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International Conferences on Recent Advances in Geotechnical Earthquake Engineering and Soil Dynamics

1991 - Second International Conference on Recent Advances in Geotechnical Earthquake Engineering & Soil Dynamics

14 Mar 1991, 10:30 am - 12:30 pm

Session 3: Discussions and Replies

Multiple Authors

Discussion of "Liquefaction Ground Deformation Predicted from Laboratory Tests" by M.H. Baziar and R. Dobry (Paper No. 3.28)

by A. Wightman and M. G. Jefferies
Klohn Leonoff Ltd., Vancouver, CANADA

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For completeness it would be useful if the authors could provide information on the relative density, plasticity, silt and 5 micron fractions for their soil specimens.

Would the authors also explain in some more detail their Newmark analysis procedure. Is it assumed that displacement begins to accumulate starting with the first occurrence of exceeding the yield acceleration, or is the calculation only started after liquefaction is assumed triggered? If the former applies, might this partly explain why the analysis of block PQR'S over-estimates the deformation?

In connection with a site that appeared susceptible to liquefaction triggering to 100 ft depth or more, we recently looked for "depth effects" in the residual-undrained strength data base of Seed, most recently presented by Seed & Harder (1990). The first thought was to try and draw depth contours on the chart, but this was quickly abandoned in favour of a $\frac{S_r}{\sigma'_{vo}}$, plot.

The results, shown on Fig 1 were obtained by estimating an average initial effective overburden pressure for each case, with the boxes representing the range in $(N_1)_{60}$ and undrained residual strengths interpreted from Seed & Harder (1990), Davis et. al. (1988) and Seed (1987).

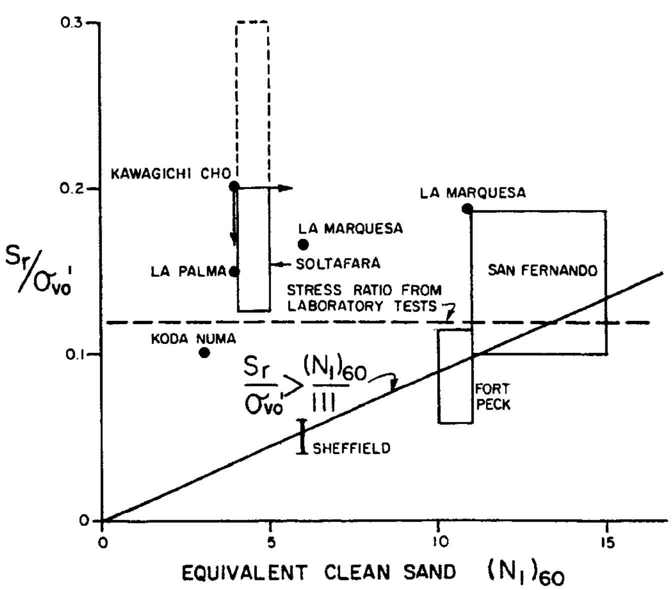

FIGURE 1

There is not a strong trend for increasing $\frac{S_r}{\sigma'_{vo}}$, with increasing $(N_1)_{60}$, but perhaps a lower bound (See Fig 1) might be expressed by

$$\frac{S_r}{\sigma'_{vo}} > \frac{(N_1)_{60}}{111}$$

The results obtained by the authors certainly fall within the range of $\frac{S_r}{\sigma'_{vo}}$ on this plot.

Reply to Discussion on Paper No. 3.28 "Liquefaction Ground Deformation Predicted from Laboratory Tests" by M.H. Baziar and R. Dobry

The authors want to thank Mr. Wightman for a most interesting discussion, as well as for sending us the table with the data he used to prepare his Fig. 1.

First, a couple of comments about the test results in layered silty sand presented in Fig. 6 of the paper. As explained in the text, $S_{us}/\bar{\sigma}_{1c}$ measured in the monotonic and cyclic tests increased from 0.12 (for $K_c = \bar{\sigma}_{1c}/\bar{\sigma}_{3c} = 1.0$) to about 0.18 (for $K_c = 2.0$). This is important, as several of the case histories plotted in Fig. 1 of the discussion correspond to flow failures where $K_c > 1.0$. For example, in the Lower San Fernando Dam, $K_c \simeq 2.0$ (Vasquez-Herrera and Dobry, 1989). Furthermore, following the practice suggested by Castro, et al. (1982), and as explained in the paper, these values of $S_{us}/\bar{\sigma}_{1c}$ correspond to $S_{us} = q_{us} \cos \bar{\phi}_{us} = 0.83\ q_{us} = 0.83\ S_u$, where the maximum shear stress on 45° planes at the time of failure, $S_u = q_{us}$, is corrected to obtain S_{us} on the plane of maximum obliquity. It is not clear if S_u or S_{us} should be used in stability analyses, and many authors work with S_u rather than S_{us}, for example in problems involving clays (Ladd, 1991). This is important because most often the "c/p" ratios reported in the literature correspond to $S_u/\bar{\sigma}_{1c}$ rather than to $S_{us}/\bar{\sigma}_{1c}$. If $S_u/\bar{\sigma}_{1c}$ is considered, the range defined by the tests presented in the paper become $S_u/\bar{\sigma}_{1c} = 0.145$ (for $K_c = 1.0$) to about 0.21 (for $K_c \simeq 2.0$). In the previous comments, no difference is made between "peak" and "large strain" strengths, consistent with the shape of the stress-strain curves of the material as shown in the paper.

Therefore, the total range for $S_r/\bar{\sigma}_{1c}$ suggested by the authors' tests (where S_r is identified with either S_u or S_{us}) is 0.12 to 0.21, with the lower end of the range corresponding to $K_c = 1.0$ and the higher end to $K_c \simeq 2.0$. This range should be compared with the plot of $S_r/\bar{\sigma}'_{vo}$ in Fig. 1 of the discussion.

The authors reanalyzed the data on S_r, $(N_1)_{60}$ and $\bar{\sigma}'_{vo}$ for several case histories provided by the discusser and included in his Fig. 1. As pointed out by the discusser, these are case histories of liquefaction failure where the residual strength S_r has been backfigured from the failure itself rather than from laboratory tests, first by Seed (1987) and subsequently by Davis, et al. (1988), and Seed and Harder (1990). In his original paper, Seed used these data to propose the correlation between S_r and $(N_1)_{60}$ included in the enclosed Fig. 1, which is widely used in engineering practice.

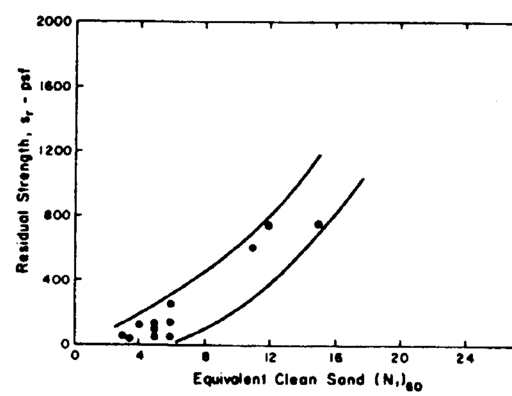

Fig. 1. Tentative relationship between residual strength and SPT N-values for sands (Seed, 1987)

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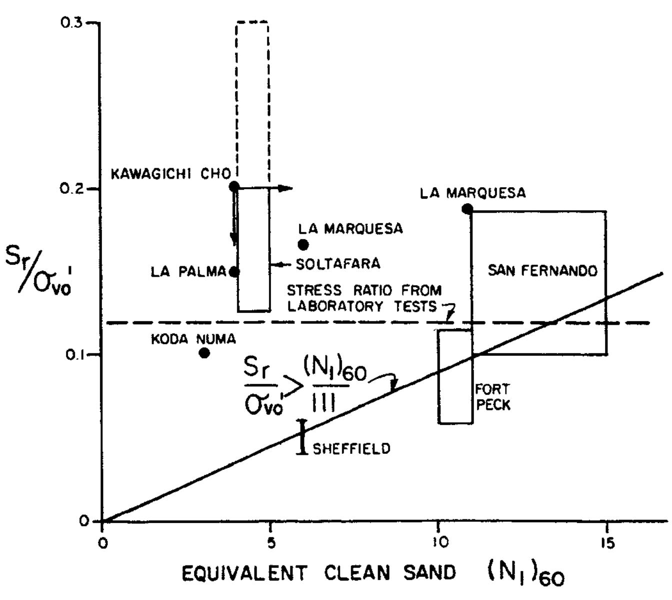

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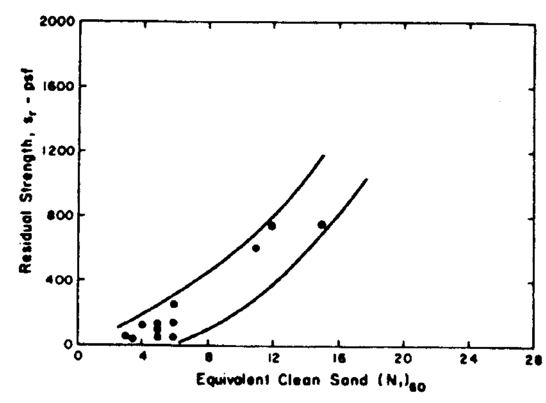

Fig. 1. Tentative relationship between residual strength and SPT N-values for sands (Seed, 1987)

The total range of S_r included in Fig. 1 is from $S_r = 35$ psf to $S_r = 750$ psf, that is, a factor of $750/35 \approx 20$. The predictive power of the correlation with $(N_1)_{60}$ shown in Fig. 1 is associated with a reduction of this factor from 20 to about 5 at $(N_1)_{60} \approx 6$ blows/ft. That is, for $(N_1)_{60} \approx 6$, the range of S_r backfigured from the field is from 50 to 250 psf, or $250/50 = 5$. For denser sands and higher values of $(N_1)_{60}$ this factor improves and is of the order of 2.

For those case histories included in Fig. 1 for which σ'_{vo} was available at the time of writing this closure, the range of S_r was a factor of 15, which is similar to the factor of 20 discussed above, while the corresponding ratio S_r/σ'_{vo} was from 0.04 to 0.20, that is a factor of 5. This is very interesting, as it shows that the use of the ratio S_r/σ'_{vo} also has predictive power and that the uncertainty involved in the prediction (factor of 5) is comparable to that of Seed's correlation in Fig. 1.

The addition of more data, and of different estimates of S_r and $(N_1)_{60}$ for the cases presented by Seed in his 1987 paper, as included in the publications by Davis, et al. (1988), and Seed and Harder (1990), does not change significantly this conclusion. The total range of S_r still corresponds to a factor of 15 or 20, while the use of the ratio S_r/σ'_{vo} reduces it to a factor of about 5 (S_r/σ'_{vo} ranging from 0.04 to 0.20, see Fig. 1 of discussion, without considering the Solfatara case history, where $S_r = 130$ psf originally included in his table by Seed (1987) is clearly too high, as discussed by Seed in the text of the same paper.)

In summary, the total range of S_r backfigured from field failures corresponds to a factor of 15 or 20, which is reduced to about 5 if either $(N_1)_{60}$ or σ'_{vo} are used to improve the prediction. Therefore, it appears that the assumption that S_r increases linearly with σ'_{vo}, as suggested by Fig. 6 of the paper, is to a large extent substantiated by the field case histories discussed by Seed, Davis, et al, and Seed and Harder. Although more work is needed to verify this preliminary conclusion, it seems that the use of the ratio S_r/σ'_{vo} predicts S_r as well as the correlation between $(N_1)_{60}$ and S_r in Fig. 1.

It is interesting that the range of $S_r/\sigma'_{vo} = 0.04$ to 0.20 obtained from failures in the field, includes the range of the ratio S_r/σ_{1c} from 0.12 to 0.21 produced by the laboratory tests reported in the paper. This is most promising and to a certain extent unexpected, as the laboratory results were limited to one very silty sand, while the case histories correspond to several materials ranging from clean sands to silty sands and including tailing dams.

Of course, the reason for the predictive power of σ'_{vo} and of the ratio S_r/σ'_{vo} is that the low values of S_r backfigured from the case histories typically correspond to shallow depth failures, and thus to low σ'_{vo} (and also to low $(N_1)_{60}$). Conversely, the high backfigured S_r correspond to deeper failures and high σ'_{vo} (and also high $(N_1)_{60}$). The following approximate consistent ranges were determined by the authors from the case history information contained in Fig. 1 of the discussion, supplemented by some additional data provided by Mr. Wightman.

σ'_{vo} (psf)	S_r (psf)	$(N_1)_{60}$ (blows/ft)
400 to 1,300	50 to 250	3 to 6
2,000 to 6,000	350 to 750	10 to 15

Note the reduction in uncertainty when going from the low σ'_{vo}/low $(N_1)_{60}$ range to the high σ'_{vo}/high $(N_1)_{60}$ range, from a factor of 5 (= 250/50) to a factor of about 2 (750/350), similar to the uncertainty of Fig. 1 of this closure.

If the reasonable assumption is made that $(N_1)_{60}$ correlates with the degree of densification of the soil, and that the reason why both S_r and $(N_1)_{60}$ increase when σ'_{vo} increases, lies in the smaller void ratio of the loose hydraulic fill or fluvial deposit as the soil consolidates (see Fig. 2), then it becomes clear that S_r should correlate well with both σ'_{vo} and $(N_1)_{60}$. Of course, this is exactly what happens.

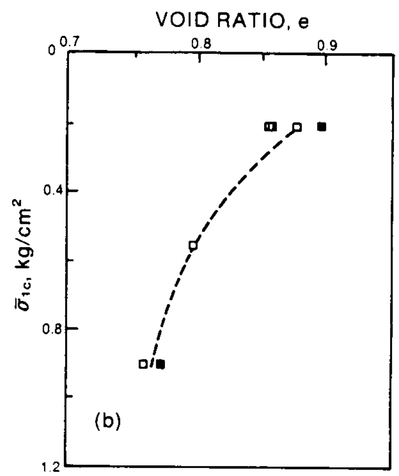

Fig. 2. Void ratio after consolidation versus $\bar{\sigma}_{1c}$ for tests of Fig. 6 (Dobry and Baziar, 1990).

To finalize, the point raised by the discusser is legitimate and the authors certainly agree with him. Furthermore, the considerations included above strongly suggest that σ'_{vo} and the ratio S_r/σ'_{vo} are alternative candidates to $(N_1)_{60}$ when preliminary estimates of S_r are needed for flow failure or lateral spreading evaluation (see also Dobry and Baziar, 1990).

Figure 3 shows the grain size distribution of the silty sand tested, which had the following Atterberg limits: LL = 24, PI = 4. The authors do not believe that the concept of relative density can be applied to the layered silty sand tested, but Fig. 2 shows the corresponding void ratios. In their use of the Newmark procedure, the same constant yield acceleration was assumed to exist from the beginning of the shaking. This is consistent with the shape of the stress-strain curves measured in the laboratory (e.g., see Fig. 3 of paper), which did not exhibit a significant drop in strength past the peak, but instead had an overall shape approaching the elasto-plastic or rigid-plastic response assumed in the Newmark technique.

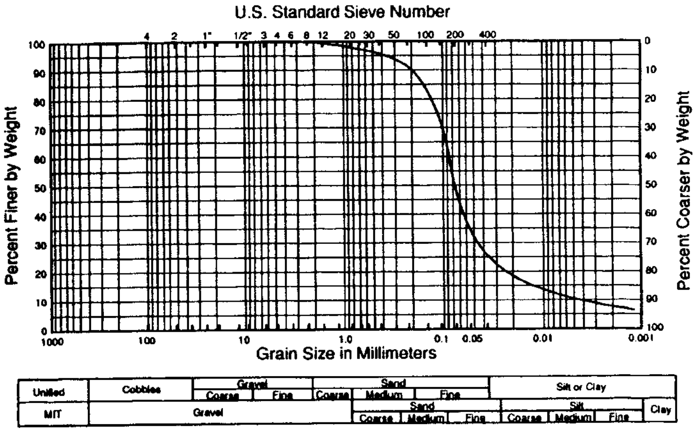

Fig. 3. Grain size distribution curve of soil SF-7.

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Discussion on
"Assessment of Liquefaction Potential and Post-Liquefaction Behavior of Earth Structures: Developments 1981-1991" by: W. D. Liam Finn
(Paper No. SOA11)

by Tzou-Shin Ueng
Lawrence Livermore National Laboratory,
Livermore, CA 94550
formerly, Department of Civil Engineering
National Taiwan University
Taipei, Taiwan, China

The author indicated the confusion and inadequacy of information on the effect of fines content on liquefaction behavior of sands. Here are some results of our studies which may give additional data on this subject. Various amounts of clay (kaoline) contents were added into Fulung (silica) sand to investigate the effect of fines content on liquefaction potential of the sand. The results (Ueng and Chang, 1982) showed that for the same void ratio or relative density of the sand skeleton, the liquefaction resistance increased and the deformations decreased with increasing clay content. However, the liquefaction resistance decreased with increasing clay content for the same dry density of the soil including sand and fines. It was found that the sand skeleton played a more important role than the fines in the liquefaction behavior. We prefer considering the liquefaction potential based on the same sand skeleton void ratio.

The effect of fines content on the static effective shear strength of the sand was found insignificant for clay content less than about 10%. Nevertheless, the dilatancy of the sand in the static triaxial tests increased with increasing clay content. Thus, the dilatancy rate of a sand in the static triaxial drained test was proposed to evaluate the liquefaction potential of sands (Ueng, 1986). The dilatancy rate of a sand was found to be a good indicator of many factors affecting the liquefaction potential of the sand.

The effect of clay content on the dynamic shear modulus and damping of Fulung sand was also investigated (Ueng and Lin, 1984). In resonant column tests, shear strains from 10^{-4} to 10^{-2}%, the shear modulus and damping ratio increased very slightly with the increase of clay content. However, the dynamic triaxial test results showed little effect of clay content on shear modulus at shear strains from 10^{-2} to 10^{-1}%, whereas the damping ratio of Fulung sand with 2% and 5% clay contents was higher than that of clean sand for shear strains above 5×10^{-2}% and the difference increased to more than 5% with increasing shear strain. This may be one of the reasons why fines content has little or no effect on the shear wave velocity for liquefaction correlations as mentioned by the Session III General Reporter, since damping may have an important effect on the liquefaction resistance of soils, but it does not affect the shear wave velocity.

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