SOILS AND FOUNDATIONS Vol. 19, No. 1, Mar. 1979
Japanese Society of Soil Mechanics and Foundation Engineering

DISCUSSION

ON THE INFLUENCE OF PROGRESSIVE FAILURE ON THE BEARING CAPACITY OF SHALLOW FOUNDATIONS IN DENSE SAND*

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Dr. Oda's remarks on the authors' explanation on the scale effect of footings in dense sand seems to consist of following two points;

(1) disregard of marked dependency of the relationship between the friction angle ϕ' and the shear strain γ' upon cell pressure σ_3'.

(2) disregard of the anisotropic effect induced in models.

These two points will be explained in the sequence.

(1) The authors were well aware of the dependency of the $\phi'-\gamma'$ relationship upon cell pressure σ_3' or mean normal stress σ_m', as it had been mentioned in one of the previous papers (Yamaguchi et al., 1975). The reason why the authors assumed a unique relationship between ϕ' and γ' was that the level of σ_m' in the areas that gave predominant influence on the bearing capacity was estimated to be not less than 1.5 kg/cm², as far as the authors' experiments were concerned. For this range of mean normal stress σ_m', the dependency of ϕ' upon γ' seemed to be not so significant.

The plane strain test data on Toyoura sand obtained by the authors are given in Fig. 15 (Fuji-i, 1976). In Table 6 the bearing capacity factor N_γ calculated by taking into account only the dependency of the maximum friction angle $\phi'_{p\,\max}$ upon σ_m' is compared with the observed values for various footing sizes. A hyperbolic type of relationship between $\phi'_{p\,\max}$ and σ_m'

$$\phi'_{p\,\max}=\frac{\sigma_m}{-0.003+0.022\sigma_m}\leqq 53^\circ\ (\sigma_m\sim \mathrm{kg/cm^2})$$

was deduced from Fig. 15 by taking into account the initial void ratio of centrifuge models and it was utilized in the computation. Iterative computations were continued until almost perfect matching was obtained for the values of $\phi'_{p\,\max}$ at each node.

Although the authors do not reject completely the dependency in discussion as a cause for the scale effect of footings in dense sand, it seems to be difficult to attribute the scale effect solely to such dependency, as is demonstrated by the discrepancy between the computation and the observation in Table 6. The authors, therefore, do not agree to a discusser's view that the scale effect can best be explained by the dependency of $\phi'_{p\,\max}$ upon σ_3'.

* Vol. 16, No. 4, Dec. 1976, pp. 11-22.
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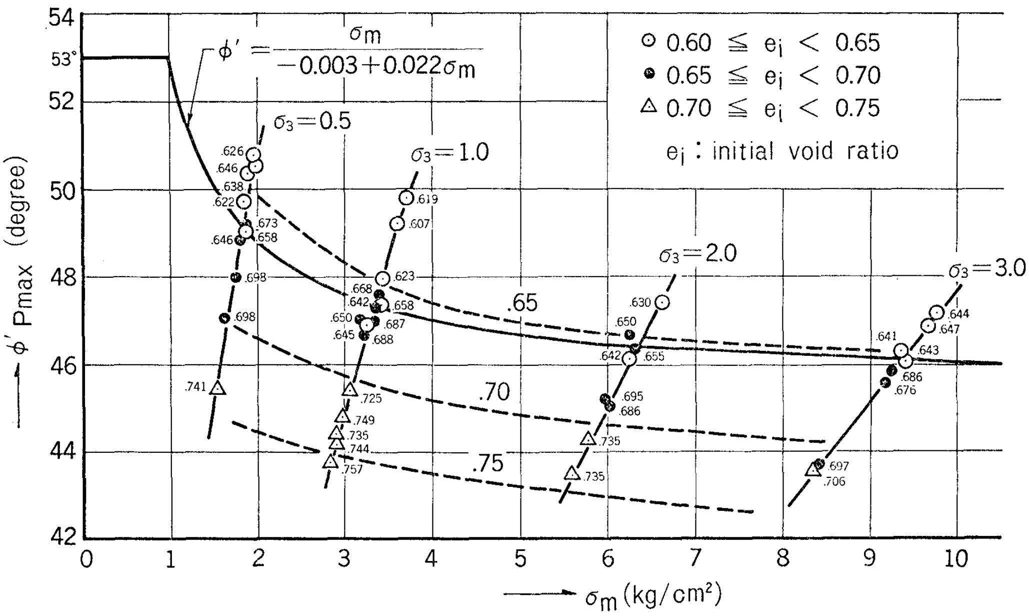

Fig. 15. Influence of mean normal stress on friction angle

Table 6. Comparison of computed bearing capacity factor with observation

Breadth of Footing	3 cm	60 cm	120 cm	180 cm
Observation	560	350	280	270
Computation	989	667	561	511

(2) The discusser pointed out that considerable anisotropy might be induced in models prepared by the authors as a result of the maximum compaction effort. Fig. 16 shows the authors' results of plane strain tests on Toyoura sand samples with different values of angle δ between the plane of bedding and the direction of the major principal stress σ_1', for σ_3' of 3 kg/cm^2. As was reported by Arthur and Menzies, as well as the discusser, anisotropy clearly exists in dense samples for plane strain tests (Arthur and Menzies, 1972; Oda, 1977).

On the other hand, in the bearing capacity tests, anisotropy does not seem to give rise to significant effect on the ultimate bearing capacity, probably due to reorientation of the particulate structure. This is shown in Fig. 17, where the bearing capacity factor N_γ is plotted against the footing size. The difference in the bearing capacity for $\delta=90°$ and $\delta=0°$ is found to be approximately 9% on an average. The average value of the density for this series of the tests is listed in Table 7, which shows that the density of the models for $\delta=90°$ tests is slightly higher than that for $\delta=0°$ test models. If the density for both models is made identical, which the authors found extremely difficult, further decrease in the difference in the bearing capacity are expected.

The bearing capacity was calculated by incorporating an elliptical approximation of the relationship between ϕ'_{pmax} and δ into Kötter's equations. The results are given in Fig. 17, which also confirms that the effect of anisotropy on the bearing capacity is slight, if any.

References

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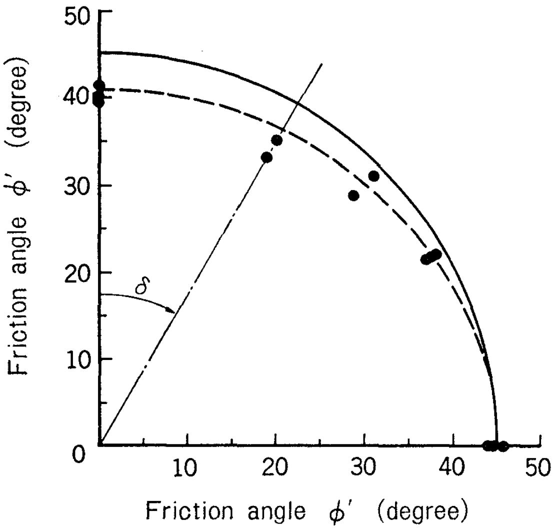

Fig. 16. Variation of plane strain strength of Toyoura sand with angle δ

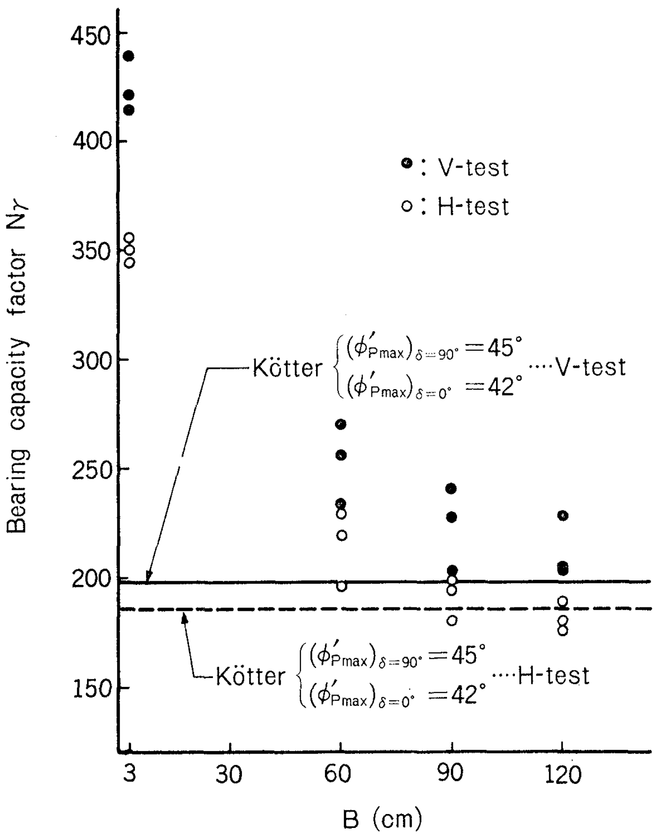

Fig. 17. Bearing capacity factor for V-test and H-test

Table 7. Density of centrifuge models

	1G		20G		30G		40G	
	V	H	V	H	V	H	V	H
Density γ(g/cm^2)	1.58	1.55	1.56	1.55	1.58	1.53	1.54	1.53
	1.58	1.54	1.58	1.54	1.58	1.54		1.54
	1.58	1.54	1.58	1.55	1.59	1.55	1.56	1.54
						1.55	1.58	
Average	1.58	1.54	1.58	1.55	1.58	1.55	1.56	1.54

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