General Report on Theme I

Soil and Foundation Conditions Relative to Earthquake Problems

by

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Eighteen papers have been allocated to Theme I.

The paper entitled "Tectonic and Earthquake Risk Zoning in New Zealand", prepared by a subcommittee of the Royal Society of New Zealand, consisting of Messrs. R.H. Clark, R.R. Dibble, H.E. Fyfe, G.J. Lensen and R.P. Suggate, is an authoritative treatment on this important subject. This paper is one of three reports produced by this group and the reports are published in the Transactions of that Society.

It is stated that most of the historical major earthquakes in New Zealand have been accompanied by measureable tectonic deformations as revealed by warping, tilting or faulting of the earth's surface. New Zealand, being a recently settled country, does not possess instrumental records extending long into past years but there is enough evidence available to show that even a country the size of New Zealand cannot be regarded as a single entity from the tectonic point of view and hence from the seismic risk point of view, as well.

The paper considers care fully the geological setting for the quaternary tectonic movement and deformation as well as the historic tectonic deformation and earthquakes. The paper indicates the earthquake risk zones based on delineation of tectonic zones for New Zealand and deserves careful study by both seismologists and engineers.

Prof. R.F. Scott, in his paper entitled "Soil Mechanics and Foundation Engineering Aspects of the Alaskan Earthquake of March 27, 1964" describes the general geology and soil profiles of the Anchorage area that suffered serious damage from the above mentioned earthquake.

The effects of the earthquake in creating slope failures and landslides that were principally responsible for the extensive damage are described and the stability of slopes, groundwater and porewater pressures, soil freezing and thawing in the area are discussed.

The author's on-the-spot observations on the seismic damage in the city of Anchorage itself and the residential area of Turnagain Heights that experienced a large laterally spreading type landslide are given.

The relatively high sensitivity of clay or the lowered strength on remolding caused by the earthquake is believed to have been a factor in the extended landslides.

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The decrease in pore pressures will gradually increase the stability of affected areas but suitable remedial measures are believed necessary to present slope failures and slides in the Anchorage area under static and/or seismic conditions in the future.

The paper entitled "Earthquake Spectrum Prediction for the Valley of Mexico", by I. Herrera, E. Rosenblueth, and O.A. Rascon deals with field and laboratory tests to determined the dynamic properties of Mexico City clay. The data are used in conjunction with a linear, one-dimensional theory of multiple wave reflection in stratified media and the results are treated in accordance with an approximate theory which permits computing the probability distributions of spectral responses for various degrees of damping. The expected spectra have been compared with those obtained from past earthquake records. Information not available for deep strata has been found by trial and the velocities measured for the upper layers have been adjusted on reasonable assumptions.

Field investigations were carried out at Alemeda Central Park of Mexico City and theoretical studies at the National University of Mexico.

The paper "Response Spectra on Stratified Soil" by I. Herrera and E. Rosenblueth concerns the probability distribution of spectral responses of viscously damped single-degree systems resting on stratified visco-elastic soil. The soil is assumed to rest on homogeneous half space of rock and the motion arriving at the rock-soil interface is idealized as a stationary Gaussian process. The work is kept within the framework of one-dimensional wave transmission and linear behavior of both the soil and the simple structure. The transfer function for the soil formation is treated independently for each vibration frequency of interest, in order to allow for dependence of visco-elastic parameters on the wave frequency, and this is accomplished through use of a matrix formulation. The discussion begins with the case of a white-noise disturbance and is extended to cover more generalized responses on soft ground.

The methods described in the paper have been illustrated by a numerical example presented in the paper with a discussion on pertinent points of interest.

The paper entitled "Ground Investigations in City-Areas in Japan" by N. Nasu stresses the importance of adequate investigation of the ground formation in selecting the site for industrial facilities and in determining areas for city planning. The ground stratification will affect the cost of foundation construction as well as determine seismic hazards. Ground subsidence has become a factor of considerable importance in many Japanese cities, especially in areas with weak and soft soils.

The paper describes the nature of ground investigations carried out by the Ministry of Construction since 1960 by the specially created committee consisting of geologists, seismologists, engineers and government officials. The results of investigations are published promptly for the benefit of the public.

The paper by R.L. Kondner and R.J. Krizek entitled "Dynamic Response of Cohesive Soils for Earthquake Considerations" is concerned with the energy storage and dissipation characteristics of cohesive soils which are important in earthquake engineering. Some of the factors involved have been studied in

steady state vibratory uniaxial compression. The soil response is represented in terms of viscoelastic parameters and shows definite nonlinear (under-linear) behavior, even at small values of dynamic strain. Phase angles (dissipation measure) between applied strains and resulting stresses are small and require special instrumentation. Nonlinear response gives calculated compression moduli and propagation velocities which decrease with dynamic stress or strain level. For the range investigated, it has been found that the applied static stress level has little effect on the dynamic response.

This paper deals with various aspects of the dynamic stress-strain response of cohesive soils under steady state dynamic loading conditions using cylindrical specimens compressed uniaxially and sinusoidally imposed deformations. Theoretical considerations are first discussed, followed by the soils used, the experimental procedure and the results obtained.

The paper entitled "Dynamic Properties of Foundation Subsoils as Determined from Laboratory Tests" by P.W. Taylor and J.N.O. Hughes describes a series of dynamic tests on soil samples in which the effects of amplitude and number of repetitions of loading are particularly investigated. Elastic and energy dissipation properties of clays are required in the dynamic analysis and design of earthquake resistant structures founded on such materials. It has been found that the elastic modulus decreases as the number of cycles of loading increases. Also, that the measured value of the elastic modulus is markedly dependent on the strain amplitude, being greatest at small amplitudes. The implications of the results obtained from this investigation, as affecting the dynamic response of structures, are fully discussed in the paper.

The paper entitled "Stability of Saturated Sand During Earthquake" by Z. Bazant considers the state of stress in dynamically excited sand due to earth tremors. The acceleration of the earthquake may create 1) dynamic stability, 2) compaction, or 3) liquefaction of sand depending on conditions. The large damage to structures and buildings from liquefaction of sand due to earthquakes in the United States, India, Japan and Mexico are cited to show the seriouness of this problem. The author has studied the problem theoretically and has developed a general expression including the relative dry density, relative frequency, relative critical acceleration, the form factor, and the relative amplitude. The effects of these factors have been studied experimentally and the results considered from various viewpoints. By utilizing the general expression, it is possible to predict the behavior of saturated sand during earthquakes.

In the paper entitled "Dynamic Pore Water Pressure Acting on Quay Walls During Earthquakes" by H. Matuo and S. O-hara, the problem of pore water pressure in saturated sand on quay walls during earthquakes has been further investigated. The problem is first considered from the theoretical point of view followed by model experiments on saturated sand to obtain the relation of the rigidity of the pressure cell-membrane and the recorded pressures. Also, experiments were carried out to measure the pore pressures at various locations to note the variations. It has been found possible to explain the irregular pressure distribution in saturated sand during vibration by assuming periodic negative pore pressures due to dilatancy of the sand mass. Rigidity of pressure-cell membrane on the pressure distribution has also been found to be of significance.

J. Takeda and H. Tachikawa discuss the effects of loading rate on the bearing capacity modulus of subgrade reaction of sand and other matters when subjected to vertical and diagonal loadings from a shallow footing in their paper entitled "Mechanical Properties of Sand Subjected to Dynamic Load by Shallow Footing". The experiments were carried out using dense and loose, air dried and saturated sands and loaded at rates ranging from 10^{-4} to 10^{2} kg per sq cm per sec. A circular, steel footing 15 cm in diameter was used. The applied loads and footing settlements were measured electrically. It has been found that under vertical loads the bearing capacities of both air-dried and saturated dense sand increased considerably with the sinking rate of the footing (or the loading rate). This was not observed for the same case in loose sand. The moduli of subgrade reaction were found to increase nearly proportionally with the logarithm of sinking rate of footing in all tests. With reference to diagonal loading tests, the bearing capacities were considerably smaller than for vertical loading tests and the sinking rate of the footing had practically no effect on the bearing capacity.

In the paper entitled "Characteristic Periods of Cohesive Soil-Foundation Systems" by R.L. Kondner, the characteristic periods associated with both resonant and zero force level phenomena and important in the design of soil-structure systems under transient loadings are presented for the prototype circular footings supported on a cohesive soil. Interrelated effects of footing diameters ranging from 5 ft - 2 in to 10 ft - 4 in, total weights from 6.41 tons to 25.64 tons, static pressure levels from 2.56 psi to 10.25 psi, and level of dynamic loading are considered. The periods vary as a power of the total weight and inversely as a power of the contact footing area. Dynamic force level effects indicate a nonlinear (under-linear) nature for the cohesive soil-foundation systems that have been considered.

J.F. Fleming, F.N. Screwvala, and R.L. Kondner, in their paper entitled "Foundation-Superstructure Interaction under Earthquake Motion", present a method of analysis for determining the dynamic response of structures under earthquake motion, taking into account the flexibility of the foundation. The structure is replaced by a lumped mass mathematical model which is attached to the moving rock layer by a flexible member having the same force-displacement relationship as the foundation. Several example problems are discussed which show the effect of the soil stiffness on the response of the structure. The study has shown that the stiffness of the soil is very important and any method of analysis for the response of a structure to an earthquake can lead to completely erroneous results if the foundation-superstructure interaction is not considered. Better information concerning the intensity of actual earthquakes is necessary and it is suggested that the acceleration of the rock layer below the structure might serve as a better standard for a more rational approach to earthquake design.

The paper entitled "Vibrational Property and Earthquake Response of Tall Buildings Supported with Caisson or Piles" by T. Tajime, S. Terada and T. Mochizuki considers the action of earthquakes to buildings with different types of foundation in the soft upper soil layer and investigates the possibilities of constructing talls buildings on soft upper soil layer. The results of the study show that the damping constants for models supported by caisson foundation or by piles are much greater than for the model supported directly on the bearing stratum. The displacement response by forced vibrations on the model supported by piles in the soft upper layer (natural period less than

0.14 sec) is small but the response for models supported by caissons or directly supported on the soil stratum has been found to be greater and almost alike.

M. Hatanaka in his paper entitled "An Experimental Study on the Earthquake Resistant Property of Breakwaters of the Cylindrical Shell Type" considers this type of prestressed concrete breakwaters which is coming into greater use. The stability of this type of breakwater during earthquakes, however, is not clear due to lack of performance data.

Vibration tests have been performed for two types of breakwater models, A and B, to obtain information on their stability. The equiptment used for model testing, test results, and some considerations on the earthquake resistance of the models, and conclusions are given.

The paper entitled "Earth Dams Subjected to Earthquakes" by J. Krishna and S. Prakash presents factors affecting the stability of an earth dam under earthquake forces with particular reference to the 122 m high Ramganga Dam in India. To determine the dominant period of the ground and other necessary data, field blasting tests have been performed. Also, results on model study of certain typical sections on a large vibration table 5.2 m x 2.8 m are presented which permit good qualitative study of the problem of stability under earthquake loads. It is shown that the variation of acceleration with the height of the dam is similar to that predicted by theory.