付　属　資　料

Preliminary Report

OCTOBER 12 , 1992 CAIRO EARTHQUAKE

-Preliminary Investigation and Recommendations-

by

Japanese Expert Team
as dispatched by the Japanese Government
through Japan International
Cooperation Agency (JICA)

November 10, 1992

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1. Introduction

This report briefly describes the activities of the Japanese Expert Team dispatched by the Japanese Government through the Japan International Cooperation Agency (JICA) to cooperate with the Ministry of Scientific Research, and other organizations related to earthquake hazard in the Arab Republic of Egypt in estimating the October 12 Cairo earthquake and its damage, in rehabilitating the damaged structures, and in establishing the future earthquake preparedness.

The report also includes preliminary recommendations for the earthquake preparedness in future.

A final report will be prepared later based upon detail analysis of the data since the stay in the Arab Republic of Egypt is quite limited.

2. Itinerary and Members

2.1 Itinerary

DAY	SCHEDULE			
10.30 (FRI)	00:30 Ar.CAIRO by KL 553			
10.31 (SAT)	08:45 Lv. HOTEL 09:00 Courtesy Call on EMBASSY OF JAPAN 10:00 Courtesy Call on STATE MINISTER OF SCIENTIFIC RESEARCH 11:00 Observation Epicenter (Dahshur) 17:10 Ar. HOTEL			
11.01 (SUN)	09:00 Lv. HOTEL 10:00 NATIONAL RESEARCH INSTITUTE OF ASTRONOMY AND GEOPHYSICS (Hearing About the Situation of the Earthquake, etc) 17:20 Ar. HOTEL			
11.02 (MON)	09:45 Lv. HOTEL 10:00 STATE MINISTER OF SCIENTIFIC RESEARCH 11:00 City Observation 17:00 Ar. HOTEL			
11.03 (TUE)	EARTHQUAKE PREVENTION GROUP		EARTHQUAKE GROUP	
	09:45 Lv. HOTEL 10:00 CONSTRUCTION RESEARH CENTER 12:50 Observation of under construction buildings 17:00 Ar. HOTEL	Making Report at HOTEL 11:30 Lv.HOTEL 11:45 GENERAL ORGANIZATION FOR GRATER CAIRO WATER SUPPLY AUTHORITY 17:00 Ar.HOTEL	09:00 Lv. HOTEL 10:00 NATIONAL RESEARCH INSTITUTE OF ASTRONOMY AND GEOPHYSICS 17:00 Ar. HOTEL	
11.04 (WED)	EARTHQUAKE PREVENTION GROUP		EARTHQUAKE GROUP	
	09:00 Lv. HOTEL 09:30 CAIRO UNIV 11:30 Observation of damaged area (GIZA) 17:00 Ar.HOTEL	11:30 GENERAL AUTHORITY for ROADS & BRIDGES 18:00 Ar.HOTEL	09:15 Lv.HOTEL 09:40 EGYPTIAN GEOLOGICAL AUTHORITY 17:00 Ar.HOTEL	Making Report at HOTEL
11.05 (THU)	EARTHQUAKE PREVENTION GROUP		EARTHQUAKE GROUP	
	11:30 Lv. HOTEL 12:00 STATE MINISTER OF SCIENTIFIC RESEARCH 13:30 Ar.HOTEL Making Report at HOTEL	09:00 Lv.HOTEL 09:30 GENERAL ORGANIZATION FOR GRATER CAIRO WATER SUPPLY AUTHORITY 10:30 GENERAL AUTHORITY for ROADS & BRIDGES 17:00 Ar.HOTEL	09:00 Lv.HOTEL 10:00 NATIONAL RESEARCH INSTITUTE OF ASTRONOMY AND GEOPHYSICS 17:00 Ar.HOTEL	Making Report at HOTEL

DAY	SCHEDULE		
11.06 (FRI)	09:00 Lv. HOTEL Obsertvation around GIZA area 17:00 Ar. HOTEL		
11.07 (SAT)	EARTHQUAKE PREVENTION GROUP Making Report at HOTEL 13:00 Lv. HOTEL Observation of damaged area (AIYAT) 17:00 Ar. HOTEL	05:15 Lv. HOTEL 07:00 Lv. CAIRO by MS 433 08:15 Ar. ASWAN 08:45 SEISMOLOGY CENTER 21:15 Lv. ASWAN by MS422 23:15 Ar. CAIRO 23:45 Ar. HOTEL	EARTHQUAKE GROUP
11.08 (SUN)	EARTHQUAKE PREVENTION GROUP 11:00 MINISTRY of CONSTRUCTION 17:00 Ar.HOTEL	07:30 Lv.HOTEL 08:00 CAIRO UNIV 11:30 MINISTRY OF INTERIOR 17:00 Ar.HOTEL	EARTHQUAKE GROUP 11:30 Observation of damaged area (FAYUM) 17:00 Ar.HOTEL
11.09 (MON)	EARTHQUAKE PREVENTION GROUP 08:10 Lv.HOTEL 08:30 Courtesy Call on Dean of Fuc ulty of Engine ering 09:30 Ar.HOTEL Making Report at HOTEL	08:00 Lv.HOTEL 08:30 Observation of bridges (NILE D ELTA) 19:00 Presentation for Bridge Sei smic Design 21:00 Ar.HOTEL	EARTHQUAKE GROUP Making Report at HOTEL
11.10 (TUE)	10:15 Lv. HOTEL 10:30 EMBASSY OF JAPAN 11:00 Recommend to STATE MINISTER OF SCIENTIFIC RESEARCH 12:00 Press Release 13:00 Ar. HOTEL 19:00 Reception by JAPAN DESASTER REIIEF TEAM		
11 ' (WED)	09:00 Lv. HOTEL 10:00 Seminar (CONSTRUCTION RESEARCH CENTER) 13:00 Ar. HOTEL		
11.12 (THU)	06:00 Lv. HOTEL 08:25 Lv. CAIRO by BA 154		

2.2 Members

エジプト地震国際緊急援助隊（専門家チーム）メンバーズ・リスト
JAPAN DISASTER RELIEF TEAM (EXPERT TEAM) FOR EGYPT EARTHQUAKE

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3. Comments on the Earthquake and Damage

3.1 The main shock of the 1992 Cairo earthquake

The earthquake with moment magnitude of 5.8 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, M_D = 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
Location = 29.826°N, 31.228°E, Depth = 30 km

where M_D 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 that obtained by the NRIAG and the USGS. Both parameters are preliminary ones and the final 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) = (N174°, 46°)
2. (strike, dip) = (N304°, 56°)

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

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

On the basis of the value typical for shallow earthquakes of magnitude 5.5 to 6, the fault length is estimated to be 10 to 15 km and that width is to be 5 to 8 km. The displacement is also estimated to be around 28-50 cm.

Recommendation

More dense seismic network are 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.

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 yet determined now. M3.7 event occurred within a day after the main shock and the epicenter was located at about 10 km northeast to that of the main shock. Major aftershocks seems 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. Base 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 56 and the fault length to be around 10 km.

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.

3.3 Macro-Seismic Intensity

Seismic intensity scale is a combination of the intensity of seismic shaking and degree of earthquake damages. To obtain the accurate intensity of the seismic shaking, the strong motion records are indispensable. The degree of earthquake damages varies with the quality of damaged structures. Even at a certain location, damages to well designed structure may be minor while intensive damages can be found in the non-engineered structures. Strong motion records are also necessary to evaluate not only the strength of the damaged structures but also the safety factor of the undamaged structures.

Devastating damages are reported in downtown Cairo but major part of the damages occurred to old masonries. Adobe structures also have been damaged seriously in the suburbs such as in the vicinity of El Faiyum and Al Aiyat.

The areas where such devastating damages occurred are located in the Cairo Delta, along Nile River and in the Faiyum basin. These areas could be 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 which is based upon the information obtained by the members of the Japanese Expert Team from NRIAG, EGSMA, Cairo Univ., etc.

Compilation effort for comprehensive intensity map is under way at NRIAG based on the questionnaire disseminated through a news paper. Though the questionnaire through a news paper is very effective to obtain data covering wide area, it takes many days. The intensity distribution map is a key tool for post earthquake measures such as dispatching rescue and medical teams, emergency supplies as well as rehabilitation, and therefore it is needed as soon as possible.

Recommendations:

1) Installation of the strong motion seismographs is necessary to obtain the accurate intensity of the seismic shaking as well as other engineering purposes.

2) Two kinds of seismic intensity map is necessary; one for better understanding of the earthquake effects and the other one for post earthquake countermeasures. The later one should be made as

soon as possible for post earthquake measures while the former one should be made as carefully as possible.

3) The later one could be made by the information from people who have some knowledge on earthquake, such as local authorities, police men, fire fighters and school teachers. Education to these people is necessary to get correct information on seismic intensity.

4) Also, standard procedure to evaluate the effects of earthquake to structures is desirable to be established.

3.4 Geological Conditions

It is the general understanding that the African Continent where Egypt is located is a stable region in terms of the crustal dynamics such as earthquake. However, there have been many earthquakes taken place in the territory of the Egypt along three major geologic trends, namely Red Sea Trend running NNW-SSE, Gulf of Aqaba Trend running NNE-SSW and Mediterranean Trend running E-W.

Though the detailed characteristics of these faults have not been obtained during the site survey of the Japanese Expert Team, it is evident that Aswan Earthquake of 1981 occurred along one of these three, the East-West trending Kalabsha Fault. The focal mechanism and distribution of the aftershocks of October 12 earthquake implies the re-activation of a deep seated fault of the Red Sea Trend.

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

The geological structure especially the faults structure underneath the metropolitan Cairo is not revealed yet. Judging from geologic maps, there might be some faults underneath the metropolitan Cairo but their detailed characteristics are not known yet.

Recommendations:

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

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

3) Detailed geological survey of the faults suspected underneath the metropolitan Cairo is necessary for the earthquake countermeasures of the city.

3.5 Subsoil Conditions

It is evident that thick unconsolidated sediments develop in the Nile Delta region and along Nile River. According to some geologists in Egyptian Geological Survey, the thickness of the sediments in the Metropolitan Cairo area reaches 80 meters, at least. The thickness of the sediments along River Nile varies from place to place, but it is estimated some 50 meters around Helwan and it's vicinity.

The under-ground water table is also an important factor for the stability of the ground. It is estimated 2 to 3 meters below surface in the Metropolitan Cairo as well as the area along River Nile. Very shallow water table is also observed in El Faiyum basin where irrigation system is implemented. On the other hand, in the western desert it is estimated to be more than 70 meters. The higher seismic intensity is observed in the regions where the thick sediments develop and water table is shallow, but the detailed stratigraphy, distribution and thickness, and dynamic behaviors of the sediments have not been obtained. Liquefaction is also observed in these regions, such as El Aiyat, El Beleada and Al Akwan about 20 kilometers from the epicenter.

Recommendation:

Subsoil conditions such as the stratigraphy, distribution and thickness, and dynamic behaviors of the sediments should be studied in detail and should be shared with all scientists and engineers who are involved in earthquake researchers and counter-measures.

3.6 Seismicity

Most of earthquakes 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 (Kebeasy, 1990). Figures 3.6.1 and 3.6.2 show the distribution of epicenters of micro earthquakes 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 the northern African plate is characterized by the spreading 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 in terms of the interaction between the African, Alabian and Eurasian plates.

For these reasons, Cairo has long been suffered by disastrous earthquakes. However, the largest magnitude of earthquakes which occurred in and around Cairo since B.C. 2200 is less than

6.5. Magnitude of 6 to 7 is usually classified to be a moderate earthquake in the world wide scale. Figure 3.6.4 represents epicentral distribution in the whole world. Looking at this figure, the northern part of the African plate is rather seismically quiet compared with the circum pacific region. Although the 1992 Cairo earthquake with magnitude 5.8 belongs to a large event in the African plate, magnitude of 3 to 5 is usually classified to be a small event. Therefore the magnitude 5.8 event belongs to a small event rather than a large one in the worldwide scale.

References

Albert, R.N.H, 1969, Seismicity of the Zafarana area, Gulf of Suez, Egypt.

Kebeasy, R. M., 1990, Seismicity of Egypt, I Workshop on MedNet, the broad-band seismic network for the Mediterranean, Sep. 10-14, 1990.

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.

3.7 Strong Motion Records

Because no strong motion accelerographs were installed in the vicinity of Cairo and the epicentral area, the strong motion data, which are important for estimating ground acceleration at the damaged area, were not recorded. Although there are several velocity-type records which are for seismological purpose, no complete data useful for engineering purpose were obtained except the magnitude and the location of epicenter. An evaluation of the intensity of ground shaking at the damaged area is difficult based on the instrumental records.

Based on a number of the strong motion accelerations recorded at free field sites in Japan, an empirical formula for attenuation of peak ground acceleration is given as

$$a_{max} = 233 \times 10^{0.313M} \times (R + 30)^{-1.218} \qquad (3.7.1)$$

where

a_{max} : peak ground acceleration (cm/sec2)
M : earthquake magnitude
R : epicentral distance (km)

Assuming the surface magnitude of 5.3, the attenuation of peak ground acceleration by Eq.(3.7.1) is represented as shown in Fig.3.7.1. Because the epicentral distance is ranging from approximately 30 km to 40 km at Giza and Cairo area, respectively, the peak ground acceleration a_{max} predicted by Eq. (3.7.1) is about 70 cm/sec2 at Giza and 60 cm/sec^2 at Cairo. These values give the preliminary insight for the ground acceleration developed at the damaged areas. However the attenuation of ground motion depends on the site, it should be noted that these values are only approximate estimation based on the Japanese empirical attenuation. It should be also noted that Eq.(3.7.1) gives the mean value of the measured acceleration, and has a considerable scatter. When one considers one standard deviation from the mean value, the value predicted by Eq. (3.7.1) has to be multiplied by 1.7 and 1.1.7.

Six strong motion accelerographs (SMA-1) are installed on and in the gallery of the Aswan High Dam. An additional strong motion accelerograph is installed at the free field site 60 km apart from the dam. Because they are far from the epicenter of the October 12 earthquake, no records were triggered. At this moment, the triggering level for the seven strong motion accelerographs is set as 0.1 g. Because noise is very small at the sites it is suggested to lower the triggering level from 0.01 g to about 0.002 g so that strong motions induced by an earthquake which will break off near the dam be recorded.

A strong motion acceleration record provides valuable data for engineering estimation on ground intensity. This gives the fundamental information on the seismic design force and the structural response. Therefore, it is recommended to install several strong motion accelerographs in the vicinity of Cairo. It is also recommended to extend the installation of the strong motion accelerographs at various seismic areas in Egypt so that strong motion network can be formulated in the future. This will enable to formulate the attenuation equations which include the characteristics of propagation path and site conditions in Egypt.

3.8 Seismic Design of Buildings

3.8.1 Background

In Egypt,it had been considered that Egypt was a seismic-hazard free country. In 1988, The Egyptian Society for Earthquake Engineering (ESEE) proposed the model seismic design code "Regulations for Earthquake-Resistant Design of Building in Egypt" whose design concept is similar to the UBC code. However, it is generally said that this code has not been used. In late 1989, The Ministry of Housing and New Communities in Egypt published "The Egyptian code for Design and Execution of Reinforced Concrete Constructions". This version of code, contrary to the last one published in 1912, includes the seismic effects on buildings.

Before this version, it was uncertain whether the seismic design had been conducted or not, although the structural design against wind had been regulated. However, most of the outstanding buildings are supposed to have been designed by referring to seismic design procedures of foreign countries such as U.S.A.

In the revised code in 1989, both of the working stress design method and the limit state design method are specified, and the former is widely used. The dynamic response is also conducted for some of high-rise buildings of about 30-40 stories.

There is no seismic regulation for masonry buildings whose damage caused by Oct. 12 Earthquake is distinguished.

3.8.2 Seismic loads in R.C Code

a) Seismic zone

Egypt is divided into two seismic zones according to the seismic activity. Cairo, Giza and the places near these cities where Japanese expert team had mainly surveyed earthquake damage, are classified in the first zone. Buildings laying in the first zone are supposed to be subjected to earthquake with low intensity resulting in relatively small damages and designed with 1% base shear coefficient,meanwhile an earthquake of moderate intensity is supposed in the second zone.

In the ESEE Regulations, the detailed seismic zoning map is proposed. Further researches and discussions are recommendable for this field.

b) Equivalent static design forces for the seismic effect.

The total horizontal static forces in the second zone is to be taken according to equation (3.8.1)

$$V = 0.3\ K\ C\ I\ W \qquad (3.8.1)$$

where :

V = the total horizontal static force,

K = coefficient depending on the ductility ranging from 2/3 to 4/3,

C = coefficient of standard spectrum,

I = importance factor and,

W = total equivalent vertical force of the building.

The total horizontal static force shall not be less than 1% and 2% of the equivalent vertical loads for buildings in the first zone and in the second zone, respectively.

Roughly speaking, it is supposed that the maximum acceleration of about 30 gals to 40 gals with the condition of reduction factor of member strength of 1.5, is considered for the design earthquake ground motion in the second zone.

The ESEE Regulations determines the seismic design shear force by defining other factors such as risk factor, construction quality factor as well as the factors mentioned above. The return period of major earthquakes in Egypt is far longer than that in other countries which are famous for high seismicity. This fact should be considered in determining the seismic design shear force. The factors such as importance factor, risk factor might be appropriate for that purpose.

Strong motion records are highly recommended in order to discuss the level of the seismic design shear force.

3.9 seismic Design of Infrastructures

3.9.1 General

Infrastructures include road, bridges, railway, electricity, water, sewage, gas, telephone and telecommunication. Because they cover wide aspects of structural components, it was unable to survey the overall earthquake preparedness of these infrastructures. Therefore the description at this section concentrates only on the road bridges and a water plant where the survey could be made with the support of the General Authority for Roads and Bridges and the General Organization for Greater Cairo Water Supply.

3.9.2 Bridges

Comprehensive descriptions on loads, materials and allowable stress are specified in the Egyptian Code of Practice for Steel Constructions and Bridges (Ministerial Decree, No. 451-1989) and the Egyptian Code of Practice for Soil Mechanics and Foundation (Part 1- Part 10, Ministerial Decree, No.451-1989). However descriptions on seismic effects are few. Only some descriptions on soil liquefaction are provided in the Egyptian Code of Practice for Foundations Subjected to Vibrations and Dynamic Loads (Ministerial Decree, No. 449-1991). But the treatment of the liquefied soil in design is not precisely stipulated.

Based on the situation, the seismic effect is disregarded in design of road bridges. However various considerations and construction practices have been taken in the previous design and construction. According to the General Authority of Roads and Bridges, the following considerations were at least made, which may be effective for increasing seismic capability of road bridges:

1) In-situ loading tests were made for at least two piles per site to the study the load bearing capacity in vertical direction. Piles were subjected to vertical loading up to 2 times and 3 times of the design loading for the bearing piles and the friction plies, respectively, so as to confirm the yielding load. For example, a pile was subjected to 480 tf, which is twice as large as the design loading, at Faraskour Bridge.

2) Design strength of concrete is taken as 300-350 kgf/cm2 for the pier which is one of the most critical components for seismic safety.

3) Soils up to 8m below the river bottom is generally disregarded in design of pile foundations as a design measure for scouring effect. Because the effect of soil liquefaction is not considered in design, such consideration may be effective to increase the lateral stiffness of piles.

It is recommended to consider the seismic effect for design of road bridges. Following measures may be effective:

a) Design lateral force

Design lateral force which takes account of seismicity, bridge response and ground condition needs to be considered for design of piers, bearings and foundations.

b) Device for preventing falling-down of superstructure from substructures.

For preventing unexpected collapse during a significant earthquake, an installation of the following devices may be effective:

1) Stopper at movable bearings for preventing excessive movement
2) Restrainer between adjacent decks
3) Connection of superstructure to substructures

c) Soil liquefaction

Evaluation of vulnerability to soil liquefaction and countermeasures need to be considered for design of foundation.

After formulating the seismic design method, it is recommended to inspect the existing bridges in view of the possible strengthening required.

3.9.3 Water Supply Systems

Water supply systems consist of various structural components with different structural response, such as buildings intake towers, pumping stations, pipes, ducts and filtration plants.

No special considerations are currently taken into account for design of these structure and facilities.

3.10 Overall Damage and Damage Evaluation

The damages by the earthquake of 12 October in 1992 are summarized as follows :

(1) Human damage	
Casualty	561
Injured	12,192
Needs treatment in Hospital	2,270
No needs treatment in Hospital	9,922
(2) Damage to Educational facilities	
Needs major Repair	2,301
Needs Minor Repair	3.569
Can not be Used	1,087
(3) Damage to Mosque	
Needs major Repair	211
Needs minor Repair	544
(4) Damage to Monuments	
Needs major Repair	14
Needs minor Repair	104
(5) Damage to Homes and Houses	
Needs major Repair	4395
Needs minor Repair	22,235
Can not be Used	7,796

Notes :(1)-(4) are from the announcement of 31 October by Prime Minister
(5) is from General Ameen of local Administration

The largest number of casualties and injured were reported in Cairo, Giza and Faiyum.

Almost 200 children were killed in a panicked stampede rather than by the earthquake itself.

73 people had been killed beneath the collapsed apartment building of 14 storied in Heliopolis.

Fire by the earthquake did not occurred.

As far as the site investigation evidenced serious damage to the buildings was observed in Giza and Faiyum.

Soil liquefaction was observed in southern part of Giza between EL AIYAT and Dahshor but damage to houses was not reported.

Damages to civil engineering constructions were small.

Comments

The damage estimation for buildings referred here was done quickly by many engineers after the earthquake.

The inventory estimation sheet for damage estimation of school buildings was prepared by Ministry of Education.

However, there are still many buildings classified as "not to be used", which may include buildings that can be used by repair or strengthening, because the judgments were made mainly depending upon the engineers' individual estimation.

Therefore,a guideline to evaluate the degree of damage should be developed for each structural type of buildings such as shown in the Appendix I-8,9,10

3.11 Damage to Buildings

3.11.1 General

Earthquake damages were inspected at four districts Eastern part of downtown Cairo, downtown Giza, countryside of Giza, northern parts of Fayoum.

Generally speaking, it is judged from the damage level and its frequency that the estimated intensities at these districts from the seismic viewpoint, are appropriate.

The severe damage was found mostly in old masonry buildings and in illegal or non-engineered reinforced concrete buildings. Meanwhile, it is not reported that high-rise buildings suffered remarkable earthquake damage.

3.11.2. Earthquake damages in each type of structures

a) Masonry buildings

It was reported that many adobe and brick masonry buildings without steel reinforcement collapsed completely or suffered severe damages.

Most of these old masonry buildings utilized as residential buildings at Old Cairo have three to five stories. This number of stories is unusual in countries with high seismicity. There are many old buildings which a slight shock will trigger their total collapse. The repair and strengthening works may be impossible without costly measures compared to their original construction cost.

Stone masonry is typical for antique mosques. Some of them were severely damaged. The permanent rehabilitation should be considered. Pouring epoxy mortar into cracks may help for that purpose. The details should be improved for the roofing system and dome.

The adobe houses which are popular in villages suffered tremendous damages.

As for the roof system of the adobe buildings, from the bottom of the roof, there are wooden beams made mostly of palm tree rested on the top of two opposite walls, a layer of stems of palm tree leaves, a layer of mud, and a layer of light-weight plant. The weight of the roof depends on the thickness of the mud layer.

Major damage of adobe was roughly classified into two types depending on the weight of the roof, consequently on the thickness of the mud layer : One is falling down of roofs due to flexural failure of wooden beams at center in case of heavy-weight roof system and the other is falling down of bearing walls outside the house due to week protection against out-of-plane movement in case of the light-weight roof system.

b) Reinforced concrete buildings

It has been reported that there are many buildings whose upper stories were accumulated illegally. The fourteen-story reinforced concrete building at Heliopolis which completely fell down and killed about seventy persons was one of such buildings.

It has been also reported that many school buildings suffered earthquake damage and the main reason for this outstanding damage is poor construction work. This was confirmed by the damage inspection of some school buildings especially around the cold joint at the top of columns. The effect of settlement on damages was observed in some buildings.

c) Mixed Buildings

Mixed buildings, which are common in old structures in Egypt, consist of combination of any two, or more, structural types of adobe, brick, stone masonry, and reinforced concrete, in plane or in elevation. This type of buildings are non-engineered and suffered damage in the weakest portion.

d) Steel Buildings

There is no report about damage of steel buildings. For buildings of steel members and reinforced concrete members, which are mostly high-rise buildings, no damage is also reported.

e) Houses

(1) Outline of Damage of Houses

According to Ministry of Housing and New Communities, Damage of houses in Giza district is the biggest, especially in the villages around El Aiyat which had the major damage.

For example, in Berwash Village which located near the epicenter and has population about 5,000 persons and about 1,000 housing units, the Japanese expert team received the following information :

(i) 16 persons were killed, (One died in a collapsed school),
(ii) 100 persons were wounded,
(iii) about 300 house units (30% at total number) collapsed,
(iv) about 500 houses units (50% of the total number) severely cracked,
(v) about 100 houses units (10% of total number) lightly cracked, and
(vi) 1,000 to 1,500 persons now live in tents.

In Cairo city, old crowded housing areas have heavy damage such that 23,000 houses can not be repaired and 13,000 houses should be repaired . And the other areas in Cairo have damage such that 700 houses can not be repaired and 1,300 houses can be repaired.

(2) Countermeasures for suffered people

Government, as emergency measures, compensate those people who lost their houses because of the earthquake many tents and so on. And 50,000 new housing units which are under construction in new towns will be quickly completed and supplied for the people living in tents. Still more they are preparing new law: the Law for the Compensation of those who has been suffering from the Earthquake.

(3) Restoration of damaged houses in urban areas

Government established Joint Committee which consists of Ministry of Housing and New Communities, Technical Defense Academy and City governors. The authorities of Local Administration surveyed damage and classified building damage into 3 classes. The buildings classified as the first class can not be used, the second class needs major repair, and the third class needs slight repair. According to the Ministry of Housing and New Communities, the countermeasures for the old houses classified into these three classes are as follows: The houses of the first class will be urgently reconstructed by the government, especially in areas around historical spots, such as Al Azhar. Also the houses of the second class will be redeveloped by the government and the houses of the third class will be repaired by their owners.

(4)Restoration of damaged houses in villages

Ministry of Housing and New Communities is now investigating two methodologies. One is to reconstruct damaged houses, the other is to study and construct new type of houses.

Anyway, the Ministry must consider how to reconstruct houses in villages. Japanese technical cooperation can be expected.

(5) Comments

One reason why the villages have such severe damage is their location near the epicenter. Moreover, this shallow earthquake heavily attacked the villages and its intensity is stronger than in Cairo City. In addition adobe structures with heavy thick mud roofs increased damage.

So it is recommended that another type of structure should be used for new buildings rather than adobe structures. A brick house might be one of the promising alternatives if it is well reinforced.

3.12 Damage to Infrastructures

3.12.1 General

Description is given only for road bridges and a water plant where damage survey could be made with the support of the General Authority for Roads and Bridges and the General Organization for Greater Cairo Water Supply.

3.12.2 Road Bridges

Damage survey was made for Zamalek Overcrossing, Beni Suef Bridge, Faraskour Bridge and Dessuk Bridge. No seismic damage was observed to those bridges.

3.12.3 Water Supply Facilities

A visit to Rod El Farag Water Plant, Greater Cairo Water Supply was made. No serious damage so as to affect the water supply was not developed by the earthquake of October 12. Only minor damage was developed at:

a) Cracks at masonry wall of a finished water pump station.
b) Increase of water leakage at a duct in the filters.
c) Offset and dislocation of a concrete wall of the clarifier.

3.13 Soil Liquefaction

Soil liquefaction was observed at Barmasht area. Several sand blow holes with a diameter as large as 4 m and a depth of 2 m were developed. Because the site visit was made on November 8, almost one month after the earthquake, typical sand valves were not observed. The sand spread over a paddy field.

Although soil boring data at the site is not available, it is considered from the site inspection that the soil consists of saturated loose fine sand overlaid by the cohesive clay with the thickness of 1 - 2 m. The cohesive clay may be the reason for causing the large blow holes because it prevented the blow-up of water associated with the increase of pore-water pressure of sandy layer.

The sand blew up is rather fine. The grain size seems 0.1 - 0.3 mm.

According to the eyewitnesses, the water and sand blew up as high as 3 m, and it continued about 45 minutes. There were eyewitnesses at other site that the blow up lasted for two hours.

Based on the past experiences in Japan, it is known that the soil liquefaction tends to be developed in the area with a radius R from the epicenter as

$$\log R = 0.77\, M - 3.6 \qquad (3.13.1)$$

where

R : radius (epicentral distance)
M : earthquake magnitude

Fig. 3.13.1 shows the relation predicted by Eq. (3.13.1) as well as the observed data at Barmasht (M = 5.3, R = 19 km). It is clearly seen that during the October 12b earthquake the liquefaction occurred far from the threshold predicted by Eq.(3.13.1). This may be attributed to the fact that the sand at Barmasht area is extremely loose.

Because soil liquefaction is quite important for seismic design, it is recommended that more comprehensive analysis be made. The formulation of the empirical equation in the form of Eq.(3.13.1), which can be applied to Egypt, is useful for assessing the vulnerability associated with soil liquefaction.

3.14 Delivery of Earthquake Information

3.14.1 How was the Mainshock informed?

1) The NRIAG immediately determined, on the basis of the available seismic data in Helwan station, the preliminary epicenter of the mainshock after 1-2 hours of its occurrence. The mainshock occurred at 15 h 09m (Local Time), Oct. 12, 1992. NRIAG sent its information to the Ministry of Scientific Research.

2) A lot of TV, Radio and Newspaper interviewers came to the Institute in a hurry which caused considerable confusion to the Institute staff.

3) The earthquake information on the mainshock was formally issued on Oct. 14 as a result of precise determination of the epicenter by using many seismic data from different stations.

3.14.2 Earthquake Information on the aftershocks.

1) NRIAG reports the number of aftershocks twice (9:30, 15:30) a day to the Ministry of Scientific Research.

Besides, when an earthquake of magnitude equal to or larger than 3.0 occurs, the Institute staff have to pass the information to the Ministry of Scientific Research as soon as possible.

This process is treated as one of the emergency case.

2) There is no section responsible for publishing Earthquake Information in NRIAG nor in the Ministry Office.

Thus, seismologists and researchers in NRIAG are forced to respond to various requests from the press and people.

3) In NRIAG two operators routinely watch seismic records in 6-hour shifts a day and they judge whether the preliminary magnitude of an event is equal to or larger than 3.0 or not in order to report to the Ministry of Scientific Research at moment.

3.14.3 Earthquake Information on the ordinary seismic activity.

1) There is no Egyptian Governmental office which has the system to deliver Earthquake Information to public.

2) NRIAG, however, has a lot of valuable results, including not only historical data but up-to-date ones, investigated by its seismologists and it also has the potential to make use of Earthquake Information.

3.14.4 Recommendation

When a large earthquake occurs, it is extremely important to provide quick and accurate information about it not only to Administrative Organizations but also to public for mitigating earthquake disaster.

For this purpose, several countermeasures are necessary to be carried out as follows:

1) To enhance the ability of preliminary determination of epicenter location.

2) To improve the data processing system in order to know the accurate change of the seismic activity in time and in space.

3) To make a system for sending and receiving earthquake information among Administrative Organizations, the press, and other organizations and public requiring the earthquake information.

4) To allocate experts in charge of publicity in organizations including the Ministry of Scientific Research.

5) To educate people in regard to not only scientific knowledge on earthquake but also what to do during an earthquake by the above-mentioned experts.

3.15 Training and Education on Earthquake

The Civil Defense Department, Ministry of Interior is responsible for rescuing victims under collapsed buildings by an earthquake, fire fighting,..etc. The existing equipments in the department have been maintained under a very good condition and the moral of the rescue team is excellent. Training seems to be put into practice by rescue team members or occasionally by citizens. Education to the public seems to be given in the room of the Public Relations Section of the department, using video equipment. This kind of rooms are located in some other places. Even before October 12 earthquake, education and drill had been carried out to the public in consideration of their importance.
It is reported that during the earthquake children in schools panicked and many of them were injured or pressed to death when they tried to escape from the buildings. In order to prevent such panic, public education and information dissemination in proper way are essential. Taking into account the evidence of the earthquake that involved a wide area and wide variety of citizens, earthquake preparedness is necessary at local governments, schools and other agencies, not only at the central government.
Egyptian people had been in fear of aftershocks for long time since October 12. Also, questions we have had from mass-media were focused on the aftershocks. Timely and proper information dissemination is necessary together with public education. Information dissemination without education may cause panic. On the other hand, no information may cause unnecessary fear among the public.

4. *Summary of the Recommendations*

Recommendations on the further earthquake preparedness as well as earthquake studies are described in Chapter 3. Here, they can be summarized as follows:

1) More dense seismic observation 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 needed.

2) It is recommended to install strong motion accelerographs on ground and structures for evaluating strong ground motion and structural response.

3) In general, two kinds of seismic intensity maps are necessary; one for better understanding of the earthquake effects and the other one for post earthquake countermeasures. The later one should be made as soon as possible for post earthquake measures while the former one should be made as carefully as possible.

4) A standard procedure to evaluate the effects of earthquake to structures is desirable to be established.

5) Geological studies especially seismotectonic researches should be enhanced for better understanding of the occurrence of the geological hazards such as earthquake.

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

7) Detailed geological survey of the faults suspected underneath the metropolitan Cairo is necessary for the earthquake countermeasures of the city.

8) Subsoil conditions such as the stratigraphy, distribution and thickness, and dynamic behaviors of the sediments should be studied in detail and should be shared with all scientists and engineers who are involved in earthquake researchers and countermeasures.

9) It is recommended to review the provisions for seismic design in the R.C. code especially about seismic zoning, ductility demand and detailing of reinforcements to increase ductilities. A comparative study with the ESEE regulation is also recommended.

10) It is recommended to formulate seismic design codes for other structural types of buildings rather than reinforced concrete buildings.

11) Guidelines to evaluate the seismic capacity of existing buildings and the degree of damage of damaged buildings should be

developed for each structural type of buildings .

12) Stone masonry is typical for antique mosques. Some of them were severely damaged. The permanent rehabilitation should be considered. Pouring epoxy mortar and epoxy injection into cracks may help for that purpose. The details should be improved for the roofing system and dome.

13) In repair and strengthening of adobe houses, the means to prevent failures as observed in some villages should be considered. It is recommended that another type of structure should be considered for new buildings rather than adobe structures. Brick houses can be used in villages due to low cost and their adequate conditions, if they are well reinforced .

14) In the damaged reinforced concrete school buildings, effects of inadequate construction work particularly at the construction joints, non-existence of lateral reinforcement in columns and collision at the expansion were observed. These factors should be considered in repair and strengthening works.

15) It is recommended to formulate seismic design method of buildings taking account of design lateral force, device for preventing falling-down of superstructure from substructures, and soil liquefaction.
After formulating the seismic design method, it is recommended to inspect the existing bridges in view of the possible strengthening required.

16) It is important to provide quick and accurate information about earthquakes not only to administrative organizations but also to public for mitigating earthquake disaster. For this purpose, several countermeasures are necessary such as;
a) To enhance the ability of preliminary determination of epicenter location.
b) To improve the data processing system in order to know the accurate change of the seismic activity in time and in space.
c)To make a system for sending and receiving earthquake information among Administrative Organizations, the press, and the other organizations and puplic requiring the earthquake information.
d) To allocate some experts in charge of publicity and establish the necessary section for them in Organs, such as the Ministry of Scientific Research.
e) To educate people in regard to scientific knowledge of earthquake by the above-mentioned experts.

17) During the earthquake children in schools panicked and many of them were pressed to death when they tried to escape from the buildings. To prevent such panic, public education and information dissemination in proper way are essential.

5. Acknowledgements

This work could not be completed successfully without the assistance and support provided by Ministry of Scientific Research and Technology, National Research Institute of Astronomy and Geophysics, Ministry of Housing and New Communities, Ministry of Transportation, Egyptian Geological Survey and Mining Authority, University of Cairo, and local authorities of Arab Republic of Egypt.

Voluntary effort by the Japanese who live in Cairo is also acknowledged.

The team would like to extend their heartfelt gratitude to those who worked hard with them in carrying out the team's duties.

Appendix

Appendix I: List of Materials Provided to the Ministry of Scientific Research

1. "Recommendations on damage evaluation, repair and strengthening for buildings damaged by the September 10-20, 1985 Mexico Earthquakes", The Japan International Cooperation Agency Mission, Nov. 21, 1985.
2. "Report of Japan Disaster Relief Team on Earthquake at Spitak, Armenia, USSR", Japan International Cooperation Agency, Feb. 1990.
3. "Report on Expert Team of Japan Disaster Relief Team (JDR) on the earthquake in Philippines of July 16, 1990", Japan International Cooperation Agency, Aug. 1990.
4. "Standard for evaluation of seismic capacity of existing reinforced concrete building", Japan Building Disaster Prevention Association, 1977.
5. T. Okada, et al., "Standard for evaluation of seismic performance of reinforced concrete block masonry school building in Japan - Draft", March 1985.
6. T. Okada, "Evaluation of seismic capacity and strengthening of existing reinforced concrete buildings"
7. H. Umemura, et al., "Post-earthquake inspection and evaluation of earthquake damage in reinforced concrete buildings", Proceedings of 9th WCEE, Aug. 2-4, 1988.
8. M. Ohkubo, et al., "The outline of post-earthquake damage evaluation guidelines of reinforced concrete buildings", International Conference on Reconstruction, Restoration and Ur ban Planning of Towns and Regions in Seismic Prone Area, Skopje, Yugoslavia, Nov. 5-9, 1985.
9. M. Ohkubo, "Current Japanese system on seismic capacity and retrofit techniques for existing reinforced concrete buildings and post-earthquake damage inspection and restoration techniques", Report No.SSRP-91/02, University of California, San Diego.
10. "Guideline for Damage Evaluation and Repair of Earthquake Damaged Buildings", Japan Building Disaster Prevention Association. (in Japanese)
11. Introduction to the building standard law" The Building Research Center of Japan.
12. A quick look at housing in Japan", The Building Center of Japan.
13. "Earthquake Disaster Countermeasures in Japan", National Land Agency, Japan.
14. "Disaster Countermeasures in Japan"
"Disaster Countermeasures Basic Law"
"Basic Disaster Prevention Plan"
"Essentials of Earthquakes Countermeasures for Lager Cities"
15. "What to do during earthquakes", Tokyo Metropolitan Government.
16. "Disaster Prevention and Restoration in Japan", Ministry of Construction, Japan.
17. "To ensure Safety in the Future", video tape, National Land Agency, Japan.

18. "Yogi Bear's Earthquake Preparedness", video tape.
19. "Earthquake and Tsunami monitoring and countermeasures", Japan Meteorological Agency.
20. "The technical report on the Naganoken-Seibu Earthquake on September. 14, 1984", Japan Meteorological Agency.
21. "The map of the vertical distribution of hypocenters in the Kanto-Tokai district, central Japan", National Research Institute for Earth Science and Disaster Prevention.
22. "National Research Institute for Earth Science and Disaster Prevention".
23. Public works Research Institute : Manual for Repair Methods of Civil Engineering structures Damaged by Earthquakes, Technical Note of PWRI, Vol. 45., English Version published by National Center for Earthquake Engineering Research, December 1986
24. Public works Research Institute : List of Publications 1969-1991, Panel on Wind and Seismic Effects, UJNR, Technical Memorandum of PWRI, No 3095, March 1992.
25. Public Works Research Institute :Recent Selected Publications at Earthquake Engineering Division, PWRI, Technical Memorandum, No. 3035, October 1991
26. Kawashima, K. et al : Attenuation of Peak Ground Acceleration, Velocity and Displacement on Multiple Regression Analysis of Japanese Strong Motion Records, Earthquake Engineering and Structural Dynamics, Vol. 14, 1986.
27. Kawashima, K. et al : Bracketed and Normalized Duration of Earthquake Ground Acceleration, Earthquake Engineering and Structural Dynamics, Vol. 18, 1989.
28. Kawashima, K. et al : Attenuation of Peak Ground Motions and Absolute Acceleration Response Spectra of Vertical Earthquake Ground Motion, Proc. of Japan Society of Civil Engineers, Vol. 2, No.2, 1985.
29. Kawashima, K. Seismic Design, Seismic Strengthening and Repair of Highway Bridges in Japan, 1st U.S.-Japan Workshop on Seismic Retrofit of Bridges, Tsukuba, Japan, 1990.
30. Kawashima, K. et al : An Inspection Method of Seismic Vulnerability of Existing Highway Bridges, Proc. Japan Society of Civil Engineers, Vol. 7, No. 1, 1990.

Appendix II: A Tentative Comment to Minister of Scientific Research from Japanese Expert Team for Disaster Relief

Based upon the information of the decay of aftershocks number with time and the aftershocks area, which were provided by the National Research Institute of Astronomy and Geophysics, as well as the Japanese experiences on seismic activities, it seems that the major seismic activity of the October 12 Earthquake is almost coming to be ceased.
However, there is still a possibility that minor aftershocks, which may not cause damage to structures, occur.

Attachments;

1) Decay of aftershocks with time
2) Space distribution of aftershocks

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:

$$I = 1.43\ M - 3.9 \log r + 4.37$$

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_o	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_o : Maximum intensity at the epicenter.

M : Helwan magnitude scale.

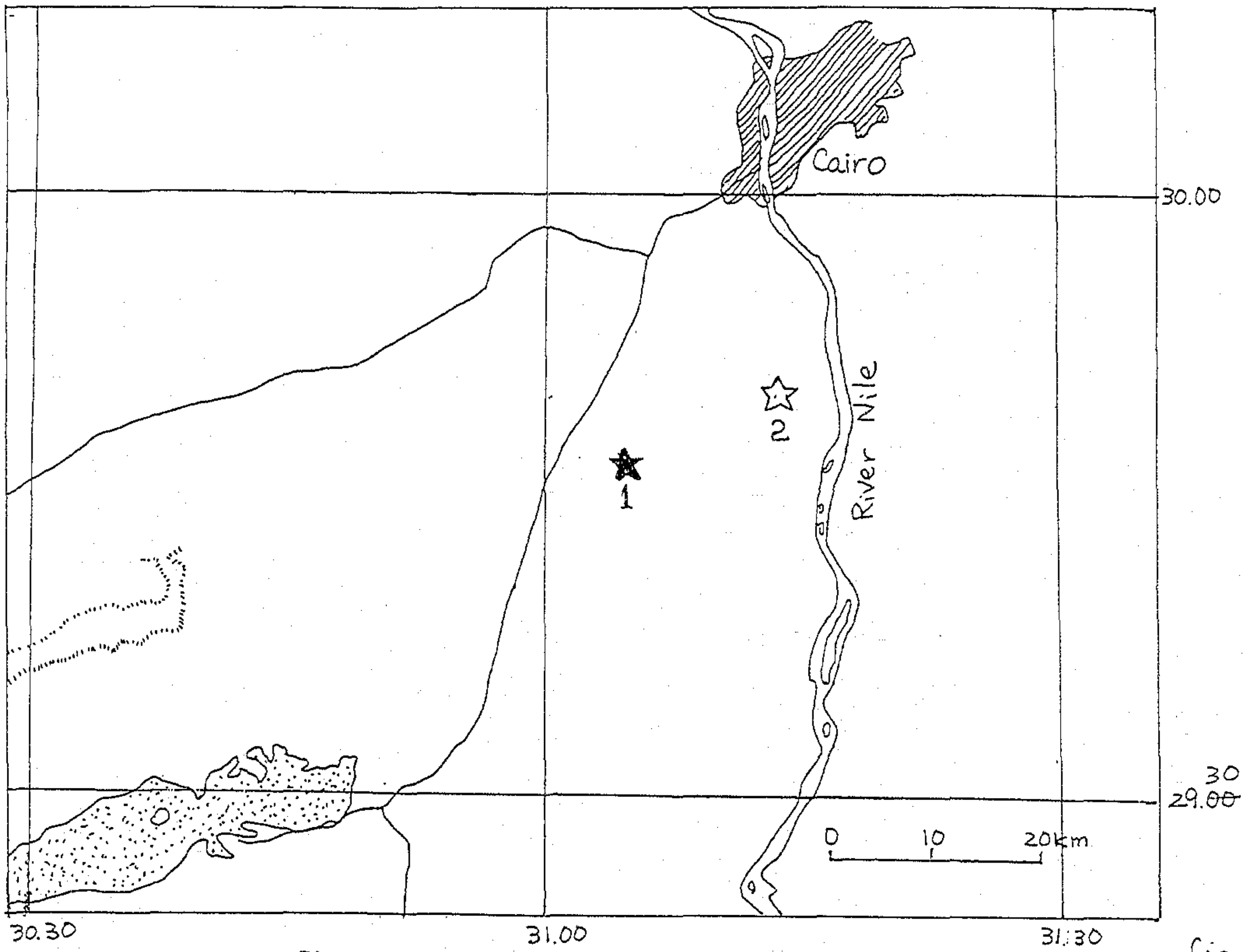


Figure 3.1.1 The location of the 1992 Cairo earthquake
1: the location by the NRIAG

fig. 3.1.1

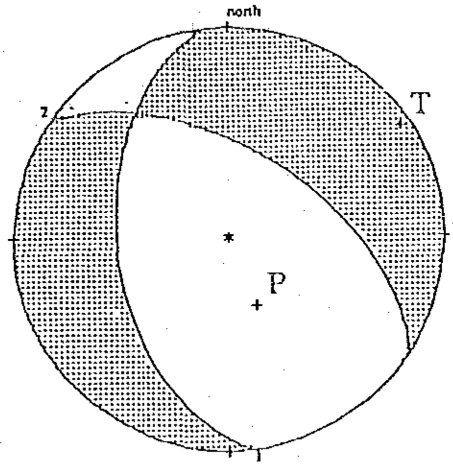


Figure 3.1.2 Focal mechanism diagram of the 1992 Cairo earthquake (after the USGS)
The shaded areas on the focal mechanism represent the compressional area projected on the lower hemisphere of the focal sphere.

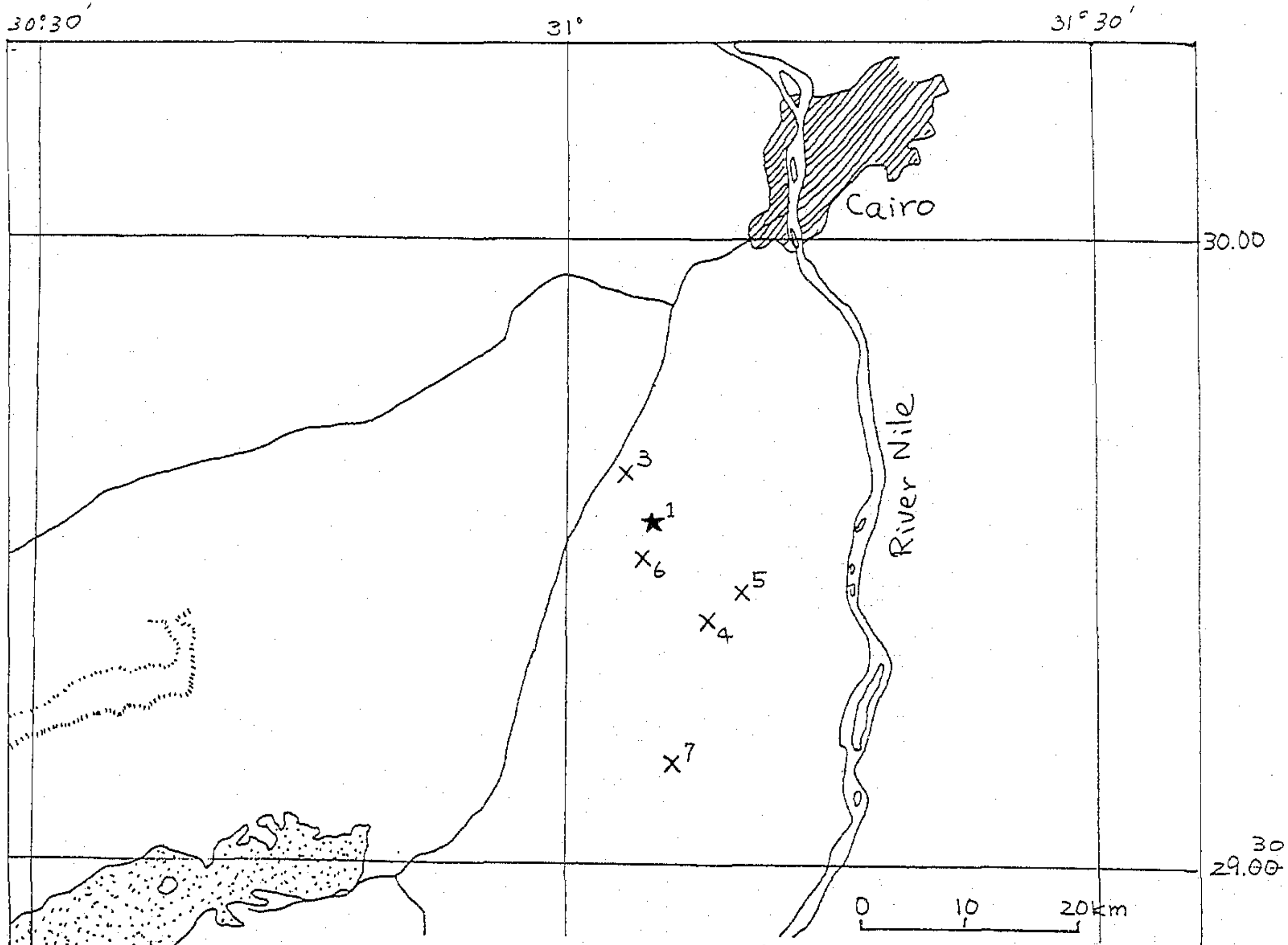
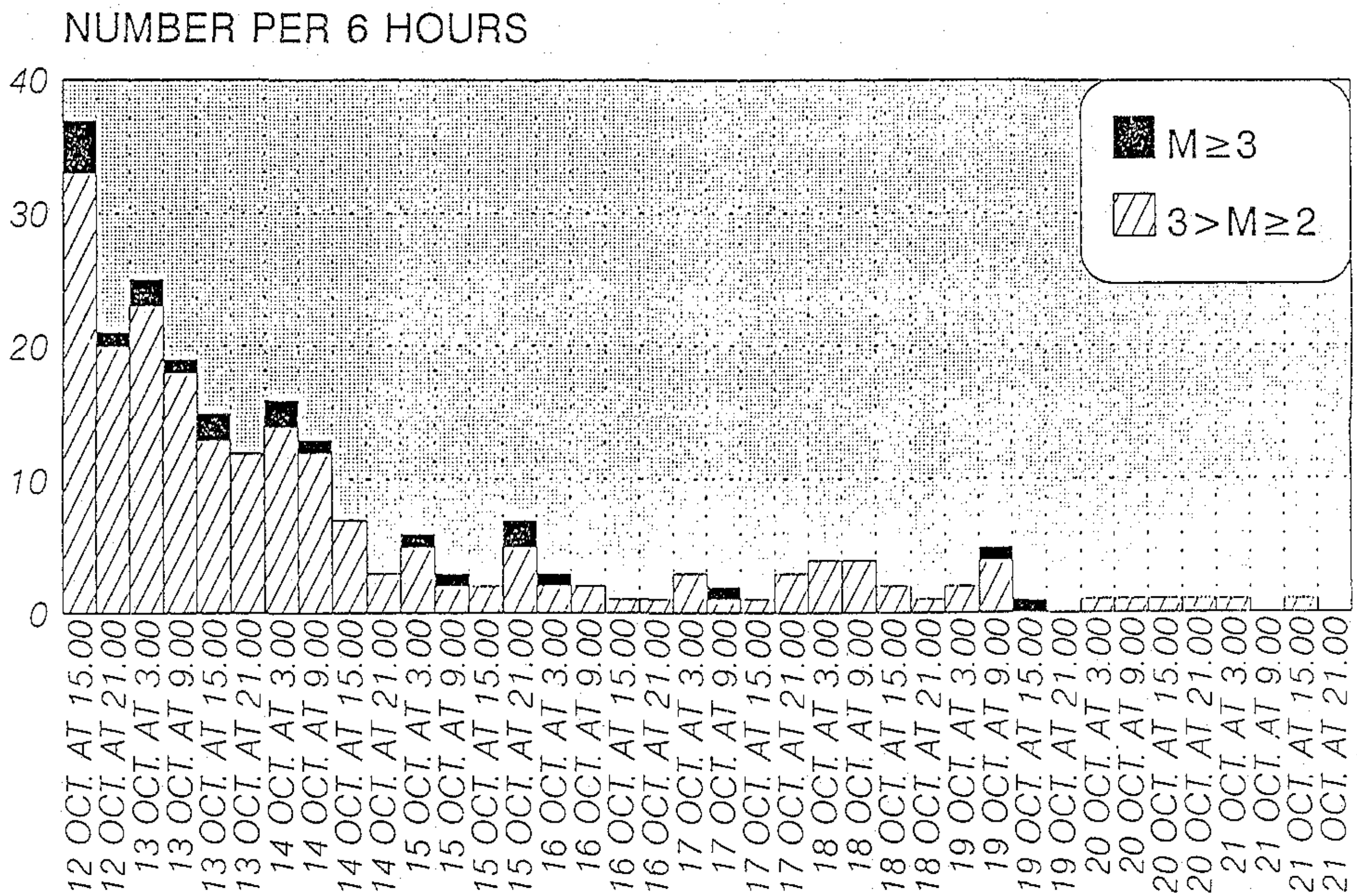


Figure 3.2.1 The epicentral distribution of the main shock and the major aftershocks.
1: Oct. 12 13:09 M5.3, 2: Oct. 12 15:25 M4.3, 3: Oct. 12 21:31 M3.7, 4: Oct. 13 18:09 M3.6, 5: Oct. 14 09:40 M4.0, 6: Oct. 14 03:50 M3.7, 7: Oct. 22 17:38 M4.2.
M is the duration magnitude. Event 2 is not shown in this

fig. 3.2.1

NUMBER OF AFTERSHOCK^ EACH 6 HOURS AFTER ¹2 OCT. 1992 EARTHQUAKE



DATA FROM NAT. RES. INST. OF ASTRONOMY AND GEOPHYSICS fig. 3.2.2

MADE BY AHMED, K. A. 1992

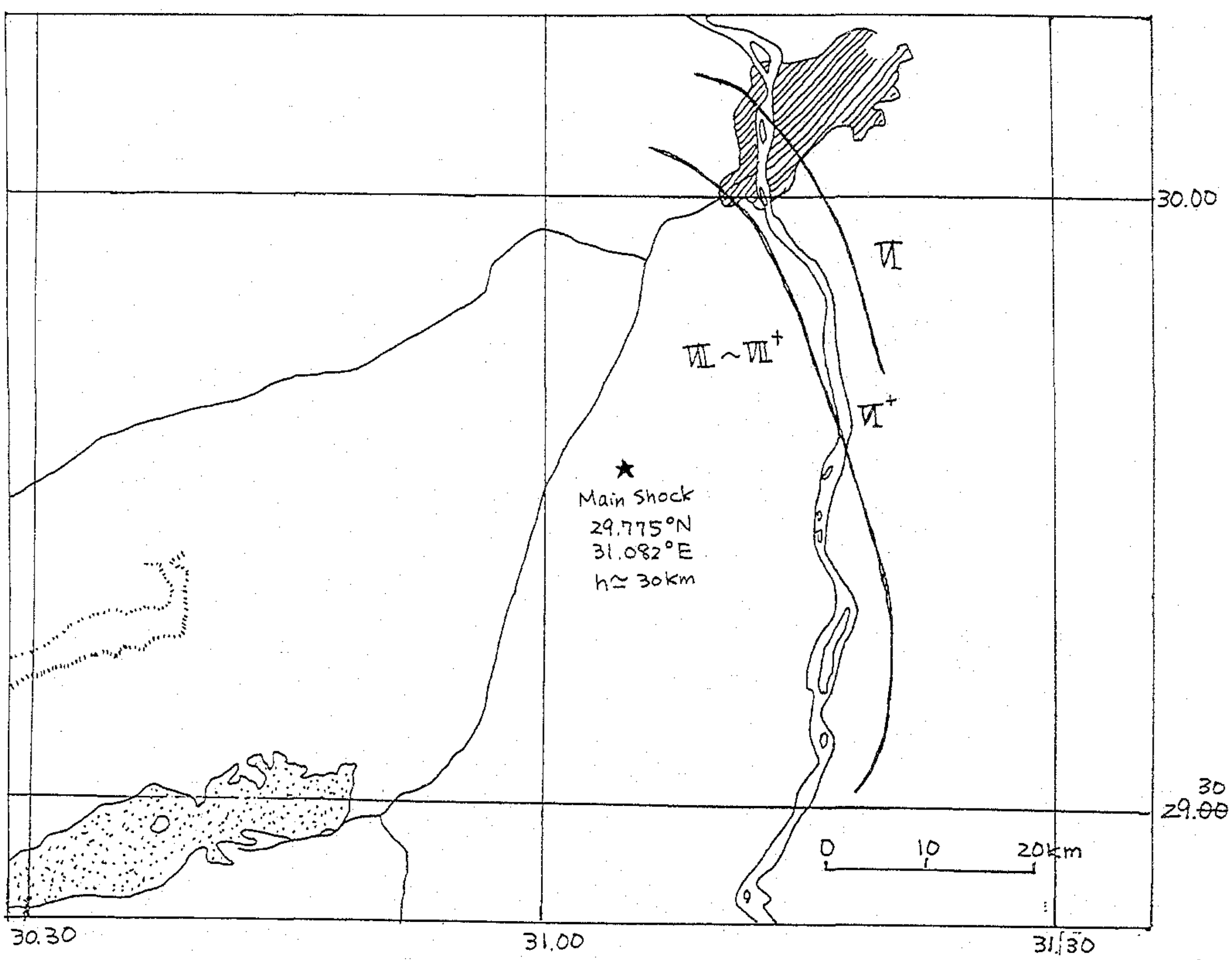

30.00
30
29.00
30.30
31.00
31.30
VI
VII ~ VII+
VI+
Main Shock
29.775°N
31.082°E
h≃ 30km
0
10
20km

fig. 3.3.1

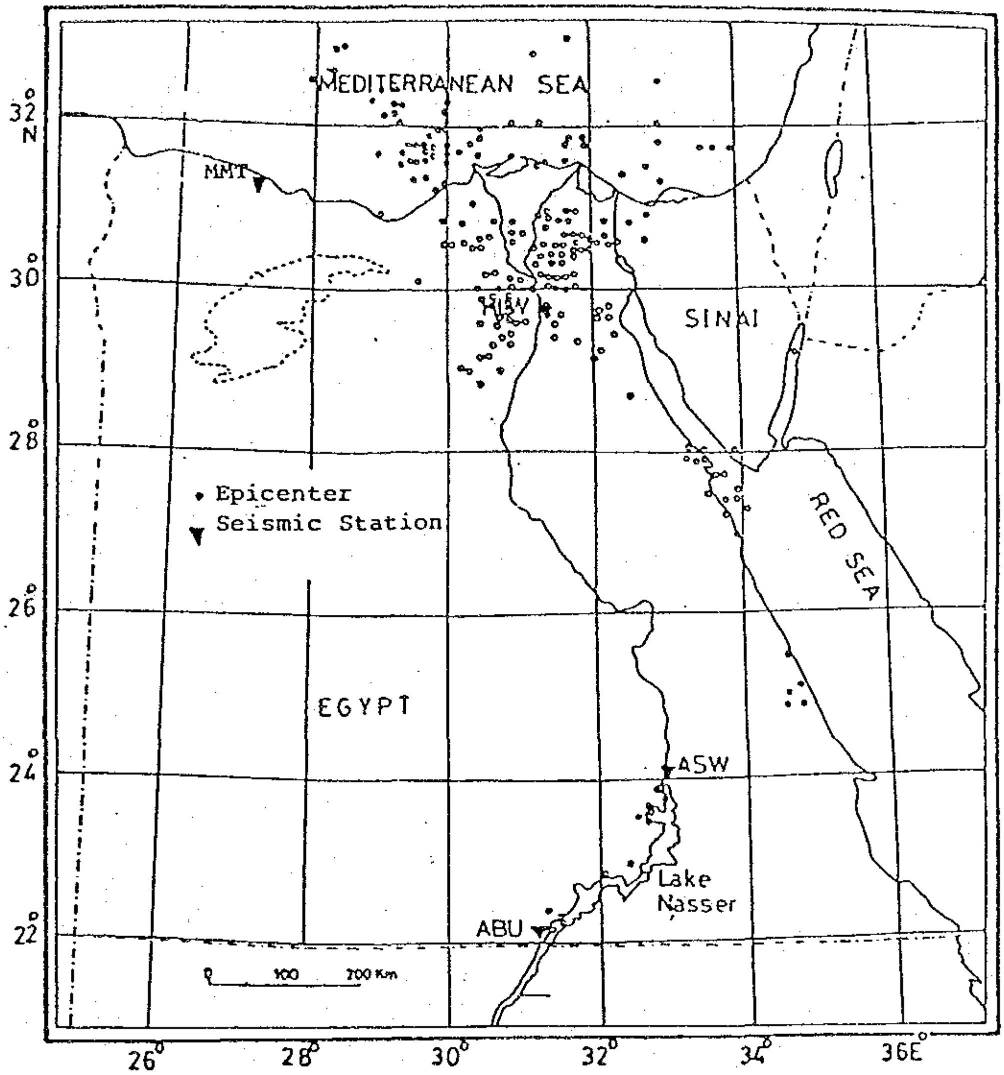


Figure 3.6.1 Epicentral distribution of recent microearthquakes (Kebeasy, 1990).
Solid inverted triangles indicate permanent seismic stations.

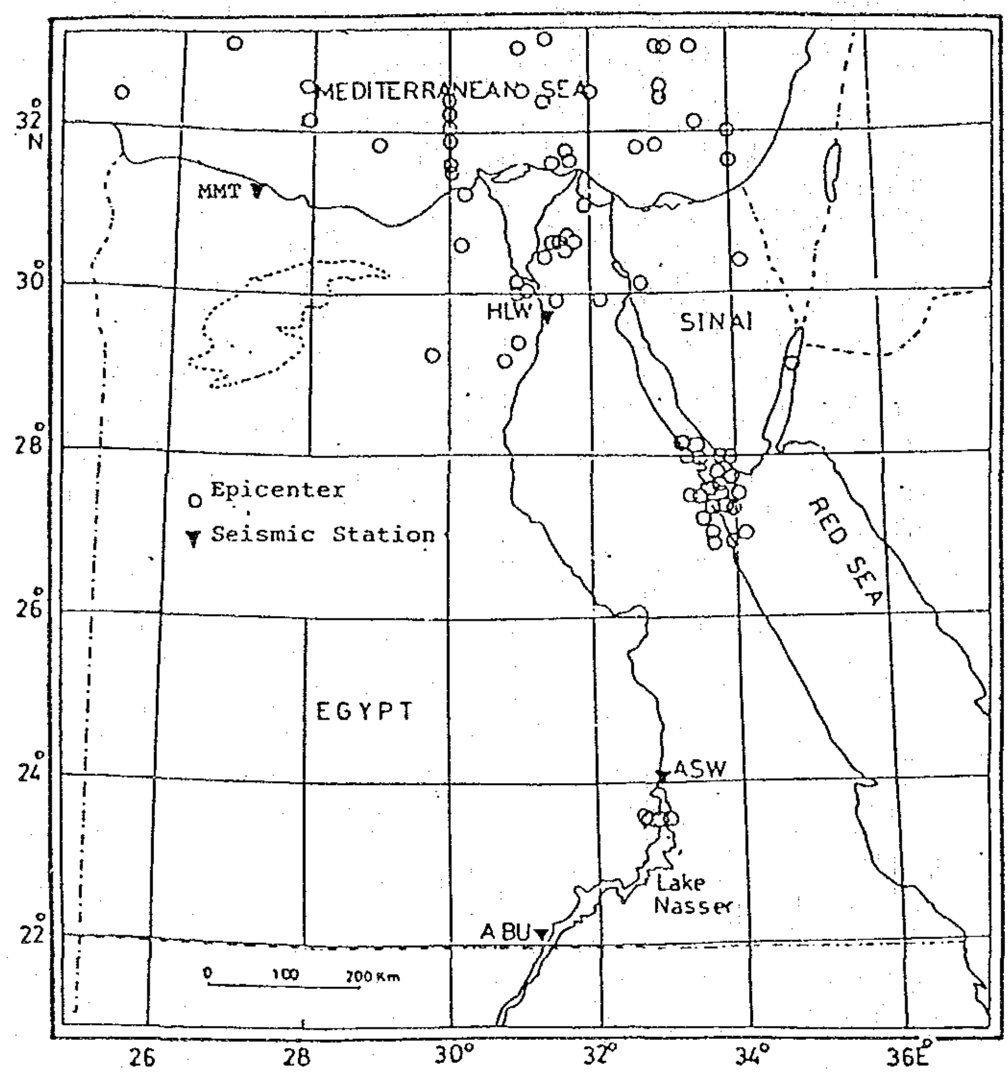


Figure 3.6.2 Epicentral distribution of recent small earthquakes (Kebeasy, 1990).
Closed triangles indicate permanent seismic stations.

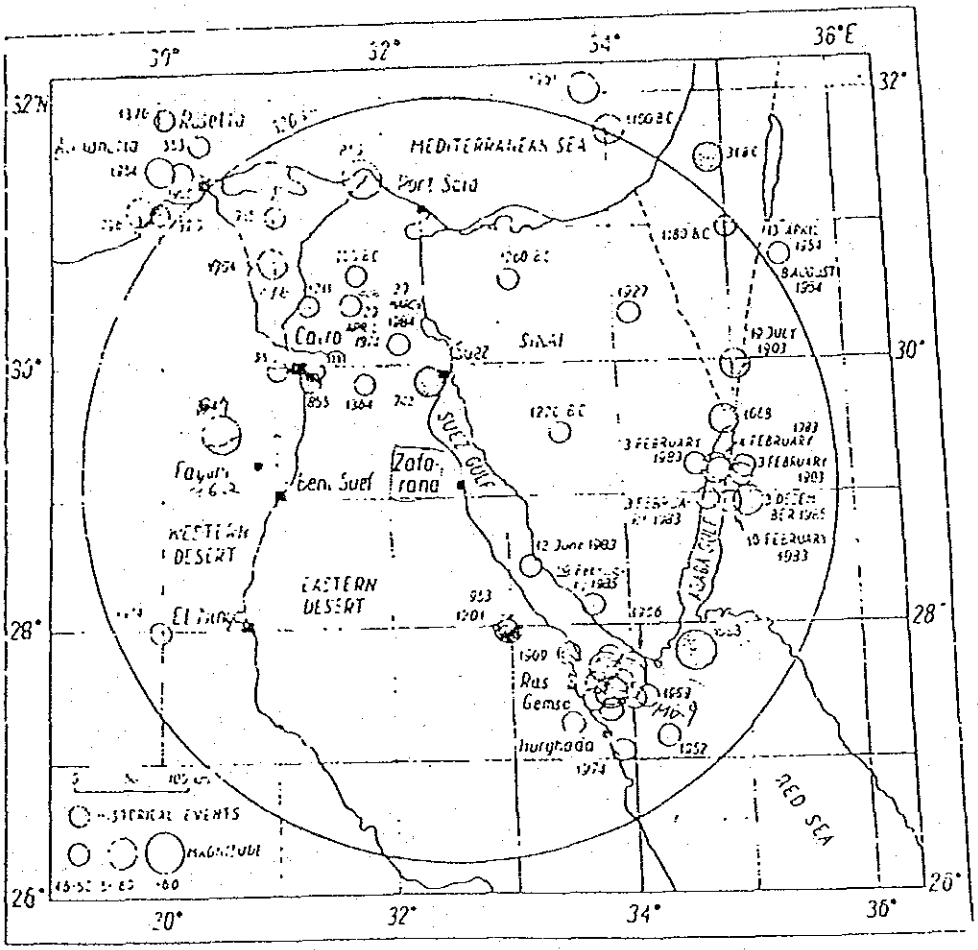


Figure 3.6.3 Epicenral distribution of earthquakes with magnitude greater than 4.5 around the Zafarana area (Albert, 1969). The circles with a radius of 320 km is marked.

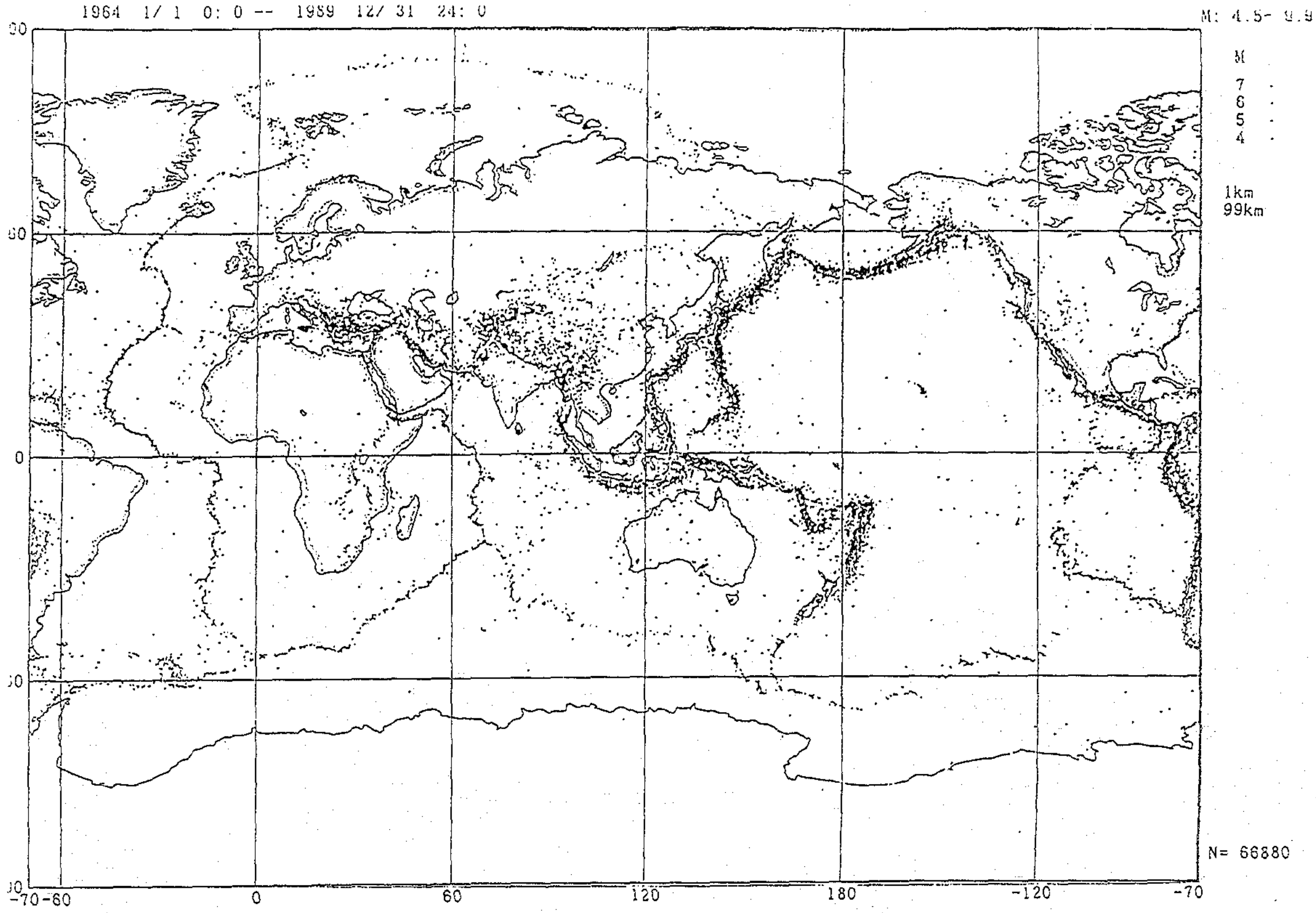


Figure 3.6.4 Epicentral disribution of earthquakes shallower than 100 km, occurring during the period from 1964 to 1989 (after the ISC).

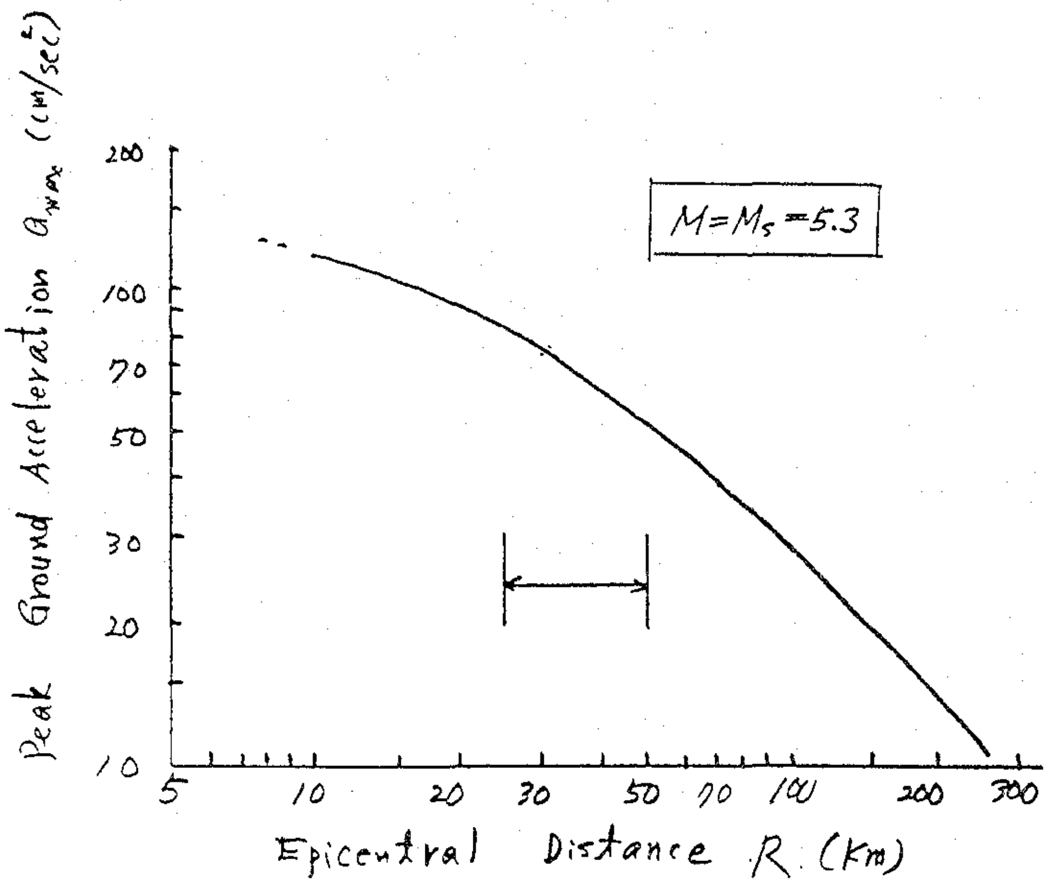


Fig. 3.2.1 Attenuation of Peak Ground Acceleration predicted by Eq. (1)

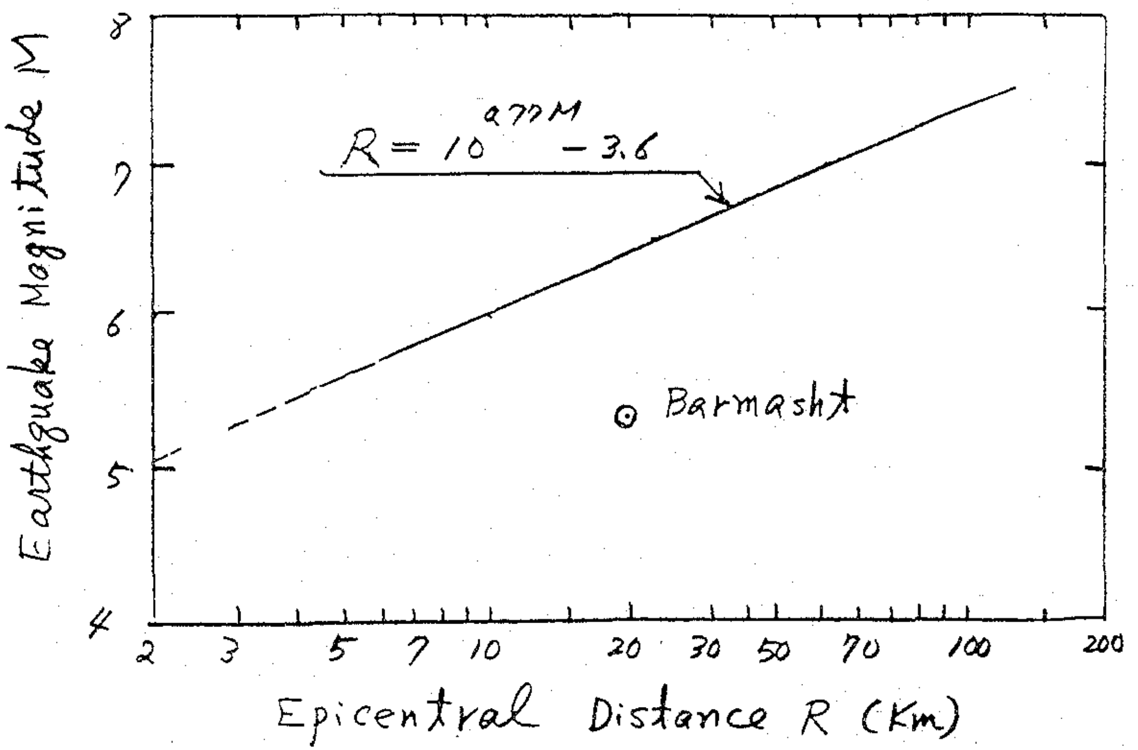


Fig.3.13-1 Epicentral Distance within which soil Liquefaction was likely developed in the past Earthquakes in Japan

JICA