INVESTIGATION OF THE PERUVIAN EARTHQUAKE OF OCTOBER 3, 1974 AND SEISMIC PROTECTION STUDIES OF THE LIMA METROPOLITAN AREA

by

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SYNOPSIS

Many developing countries located in earthquake prone areas have a large percentage of their population concentrated in their capital city and a great percentage of their economic and industrail activities take place there. They are highly vulnerable to earthquake damage as provisions for earthquake resistant design have only recently been adopted. This paper deals with the studies being made in Lima, Peru, since early 1973, of the probable effects of a serious earthquake on the buildings and lifeline networks of that city. The study of the damage caused by the October 3,1974 earthquake added very valuable new information for the investigation.Short, medium and long-range plans for improving the earthquake safety of Lima are being proposed to the Peruvian government through the National Committee, of Civil Defense, based on the preliminary results of the studies.

INTRODUCTION

The May 31, 1970 earthquake in Peru (1), and the December 23, 1972 earthquake in Nicaragua (2) (3) showed the vulnerability of the populated areas of those developing countries located in areas of high seismic activity. In order to clarity the most critical earthquake problems of Lima, the capital city of Peru, a study was started in March, 1973. Nearly one fourth of the population (four million persons) and seventy percent of the country's economic activities are concentrated in the Lima area. Most of Metropolitan Lima is located on an alluvial fan adjacent to the western foothills of the Andes,about 100 meters above sea level,with a gentle slope westward toward Callao, Lima's Pacific port. The tip of a narrow peninsula, forming part of Callao, is less than 5 meters above sea level.

Lima has a long story of documented earthquakes since 1540. The worst was in 1746 when the city was completly destroyed and Callao razed by the tsunamis.

When this study was started the hypothetical damage distribution was mainly based on the isoseimal maps of the 1940, 1966 and 1970 earthquakes which were quite similar,even though they correspond to events with different parameters, showing the strong influence of the local soil and geologic conditions. Places located only a few kilometers apart have shown up to three degrees of difference in intensity. The October 3, 1974 earthquake, the strongest in Lima in the present century, and that of 1940 had similar intensity distributions, but the 1974 earthquake offered a broader view, since the city had expanded nearly six times in size between 1940 and 1974.

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Most of the investigation has been made in the form of Civil Engineering thesis at the National University of Engineering, with some economic support from the Civil Defense Committee.

METHOD OF STUDY

First the available data on population, damages of past earthquakes, recorded seismograms and processed spectrums, seismicity studies, geology, topography and soil mechanics studies were collected. Then the "most probable earthquake" was selected, considering not only the parameters normally used in this type of study, but also foreseeing the final results, so that the improvement work would be kept within proctical margins. The intensity distribution considered was slightly stronger than that of the 1940 earthquake, as is shown in Fig. 1.

To estimate the degree of destructiveness to the different types of buildings at different intensities, a table of building classifications was prepared for adobe (a_1 and a_2 types), brick (b_1, b_2, b_3, and b_4) and reinforced concrete (c_1, c_2, and c_3) according to their strength, age, preservation, existance of defects (large excentricity, short column, etc.). To estimate the percentage of losses for these types of buildings, additional tables were prepared for intensities VII, VIII, IX MM. To prepare these tables a great deal of judgment was used, based on experience gained during 1970-1975, when thousands of buildings damaged by the 1970 and 1974 earthquakes were studied. About 2000 brick and 100 reinforced concrete buildings were analysed in detail at this time, when restoration projects were prepared for them (4)(5).

Taking into consideration the government agency that might tackle the problem, the buildings in this study were classified as housing, school, hospital or industrial. In Metropolitan Lima, there are hundreds of thousands of dwellings, so in the survey, the statistical method was used. First, the wards to be studied were divided according to building and soil characteristics. From each section with similar characteristics, 5% of the city blocks were selected, and from each of them, 10% of the houses were studied, using specially prepared forms. Extrapolating the results, the possible total losses were estimated. Similar sampling methods were used for schools, hospitals, and industrial buildings. Since the main aim is to protect people, some social aspects were also studied.

To study the lifeline networks, data of damage in past earthquakes in Peru and in other countries has been collected, along with other studies, especially those from the United States and Japan. In the light of this information,the existing networks have been under study since January,1975. In respect to secondary effects such as tsunamis and fires, the areas susceptible to damage by the first have delimitated and possible escape routes have been selected.At this time only the danger of fire in industrial instalations have been studied and the strength of the fire stations analyzed.

RESULTS

To simplify the interpretation of the results, the buildings were grouped into four types (A,B,C, and D) according to the expected damage (75%, 50%, 20%, and less than 5%). Then for each type, the percent of buildings existing in each ward section was plotted on a colored map, indicating "more than 80%", "80-60%", "60-40%", "40-20%", and "less than 20%". By looking at these maps it is evident which are the more dangerous and which are the safer areas. This knowledge will be useful to the National Committee of Civil Defense for planning the action to take, before, during, and after an earthquake disaster.

The most critical areas are in the old section of the city where a significant percentage of adobe construction still exists. Some of them are overcrowded and have only a narrow passageway as an escape route. Some old adobe buildings are being used as schools for the younger students (6 to 12 years old). Fig. 2 shows an old adobe apartment building.

Many brick and reinforced concrete buildings are not earthquake resistant. The Seismic Code was only officially adopted in 1970 and many buildings still have the same defects that caused thousands of building failures in the past (short columns, large excentricity, resistance in only one direction, etc.). Buildings with these characteristics located in areas where the seismic amplification is high, were the ones that received the worst damage in the latest earthquakes.

In the industrial area, many times costly equipment is housed in unappropriate and weak buildings and little attention is paid to the possibility of earthquakes or fires. Some of the hospitals are old and may be put out of working order in case of an earthquake. The access to some will be greatly affected by vehicular congestion either because the hospital has been mislocated or due to improper orientation of the entrances. Because of the limited space and the local interest of the specific results of this study, only general results are given here.

COMPARISON WITH JAPANESE STUDIES AND FUTURE RESEARCH WORK

One of the authors spent three months in Japan studying the protection of urban areas from destructive earthquakes. Special attention was taken of the Tokyo Metropolitan area (6), Kawasaki (7), and Osaka (8). The Earthquake Disaster Prevention studies of the Tokyo Metropolitan area have as their purpose to establish the regional danger degree of an earthquake disaster in order to minimize damage and to determine the physical impact than an earthquake and its sequels (fires, floods, tsunamis, etc.) have on urban facilities and activities.

The studies were started more tnan 10 years ago with the enthusiastic participation of the late Prof. Kawasumi. They are very detailed and in some cases, very sophisticated. For example, for every five hundred meter square area, studies are made considering up to 20 different types of earthquakes and a non-lineal analysis is made of their effect on wooden houses. The partial results of each study is expressed in a numerical way and added up to obtain the final result, which is represented on a colored map.

Most of the studies are in the fields of seismology, engineering and sociology. Studies made in the other cities are similar and have been carried out with the participation of many persons and institutions.

In the case of Lima, relatively few persons have been participating and locally developed methods have been used to try to define the most critical problems. Inevitably simplifications have been necessary but it has been possible to clarify some of the problems. More detailed studies are necessary. Proposed future studies are shown in the accompanying Fig.3. The Japanese experience in the field is going to be very useful, together with the information from the studies made in San Francisco, California, and the paper presented at the Intergovernmental Conference on the Assessment and Mitigation of Earthquake Risk held in Paris in February, 1976.

CONCLUDING REMARKS AND RECOMMENDATIONS

Due to the complexity and extent of the problem, this study should be considered preliminary. Strong support from local authorities is needed to make more detailed studies.

To minimize losses in future earthquakes, efforts should be made in two directions: improving existing buildings, and demolishing those in precarious condition. Since a vast investment is needed, tax advantages should be offered to those persons who help solve this problem.

In fifteen years Lima will have doubled her population. The results of this study must be taken into consideration and the new infraestructure must be earthquake resistant. As a long range goal, the excessive growth of Lima must be controlled.

ACKNOWLEDGMENTS

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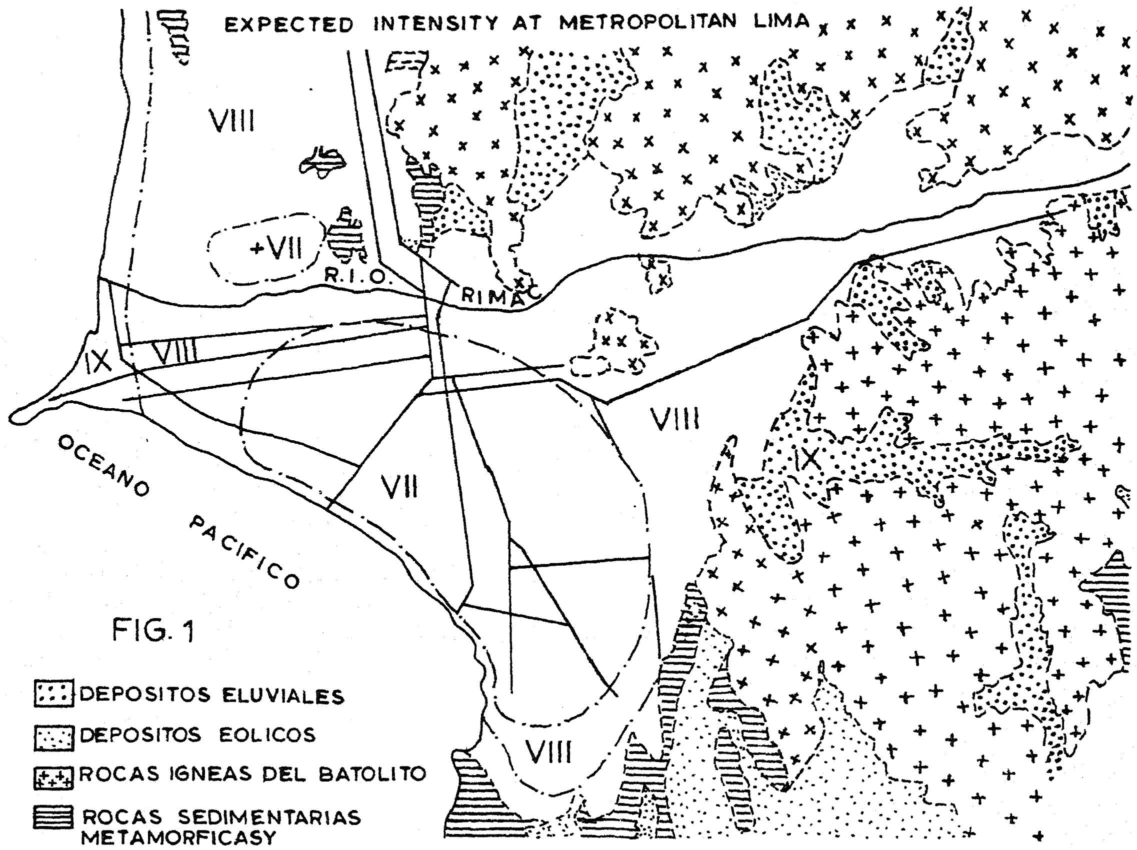

EXPECTED INTENSITY AT METROPOLITAN LIMA
VIII
+VII
R.I.O.
RIMAC
IX
VIII
VIII
OCEANO PACIFICO
VII
IX
VIII
DEPOSITOS ELUVIALES
DEPOSITOS EOLICOS
ROCAS IGNEAS DEL BATOLITO
ROCAS SEDIMENTARIAS METAMORFICASY

FIG. 1

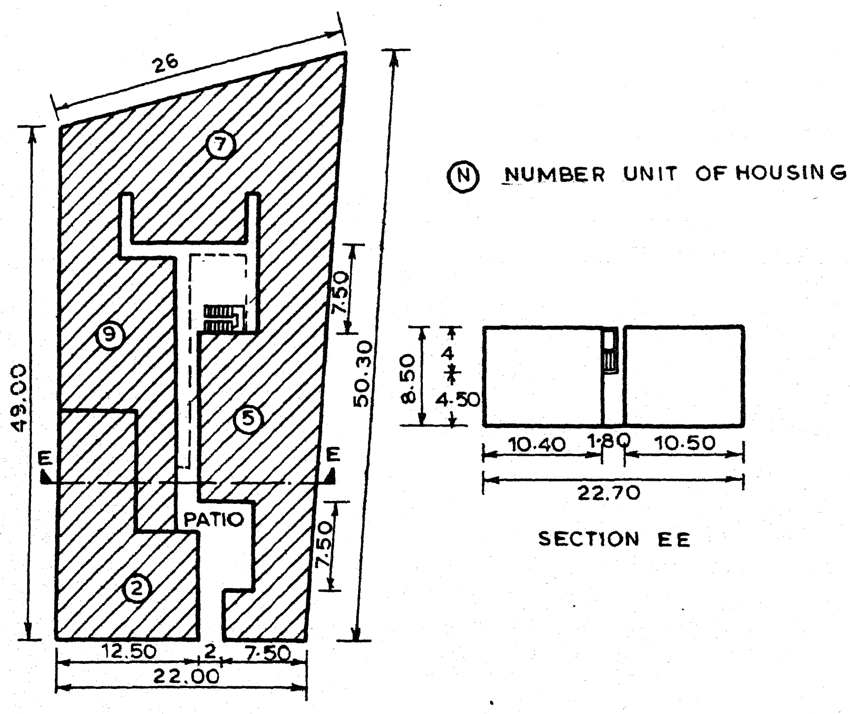
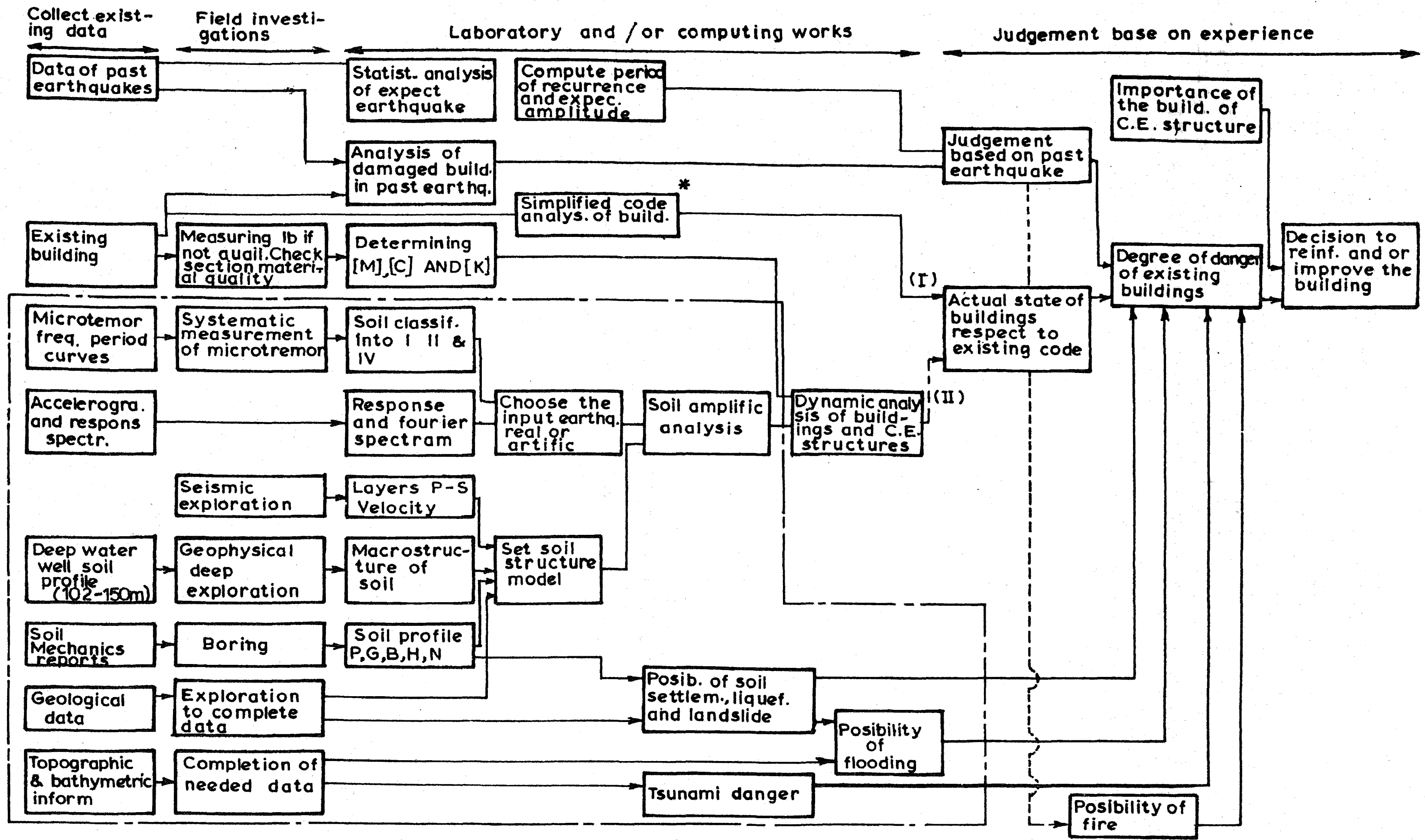

26
7
9
5
2
PATIO
E
E
49.00
50.30
7.50
7.50
12.50
2
7.50
22.00
N NUMBER UNIT OF HOUSING
8.50
4
4.50
10.40
1.80
10.50
22.70
SECTION EE

FIG. 2



NOTES

* THE MOST PROBABLE INTENSITY MAP MAY BE USED

[ ] MICROZONING STUDIES

NOTE THAT THERE ARE TWO WAYS TO DETERMINE THE ACTUAL STATE OF THE BUILDINGS

I – SIMPLIFIED STATICAL ANALYSIS

II – DYNAMICAL ANALYSIS, INCLUDING SOIL AMPLIFICATION STUDIES

FIG. 3_ FLOW CHART TO ESTIMATE THE SEISMIC RESISTANCE OF EXISTING BUILDINGS