

# An investigation of recent earthquake disasters from a viewpoint of urban engineering

H. Hokugo & S. Ichihashi  
*Nippon Institute of Technology, Saitama, Japan*

**ABSTRACT:** Earthquake disasters in the world's modern cities have been conspicuous in recent years. This report will analyze these disasters from the view point of urban engineering. The paper will concentrate on the following subjects: ground conditions affected cities, matter related to the urban infrastructure established in the cities and the current urban living environment.

## 1 INTRODUCTION

The earthquake disasters of the last 15 years(1976-1990) are shown in Table 1. The damage to human and physical resources has become bigger in these regions, especially the number of dead and injured tends to increase. For example, earthquakes have created havoc in Tangshan City, Mexico City, the Armenia Republic, Iran Manjir and Luzon Island since 1976.

The various social scientific problems existing at the back ground of these disasters are very important subjects to study in order to maintain the security of all citizens against such calamities. About these problems, this report considers and investigates from several point of view. These incidents have something in common in terms of urban engineering. Besides, of course, each earthquake has its unique aspects and it is also very valuable for future prevention efforts.

These investigations are based on several hold surveys conducted just after the disasters and this paper will aid in city disaster prevention.

## 2 CHARACTERISTICS OF RECENT URBAN EARTHQUAKE DISASTERS

The urban earthquake disasters are generally classified into two categories. One is about human, another is about articles including buildings. However, the relative importance for social impact has been enlarged at recent earthquake disasters in addition to described two points. In this section the characteristics of the urban earthquake disasters by the recent earthquakes occurred in the world are described.

### 2.1 Increase for the human disasters.

It has been conspicuous that there were a lot of deaths at each earthquakes remarkably. It is obvious from data in Table 1 that there were over ten earthquakes at that over one thousand deaths were arisen. About 30 thousand people were dead on the average at every year with each earthquakes. Over half of inhabitants were dead at Spitak

Table 1. The main recent earthquake disasters in the world from 1976 to 1990

| Date | Epicenter | Zone                                 | M   | Casualties |         |
|------|-----------|--------------------------------------|-----|------------|---------|
|      |           |                                      |     | Dead       | Injured |
| 1976 | 2         | Guatemala                            | 7.5 | >23000     | large   |
|      | 6         | West Iran                            | 7.1 | 6000       |         |
|      | 7         | N.E. China<br>(Tangshan)             | 7.6 | 242769     | 707000  |
|      | 8         | Mindanao<br>(Philippine Island)      | 7.7 | 5-8000     |         |
|      | 11        | N.W. Iran-USSR<br>Border             | 7.3 | 5000       | large   |
| 1978 | 6         | Miyagi, Japan                        | 7.4 | 23         |         |
|      | 9         | Iran                                 | 7.8 | 18320      |         |
| 1979 | 4         | Yugoslavia                           | 7.3 | 156        | >1000   |
|      | 12        | Ecuador                              | 7.9 | >600       | >20000  |
| 1980 | 10        | Algeria                              | 7.7 | 3500       | 9000    |
|      | 11        | Southern Italy                       | 7.2 | 4680       | 7671    |
| 1981 | 7         | Iran                                 | 7.3 | 1500       | 1000    |
| 1983 | 5         | Japan Sea                            | 7.7 | 104        |         |
| 1985 | 9         | Michoacan(Mexico)                    | 8.1 | >9500      |         |
| 1986 | 11        | Taiwan(Taipei)                       | 7.5 | 15         |         |
| 1987 | 3         | Columbia-Ecuador<br>Border           | 7.0 | 1000       | 4000    |
|      | 12        | Chiba, Japan                         | 6.7 | 2          | 138     |
| 1988 | 12        | Turkey-USSR<br>Boder(Armenia Spitak) | 7.0 | 25000      |         |
| 1989 | 1         | Tajik USSR                           | 5.3 | 274        |         |
|      | 10        | California<br>(San Francisco)        | 7.1 | 62         |         |
|      | 10        | Algeria                              | 5.9 | >50        |         |
|      | 12        | S.E. Australia<br>(Newcastle)        | 5.4 | 12         |         |
| 1990 | 5         | Romania                              | 7.1 | 14         |         |
|      | 6         | West Iran                            | 7.7 | 4-50000    |         |
|      | 7         | Luzon<br>(Philippine Island)         | 7.8 | >1621      |         |

Annual Report of Science(Volume 65). Edited 1992. Japan

in Armenia, and at Tangshan in China. It had been reported that there were a lot of another middle and small cities including the villages which were destroyed at the predicted scale.

## 2.2 Change of the article disasters

1. It would be necessary for us to take up the buildings' disasters first as the subject for our discussion. The streets of stores and houses in the modern cities were almost constructed by using the reinforced concrete structures. There were many collapsed and seriously damaged middle storied buildings that had from 5 floors to 10 floors in these Mexico, Spitak and Tanshan cities. These almost buildings were constructed with both the cast-in-place concrete method and the industrialized pre-fabrication method. Of course, a lot of low storied concrete block buildings and brick buildings that had some stories less than 5 floors were struck by the earthquakes. Besides the masonry buildings, there were big disasters at the buildings used for living made of woods near San Francisco Bay, and adobe at Algeria and Iran. These soil structures were prohibited to build with the law now. There were big disasters by fires at San Francisco in 1906, and at Tokyo in 1923. The disasters with the fires had been decreased when the earthquakes occurred as typical change for the buildings disasters.

2. The bridges that were very important facilities for the transportation systems had been dropped and the 2nd floor parts of the Cypress highway were destroyed by the Loma Prieta earthquake. The traffic stoppages by the destructions for general railways and roads were remarkable near the epicenters in the cases of every earthquakes. These problems came to the notable positions more than buildings' disasters by reflecting that the impatient improvements had been performed recently for the traffic network systems.

3. Recently, it had been necessity for the people to turn their eyes about the comprehensive disaster occurred at the cities as the problems to propose remarkably. The facilities of the cities at Tanshan, Spitak, and Rudobar in Iran had been destroyed nearly completely. Over half of the cities were struck by the earthquakes at Leninakan in Arumenia, and at Baguio and Dagupan in Luzon island. There would be same disasters that were occurred at Alameda district in Mexico, and at Watson ville and Santa Cruz from the point of view that the centers of the cities had been destroyed. Why is it necessary to focus on the problem about these huge City's disaster as one equipment? It is the reason that the modern cities have been developed remarkably the big centralization of population world occur quite locally in the cities.

## 2.3 Submission the social problems

1. At the first, it is necessary to consider that transmitting information facilities would work the very important roles in according to the developments of many media like today. It is the real fact that all of the informations runs around the world very quickly and at the short time. By these reasons, Anxiety in the people would be promoted and people would be confused when the stoppage or

delay of news at the accidents. The central equipments of electronic communications had been destroyed in Mexico city at the Mexico earthquake in 1985. With this trouble, nothing of the communications were performed for 24 hours after the first news about occurrence of the big earthquake were reported. There would be many well informed people who remember that people in other world were confused for these time. It look several days to know the outline for the disasters under a little equipments of the communications in the Manjir earthquake at Iran and the Luzon earthquakes in Philippine. It is said that people were stunned by the reports that the death were increased from several to several ten thousand.

2. When the big earthquake occurred at Loma Prieta much mental perturbation were given to the citizens in the city by the large sway. By the news from the scene of that disaster, the following problems were emphasized:

- 1) Increase of feeling for fear
- 2) Calamity of the action in the office
- 3) Anxiety for the counter measure at the earthquake

These problems were showed from the questionnaire survey for the citizens after one month passed from the time that the earthquake occurred. People told that there were some people who were considering to change the people to live and the office seriously. It was the fact that some one moved actually. These social problems in the modern cities have been highlighted seriously now. It has been heard as the news that the limitation to construct the high-rised buildings is performed at Mexico City, and the city areas are destroyed in Spitak. These facts show truly disasters by the earthquakes give a big damage and injurious consequence to the social environment in the cities. These are very important and serious problems that we, Japanese, must not neglect, though we couldn't realize those terror, because recently the huge earthquakes has not come to Japan.

## 2.4 Submission the structural strength problems

Some structural problems about the big disasters at the buildings and equipments are recognized that were described in the article disasters at section 2.2, by the surveys and analysis. The main problems are pointed out as followings.

1. The districts struck seriously by the earthquakes were places where the soil structures were commonly not strong. Those places are Mexico City, north cities in Armenia, cities near the San Francisco Bay, cities beside Caspi coast, and a tract of land from Akita to north areas faced to the Japan Sea. These districts had been heaped up with soft geologic strata that were layered at coasts, rivers including valleys, and crater lakes. There would be other wrong districts at inclined planes besides mountainous region, and grounds prepared for housing near the hills. There are those places in Manjir district in Iran, at Baguio City in Luzon, at Nepal area, at Tajik, and in the suburbs of Sendai in Japan.

2. Three remarkable problems were listed as followings from the point of structural planning.

1) The buildings were destroyed for their own insufficient rigidities, because these buildings have

earthquake resisting walls a little to perform much reasonable economic design. There were low and middle story reinforced concrete buildings in Mexico City as these examples.

2) There were many buildings that had high tendency to move themselves in a twisting direction. These buildings had big open spaces to put much facilities as the equipments in the cities. There were big differences for each rigidities at each directions from the point of the plane planning. Office buildings, hotels and wooden houses in the area around San Francisco Bay and the buildings that had the garages for cars at the first floor in Mexico City would be the examples as these cases. There were same kinds of buildings that have much eccentricities, and piloties in the broad sense. Hotels and schools in Baguio would be this example.

3) There were the structures that had weak point at the joint parts. For this example, there were shear key parts that hadn't sufficient strength at the column bases of the upper floors in the two story high way called 880 line. The low and middle prefabricated buildings by the modern industrialized technology in Armenia and in Tangshan, and houses made of light-weight steels and bricks at the north area in Iran.

3. There were estimated maps for seismic intensities in every countries. The actual seismic intensities at Algeria, Tangshan, Mexico and Armenia would be more than estimated intensities. The researchers had been surprised by the unexpected strength of the vibrations that were more than the calculated strength by using the magnitude and the distance from the epicenter of the earthquake in San Francisco Bay coast. Another new important problem is that there were twelve deaths at Newcastle in East-south Australia where nobodies have experiences to be attacked by the earthquakes.

### 3 CONSIDERATION FOR EARTHQUAKE DISASTERS FROM URBAN ENGINEERING

In this section, summary about the characteristics of the earthquake disasters would be showed through the organization and development of the cities.

#### 3.1 Organization and dilatation with the progress for cities.

There are many faces in the cities. Mexico City had been formed on the soils that were layered into the crater lake at the southern central plateau areas in Northern American Continent(Fig.1). This city had been developed from the temple as the central place of this city in ancient Asteca generation. Still now, many prehistoric sites have been remained in the Zocalo district. After Spain governed these area once, people obtained their independence in 1821 and have now been living there. People are proceeding to make efforts to keep their economical position next to most progressed countries, and to maintain relatively stable of affairs in a country by carrying huge debts on their back. Armenia has a great old histories as the Christian country from epoch. America was discovered before 500 years and has been developing by the European people. This country also are raising

nations from the historical point of view. However, America is the biggest power nation that hold sway over the world. America has many famous much modern cities that have been formed gradually by the people, such as New York, Boston, Los Angles and San Francisco.

The population in the world has been increasing rapidly. There are over 5 billions in the 1990s. It is the fact that those increasing people are concentrating almost to the big cities, or living the artificial developing area. The expanding region at the central area around San Francisco Bay is showed in Fig.2. It is said that this bay was formed by the subsidence of the land. The soils around this bay were heaped with soft mud. The areas along this bay quite widely have been filled up to spread the urban districts at modern ages. Areas at the West Coast in America have a small history, about 200 years, from the starting time to develop. The areas faced to the Pacific Ocean in America has been developing remarkably for only these 100 years. On according to these developments of the cities, population in the cities has been increasing rapidly. The flows of inhabitants in Mexico City have been enlarging with increasing speed. At present, the population reaches twenty millions in the Metropolitan area(Fig.3). This is the big one city in the world. There

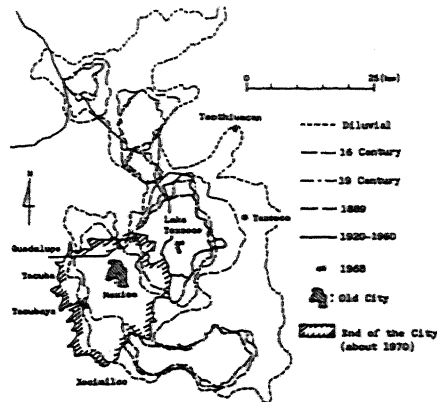


Fig.1 Variation of Mexico Valley (UNAM)

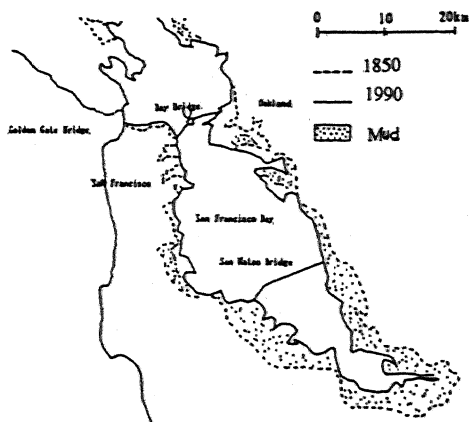


Fig.2 Change of Shoreline of San Francisco Bay (AII)

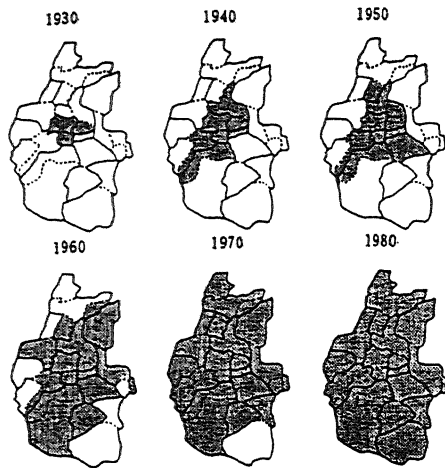


Fig.3 Extension of Zona Metropolitana de la Mexico (ZMCM)

are many people who are overflowing into the districts around Tokyo. People are using the word usually, "concentration of the population into one area". Tokyo Bay is now filling up with soils and developing to keep the lands. It is the situations how many cities in the world are progressing. By considering such problems with relating to the earthquake disasters, it would be correct that new filling and developing lands has faults for the aseismic characters. There are tendencies progressed by the administration to build the high-rise buildings at the existing lands to use them efficiently. This would make the dangerous conditions by, that are concentration of population and densely built-up area, by considering the disaster prevention of the cities.

### 3.2 Relation with city ground and earthquake disaster

By the expanding of city, as a matter of course, the buildings become to spread, either horizontally or vertically. That is, the weighty things load on city ground and its imposed a big burden in whole area and in local part.

The large scale settlement diagram in the central part of Mexico City is shown historically in Fig.4 as one meter at average one decade. These phenomena had continued until the earthquake came in 1985. The isoseismal map with seismic acceleration and the damage area at the Mexico earthquake in 1957 is also shown in Fig.5 (M=7.9 at the site of epicenter under the Pacific Ocean). As the settlement curve of the ground agrees with those data quiteily, the disaster is caused bigger with this matter. They says same phenomenon was occurred at the Mexico earthquake 1985. It shows that the site settlement affects considerably to the increase of the earthquake disaster.

At the Lomz Prieta earthquake in 1989, it has been confirmed that the whole neighborhood at 880 Cypress free-way suffering destructively from the big earthquake has been settled irregularly. There were same phenomena in the central part of Watson ville City and Santa Cruz City. The disaster areas by this earthquake are showed in Fig.6.

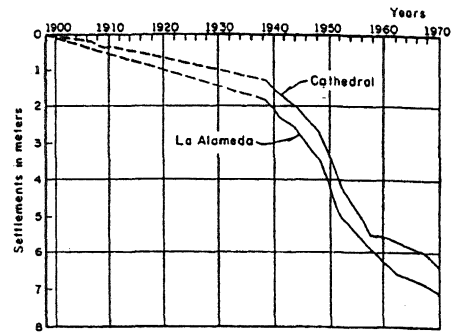


Fig.4 Settlement of Central Mexico (UNAM)

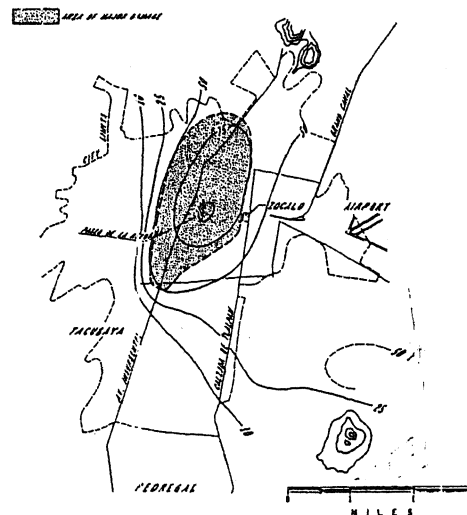


Fig.5 Isoseismal Map, Mexico City Earthquake 1957. (2nd WCEE)

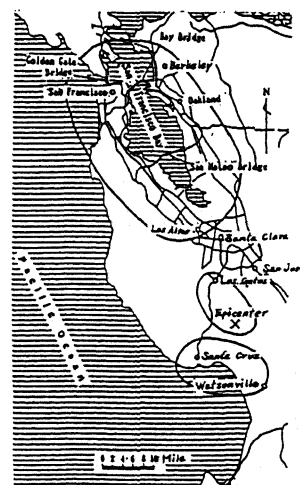


Fig.6 Area of Hardry Damage Buildings (AIJ)

By the differential settlement, the upper parts of structures on the ground bears for the big added stresses. Many buildings had been collapsed in a moment without endurance against the big over stresses at Mexico City earthquake in 1985. So, there were many deaths.

The under-ground water must be considered in the case of study about the weak ground subsoils. It is used for drinking and industry with drawing up. Consequently it is evident that the settlement is encouraged. In the report about Mexico City earthquake disaster in 1985, some explanations about the water including into the subsoils were performed by H.Hokugo as followings. And those water plays a very important roles in the transmission and amplification for the seismic waves. Especially, water may makes the seismic waves amplify in the vertical direction more bigger. The data obtained at the Loma Prieta earthquake is showed in Table 2 and the acceleration diagram collected at the Mexico City earthquake is also showed in Fig.7. Moreover, the movement of under-ground water cause the liquefaction, the collapse of the slanted ground surface and the damage for the structures' foundation at the earthquake.

Table 2. Peak Acceleration for selected recorded ground motion (USGS)

| Station                 | Distance (Km) | Direction | Peak Acceleration |
|-------------------------|---------------|-----------|-------------------|
| Corralitos              | 5             | EW        | .478              |
|                         |               | NS        | .629              |
|                         |               | Vertical  | .439              |
| Santa Cruz              | 20            | EW        | .409              |
|                         |               | NS        | .441              |
|                         |               | Vertical  | .331              |
| Foster City             | 48            | EW        | .283              |
|                         |               | NS        | .257              |
|                         |               | Vertical  | .103              |
| Oakland 2story Building | 76            | EW        | .243              |
|                         |               | NS        | .191              |
|                         |               | Vertical  | .144              |

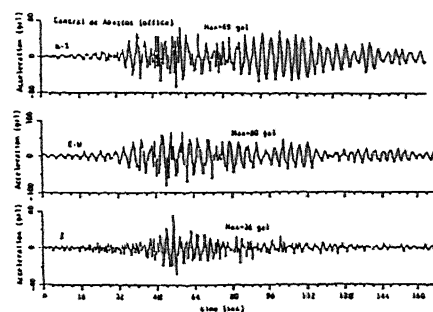


Fig.7 Mexico' Record Central de Abastos (UNAM)

### 3.3 The urban fatigue and the aged declining of the structures

Under several alternation on the earth with the nature that are wind, snow, rain, earthquake and so on, all the structures must be commonly fallen into the declining

through the long time. The structures buried into soils continue to expose into the movement occurred with the traffics, repeating works for the excavations and seismic vibration. The structures would be under the cyclic fatigue load testing.

The buildings themselves would be in the state of aged declining rather than under added stresses as described before. The buildings would be perhaps in the same situation at Armenia and Tangshan. It would be the fact that the fatigues for all equipments in the cities would be accelerated. We must consider how the cities would be changed, when a huge one would attack them under those situations. There would be a very important and unavoidable theme for the future disaster prevention of the cities, only when we must discuss about those problems with each other.

### 3.4 Some social problems occurred in the city by the earthquakes

The present day is the information-oriented society. It has been proved at Mexico City in 1985 that the stoppage of communication give terribly anxious feelings to the world being. It means that the correct and rapid communication is the most requisite factor at the time of disaster.

The traffic facilities are indispensable necessities in urban life. The collapse and fall of several bridges at the 1989 San Francisco Bay earthquake disasters were the very key damages to the life line in the city. Fortunately, by the quick and efficient response of state government, the city got through without much confusion. However, other life line equipments in the city considerably suffered from the earthquake. The government seems to have dealt with the damages with the highest priority right after that.

The earthquake disasters give the severe mental pain to the humans. The citizens in Mexico, Armenia and Iran, who suffered great number of deaths in an instant from earthquakes exclaimed "Construct the building immune to earthquakes". And the San Francisco citizens cried the need for non-shaking buildings to reflect the mood of high fear complex developed after the earthquake. These matters mean that the city habitants desire the stable living environment, and are more concerned about the need for secured living conditions vis-a-vis coats of their housings and buildings.

## 4 THE POLICY FOR MODERN CITY EARTHQUAKE DISASTER PREVENTION

The radical expansion of the city thwarts urban revitalization. The expansion of the city has destabilized formerly unified response mechanism which were designed to deal with disaster. As aforementioned, the city began to show signs of aging and fatigue. We have seen an increase in injuries and casualties and noticeable rise in social discontent.

Consequently, in order to protect prosperity of the city, one must construct the proper disaster prevention system. Such a system must include the following:

1. The scale of the city should respect geographical limitations. High concentrations of people are unpleasant and should be avoided. The infrastructure of the city

sets a natural limitation on city population capacity. The construction of crowded buildings will disturb pedestrian trail and increase the probability of disaster. The crowded structures will increase the damage caused by settlement of the ground during earthquakes.

2. The city structure must be designed securely by taking into account possible earth movement during tremor. Because each site responds to seismic shock waves with its own characteristic pattern, corresponding strict seismic risk microzonation must be used.

3. Post-quake city disaster prevention policies must be efficiently organized. For example, the city government of San Francisco took quick action in response to the Loma Prieta earthquake in 1989. Their splendid efforts are still admirable. About 200 inspectors participated in consulting homeowners in the Marina region, evaluating earthquake damage and serving as volunteers. Fire-protections worked actively and effectively, putting out raging flames in only one night. The potential traffic nightmare that could have resulted from the sundering of a large section of the highway was adroitly averted through the use of the Bart subway system, ferryboats and detours as alternate transportation routes. Only with a well prepared disaster prevention system was this city able to defend against the confusion caused by an earthquake. And the Mexican governments immediate action response to their earthquake obtained very good results as well.

4. Concerning telecommunications during earthquakes, it is highly recommended matter that fundamental telephone facilities be better prepared for earthquakes through the employment of multiple back-up systems. Recent earthquakes in developing countries have revealed many defects in communication networks. This is a matter of great importance for people everywhere.

## 5 CONCLUSION

In sum, the foregoing analysis bears the following conclusions:

1. Cities with expanding and high concentrations of people will suffer problems in their development. They will find it increasingly difficult to prevent disasters.

2. These damaged cities are on the bad ground that is, due to crowding, increasingly soft, so careful planning is needed to prevent earthquake calamities. It is especially necessary to pay great attention to settlement, liquification and landslide.

3. The structures(houses,buildings,public works) on soft ground in modern cities must be made more secure and earthquake-proof. Careful consideration must be given to structural fatigue.

4. The recent transformation of the global environment tends to ignore the historical lessons of earthquake tragedies. Such tendency, will increase the likelihood of disaster wherever earthquake occur.

5. Rapid and effective communication is very important to disaster prevention. Accordingly, it is desirable that multiple back-up equipment will be used and, if possible, the existence of a global hotline is demanded fastly.

6. At the present time, it seems that social systems are more focused on the threat of earthquake disaster than seismic structure engineering. The construction of earthquake prevention systems is urgent necessary for the need to respect and protect human life.

## REFERENCES

- Annual Report of Science Volume 65: National Astronomical Observatory Edited 1992 Japan
- Architectural Institute of Japan. 1987. Reports on the damage Investigation of the 1985 Mexico Earthquake
- Architectural Institute of Japan. 1990. Reports on the damage Investigation of the 1989 Loma Prieta Earthquake
- Governor's Board of Inquiring on the 1989 Loma Prieta Earthquake, the. (May 31,1990 Competing Against Time
- Hokugo, H.1988. General Report on Investigation of 1985 MexicoEarthquake Disaster Report of Researched: Nippon Institute of Technology No. 88-02 1988.
- Hokugo, H. (1990.2-1991.11). Research of The Investigation of 1989 San Francisco (Loma Prieta) Earthquake Disaster: Nippon Institute of Technology Report V.19-4-V.21-3
- Marsal, R.J. Contribution of the Institute de Ingenira to the International Clay Conference. UNAM.
- Rosenbluth, E. 1960. The Earthquake of 28 July 1957 in Mexico City, Proc. 2nd W.C.E.E
- Yamazaki, H. 1957. Mexico City. :Tokyo University Press