NATIONAL CENTER FOR EARTHQUAKE ENGINEERING RESEARCH

State University of New York at Buffalo

Engineering Aspects of the October 12, 1992 Egyptian Earthquake

by

A.W. Elgamal, M. Amer, K. Adalier and A. Abul-Fadl

Rensselaer Polytechnic Institue
Department of Civil Engineering
Troy, New York 12180-3590

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NOTICE

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1 Associate Professor, Civil and Environmental Engineering Department, Rensselaer Polytechnic Institute
2 Associate Professor, Civil Engineering Department, Faculty of Engineering, Cairo University
3 Graduate Research Assistant, Civil and Environmental Engineering Department, Rensselaer Polytechnic Institute
4 Research Engineer, Civil Engineering Department, Cairo University

NATIONAL CENTER FOR EARTHQUAKE ENGINEERING RESEARCH
State University of New York at Buffalo
Red Jacket Quadrangle, Buffalo, NY 14261

ABSTRACT

On October 12, 1992 a moderate earthquake $M_B = 5.9$ ($M_s = 5.2$) occurred about 18 km southwest of the center of Cairo and resulted in significant damage to numerous old and/or poorly constructed structures. Soil liquefaction associated with the occurrence of large sand–boils was observed close to the epicenter. In this study, the earthquake characteristics, along with typical examples of induced damage, are discussed. The observed liquefaction mechanisms provide valuable information on the seismic response of Nile deposited alluvial soils. Such soils constitute much of the inhabited area of Egypt.

ACKNOWLEDGMENTS

The first author acknowledges the National Science Foundation (Dr. Clifford Astill, Division of Biological and Critical Systems) for providing travel arrangements to conduct earthquake soil–effects reconnaissance in Egypt. Preliminary site investigations and report preparation were supported by the National Science Foundation (NSF), the National Center for Earthquake Engineering Research (NCEER), USA; and the Soil Mechanics and Foundations Laboratory (SMFL) of Cairo University, Egypt. The assistance of Professor Dr. Magda Abdel–Rahman, Head of SMFL, Mr. Hatem Hamdi, and Mr. Tarek Abdoun in compiling relevant reconnaissance information is also gratefully acknowledged.

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SECTION 1
EARTHQUAKE CHARACTERISTICS AND STRUCTURAL DAMAGE

1.1 Introduction

The October 12, 1992 Cairo (Dahshure) Earthquake ($M_B = 5.9$) occurred at about 3:00 p.m. It was estimated that about 8,300 dwellings were destroyed, 561 people were killed, and 6,500 were injured (Hadjian, et al. 1992; JICA 1992; Khater 1993; Sykora, et al. 1993; Thenhaus, et al. 1993; Wight 1992; Youssef, et al. 1992). Many casualties resulted from the rush to exit buildings during earthquake excitation. No strong motion instruments were available to record the imparted seismic excitation. In fact, before this earthquake, Cairo had not experienced any appreciable destructive seismic excitation since 1847 (Kebeasy 1990). At first, the sway of buildings was not attributed by most to earthquake shaking, but rather to an imminent collapse solely under the action of own weight (due to a perception of poor quality control practices).

The observed liquefaction near the earthquake epicenter occurred in an agricultural area of alluvial Nile deposits. Throughout centuries, the Nile River flooded the plains along its path every summer (until the construction of the Aswan High Dam in 1971). In the flood period, sediments carried by water were deposited to constitute agricultural land along the Nile Valley and Delta (figure 1-1). The October 12, 1992 earthquake demonstrated that liquefaction may be an important seismic response mechanism at many densely populated locations along the Nile's South to North path throughout Egypt (figure 1-1).

1.2 Seismicity of Egypt

Egypt may be considered as an area of moderate seismicity. Evidence of earthquakes dates back to as early as B.C. 2200 (Kebeasy 1990). It is believed that three main seismically active trends exist (figure 1-1): i) along the Mediterranean, ii) along the Gulf of Aqaba in the Northern Red Sea, and iii) along the Northern Red Sea–Gulf of Suez (active extensional tectonics). Kebeasy, et al. (1981) report 12 moderate earthquakes $5.0 < M < 7.0$ to have caused significant damage in the densely populated areas of Northern Egypt during the last 1,000 years. These areas (figure 1-1) include cities along the Mediterranean (such a Alexandria), the Nile Delta, Cairo, and El–Fayum (about

100 km Southwest of Cairo). Two moderate, but destructive, earthquakes occurred in 1303 and 1847 at El–Fayum (near the epicenter of the recent 1992 earthquake; figure 1-1). In 1847 (estimated $M = 6.2$), 3,000 houses and 42 Mosques were reported to have been destroyed (Kebeasy, et al., 1981; Ambraseys, 1991). Based on historical records, it is inevitable that future destructive earthquakes will continue to occur in Egypt.

1.3 The October 12, 1992 Earthquake

The $M_B = 5.9$ ($M_S = 5.2$) earthquake epicenter was located Southwest of Cairo (figure 1-1) near the City of Dahshure. Currently, the information available about epicentral coordinates, provided by the National Earthquake Information Service (NEIS), are latitude 29.89° N and longitude 31.22° E (Thenhaus, et al. 1993). Focal depth below ground surface was estimated at about 25 km, with no visible surface fault dislocation. A Northwest–striking fault plane (figure 1-2) was thought to be probable based on the documented information about local geology (Thenhaus, et al. 1993).

A map that depicts the Modified Mercalli Intensity (MMI) distribution is shown in figure 1-3. Soil liquefaction was observed in the maximum MMI zone VIII near the Village of Manshiyat Fadil on the West side of the Nile River (figure 1-3).

1.4 Damage in Cairo

Most buildings in Cairo sustained minor damage in the form of hair-line cracks in masonry walls and other non-bearing partitions (Youssef, et al. 1992; Khater 1993). Shear cracking in unreinforced masonry walls reveals a level of shaking that is probably in excess of 0.1 g (figures 1-4 and 1-5). The structures in Cairo may be divided into four categories as follows.

1. Modern reinforced concrete skeleton with infilled masonry walls

Only one such structure (14 story) was found to have totally collapsed (figure 1-6) due to seismic excitation (Khater, 1992). This particular building was later found to have been erroneously underdesigned and very poorly constructed. Despite the absence of any aseismic design considerations in these structures, no significant damage occurred due to: i) the static factor of safety, ii) the significant lateral resistance provided by the infilled masonry walls (these walls are not included in the original design as load bearing components). JICA (1992) reports that the construction procedure in Egypt dictates that the reinforced concrete beams are poured directly on the pre-constructed masonry walls; thus providing for significant lateral resistance even at low-strain levels.

In the aftermath of the earthquake, post-earthquake inspections revealed reinforcement corrosion at the basement level in some of the supporting reinforced concrete columns of many buildings (long-term elevated groundwater problem not related to the earthquake but due to malfunction of water and sewer systems in Cairo). Such columns have since been retrofitted by constructing reinforced concrete jackets.

2. Masonry and Stone Load-Bearing Structures

Thousands of older structures (50 - 200 years old or more) in the cities of Cairo and El-Faiyum are built of masonry or stone with mortar or cement bonding. The floor/roof systems in these structures are often composed of wood beams with or without steel reinforcement strips. Aside from typical cracks due to the imparted shear loads (figures 1-7 and 1-8), much destruction was observed in non-structural elements such as: i) plaster finish on outside (figures 1-9 through 1-12) and inside walls (figure 1-13); ii) heavy masonry and plaster decorative ornaments (figure 1-14); iii) balcony and roof parapets (figure 1-15), and sometimes entire nonstructural walls (Khater, 1992). Many of the casualties and loss of property resulted from such falling objects during the earthquake.

3. Modern Poorly Constructed Reinforced Concrete Buildings

Some buildings were constructed recently without adequate inspection. A number of these buildings sustained significant damage (without collapse) and were later demolished (in Cairo, El-Faiyum and in the epicentral region).

Many side-by-side buildings were found to show signs of relative settlement after the earthquake. Such buildings were often reported to have collided during the earthquake, causing a loud fearful rumble. The most visible signs of earthquake-induced deformation were manifested in: i) opening of a permanent gap between adjacent buildings (figures 1-16 through 1-24); and ii) tilting of some buildings relative to the adjacent structures (figures 1-25 through 1-29). In general, a portion of these deformations might have existed before the earthquake.

4. Antiquities

Cairo is known as the city of 1,000 minarets, denoting the large number of Mosques and Churches that currently exist and date back to as much as 1,000 years or more. Site reconnaissance efforts (Wight, et al. 1992; Sykora, et al. 1993) have pointed to an urgent need to retrofit the foundations of these structures which have been severely compromised by the presence of an elevated water table (primarily due to malfunction of water and sewer systems). This water table has dissolved the silty mortar between stones, and severely weakened the foundation stone walls.

The top sections of a number of Mosque minaretes suffered partial or full collapse (figure 30) during the earthquake. At Al-Hanafi Mosque, three of the four unreinforced stone top minaret sections toppled and fell to the street (figures 1-31 through 1-36). Cracks, mostly initiated prior to the earthquake, were abundant between minarets and attached buildings due to the difference in inertial properties at Sultan El-Ghuri Mosque (figures 1-37 through 1-42). Shear cracks were intensified along window openings in large load bearing stone walls (figure 1-43). In figures 1-44 through 1-46, a partially collapsed masonry minaret top is shown.

A large program of retrofit and rehabilitation is necessary for these invaluable historical structures. Along with aseismic retrofit, the elevated groundwater table problem must be resolved in order to protect the underlying masonry foundations (Wight, et al. 1992; Sykora, et al. 1993). Many tilting minarets (figures 1-47 through 1-49) should be reinforced, and restored to their original vertical position as part of this retrofit process.

1.5 Damage in the MMI Zone VIII

The MMI Zone 8 encompassed a number of agricultural villages with many poorly constructed residential structures. Widespread damage and total destruction of adobe constructions (figure 1-50) prevailed in the MMI Zone VIII (figure 1-3).

Lateral seismic loads acting on a single span bridge resulted in shear damage to the supporting masonry abutments (figure 1-51). Shear induced cracking also appears in an adobe wall in the background (figures 1-51 and 1-52). Such cracking was intensified around windows (and other open sections), and at interfaces between masonry and concrete (figures 1-53 and 1-54).

In figure 1-55, cracks along the end of a short 1.5 m high gravity retaining wall were observed. A vertical crack appears along the wall-soil interface, and an inclined crack demarks the deformed soil wedge boundary. Figures 1-56 and 1-57 show the failure of a retaining wall constructed of cemented stone along with a portion of the supported backfill soil. Soil liquefaction associated with the occurrence of large sand boils was observed close to the epicenter. As a consequence, a main road suffered a maximum settlement of about 1.75 m. This liquefaction case history is discussed in the following sections.

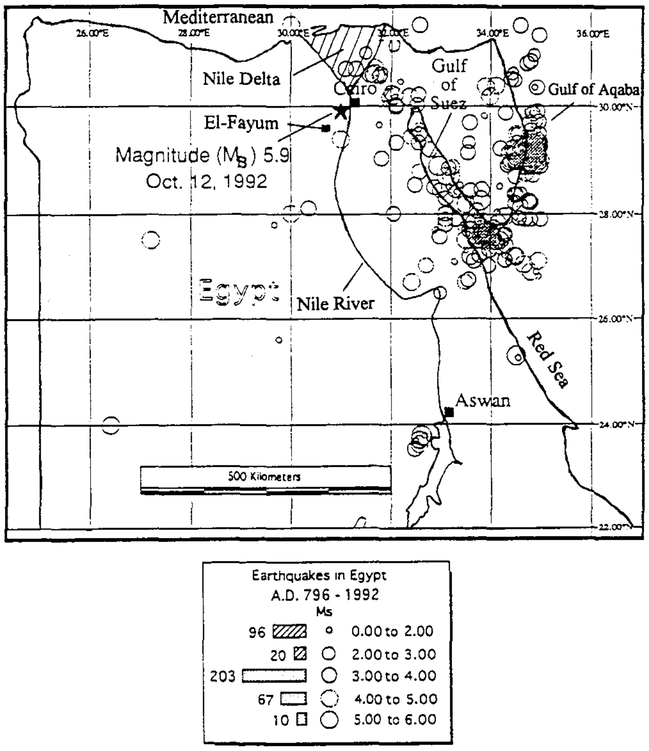

FIGURE 1–1 Distribution of earthquake epicenters in Egypt, A.D. 796-1992 (after Thenhaus et al. 1993).

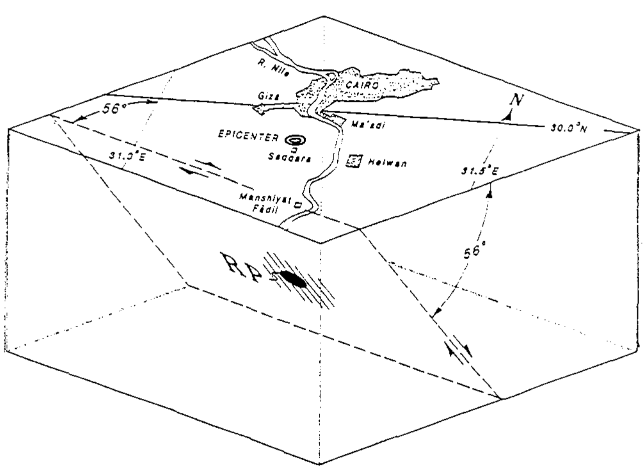

FIGURE 1–2 A transparent earth model of the Cairo region for the October 12, 1992 earthquake. The block is a 60.6 km square on the surface and 40 km deep. Intercepts of the plane of the activated fault are shown with dashed lines, but new rupture is confined to the black patch labelled "RP" (radius 2.6 km); down-dip parallel rulings show unbroken parts of the fault plane around the rupture patch. Arrow pairs show relative horizontal and vertical sense of motion at the rupture patch. Adapted from data of NEIS and G. Ekstrom and M. Salganik of Harvard University (Thenhaus et al. 1993).

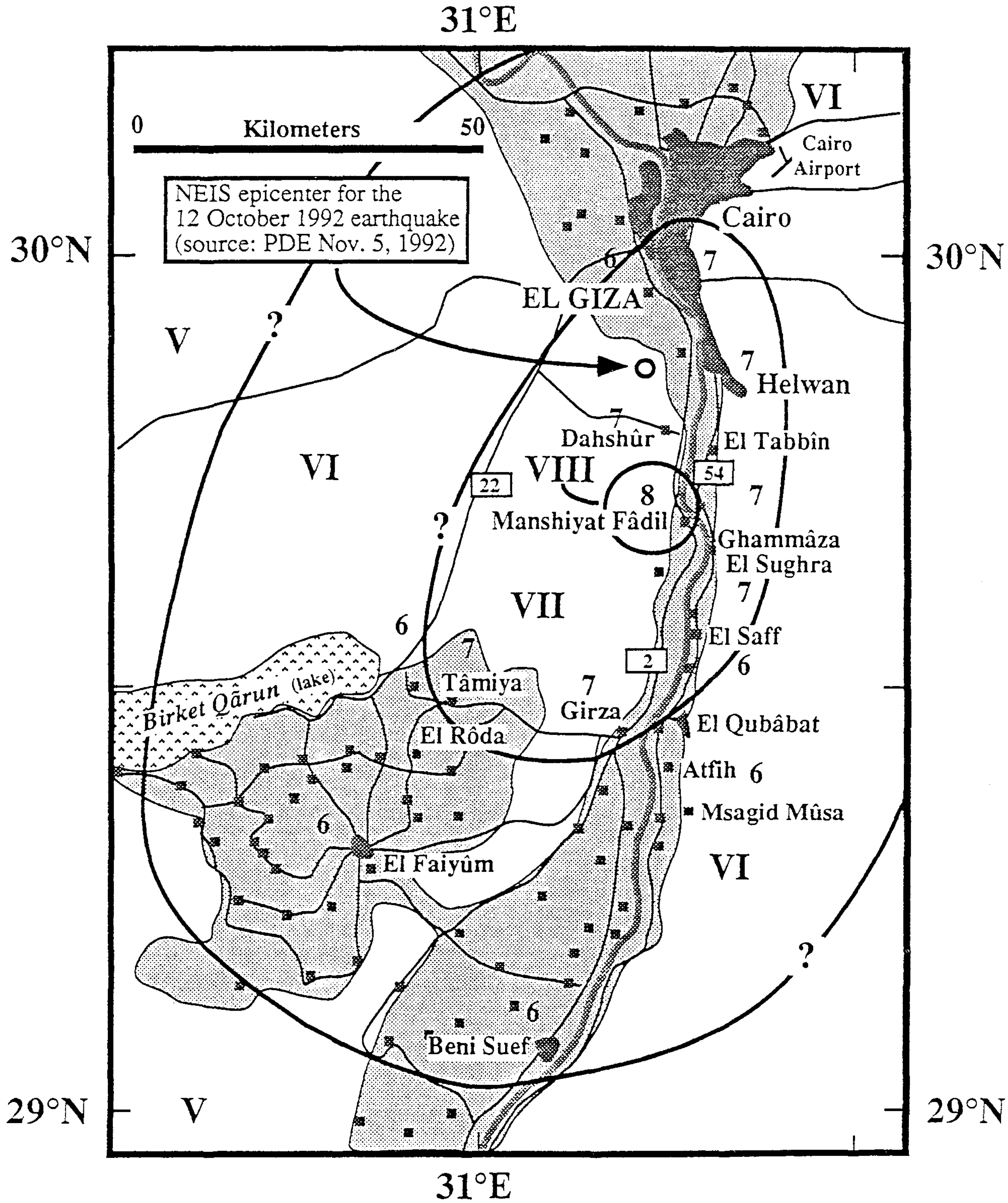

FIGURE 1–3 Modified Mercalli Intensity (MMI) distribution, October 12, 1992 Dahshure, Egypt earthquake (Thenhaus et al. 1993). PDE: Preliminary Determination of Epicenters, USGS, NEIS, Golden, CO.

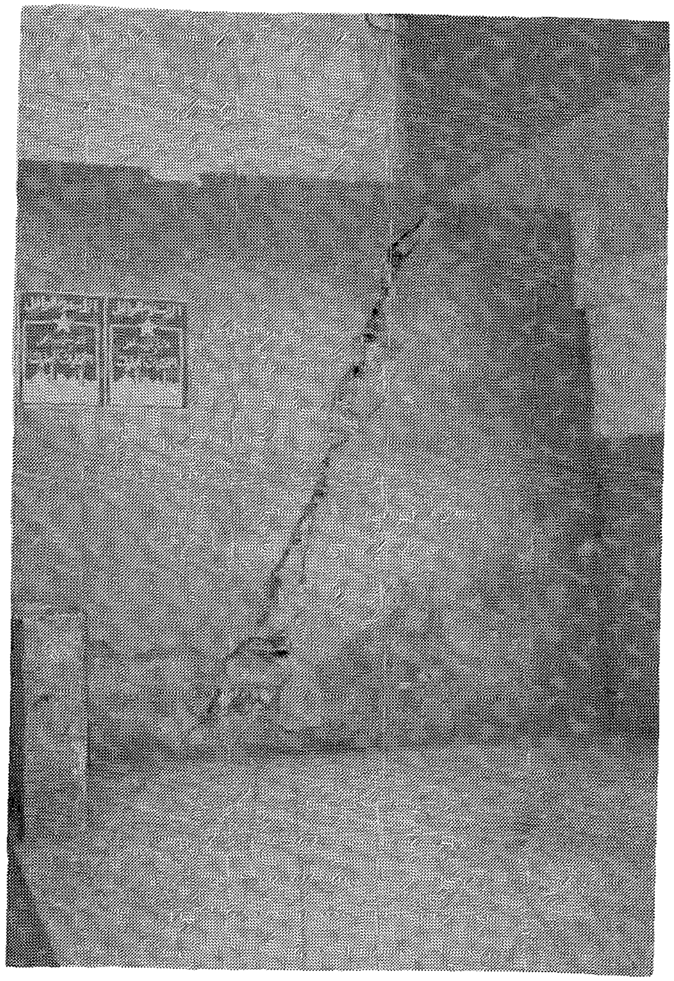

FIGURE 1–4 Shear crack in masonry wall, Misr Elkadima district (Old Egypt).

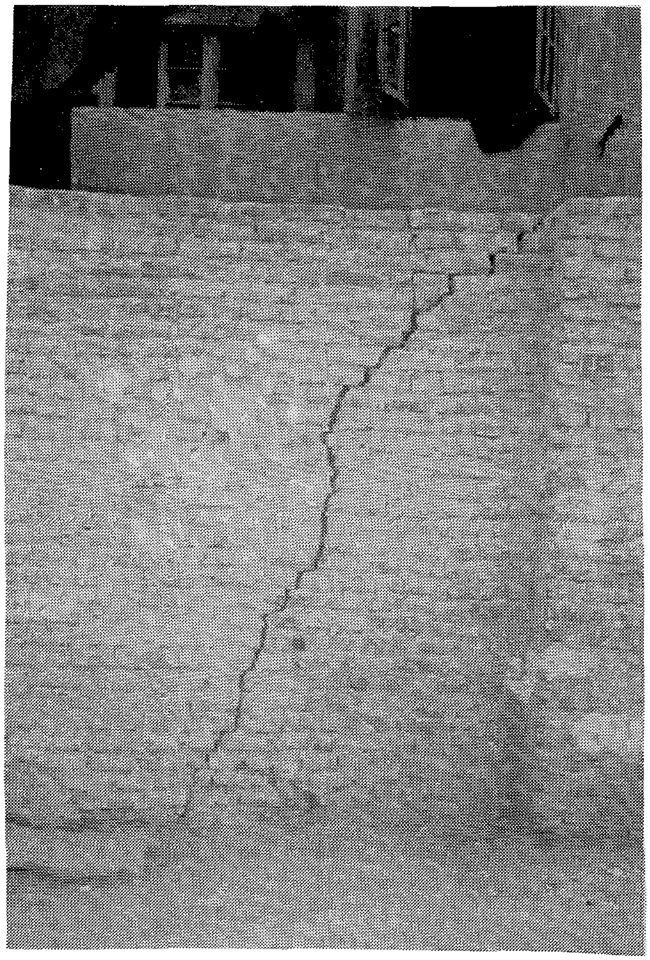

FIGURE 1–5 Shear crack in red brick wall, Misr Elkadima district (Old Egypt).

FIGURE 1–6 Collapsed 14-story reinforced concrete structure (Heliopolis district). [National Geographic, Vol. 183, No. 4, April 1993.]

FIGURE 1–7 Shear crack at window corner (Elsayyeda Zenab district).

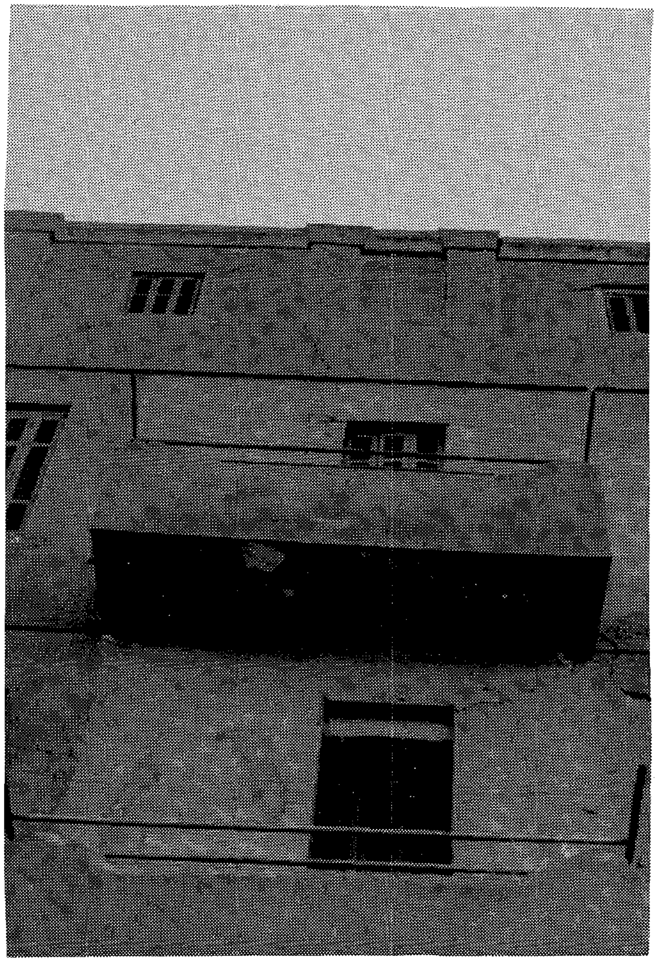

FIGURE 1–8 Shear cracks in masonry walls.

FIGURE 1–9 Fallen plaster around window in a load bearing wall of a building in Elsayyeda Zenab district.

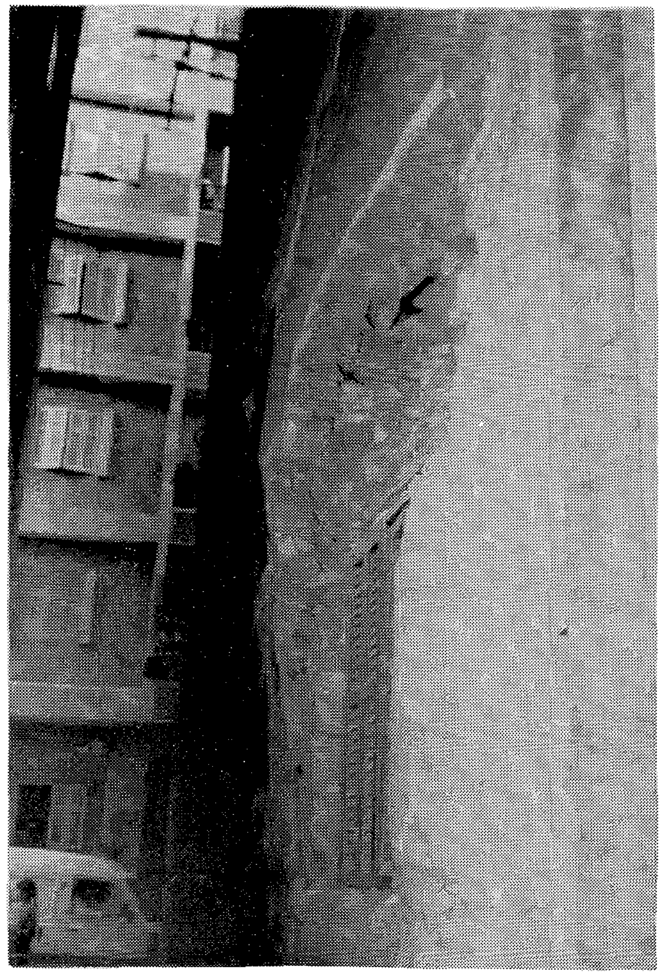

FIGURE 1–10 Fallen plaster exposed stone/mortar wall.

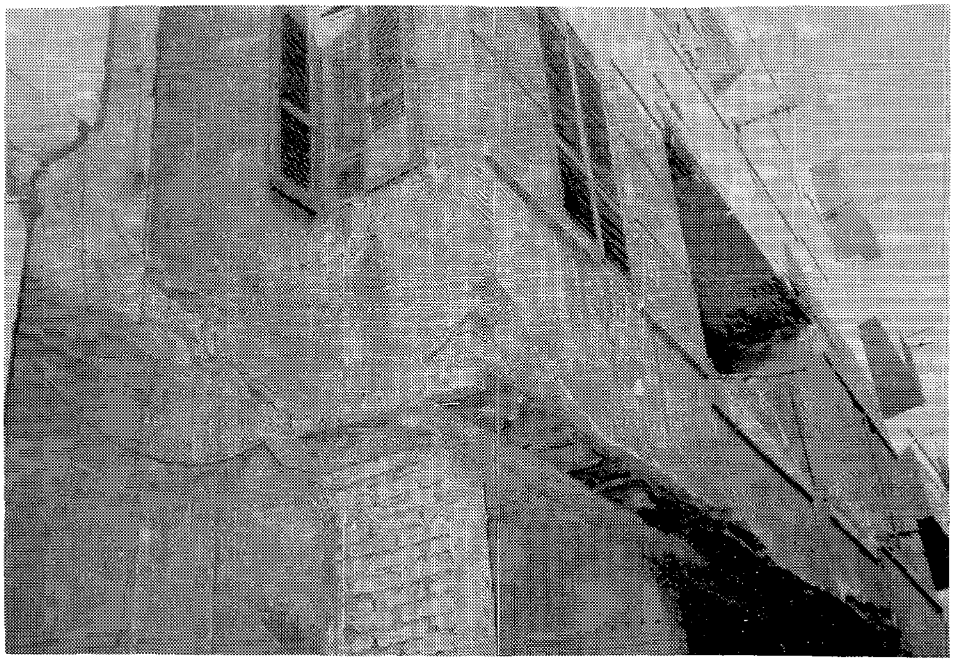

FIGURE 1–11 Fallen plaster exposed wood beams in ceiling.

FIGURE 1–12 Fallen plaster along wood beam ceiling, Misr Elkadima district.

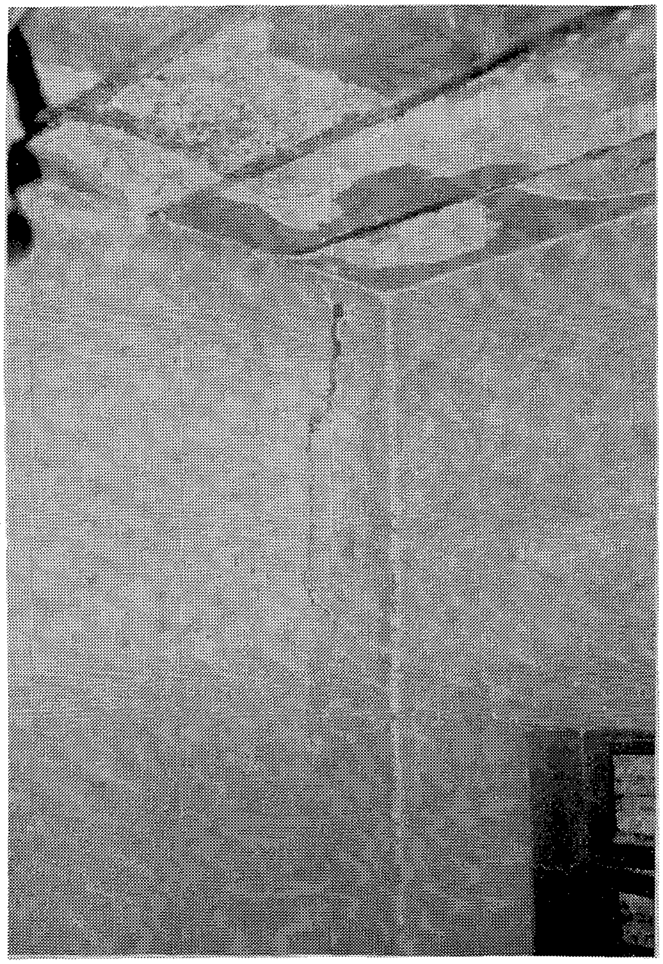

FIGURE 1–13 Fallen plaster and cracks inside an apartment, Mohamed Ali Street.

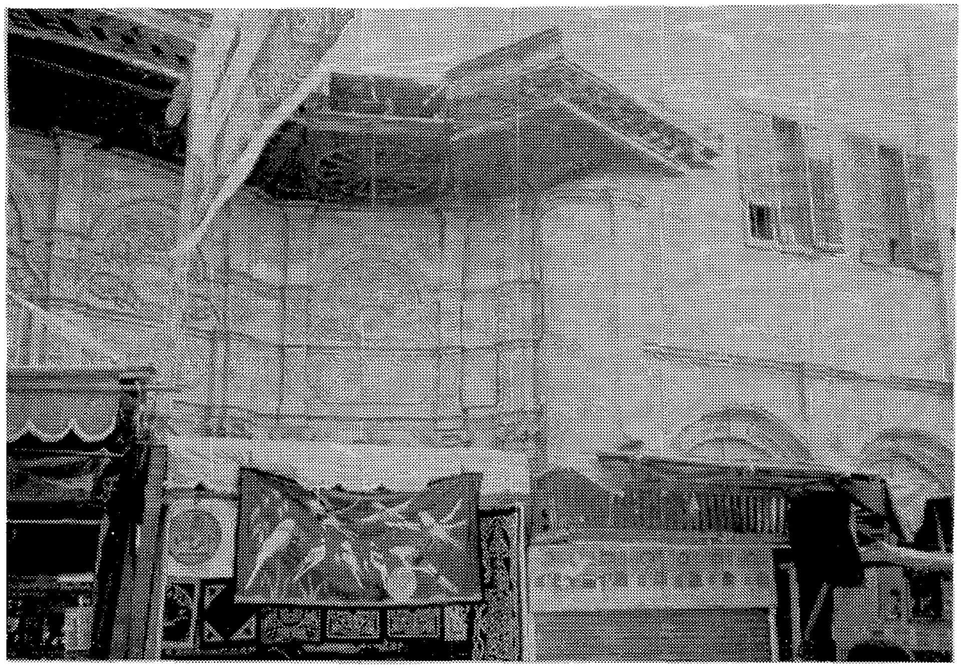

FIGURE 1–14 Fallen and dislocated heavy stone ornaments in an antique building in Elghouriah district.

FIGURE 1–15 Dislocated stone balcony parapet (El-Khalaa district).

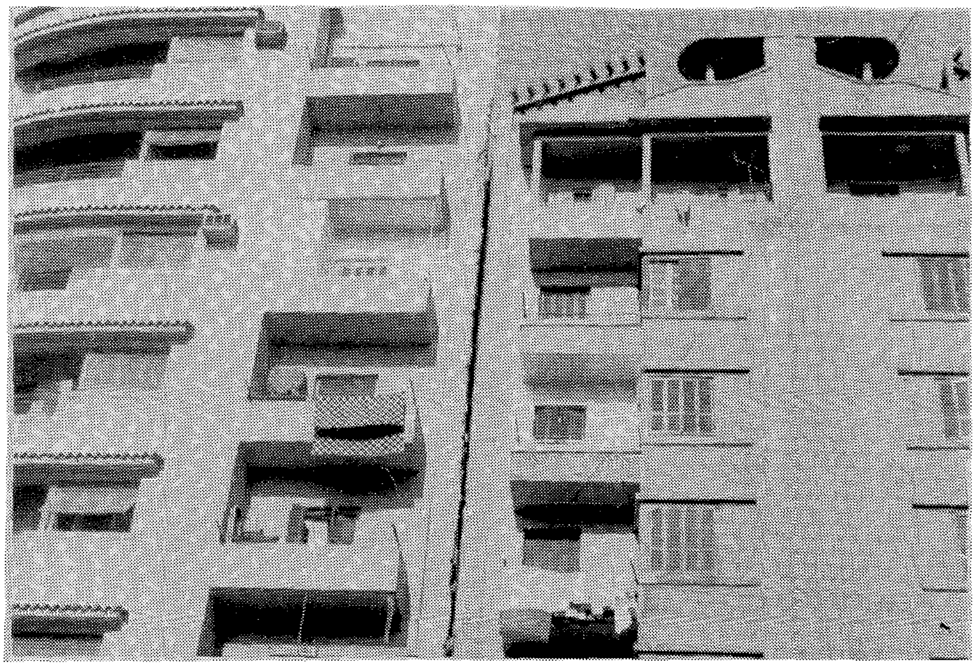

FIGURE 1–16 Open crack between reinforced concrete building 1 (Kadri St., Elsayyeda Zenab district).

FIGURE 1–17 Open crack between reinforced concrete building 2 (Magless Elshaab Street, close to Elsayyeda Zenab).

FIGURE 1–18 Close-up of Figure 1–17.

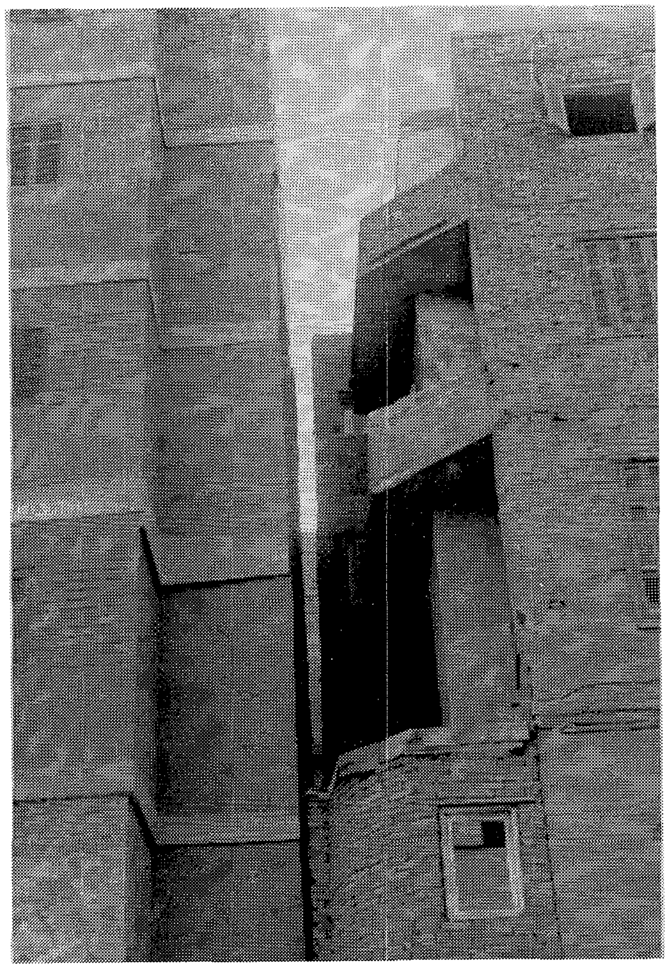

FIGURE 1–19 Open crack between reinforced concrete building 3 (Kadri Street, Elsayyeda Zenab).

FIGURE 1–20 Open crack between reinforced concrete building 4 (Kadri Street, Elsayyeda Zenab).

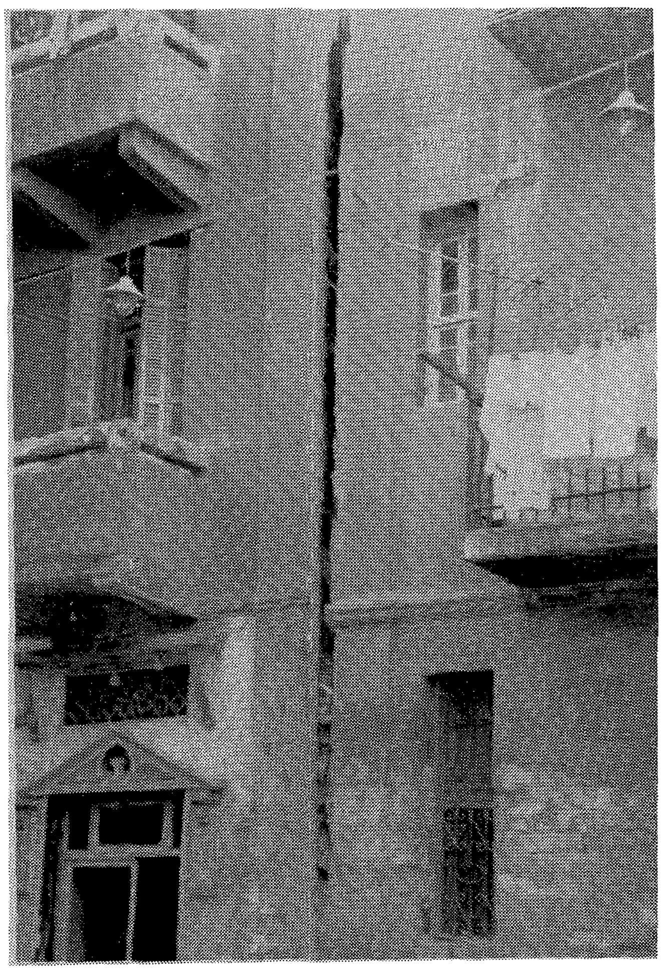

FIGURE 1–21 Close-up of Figure 1–20.

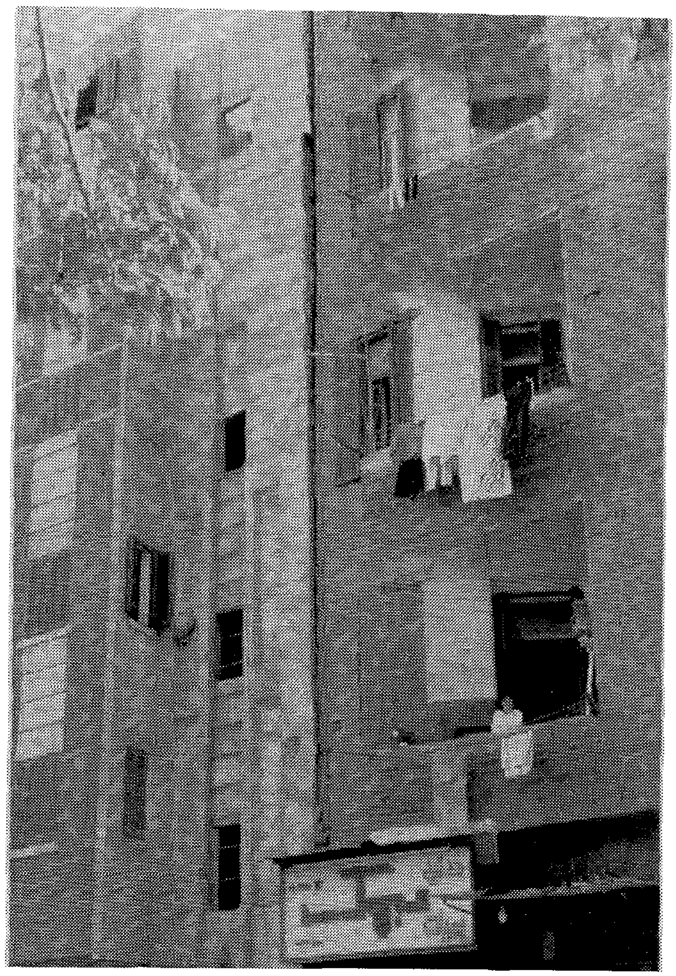

FIGURE 1–22 Open crack between reinforced concrete building 5 (Magless Elshaab Street, across from building of Figs. 1–17 and 1–18).

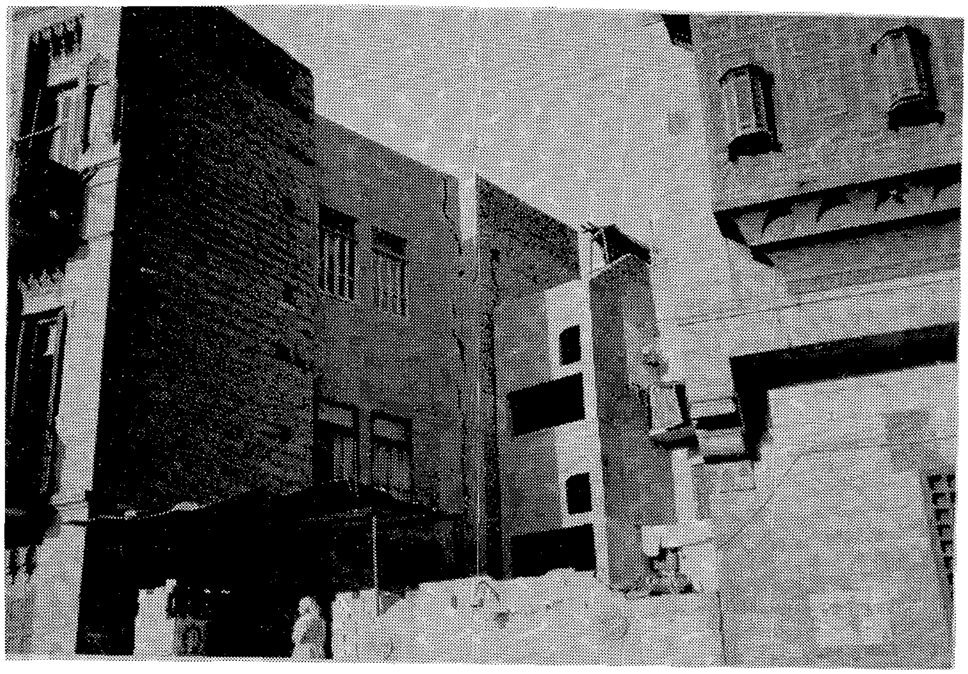

FIGURE 1–23 Open crack between reinforced concrete building 6 (Elkalaa district).

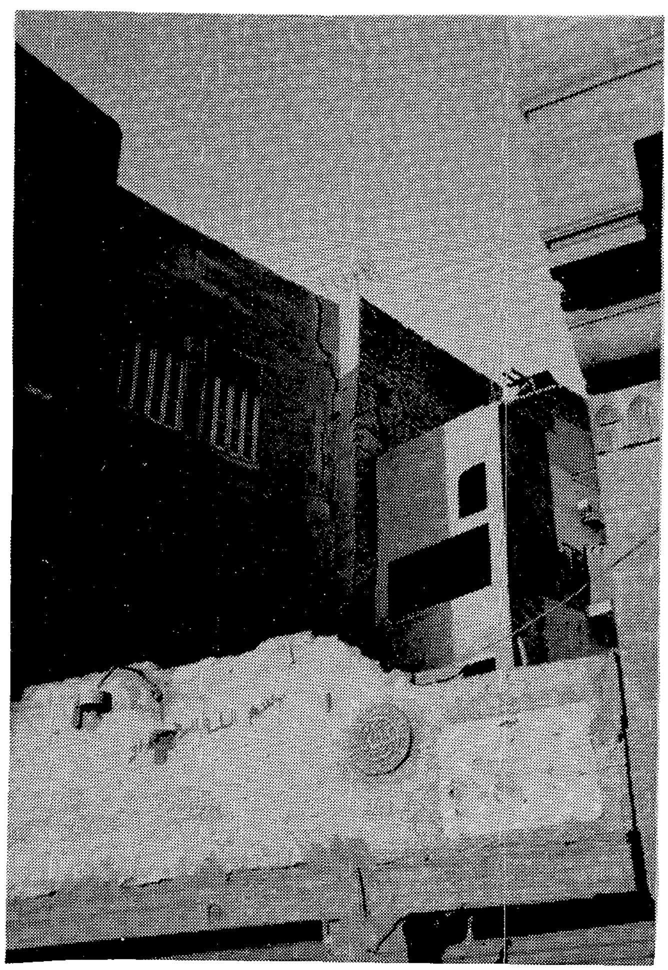

FIGURE 1–24 Close-up of Figure 1–23

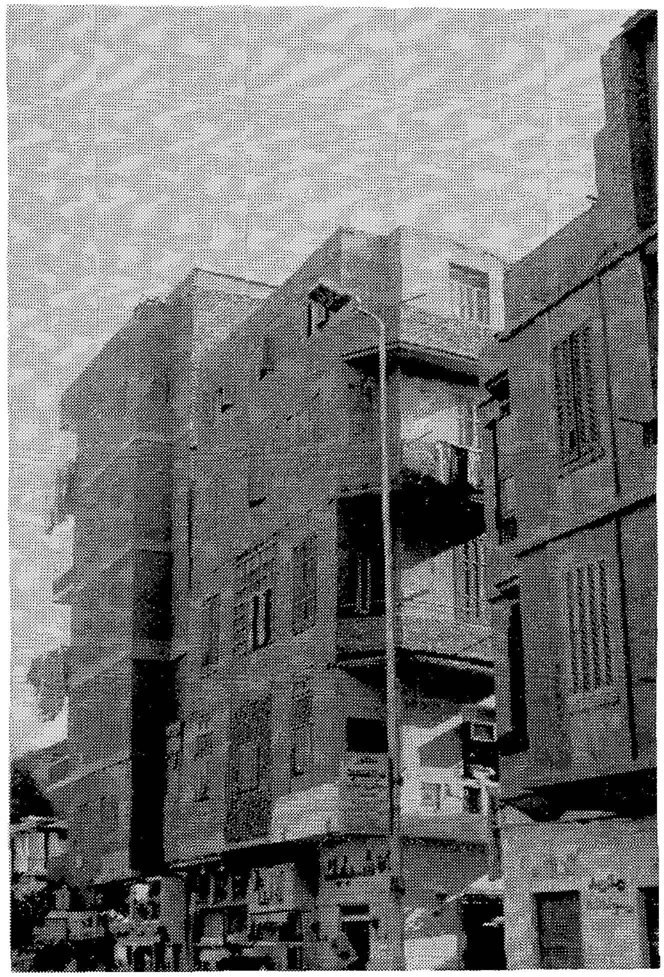

FIGURE 1–25 Tilting reinforced concrete building.

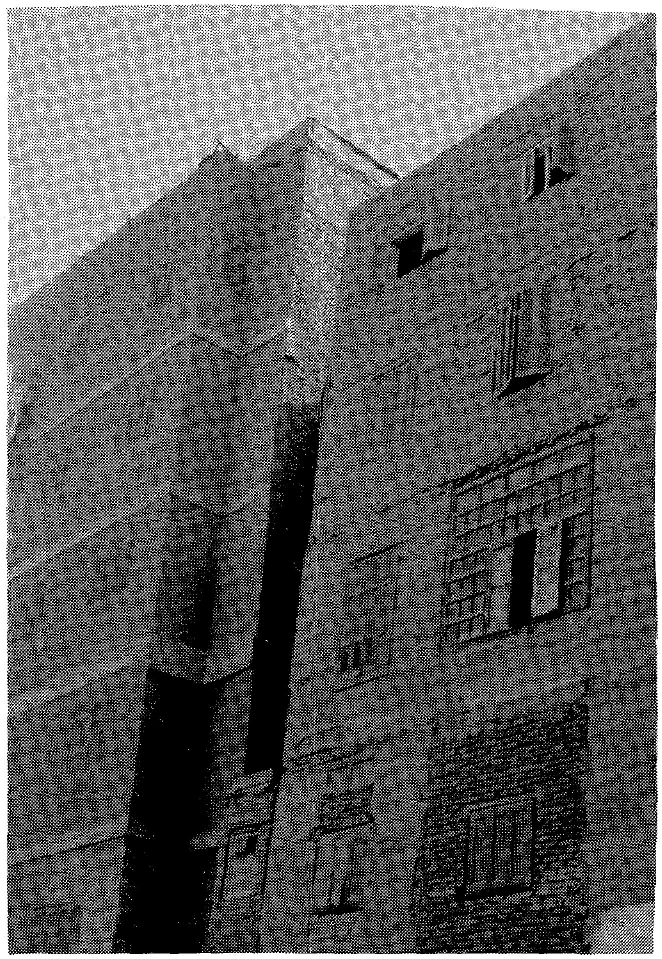

FIGURE 1–26 Tilting reinforced concrete building.

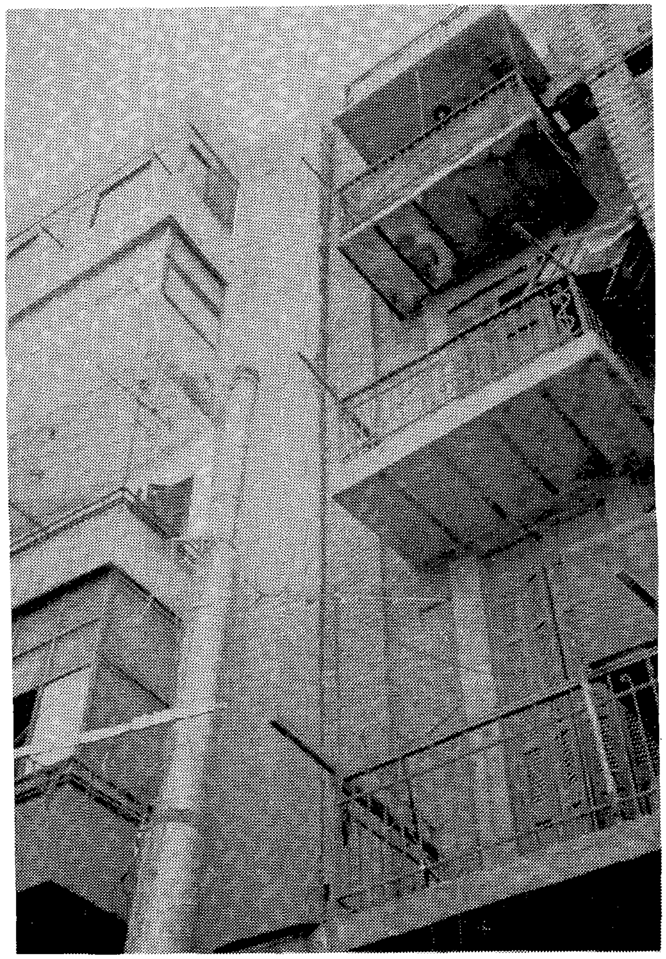

FIGURE 1–27 Tilting reinforced concrete building.

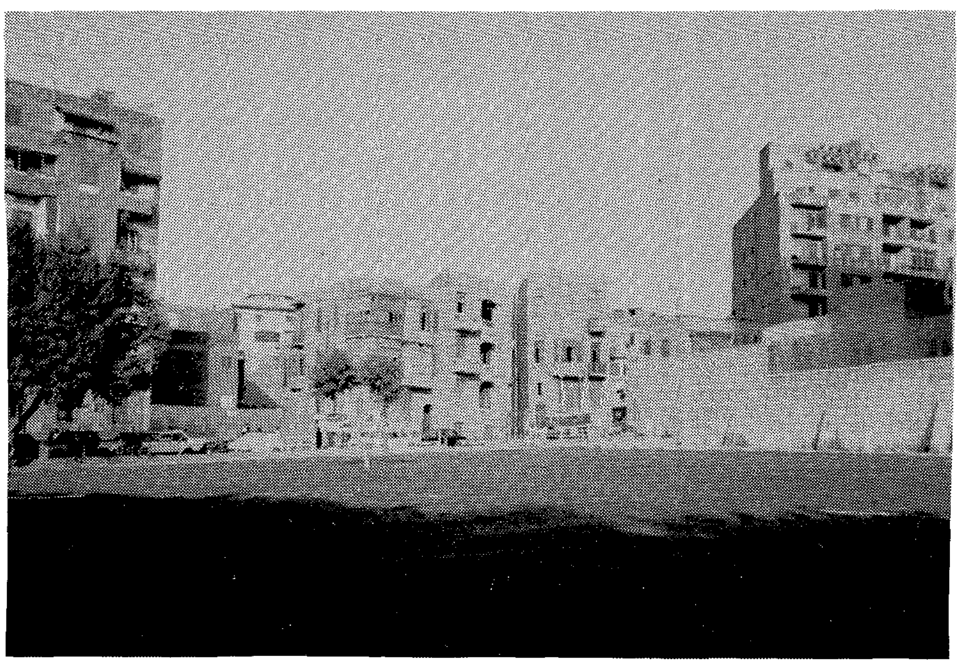

FIGURE 1–28 Group of tilting buildings; tilt increased after earthquake and buildings were evacuated (Elkalaa district, across from Elsultan Hassan Mosque).

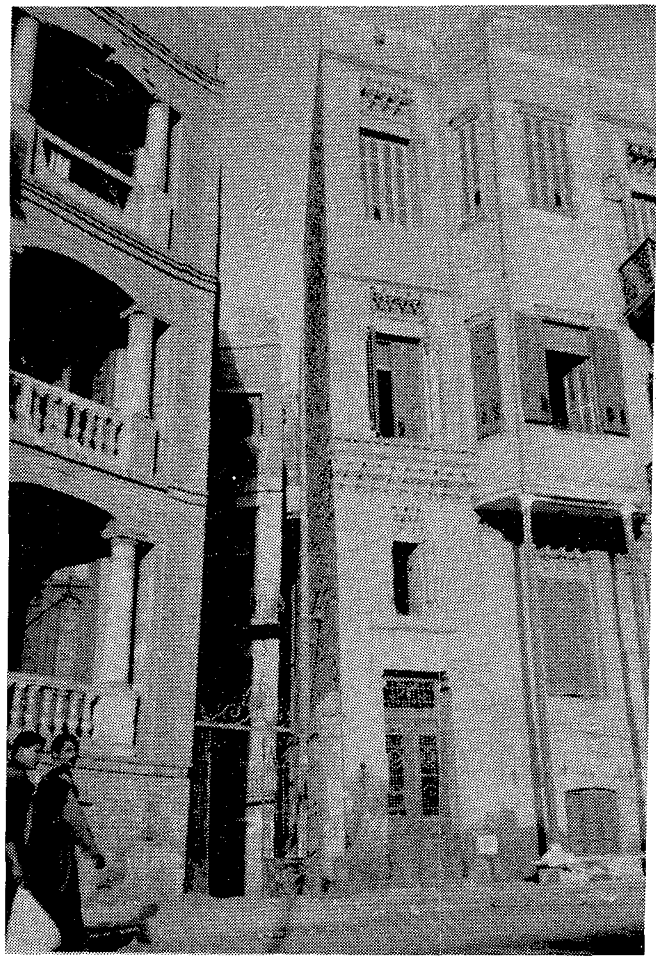

FIGURE 1–29 Close-up of Figure 1

FIGURE 1–30 Dislocated tip of minaret (Elhossein Mosque).

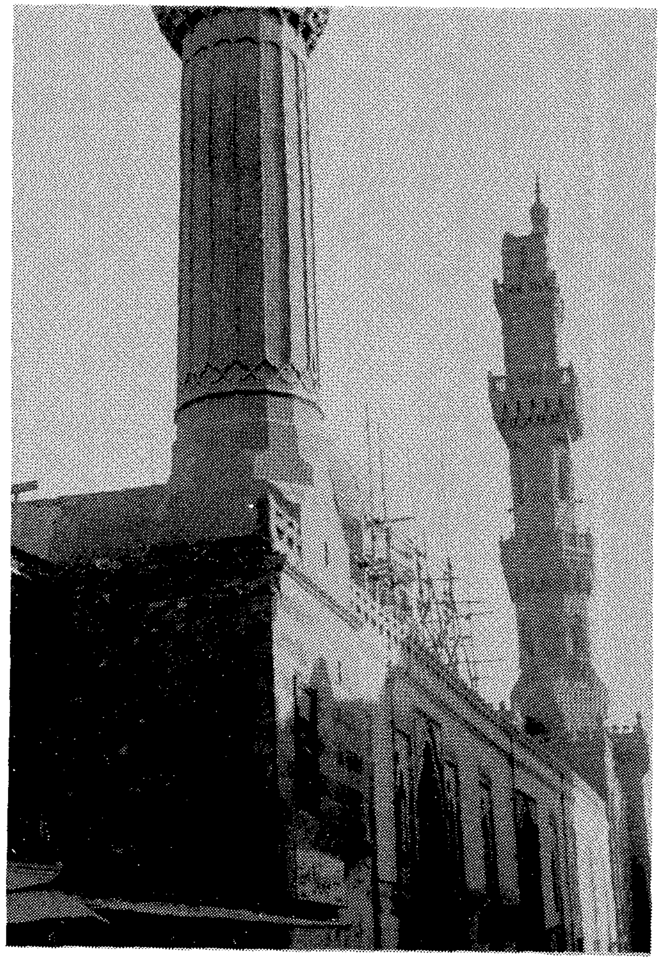

FIGURE 1–31 Al-Hanafi Mosque: missing minaret top (Elsayyeda Zenab district).

FIGURE 1–32 Close-up of Figure 1–31.

FIGURE 1–33a Toppled minaret tops (Al-Hanafi Mosque).

FIGURE 1–33b Toppled minaret tops (Al-Hanafi Mosque).
[National Geographic, Vol. 183, No. 4, April 1993.]

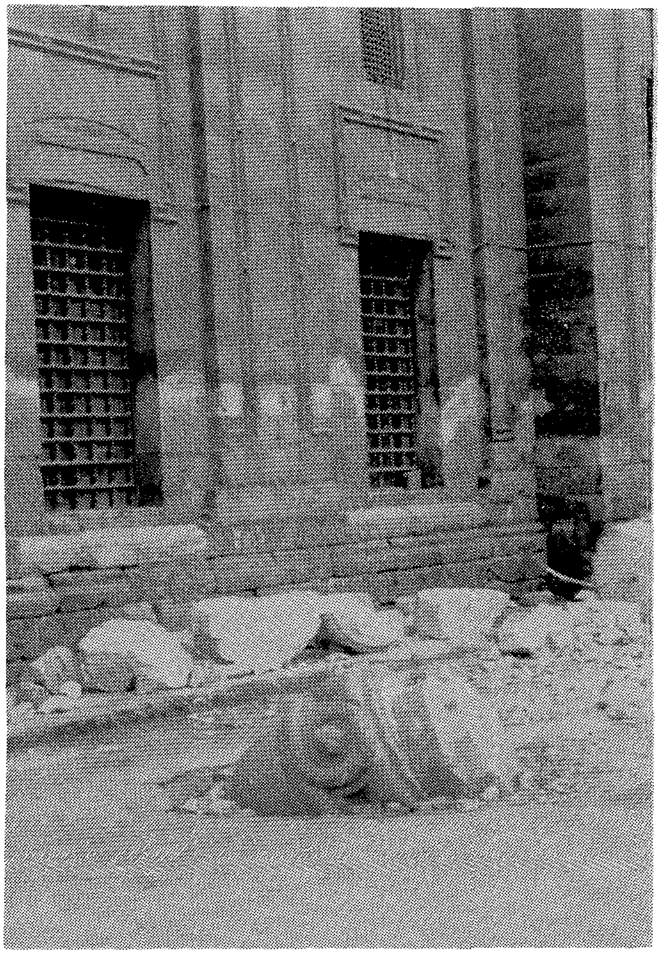

FIGURE 1–34 Toppled minaret tops (Al-Hanafi Mosque).

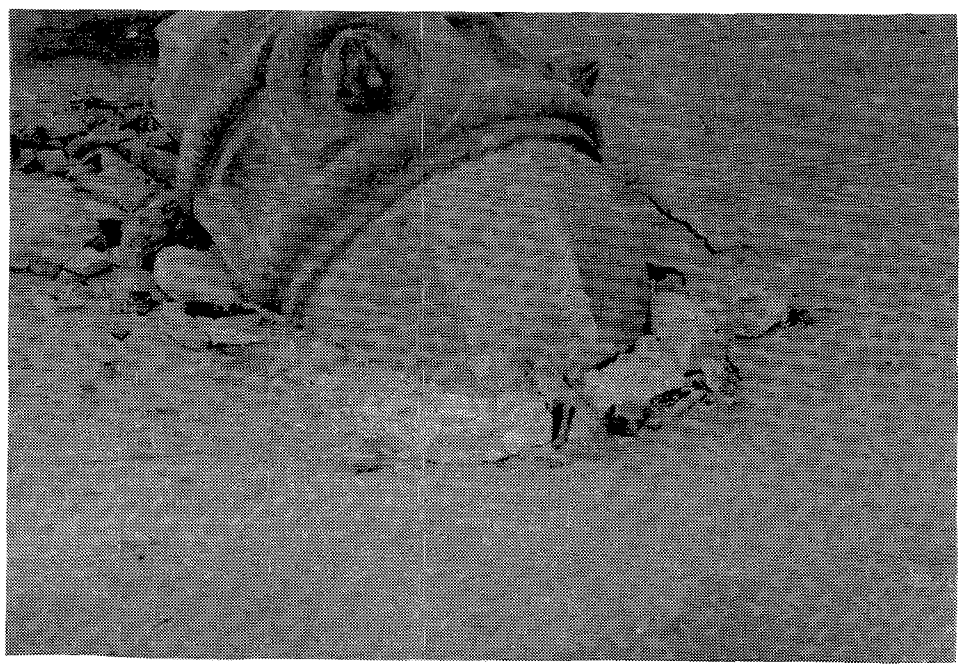

FIGURE 1–35 Toppled minaret tops (Al-Hanafi Mosque).

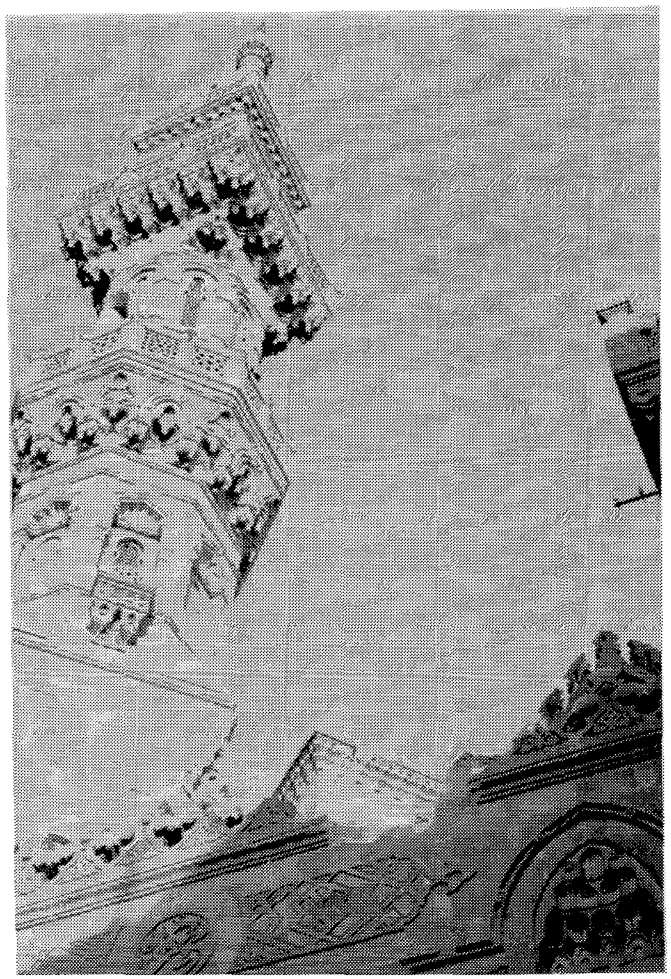

FIGURE 1–36 Broken ornaments due to toppled minaret top (Al-Hanafi Mosque).

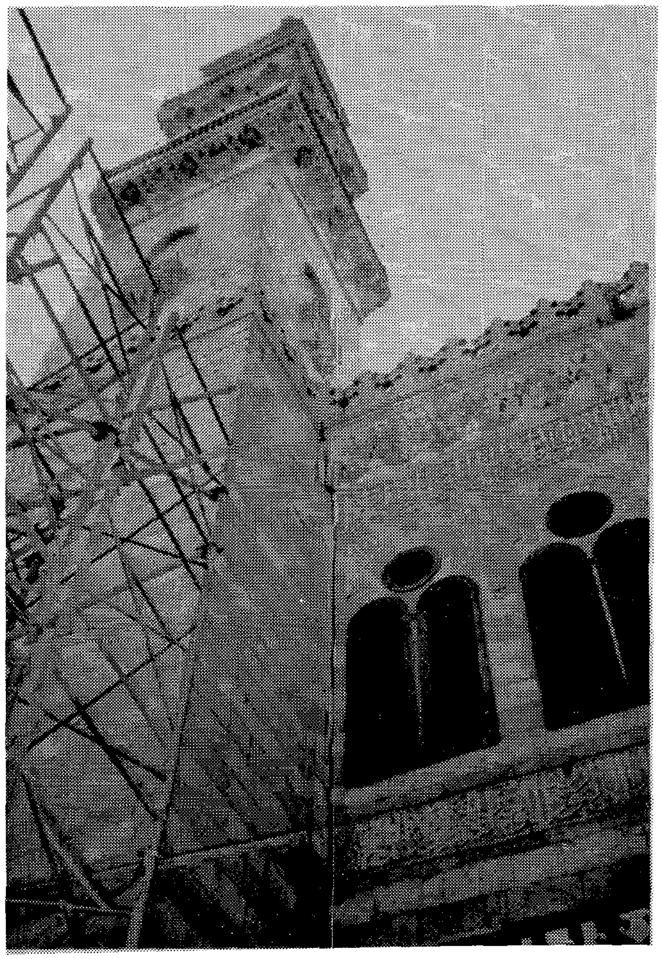

FIGURE 1–37 Crack between minaret and Mosque (El-Ghuri Mosque); cracks aggravated by earthquake; Schaffelding was placed for routine maintenance before earthquake.

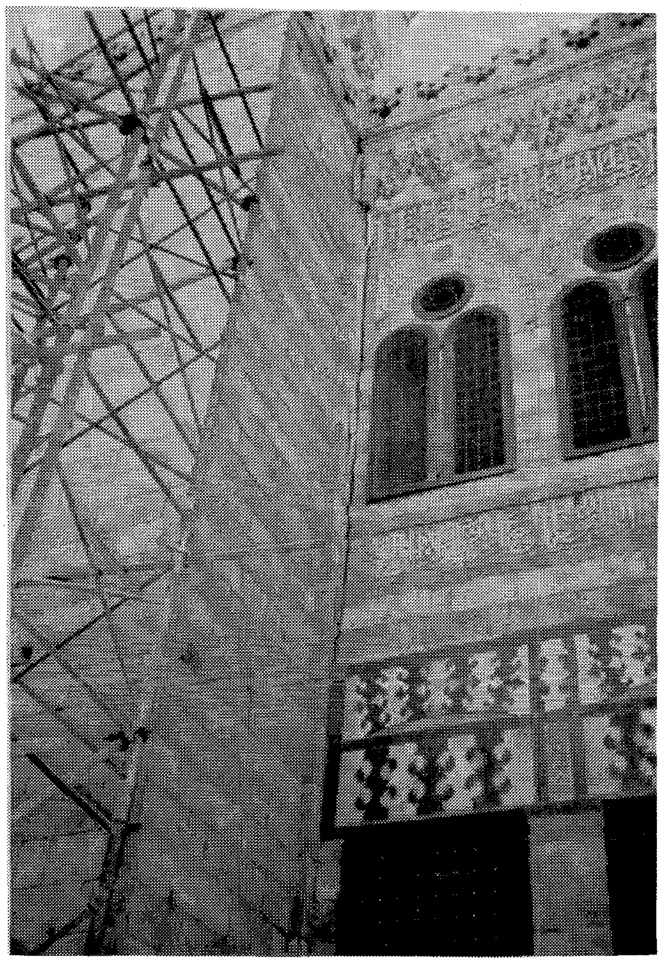

FIGURE 1–38 Close-up of Figure 1–37.

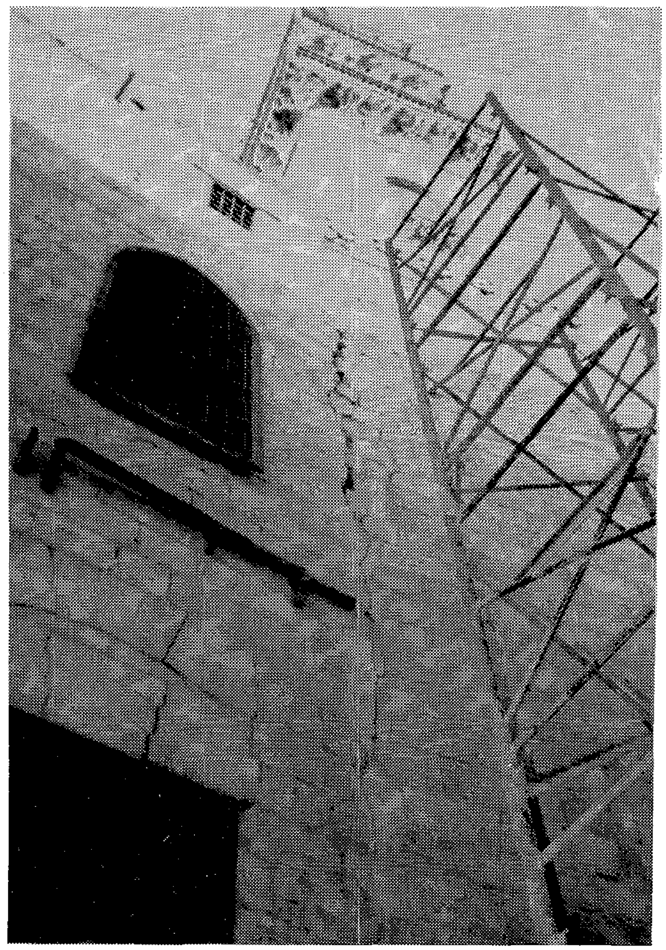

FIGURE 1–39 Crack between minaret and Mosque (El-Ghuri Mosque); cracks aggravated by earthquake.

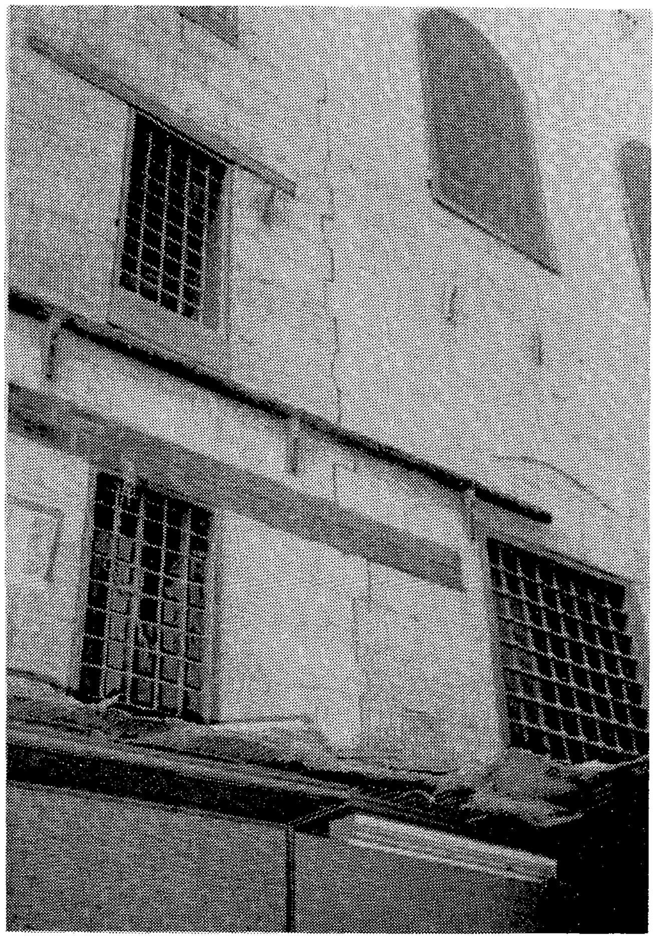

FIGURE 1–40 Sultan El-Ghuri Mosque: Crack in mortar cemented stone wall (cracks aggravated by earthquake).

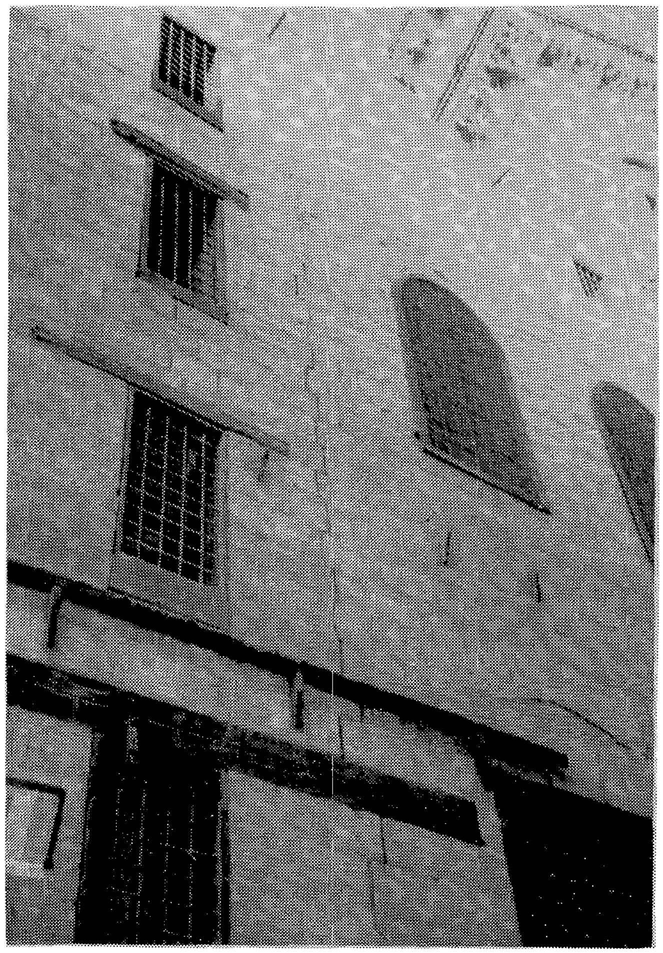

FIGURE 1–41 Sultan El-Ghuri Mosque: Crack in mortar cemented stone wall (cracks aggravated by earthquake).

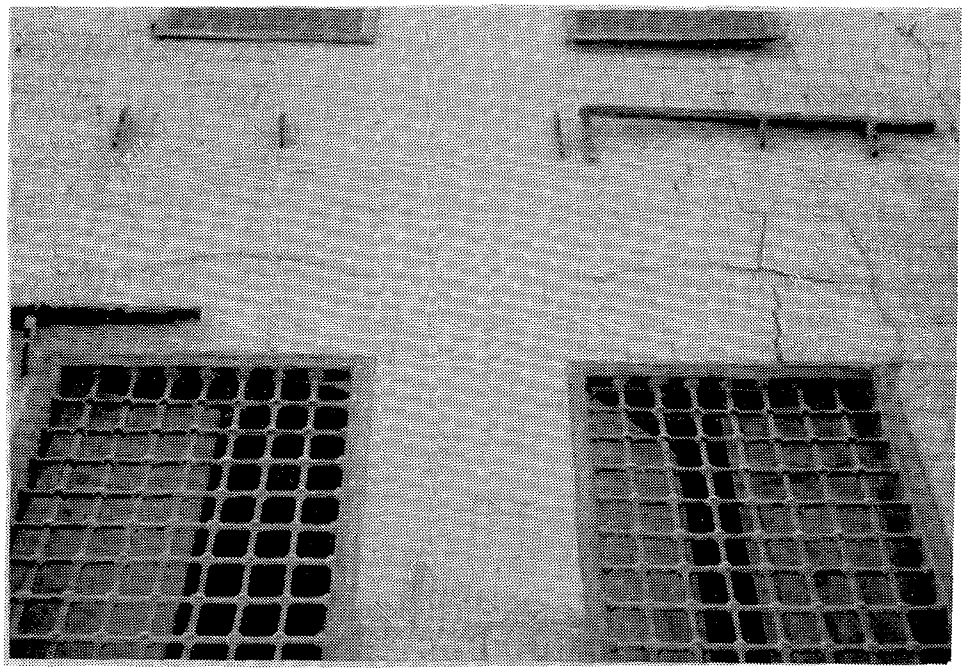

FIGURE 1–42 Sultan El-Ghuri Mosque: Cracks in mortar at keystone above window.

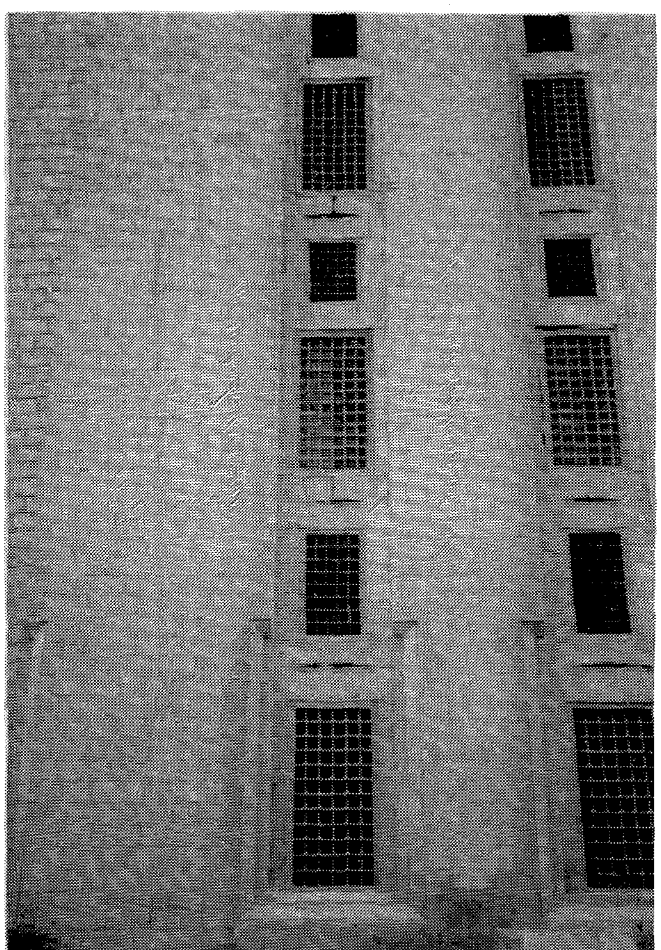

FIGURE 1–43 Cracks in mortar at keystone above windows (with stone dislocations); Sultan Hassan Mosque, Alazhar district, close to Sultan El-Ghuri Mosque.

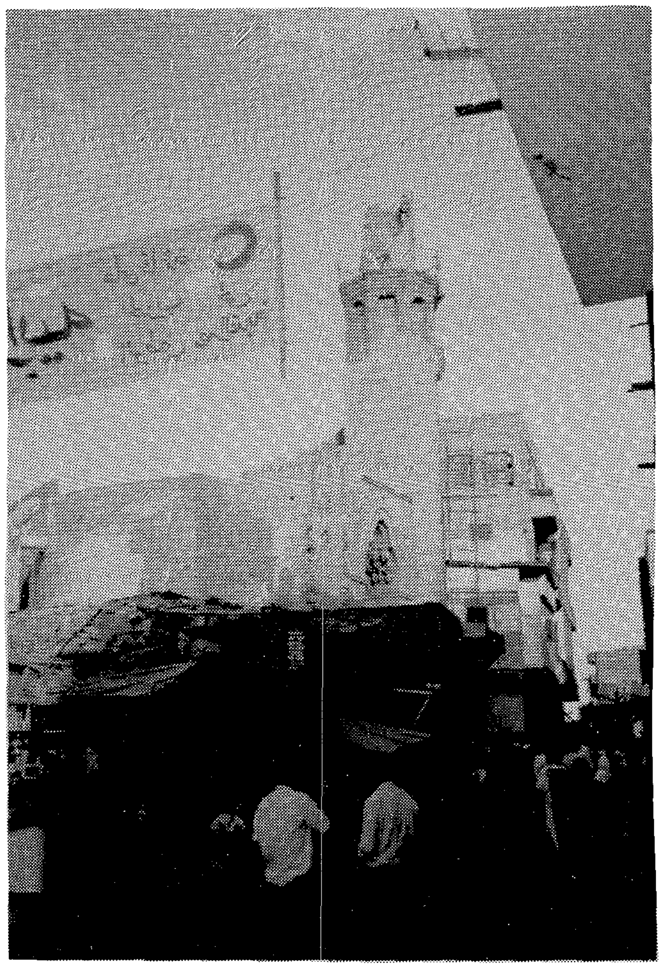

FIGURE 1–44 Partially collapsed masonry minaret top (Port-Said Street, Sayyeda Zenab district).

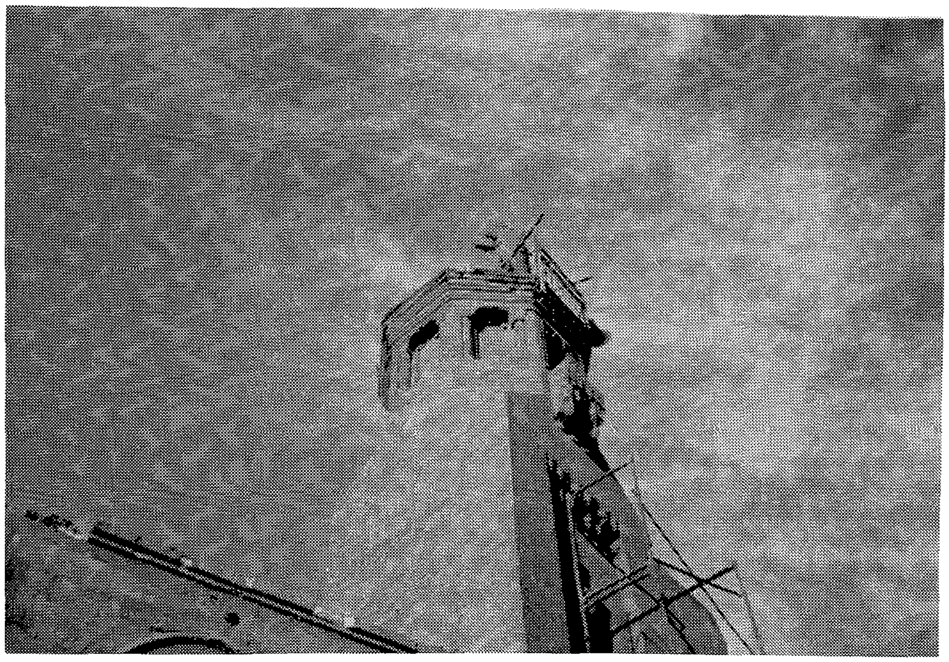

FIGURE 1–45 Close-up of Figure 1–44.

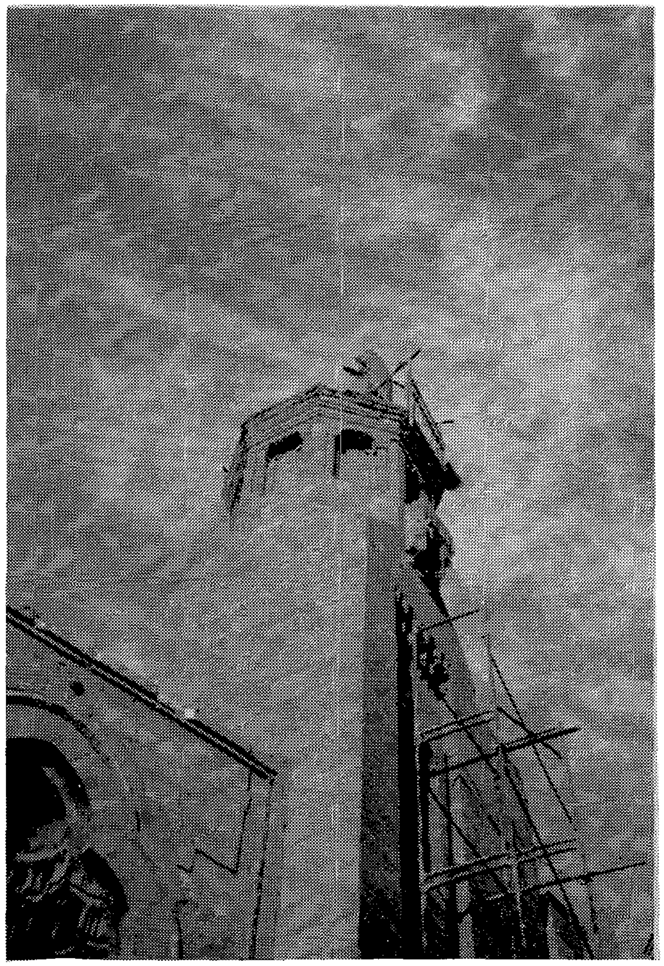

FIGURE 1–46 Close-up of Figure 1–44.

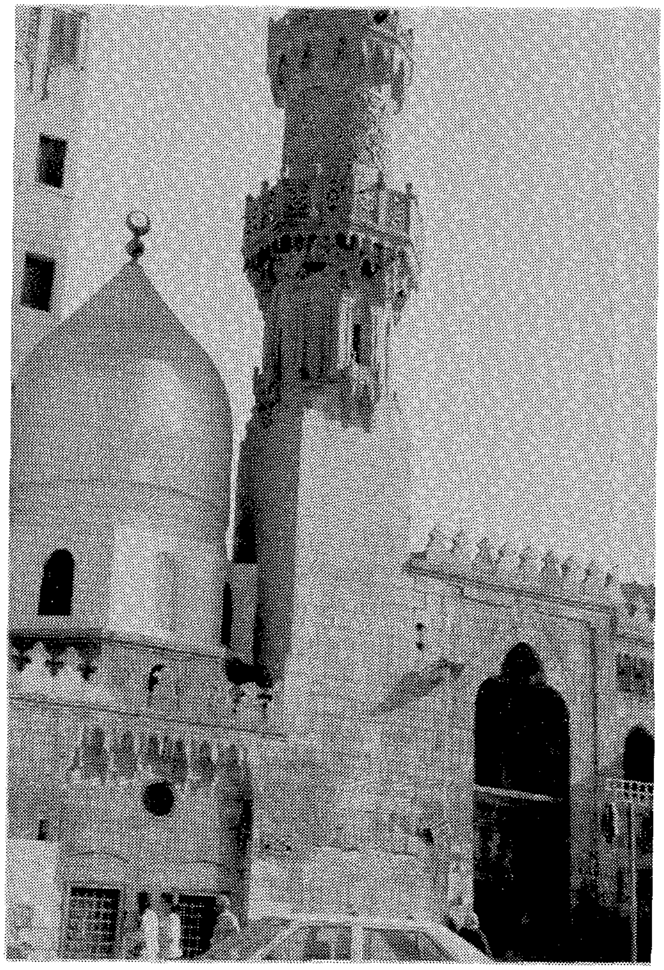

FIGURE 1–47 Slightly tilted minaret (tilting increased due to earthquake).

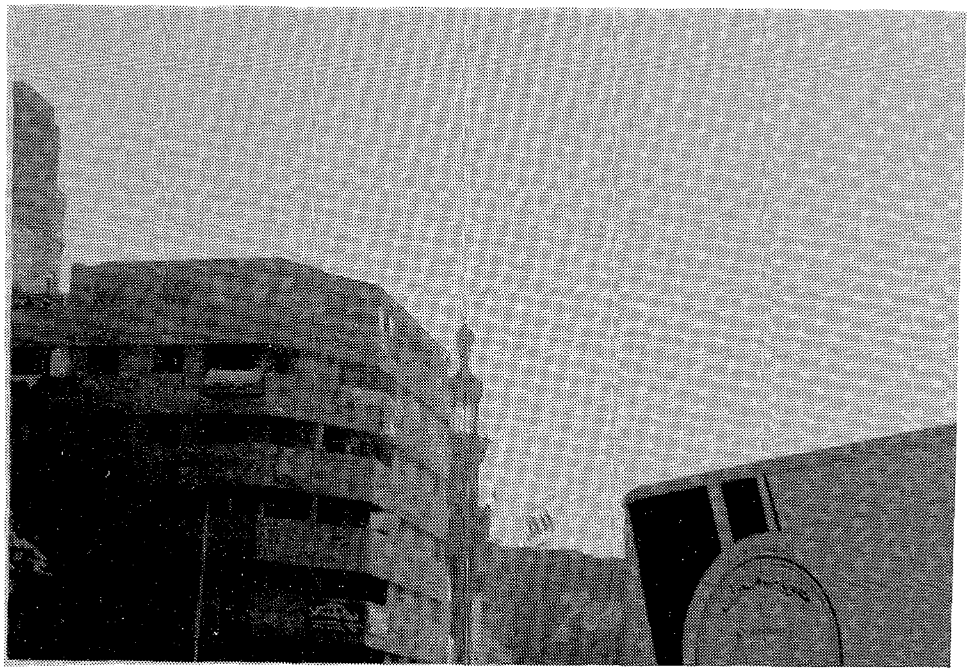

FIGURE 1–48 Tilted minaret of Figure 1–47 shown relative to adjacent building.

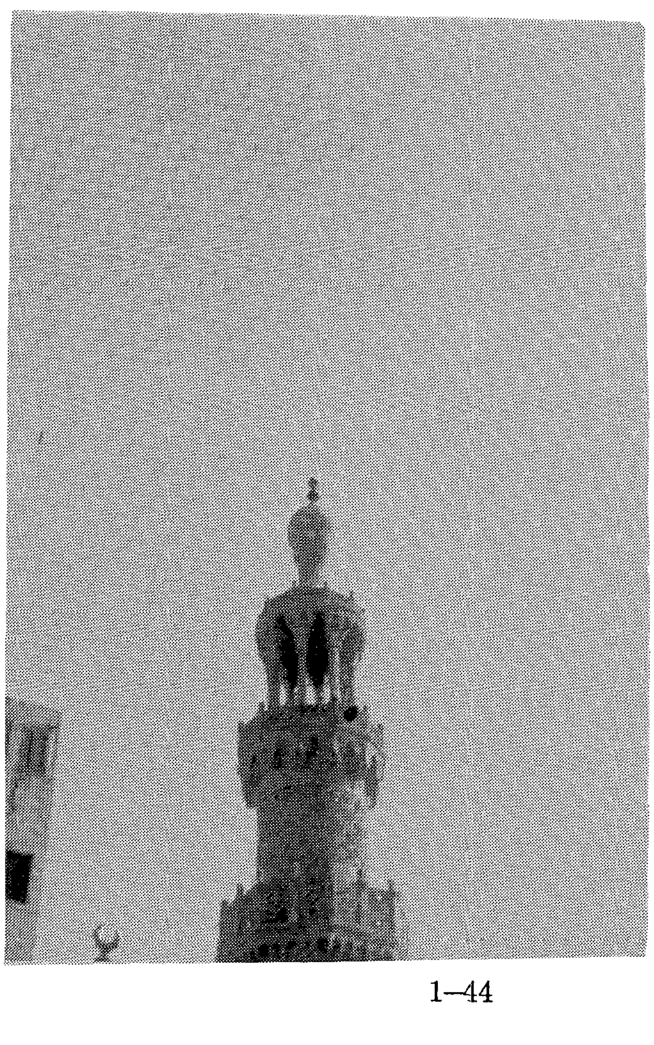

FIGURE 1–49 Close-up of Figure 1

FIGURE 1–50 Poorly cemented collapsed structure of adobe and stone fragments.

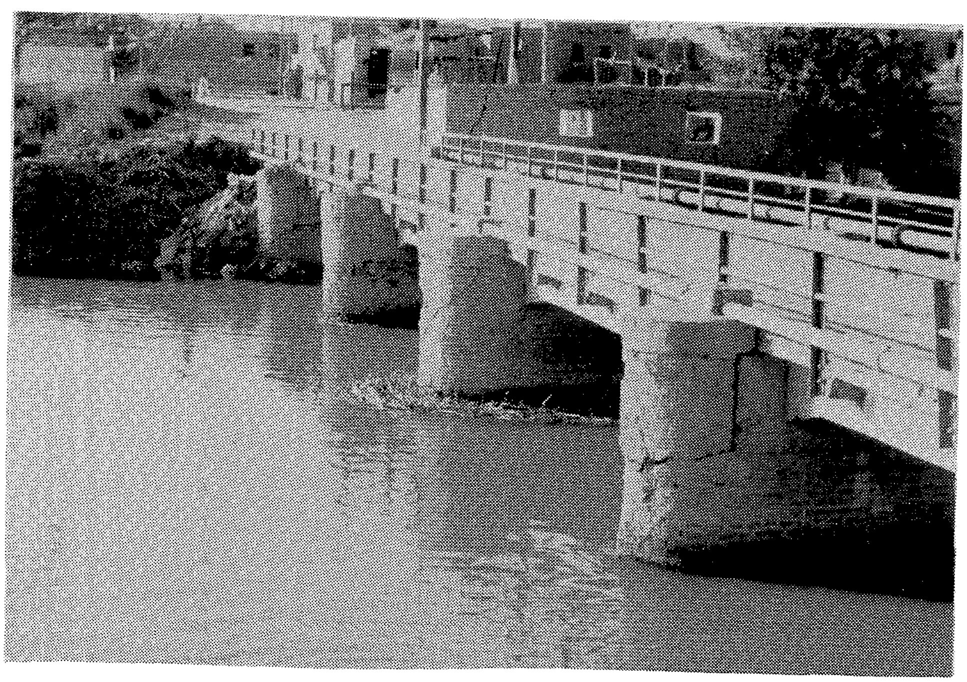

FIGURE 1–51 Cracks in masonry piers of bridge due to lateral siesmic loads.

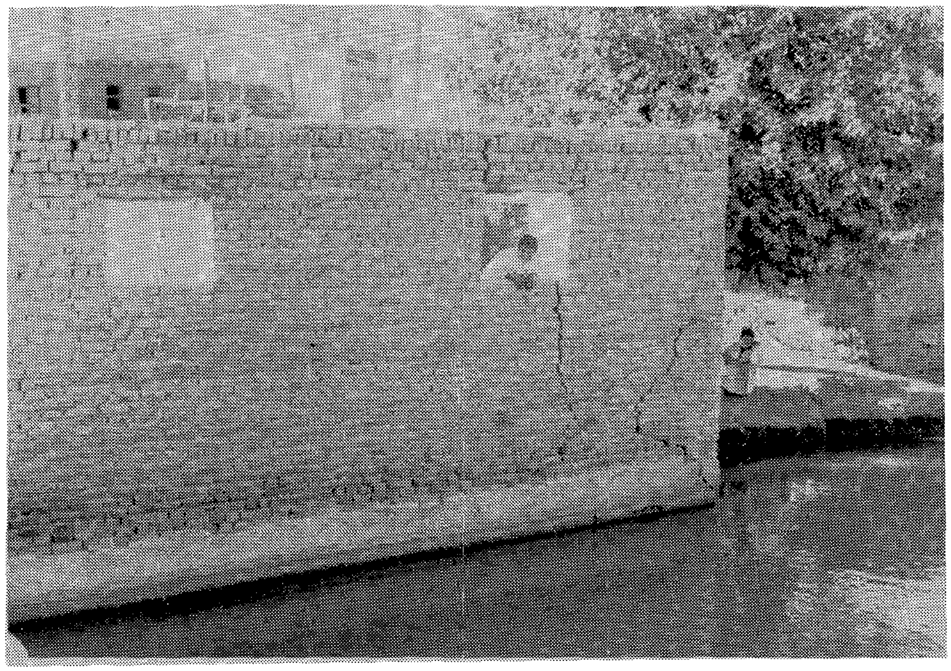

FIGURE 1–52 Shear cracking in masonry wall.

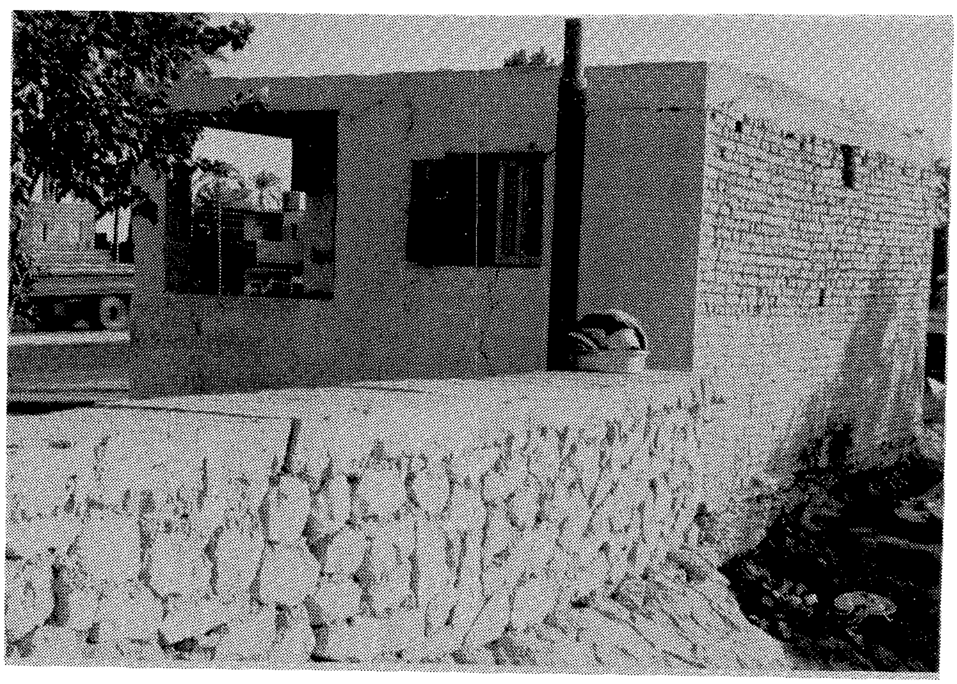

FIGURE 1–53 Crack around windows and along masonry-concrete interface.

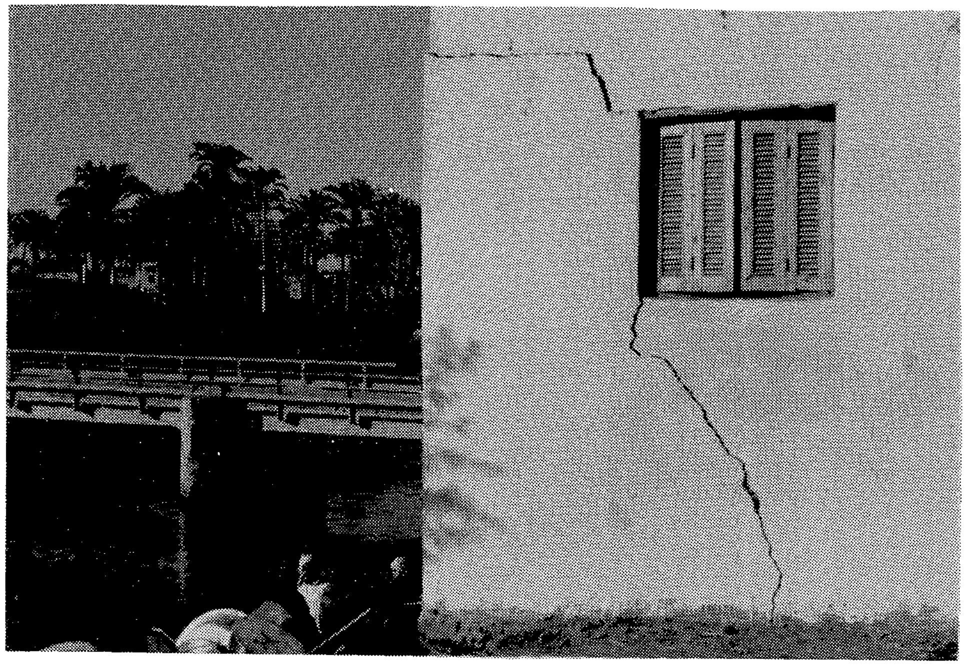

FIGURE 1–54 Crack around windows and along masonry-concrete interface.

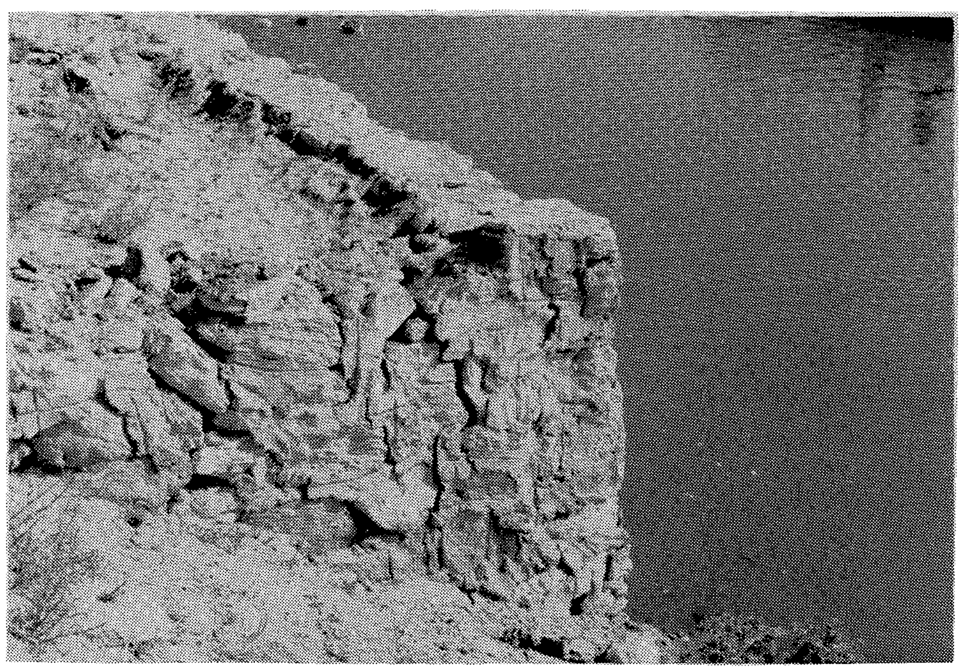

FIGURE 1–55 Cemented stone retaining wall with cracks in backfill and wall-soil interface.

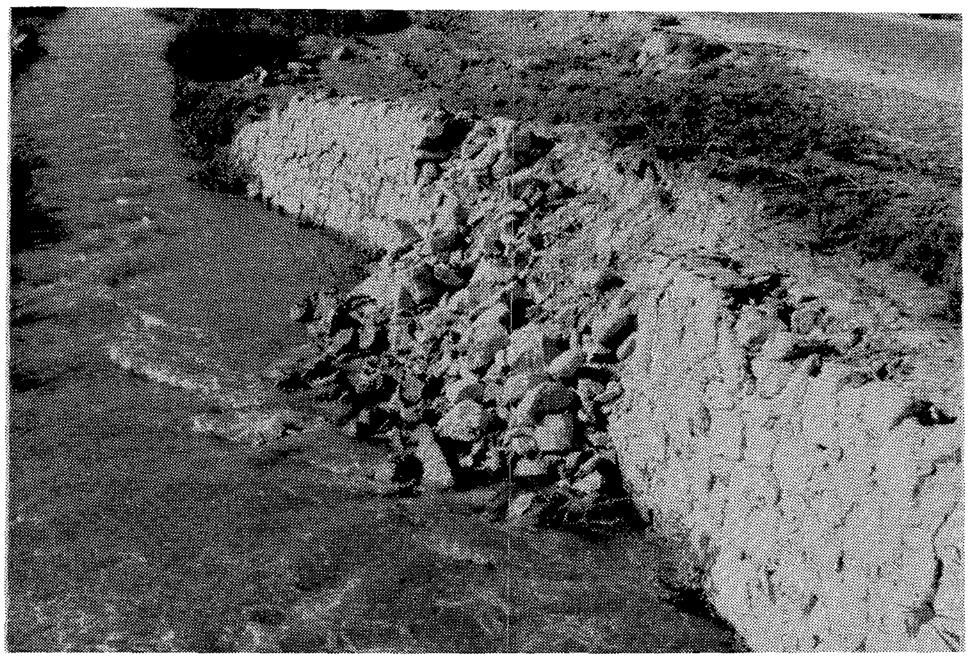

FIGURE 1–56 Partially collapsed cemented stone wall and backfill.

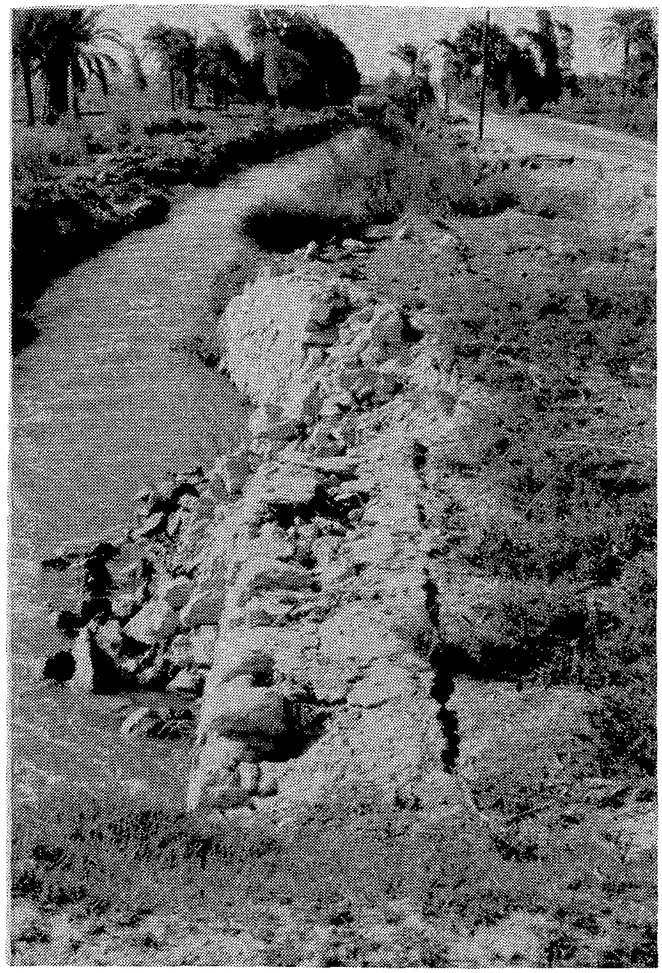

FIGURE 1–57 Close-up of Figure 1–56.

SECTION 2
LIQUEFACTION AND SAND BOILS

2.1 Mechanism of Sand Boils

One of the most commonly observed manifestations of soil liquefaction is the occurrence of sand boils along the ground surface (NRC, 1985). In the United States, significant sand boils have been observed during the earthquakes of Charleston 1886 (Clough and Martin, 1990), San Francisco 1906 (Lawson, 1908; Youd and Hoose, 1976), Alaska 1964 (Seed, 1970), Imperial Valley 1979 (Muir and Scott, 1982), and Loma Prieta 1989 (Bennett, 1990; Seed, et al., 1990; Bardet and Kapuskar, 1993), among others. These volcano–like features indicate that the earthquake shaking has generated high excess pore water pressures within the soil deposit (liquefaction), causing upward flow of water laden with soil sediments. Such flow, which is apt to concentrate in channels of relatively higher permeability (due to soil inhomogeneity), eventually erupts to the surface in the form of a sand boil (Elgamal, et al. 1990). The outflowing water typically carries sediments from the liquefied and overlying layers.

Housner (1958) discussed the formation of sand boils in terms of soil porosity, permeability, elasticity, and degree of consolidation. Sand boils were attributed to inhomogeneities in permeability near the ground surface. Scott and Zuckerman (1972) presented both experimental and analytical studies on the mechanics of liquefaction and sand boil formation in sandy soil deposits. They found that the presence of silt or a similar fine grained layer at the surface (above the liquefied layer) was conducive to the generation of sand boils. In contrast to "piping," sand boils were observed to propagate from the source of pressure to the outlet by a mechanism of cavity formation. Adalier (1992) also demonstrated that stratified soil profiles are conducive to sand boil formation. It was shown that low permeability and cohesion of an overlying upper layer may lead to the formation of large sand boils, as the extruded water mainly travels through cracks and weak zones within this upper layer.

2.2 Liquefaction Near Earthquake Epicenter

Two sites about 2.0 km apart (in the MMI zone VIII of figure 1-3) displayed significant sand boil activity as described below. Both sites are located on the West side of the Nile River, near the village of Manshiyat–Fadil (figure 1-3). This locality is seen to essentially coincide with the intersection of the activated fault plane with the Nile River (figure 1-2). Thus, liquefaction may have been triggered by the strongest near–epicenter shaking, as similar soils may be expected to exist along the Nile Valley throughout this area (figure 1-3).

1. Site I: Upper Egypt (Giza–Assyut) Road West of the Nile

One of the two main roads that connect Cairo and Giza to the South of Egypt (Upper Egypt) was found to have settled (at El–Atff, near the Village of El–Beleda) by as much as 1.75 m shortly after the earthquake (figure 2-1). The road is composed of 2 traffic lanes in each direction with an intermediate median and is about 25 m in width (figure 2-2). At the location of observed settlement (about 1.0 km away from the Nile), the road is bordered on one side by an irrigation canal; and on the other by a drain and agricultural land (figure 2-2). After the earthquake, the road was promptly repaired by: i) building a new sub–base of crushed stone to bring the road to its original elevation, ii) restoring the shoulders and slopes on both sides of the road, and iii) placing a new asphalt pavement (figure 2-1).

It is believed that soil liquefaction below the road was the primary reason behind the observed 1.75 m settlement. This settlement was gradual over a distance of about 200 m, and essentially uniform along the entire 25 m road width. Liquefaction effects were evident in the agricultural field adjacent to the road (figure 2-2). In this field, water laden with sediment erupted through fissures and spread along the ridged (due to prior plowing) agricultural ground surface (figures 2-3 and 2-4). The fissures appeared at a distance of about 20 m away from the road, adjacent to the zone of settlement (figure 2-2).

No clear signs of lateral spreading were observed, however. Settlement was essentially vertical and was probably driven by the relatively higher elevation of the road with respect to the surrounding terrain (figure 2-2); thus constituting a localized overburden vertical stress. No sediments were observed to have flowed into the adjacent canal or drain (some sediment migration might have occurred below the water level).

A soil profile and SPT-values from a boring near the road, taken after the earthquake is shown in figure 2-5a. In figures 2-5b and 2-5c, CPT values at a nearby location along with corresponding SPT values (Das, 1990) are shown. The SPT and CPT results denote that liquefaction could have occurred anywhere within the zone bounded by elevations -3.0 m to -9.0 m. In this zone, significant stratification is evident, and low SPT silts and sands appear to be prone to liquefaction. Indeed, the soil ejected to ground surface during liquefaction was thought to be mostly constituted of fine silty sand. A more thorough program of site investigation and laboratory dynamic testing is needed in order to clarify the involved liquefaction mechanisms at this site.

2. Site II. Bedsa Village

The Village of Bedsa, about 2 km away from the road settlement zone consisted mostly of 1– and 2–story adobe buildings that were severely damaged during seismic excitation. In a nearby agricultural field (away from Site I), large sand–boil craters occurred at the locations shown schematically in figure 2-6 (2.5 km away from the Nile, and 1.0 km West of El–Beleda Village). These craters are shown in figures 2-7 through 2-12.

Sand–boil activity was reported to have initiated immediately after the earthquake. Ejection of sediment was thought to have continued for about 45 minutes after the primary shaking event. Initially, the ejected sediment was claimed to have reached a height of 2 m or more above ground surface. No indications of lateral spreading were observed at this site of fairly flat terrain.

The ejected soil was found to spread evenly by runoff, and cover a large area of ground surface around each crater. About 20,000 m^2 of surface area were covered with ejected soil to a thickness of approximately 0.1 m (2,000 m^3 of soil were ejected). A preliminary grain size analysis of the ejected sediments is shown in figure 2-13. As may be noted, about 65% is fine sand, with a 30% content of even finer silt– and clay–size particles (mostly silt as noted by visual inspection). These fine particles appear to have remained in suspension after ejection, and were thus spread along the ground surface by the observed runoff process. The estimated 45 minute duration of sand–boil activity might have been influenced by the presence of this significant fine–particle content. Such fine particles were shown to reduce permeability and greatly prolong the post–liquefaction soil–resolidification phase (Adalier, 1992).

The ejected soil was distinctly gray in color (original ground–surface soil was brown). Careful visual inspection revealed the presence of shiny particles (roughly 5%), that were thought to denote the possible presence of micaceous materials that may have influenced the observed liquefaction (Idriss, 1992). A sample of the ejected soil is currently being chemically analyzed in order to identify its constituent minerals.

Figure 2-14a depicts the soil profile and SPT blow counts obtained from a boring at Bedsa. CPT data and corresponding SPT data (Das, 1990) at a nearby location are shown in figures 2-14b and 2-14c. Underlying a low permeability silty–clay stratum, low SPT blow counts are seen to prevail in the upper 7 m of liquefiable sandy and silty soil materials (elev. -8 m to -15 m). The gray color of these materials is similar to that of the sediments ejected to ground–surface during the sand–boil process. Soil samples from this site are needed in order to further analyze the involved pore-pressure and post-liquefaction mechanisms.

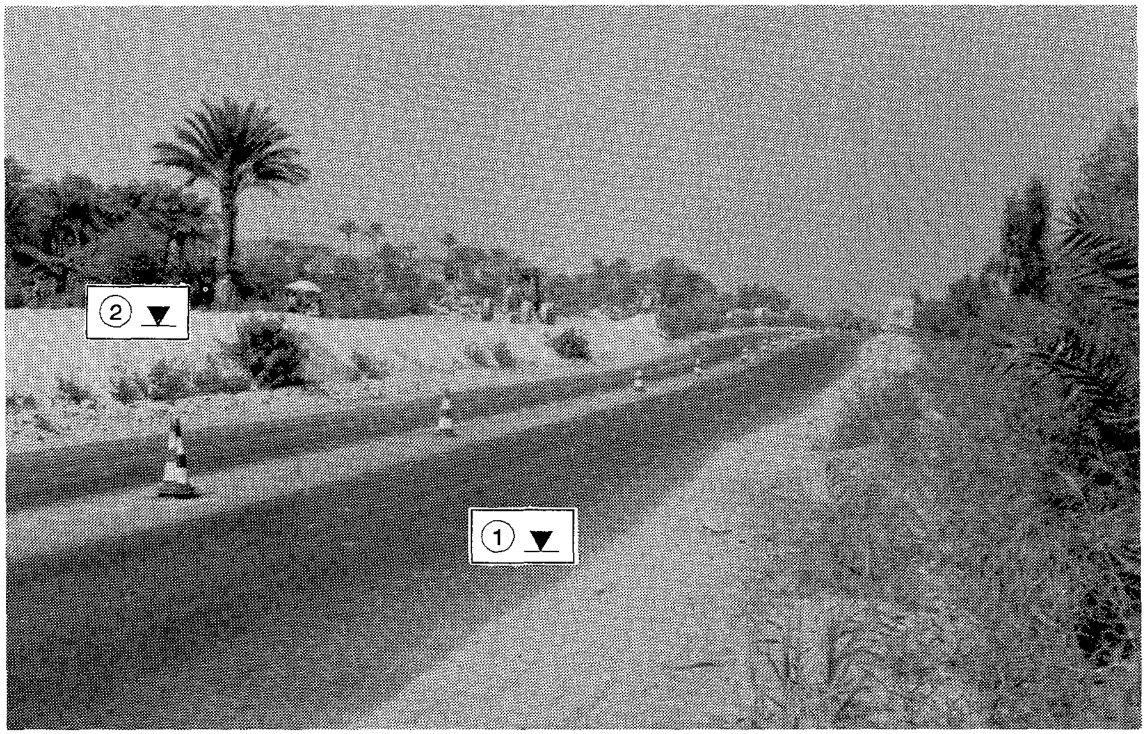

FIGURE 2–1 Liquefaction induced settlement at Upper Egypt Road West of the Nile: 1) road elevation after earthquake (2 right lanes); 2) original road elevation being restored during repair (2 left lanes).

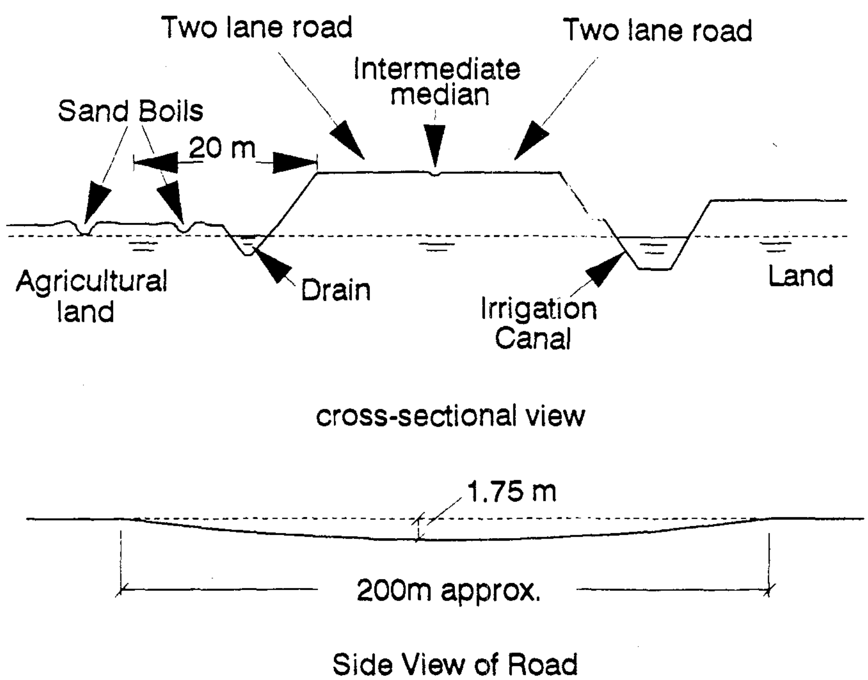

FIGURE 2–2 Cross-sectional view of Upper Egypt Road site; and side-view after earthquake.

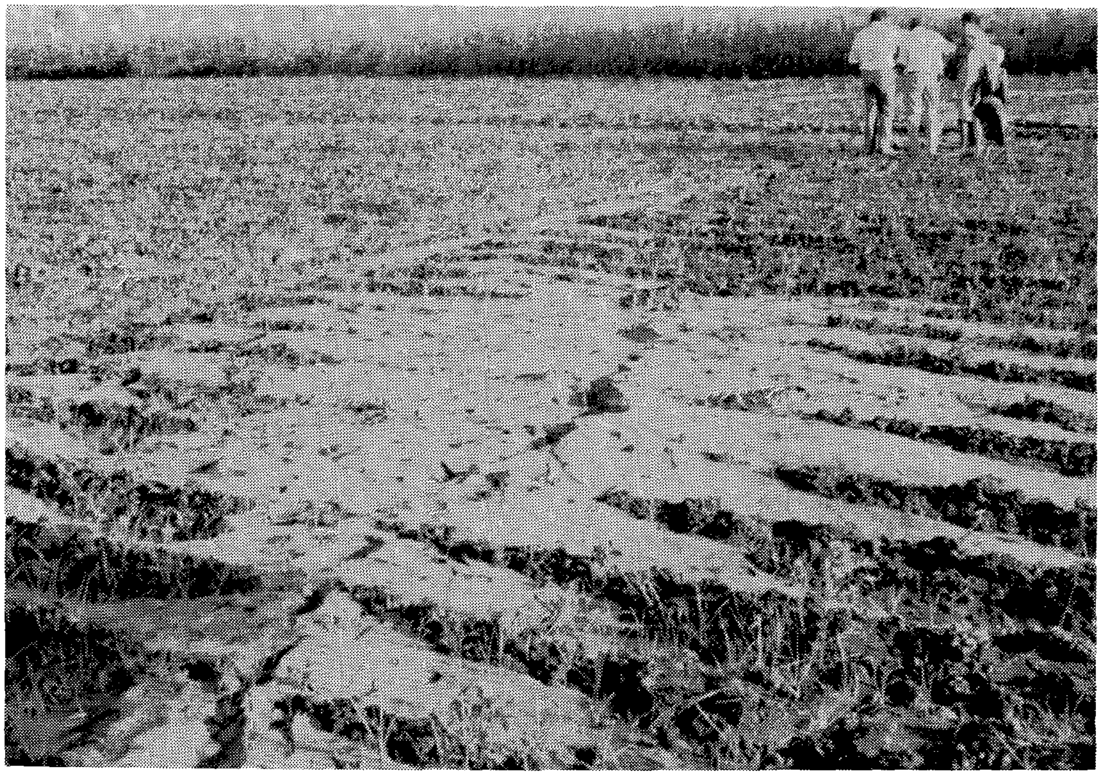

FIGURE 2–3 Ground fissure and sediment eruption.

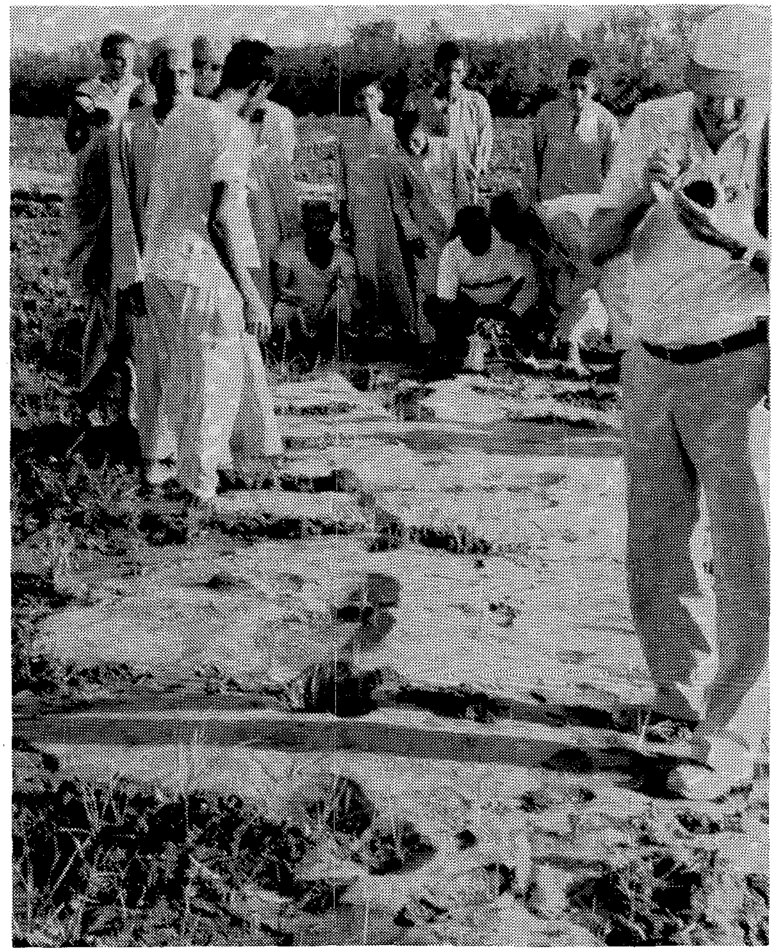

FIGURE 2–4 Close-up of sediment eruption shown in Figure 2–3.

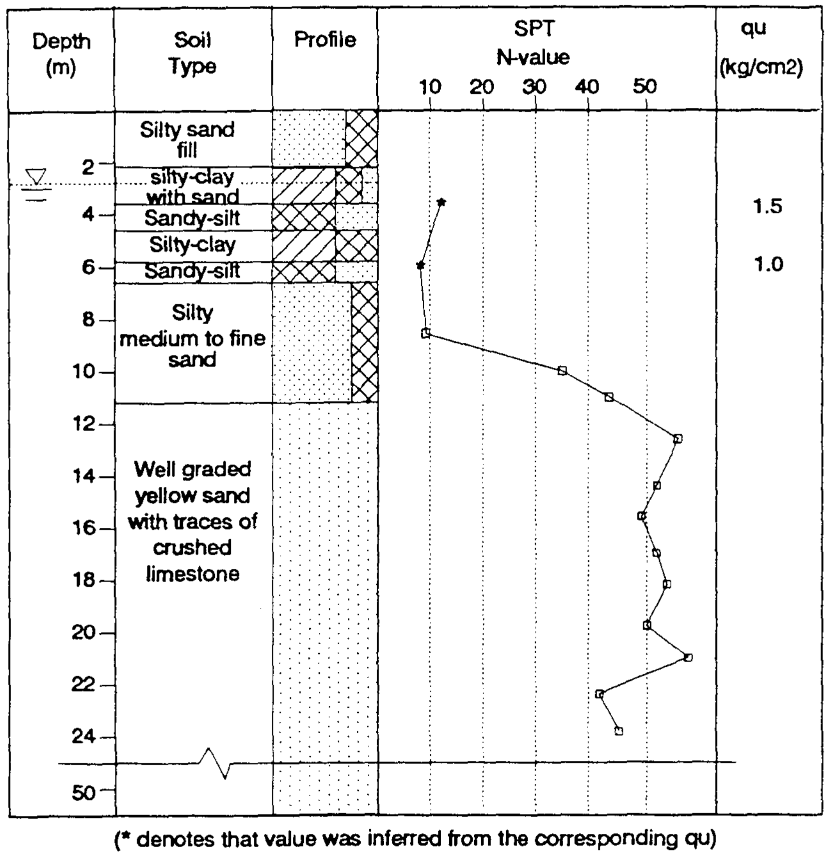

FIGURE 2–5a Soil profile near the road settlement area.

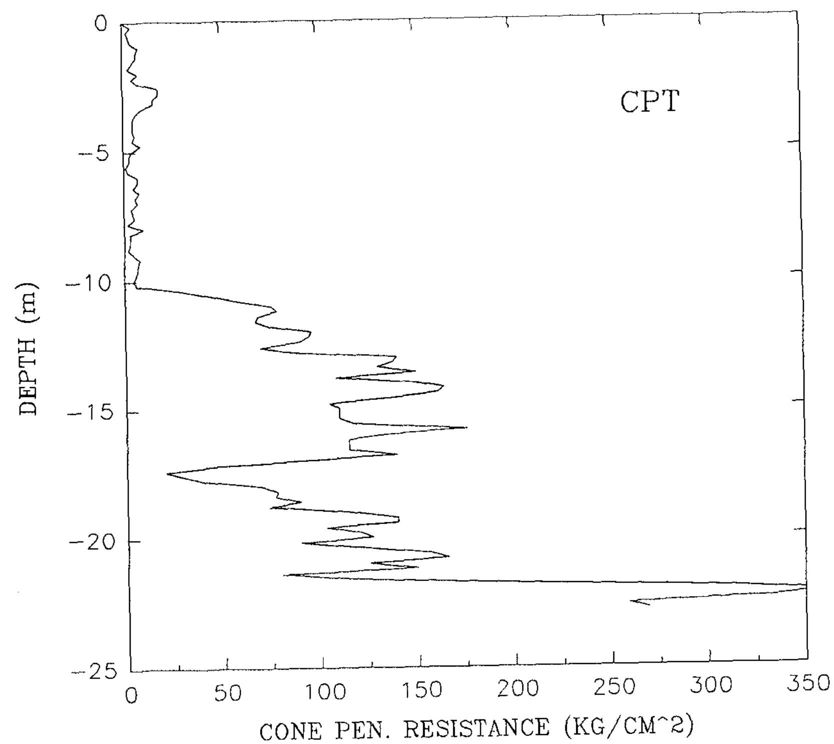

FIGURE 2–5b CPT values measured near road settlement area (location near boring of Figure 2–5a).

CORN FIELD

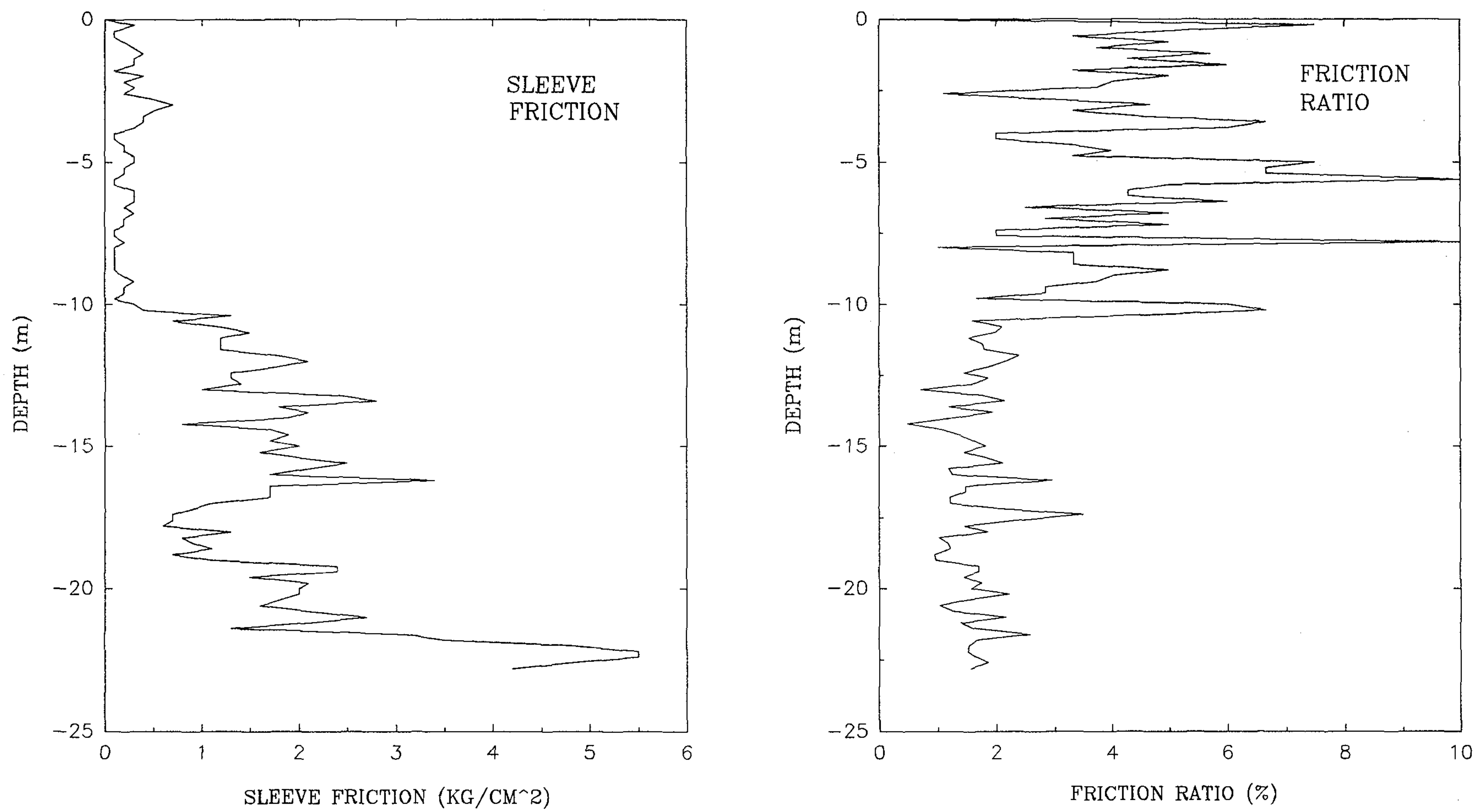

FIGURE 2–5b Continued.

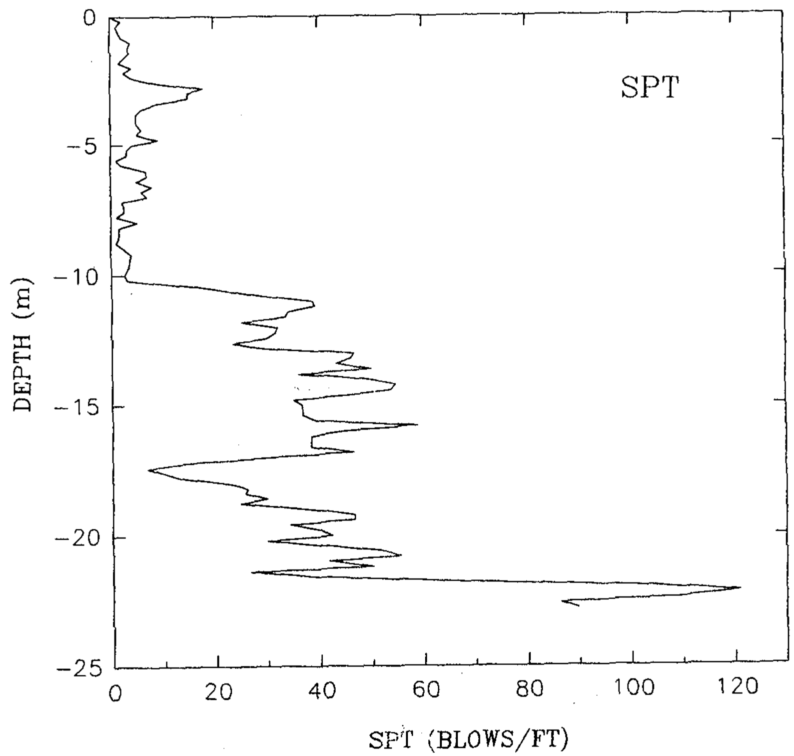

FIGURE 2–5c SPT values calculated from measured CPT values (Figure 2–5b) for road settlement area.

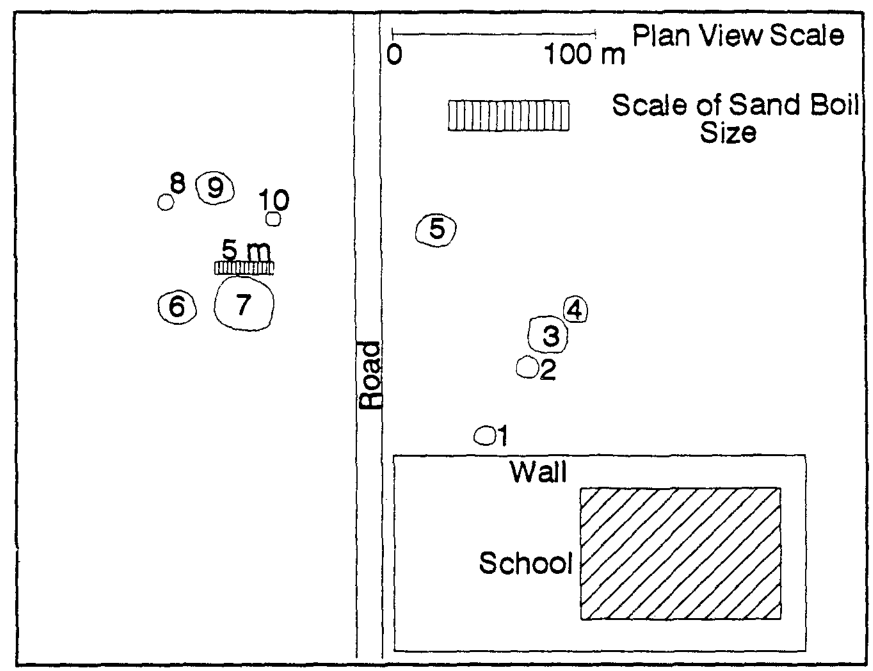

FIGURE 2–6 Schematic of sand boil locations at Bedsa Village.

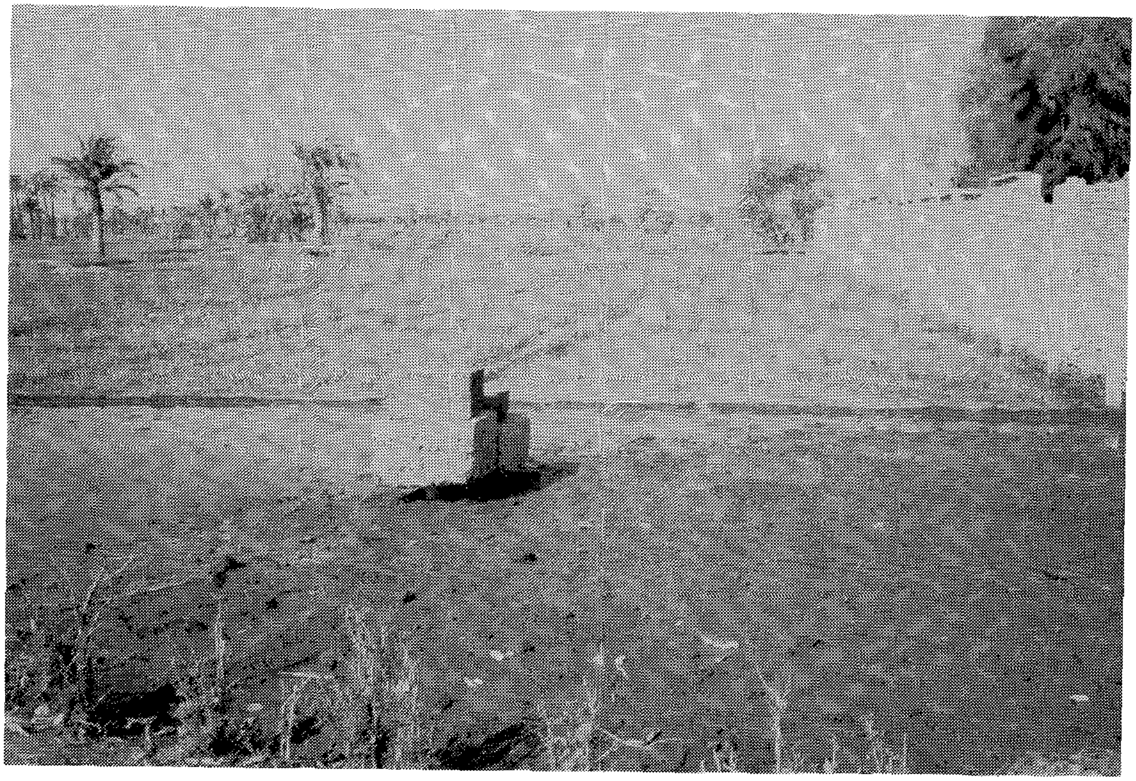

FIGURE 2–7a An abandoned steel pipe covered with a concrete block moved upwards relative to the surrounding soil.

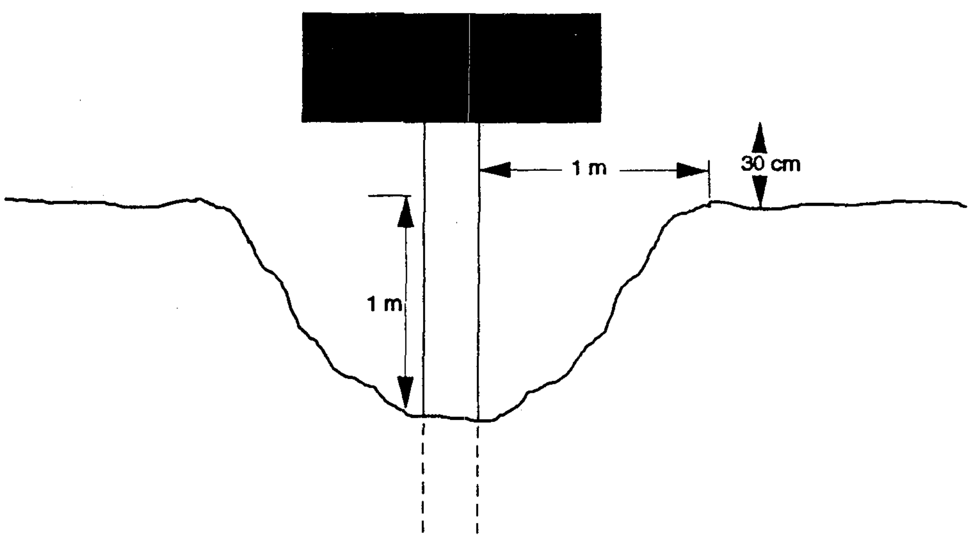

FIGURE 2–7b Schematic of sand boil formed around steel pipe (Figure 2–7a) after earthquake (observed on videotape). Crater No. 1 of Figure 2–6.

FIGURE 2–8 Craters Nos. 2, 3, and 4 of Figure 2–6.

FIGURE 2–9 Crater No. 5 of Figure 2–6.

FIGURE 2–10 Craters Nos. 6, 7, 8, 9, and 10 of Figure 2–6.

FIGURE 2–11 Close-up of Crater No. 7 of Figure 2–6.

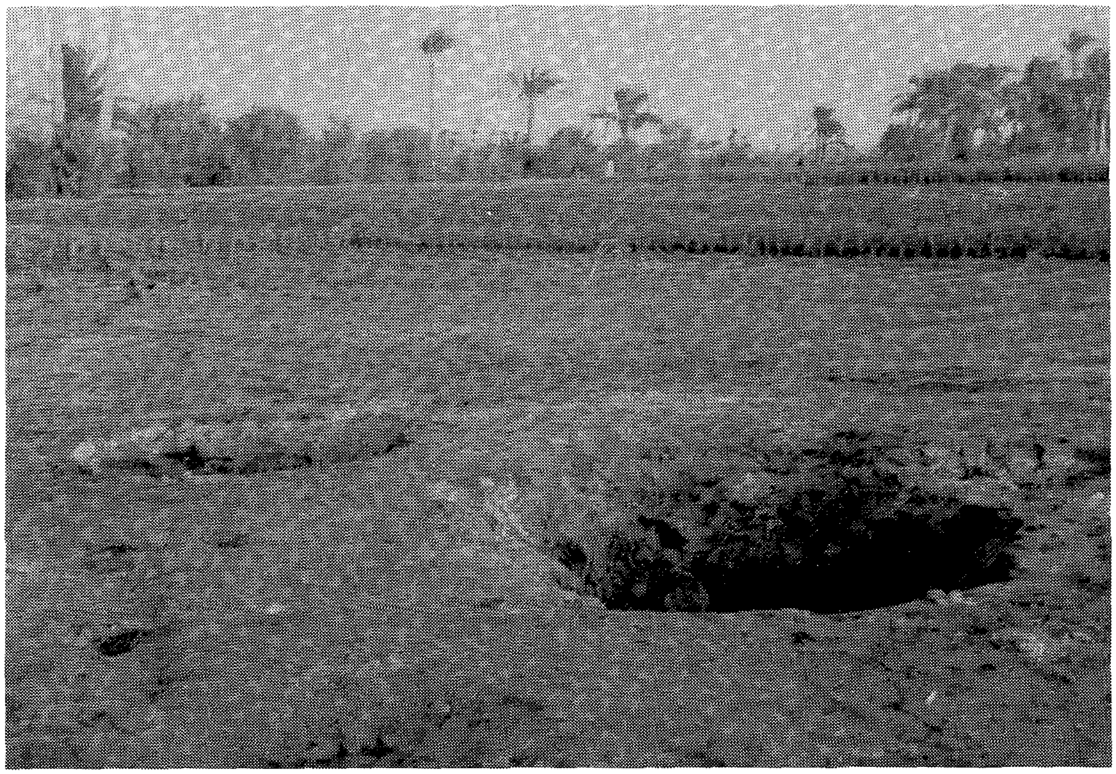

FIGURE 2–12 Close-up of Crater Nos. 8 and 9 of Figure 2–6.

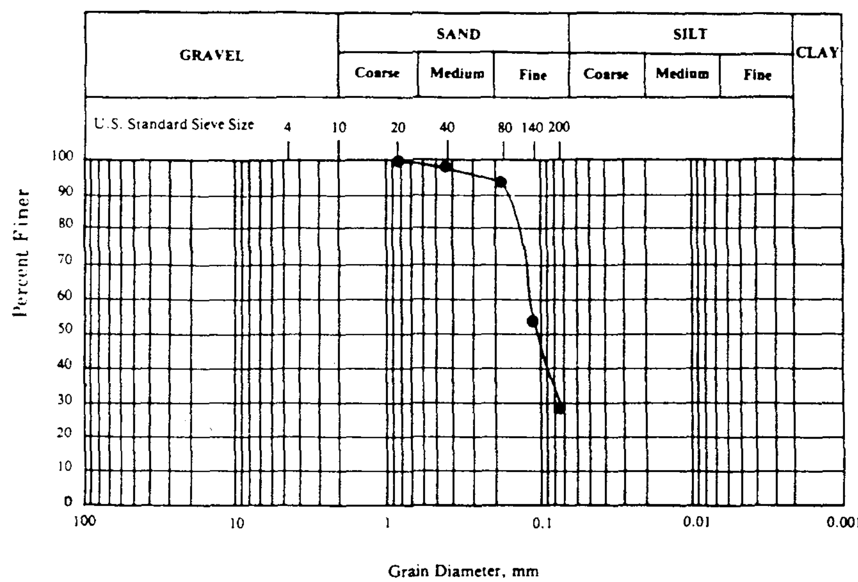

FIGURE 2–13 Preliminary grain size distribution of ejected material.

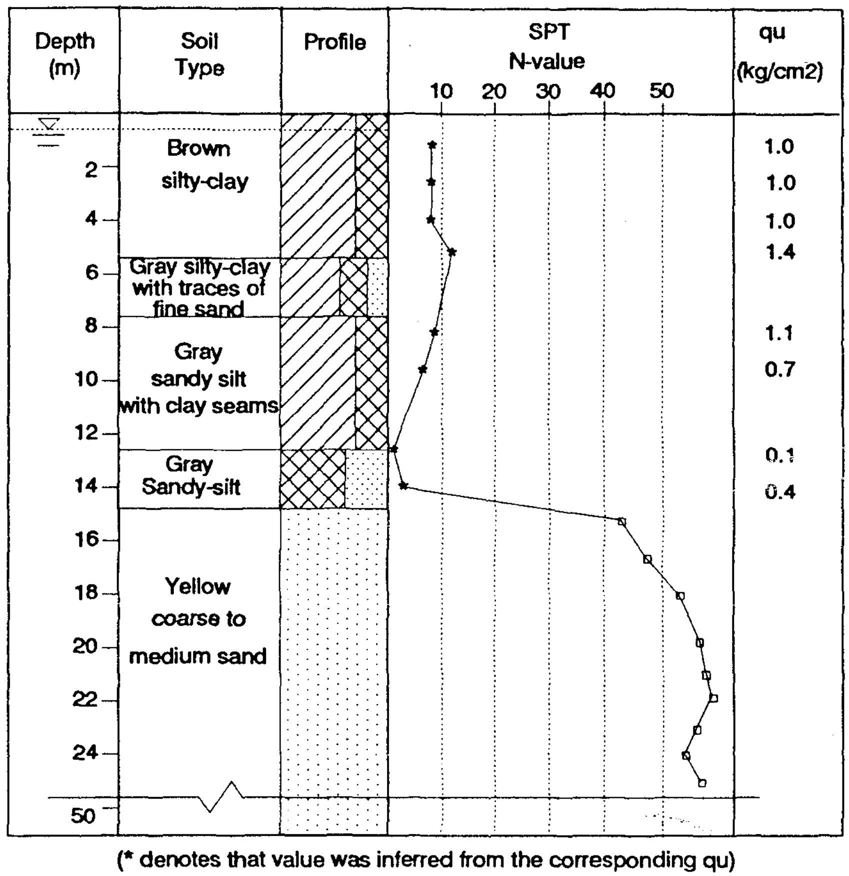

FIGURE 2–14a Soil profile near sand boils at Bedsa.

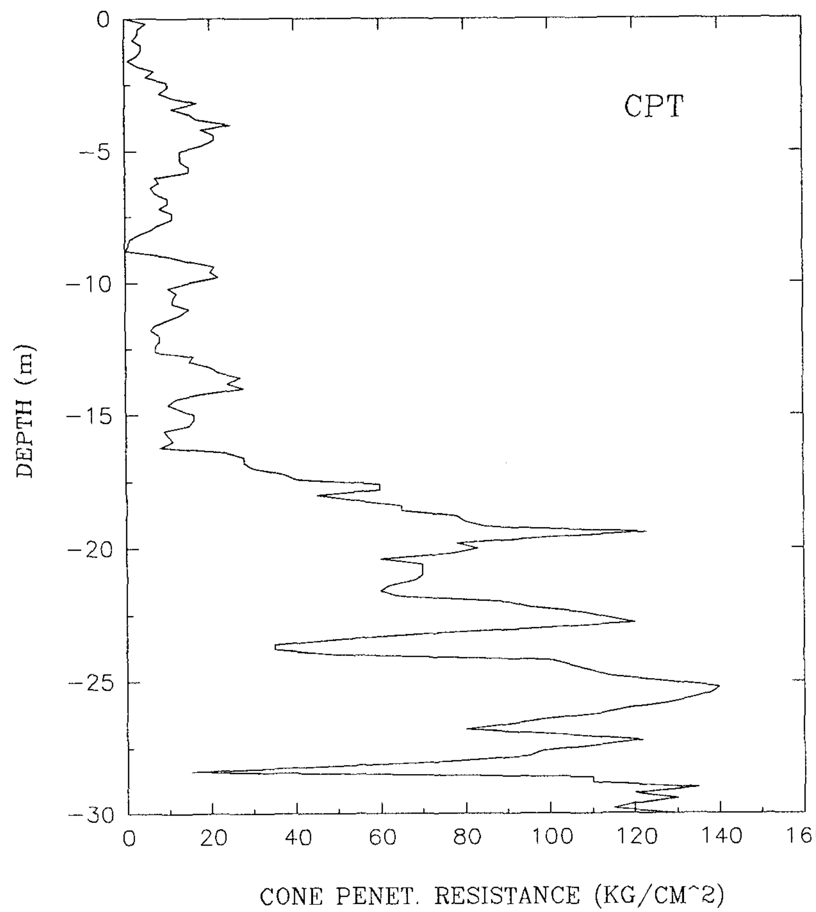

FIGURE 2–14b CPT values measured near sand boils at Bedsa (location near boring of Figure 2–14a).

SCHOOL

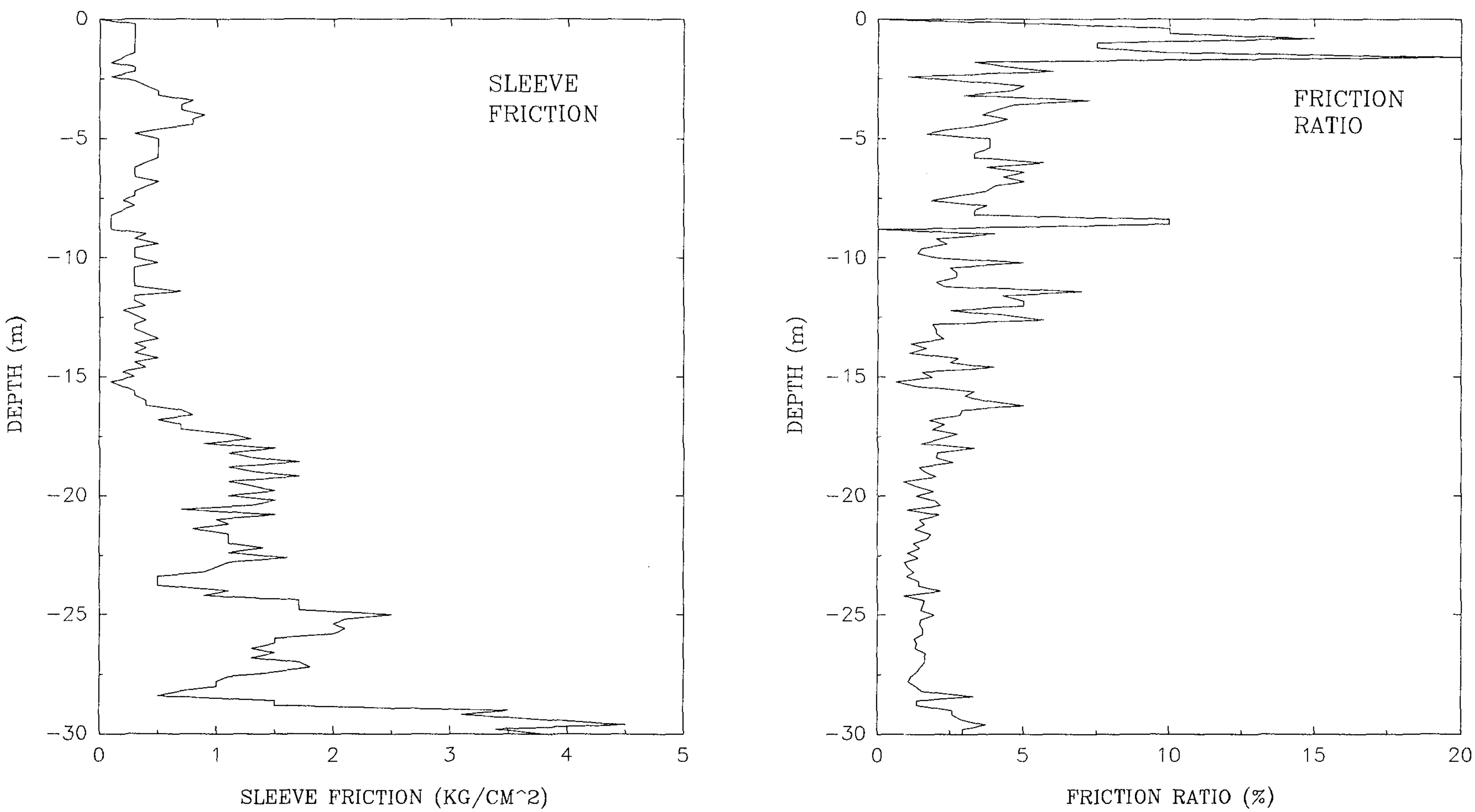

FIGURE 2–14b Continued.

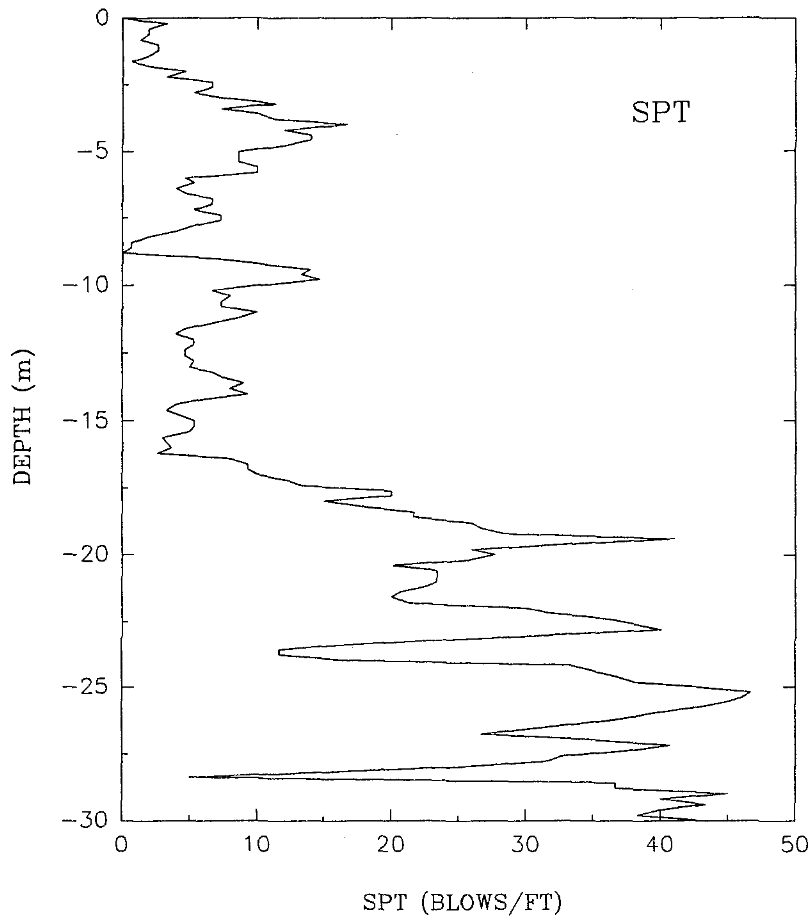

FIGURE 2–14c SPT values calculated from measured CPT values (Figure 2–14b) for the area near sand boils at Bedsa.

SECTION 3
SUMMARY AND CONCLUSIONS

Moderate levels of damage were observed to occur in the cities of Cairo and El-Faiyum, and in many villages in the epicentral area. Most of the collapsed structures were old adobe/stone structures with poor mortar materials. The earthquake resulted in soil liquefaction and significant sand–boil activity in its maximum MMI zone VIII. A main road was found to have settled by as much as 1.75 m due to this liquefaction. In addition, large sand–boil craters occurred in an agricultural field at the Village of Bedsa.

The soil profile characteristics at Bedsa might bear significant similarity to large areas along the densely populated Nile Valley and Delta. Consequently, this liquefaction case history is of particular importance, and might be representative of the seismic response of vast areas along the Nile Valley. A thorough analysis of this case history would establish a valuable benchmark for liquefaction susceptibility analyses of Nile sedimented soils throughout its valley.

SECTION 4
REFERENCES

Adalier, K. 1992. "Post–Liquefaction Behavior of Soil Systems," *M.S. Thesis*, Dept. of Civil Engineering, Rensselaer Polytechnic Institute, Troy, NY.

Ambraseys, N. N. 1991. "Seismicity of Egypt: The Earthquakes of 1811, 1847, and 1899," *Ch. 11, Neotectonics and Resources*, J. Cosgrove and M. Jones (eds.), Belhaven Press, NY.

Bardet, J. P., and M. Kapuskar 1993. "Liquefaction Sand Boils in San Francisco During 1989 Loma Prieta Earthquake," *ASCE, J. Geotechnical Engineering Div. 119(3)*, pp. 543–562, March.

Bennett, M. J. 1990. "Ground deformation and liquefaction of soil in the Marina District," *Effects of the Loma Prieta Earthquake on the Marina District*, San Francisco, CA, *U.S. Geological Survey Open–File Report 90–253*, Dept. of the Interior, USGS, Washington, DC.

Clough, G. W., and J. R. Martin, II 1990. "Geotechnical Setting for Liquefaction Events in the Charleston, South Carolina Vicinity," *H. Bolton Seed, Vol. 2: Memorial Symposium Proceedings*, May 1990, J. Michael Duncan (ed.), BiTech Publishers Ltd., Vancouver, BC, Canada, pp. 313–334.

Das, Braja M. 1990. "Principles of Foundation Engineering," PWS-Kent Pub. Company, Boston, MA.

Elgamal, A.–W., R. Dobry, and K. Adalier 1989. "Study of Effect of Clay Layers on Liquefaction of Sand Deposits Using Small–Scale Models," *Proceedings, 2nd U.S.–Japan Workshop on Liquefaction, Large Ground Deformations and Their Effects on Lifelines*, T. D. O'Rourke & M. Hamada (eds.), NCEER, SUNY–Buffalo, Buffalo, NY (held at Grand Island, NY & Cornell Univ., Ithaca, NY, Sept. 26–29, Tech. Report NCEER–89–0032), pp. 233–245.

Hadjian, A. H., et al. 1992. "Cairo Earthquake of October 12, 1992," *Bechtel Evaluation Team Report*, Intl. Bechtel Inc., Egypt, November.

Housner, G. 1958. "The Mechanism of Sand Blows," *Bull. Seismological Society of America, 58*, pp. 155–161.

Idriss, I. M. 1992. Personal communications at Bedsa Village, Egypt.

Japan International Cooperation Agency (JICA) 1992. "October 12, 1992 Cairo Earthquake–Preliminary Investigation and Recommendations," Preliminary Report, November.

Khater, M. 1992. "Reconnaissance Report on the Cairo, Egypt Earthquake of October 12, 1992," *Technical Rept. NCEER–92–0033*, SUNY–Buffalo, Buffalo, NY, December.

Kebeasy, R. M. 1990. "Seismicity of Egypt," Workshop on MedNet, the Broad–Band Seismic Network for the Mediterranean, Sept. 10–14.

Kebeasy, R. M., M. Maamoun, R. N. H. Albert, and M. Megahed (1981), "Earthquake Activity and Earthquake Risk Around Alexandria, Egypt," *Bull. IISEE*, Japan, 19, pp. 93–113.

Lawson, A. C., et al. 1908. "The California Earthquake of April 18, 1906," *Report, State Earthquake Investigation Commission*, Carnegie Institute of Washington, Washington, DC, pp. 404–405.

Muir, S. G., and R. F. Scott 1982. "Earthquake–Generated Sandblows Formed During the Main Shock," The Imperial Valley, California, Earthquake of October 15, 1979, *U.S. Geological Survey Professional Paper 1254*, U.S. Government Printing Office, Washington, DC, pp. 247–250.

NRC 1985. "Liquefaction of Soils During Earthquakes," Report by Committee on Earthquake Engineering, National Research Council, National Academy Press.

Scott, R. F., and K. A. Zuckerman 1972. "Sand Blows and Liquefaction," *Great Alaskan Earthquake of 1964 – Engineering Volume*, Committee on the Alaska Earthquake, Div. of Earth Sciences, National Research Council, National Academy of Sciences, Washington, DC, pp. 179–189.

Seed, H. B. 1970. "Soil Problems and Soil Behavior," *Earthquake Engineering*, R. L. Wiegel, Coordinating Editor, Prentice Hall, Englewood Cliffs, NJ, pp. 227–251.

Seed, R. B., et al. 1990. "Preliminary Report on the Principal Geotechnical Aspects of the October 17, 1989, Loma Prieta Earthquake," *Rept. No. UCB/EERC–90/05*, Earthquake Engineering Research Center, University of California, Berkeley, CA.

Sykora, D., D. Look, G. Croci, E. Karaesman, and E. Karaesman 1993. "Reconnaissance of Damage to Historic Monuments in Cairo, Egypt, following the October 12, 1992 Earthquake," Rept. to Natl. Science Foundation, WES, U.S. Army Corps of Engineers, Vicksburg, MS; NCEER Technical Report 93–0016, University at Buffalo, Buffalo, NY, October.

Thenhaus, P.C., R. V. Sharp, M. Celebi, A.–B. K. Ibrahim, and H. Van de Pol 1993. "Reconnaissance Report on the 12 October 1992 Dahshur, Egypt, Earthquake," *U.S. Geological Survey, Open–File Report 93–181*, Golden, CO.

Wight, J. 1992. "Earthquake Effects on Antiquities and Monuments," *EERI Newsletter*, Vol. 26, No. 12, December.

Wight, J. K., R. D. Hryciw, and A. E. Naaman 1992. "Field Investigation of Damage to Islamic Monuments Caused by the Egyptian Earthquake of October 12, 1992," *Rept. No. UMCEE 92-31*, Civil and Environmental Eng. Dept., University of Michigan, Ann Arbor, MI.

Youd, T. L., and S. N. Hoose 1976. "Liquefaction During the 1906 San Francisco Earthquake," *J. Geotech. Eng. Div., ASCE 112(5)*, pp. 425–439.

Youssef, N., S. Adham, M. Celebi, and J. Malilay 1992. "Cairo, Egypt, Earthquake of October 12, 1992," *EERI Newsletter*, Vol. 26, No. 12, December.

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