REPORT OF JAPAN DISASTER RELIEF TEAM
(EXPERT TEAM)
ON THE EARTHQUAKE
IN
ARAB REPUBLIC OF EGYPT
OF
OCTOBER12, 1992

MARCH, 1993

JAPAN INTERNATIONAL COOPERATION AGENCY
(JICA)

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PREFACE

On October 28, 1992, the Government of Japan decided to provide emergency disaster relief services, based on the request of the Government of Arab Republic of Egypt, for the earthquake damage which occurred on October 12, 1992 in Capital Cairo and its outskirts.

The Japan International Cooperation Agency, in response to the request of the Government, dispatched a Japan Disaster Relief Team (expert team), headed by Professor Tsuneo Okada, Institute of Industrial Science, University of Tokyo, to Egypt from October 29 to November 13. The expert team provided technical advice regarding emergency measures and restoration, and suggestions for prevention of future disasters. The team members have summarized their field activities in this report, prepared after their return to Japan.

I hope that this report will serve to assist the Arab Republic of Egypt in their plans for permanent disaster relief and restoration to be made in the future, and will contribute toward further development of friendly relations between the two countries.

At this opportunity I wish to express my deepest appreciation for all concerned who have expended a great cooperation and assistance in the disaster relief activities.

March, 1993

Sekai Nishino, Vice President
Japan International Cooperation Agency

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PREFACE

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1. Foreword

An earthquake with a magnitude of 5.4 and with an hypocentre 35km southwest of Cairo, the capital of Egypt, occurred at 15.09 local time on October 12th, 1992, wreaking immense damage including 561 deaths and 12,192 injuries. Although, if anything, the earthquake would have been defined as "small-scale" had it occurred in Japan, this immense damage occurred because normally earthquakes hardly ever occur in this region, and because therefore hardly any earthquake countermeasures had been implemented.

Following a request from the government of Egypt, the Japanese government dispatched a Japan Disaster Relief Team (expert team) consisting of 9 experts, headed by Professor Tsuneo Okada of the University of Tokyo's Institute of Industrial Science, to offer cooperation in a broad range of fields such as earthquake assessment, the state of damage to buildings, and earthquake countermeasures.

The expert team offered technical cooperation, including field surveys mainly in the Cairo capital area and meetings with competent local authorities, over the space of 16 days from October 29th to November 13th, 1992. During this period, the team issued an interim report in the form of a memorandum on after-shock seismic activity on November 5th, submitted a provisional report (40 pages, in English) including a 17-point proposal to the Egyptian government on November 13th, and made efforts towards technical cooperation by holding a press conference on the basis of the report and a seminar aimed at technicians.

This report gives a summary of the Cairo earthquake as elucidated by these surveys, based on the provisional report and subsequent study results.

2. Itinerary and Composition of the Survey Team

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2.1 Itinerary

Thursday Oct.29th

10.30	Inaugural ceremony and meeting at Narita Airport Attended by Director of Disaster Relief Division, Economic Cooperation Bureau, Ministry of Foreign Affairs; Managing Director of Secretariat of Japan Disaster Relief Team, JICA; and other relevant persons
11.15- 11.50	Press conference
12.30	dep. Tokyo (KL862)
16.45	arr. Amsterdam
19.10	dep. Amsterdam (KL553)

Friday Oct.30th

00.30	arr. Cairo. Met by Japanese Ambassador Watanabe and Dr.Adel Ezz, Minister of Scientific Research and Technology
00.45 - 01.30	Press conference (Al Aharam, Al Gomhoria)
01.45	Arr. Meridian Hotel, Cairo
12.10 - 13.20	Survey Team meeting
14.30	Survey of local state of earthquake disaster
17.00	arr. hotel

Saturday Oct.31st

08.45	dep. hotel
09.00	Meeting at the Japanese embassy
10.00	Meeting at the Ministry of Scientific Research and Technology The Minister of Scientific Research and Technology explained the state of damage in Egypt
11.00	Survey of the earthquake epicentre (Dahshur region)
17.10	arr. hotel
17.30	Team meeting

Sunday Nov.1st

09.00	dep. hotel
10.00	Heard explanation of the occurrence of earthquake disasters and others, at the National Research Institute of Astronomy and Geophysics, Helwan Institute
17.20	arr. hotel
17.30	Team meeting

Monday Nov.2nd

09.45	dep. hotel
10.00	Ministry of Scientific Research and Technology
11.00	Survey of state of disaster in Cairo
17.00	arr. hotel
17.30	Team meeting

Tuesday Nov.3rd

Divided into sub-teams and started survey activities

	Earthquake disaster prevention team				Earthquake team
09:45	dept. hotel		Collating data at hotel	09:00	dept. hotel
10:00	Construction Research Center	11:30	dep. hotel	10:00	National Research Institute of Astronomy and Geophysics in Helwan
12:50	Survey of building site	11:45	Greater Cairo Sewage Authority		
17:00	arr. hotel	17:00	arr. hotel	17:00	arr. hotel
17:30	Team meeting				

Wednesday Nov.4th

09:00	dep. hotel			09:15	dep. hotel	Collating data at hotel
09:30	Cairo University			09:40	Egyptian Geological Authority	
11:30	Survey of the Giza disaster area	11:30	General Authority for Roads and Bridges			
17:00	arr. hotel			17:00	arr. hotel	
17:30	Team meeting	18:00	arr. hotel			

Thursday Nov. 5th

11:30	dep. hotel	09:00	dep. hotel	09:00	dep. hotel	Collating data at hotel
12:00	Interim report on state of survey at the Ministry of S.R.&T. (submission of brief report)	09:30	Greater Cairo Sewage Authority	10:00	National Research Institute of Astronomy and Geophysics in Helwan	
		10:30	General Authority for Roads and Bridges			
		17:00	arr. hotel			
13:30	arr. hotel					
17:30	Team meeting			17:00	arr. hotel	

Friday Nov. 6th

09:00	dep. hotel
	Survey of disaster conditions in the region around Giza
17:10	arr.hotel
17:30	Team meeting

Saturyday Nov. 7th

Earthquake disaster prevention team		Earthquake team	
	Collating data at hote	05:15	dep. hotel
		07:00	dep. Cairo on MS433
		08:15	Arr. Aswan
13:00	dep. hotel	08:45	Earthquake Centre Inspect the Array Earthquake Observation Telemeter System, the Aswan High Dam Earthquake Observation System, and others
	Survey of the Aiyat disaster area		
17:00	arr. hotel		
		21:15	dep. Aswan on MS422
		23:15	arr. Cairo

Sunday Nov. 8th

07:30	dep. hotel			07:00	dep. hotel
08:00	Cairo University				
11:00	Ministry of Construction	11:30	Ministry of Interior	11:30	Survey of the Fayoum disaster area
17:00	arr. hotel		Inspect disaster relief facilities		
17:30	Team meeting	17:00	arr. hotel	17:00	arr. hotel

Monday Nov. 9th

08:10	dep. hotel	08:00	dep. hotel		Collating data at hotel
08:30	Courtesy visit to Dean of Fuculty of Engineering, Cairo University	08:30	Survey of bridges in the Nile delta area		
09:30	arr. hotel Collating data at hotel	19:00	Seminar on design of seismic design for briges		
17:30	Team meeting	21:00	arr. hotel	17:30	Team meeting

Tuesday Nov. 10th

10:15 dep.hotel
10:30 Meeting at the Japanese Embassy
11:00 Submission of proposals from the Survey Team to the Minister of Scientific Research and Technology
12:00 Press conference (Al Aharam, Al Gomhoria, NHK, others)
13:00 arr. hotel
19:00 Party hosted by the Japan Disaster Relief Team at the Meridian Hotel, Cairo
20:30 Courtesy visit to Prime Minister Atef Muhammad Naguib Sidki; explained an outline of the survey

Wednesday Nov. 11th

09:00 dep. hotel
10:00 Seminar given by the JDR team at the Construction Research Centre
16:00 arr. hotel
19:30 Dinner hosted by Dr. Adel Ezz, Minister of Scientific Research and Technology

Thursday Nov. 12th

06:00 dep. hotel
08:25 dep. Cairo on BA154 arr/dep London NH202

Friday Nov. 13th

13:45 arr. Narita
14:15 Closing ceremony at Narita Airport
Attended by Director of Disaster Relief Division, Economic Cooperation Bureau, Ministry of Foreign Affairs:Managing Director of Secretariat of Japan Disaster Relief Team, JICA; and other relevant persons.

2.2 Japan Disaster Relief Team (Expert Team) for Egypt Earthquake

	Name	Occupation	Assignment
Leader	Dr. Tsuneo OKADA	Professor, Institute of Industrial Science, University of Tokyo	Leader
Member	Dr. Mizuho ISHIDA	Head. Seismic Activity Laboratory, Solid Earth Science Division National Research Institute for Earth Science and Disaster Prevention, Science and Technology Agency	Seismology
	Mr. Tomomitsu FUJII	Director of Earthquake Disaster Countermeasures Division, Disaster Prevention Bureau, National Land Agency	Earthquake Disaster
	Dr. Yoshihiro KINUGASA	Director of Seismotectonic Research Division, Environmental Geology Department, Geological Survey of Japan, Ministry of International Trade and Industry	Geology, Seismotectonics
	Mr. Takaji KURIHARA	Director of Earthquake Prediction Information Division, Seismological and Volcanological Department, Japan Meteorological Agency	Earthquake Observation and Prediction
	Mr. Michio OHYA	Director for International Codes and Standards Housing Bureau, Ministry of Construction	Building Standard• International Cooperation
	Dr. Kazuhiko KAWASHIMA	Head of Earthquake Engineering Division Earthquake Disaster Prevention Department, Public Works Research Institute, Ministry of Construction	Earthquake Engineering
	Dr. Hisahiro HIRAISHI	Head of Structure Division Structural Engineering Department Building Research Institute, Ministry of Construction	Structural Engineering
	Mr. Satoshi KIMURA	Staff, Relief Coordination Division Secretariat of Japan Disaster Relief Team, Japan International Cooperation Agency (JICA)	Coordination

3. Survey Results

3. Survey Results

3.1 The 1992 Cairo earthquake

The earthquake with magnitude (Msz) 5.3 occurred at about 30 km southwest of Cairo city. This earthquake is the first disastrous one to have occurred near Cairo city since 1847. The source parameters for this event are reported by the National Research Institute of Astronomy and Geophysics, Helwan Institute (NRIAG) and the United States of Geological Survey (USGS). Those obtained by the NRIAG are:

Origin time = 12 Oct. 1992, 13:09 UT, MD = 5.3
Location = 29.775°N, 31.082°E
Depth = 30 km

and those obtained by the USGS are:

Origin time = 12 Oct. 1992, 13:09 UT, Mb = 5.9, Msz = 5.3
Location = 29.826°N, 31.228°E
Depth = 25 km

where MD and Mb are estimated by using the duration time and amplitude of the body wave, respectively. The location of the hypocenter is slightly different between those obtained by the NRIAG and the USGS. Both parameters are preliminary and the official results will be obtained in a few months.

The focal mechanism, seismic moment and moment magnitude of the main shock are determined by the Harvard University, USA. Those are:

1. (strike, dip, slip) = (N174°E, 46°, -50°)
2. (strike, dip, slip) = (N304°E, 56°, -124°)

P-axis: (plunge, azimuth) = (62°, N157°E)
T-axis: (plunge, azimuth) = (5°, N57°E)
Seismic moment = 0.08×10^{26} dyne cm
Moment magnitude (Mw) = 5.8

The focal mechanism shows normal faulting with slightly strike-slip component.

On the basis of the value typical for shallow earthquakes of magnitude 5.3 , the length of the fault zone is estimated to be around 7.1 km and the width of that is to be around 3.5 km. The displacement is also estimated to be around 22 cm.

Recommendation

More dense seismic network is required to locate the hypocenter in good accuracy. At least the three-component seismometer should be equipped at each station and telemetry system is also necessary for real-time data processing.

In order to examine the fault mechanism, a few broad-band seismic stations are also need.

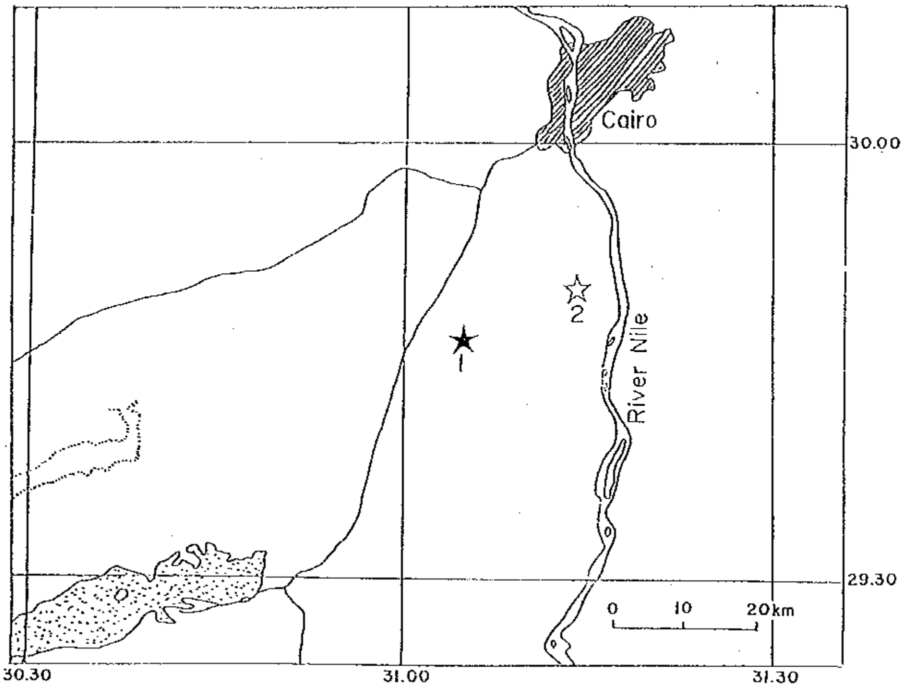

Figure 3.1.1 The location of the 1992 Cairo earthquake
1: the location by the NRIAG
2: the location by the USGS

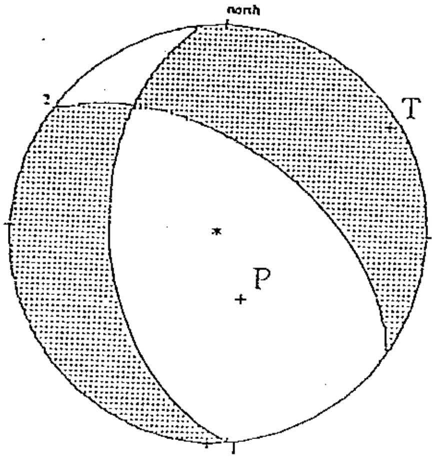

Figure 3.1.2 A diagram showing the mechanism of occurrence of this qarthquake (CMT analysis courtesy of Harvard University) Shaded areas show the initial thrust.
Lower equal load projection.
Focal mechanism diagram of the 1992 Cairo earth quake (after the USGS)

The shaded areas on the focal mechanism represent the compressional area projected on the lower hemishere of the focal sphere.

3.2 Aftershocks of the 1992 event

Many aftershocks followed the main shock. The hypocenters of major aftershocks are located by using the local seismic network of the NRIAG. The epicenters of those events are indicated in Figure 3.2.1. The largest aftershock took place at about 2 hours after the main shock, but the hypocenter was not determined yet. M3.7 event occurred within a day after the main shock and the epicenter was located at about 5 km north to that of the main shock. Most of major aftershocks seem to be active on the east side of the main shock and the depth of those aftershocks is determined to be around 17-25 km, which is shallower than that of the main shock. Based on the above observations and the focal mechanism of the main shock, the possible fault plane of the main shock is assumed to be the normal faulting with the strike of N174°E and the dip of 46° and the fault length to be around 7 km. But the trend of aftershock distribution seems to be the northwest-southeast. Based on this observation, the possible fault plane of the main shock is assumed to be the normal faulting with the strike of N304°E and the dip of 56°. We need more accurate information about the aftershock distribution to conclude which of the nodal planes corresponds with the seismic fault of the Cairo earthquake.

The frequency of the aftershocks per six-hours, modified the original data of the NRIAG, is shown in Figure 3.2.2, of which the tentative one has already been represented to the state Minister of the Scientific Research and Technology on 6 Oct. 1992. According to this figure, the level of the aftershock activity is gradually decreased with time, although the activity becomes intermittently high in and around the fault zone.

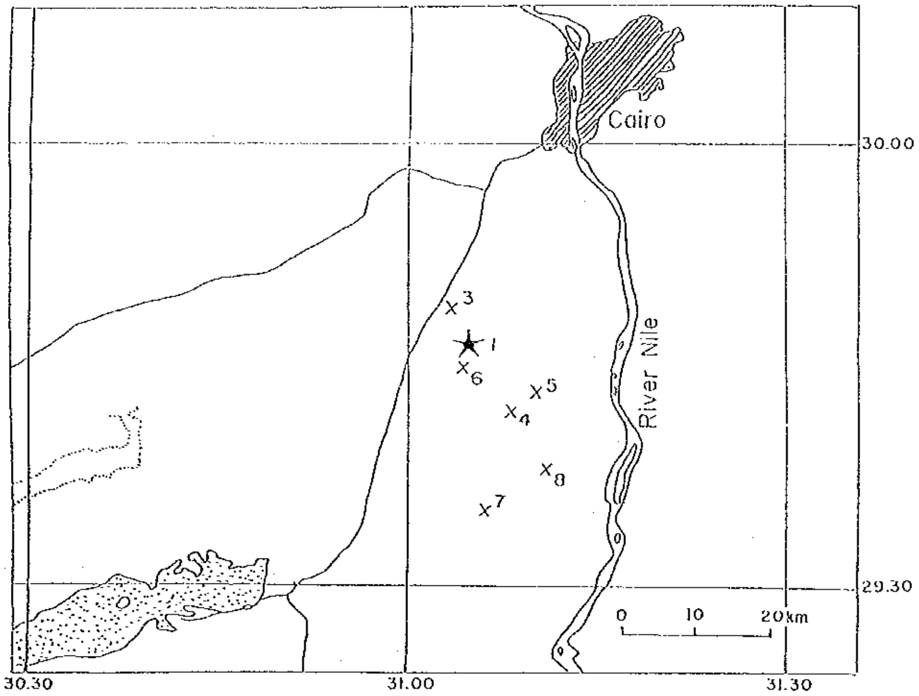

Figure 3.2.1 The epicentral distribution of the main shock and the major aftershocks

1: Oct. 12 13:09 M5.3, 2: Oct. 12 15:25 M4.3, 3: Oct. 12 21:31 M3.7,
4: Oct. 13 18:09 M3.6, 5: Oct. 14 09:40 M4.0, 6: Oct. 14 03:50 M3.7,
7: Oct. 22 17:38 M4.2.

M is the duration magnitude. Event 2 is not shown in this figure.

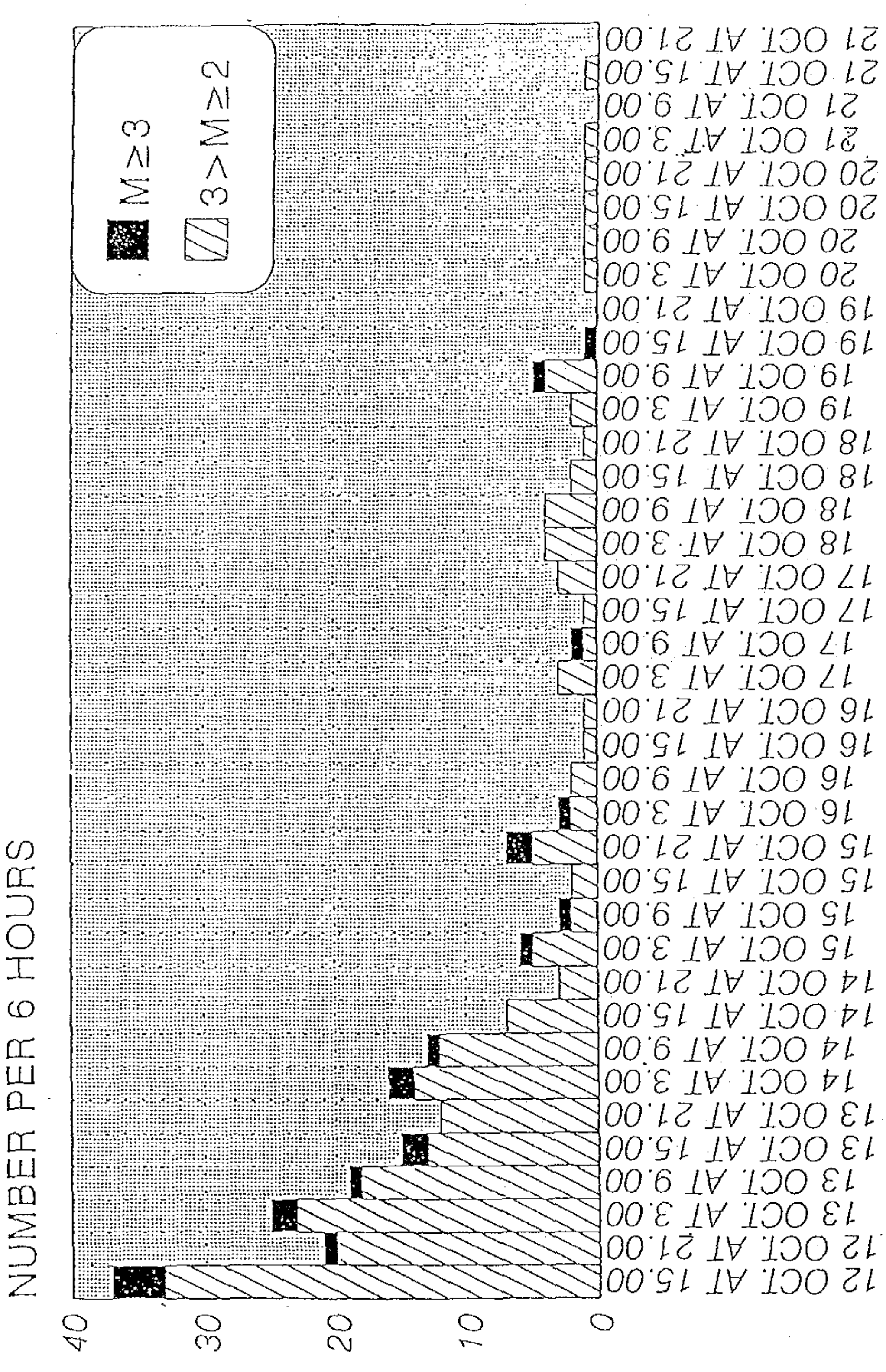

Fig. 3.2.2 The number of aftershocks per six hours (after the NRIAG)

3.3 Macro-Seismic Intensity

Seismic intensity is a combination of the intensity of seismic shaking and degree of earthquake damages. To obtain the accurate intensity values of seismic shaking, strong motion records are indispensable. The degree of earthquake damages varies widely with construction and engineering quality of structures. At a specific location, damages to properly designed structures may be minor while extensive damage can be found in the non-engineered structures. Strong motion records are also necessary for evaluating the remaining strength of the damaged structures and the safety factor of undamaged structures.

Devastating damage was reported in down town Cairo but most damage was confined to old masonry structures. Minor damage such as cracks on walls and falling plaster typify the damage incurred by modern buildings in down town Cairo, the collapse of RC building in Heliopolice being the primary exception. Based on these damages, the seismic intensity in down town Cairo is estimated as VI$^+$ on the MSK scale.

Adobe structures in the suburban areas such as El Faiyum and Al Aiyat have been seriously damaged (VII to VII$^+$). Damage statistics for villages in the epicentral region (see 3.11.2) imply at intensity of VII$^+$.

The areas where such devastating damages occurred coincide with the Nile Delta, along the Nile River and in the Faiyum basin. These areas are characterized as the areas where thick unconsolidated sediments develop. Distribution of the macro-seismic intensity is roughly estimated as shown in Fig. 3.3.1 based upon the information obtained by the members of the Japanese Expert Team from NRIAG, EGSMA, Cairo Univ., etc.

A compilation effort for development of a comprehensive intensity map is under way at the NRIAG based on a questionnaire disseminated through a news paper. Although the questionnaire survey is a very effective procedure to obtain data covering a wide area, it takes many days to complete. The intensity distribution map is a key tool for post-earthquake operations such as dispatching rescue and medical teams, emergency supplies as well as strengthening and repair of damaged structures, and therefore, it is needed as soon as possible.

Recommendations

1) Installation of strong motion seismographs is necessary to obtain accurate seismic intensity measurement and for other engineering purposes as well.
2) Two kinds of seismic intensity maps are necessary; one for developing a better understanding of the earthquake effects and the another for determining prudent post-earthquake operations. The later should be made as soon as possible for use in developing post-earthquake operations while the former should be made as carefully as possible.
3) The later could be made by the information from people who have some knowledge about earthquake, such as local authorities, police men, fire fighters and school teachers. Educating these people is necessary to get correct information on seismic intensity.
4) Also, a standardized procedure for evaluating damage to structure and ground effects should be established.

Table 3.3.1 Comparison Table of Various Seismic Intensity Scares

JMA Intensity Scale (1949)	MM Intensity Scale (1931)	MSK Intensity Scale (1964)
0: (unfelt) Not felt by the human body but felt only by seismograph.	(Unfelt) Felt only by seismograph.	
I: (slight shock) Felt only by people at rest or by very careful people.	I: Felt by a small number of people in places that are very sensible. II: Felt by a small number of people on upper floors. Unfixed objects shake slightly.	I: (unfelt) Not felt by the human body but shock is known by seismograph. II: Felt only by people sit still inside or upper floors.
II: (weak shock) Felt by many people and paper sliding doors or pot flowers move slightly.	III: Felt strong by people on upper floors and automobiles in stop slightly shake, but the shock is little felt by many people. IV: Felt by many people inside during daytime. Dishes, window glasses and doors shake. Automobile in stop violently shake.	III: Felt only by a small number of people. Can be felt some people inside. Cautious people often note that suspended objects are shaking. Shock is the level that is felt when lightweight trucks are passing by. IV: Felt by most people. Shock is felt by most people inside and a few people outside. Windows and doors, and dishes rattle. Water in container slightly move. Shock is felt in automobile in stop.
III: (rather strong shock) Houses shake, sliding doors rattle, suspended lights violently shake, and water move in container.	V: Felt by most people and people in bed are awaken. Unstable objects fall down and pendulum clocks stop to swing.	V: Felt by all people inside and many people outside. People in bed are awaken and some people jump out. Pendulum clocks often stop to swing and water often flows out of container. Type A buildings can often be damaged.
IV: (strong shock) Houses violently shake, rickety flower pots fall down, and water flows out of container. Shock can be felt by people on road and many people tend to jump out of house.	VI: Felt by all people and many people jump out. VII: Almost all people jump out. Unstable objects and buildings of poor design can be seriously damaged. Shock is felt by drivers of forwarding automobiles and large bells start to gong.	VI: Felt by most people outside and people inside jump out. Many Type A buildings are damaged. Type B buildings are often damaged. Cracks occur and precipices often collapse. VII: Most people jump out. Shock is felt by automobile drivers. Large bells start to gong. Type C buildings are slightly damaged. Type B buildings receive moderate damage, and Type A buildings receive major damage. Cracks occur on road surfaces and well water level changes.
V: (very strong shock) Cracks occur on walls, tomb stones or stone lanterns fall down, chimneys and stone masonry fences can be damaged, wood houses and warehouses often fall down, cracks occur on ground surfaces, and well water level changes.	VIII: Rigid buildings can be damaged and chimneys, monuments, walls, and furniture over turn. Mud water is discharged from ground and well water level changes. Automobiles are difficult to drive and tree trunks often move.	VIII: It becomes difficult to continue driving automobiles. Heavy furniture often over turn. Type C buildings can be moderately damaged. Type B buildings are seriously damaged, and Type A buildings mostly collapse. Tomb stones are over turned, monuments slip, and stone masonry walls fall down. Slips occur on road embankments.
VI: (disastrous shock) The rate of collapsed houses is less than 30%, slides or ground fissures occur, and people can rarely stand of foot. Railroads are bent, banks can be seriously damaged. Significant fissures occur in soft and damp ground and mud water is discharged.	IX: Earthquake resistant brick masonry and old stone masonry buildings can seriously be damaged. Cracks occur on concrete walls. Chimneys are all damaged. X: Most stone masonry structures are damaged, large cracks occur in ground, and railroads are bent.	IX: Many Type C buildings are seriously damaged and some collapse. Type B buildings mostly collapse. Monuments are over turned and railroads are bent. Mud water is discharged in flat ground. Cracks of 10 cm ore more in width can often occur in ground. Slips occur on mountains and slopes. Water surfaces get rough. X: Some of Type C buildings collapse. Many Type B buildings totally collapse. Type A buildings all collapse. Bridges are seriously damaged. Dams and banks are exposed to damage. Fissures of 10 cm wide and 1 m deep can occur.
VII: (severe shock) The rate of collapsed houses totals 30% or more. Slips, fissures and faults can occur. Cracks occur at many places and rocks fall down. River banks are depressed over extensive areas and water flow channels often change. Geographical configurations change significantly.	XI: Buildings are rarely remained undamaged. Bridges are damaged, and ground fissures occur. XII: Almost all objects are damaged. Ground surfaces are waved. Some people are thrown up.	XI: Excellent buildings, bridges, dams and railroads are seriously damaged. Highways become unserviceable. Underground piping is damaged. XII: All structures, both aboveground and underground, are seriously damaged or collapse. Ground surfaces significantly change in configuration. A number of cracks occur, rocks fall down, and embankments are depressed in extensive areas.

Type A Building: Stone masonry, adobe, and clay construction.
Type B Building: Normal brick masonry, prefabricated, and semi wood construction.
Type C Building: Reinforced concrete and well designed wood buildings.

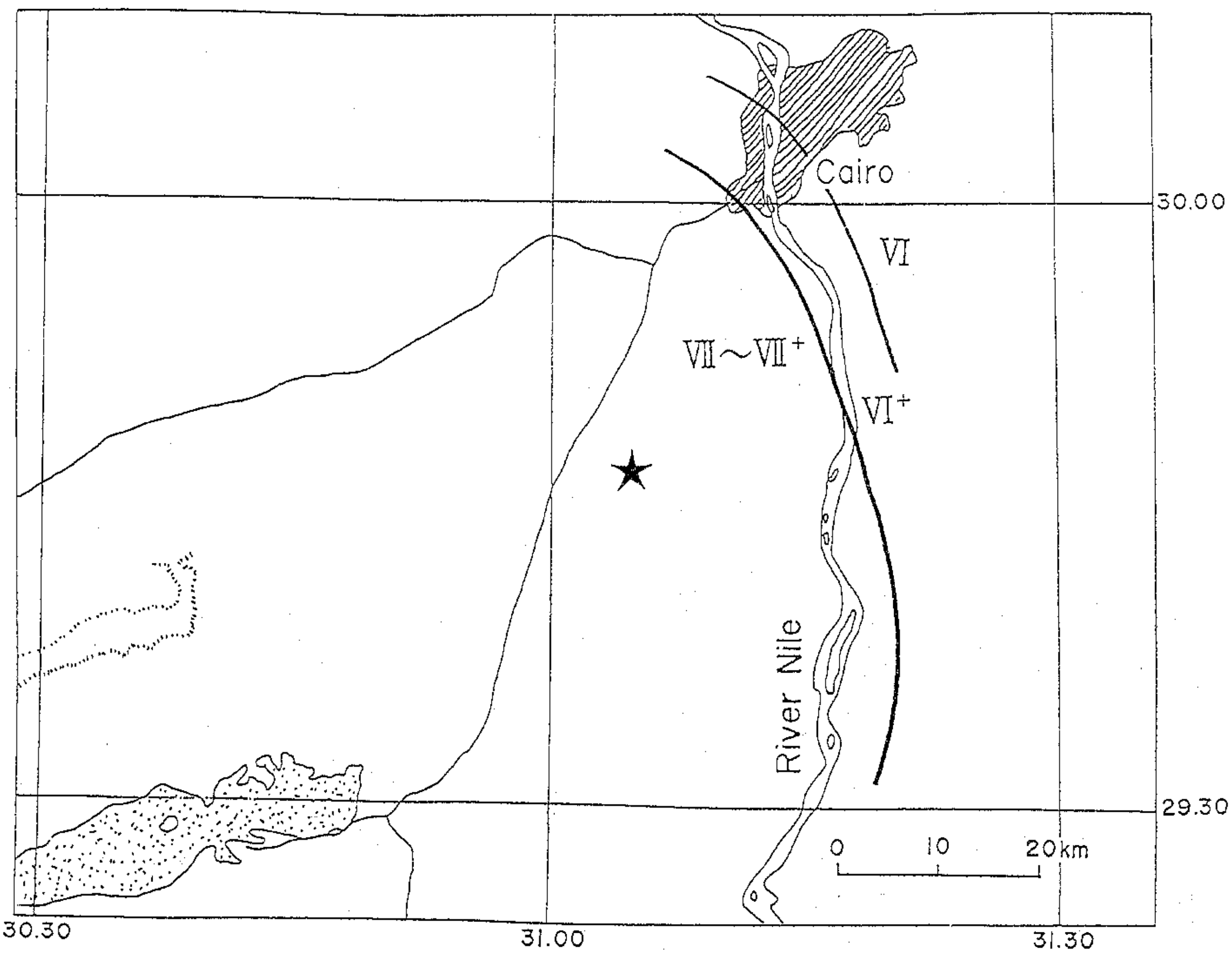

Fig. 3.3.1 Macro-Seismic Intensity in MSK Scale ★ : Epicenter of the Main Shock by NRIAG

3.4 Geological Conditions

Egypt is located at the northeastern part of the African Continent. In terms of crustal dynamics such as earthquakes and volcanoes, it is generally agreed that the African Continent is a stable region except the East African rift which runs through Mozambique, Kenya, and Ethiopia. The East African rift branches in northern Ethiopia into a rift along the Red Sea and another rift along the Gulf of Aden. The Red Sea rift branches into the Gulf of Suez and the Gulf of Aqaba. The Gulf of Aqaba is known as a region of intensive crustal movement. The African continent collides with Eurasian continent at the Mediterranean.

In the territory of Egypt, three major geologic trends are recognized, namely the Red Sea trend oriented NNW-SSE, the Gulf of Aqaba trend oriented NNE-SSW, and the Mediterranean trend oriented E-W. Faults and lineaments in these trends are shown on geologic maps and satellite photos (Egyptian Geological Survey, 1981; Egyptian General Petroleum Cooperation, 1987; Remote Sensing Center, 1990).

Although the detailed characteristics of these faults were not obtained during the site survey of the Japanese Expert Team, it is evident that the Aswan Earthquake of 1981 occurred along one of these trends, namely the East-West trending Kalabsha Fault (El Shazly and Abdel Hady, 1984, 1985; Kebeasy, 1991).

In the epicentral region of the October 12 earthquake, NNW-SSE trending faults are clearly recognizable paralleling to the Red Sea trend (Egyptian Geological Survey, 1981. see Fig. 3.5.1). The focal mechanism and distribution of aftershocks of the earthquake implies the re-activation of a deep seated fault in the Red Sea trend.

Some fresh ground cracks have been observed in the epicentral region by the scientists of the NRIAG and the EGSMA. These cracks show non-systematic orientation and no systematic displacement (Photo 3.4.1 and 3.4.2). Judging from these characteristics and field observations, these cracks may not be directly related to the fault which caused the October 12 earthquake. However, detailed geological and geophysical survey of the epicentral region is necessary for a better understanding of the October 12 earthquake and seismotectonics of the region.

The detailed geological structure, especially the fault structure, beneath the metropolitan Cario area is poorly understood. Judging from geologic maps (Egyptian Geological Survey, 1983), there are possible faults underneath the metropolitan Cario but their detailed characteristics are not known.

Recommendations

1) Geological studies, especially seismotectonic research, should be enhanced for better understanding of the occurrence of the geological hazards such as earthquakes.

2) Geological and geophysical surveys of the epicentral region are necessary for developing a better understanding of the October 12 earthquake and seismotectonics of the region.

3) Detailed geological survey of the suspected faults beneath the metropolitan Cairo area is necessary for developing prudent earthquake countermeasures for the city.

Reference:

1) Egyptian Geological Survey: Geological Map of Egypt, 1:2,000,000, 1981.

2) Egyptian General Petoroleum Corporation: Geological Map of Egypt, 1:500,000, 1987.

3) Remote Sensing Center: Space Atlas of MISR, 1990.

4) El Shazly, E.M. and Abdel Hady, M.A.: Earthquake Studies in Aswan Environment, Egypt, Applying Space-Borne Imagery Interpretation and Other Techniques, Remote Sensing Center, 12p., 1984.

5) El Shazly, E.M. and Abdel Hady, M.A.: Space-borne imagery interpretation: earthquake studies in Aswan, Earth-Orient. Applic Space Technol., Vol. 5, No. 1/2, pp. 139-149, 1985.

6) Kebeasy, R.M.: Seismicity of Egypt, MedNet — The Broad-band seismic network for the Mediterranean, pp. 467-494, 1991.

7) Egyptian Geological Survey: Geological Map of Greater Cairo Area, 1:100,000, 1983.

Photo 3.4.1 Ground Cracks at Dahshur
No systematic trend observed

Photo 3.4.2 Ground Cracks at Dahshur
No displacement observed

3.5 Subsoil Conditions

In the epicentral region, the Tertiary formations are widely distributed. These rocks are overlain by thick, unconsolidated Quaternary sediments in the Faiyum basin, the Nile Delta, and along the Nile River (see Fig. 3.5.1). In these areas, Pre-Tertiary formations are distributed only as a small mass in the Giza district. On geological maps (Egyptian Geological Survey, 1981, 1983; Egyptian General Petroleum Cooperation, 1987), Precambrian formations are shown in the mountain ranges along the Red Sea. Jurassic and Cretaceous formations overlie the Precambrian formations, dipping toward the northwest direction.

Overlying these older units, limestone and clastic sediments of Paleogene age are widely distributed on the eastern side of the Nile River and comprise the basement of the Faiyum basin. Neogene formations are distributed in the northeastern part of Cairo and in the western and northern part of Giza. These formations dip slightly to the northwest but no other obvious deformation can be seen.

Sediments along the Nile River are classified into the Proto-Nile, Pre-Nile, Neo-Nile and Nile-silt (Egyptian General Petroleum Cooperation, 1987; Herman et al., 1989). The Proto-Nile is a Pliocene to Pleistocene formation which consists mainly of gravel. The Pre-Nile formation consists of intercalated beds of fluvial sand and aeolian sand. The Neo-Nile and the Nile-silt consist of fine clastic sediments. The Proto-Nile, the Pre-Nile and Neo-Nile form terraces along the Nile River. The Nile-silt blankets the alluvial lowland along the river. The thickness of the alluvial sediments is estimated to be around 80 meters in Metropolitan Cairo, and 50 meters in Helwan and its vicinity.

The ground water table is an important factor effecting the stability of the ground. It is estimated to lie 2 to 3 meters below the ground surface in Metropolitan Cairo and in the area along the Nile River. A very shallow water table is also observed in the El Faiyum basin where an irrigation system has been implemented. On the other hand, the water table is estimated to be more than 70 meters below the ground surface in the western desert.

In general, higher seismic intensity was observed in regions where thick sediments develop and the water table is shallow. However, important factors including detailed stratigraphy, sediments distribution and thickness, and their dynamic behavior have not been evaluated. Liquefaction is also observed in these regions, such as El Aiyat, El Beleada and Al Akwan, located about 20 kilometers from the epicenter (see also Chapter 3.11).

Recommendations

1) Subsoil conditions including the stratigraphy, sediments distribution and thickness as well as their dynamic behavior should be studied in detail and the result of these studies should be shared with all scientists and engineers involved in earthquake research and countermeasure development and implementation.

Reference:

1) Egyptian Geological Survey: Geological Map of Egypt, 1:2,000,000, 1981.
2) Egyptian Gelogical Survey: Geological Map of Greater Cairo Area, 1:100,000, 1983.
3) Egyptian General Petoroleum Corporation: Gelological Map of Egypt, 1:500,000, 1987.
4) Herman, M., Klitzch, E. and List, F.K. (ed.): Stratigraphic Lexicon and Explanatory Notes to the Geological Map of Egypt 1:500,000, Conono Inc., Egypt, 264p., 1989.

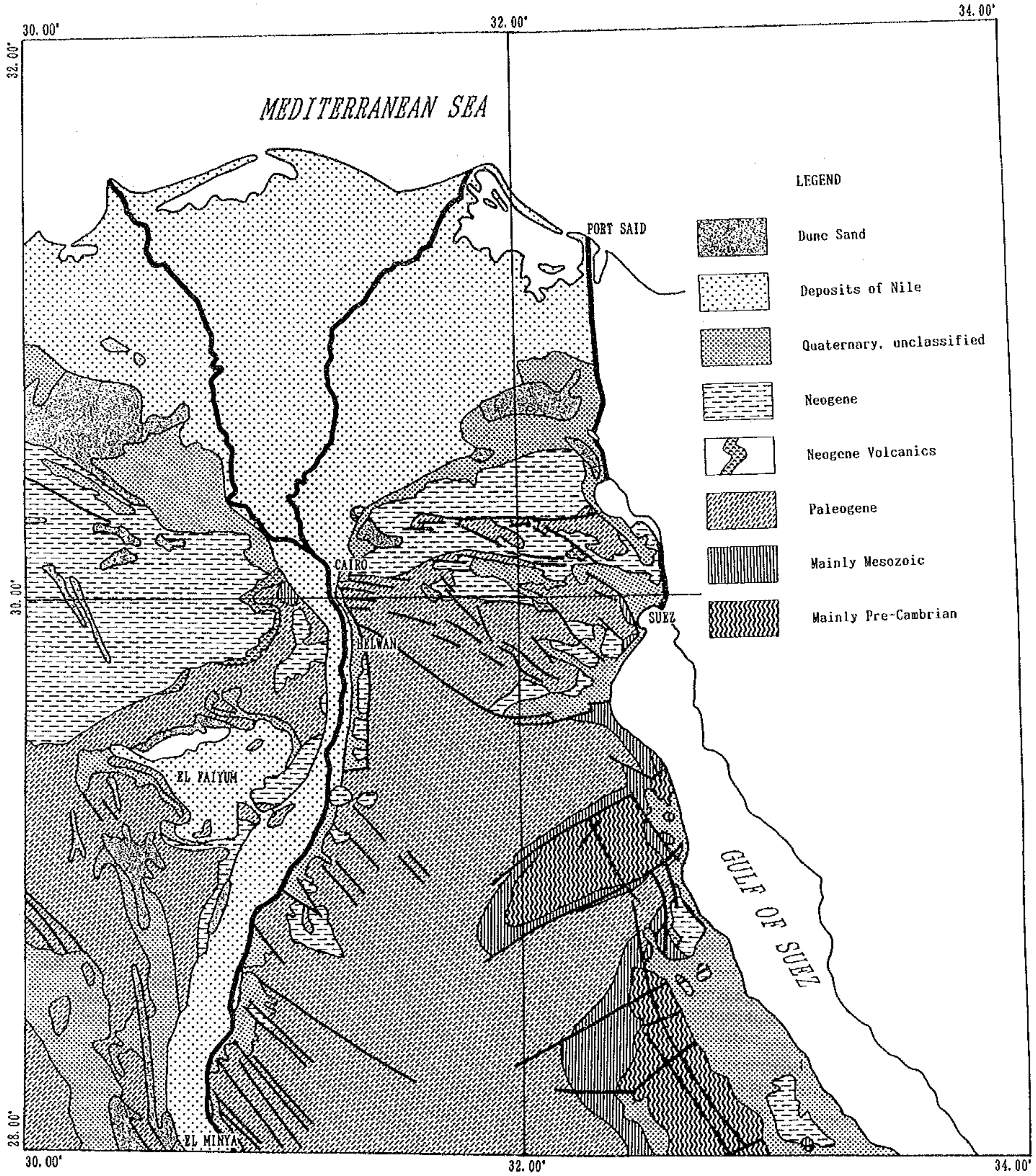

Fig. 3.5.1 Geologic Map of the Northern Egypt Simplified from Egyptian Geological Survey (1981)

3.6 Seismicity

Most of earthquakes tend to occur along the three main active trends. Those are: 1. Northern Red Sea-Gulf of Suez-Cairo-Alexandria Clysmic trend, 2. East Mediterranean-Cairo-Fayum Pelusiac trend, 3. The Levant-Aqaba trend (R.M.Kebeasy, 1991). Figures 3.6.1 and 3.6.2 show the distribution of epicenters of microearthquakes and small earthquakes in and around Cairo city, respectively. Epicenters of historical and instrumentally recorded earthquakes are shown in Figure 3.6.3. Historical large earthquakes around Alexandria are listed in Table 1 and recent major earthquakes in Table 2. According to those figures and tables, the area along the northern Red Sea, Gulf of Suez, Cairo, Alexandria and the north west in the Mediterranean Sea is the most seismically active zone in Egypt. Cairo-Suez district, northern part of Egypt is tectonically unique. The east boundary of northern African plate is characterized by the divergence being accompanying the extension and the north boundary of that is characterized by the convergence being accompanying the compression. The high level of seismic activity in Cairo-Suez district is interpreted to be a result of the interaction between the African, Arabian and Eurasian plates.

For these reasons, Cairo has long suffered from disastrous earthquakes. However, the largest magnitude of earthquakes which occurred in and around Cairo since B.C. 2200 is less than 6.8. Magnitude of 6 to 7 is usually classified to be a moderate earthquake. Figure 3.6.4 represents epicentral distribution in the world. Looking at this figure, the northern part of the African plate is rather seismically quiet compared with the circum-pacific region. The 1992 Cairo earthquake with magnitude 5.3 belongs to a large event within the African plate, however magnitude less than 6 is usually classified to be a small event and that of 6 and larger a large event in the world-wide scale. Therefore the magnitude 5.3 event belongs to a smaller event rather than a larger one.

Recommendation

1) Since Egypt is said to possess records on historical earthquakes dating back 4,800 years, these past records ought to be organized and collated.
2) Eathquakes in Egypt since the start of mechanical observations should be listed and organized into distribution charts, and should be used to gain an understanding of the current situation.

References:

1) Albert, R.N.H, 1969, Seismicity of the Zafarana area, Gulf of Suez, Egypt.
2) Kebeasy, R. M., 1990, Seismicity of Egypt, I Workshop on MedNet, the broad-band seismic network for the Mediterranean, Sep. 10-14, 1990.
3) Kebeasy, R.M., M. Maamoun, R.N.H. Albert and M. Megahed, 1981, Earthquake activity and earthquake risk around Alexandria, Egypt, Bull. IISEE, 19, 93-113..pa

Table 3.6.1 List of historical large earthquakes (Kebeasy et al., 1981)

Date	Region	I_0	M	Remarks
2200 B.C.	Tell Basta	VII	5.8	Deep fissures.
24-20	Alex. off shore	IV	4.0	Strong sea waves.
320 A.C.	Alex. off shore	VII	5.9	Many houses destructed.
553	Alex. off shore	V	4.8	
4.796	SE Med. Sea	VI	5.2	Felt at different localities of Egypt, partical damage of Alexandria light house.
859	Belbeis	VI	5.5	Felt in Nile Delta and Alexandria.
26.5.1111	East Cairo	VII	5.8	Destruction in Rehachope Temple.
8.8.1303	Fayum	VIII	6.5	Severe earthq., many places in Cairo destructed, affected the Nile valley till Quoos and little damage in Alex.
1326	Alex. off shore	V	4.8	Light house was shocked, felt in many places in Egypt.
3.1687	Alex. off shore	VI	5.2	Alexandria was vibrating for 10-12 days.
2.10.1698	Rosetta	VI	5.5	Nile valley.
9.1754	Tanta	VIII	6.0	Destructive earthq., 2/3 of Cairo buildings were damaged, thousands of people were killed.
7.8.1847	Fayum (29.5° N, 30.5°E)	VIII	6.2	Severe earthq., 3000 houses and 42 mosques were detroyed, 85 persons were killed and 62 were injured; strongly felt on the 10th of August.
24.6.1870	East of Med. (32°N, 30°E)	VIII	6.5	Severe earthq., felt in vast area.
11.7.1879	Alex. off shore	V	4.8	Strongly felt earthquake.
28.12.1908	Alex. off shore	V	4.8	Felt earthquake.

I_0 : Maximum intensity at the epicenter.
M : Magnitude as derived from the equation:
$I = 1.43M - 3.9 \log r + 4.37$
by M. Maamoun (1979) [9],
where I, M and r are the intensity, magnitude and focal depth respectively.

Table 3.6.2 List of recent major earthquake (Kebeasy et al., 1981)

Date			O.T. (G.M.T.)			Lat.	Long.	h (km)	I_0	M	Remarks
D	M	Y	h.	m.	s.	N	E				
01	10	1920	02	10	00.0	29.4°	31.0°	20	7.0	5.8	
28	05	1951	14	16	21.0	31.8	27.0	N	6.7	5.6	
24	07	1954	00	52	00.0	31.5	30.0	N	6.7	5.7	Flet in Alex.
28	10	1954	13	39	01.0	32.4	31.4	N	6.0	5.4	
12	09	1955	06	09	22.0	32.2	29.6	N	9.0	6.8	
29	04	1974	20	04	39.7	30.5	31.7	N	5.0	4.9	

O.T. : Origin time.

h : Focal depth, N normal depth.

I_0 : Maximum intensity at the epicenter.

M : Helwan magnitude scale.

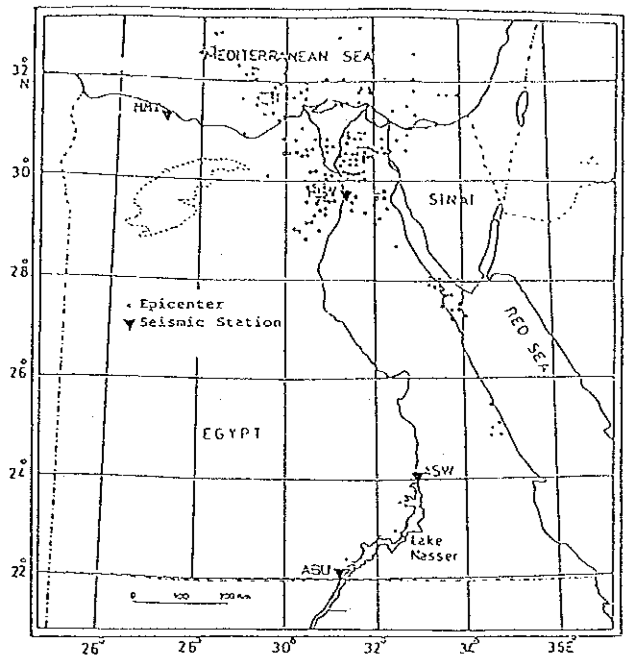

Fig. 3.6.1 Solid inverted triangles indicate permanent seismic stations. Epicentral distribution of recent microearthquakes (Kebeasy, 1991)

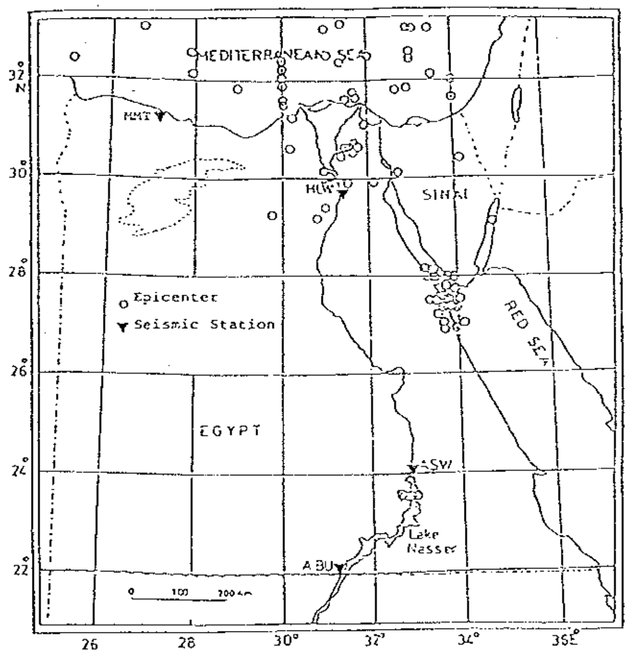

Fig. 3.6.2 Epicentral distribution of recent small earthquakes (Kebeasy, 1991) Closed triangles indicate permanent seismic stations

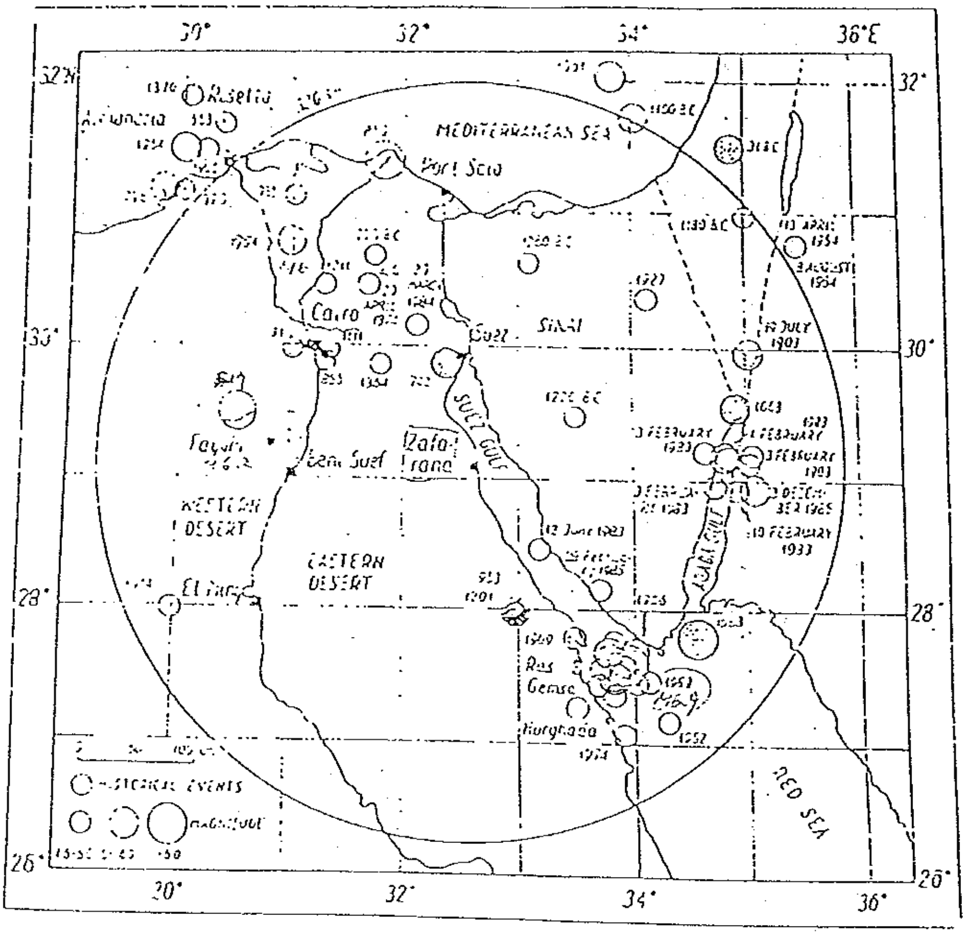

Fig. 3.6.3 Epicentral distribution of earthquakes with magnitude greater than 4.5 around the Zafarana area (Albert, 1969)
The circles with a radius of 320 km is marked

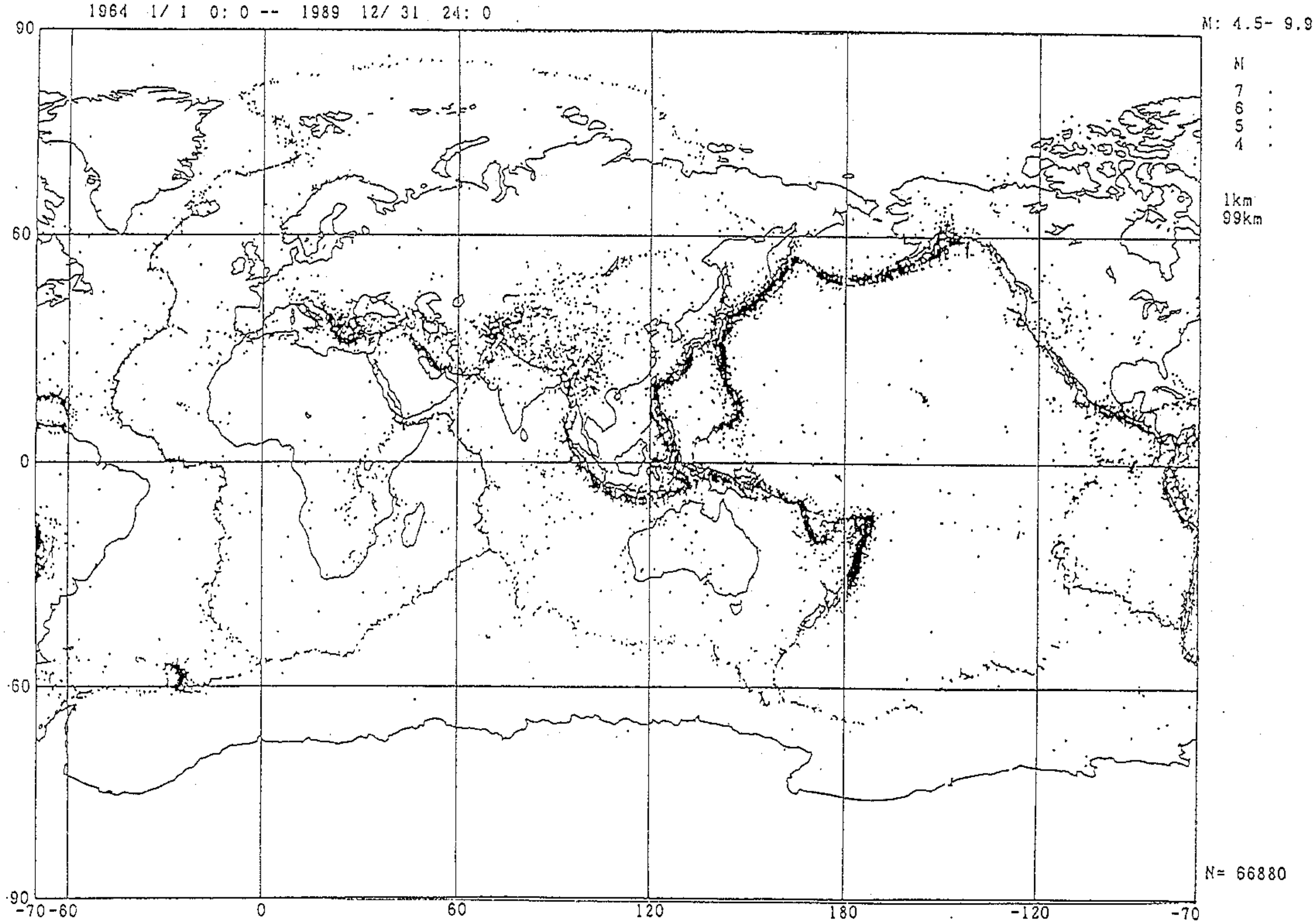

Fig. 3.6.4 Epicentral distribution of earthquakes shallower than 100 km, occurring during the period from 1964 to 1989 (after the ISC).

3.7 Strong Motion Seismogram

In Egypt, there are no strong motion accelerographs installed in Cairo and its vicinity, but there are six accelerographs at Aswan High Dam and one at an area approximately 60 km from the dam. Since there were no strong motion accelerographs available in the area of the last earthquake, there was no way for estimating the ground motion intensity. Therefore, peak ground acceleration was evaluated based on the results of statistical analyses on 394-component strong motion records in Japan. It is known that the peak ground acceleration attenuates depending on the eqrthquake magnitude and epicentral distance as$^{1)}$.

$$a_{max} = 232.5 \times 10^{0.313M} \times (\Delta + 30)^{-1.218} \qquad (3.7.1)$$

where,

a_{max} = peak ground acceleration (gal=cm/sec^2)
M = earthquake magnitude
V = epicentral distance (km)

Since the earthquake magnitude was approximately 5.4, the attenuation of peak ground acceleration obtained from Eq. (3.7.1) became as shown in Fig. 3.7.1. As stated later, damage from this earthquake occurred mainly in Giza City and Capital Cairo, and the epicentral distances range from 30 km to 45 km. Therefore, the ground acceleration at Giza City and Capital Cairo, obtained from Fig. 3.7.2, will be approximately 60 gal.

Comments on the earthquake shocks felt by Japanese residents, engaged in construction business in Egypt, were collected and tabulated as shown in Table 3.7.1. There were many Egyptians who burst out in excitement, but few objects fell or were overturned, except for a few lighting reflectors dropped from the ceiling. It can be presumed that the shocks were at a level that would cause unlocked desk drawers to slide out.

When questioned about experience with shocks of similar magnitude, comments given by two of the persons who answered, Mr. C and Mr. D, were very interesting for estimating the Capital Cairo quake, as they gave specific earthquake names and locations. According to their comments, the magnitude of the shock was nearly equal to that of the Miyagi-Oki earthquake (magnitude of 7.4) experienced by Mr. C in Tomioka-cho, Fukushima-Ken in 1981, and that of Chiba Toho-Oki earthquake (magnitude of 6.7) experienced by Mr. D in Abiko City, Chiba-Ken on February 17, 1987. At the time of Miyagi-Oki earthquake, strong motion records were obtained at two locations in Iwaki City very close to Tomioka-cho. The peak ground acceleration in a horizontal direction ranged from 50 to 80 gals. It is presumed that the peak acceleration recorded in Abiko City at ChibaToho-Oki earthquake was nearly 100 gals.

Taking into account the comments by Mr. C, Mr. D, and other persons, it can be seen that the above estimation by Eq. (3.7.1) is roughly adequate.

Another interesting point noted in Table 3.7.1 is that many people felt shocks in Suez City, 140 km or more away from the focus, and not a few Egyptians were stricken with serious panic. Based on Eq. (3.7.1), it can be estimated that the maximum acceleration in Suez City was approximately 25 gals.

Reference:

1) Kawashima, K. et al.: *Attenuation of Peak Ground Acceleration, Velocity and Displacement Based on Multiple Regression Analysis of Japanese Strong Motion Records*, Earthquake Engineering and Structural Dynamics, Vol. 14, 1986

Table 3.7.1 Earthquake Shocks Felt in Cairo and Suez by Japanese Engaged in Construction Business (1)

Eye Witness	Place of shocks felt		How the shocks were felt during this earthquake?	Any similar shocks experienced in Japan?	JMA Seismic Intensity	Response of Local People at time the earthquake occur?
	Location	Building				
Mr. A	Rodus Island, Cairo	Canvas road in University of Cairo	• Initial micro shock (vertical shock one or two seconds) was felt like large truck or trainer truck was running for about 5 meters. • Mainshock (5 to 7 seconds) was not felt greatly. Did not feel uneasy while standing on feet slightly apart.	Similar to the level of intensity III experienced in Tokyo.	III	About 30% of people jumped out of the hospital building (4-story) annexed to the university. A few ladies began to cry with fear. Most people were very excited.
Mr. B	Zamalek, Cairo	Home, RC building	Significant shocks were not.	Similar to those occur once in every one or two years in Japan.	III — IV	Egyptian employees in meeting were shocked and attempted to jump in elevator.
Mr. C	Cairo	Office at the top of 3-story building	Reflector of ceiling light slipped off. The shock continued for one minute.	Similar to the level of shock felt at the construction site of nuclear generation plant at Tomioka-cho, Futaba-gun, Fukushima Pref at the time of Miyagi-Oki Earthquake in June 1978.	III — IV	One of office employees jumped out and two e
Mr. D	Cairo	8th floor of 26-story building	Felt like as shot by rocket. Was awfully shocked more than that felt in Japan.	Similar to that felt in Abiko City, Chiba at the time of Chiba-Toho-Oki Earthquake in 1920.	III or more — IV	Many Egyptians were stricken with panic. People jumped out to the hallway turned pale and were trembling.
Mr. E	Cairo	2nd floor of 10-story apartment	Felt like large objects fell down from upper floor.	Similar to that felt in Ryujin-mura, Wakayama Pref 12 or 15 years ago.	IV	People were stricken with panic. Some people were praying and some people were jumping out in naked feet.
Mr. F	Mohades Sean, Cairo	23rd floor of 25-story building	Unlocked desk drawers slid out. Blinds vigorously slapped window glass.	Never felt in the past.	Unknown	Some people jumped out of room and rushed into stairway as soon as shocks were felt. Some people stepped off the stairway and some cried with fear.

Table 3.7.1 Earthquake Shocks Felt in Cairo and Suez by Japanese Engaged in Construction Business (2)

Mr. G	Suez	Top floor of 6-story building	Weak shocks gradually became strong. Cups started to rattle on table. The shock continued for about 20 seconds.	Similar to that felt while sleeping in Kagoshima 7 or 8 years ago. I was jumped out at that time.	III	Heard children were crying. People were fell into panic for about an hour.
Mr. H	Suez	ditto	The shock continued for one minute. Nothing was damaged or fallen in the office.	Similar to the shocks felt twice (both the level of V) in Tokyo.	III — III+ (3.5)	People were relatively calm.
Mr. I	Suez		A carpenter working in the yard of the next door jumped out of the window.	Have felt similar shocks in Uwajima, Aichi and Tokyo.	II	Office employees were very much excited with the first experience. The work slowed down for the day.

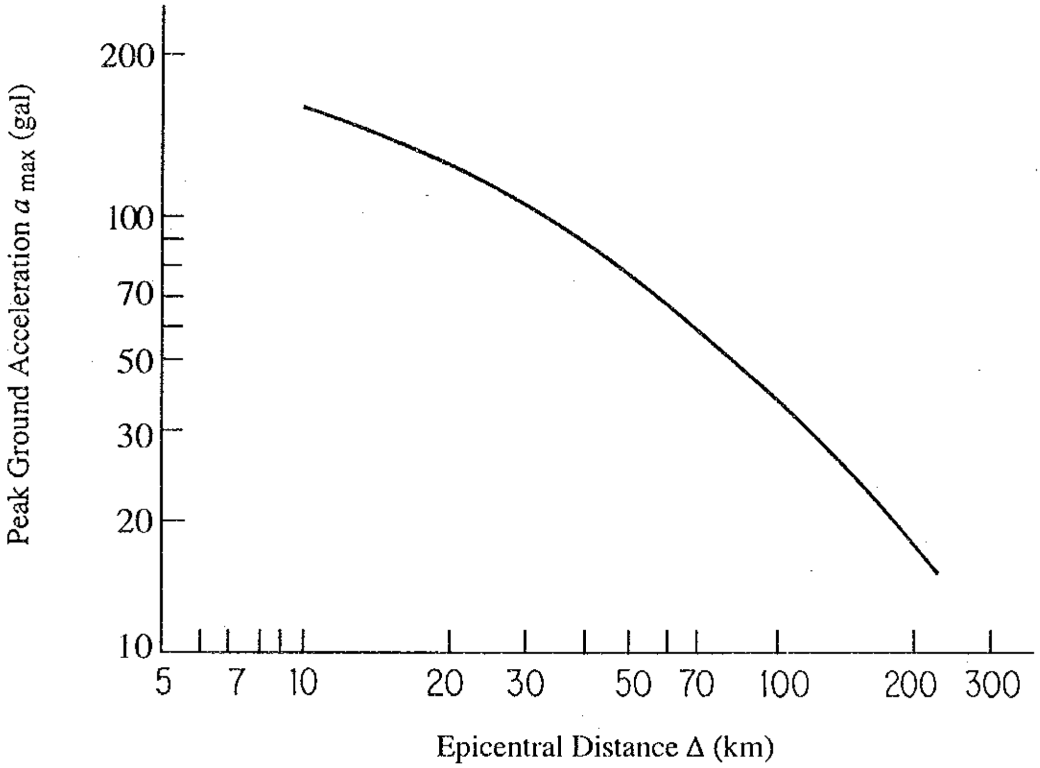

Fig. 3.7.1 Attenuation of Peak Ground Acceleration

3.8 Seismic Design Code for Buildings

3.8.1 Background

It had been believed in Egypt that the country was free from earthquake disasters. Therefore, the seismic design code was established only recently. In 1988, the Egyptian Society for Earthquake Engineering (ESEE) proposed a model code titled, "Regulations for Earthquake-Resistant Design of Building in Egypt," which is similar to the Uniform Building Code (UBC) of the United States. Unfortunately, it is said that these guidelines have not actually been put into practice. In late 1989, the Ministry of Housing and New Communities of Egypt issued a publication titled, "The Egyptian Code for Design and Execution of Reinforced Concrete Constructions." This code is a revised version of a 1912 edition and contains the first legal seismic design requirements.

Prior to the issuance of this revised version, wind resisting structural designs had been enforced in Egypt but it is not clear whether or not seismic design requirements had been enforced. However, the prominent buildings in Egypt, including skyscrapers, were supposed to be earthquake resisting, designed in accordance with seismic design procedures of the United States or other foreign countries. In the revised code of 1989, two design procedures, allowable stress design and ultimate strength design, are specified, but the former has been more widely used. Structural design based on dynamic response analysis is often provided for high-rise buildings of 30 to 40 floors.

In the meantime, seismic design requirements have not been specified for masonry structures such as those that were seriously damaged from the earthquake of October 12.

3.8.2 Seismic Loads in the Reinforced Concrete Structural Design Code

(1) Seismic Zone

The country of Egypt is classified into two seismic zones by seismic activity. The areas including Capital Cairo, Giza, and their outskirts, where the Disaster Relief Team mainly serveyed earthquake damage, belong to the first zone. Low seismic intensity is assumed for the first zone, where buildings are designed to withstand the shear force at 1% base shear coefficient, on the assumption that damage to buildings is supposed to be relatively small. Conversely, moderate seismic intensity is assumed for the second zone.

Meanwhile, detailed seismic zoning map is provided in the ESEE guidelines, but it is felt from our experience in Japan that there are grounds for controversy with regards to the adequacy of these maps. It is desirable that further studies and analyses be made in this field.

(2) Design Static Seismic Force

The total static horizontal force for the second zone can be obtained by Eq. 3.8.1.

$$V = 0.3\ KCIW \qquad (3.8.1)$$

Where,

V = total static horizontal force,
K = coefficient depending on ductility (K ranges from 2/3 to 3/4),
C = standard spectrum coefficient,
$C = 1/(15\sqrt{T})$
$T = 0.09H/\sqrt{B}$) (sec.)

H = height of building (m)
B = width of building toward related direction (m)
I = importance factor,
I = 1.5 (important buildings),
I = 1.0 (ordinary buildings), and
W = equivalent total vertical load.

The total static horizontal force should not be less than 1% and 2% of the equivalent total vertical load for buildings in the first and second seismic zones, respectively. Generally speaking, the maximum acceleration of design earthquake motion of about 30 to 40 gals is considered for the second seismic zone. However, it is necessary to increase this acceleration by 1.5 times to compare with the design acceleration used in Japan because a reduction factor of 1.5 in the Egyptian Code, is consider for the design strength of structural members.

The ESEE guidelines provide for the design shear force to be applied simultaneously with the forces described above, as well as a risk factor and a construction quality factor. Regardless of administrative definitions, it can be determined that these requirements for design shear force are complete from the engineering standpoint. Another important factor in evaluating design seismic forces in Egypt is the recurrence period of earthquakes. The recurrence period in Egypt for major earthquakes is significantly longer than that considered in other countries known to be in highly active seismic zones. It might be appropriate for the risk factor and the importance factor to also evaluate this recurrence period.

Since strong motion seismograms, required for discussing the magnitude of design earthquake motions, were not placed in Egypt, it is highly recommended that observations and studies in this field be strengthened in the future.

3.9 Earthquake-Resisting Design Criteria for Public Infrastructure

Current design criteria applied for public infrastructure construction in Egypt are the ministerial decrees established by the Housing and Utilities, New Communities, Ministry of Development. These criteria are classified into four categories, as shown below.

1) Steel Construction and Bridges (Ministerial Decree No. 451-1989)
2) Plastering Finish (Ministerial Decree No. 454-1991)
3) Reinforced Concrete Structures (Ministerial Decree No. 464-1989)
4) Soil Mechanics and Foundations
    ① Field Investigation (Ministerial Decree No. 444-1991)
    ② Laboratory Test (Ministerial Decree No. 445-1991)
    ③ Shallow Foundations (Ministerial Decree No. 446-1991)
    ④ Deep Foundations (Ministerial Decree No. 447-1991)
    ⑤ Soil Properties (Ministerial Decree No. 448-1991)
    ⑥ Foundations Subject to Vibration and Dynamic Loads (Ministerial Decree No. 449-1991)
    ⑦ Retaining Walls (Ministerial Decree No. 450-1991)
    ⑧ Stabilization of Slopes (Ministerial Decree No. 451-1991)
    ⑨ Shoring and Earth Anchors (Ministerial Decree No. 452-1991)

The steel structures referred to in "Steel Construction and Bridges" refer principally to the superstructure of bridges. The reason for this is because the superstructures of bridges were often constructed of steel in the past, whereas these days they are usually constructed of concrete, including prestressed concrete. Therefore, it can be determined that the "Steel Construction and Bridges" means the superstructure of bridges. The requirements are divided into the two sections of design and construction. The design section contains requirements for design loads, allowable stresses, fatigue factors, buckling, inspections, quality control, and permissible variations. However, requirements for earthquake-resisting design are not included.

"Soil Mechanics and Foundations" is divided into ten different ministerial decrees. The contents could not be fully understood because the criteria are written in Arabic, but the criteria appeared to be properly compiled. For instance, the section for "Retaining Walls" specifies the requirements for earth pressures, and the section for "Foundations Subject to Vibration and Dynamic Loads" specifies basic requirements including response spectrum, liquefaction, vibration tests using a vibration generator, ground reaction constant, attenuation constant, and proper period of oscillation. However, the latter criteria introduce only the seismic engineering requirements and their actual applications are not specifically described.

As stated above, relatively severe criteria are set forth but earthquake-resisting design requirements have not been established. The only exception is the Regulations for Earthquake Resistant Design of Buildings in Egypt, proposed by the Egyptian Society for Earthquake Engineering in 1988 [2)]. It appears that these regulations have rarely been applied in actual designs, but it is very interesting to know how such earthquake-resisting design criteria have been proposed and discussed among specialists. Therefore, we will introduce here a part of these criteria. These criteria are based on the concept of allowable stress design, and the allowable stresses or primary loads are assumed to be 1/3 of the design strength for concrete and 0.6 times the yield strength for steel, taking into account the following loads in combination.

1) $D + L_R + E$

2) $0.85D + E$ (3.9.1)

Where, D = dead load, L_R = live load, and E = seismic load. Design lateral seismic factor to determine the seismic load can be obtained by the following equation.

$$C_s = ZISMRQ \tag{3.9.2}$$

Where,

C_s = design lateral seismic factor,

Z = area correction coefficient, this can be obtained by the following equation.

$$Z = ACF \tag{3.9.3}$$

A = reference value of ground acceleration, based on Table 3.9.2,

C = standard acceleration response spectrum, based on figure 3.9.1,

F = ground correction factor, based on Table 3.9.2,

I = importance correction factor (1.0 to 1.5),

S = structural type correction factor (0.67 to 1.6),

M = material correction factor (0.8 to 1.2),

R = risk correction factor (1.0 to 3.0), and

Q = construction accuracy correction factor (1.0 or 1.2)

Each correction factor is specified in detail. For example, the importance correction factor (I) is the correction factor that represents the importance of the structure. This is supposed to be 1.5 for structures such as hospitals which become very important after earthquakes, 1.3 for structures which are most often used, and 1.0 for general residential buildings. The structural type correction factor (S) varies depending on the type of structure and how they withstand seismic forces. For instance, this is supposed to be 1.0 for moment resisting frame structures and 0.67 for ductile moment resisting frame structures. The material correction factor (M) is supposed to be 1.0 for reinforced concrete, 1.2 for prestressed concrete, and 0.8 for steel. The risk correction factor (R) varies depending on the risk of release. This is supposed to be 3.0 for dangerous objects such as noxious gas, 2.0 for natural gas, and 1.0 for any other containments that are not significantly dangerous. The construction accuracy correction factor (Q) is a very unusual factor. This is supposed to be 1.0 when requirements for inspection of construction at major phases are significantly prescribed in the contract agreement and 1.2 for other cases.

Let us try to obtain the design lateral seismic factor based on the above factors. Assuming that seismic zones are Zone 3 of the highest intensity and Zone 2 which is applicable to Cairo, the ground type to be Type 1 through Type 3, and the period of oscillation for bridges to be 0.4 second and 1 second, design lateral seismic factors, C_s, obtained by Eq. 6 and 7 will become as shown in Table 3.9.3. Importance correction factor (I) was assumed to be 1.3, applied to structures that are most often used. Calculations show that the design lateral seismic factor for Capital Cairo is between 0.03 and 0.08.

References:

1) Ministry of Development, New Communities, Housing and Utilities: Egyptian Code of Practice for Steel Constructions and Bridges (Ministerial Degree No. 451-1989), Egyptian Code of Practice for Plastering (Ministerial Decree No. 454-1991), Egyptian Code of Practice for Reinforced Concrete (Ministerial Decree No. 464-1989), Egyptian Code of Practice for Soil Mechanics and Foundations. For Egyptian Code of Practice for Reinforced Concrete, the following publication was referenced: El-Behairy, S.: Reinforced Concrete Design Handbook, Vol. 2, Application to the New Egyptian Code for Design and Construction of Reinforced Concrete Structures, Ain Shams University, 1990.
2) Egyptian Society for Earthquake Engineering: Regulations for Earthquake Resistant Design of Buildings in Egypt, 1988

Table 3.9.1 Standard Ground Acceleration Value

Zone	MM Seismic Intensity	Ground Acceleration A
0	≤ V	0
1	VI	0.02 g
2	VII	0.04 g
3	VIII	0.08 g

Table 3.9.2 Correction Factor by Ground Category

Ground Category	Definition	Correction Factor
1	Rock, firm or very coarse soil, very hard or hard coarse soil, firm and fine soil of 15 m of less in thickness.	1.0
2	Relatively firm and coarse soil, firm fine soil of 15 m or more in thickness, very loose or loose coarse soil of 15 m or less in thickness, very soft or soft fine soil.	1.3
3	Very loose or loose coarse soil, very soft or soft fine soil of 15 m or more in thickness.	1.5

Table 3.9.3 Estimated Design Horizontal Seismic Intensity for Bridges

(a) For Zone 3 (A = 0.08 g)

Proper Period	Type 1	Type 2	Type 3
0.4 sec	0.10	0.14	0.16
1 sec	0.05	0.07	0.08

(b) For Zone 2 (A = 0.04 g)

Proper Period	Type 1	Type 2	Type 3
0.4 sec	0.05	0.07	0.08
1 sec	0.03	0.03	0.04

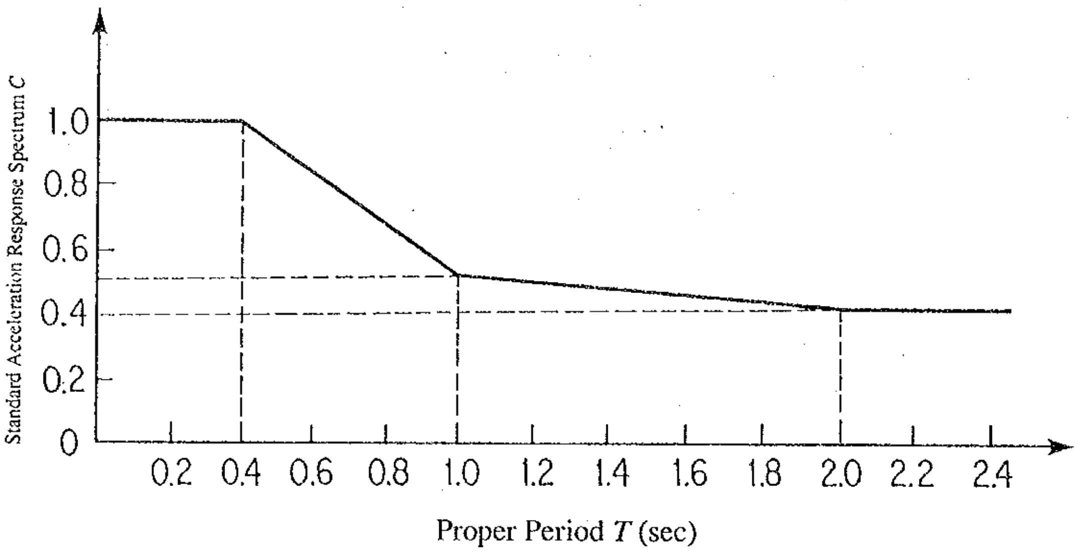

Fig. 3.9.1 Standard Acceleration Response Spectrm (Attenuation Constant 5%)

3.10 Overall Damage Evaluation

Details of damage resulting from the 12th October 1992 earthquake are shown below.

(1)	Personal	
	Deaths	561
	Injuries:	12,192
	hospital treatment required	2,270
	hospital treatment not necessary	9,922
(2)	Educational facilities (number of institutions)	
	Major repairs necessary	2,301
	Minor repairs only	3,569
	Totally unusable	1,087
(3)	Mosques	
	Major repairs necessary	211
	Minor repairs necessary	544
(4)	Historic sites	
	Major repairs necessary	14
	Minor repairs necessary	104
(5)	Housing	
	Major repairs necessary	4,395
	Minor repairs necessary	22,235
	Totally unusable	7,796

Sources: (1) - (4): Figures released by the Prime Minister October 31.
(5): Data from General Ameen of Local Administration.

Overall Cairo, Giza and Fayoum suffered the greatest human casualties. In one incident 200 students died not as a result of the earthquake itself but in stairways and similar locations during the subsequent stampede in the panic to evacuate. In Helipolice 73 people died when an aging 14-storey apartment building on wooden supports collapsed. Fortunately there were few outbreaks of fire.

As far as could be determined from the investigation, property damage was greatest in Giza and Faiyum. In some cases tents had been set up in the school grounds and classes had restarted from as early as 31st October. We also saw temporary housing in the form of tents set up near damaged homes. These are shown in Photographs 3.10.1 to 3.10.5.

Liquification was observed between Al Aiyat in the south of Giza and Dahshor, but this did not appear to have caused damage to housing or other structures. There was little damage to civil engineering works.

The above damage assessment was carried out directly after the earthquake by a large number of engineers in an atmosphere of great urgency, with the relevant forms for educational facilities being handled by the Ministry of Education. The majority of the reports inevitably reflect the subjective assessments of individual engineers. Many buildings which are now fit for use following repairs and/or strengthening work are nevertheless still classified as 'totally unusable'. To avoid this it is necessary to develop a set of damage assessment guidelines covering all building types, similar to those shown in Appendices I-8, 9 and 10.

Photo 3.10.1 Damaged school (El Aiyat)

Photo 3.10.2 Tent classroom (El Aiyat)

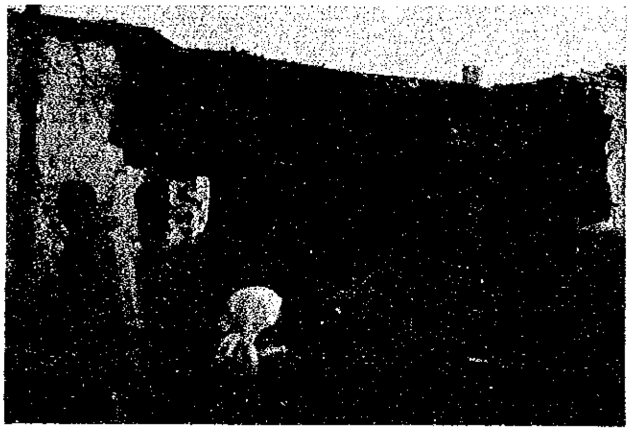

Photo 3.10.3 Damaged housing (El Aiyat)

Photo 3.10.4 Temporary tent housing (El Aiyat)

Photo 3.10.5 Temporary tent housing (El Aiyat)

3.11 Damage to Buildings

3.11.1 General Description

The Disaster Relief Team conducted investigations on damage to buildings from the earthquake in four districts: the east part of downtown Cairo, Giza City and its suburb, and the north area of Fayum.

Buildings were generally damaged to a degree corresponding to the seismic intensities that were estimated based on seismic engineering procedures.

Significant damage was found mostly in adobe or old non-reinforced masonry buildings and non-engineered reinforced concrete buildings. Meanwhile, no damage to high-rise buildings was reported (see Photos 3.11.1 and 3.11.2).

3.11.2 Earthquake Damage by Type of Structure

(1) Masonry Buildings

It was reported that a number of adobe (sun-dried clay brick) and non-reinforced brick masonry buildings were totally destroyed or severely damaged.

Many of these old, 3 to 5-story masonry buildings are concentrated in Old Cairo. These buildings are mainly used as residential buildings, the materials were extremely deteriorated and the level of damage is significant (see Photos 3.11.3 through 3.11.5).

With respect to the number of floors, masonry buildings of such a large number of floors are unusual in highly seismic countries. It will be impossible to repair or retrofit these buildings without costing more than the new construction. Some of these buildings were temporarily shored with square lumber what we call props (see Photo 3.11.6). It is doubtful if this type of reinforcement can be effective for heavy masonry buildings. More effective measures should have been provided earlier. Most of these buildings have cantilever stairways built of stone inside the buildings. These stairways were found damaged in several buildings (see Photos 3.11.7 and 3.11.8).

In Egypt, most old mosques were constructed of stone masonry. Some of these mosques were found damaged (see Photos 3.11.9 through 3.11.12). However, some of the damage to these buildings could have had occurred before this earthquake. In any event, these are historical buildings and it is desirable that permanent repair of cracks be accomplished by injecting epoxy resin grout . It is considered that the current roofing system and the structural detail of dome should be improved. In areas outside the city, damage to stone masonry schools and residential buildings were noted, in addition to the damage to mosques (see Photos 3.11.3 and 3.11.4).

Adobe buildings (see Photos 3.11.15 and 3.11.6), which are typically used for housing in rural areas of Egypt, are characterized by a peculiar roofing structure. This could cause serious damage to adobe buildings. In Egypt, the roof structure is simply supported by cross beams (mainly made of palm trees) laid on the top of two opposite bearing walls. The roof structure is covered with layers of palm leaf stems and layers of mud. The top of mud layer is covered with lightweight dried plant products. Therefore, the weight of roofing varies depending on the thickness of the mud layers. The damage to adobe buildings can be classified into two types by the weight of the roof. The first type is the fracture by bending of the central part of the cross beams, resulting from the heavy load of the roofing (see Photos 3.11.17 and 3.11.18); the second is a type of damage that is often seen on lightweight roofing. This is damage by overturning of bearing walls because the roofing system can little withstand the out-of-plane movement of the bearing walls (see Photos 3.11.19 and 3.11.20).

Future disaster prevention planning should include measures to protect adobe buildings from earthquake damage, taking into full account such types of damages that occurred this time.

(2) Reinforced Concrete Buildings

Prior to describing the damage to reinforced concrete buildings, let us first discuss the general description of reinforced concrete structures in Egypt.

It is said that concrete having a compressive strength of 20 to 30 MPa is normally used. The maximum size of aggregate is specified, but large rocks over 5 cm diameter, which greatly exceeds the specified size, have actually been used (see Photo 3.11.21). The manufacture of deformed bars was started in Egypt a few years ago and these bars are being used in civil engineering structures and high-rise buildings, but plain round bars are still used in general building construction.

Critical points that should be modified from the standpoint of construction include the improvement of poor construction joints in concrete and improvement of re-bar arrangement. The poor construction joints in concrete could be caused by poor formwork, because of a shortage in wood materials (see Photos 3.11.22 and 3.11.23). Regarding the arrangement of re-bars, main bars were found spliced without hooks, and ends of lateral re-bars were often bent to a 90° hook instead of 135° (see Photos 3.11.24 and 3.11.25). This type of re-bar arrangement is not recommended in seismic countries. Further improvement is desirable.

Observing the plan of residential buildings, columns were aligned offset to the center line (see Photo 3.11.26). Extreme precautions are necessary for buildings with offset columns because such buildings often show poor structural performance.

Significant damage was noted mostly in buildings that were illegally constructed or constructed by poor construction work. Typical illegally constructed buildings were those modified with additional floors. These types of buildings were noted in many places in Egypt. It was reported that upper floors, beyond the approved number of floors, were added illegally after the construction permit was approved. The 14-story reinforced concrete frame building in Heliopolis which was totally destroyed, and where more than 60 persons were killed, was one of these illegal buildings. It is said that this building was first approved as an 8-story building but six more floors were added after the approval of construction (see Photos 3.11.27 and 3.11.28). This building has the typical plan of moderate and high-rise buildings in Egypt, and columns are aligned offset to the centerline as described earlier (see Photo 3.11.29). Columns had a flat cross section and plain re-bars were used for longitudinal bars (see Photo 3.11.30). Re-bars were arranged in a manner very similar to frame structures with wall columns in Japan. It was reported that this building collapsed after shaking with large amplitude for a few minutes. It is said that the eighth floor, at the bottom of added floors, failed first and resulted in the collapse of the overall building.

Typical examples of poor construction work are school buildings. Since school buildings are public facilities, they are not bound by the insurance systems legally applied to private buildings. These insurance systems are considered to be the important key to quality assurance of buildings in Egypt. Therefore, the quality of concrete and construction was generally worse than that of other construction. Damage that apparently had occurred prior to this earthquake was often noted in structures (see Photos 3.11.31 and 3.11.32).

There were same damage examples which provided evidence that structural plans were deficient, rather than poor construction work. Since little expansion joint space had been provided between buildings, damage was accelerated by the collisions of adjacent buildings (see Photos 3.11.33 and 3.11.36). The reason for school buildings often being provided with expansion joints may be that the government funds are allocated in each fiscal year. The collision of buildings can often cause severe damage, beyond expectations, as seen in the

Mexico Earthquake of 1985. During this earthquake, not only were expansion joints damaged, but shear failures occurred in columns and brick masonry walls. Collapsed columns were not reinforced with lateral rebars at the spacing specified (or such a reinforcement was little found). This can be a cause of great damage.

(3) Composite Construction

Old buildings in Egypt are composed of different materials, such as adobe or brick, stone masonry, and reinforced concrete; the various materials mixed in plane or three-dimensionally. With these types of buildings, the weaker portions were severely damaged.

(4) Steel Frame Construction

Damage to steel frame structures was not reported. Also, no damage was reported to composite high-rise buildings that are composed of steel and reinforced concrete.

(5) Residential Buildings

a) General Description of Damage

Damage to residential buildings was most significant in the district of Giza. Rural communities in El Aiyat were damaged in particular. For example, damage to Berwash village (population approximately 5,000 and the number of houses 1,000), located near the focus, was roughly as described below, as noted by the investigation team.

① Deaths: 16 persons (one person was crushed to death under a collapsed school).
② Injured: about 100 persons
③ Houses totally collapsed: about 300 (30% of the total)
④ Seriously damaged houses: about 500 (50% of the total)
⑤ Lightly damaged houses: about 100 (10% of the total)
⑥ It was explained that 1,000 to 1,500 persons were still living in tents.
(see Photos 3.11.37 through 3.11.39)

According to Ministry of Housing and Communities, damage was significant in the deteriorated houses densely distributed in urban areas such as Cairo, and collapsed or unrepairable houses totaled 13,000 and repairable houses totaled 23,000 (see Photos 3.11.40 and 3.11.41).

b) Accommodations for Earthquake Victims

The Government of Egypt provided emergency tents to accommodate victims, and determined to rush the completion of 50,000 houses that had been under construction in a new town to divert them for victims.

In addition, the new law "Compensation Law for Victims from Earthquake" was to be legislated.

c) Restoration of Residential Houses in Urban Districts

The Government of Egypt established a joint committee of the Ministry of Housing and Communities, Defense Technological Bureau, and City Government. Local governments conducted inspections of damage to buildings, which was classified into three categories. Category 1 is "unrepairable," Category 2 is "major repair is required," and Category 3 is "minor repair is required." The Ministry of Housing and Communities provided the guidelines of immediately restoring Category 1 damage, including damage to historical spots such as Az Har District with priority to others, by the government, Category 2 damage also by the government, and Category 3 damage by owners.

d) Restoration of Houses in Rural Areas

The Ministry of Housing and Communities is now preparing two plans for restoration of housing in rural areas. The first plan is to rebuild houses equal to those damaged. The second plan is to construct new type houses after a study. In either case, the Ministry of Housing and Communities was under pressure to promptly cope with the restoration of damaged houses. Technical cooperation of the Government of Japan was strongly anticipated.

e) Comments

The reason the rural areas were severely damaged is mainly because the areas were close to the focus and heavily subjected to direct shocks of high intensity. In addition, the adobe structure and thick mud roofs further accelerated the damage.

Therefore, new structures should be constructed of materials other than adobe.

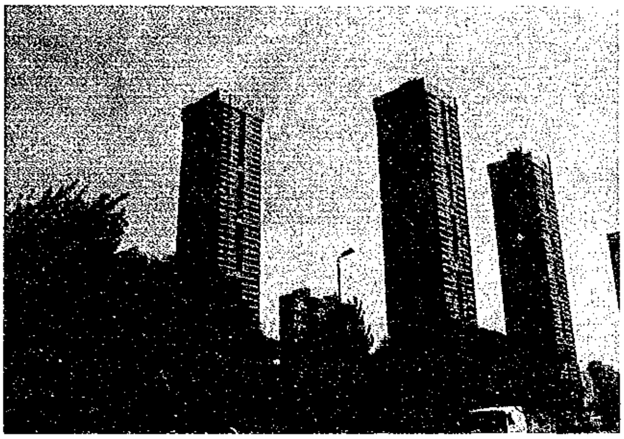

Photo 3.11.1 42-story skyscrapers in the Capital Cairo

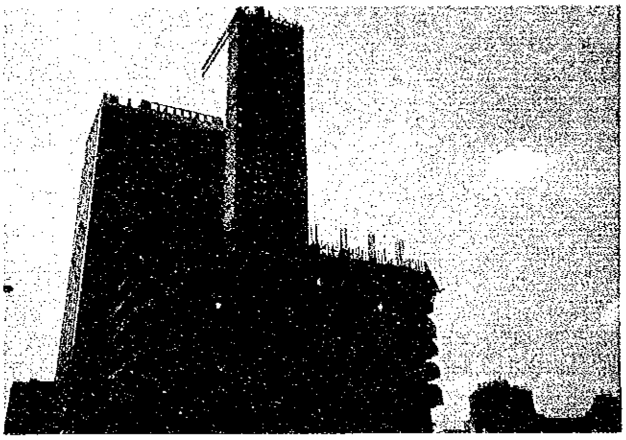

Photo 3.11.2 Reinforced concrete skyscraper under construction

Photo 3.11.3 5-story non-reinforced masonry residential building crushed to mud (building seen in the rear is the same type building)

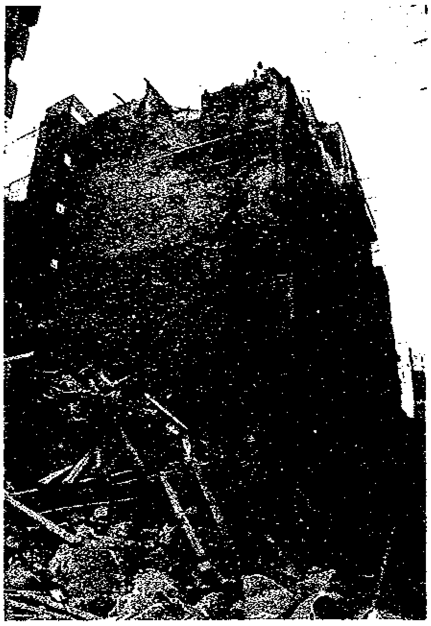

Photo 3.11.4 Closed up of the building in the rear side in Photo 3.11.3 (materials have deteriorated significantly and the building is ready to collapse at any time)

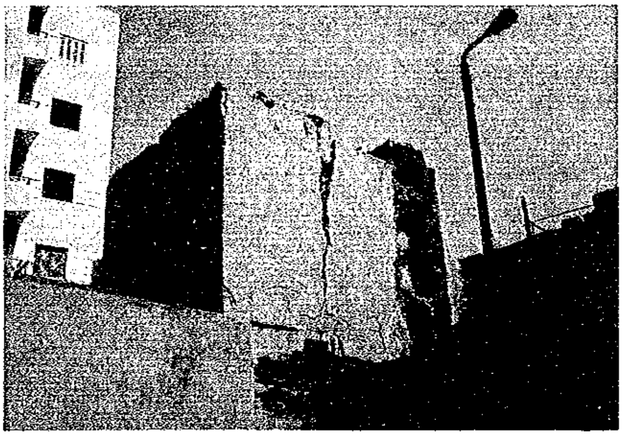

Photo 3.11.5 Non-reinforced masonry building (walls fell off out-of-plane)

Photo 3.11.6 Temporary retrafit masonry buildings by wood supports

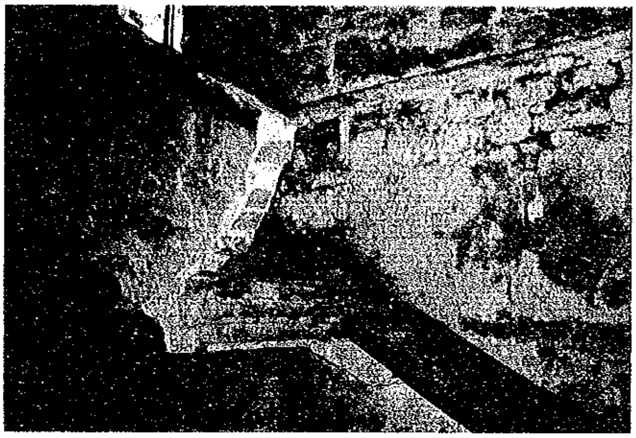

Photo 3.11.7 Damaged interior stone stairways of non-reinforced masonry building (1/2)

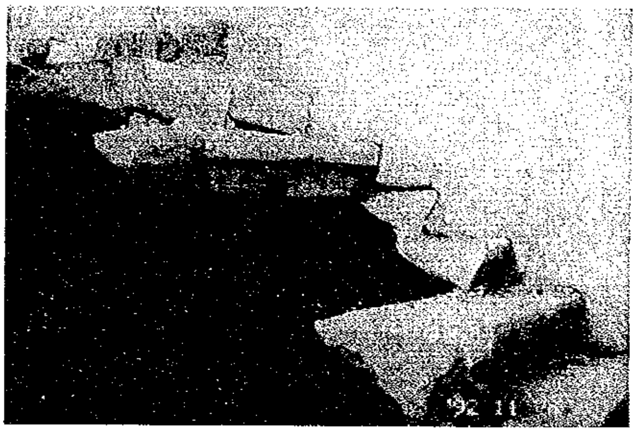

Photo 3.11.8 Damaged interior stone stairways of non-reinforced masonry building (2/2)

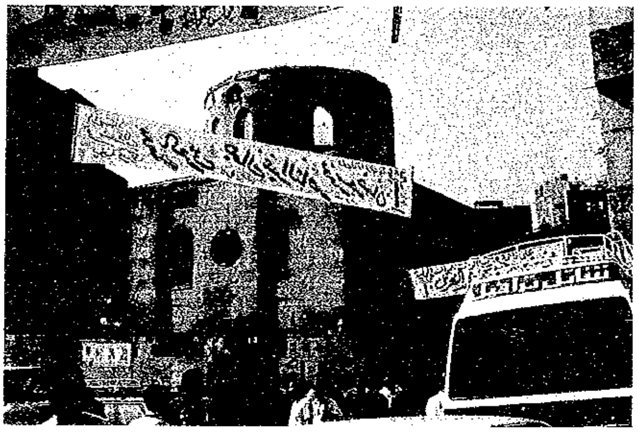

Photo 3.11.9 Old stone masonry mosque with its dome collapsed

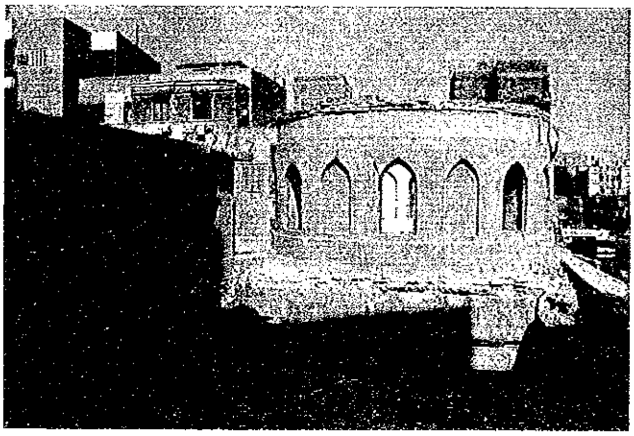

Photo 3.11.10 Structure of the mosque exposed after the dome collapsed and roof destroyed by dome

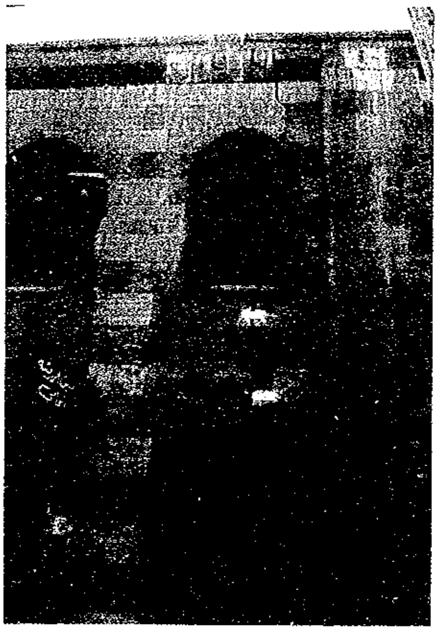

Photo 3.11.11 Cracks occurred on exterior wall

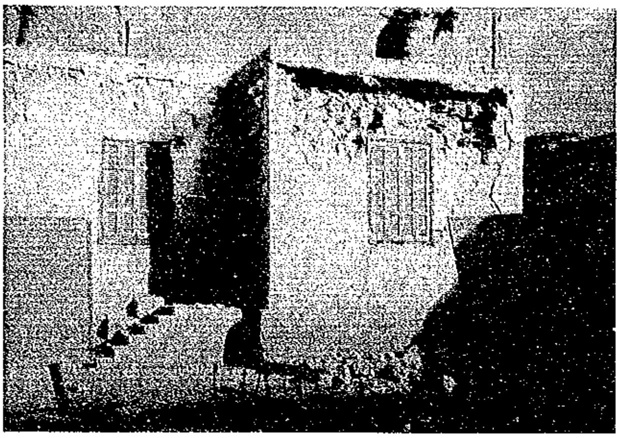

Photo 3.11.13 Damaged stone masonry school building

Photo 3.11.12 Cracks occurred on the wall above the arch which is supported by steel pipe

Photo 3.11.14 Totally collapsed stone masonry building

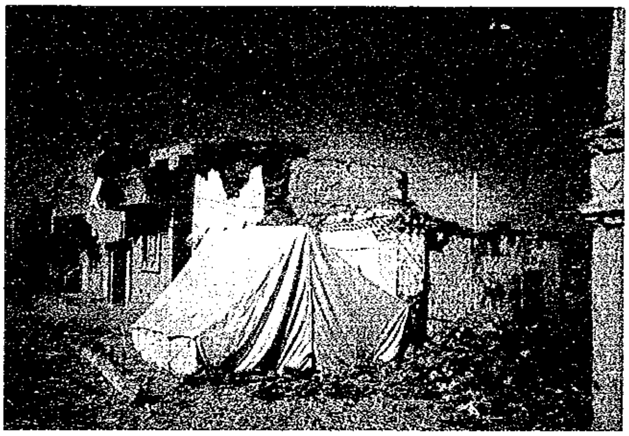

Photo 3.11.15 Collapsed adobe building and the relief tent (Second story which supported roof is badly damaged in most cases)

Photo 3.11.16 Sun-dried bricks used for adobe building

Photo 3.11.17 Roof collapsed almost

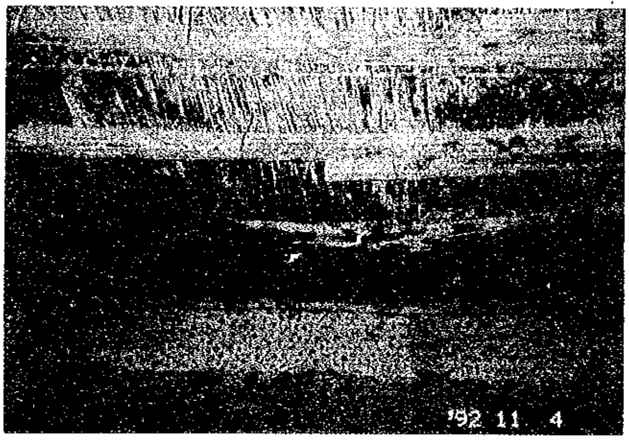

Photo 3.11.18 Cross beams are bent at the center due to vertical loads and about to fall down

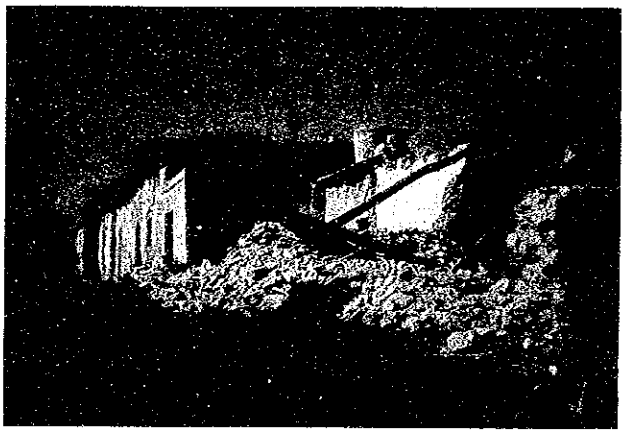

Photo 3.11.19 Adobe building collapsed by out-of-plane overturning of walls

Photo 3.11.20 Wall overturning toward out-of-plane direction (walls are little bound by the roof)

Photo 3.11.21 Aggregate for concrete (white object on the center is rubber eraser)

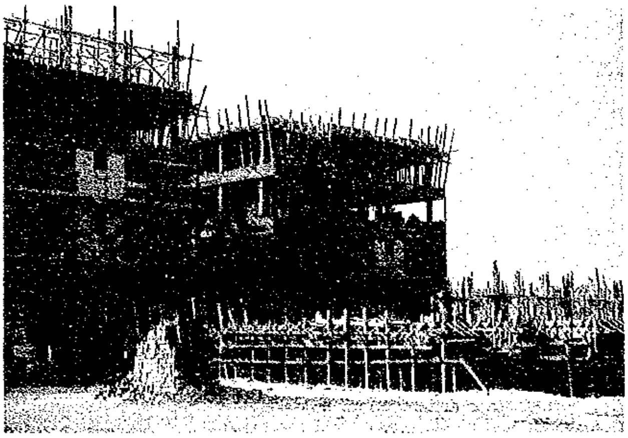

Photo 3.11.22 Reinforced concrete residential buildings under construction

Photo 3.11.23 Poor construction joint in the column

Photo 3.11.24 Reinforcement for the bottom of column (lapping splices without hook)

Photo 3.11.25 Arrangement of reinforcing bars for column (ends of shear rebars are recommended to be bent to 135• hook)

Photo 3.11.26 Girders and beams of resiential building (columns are laid out offset)

Photo 3.11.27 14-story residential building collapsed in Heliopolis prior to the earthquake (contributed by the Egyptian Gajette)

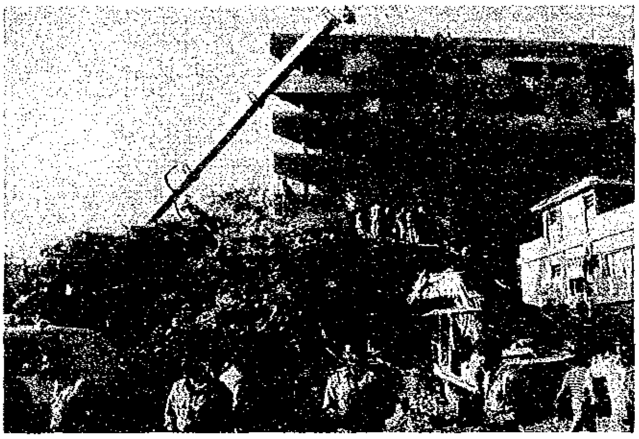

Photo 3.11.28 14-story residential building after collapsed (contributed by Mr. Furuichi, Kajima Corporation)

Photo 3.11.29 Foundations of 14-story residential building collapsed in Heliopolis

Photo 3.11.30 Damaged column and its reinforcement of 14-story residential building collpased in Heliopolis (cross sectional dimension: approx. 130cm×30cm)

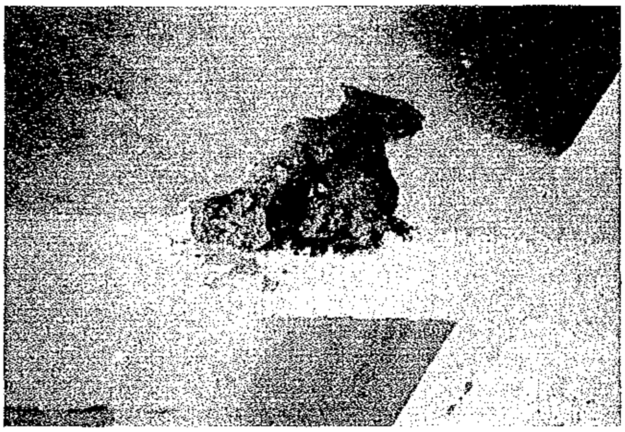

Photo 3.11.31 Concrete cover spalled and main re-bars exposed in beam (the splice of main bar is exposed and cover concrete around the hook dropped off.)

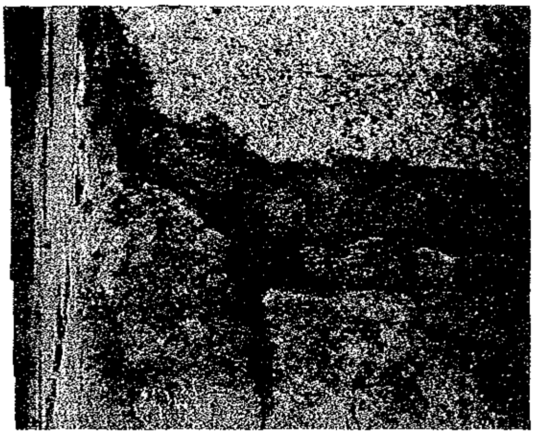

Photo 3.11.32 Shear failure occurred in the beam-column joint (this damage had occurred prior to the earthquake.)

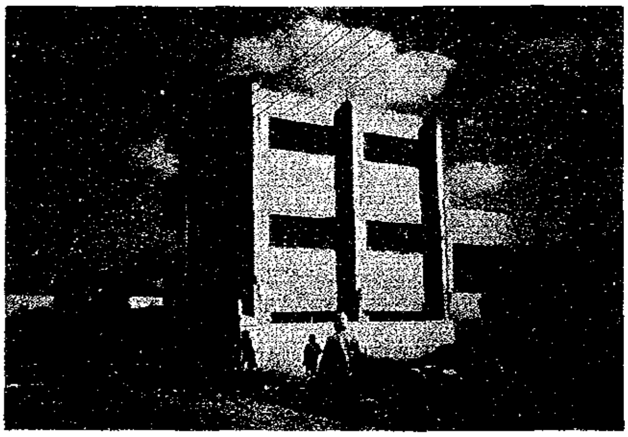

Photo 3.11.33 School building damaged by the collisions of buildings (1/2) (wide crack observed at expansion joint)

Photo 3.11.34 Shear failure of column facing expansion joint (lateral re-bars cannot be seen)

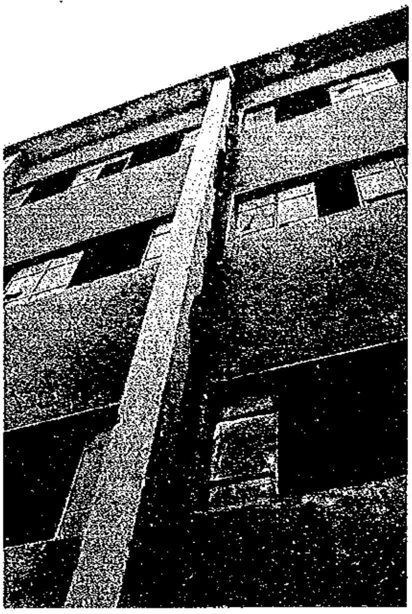

Photo 3.11.35 School building damaged by the collision of buildings (2/2)

Photo 3.11.36 Shear failure occurred in column of the above building

Photo 3.11.37 Damaged house in rural area (El Aiya)

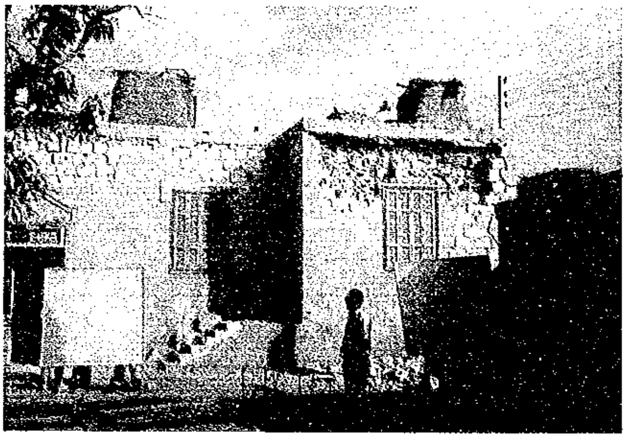

Photo 3.11.38 Damaged stone masonry elementary school building in Berwash

Photo 3.11.39 Classroom in tent

Photo 3.11.40 Adobe masonry house collapsed in Cairo

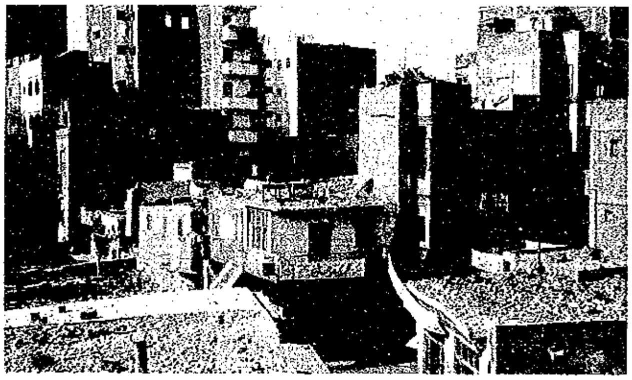

Photo 3.11.41 Densely inhabited residential district in Cairo

3.12 Damage to Infrastructure

3.12.1 Damage to Roads and Bridges

Fortunately, during this earthquake roads and bridges were not damaged, except for one cave-in. With the assistance of the General Authority for Roads and Bridges, Ministry of Transport, we could inspect four bridges in Cairo and its outskirts. The following is the report of the inspection.

(1) Zamalek Bridge

This is an elevated PC continuous box girder bridge, crossing over July 26th Street in downtown Zamalek, located on Gezira Island in Capital Cairo. The bridge was completed in April 1986. The bridge is characterized by continuous multiple spans, and consists of one section with 21 continuous spans (20 × 25 m + 23.5 m = 523.5), and another with 12 continuous spans, with one span in the center. The structure is of box girders with a cross section shown in Fig. 3.12.1, supported on rubber bearings. However, both the 21-span and 12-span structures are anchored to fixed piers at one place. Piers are hollow having the shape of a reversed trapezoid, taking into consideration the appearance to match the view of adjacent areas. Since seismic forces are not considered, the fixed piers have the same cross section as that of other hollow piers. Photos 3.12.1 and 3.12.2 show the details of the elevated bridge.

The bridge is located in Cairo where a number of buildings were severely damaged, but it appears to be stable, significantly different from the damaged buildings described earlier.

(2) Faraskour Bridge

The Nile River is divided into two channels, called Rosetta (west side) and Damietta (east side), in the Nile delta north of Cairo. The Faraskour bridge is an 18-span PC bridge being constructed over the channel on the Damietta side near the river mouth in Faraskour (150 km north of Cairo and 180 km from the focus). Photos 3.12.3 through 3.12.5 show the bridge, which has a total length of 720 m (40 m × 7 + 50 m + 60 m + 50 m + 40 m × 8). The depth of water ranges from 4 to 6 m. The ground is composed of soft clay to a depth of 29 m below the river bottom, with a sand layer to a depth of 30 m, then bedrock. Foundations are constructed of Benoto piles of two different sizes, 1.08 m and 0.88 m diameter. Both size piles were designed as bearing piles, ignoring side friction.

Of great interest is that load tests are conducted for any bridge over a certain size, on at least two piles for each bridge, prior to the start of pile driving. Load tests are performed to check the resisting strength of piles, normally with a load of three times the design bearing capacity for friction piles and with a load of two times the design bearing capacity for bearing piles. Photo 3.12.6 shows the piles (1.08 m diameter) tested for construction of this bridge. It is said that the piles were tested to verify the yield strength, with vertical loads up to 480 tf, two times the design bearing load of 240 tf. These piles were assumed to have the bearing stress of 28 kgf/cm^2 in a vertical direction at the tip of pile. This anticipates a safety factor of 2 to 2.5 against the yield stress.

Another interesting point in design of piles is that the vertical bearing strength of the ground within the range from the river bed to a depth of 8 m has been ignored. Seismic forces were not considered, but these considerations can be effective for assuring lateral restoring for pile foundations in the river bed.

(3) Mansula Bridge

This is a 24-continuous-span bridge being constructed over the Nile River on the Damietta side in Mansula City, 140 km from Cairo. The bridge has a total length of 984 m. Continuous span bridges with as many as 24 continuous spans are not seen in Japan. The design appears very aggressive, but such a long continuous-span bridge could be designed because seismic forces are not considered in Egypt , the superstructure can be less expensive, comfort driving can be maintained, and the number of joints can be minimized. Foundations are Benoto piles, 1.08 m in diameter. The piles have the lengths of 30 to 35 m. Photos 3.12.7 through 3.2.10 show the details of the Mansula Bridge.

(4) Benisuef Bridge

This is a PC bridge, 1,086 m long and 21 m wide, crossing over the Nile River at a location 110 km south of Cairo, 80 km from the focus. Photos 3.12.11 and 3.12.12 show overall views of the bridge and Photo 3.12.13 shows a bearing shoe. The middle part of the bridge consists of 3 continuous PC box girder spans, a center span of 80 m and a total length of 174 m, constructed by the Dywidag prestressing method. Foundations are constructed of 1.3 m diameter Benoto piles.

(5) Various Bridges

Photos 3.12.14 through 3.12.21 show various elevated bridges in Cairo. Photos 3.12.22 and 3.12.23 show the arrangement of reinforcing bars for bridge piers under construction in Cairo. Deformed bars made in Egypt from a few years back were used, and hoop ties were properly placed. Photo 3.12.24 shows a pedestrian crossing a bridge in Cairo.

A number of rotary bridges, as shown in Photo 3.12.25, are crossing over the Damietta tributary of the Nile River. These bridges are provided because the tributary plays a role of a canal. Photo 3.12.26 shows a rotary bridge under construction.

3.12.2 Damage to Lifelines

Lifelines include various facilities such as water supply systems, drainage and sewage systems, electrical power lines, and telephone communication lines. Since the time for investigation was very limited, all of these facilities could not be fully investigated. The following facts were determined as a result of the limited investigations.

(1) Water Supply System

The water supply system for the capital region is operated by the Greater Cairo Water Supply Authority under the jurisdiction of the Ministry of Housing and Communities. The Greater Cairo Water Supply Authority is organized as shown in figure 3.12.2 [1]. Potable water is distributed from 11 purification plants and 5 deep wells for the capital region. Figure 3.12.3 shows the layout of purification plants.

The current demand population is 2 million and the maximum distribution capacity is approximately 4 million m^3/day, 90% taken from the Nile and the remaining 10% from deep wells [1]. If the leakage, described later, can be ignored, 200 liters of water can be supplied for each person. This is a very excellent number. According to the Water Supply Authority, the average demand is 300 liters/person in the center of the city and 150 liters/person in the outskirts.

Current problems that must be resolved are the deteriorated piping and high rate of leakage. It is said that the piping is often terminated without circulation and that the distribution network systems have not been properly established [2]. The rate of leakage is less than 15% in new systems but it reaches 30 to 40% in the old systems. Major causes for leakage are because asbestos cement pipes, that are prohibited in Japan for health reasons, are still used in many places and polyvinyl chloride pipes are often mixed and joints are not tightly fastened.

Door-to-door water supply is not available in some areas in the Capital Cairo. Common faucets are often provided as shown in Photo 3.12.27. Photo 3.12.28 shows a common water faucet in Fayoum District. Common faucets are seen in many places in local areas. Well water is also frequently used.

Water supply systems received minor damage, but were not affected to the degree that the water supply was interrupted.

It is said that door-to-door water supply systems are almost complete in the Capital Cairo. Photo 3.12.29 shows an overall view of the Rod El Farag purification plant [1]. Two systems, old and new, are employed in this plant, which distributes water in the amount of 750,000 m^3/day. In this plant, the leakage from the drainage duct of the sedimentation basin, shown in Photo 3.12.30, increased after the earthquake, joints in the concrete reservoir slipped, as shown in Photo 3.12.32, and shear cracks occurred in the non-reinforced brick walls of the pumping room, as shown in Photo 3.12.33.

Photo 3.12.34 shows an overall view of the Derasa Water Reservoir being constructed in the east part of Cairo. This reservoir is reinforced concrete construction, 80 m in diameter and 7 m high, with a storage of capacity of 30,000 m^3. Photo 3.12.35 shows the 1.2 m diameter ductile cast iron pipe to be used for the distribution system. The ductile cast iron pipe was rigidly connected with the reservoir tank as shown in Photo 3.12.36. In Japan, a flexible connector is often used at locations of soft ground because the piping can move at an amplitude different from that of reservoir tank and can be easily damaged during earthquakes. The reservoir had a rigid construction and the joints between columns and the ceiling inside the tank was reinforced with the bent bars of column reinforcement and tightly fastened with hoop ties, as shown in Photo 3.12.37.

(2) Drainage and Sewage Systems

We had no time to directly inspect the drainage and sewage systems. The results of questioning and a literature survey [2] are as described below.

Drainage and sewage systems in Cairo are administered by the Greater Cairo Sewage Authority also under the jurisdiction of the Ministry of Housing and Communities. The Greater Cairo Sewage Authority is organized as shown in figure 3.12.4.

Public drainage and sewage systems are not complete in many areas in the Capital Cairo. In those areas, common cesspools maintained by several families are vacuumed at a frequency of two times a week.

Drainage and sewage piping systems have not been constructed based on an established plan, but the network has been expanded as necessary, depending on the development of the urban area. In some areas, two pipelines are laid out under a narrow road. There are also public piping systems constructed by the city, amongst private systems. Technical standards are little observed for the latter. Where water distribution piping is provided, water cannot be distributed to the sewage system because of the difference in elevation. In these areas cesspools are still being used.

Under the circumstances stated above, the affects of the earthquake could not clearly be determined, but it is sure that the systems were not significantly affected.