Seismic Effects on the Soils of Peru

Effets des Tremblements de Terre dans les Sols au Pérou

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SYNOPSIS The effects which severe earthquake occurrences have developed in the soils in Peru are examined,establishing some correlations between the distribution of intensities in accordance with the Modified Mercalli Scale,caused by the 1974 earthquake and the elastic modulus of the various types of soil which exists in the city of Lima and its vecinity.Typical values of intensities being found for each type of soil and ranges of the elastic modulus in each case,concluding that the intensity is greater in the soils of lower elastic modulus and that - they tend to undergo ground amplification effects or soil settlement,while the soils of greater elastic modulus present lower intensity and damages.

INTRODUCTION

An examination performed on the effects developed by severe earthquakes in Peru,show that the phenomena associated with the anomalous behaviour of soils,have caused considerable damages and a number of deaths,estimating that the latest 1966,1970 and 1974 earthquakes have killed 70,178 people and produced economical losses as high as 2,500 million dollars.

There are different types of soil in Lima and its suburbs,from the most consistent ones formed by gravel-sand mixtures to the soft ones formed by totally or partially saturated silt or clay,in which the wave propagation develops refraction,reflection or amplification,as well as a tendency to undergo densification - or liquefaction effects,which have damaged - tall structures as well as others of less importance.(Carrillo,1975).

This paper intends to evaluate and analice - the studies and results of some test performed in order to determine the behaviour of - the soil,which were carried out within Lima's urban limits,correlating them with the earthquake intensity caused by the 1974 earthquake.

TEST RESULTS

In the investigation of the elastic deformation process of the soils of Lima and suburbs, the solid particles of the constituents of - the compacted conglomerate which exist in downtown Lima,may be considered absolutely rigid elements deposited in the heavy stratum, as well as in the soils of the southern zone which have a fine texture and medium plasticity,where is evident that the assumption can be made that they consist of homogeneous material,since any discrete system including the soil that is formed by statically uniform particles, may be considered homogeneous and in an element of consideration whose dimensions are large in comparison to the dimensions of the soil particles, the elasticity properties can be constant throughout the element(Barkan, 1960).

From the analisis of a number of boring made with subsurface exploration purposes and the inspection of 65 records of well-log for the purpose of obtaining water from the underground,it has been determined that they show a generalised lithology in accordance with the hypotheses,except for a few highly localized cases.

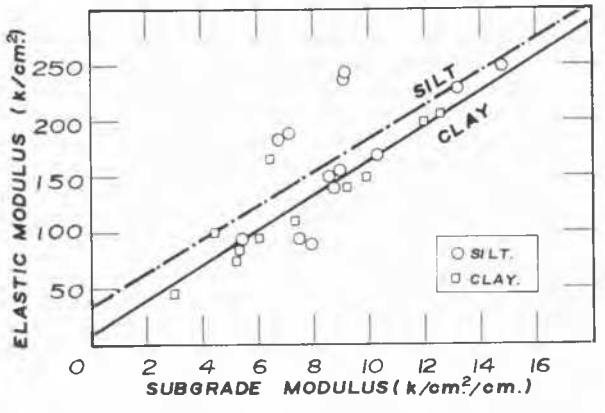

Fig. 1.-Elastic Modulus and Subgrade Reaction. Fine Soils, Lima's urban limits.

Ninety nine plate-test,whose results are shown in figures 1 and 2 have been evaluated, - and which were carried out in different places within urban limits and of soils generally regarded as: gravel(conglomerate, sandy gravel,gravel-sand mixtures),sand (sand mixed with some gravel,poorly and well graded sand,sandy silt),silt (pure silt,silty clays,

silty sand) and clay (clays of medium plasticity and stiff or soft clays).From this analysis,it is established that in the compacted sand,the application of repeated cyclical loads produce elastic deformation modulus which are 40 % greater than those performed by the application of a static uniform load and that, in the case of compacted gravel,this increase ranges between 40 % to 50 % while in the case of clay,the elastic modulus appears to be from 10 % to 40 % smaller. In the case of intermediate soils or silt,it was found that there exist no significant changes (Carrillo , 1969).

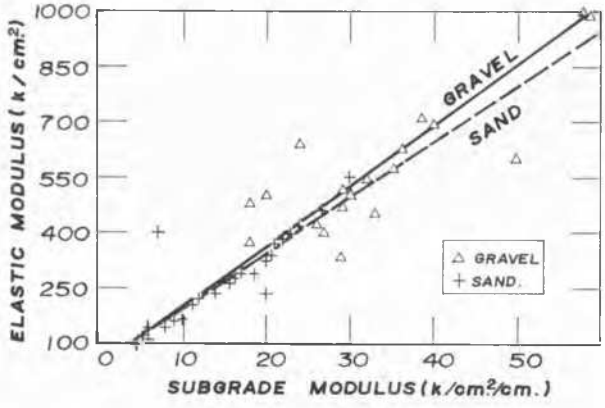

Fig.2.-Elastic Modulus and Subgrade Reaction. Granular Soils,Lima's urban limits.

SOIL BEHAVIOUR

From the comparisons of the test results with the evaluation of the intensity distribution in the Lima earthquake of October 3, 1974 (Espinosa,et al.,1975),an adequate correlation has been found in most of the cases,between the type of soil underlaying each location and the damage evaluation performed. It is established that,for an earthquake of Ms = 7.6, 0.19g of maximum acceleration and 100 seconds of approximate duration,the gravel-sandy soils present average intensities of VI MMI (Modified Mercalli intensity) and elastic modulus ranging from 150 kg/cm2. to 500 kg/cm2. The silty soils varying between the VI and VII MMI intensities with elastic modulus ranging from 90 kg/cm2. to 250 kg/cm2.;clays presenting intensities ranging between VIII and IX MMI and modulus from 45 kg/cm2. to 210 kg/cm2.

Furthermore,it is established that,for average elastic modulus corresponding to each of the types of soil specified,that in the materials where the damage have always been lower in any of the past earthquakes,the elastic modulus are high and range from 170 kg/cm2.to 975 kg/cm2. and that its value increses upon the application of cyclical repeated loads ; whereas in the soils where cases of amplification,refraction and reflection of the seismic wave or densification and liquefaction effects have appeared,the elastic modulus are low and are ranged between 98 kg/cm2 and

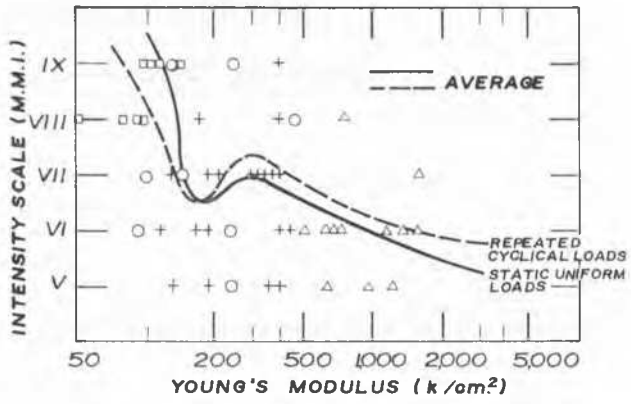

Fig. 3.- Elastic Modulus and Intensity Scale, Lima Earthquake,1974.

130 kg/ cm2. decreasing or remaining stable when cyclical repeated loads are applied(fig. 3).

CONCLUSIONS

1.-The earthquake behaviour of the soil in Lima and suburbs for a 7.6 degree earthquake, shows a greater intensity (MMI) for soils of lower elastic modulus and less intensity for soils of greater elastic modulus.

2.-The dry and compacted gravel and sandy soils can be regarded as "stable" with intensities between VI to VII MMI and elastic modulus ranging from 150 kg/cm2. to 1650 kg/cm2,verifying that elastic deformation modulus increases under application of cyclical repeated loads.

3.-As for silt and clay soils,with intensities between VI and IX MMI,effects of amplification,reflection and refraction of the seismic waves have been verified and in some cases,even densification and liquefaction,enabling them to be considered as "unstable" with elastic modulus ranging from 45 kg/cm2 to 250 kg/cm2,indicating a further decrease of the modulus due to the application of cyclical repeated loads.

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