Cairo, Egypt, Earthquake of October 12, 1992

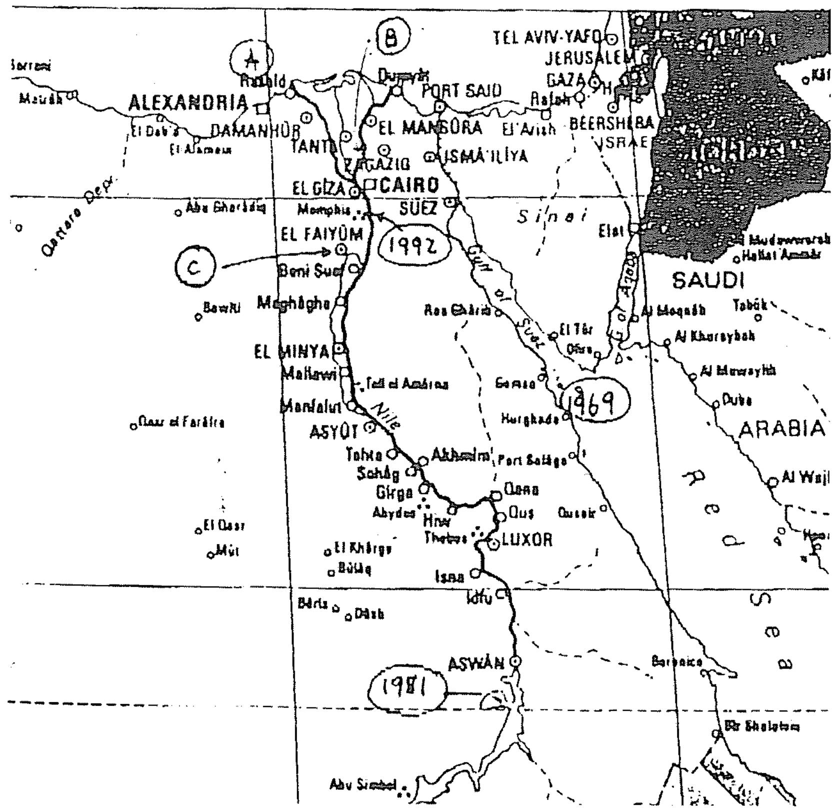
On October 12, 1992, at 3:10 p.m. local time, an earthquake of M_b 5.9 (M_s 5.4) occurred near Cairo, Egypt, that resulted in approximately 500 deaths, thousands of injuries, the collapse of a few structures, and damage to many structures in the Cairo metropolitan area (population 12,000,000).

EERI dispatched a team of earthquake engineers and scientists to investigate the effects of this event. Team members were Nabih Youssef, structural engineer, Team Leader; Samy Adham, structural engineer; Mehmet Çelebi, USGS; and Josephine Malilay, Centers for Disease Control. The following report contains information from the preliminary report filed by the team.

Historic Seismicity

This earthquake came as a surprise to the world community, despite the fact that Egypt and surrounding regions have a history of recorded earthquakes that date back to 2200 B.C. A great number of these earthquakes are unknown to the seismologists because their descriptions are scattered in various historical and geographical manuscripts.

Damaging earthquakes that have occurred near the Nile Valley surrounding Cairo for the areas of Alexandria, Faiyum, and the Delta near Cairo include 1955 (M_s 6.7), 1870, and 1690 earthquakes in the Alexandria-Rashid area; 1847 and 1303 earthquakes near Faiyum; and 1754, 1111, and 2200 B.C. earthquakes in the Nile Delta near Cairo.



Epicenters of earthquakes in 1992 south of Cairo, 1981 south of Aswan, and 1969 in the northern part of the Red Sea are shown. Historical earthquakes in area A (north of Alexandria), area B (near Cairo), and area C (near Faiyum) are mentioned in the text.

The Red Sea area is also 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_s 6.8), near Shadwan Island offshore from Gemsa and Hurghada, 380 km southeast of Cairo. Three people were killed, 15 injured, and 32 buildings were destroyed.

Geological and Seismological Observations

The earthquake of October 12, 1992, was located at latitude 30.05°N and longitude 31.18°E, as reported by the U.S. Geological Survey, at 3:10 p.m. local time. A preliminary focal mechanism produced by Harvard University showed normal (extensional) faulting at a depth of approximately 24 km. A search for surface faulting by the Egyptian Geological Survey and Mining Authority, the U.S. Geological Survey Team, and this EERI Team discovered no surface faulting from the earthquake. However, tension cracks were observed in semi-consolidated alluvium that might be related to a small amount of near-surface ground failure or compaction in a restricted area in the epicentral region. Considering the moderate size of this earthquake and its depth, the lack of surface offset from the fault dislocation is not surprising. Settlement of up to 1.5 m was reported along the main north-south highway west of the Nile River near the village of Manshiat Fadil. East of the highway at this location, soil liquefaction features (sandblows) were noted in the cultivated fields.

The liquefaction features were noted near the villages that exhibited the highest degree of damage and probably defined the general area of strongest high-frequency ground motion. Although liquefaction was restricted to a small area in this earthquake, it is likely that most areas of the Nile River Valley are susceptible to the phenomena of liquefaction and much larger areas could be affected by the occurrence of a larger magnitude earthquake.

Aftershocks following an earthquake of the size of the October 12 earthquake are common and a very normal occurrence. The following tabulation of aftershocks through October 22, 1992, was provided to the EERI Team by the Helwan Observatory:

Magnitude	Number of Events
0 - 1.9	420
2.0 - 2.9	210
3.0 - 3.9	15
4.0 - 4.9	2
5.0 - 5.9	1*

*Main shock of October 12, 1992

(Note: Other aftershocks have occurred since October 22 when these data were compiled.)

The EERI team investigators see nothing unusual concerning the aftershock sequence and feel that it is highly unlikely that the earthquake of October 12 was a prelude to an even larger event in the near future.

Observations of Earthquake Intensity

The highest intensity observed by the team was Modified Mercalli Intensity VIII in the village of Manshiyat-Fâdil and represents the epicentral intensity of the October 12 earthquake. Intensity VIII corresponds to the fall of ordinary masonry walls and complete collapse of adobe structures. The degree of this type of damage in many structures in Manshiat Fadil justifies this level of intensity. Furthermore, it is the only location where liquefaction was observed. Intensity VII was common in many villages of the Nile Valley and generally corresponds to cracks in ordinary masonry walls and the fall of adobe walls and masonry parapets that were not reinforced.

Mixture of stone and mud brick construction

Ground Motion - Valley of the Nile Site Response

The eleven strong-motion accelerographs in Egypt (some at the Helwan Observatory), part of the high Aswan Dam Project, did not trigger because they were not set up for strong ground motion recording in the vicinity of Cairo. Thus, the October 12 earthquake seismic motion was not recorded.

However, it is the writers' opinion, from the nature of the observed damage, that significant amplification of earthquake motion probably occurred in the alluvial deposit of the Nile Valley around Cairo and vicinity. The filtering of the high-frequency and acceleration spikes produced an amplified motion with long period characteristics at the deep alluvial sites. This phenomena at moderate earthquake levels and with short duration accounts for the very low damage levels in the large inventory of stiff unreinforced masonry infill buildings.

It is suggested that a strong-motion array in Cairo and its vicinity, as well as other seismically active regions of Egypt, be organized to record, assess, and establish attenuation and amplification characteristics of the Egyptian earthquakes.

Types of Building Construction and Structural Response

For the purposes of this report, buildings in the affected area have been divided into three types.

Type I Buildings have very little engineering and no seismic resistant systems and include structural systems and materials such as:

- adobe with wood floors and roofs,
- old stone masonry with wood and steel floors and roofs,
- brick (unreinforced) masonry with wood, steel, and reinforced concrete floors and roofs, and
- reinforced concrete skeletons with unreinforced masonry infill walls (low-rise, 2-5 stories).

The damage observed in these types of buildings can be categorized as follows:

- cracks and separation in the corners of the walls due to lack of tie-beams,
- roof and wall separation due to lack of adequate anchorage (roof timbers are typically not anchored nor do they extend sufficiently over the width of the walls; this problem is compounded by heavy storage on the roof), and
- collapse of laterally unsupported masonry parapets and walls.

Obvious deterioration, varying quality of brick and masonry block, and poor quality of mortar mix and placement contributed to damage in some buildings. The structures that performed well were symmetrical, were of good quality construction, and were well maintained. Thick walls with minimum openings and small height to thickness ratios contributed to low stress levels.

Old Cairo - Heavy damage to stone bearing wall buildings with unanchored wood roofs

In general, reinforced concrete framed buildings with unreinforced masonry infill performed well in this earthquake.

Type II buildings encompass engineered mid- and high-rise buildings. Buildings of this type in the affected area included:

- reinforced concrete framed buildings with unreinforced masonry infill,
- reinforced concrete buildings with reinforced concrete shear walls (site cast or precast),
- precast concrete and prestressed beam/column systems,
- a very few partially ductile moment resisting concrete framed buildings, and
- a very few steel buildings.

The damage observed in the concrete buildings appears to be mainly from random/special circumstances encompassing some of the following conditions:

<u>highly irregular stiffness distribution in the structural system</u>, such as in high-rise reinforced concrete buildings with masonry infill above the second or third level, but with ground floor and mezzanines of greater height and with no masonry infill. (Many lower level modifications are done as afterthoughts without any evaluation of seismic force and drift demands, and consequently without any proper shear or confinement reinforcement.)

<u>reinforced concrete systems with deep spandrel beams and short columns</u> without appropriate shear reinforcement;

<u>excessive overloading coupled with soft and weak stories at lower levels</u> due to illegal (not properly engineered) additions. (In Heliopolis, a 14-story structure that was designed to be 8 stories collapsed.)

<u>inadequate reinforced concrete detailing</u>, such as column ties, beam-column joints, location and length of lap splices, development length, etc.;

<u>inappropriate locations and poor workmanship at column cold joints</u>;

foundation systems on soft soil, for example, older buildings of heavy masonry which lacked piles tended to rotate and tilt with their shallow foundations. (This was partly due to the high underground water table ≃3.0 meters from the surface.)

poor construction materials (aggregate, poor concrete mix, some defective cement, undeformed reinforcing bars and ties, hollow masonry, and clay tile and mortar);

poor overall construction and workmanship; and

poorly enforced code coupled with poor maintenance and defective plumbing and sewage systems.

Type III buildings are historic structures, such as mosques, churches, and monuments. The most affected areas were old Cairo with its old stone and unreinforced brick bearing buildings, historic mosques, and Coptic churches. Many of these structures sustained previous damage from the August 1847 earthquake.

Damage included tilted, damaged, and toppled minarets in mosques; cracks at the corner stone of masonry arches; cracking and minor failure in stone walls; and distortion and failure of unsupported stone parapets. One large dome was severely damaged, and partially collapsed.

Geoscience and Structural Engineering Conclusions and Recommendations

The earthquake surprised most people, but was not without precedent in Egypt and the surrounding area. The earthquake should serve as a stimulus to efforts to assess the earthquake risk and quantify the hazard in high density urban areas of the Nile River Valley. Specific recommendations follow.

Geosciences

1. The causative fault of the October 12, 1992, earthquake remains unknown for lack of surface-breaking ruptures. Geophysical surveys could be performed to identify any geological structures that might be associated with the earthquake.

2. Seismological instrumentation stations, both permanent and portable, need to be upgraded to modern digital seismographs that are capable of recording a broad spectrum of earthquake ground motions.

3. Strong motion instrumentation is needed in the Cairo area to measure earthquake ground motions (characteristics) for applications in engineering design and the identification of areas prone to ground motion amplification, liquefaction, etc.

Structural Engineering

1. Earthquakes have caused damage in the vicinity of Cairo since Biblical times and undoubtedly will occur in the future. The best preparation for this earthquake hazard is the development and enforcement of a code for building design that accounts for the expected ground motions.

2. For non-engineered buildings (mostly housing), the construction practices and the repairs or strengthening schemes must be developed to take into account the needs of the people and the resources available. Guidance and education could be provided with simple and understandable posters showing "what to do," "what not to do," "how to do it," and "where to go." These posters could demonstrate the dangers caused by parapets, show how to mix concrete, illustrate proper anchorage of walls to roofs, etc.

3. For engineered buildings (new buildings) designers and builders must avoid contributing to vulnerability:

- avoid building irregularities, abrupt changes in stiffness, and weak/soft stories;
- provide for demand imposed on short columns by framed deep spandral beams, and designing and installing necessary reinforcing details;
- give appropriate attention to beam-column joints, and the need for stable ductile behavior in the immediate regions near the joints;
- pay special attention to precast and prestressed construction and the need for good continuity details at the joints; and
- define quality assurance and quality control programs for design, construction materials, and workmanship.

4. For existing hazardous buildings a national effort to assess risks and a hazard reduction plan to mitigate life safety threats are needed. Additionally, attempts should be made to provide follow-up practical seminars in Egypt for evaluation, repair, and retrofit of buildings.

5. Courses in earthquake engineering related subjects should be further emphasized in university curricula.

Acknowledgement

Participation in this effort by T. Topozada of CDMG, and Paul Thenhaus and Bob Sharp of USGS is highly appreciated.

Emergency Response and Social Impacts

The occurrence of the October 12, 1992, earthquake near Cairo provided an opportunity to develop important insights that can be used to lessen human and structural loss from earthquakes elsewhere in the world. In addition to investigating geophysical and engineering aspects of the earthquake, the EERI team evaluated emergency response and social science impacts—including mortality and morbidity, search and rescue, displaced persons, economic and social impacts, and mitigation and preparedness—and identified areas for further in-depth study.

Emergency Response

Although earthquakes occurred in the Red Sea area in 1969 and in Sharkiya Province in 1974, these disasters were not recognized as significant natural hazards in Egypt. No disaster preparedness or emergency response programs for natural hazards existed at national, regional, or local levels prior to this earthquake. Critical care facilities were able to provide adequate emergency services in the immediate response period since the structures and operations of such facilities were not severely affected by the earthquake.

Human Casualties

Reports from the Ministry of Health indicated that a total of 490 deaths had been registered officially as of October 26. Newspapers reported 557 deaths for the same period. Of the 9,900 injuries that were treated and reported to date, a total of 2,276, or 23 percent, were admitted to hospitals of the Ministry of Health. An estimated 500 of these admissions occurred during the first two days after the earthquake. A total of 41 children from 3 grade schools in the Shoubra district of Cairo were killed in stampedes. Indirect deaths and injuries are expected to increase as buildings rendered unstable by the earthquake continue to collapse on themselves or on adjacent structures. Because building collapse is a common occurrence in Egypt and the source of many injuries, it will be difficult to determine whether future structural collapses are attributable to the earthquake and its aftershocks or to inadequate construction that existed before the earthquake occurred.

Search and Rescue

Search and rescue operations were not a major requirement for this earthquake, since only one multistory structure collapsed. Foreign search and rescue teams, particularly from France, provided assistance. However, local area residents rescued most of the victims, typically from 2-3 story structures, and brought them to medical facilities by ambulance or by taxi.

Displaced Persons

According to initial reports by the Department of Humanitarian Affairs/United Nations Disaster Relief Office, an estimated 3,000 families were homeless immediately after the earthquake. This figure is expected to rise as badly damaged residential buildings are demolished. By October 18, approximately 2,000 families in Cairo were given new permanent housing in satellite towns outside Cairo. An estimated 30 shelters had been established in rural areas outside of Cairo, 20 in urban Giza, and 20 in Cairo as of October 29. A number of families, particularly in rural areas, refused to leave their plots of farmland and instead erected tents, provided by the government, on their property. Relief activities were coordinated by the Ministry of Social Affairs and the Red Crescent. The Army operated camps in the Cairo, Giza, and Qualubiya areas. Non-governmental organizations worked under the direction of the Ministry of Social Affairs and the Red Crescent, and primarily addressed sanitation issues. The Ministry of Health was responsible for providing primary health care in the camps and offered psychological consultation when requested. A foodborne outbreak arose in one camp where 28 residents purportedly ate donated hot meals that were stored at room temperature all day. According to the Egyptian Red Crescent, systems for the timely and efficient identification and distribution of appropriate drugs, relief equipment, and supplies were not in place.

Social and Economic Impacts

The earthquake exacerbated an already severe housing deficit throughout Cairo and urban Giza. In rural Giza, the earthquake leveled entire villages such as El-Beleida, El-Atf, and Bedsa. Relocation to permanent housing in new areas and in satellite towns is bound to create long-term social and economic effects. For some, the receipt of housing from the government proved to be timely and advantageous. As is commonly seen following disasters, nonvictims also attempted to secure aid from the government. Because financial compensation was granted to survivors of deceased victims, reports surfaced of applicants for assistance who presented death certificates of persons who died prior to the earthquake or of fictitious dead relatives. Moreover, some patients reportedly prolonged their stay in hospitals past recovery in order to receive assistance from foreign governments that distributed monetary aid directly to the bedside. As in Mexico City after the 1985 earthquake, opposition political parties were beginning to find support among the homeless, many of whom were still awaiting assistance from the government one week after the earthquake.

Mitigation and Preparedness

This earthquake emphasized the need for developing mitigation and preparedness measures in both private and public sectors throughout the country. Building codes were in the process of being modified at the national level, however, local authorities in rural areas expressed concern about the practice of rebuilding in the same manner as before the earthquake. In an effort to educate the local population about the hazards of natural disasters and appropriate building occupant behavior following earthquakes, the Governor of Giza had pamphlets of the U.S. Defense Civil Preparedness Agency (predecessor agency to the Federal Emergency Management Agency) translated and distributed to residents after the earthquake.

Recommendations

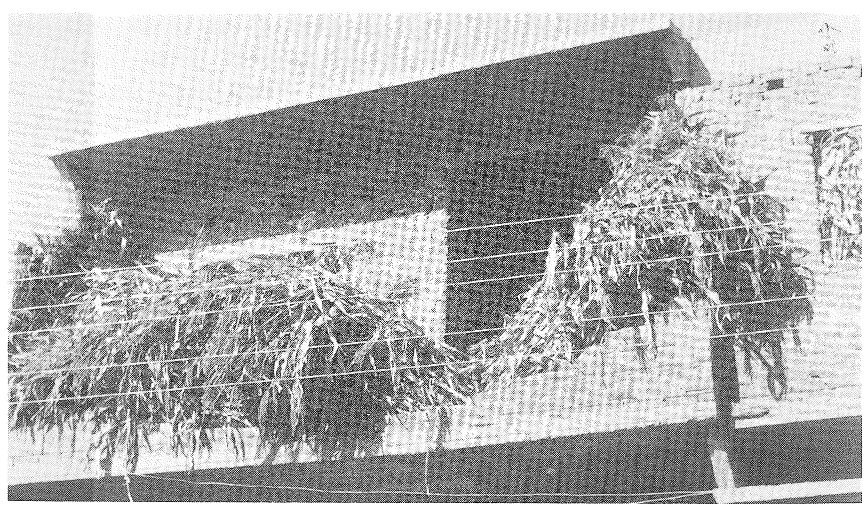
1. An emergency response and disaster preparedness program should be implemented in both private and public sectors at national, regional, and local levels.

2. Information regarding appropriate occupant actions within and outside a structure should be disseminated. Earthquake drills should be conducted in schools on a regular basis.

3. Disaster training should be conducted for all first responder organizations.

4. Emergency plans, particularly for critical facilities such as hospitals, schools, and other first responder organizations, should be developed, exercised, and revised periodically.

Building separation at expansion joints and tilting of some buildings.



Regular R.C. construction with in-filled wall performed well in villages.

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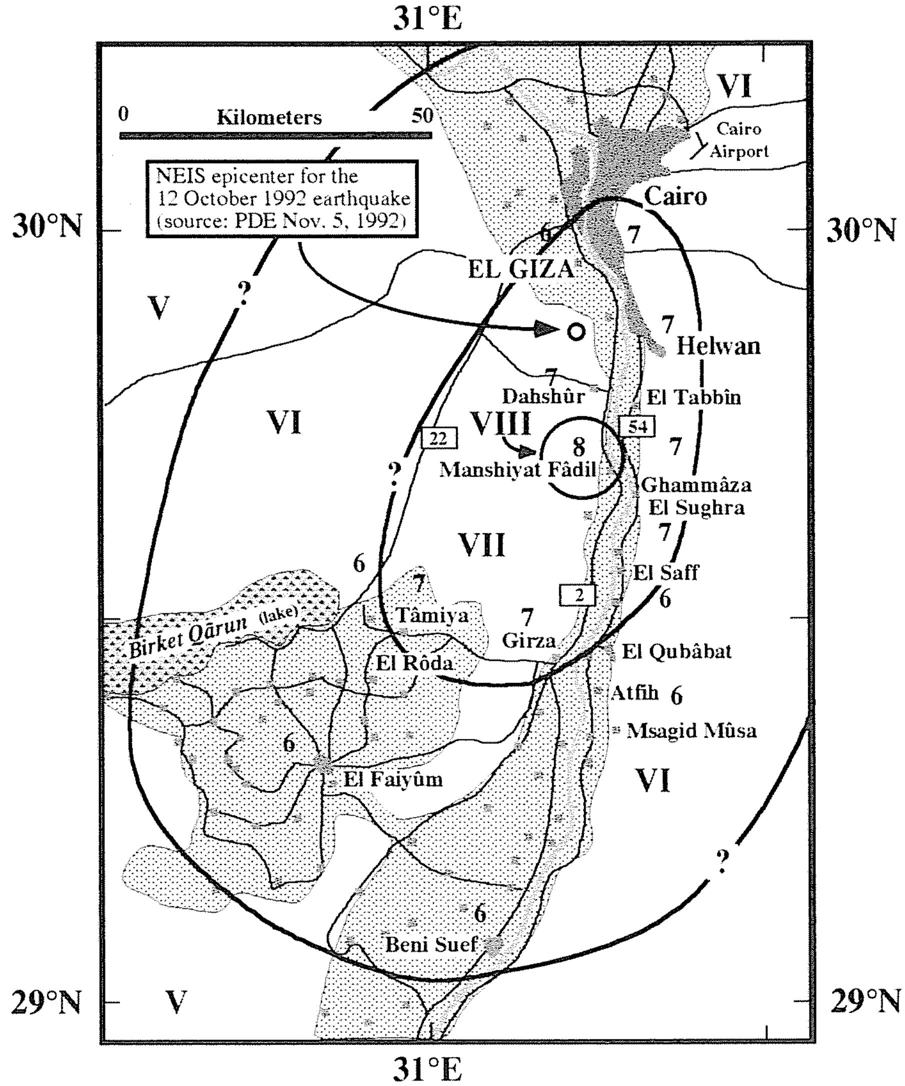
Intensity Distribution

contributed by Paul C. Thenhaus, U.S. Geological Survey

This preliminary isoseismal map is based on a four-day reconnaissance tour of damaged areas. The southern extent of the isoseismals is based on interviews with staff members of the Geological Survey of Egypt. The smoothed contours represent the highest predominant levels of Modified Mercalli Intensity (MMI) with regard to building damage, and do not preclude higher localized intensities and common lower intensities than the generalized level shown on the map. The western and eastern excursions of the isoseismals are depicted with a question mark to reflect uncertainty in their locations in desert regions characterized by very low population concentrations and little development.

In general, MMI VII effects were widespread in the villages of the Nile valley to approximately 80 km south of Cairo, which includes most of the populated area of the Giza governorship. Fallen adobe walls and collapsed roofs that had been supported by cross timbers were common. Brick-firing kilns with masonry smoke stacks approximately 20 m to 30 m tall are scattered throughout the Nile valley, but none was known to have toppled in the earthquake. This observation generally limits a maximum MMI assessment to a level lower than VIII for most of the affected area of the Nile valley. However, some maximum MMI VIII effects were observed in the village of Manshiyat-Fâdil, approximately 20 km south of the epicenter. The principal basis for this assessment was the fall of unreinforced masonry walls and more widespread damage to adobe buildings than in nearby villages.



Preliminary map of the Modified Mercalli Intensity distribution of the October 12, Cairo, Egypt earthquake.

Inspections in the city of Cairo were primarily in the southern and eastern parts of the city. Thus, the exact location of the VI-VII contour through the city is somewhat uncertain. Slight to moderate cracking in the walls of multistory concrete-framed buildings was observed at scattered locations in south Cairo. The general degree of damage was taken to indicate a maximum predominant MMI of VII.

The northeast-trending elongation of the isoseismals is due to the north-trending belt of population and development along the Nile valley and the very sparse settlement of neighboring desert regions. The isoseismal shapes should not be used to infer properties of a fault rupture, such as damage concentration along a hypothetical fault rupture or focusing of ground motion at the terminal ends of rupture. The concentration and distribution of intensity is, however, consistent with the distribution of injury and mortality rates, the highest of which were concentrated in the villages along the Nile valley.

Earthquake Effects on Antiquities and Monuments

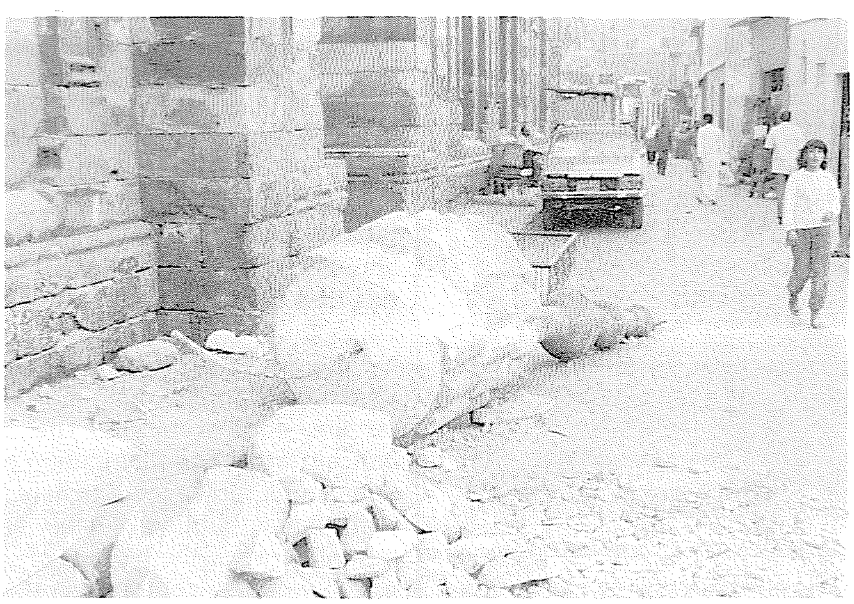
contributed by James Wight, Professor of Civil Engineering, University of Michigan

Introduction

In response to a call for assistance from the Egyptian Antiquities Organization, three University of Michigan professors from the Dept. of Civil and Environmental Engineering traveled to Cairo, Egypt to evaluate damage to ancient Islamic monuments following the October 12 earthquake. The call was transmitted to the University of Michigan via the American Research Center in Egypt, a consortium of forty-two universities and research institutions interested in studying and preserving ancient Egyptian antiquities. Members of the team were James K. Wight, a structural engineer and specialist on earthquake resistant design, Roman Hryciw, a geotechnical engineer and specialist on earthquake effects on soils, and Antoine Naaman, a structural engineer and specialist on advanced cementitious materials.

Summary of Findings

The earthquake caused damage to some of the Islamic monuments, such as cracking in the walls, arches, and domes of various mosques, and partial or total collapse of the tops of some mlnaret towers. However, except for the collapse of the tops of the minarets, the damage caused by the earthquake seems to have only added to a long and ongoing process of deterioration that had evolved prior to the earthquake. The primary reason for this accumulation of damage is the high groundwater table throughout the Islamic section of Cairo that has led to deterioration of the foundations of several monuments. Uneven settlements have caused significant cracking in several of the walls of mosques, and leaning of minaret towers.



Ornate top of minaret that failed during the earthquake (Al Hanafi Mosque).

One example is the Sultan El Ghuri Mosque. The mosque was equivalent to a three-story building with a minaret tower attached to the southwest corner. Cracks were visible on all external walls of the mosque. All of the cracks seemed to be old cracks and certainly did not originate during the earthquake. Plaster strips had been applied across some of the cracks during the three-month period before the earthquake to study movement along or across the cracks due to settlement or other causes. However, in this case the plaster strips served as an excellent indicator of movements due to the earthquake. Most of the plaster strips were not broken. Of the ones that were cracked and could be observed closely, the width of the cracks in the plaster strips varied between 0.1 to 0.2 inches. These strips were typically spanning cracks that varied in width from 0.5 to 1.5 inches.

There were several archways within the mosque and some of them had significant damage. It was reported that some of the ornate material attached to these archways had fallen during the earthquake. Plaster strips had again been applied across some of the pre-existing cracks in the arches and the majority of the strips had not been broken. In some of the smaller archways the keystone was loose and had been braced before the earthquake.

At the Al-Hanafi Mosque, three of four ornate posts on top of the minaret tower failed during the earthquake and fell to the street below. The posts appeared to be unreinforced except for a central dowel bar which apparently was used to align the concrete slices used to construct the top of each post.