Geotechnical Model for Seismic Microzonation

Modèle Gèotechnique pour la Microzones Sismique

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SYNOPSIS In Perú, as well as in many other countries situated in geographic areas of high seismicity, there is a pressing need to evaluate the seismic potential risk, and the existence of a model useful to accomplish that task as imperative.
The proposed model allows the determination, by means of a multidisciplinary study, of the local geotechnical aspects and phenomena pertinent to efficient planning and decrease of damage to engineering works due to earthquakes.
Combination of critical areas delimited in a set of maps containing information on natural factors of interest to the purpose of the study, is the basis to effect the seismic microzonation of a city or important area and, at the same time, provides effective guidelines for the formulation of a Building Code, which could reflect the potential risk of the different areas maped. In this paper, the set of maps illustrative of the model for the case of Lima-Peru is given.

INTRODUCTION

A great deal of investigative effort has been applied since 1960 in many countries located in areas of high seismicity. Research has been conducted in the U.S.A., Italy, Mexico, Chile and other countries, in the area of the Earth Sciences with emphasis in Seismology, Geology and Soil Dinamics. During the last ten years a program has been carried out in Peru to compile information for Lima, the Capital city, by A. Martinez and F. Porturas (1975), A. Martinez (1975) A. Martinez (1976), F. Romani (1973), F. Romani (1976) Maps have been prepared on the basis of this information, which has been complemented with the experience gathered from the earthquakes produced during the same interval.

The proposed model can very well be complemented and perfected with exploration and soil dynamics techniques for specific areas and individual engineering projects. Furthermore, it represents an adequate frame of reference for future efficiente planning and zoning, according to use of the land in the city or zone studied.

GEOTECHNICAL MODEL

In a given area there exist several natural conditions, which in different ways contribute to influence the seismic behavior of the terrain within the area. In the case of Lima-Peru there are two basic factors which contribute in greater or lesser degree to the manifestations of the effects of those natural conditions: 1) Most earthquakes felt in the coastal area are originated by fault ruptures in the Pacific Ocean, at variable distances from 40 to 60 kilometers away from the shoreline; 2) In the area of the Great Lima extensive areas are covered predominantly by fluvial and aluvial sediments, with variable thicknesses between a few to hundreds of meters. In several other areas of less areal importance, however, a great variety of geoforms can be observed according to A. Martinez and F. Porturas (1975), A. Martinez (1975), A. Martinez (1976).

If one wants to determine the potential seismic risk for a given area, it is thus necessary to carry out a study to combine the physical factors which can possibly influence such risk. An interesting aspect of this task is, for example for the city of Lima, to investigate the mechanism of propagation of seismic waves as a function of thickness of sediments, depositional characteristics and soil granulometry as well as frequency of the input accelerogram, which in turn is a function of earthquake magnitude and epicentral distance. F. Romani (1976).

Conclusions derived from these types of studies are resumed in maps for the different natural factors involved. Combination of information from all maps leads to a map of seismic risk useful for the purposes of interest to the study. It is necessary to admit, however, that the set of maps for Lima is not complete at this point and that further investigations need to be carried out concerning tectonics and other aspects. In spite of this fact, the usefulness of the proposed model cannot be overemphasized.

Natural factors and maps which require to be considered in the formulation of the model are the following:

Contour Map.- (Figure 1) It contains terrain features which influence soil-structure interaction during earthquakes such as slopes, depressions, discontinuities, etc.

Geologic Map.- (Figure 2) Emphasis is given to recent formations of the Quaternary and to secondary geological elements which could be important to influence soil-structure interaction.

Geomorphological Map.- (Figure 3) Occurrence of three earthquakes in Lima during the last ten years has provided a unique opportunity to match the effects produced in engineering works and the corresponding geoforms, specially in areas of erratic soils old drainage channels and others.

Hydrology Map.- (Figure 4) It contains information relevant to the position of aquifers, as well as to the location of the phreatic surface.

Soils Map.- (Figure 5) Different existing types of soils are demarked including those which have registered or contain localized conditions conducive to the occurrence of phenomena such as differential settlements, sand liquafaction and others.

Intensity Distribution Map.- (Figure 6) The seismological criteria used by Espinosa and Husid (1975), for the Lima earthquake of October, 1974, has been used, on the basis of which critical areas have been delimited. This map will be modified and/or completed in the future.

Damage Distribution Map.- (Figure 7) Areas sensitive to damage have been demarked, according to the information provided by the last earthquakes. It has been used to establish agreement with natural conditions of interest. Results of new studies and incorporation of future statistics most probably will change the configuration of this map.

Potential Seismic Risk Map.- (Figure 8) It represents the combination of all geotechnical information considered in the other maps, and constitutes a simple way of effecting a microzonation which differs from the technique used by Medvedev (1965) in that no zonation in terms of soil rigidity is done, and delimitation of areas is accomplished by the examination and study of natural conditions.

CONCLUSIONS

A model is proposed which is actually a summary of the more important geotechnical conditions to be evaluated in order to produce a microzonation on the basis of seismic risk. Lima, the capital city of Peru, is given as an example.

All compiled information is adequately combined in order to point out critical areas which could produce localized conditions conducive to damage.

Limitations of the method consist mainly in the lack of a quantitative evaluation of areas. However, application of Soil Dynamics techniques to specific areas and projects can and will produce these results.

Information provided by the model can be used for elaboration of a Building Code and planning for a city or important zone.

Guidelines provided may find frequent application in many countries where a source of expedient information with regards to potential seismic risk is needed.

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MAPS CONSIDERED FOR THE MODEL

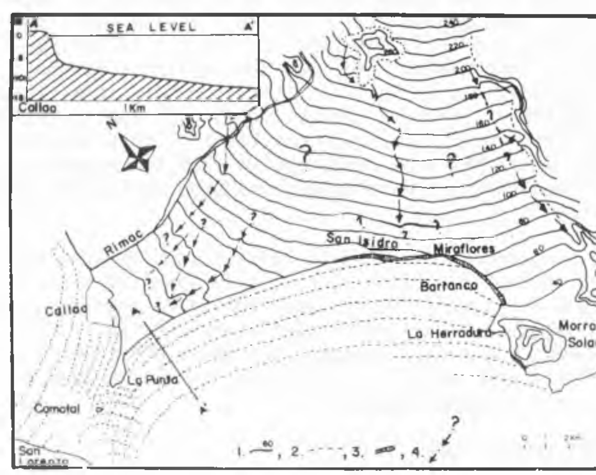

Figure 1. Topographic Map of Lima (Incomplete) after Dollfus, 1965.

1. Contour Levels 2. Batimetric Contours 3. Sea Deposits 4. Old-Channels.

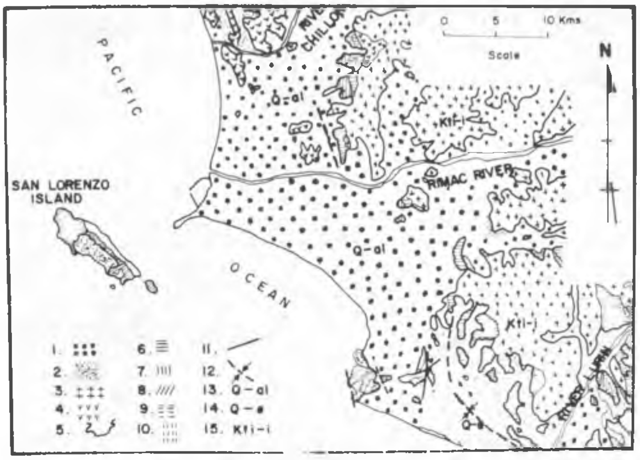

Figure 2. Geologic Map of Lima (Incomplete) After Martínez et. al. (1975)

1. Aluvial Deposits 2. Eolic Sediments 3. Granitic Intrussive Rocks, Granodiorite, etc. 4. Andesitic Volcanic Rocks 5. Outcropping Contours 6. Atocongo Formation and Metamorphic Phases 7. Pamplona Formation 8. Marcavilca Formation 9. Herradura Formation 10. Salto del Fraile Formation composed of Sandstone Sedimentary Rocks, etc. and Metamorphic Claystone Cuarcite, Shale, etc. 11. Faults 12. Anticlinal Axis 13. Aluvial Quaternary 14. Eolic Quaternary 15. Upper Cretaceous Lower Tertiary

Figure 4. Hidrogeologic Map of the Lima Aquifer After A. Morales Vanscon (1971) Modified by A. Martínez

1. Aquifer 2. Aquifer Limits 3. Electric Logs 4. Depth to Water Level < 10 meters 5. Depth to water Level 10 ≤ H < 15 meters 6. Depth to Water Level ≥ 15 meters 7. Old Spring Area 8. Impervious Zone without aquifer 9. Phreatic Level.

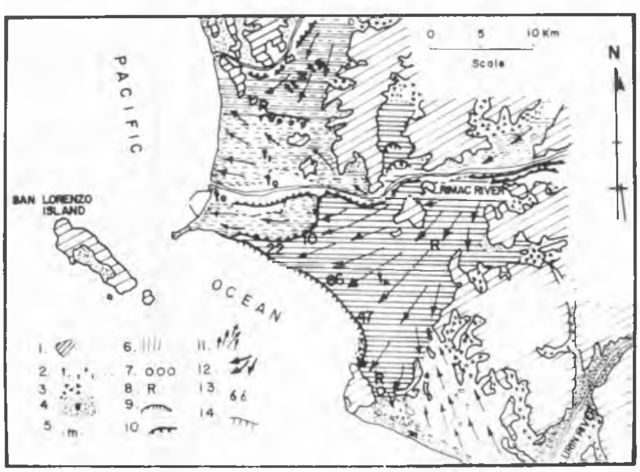

Figure 3. Geomorphologic Map of Lima (Incomplete) After Martínez et. al. (1975)

1. Hills 2. Terraces 3. Dessertic Accumulations, Coluvial Debris, Aluvial Debris 4. Eolic Deposits 5. Marine Deposits 6. Marshy Areas 7. Springs 8. Probable Areas of Damning 9. Erosion 10. Cliffs 11. Sand Migration 12. Main Torrent Course 13. Cliff Contour Level 14. Vertical Scarps

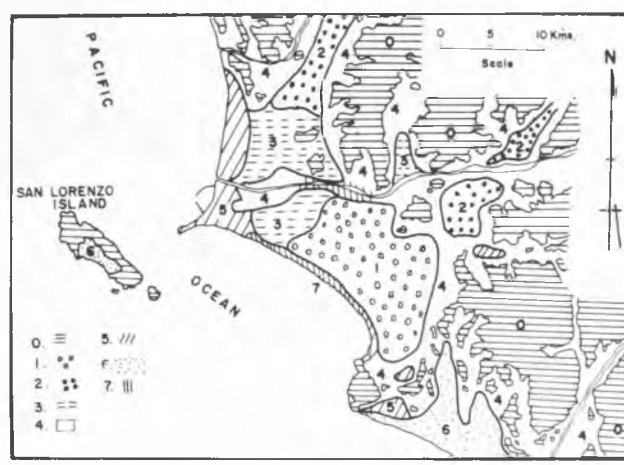

Figure 5. Soils Map (Imcomplete) After A. Martínez

0. Residual Soils 1. More or less Compact Conglomerate 2. Fairly Loose Conglomerate 3. Loose Conglomerate 4. Erratic Soils of Contact Zones 5. Heterogeneous, Erratic Fine Grained Soils 6. Eolic and Marine Sands 7. Man Made Fills.

Figure 6. Distribution of Intensity Map After Espinosa and Husid

Modified Mercalli Scale

Figure 7. Distribution of Damage Map After Espinosa and Husid

Symbology used for structures includes from 1AA for Adobe Structures to 12 for Steel Structures.

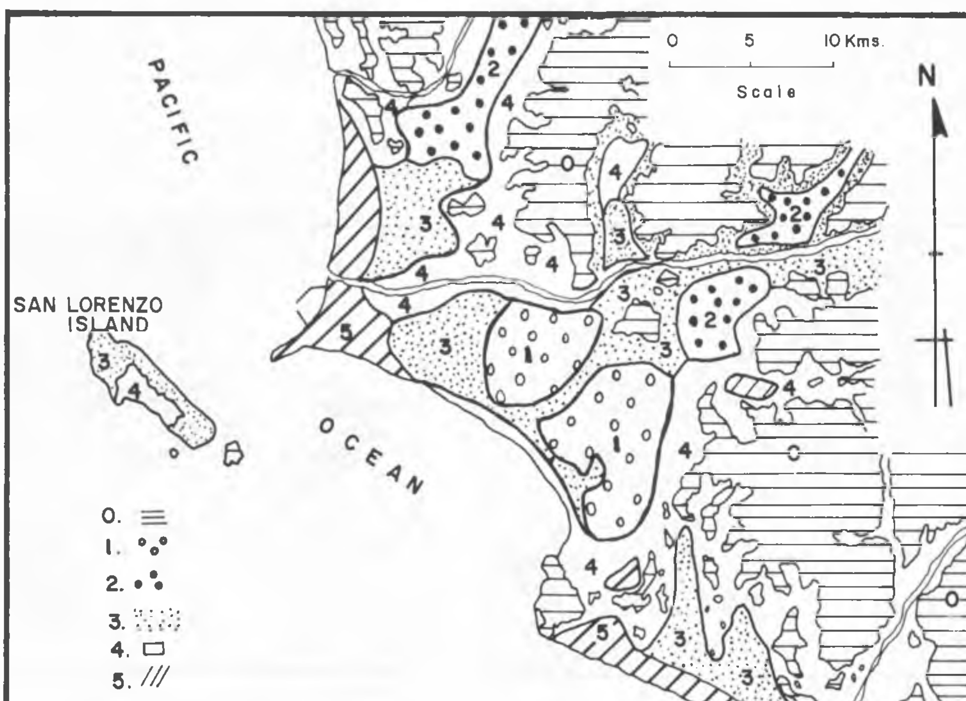

FIG. 8 SEISMIC RISK POTENTIAL MAP AFTER MARTINEZ, 1975
0. POTENTIAL RISK NULL OR VERY SMALL, 0–5%, LANDSLIDES 1. SMALL POTENTIAL RISK, 5–10%, EFFECTS NOT OBSERVED
2. POTENTIAL RISK ACCEPTABLE, 10–25%, SETTLEMENTS CAN BE CONTROLLED 3. MODERATE POTENTIAL RISK, 25–50%, DIFFERENTIAL SETTLEMENTS, SOIL AMPLIFICATION 4. HIGH SEISMIC RISK, 50–75%, SLIDES, DIFFERENTIAL SETTLEMENTS, SAND LIQUEFACTION, ETC. 5. VERY HIGH SEISMIC RISK, ALL POSSIBLE LOCAL EFFECTS