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Liquefaction Potential of Silty Sand Site

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SYNOPSIS Dynamic properties of subsurface soils at the site of a proposed nuclear power plant were determined through extensive field and laboratory tests. The liquefaction potential of the granular soils underlying the site were obtained by using field data obtained from both standard penetration resistance and cone penetration tests as well as from laboratory data obtained from cyclic triaxial compression tests. The analyses showed that comparable factors of safety may be obtained from both field and laboratory test data.

INTRODUCTION

The studies presented herein are parts of a comprehensive investigation performed in connection with preliminary site safety and confirmation studies for the site of a proposed nuclear power plant. The site, located on the bank of a river, is very flat with groundwater table at a depth of about 2m below the surface. No bedrock was encountered to the depth of 123m explored.

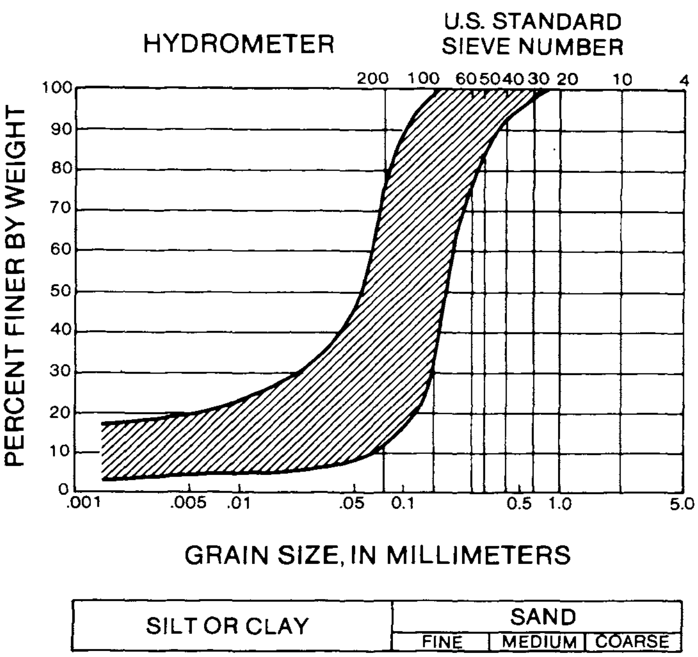

Fig. 1. Ranges of Grain Size Distribution Curves

Subsurface conditions were determined using information obtained from drilling, laboratory testing, and static cone penetration sounding programs. The general soil profile was determined to be a fine grained alluvium consisting mainly of silty clays and clayey silt. Silty sand, sand, and silt layers occur within the clayey strata with percentage of sands increasing with depth. A typical grain size distribution curve for the sandy materials is shown in Fig. 1.

In the present paper, the liquefaction potential of the granular site soils as determined by using field penetration data is presented.

CORRELATION OF CPT AND SPT RESULTS

To correlate the results of the Cone Penetration Tests (CPT) and the Standard Penetration Tests (SPT) at the site, an equivalent N-value was determined from CPT point resistance based on the results of the adjacent sets of SPT boreholes and penetrometer soundings performed. The test borings were drilled first with drilling mud used to advance the boring. A typical comparison of the results obtained from a set of adjacent SPT borehole and CPT sounding is shown in Fig. 2.

Values of the ratio q_c/N were determined for each pair of adjacent SPT borehole and CPT sounding for the granular materials. q_c is CPT point resistance in kg/cm^2 and N is measured SPT blowcounts. The value of q_c/N for the site granular materials ranges from 3.5 to 6 with an average value of 4.6. These values compare well with the typical published values of q_c/N reported by Schmertmann (1978) and Nixon (1982). A value of $q_c/N = 4.5$ was used to convert q_c values to equivalent N-values for the purposes of liquefaction analysis of granular soils.

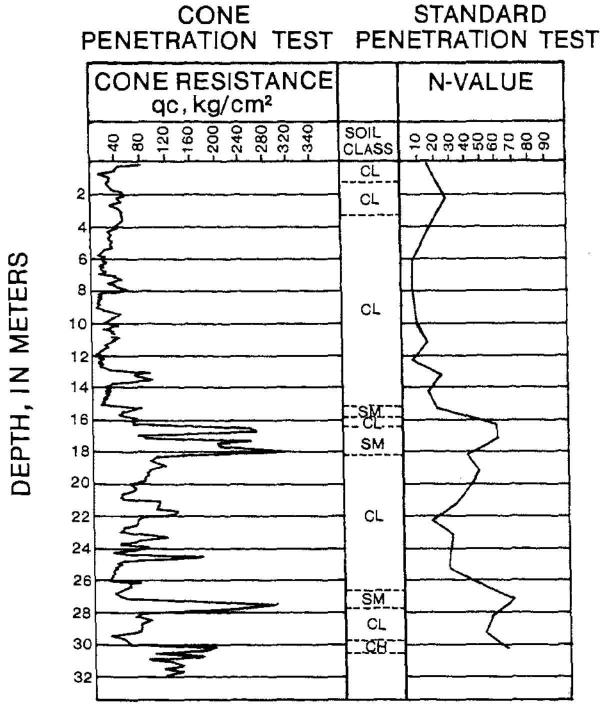

Fig. 2. Results of an Adjacent Set of SPT Borehole and CPT Sounding

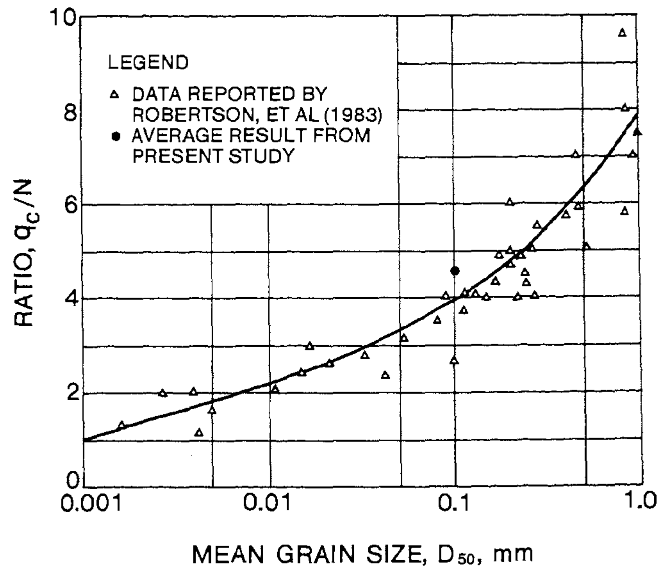

Fig. 3. Variation of q_c/N Ratio with Mean Grain Size, D_{50}

It is interesting to note the variation of q_c/N ratio with mean grain size, D_{50}. Such a variation is presented by Robertson, et al. (1983) as shown in Fig. 3. The data points shown on the figure are those reported by seventeen different investigators from 1956 through 1983. Also shown on the figure is the average result obtained in the present study which is in good agreement with those reported by Robertson, et al.

LIQUEFACTION POTENTIAL

Analyses were performed to determine the liquefaction potential of the granular layers. The analyses consisted of calculating factors of safety against liquefaction in accordance with an empirical method based on the observation of performance of sand deposits during previous earthquakes using field penetration data. The method is discussed in detail by Seed, et al. (1983). Analyses were also done by comparison of induced stress conditions from earthquakes and stress conditions causing liquefaction in the laboratory based on cyclic strength curves in a manner similar to that described by Seed, et al. The latter method is described by the authors in a separate publication (Dezfulian and Marachi, 1982), and will be discussed only briefly here.

The empirical method uses field penetration data to evaluate the in-situ soil characteristics and compares this data to that from sites where earthquakes have occurred and soils have or have not been known to liquefy by field observation. Data for the evaluation of the site soils by this method was obtained from both test borings in which the SPT was performed and from the CPT in which the point resistance, q_c, was converted to an equivalent SPT value.

The analyses were performed using maximum horizontal ground accelerations, a_{max}, of 0.25 to 0.35g postulated to be produced either by a distant earthquake of magnitude 7.5 or a near earthquake of magnitude 6.

Factors of safety against liquefaction were computed for granular layers underlying the site at various depths. For each granular soil layer the average corrected N-value was determined from the SPT and CPT data. The factor of safety against liquefaction is determined by dividing the stress ratio which is necessary to cause liquefaction by the induced maximum average cyclic stress ratio from the design earthquake. The cyclic stress ratio required to cause liquefaction is based on an overburden pressure of 1 tsf (about 1 kg/cm^2). To correct for other overburden pressures, laboratory cyclic triaxial test results were used. A relationship between the stress ratio causing initial liquefaction (approximated by 5% axial strain) at 15 cycles and confining pressure was developed and employed.

The factors of safety against liquefaction were completed for the distant and near earthquakes.

For the distant earthquake the factors of safety were found to be adequately safe against liquefaction. For the near earthquake, however, the factors of safety were considerably lower than those I computed for the distant earthquake. The factors of safety against liquefaction induced by the near earthquake were considered to be less than acceptable for a nuclear power plant, although by only a very low margin.

The liquefaction potential for the granular soil layers was also analyzed by performing a one-dimensional shear beam analysis for the determination of induced stress from representative earthquake records and comparing the induced stresses to the soil strengths under cyclic loading. The cyclic stresses induced in the ground were computed by deconvolution of a known ground surface motion by use of the computer program SHAKE (Schnabel, et al., 1972). The evaluation of the laboratory cyclic strength of the on-site granular materials was performed by using the cyclic triaxial test. The factors of safety obtained by this method and by the empirical method differ somewhat. The primary reason is attributed to sample disturbance effects affecting the laboratory cyclic strength.

CONCLUSIONS

Liquefaction potential analysis studies were performed for a silty sand site proposed for the construction of a nuclear power plant. The analyses were performed using two different methods: (1) an empirical method using field penetration data for which both SPT and CPT data were developed and used, and (2) an analytical method using laboratory cyclic strength curves. Factors of safety against liquefaction computed by the two methods were found to be in fairly good agreement.

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