between frames and infill panels.

Nonengineered Buildings

The majority of the existing buildings in many urban areas are masonry and adobe structures with roofs made of wood and dried vegetation. Most of these buildings are one or two stories in height. More than 5000 of these buildings were damaged or completely collapsed during the earthquake. This damage was concentrated in villages near to the epicentre in El-Fayuom and Giza provinces.

The huge number of the damaged buildings has demonstrated several patterns of failure. Most of these patterns are attributed to construction poor quality, inadequate anchorage between walls and lack of lateral support of roofs.

Out-of-plan movements of the outer walls is one of the common damage patterns. This led to the collapse of many walls and parapets of the upper floors causing many cases of injury and death, Fig. 7.

Fig 7 Collapse of Outer Walls of a Two Story Adobe Building

The collapse of roofs of adobe and masonry buildings, due to the lack of adequate connection between roofs and supporting walls, is another observed damage pattern which caused several cases of injury and death.

Severe wall cracks was also observed in many masonry and adobe buildings.

EFFECT ON MONUMENTS

Egypt is a historical country which contains more than one fifth of the world's monuments. These valuable monuments represent the Ancient Egyptian's age, the Christian era, the Latin culture, the Roman culture, the Ottoman Empire and the Islamic culture. Pyramids, Sphinx, annals of ancient

Egyptians, Ancient Egyptian's temples, historical churches and mosques and the historical museums are examples of these monuments.

The international organisations and agencies exert effort to provide adequate protection for the monuments specially from catastrophic events. Dahshour earthquake of 1992 is one of the events that affected the Egyptian monuments where it led to the damage of 118 of the Islamic and Coptic monuments, 18 of which need extensive repair.

The cracking of arches that led to wider cracks in the above walls is one of the damage patterns frequently observed in Islamic monuments.

The damage in mosque minarets due to their extensive deformation is another observed pattern in this earthquake. This was combined, in most cases, with the falling down of the heavy metallic crescents on the minaret top. Fig 8 gives an example of this pattern where the damage of the minaret of El-Hady El-Yousefy mosque is shown. Many cracks in the walls of this mosque were also observed. Similar damage was also observed in the historical mosques of El-Azhar, El-Sultan Barkoque, Abou Bakr Mazhar, and El-fakahany. Severe damage in the minaret of El-Sultan El-Ghoury mosque was observed where the minaret was completely separated from the mosque and tilted out-ward.

Fig 8 Damage of the Minaret of El-Hady El-Yousefy Mosque

Cracks of brick and stone masonry walls were observed in many Islamic and Coptic monuments. These cracks were mainly due to the low strength and ductility of such walls and the lack of adequate anchorage between perpendicular walls. This damage was observed in El-Sultan El-Ghoury mosque (Fig 9) , Kayit Bay mosque, Bashtak Palace, Sakefat Raddwan, the Suspended Church, El-Hady El-Yousefy mosque and several other monuments.

The Amr Ibn-El-Aas mosque, in Old Cairo, which is one of the oldest Islamic mosques in Egypt was severely damaged in this earthquake. Wide vertical and horizontal cracks took place in most of the arches. severe cracks were also observed in the outer walls and damage was detected on the minaret of the mosque.

Fig 9 Wall Cracks of El-Sultan El-Ghoury Mosque

CONCLUSIONS

1. The presence of highly-vulnerable structures in moderate-seismic areas leads to high risk level. This was the case in Egypt during the 1992 Dahshour earthquake.

2. Despite the fact that the vast majority of the engineered buildings are designed without considering seismic loading and constructed without providing adequate ductile detailing, Engineered buildings behaved well in this earthquake.

3. The effect on the non-engineered buildings in this earthquake was remarkable specially in villages near to the epicentre in El-Fayoum and Giza provinces. The observed damage is attributed to construction poor quality, inadequate anchorage between walls and lack of lateral support of roofs.

4. Attention must be paid to protect the Egyptian monuments from destructive earthquakes where the Dahshour earthquake led to the damage of 118 of the Islamic and Coptic monuments, 18 of which need extensive repair. Cracking of walls and arches, the damage in mosque minarets and the falling down of the heavy metallic crescents at their tops are the common damage patterns observed in monuments.

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