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16. Abstract (Limit: 200 words)

This report summarizes observations made after the magnitude 5.4 Cairo, Egypt earthquake of October 12, 1992. The author first reviews the historical seismicity of the region and follows this by examination of the seismic performance of both non-engineered and engineered structures. Of the former, unreinforced masonry buildings and historic monuments receive special mention. Among engineered structures, the author concentrates upon the performance of reinforced concrete frames with unreinforced masonry infill, RC shear wall buildings, and steel and RC moment-resisting frames. Observed damage mechanisms and modes of failure included pounding and soft story failure, the latter contributing to the catastrophic pancake collapse of a 14 story nonductile concrete building in Heliopolis, which killed 61 people. Damages to lifelines are also reviewed.

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Reconnaissance Report on the Cairo, Egypt Earthquake of October 12, 1992

by

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Technical Report NCEER-92-0033

December 23, 1992

National Technical Information Service
U.S. Department of Commerce
Springfield, VA

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NOTICE

Reconnaissance Report on the Cairo, Egypt Earthquake of October 12, 1992

by

M. Khater[1]

December 23, 1992

Technical Report NCEER-92-0033

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SECTION 1
INTRODUCTION

On Monday, October 12, 1992, a magnitude 5.4 (M_s; M_b = 5.9 based on the National Earthquake Information Center, NEIC) earthquake struck Cairo, the heavily populated capital of Egypt. The earthquake struck at 3:15 P.M. local time, and strong ground shaking lasted a reported 30 seconds. The earthquake was centered about 20 kilometers south of Cairo and was felt as far away as Jerusalem, about 500 kilometers to the northeast. An estimated 541 people were killed; 6,518 people injured (1,390 were hospitalized); and about 20,000 people displaced from their homes. Most casualties resulted from people being trampled in the rush to get out of shaking buildings. About 350 building structures collapsed (mainly old unreinforced masonry buildings), and 8,000 were damaged. An estimated 3,500 adobe-type buildings in the surrounding villages collapsed. Among the most catastrophic seismic-induced events was the collapse of a 14-story nonductile concrete building in Cairo, where 61 people were killed. No strong motion instruments existed in the area.

There was no seismic design code in Egypt before the earthquake, and most buildings were not designed for earthquake loads. A first-draft seismic design code for Egypt had been in preparation, and was published a few days after the earthquake. This draft seismic code divides Egypt into two zones. Zone One, which covers most of Egypt including Cairo, represents an area with the potential for earthquakes of magnitude 6.0 or lower. Zone Two represents an area with the potential for earthquakes of magnitude 7.0 or lower, and mainly includes cities on the Red Sea, south Sinai, the city of El-Faiyum, and the city of Aswan.

This report summarizes the author's observations during a brief reconnaissance visit to the area four days after the earthquake, as well as information from other sources.

SECTION 2
SEISMICITY

On October 12 an earthquake of magnitude 5.4 (M_S; M_b= 5.9) occurred at a depth of 25 kilometers--as reported by the National Earthquake Information Center (NEIC)--near the Nile Valley, about 20 kilometers south of Cairo. The location of the earthquake's epicenter has been estimated to be 29.83 N and 31.23 E (NEIC). This event was destructive over a large portion of the Cairo metropolitan area, which was entirely located at an epicentral distance of less than one focal depth. Aftershock studies will determine the trend and mechanism of the subsurface causative fault. A preliminary estimate of the Modified Mercalli Intensity (MMI) distribution in Cairo was about VII on soft soil, and about V on good soil. Figure 2-1 shows a geology map of Cairo and the surrounding area.

Egypt is considered one of the few regions of the world where evidence of historic earthquakes activity has been documented during the past 4,800 years. Information of historical earthquakes is documented in the annals of ancient Egyptian history and Arabic literature. According to Sieberg (1932), Ambraseys (1961), Karnik (1969), Maamoun (1979), Ibrahim and Marzouk (1979), Poirier & Taher (1980) and Savage (1984), about 83 events were reported to have occurred in and around Egypt and to have caused damage of variable degrees in different localities. Table 2.1 and Figure 2.2 summarize some of the historic and recent earthquakes in this area.

The most recent previous damaging earthquake (M=5.3) near the Nile Valley occurred on November 14, 1981, about 60 kilometers southwest of Aswan High Dam, and about 750 kilometers south of Cairo. Figure 2-3 shows the intensity distribution to this event (Kebeasy 1990). Aftershock studies of that event indicated right lateral strike-slip faulting at a 20-kilometer depth on an east-west trend transverse to the Nile (Toppozada et al. 1984, Kebeasy et al. 1982).

Other damaging earthquakes have occurred near the Nile Valley surrounding Cairo, as shown in Figure 2-2. In 1955 an earthquake of magnitude 6.7 offshore from Alexandria and Rashid (Figure 2-2, area a) killed 20 people, injured 106, and destroyed hundreds of buildings. In 1870 and 1698 similar earthquakes occurred in the same general area (Maamoun 1979). In 1847 an earthquake in the Faiyum area (Figure 2-2, area c), about 100 kilometers south-southwest of Cairo, killed over 212 people, injured thousands, and destroyed thousands of buildings between Cairo and Faiyum. A similar earthquake occurred near Faiyum in 1303 (Maamoun 1979). In 1754 an earthquake near Tanta (Figure 2-2, area b), in the Nile Delta 50 kilometers north of Cairo, damaged tens of thousands of buildings, and killed and injured thousands of people. A similar earthquake occurred in 2200 B.C., near Zagazig about 50 kilometers east of the 1754 event (Maamoun 1979).

The Red Sea area is seismically active, but is lightly populated compared to the area surrounding the Nile Delta. The most recent damaging earthquake in this area occurred in 1969 (M=6.8), near Shadwan Island offshore from Gemsa and Hurghada, 380 kilometers southeast of Cairo. Three people were killed, 15 were injured, and 32 buildings were destroyed (Maamoun et al. 1978).

Table 2-1

SUMMARY OF HISTORIC AND RECENT EARTHQUAKES

Year	Intensity	Location	Reference	Comments
2800 BC	XII	Sharquia Province	Kebeasy 1990	Severe earthquake
1210 BC	VI	near Abu-Simbil	Kebeasy 1990	
221 BC	VII	Siwa Oasis	Maamoun 1979	
27 BC	?	Thebes, Upper Egypt	Kebeasy 1990	Severe earthquake
1068 March 18	?	near Aqaba, at the north end of Culf of Aqaba	Melville 1984	
1303 August 8	?	Mediterranean sea	Kebeasy 1990	
		offshore of Egypt		
1847 August 7	VIII	near Fayum	Maamoun 1979	55 people were killed 3,000 houses were destroyed
1870 June 24	VII	Mediterranean sea offshore of Egypt	Maamoun 1979	
1955 September 12	VII	Offshore, near Alexan	Maamoun 1979	This event had a magnitude of 6.1
1955 November 12	?	near Abu-Dabbab	Sykes 1964	This event had a magnitude of 5.5
1969 March 31	IX	Shadwan Island MSK scale	Maamoun et al 1978	
1974 April 29	V	Abu-Hammad	Maamoun 1979	This event had a magnitude of 4.9
1978 December 9	?	Gilf El-kebir	Kebeasy et al 1990	This event had a magnitude of 5.3
1981 November 14	VIII	Kalabsha about 60 km southwest of Aswan	Kebeasy et al 1984	This event had a magnitude of 5.5
1983 February 3	?	Gulf of Aqaba	Kebeasy 1990	This event had a magnitude of 4.9
1984 July 2	?	Abu-Dabbab	Kebeasy 1990	This event had a magnitude of 5.1

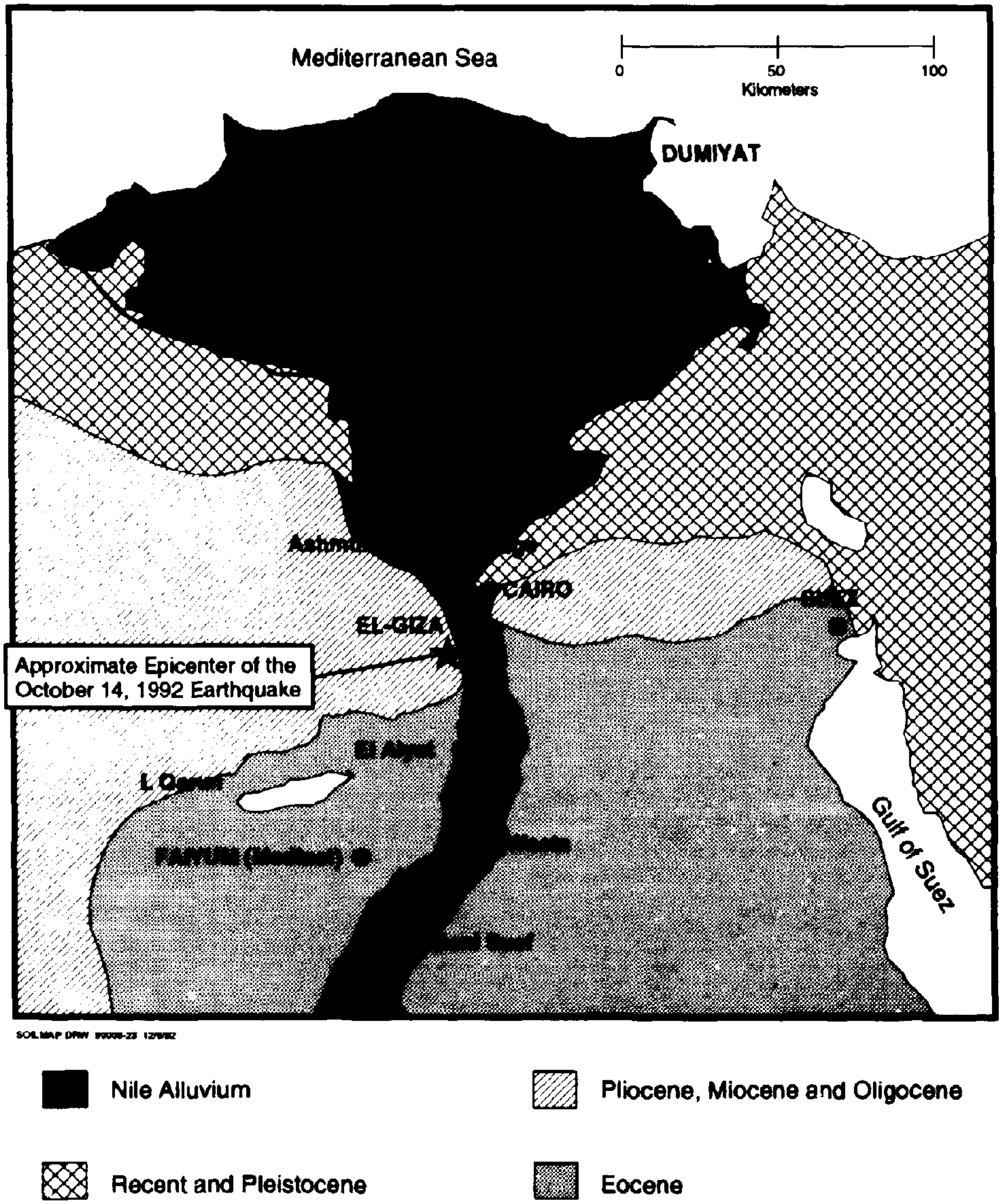


Figure 2-1: Geology map of Cairo and the surrounding area.

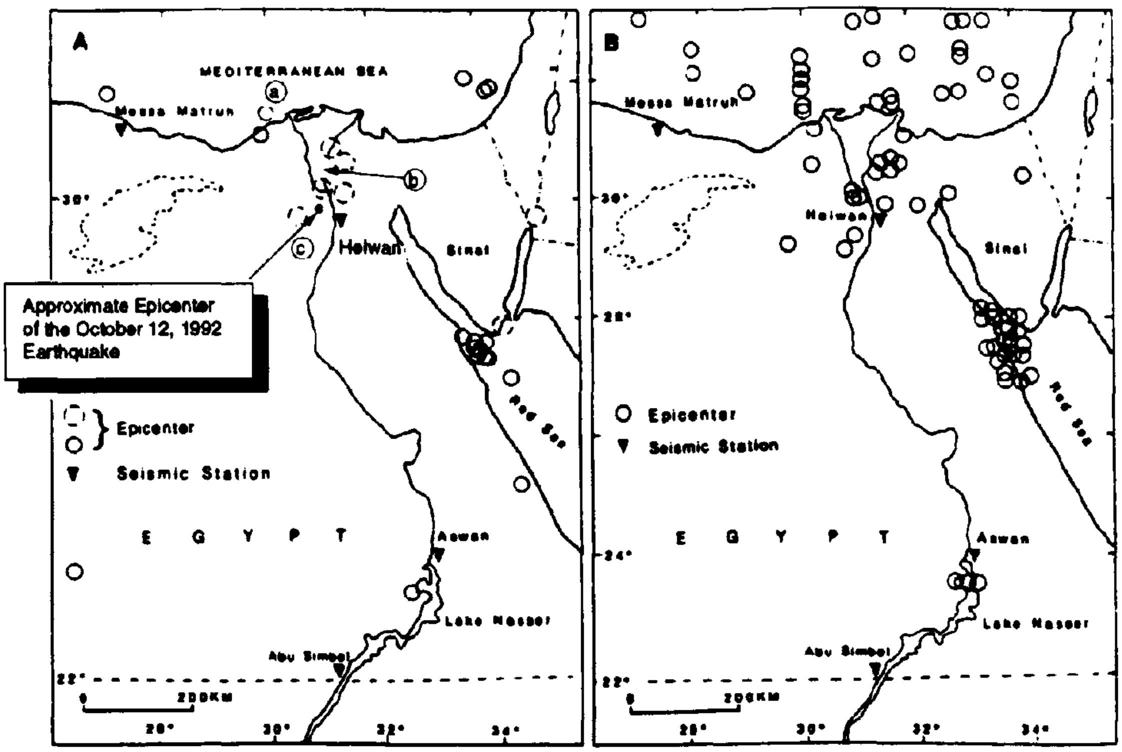


Figure 2-2: (A) Locations of epicenters of historical and recent medium to large earthquakes; (B) Epicenters of small earthquakes (Kebeasy, 1990).

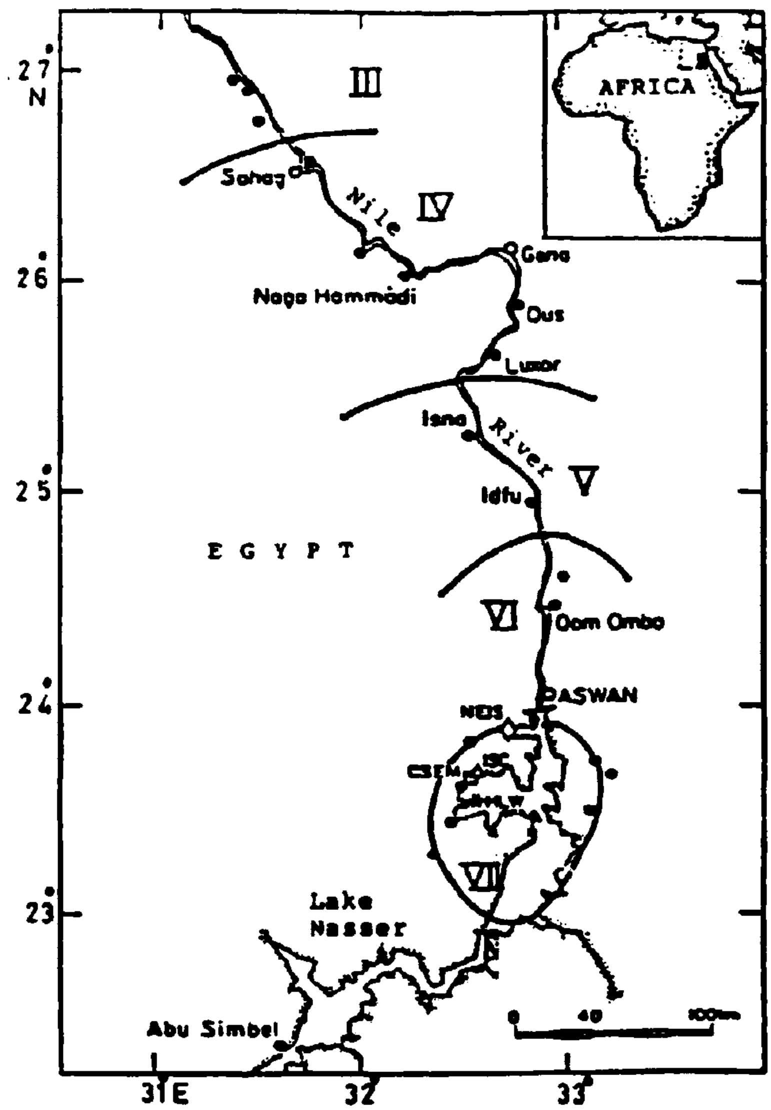


Figure 2-3: Intensity distribution of the 14 November 1981 earthquake as located by HLW = Helwan; NEIS = National Earthquake Information Service (Kebeasy, R.M., M. Maamoun, and E. M. Ibrahim, 1982).

SECTION 3
EXTENT OF DAMAGE

Buildings in Cairo and the surrounding area have been divided into two categories: (1) Nonengineered buildings, and (2) Engineered buildings. Performance, damage, and description of each type of these buildings are discused in this chapter.

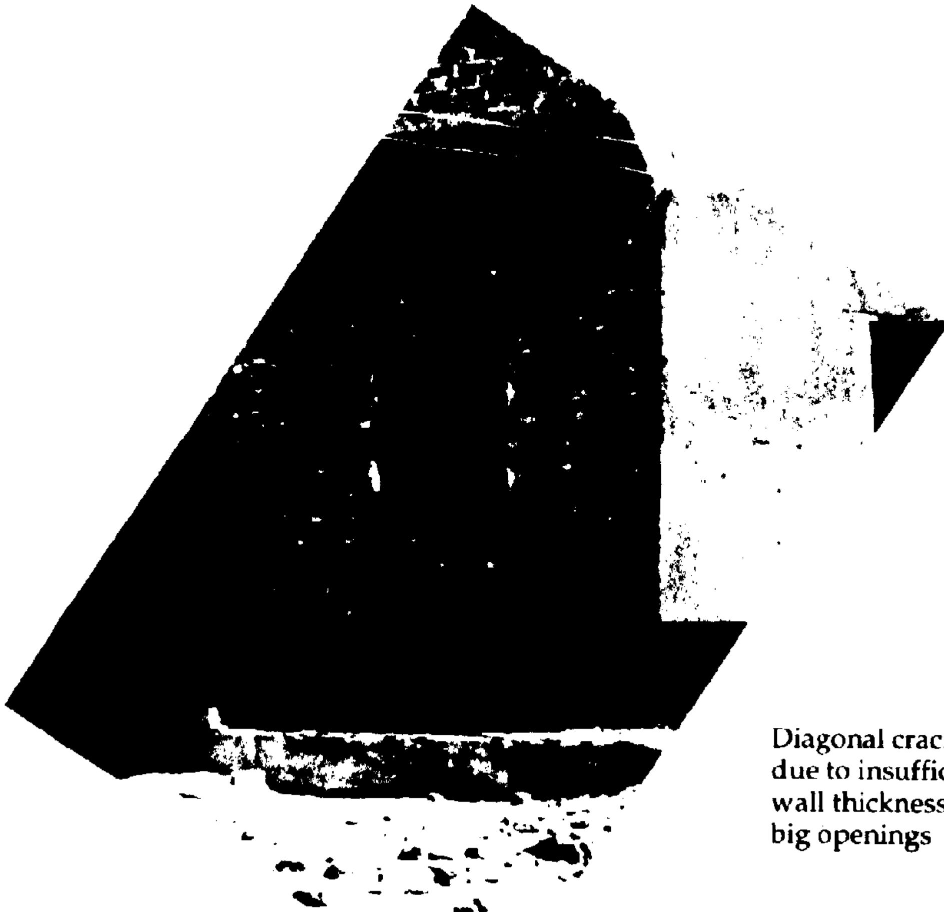
3.1 Nonengineered Buildings

This category of buildings has no seismic resistance and it includes: (a) Unreinforced masonry buildings (brick or stone) with flexible diaphragms (usually wood) or with rigid diaphragms (usually concrete or steel), and (b) adobe type buildings with wood diaphragms.

Unreinforced Masonry (URM) Buildings. In Egypt, buildings with walls of brick and stone masonry have long been regarded as solid construction, providing weather and fire resistance, an attractive appearance, and a general feeling of permanence and solidity. As a result, these materials abound in low- and mid-rise construction throughout older sections of Cairo and the surrounding area.

No surprises were observed in the Oct. 12 event, regarding URM building performance. Numerous collapses and severe damage occurred to such structures throughout the affected area, especially in soft-soil areas (Figure 3-1). Older URM buildings were generally the most damaged structures throughout the area. These buildings were responsible for the great majority of life loss associated with this earthquake. A reported 349 old URM buildings collapsed, and about 7,800 URM buildings were damaged. An estimated 500,000 URM buildings in Egypt are still in use today.

URM buildings experience different types of damage including: (1) Diagonal cracks due to insufficient wall thickness and the presence of big openings (Figure 3-1a), (2) Lack of lateral support resulted in serious damage or collapse of walls or parapets (Figure 3-1), (3) Lack of adequate anchorage in the wall diaphragm connection resulted in horizontal cracks between the wall and



Diagonal cracks
due to insufficent
wall thickness and
big openings

Figure 3-1a: Damage to unreinforced masonry buildings.

Damage to laterally unsupported walls and vertical cracks at wall connections due to lack of adequate anchorage.

Figure 3-1b: Damage to unreinforced masonry buildings.

the diaphragms, and (4) Lack of adequate anchorage between walls resulted in vertical cracks and separation in the corners at the connection between the walls (Figure 3-1b). Buildings with adequate anchorage in terms of tie-beams did not experience this type of crack.

Monuments. More than 150 monuments throughout Egypt were damaged during the Cairo Earthquake. Ancient Islamic sites in Cairo were seriously damaged. Damage included damage to mosques minarets, cracks at wall connections and wall diaphragm connections, and damage to unsupported parapets. The Valley of the Kings, the burial site of Tutankhamen, and Queen Hatshepsut's temple at Deir el-Bahri in the south, which dates from the 15th century B.C., sustained some cracking. Other well-known tourist attractions that were cracked include the Oracle Temple at Siwa Oasis near Libya, Luxor Temple, and Ramses II's mortuary temple opposite Luxor on the west bank of the Nile River.

3.2 Engineered Buildings

This category of buildings include (1) Reinforced concrete buildings with unreinforced masonry infill walls, (2) Reinforced concrete shear wall buildings, and (3) moment resisting concrete frame or steel frame buildings.

In general, buildings in this category performed well during the October 12, Cairo earthquake. Damage to these type of buildings was due to special conditions, including soft stories, building irregularity, bounding, inadequate detailing, and poor construction materials and workmanship. Examples of these types of damage are discussed below.

Nonductile concrete buildings represent the majority of larger engineered buildings in Cairo. Most of these buildings have not been designed for earthquakes, however. Ductile detailing in the form of beam stirrups, column hoops, joint reinforcement, and development lengths as required by the *Uniform Building Code* is usually not provided in most of these buildings. A high percentage of these buildings have a *soft story*, which represents a serious seismic hazard.

First Stories (or Soft Stories). The ground floor of a building is frequently the weakest part of the structure. Unlike the upper part of the structure, ground floors are seldom enclosed on all four sides by walls capable of resisting shear (or lateral earthquake-induced) forces. Ground floors are also generally taller than upper floors. Ground-floor shops, stores, lobbies, or garages normally allot most of their front wall area to doors or plate glass, leaving one side of the building with no shear resistance. Bending and shear forces induced by strong ground shaking are therefore concentrated in the ground-floor columns. The lack of ductile detailing usually contributes significantly to failure of this soft story.

Among the most catastrophic collapses was the 14-story nonductile concrete building in suburban Heliopolis (about 25 km from the epicenter) where an estimated 61 people were killed (Figure 3-2). It was the only multistory building failure or *pancake* collapse in Cairo. This building was of nonductile concrete construction with a soft story (the building was built about 1986), and had a water tank on the roof (about 30 cubic meters of water). It appears that excessive deflection of the building caused collapse as column-beam connections failed. As collapse began, the impact load of each floor slab striking the ground or the floor below added to the overload and culminated in total collapse. Inspection of the concrete indicated that it was of poor quality. Nondeformed bars were used in this building, which contributed to the low bond between the steel and concrete.

High-rise Buildings. In general, high-rise buildings in Cairo performed well during the earthquake. Most high-rise buildings are located on both sides of the Nile River. Figure 3-3 shows a set of concrete towers (in the City of Maadi about 15 km from the epicenter) that are 42 stories high. Each tower is supported on 36 concrete columns on a pile foundation about 25 meters deep. These towers performed well during the earthquake, only sustaining nonstructural damage as shown in Figure 3-3.

Figure 3-4 shows nonstructural horizontal cracks in a 14-story concrete building, and Figure 3-5 shows a 30-story concrete shear wall building, both in the city of Maadi. The 30-story building has an irregular, staircase shape and sustained a vertical crack (about 2 centimeters wide, between the concrete shear wall and the URM infill wall) at the corner of the third step, as shown in Figure 3-5.

Figure 3-2: Collapse of a 14-story concrete-frame building.

Figure 3-3: 42-story high-rise concrete buildings in Cairo experienced only nonstructural damage.

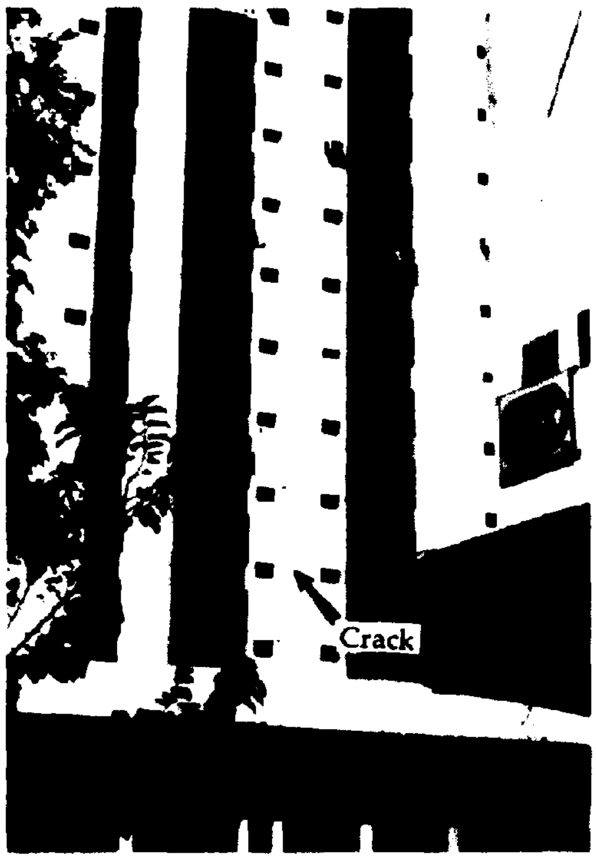


Figure 3-4: Nonstructural horizontal cracks in a 14-story concrete-frame building.

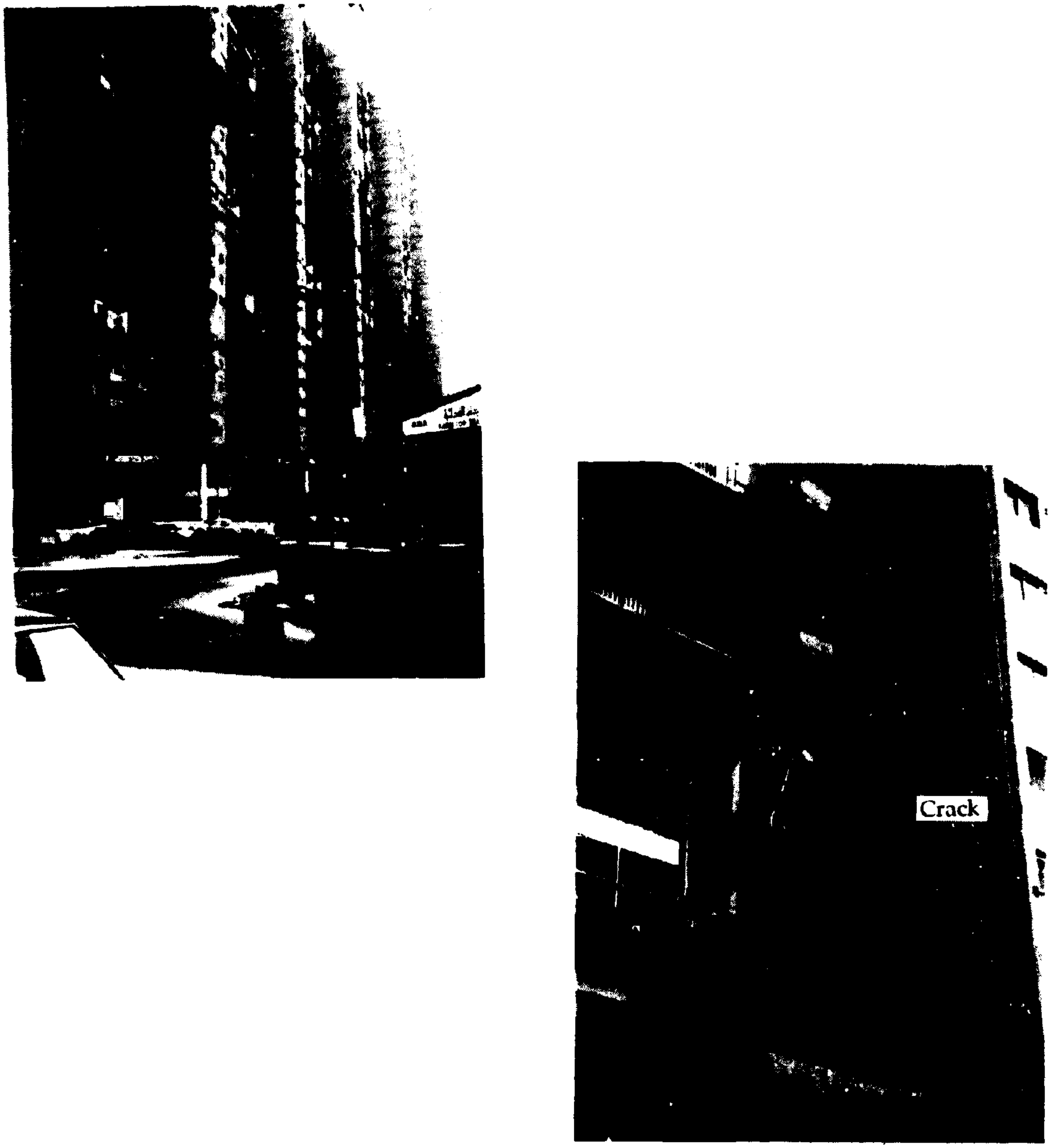


Figure 3-5: Vertical crack in a 36-story shear wall concrete building due to building irregularity.

Cairo Tower (Figure 3-6), a 30-year-old, 200-meter-high, cylindrical concrete structure with a 60-meter-deep foundation, sustained no damage from the earthquake. A restaurant located at the top of this building sustained various types of nonstructural damage.

Figure 3-7 shows a new, 30-story cylindrical hotel (about 20 km from the epicenter). The first three stories of the building are concrete, and the remaining 27 stories are of moment steel frame. The building is supported on wedge columns as shown in Figure 3-7 and sustained only nonstructural damage from the earthquake.

Pounding. Building pounding caused damage--some structural distress but not collapse--in a number of locations. Typical damage caused by pounding is shown in Figure 3-8. The tall building on the left pounded against the shorter building, resulting in damage to the corner column and beams of the shorter building.

Public School Buildings. Public school buildings were severely damaged during the Cairo Earthquake. About 100 school buildings collapsed, and about 950 school buildings were damaged and need repair. Most of the damaged buildings are old URM buildings on soft soil. Similar schools on good soil had only minor or no damage from the earthquake.

Hospitals. Most, if not all, hospital buildings lacked seismic design, but still performed well in the earthquake. A few sustained architectural damage, but there were no operational interruptions. Figure 3-9 shows a five-story hospital building (in the city of Maadi about 15 km from the epicenter) of reinforced concrete moment frame with URM infill. This building had very minor nonstructural damage from the earthquake.

3.3 Lifelines

Transportation

Road and Bridges. Roads and bridges performed well during and after the earthquake. Lateral spreading caused about 300 meters of the main road between Cairo and Asiot (near the village of El-Aiyat) (Figure 3-10), which is

Figure 3-6: The tallest structure in Cairo (Cairo Tower) sustained only nonstructural damage.

Figure 3-7: 30-story cylindrical hotel sustained only nonstructural damage.

Figure 3-8: Structural damage caused by pounding.

known as "agriculture road," to settle about 0.5 meter. The road is parallel to the Nile River, which is about 100 meters away.

There are eight bridges across the Nile River in Cairo, connecting the east and west sides of Cairo. A steel girder bridge with a concrete deck, known as Kasr El-Nile Bridge (which is more than 60 years old and one of the oldest bridges on the Nile), had minor damage to the concrete deck during the earthquake. The center part of this bridge, as shown in Figure 3-11, can be rotated to allow big ships to go through the Nile. This part of the bridge acts as a double cantilever, and a section of about 1 by 0.5 meter of the concrete deck at the end of the eastern part of this cantilever fell down. It was noted that a small part of the concrete had been broken before the earthquake. Traffic on the bridge was reduced while the broken deck was replaced, and was back to normal two days after the earthquake.

Railroads. The underground system in Cairo, "the Metro," performed well during the earthquake and sustained no damage. Operation was not interrupted during or after the earthquake. There was no reported damage to the main railroad system which connect Cairo with other cities.

Airports. Cairo's international airport (about 30 km from the epicenter) performed well during the earthquake, and there was no reported damage to airport structures or contents. Operation of the airport was not interrupted during or after the earthquake.

Water and Sewage Systems

In general, the water and sewage systems performed well during the earthquake. There was no reported damage to underground piping or treatment plants. An elevated tank of about 5,000 cubic meters and about 30 meters above ground (Figure 3-12) in the city of Giza had some damage in the roofing system. The tank is supported by 64 columns (25 by 100 centimeters). The roofing system has a skylight supported by posts (15-by-15-centimeter concrete columns), about 2 meters high. Four of these posts were damaged, and there were some cracks in the roof.

Figure 3-9: A 5-story concrete-frame hospital sustained only nonstructural damage.

Figure 3-10: A main road between Cairo and Asiot settled about 0.5 meters due to lateral spreading.

Figure 3-11: An old steel girder bridge with concrete deck lost part of the concrete deck.

Figure 3-12: The roofing system of this elevated water tank in the City of Giza was damaged during the earthquake.

Electric System

The primary source of power generation in Cairo is hydroelectric plants located at the High Dam (about 750 km from the epicenter). Long-distance transmission is by a system of 500-kilovolt lines and primary substations. Primary substations step power down to 230, 115, and 69 kilovolts for local transmission.

Experience from past earthquakes has shown that high-voltage substations are normally the weak link in earthquakes. The tall ceramic columns on high-voltage switchyard equipment have a tendency for brittle fracture and collapse. Additional problems are caused by the interaction of ceramic columns through rigid busbar connections, or by loads imposed on ceramic columns by *cable whip* from overhead lines.

The electric system in Cairo performed well during the earthquake. For most of Cairo, electricity was not lost during or after the earthquake. Some villages around Cairo lost power for few hours. A 115-kilovolt substation a few kilometers from the village of El-Aiyat had very minor ceramic damage. (Author's personal observation.)

Telecommunication System

In general, the telephone system performed well during and after the earthquake. The flood of calls that normally follow an earthquake immediately overloaded the system. Some private phone lines were temporarily blocked in order to free access to emergency lines such as hospitals, fire stations, or police headquarters. Some batteries fell off their racks in the Local Exchange Carrier (LEC) and Inter Exchange Carrier (IEC) telephone switching centers in Cairo, which caused loss of telephone lines in some areas of Cairo. (Personal communictaions, Telephone Company employees.)

SECTION 4
SUMMARY AND CONCLUSIONS

1. This earthquake demonstrated the need to increase education, awareness, and preparedness at all levels of government and the private sector. Mitigation programs should be accelerated to include preparedness planning, response and recovery planning, engineering vulnerability studies, and retrofit of hazardous buildings and structures.

2. The primary cause of death was the lack of education and awareness about earthquakes combined with the collapse of URM buildings and the high-rise concrete building in Cairo.

3. The quality of construction in Cairo is poor and clearly contributed to the number of collapses. This problem is not unique to Egypt. To ensure that a structure is properly constructed and will perform as designed, it is necessary to assure adequate quality, by having the design engineer perform inspections during the construction process.

4. Concrete-frame structures, one of the most popular types of design construction, caused about 10% of the deaths in the Cairo Earthquake. The technology to build safe concrete-frame structures and strengthen existing ones is well developed and can be applied by knowledgeable and skilled engineers. However, all too frequently, inadequately designed structures are built. The cost to strengthen existing concrete-frame buildings can be significant. It is far more cost-effective to implement a seismic quality control program during design and construction. The seismic performance of reinforced concrete frames is significantly affected by many factors. One of these is proper design and detailing to ensure a ductile (flexible) system. Such a system is a more heavily reinforced concrete frame that is capable of undergoing larger deformations without failure. Concrete-frame buildings often have infill walls of concrete block or other masonry, which may or may

not be designed as structural elements. If infill walls (which must be reinforced) are designed as nonstructural elements, it is necessary to allow for movements of the frame relative to by the infill walls.

5. In general, the newer buildings performed well; however, this earthquake did not provide the severe ground motions to adequately test them.

6. Poor performance of old buildings was due to the use of brittle construction materials, inadequate design and detailing, lack of maintenance, or deficiency in workmanship. In many cases, all these factors were present in a single structure.

7. URM buildings once again proved to be the most hazardous form of building construction. The presence of rigid diaphragms appeared to reduce the probability of total collapse of the structures.

8. Strong motion instrumentation is needed in Egypt.

SECTION 5
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NATIONAL CENTER FOR EARTHQUAKE ENGINEERING RESEARCH
LIST OF TECHNICAL REPORTS

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NCEER-87-0001 "First-Year Program in Research, Education and Technology Transfer," 3/5/87, (PB88-134275/AS).

NCEER-87-0002 "Experimental Evaluation of Instantaneous Optimal Algorithms for Structural Control," by R.C. Lin, T.T. Soong and A.M. Reinhorn, 4/20/87, (PB88-134341/AS).

NCEER-87-0003 "Experimentation Using the Earthquake Simulation Facilities at University at Buffalo," by A.M. Reinhorn and R.L. Ketter, to be published.

NCEER-87-0004 "The System Characteristics and Performance of a Shaking Table," by J.S. Hwang, K.C. Chang and G.C. Lee, 6/1/87, (PB88-134259/AS). This report is available only through NTIS (see address given above).

NCEER-87-0005 "A Finite Element Formulation for Nonlinear Viscoplastic Material Using a Q Model," by O. Gyebi and G. Dasgupta, 11/2/87, (PB88-213764/AS).

NCEER-87-0006 "Symbolic Manipulation Program (SMP) - Algebraic Codes for Two and Three Dimensional Finite Element Formulations," by X. Lee and G. Dasgupta, 11/9/87, (PB88-219522/AS).

NCEER-87-0007 "Instantaneous Optimal Control Laws for Tall Buildings Under Seismic Excitations," by J.N. Yang, A. Akbarpour and P. Ghaemmaghami, 6/10/87, (PB88-134333/AS).

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