LIQUEFACTION POTENTIAL BY TORSIONAL SHEAR

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SUMMARY

The application of torsional shear tests to evaluate the liquefaction potential started in Atkinson and Jessett (1990) and Charlie et al (1995). The torsional field shear tests were also carried out in the extension field of Hormozan University after application of SPT tests and slightly modifying the equipment to measure torque and tube rotation during the tests. The modification of the CPT test for torsional field shear test is now ongoing research in New Zealand at the department of Civil Engineering of Canterbury University. The theoretical development for drained and undrained behaviour as well as the experimental results show that there is distinctive pattern of behaviour for loose sand (contractive) and for dense sand (dilative). For loose sand the shear stress reaches a peak and further yielding is accompanied with reduction of shear stress as shear strain increases. For dense sand the shear stress continues to increase even after yield during the increase of shear strain. This pattern of behaviour makes the torsional field shear test an added tool to evaluate liquefaction potential.

INTRODUCTION

The torsional shear test to evaluate the liquefaction potential started with the work of Atkinson and Jessett (1990) and Charlie et al (1995). The torsional shear tests at Shiraz University were carried out in the laboratory on a tube embedded in sand. The torque was converted to shear stress and the rotation was converted to shear strain with the help of theory developed. The tests of Dehghani (1998) showed that the pattern of behaviour is quite different for dense sand as compared to loose sand. Further tests with the torsional shear tests in the filed as applied to SPT tube showed similar behaviour. That is dense sand during shear strain increase attains continuous increase of shear stress even after yielding while loose sand after attaining a peak in shear stress starts to decrease after yield with further increase of shear strain. The theoretical development carried out by Dehghani et al (1999) showed that for undrained behaviour the theory can represent the field behaviour. However application of the torque to SPT tube is slow and thus drained behaviour is possible. In this paper the drained behaviour is modelled numerically and the results show that similar pattern of behaviour is obtained. This implies that torsional field shear is a new added tool to evaluate liquefaction potential of sands.

EXPERIMENTAL RESULTS

The experimental results on the laboratory and field shear tests were presented by Dehghani et al (1999). For completeness purposes representative results will be presented here. Figure 1 shows the results of the laboratory torsional test. It can be seen that for low relative densities, the shear attains a peak and then starts decreasing, while for high relative densities, the shear stress keeps increasing even after yield. Figure 2 shows the results of the torsional field shear test after the SPT test is carried out.. Again the different pattern for dilative and contractive sand is clear form the figure.

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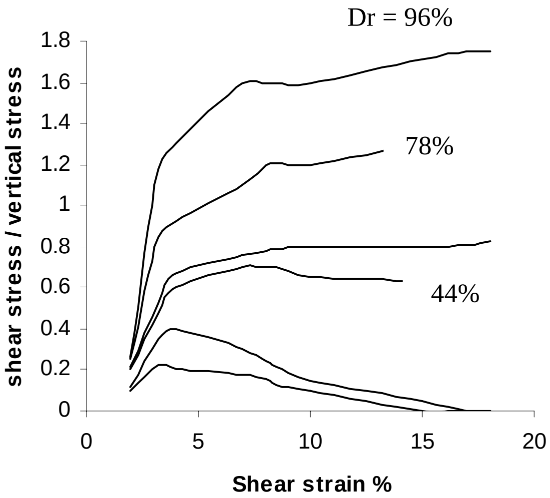

Figure 1. The results of the torsional shear test in the laboratory

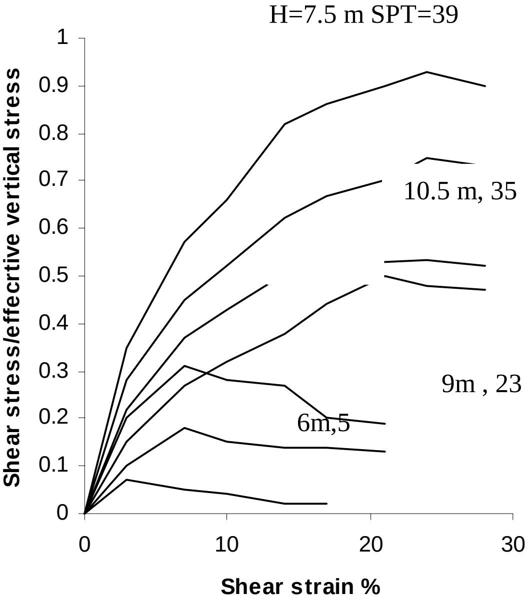

Figure 2. The results of the torsional field shear test

THEORY

The theoretical wok presented in Dehghani et al (99) assumed undrained behaviour. However the rate of the torque application in the field for sand stratum can allow the process to be drained. Therefore numerical work was carried out to see the results of the drained behaviour on the field torsional shear test. The computer program used allows for the Drucker Prager model of the soil. The angle of internal friction was taken to be 45 degrees and the angle of dilation was assumed 15 degrees. The soil cohesion was taken as 20 Kpa and the soil modulus of elasticity was taken 10000 Kpa and the SPT tube was assumed to have elastic modulus equal to steel material. The radius of the tube was taken to be 5 centimetres for numerical simulation and the boundary of the soil was taken to have 50 centimetres radius. The finite element model is shown in figure 3.

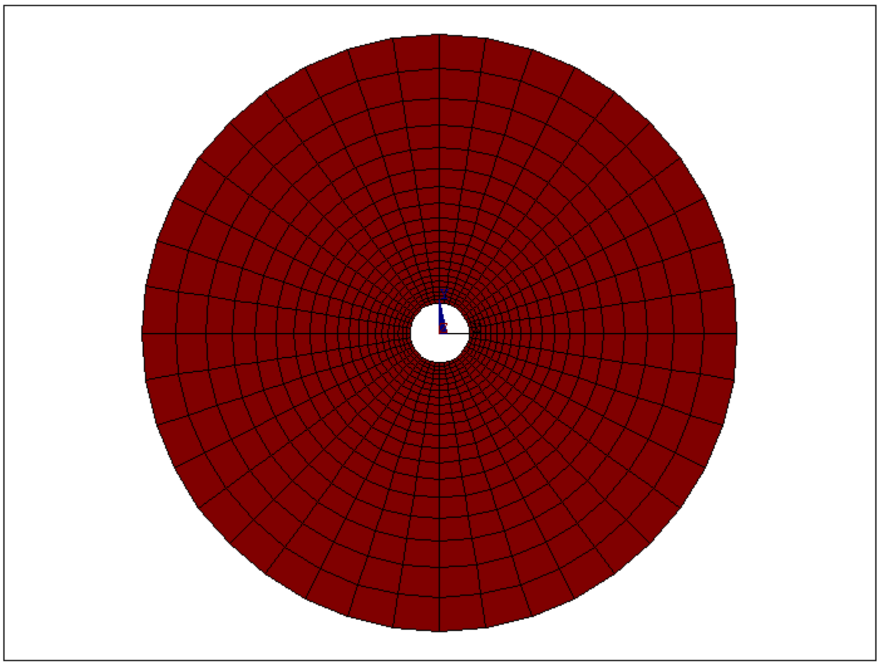

Figure 3. Finite element model of the torsional SPT field shear test.

The result of the stress distribution after rotation of the tube of 4 cm / 5 cm at the soil boundary is shown for radial stress, sx, circumferential stress sy and shear stress sxy in figure 4 in the soil medium. As can be seen the shear stress varies proportional to one over square root of r, the radial distance. The radial stress increases in the yield zone and then starts to increase slightly. However the circumferential stress increases in the yield zone and then decreases with radial distance. The initial all around pressure for this analysis was equal to 200 Kpa.

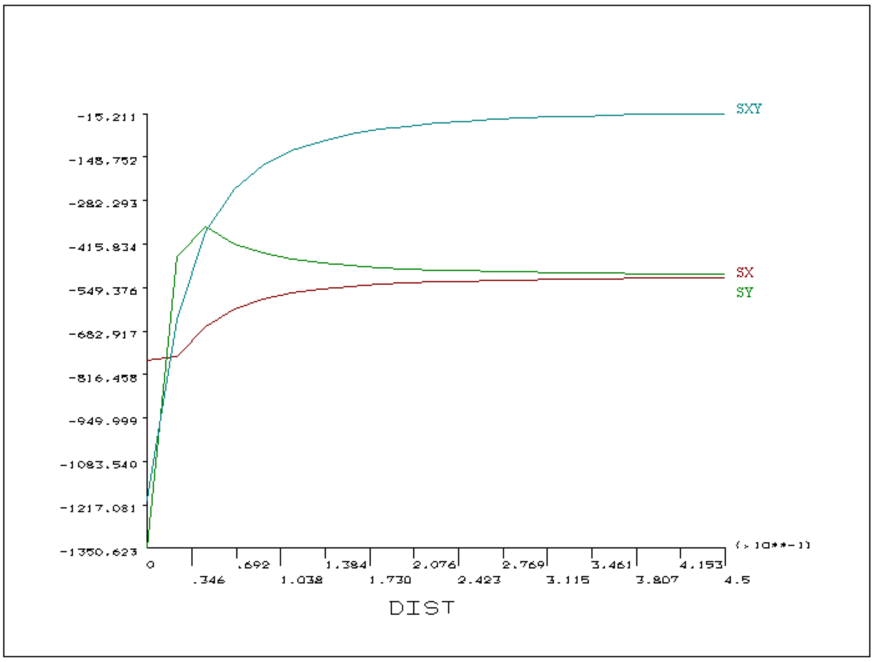

Figure 4. Distribution of radial, circumferential and shear stress in the soil medium

The distribution of the plastic shear strain and circumferential displacement is shown in figure 5. It can be seen that the yield zone is about 6 centimetres and the circumferential displacement is concentrated in the yield zone and is reduced considerably in the elastic zone.

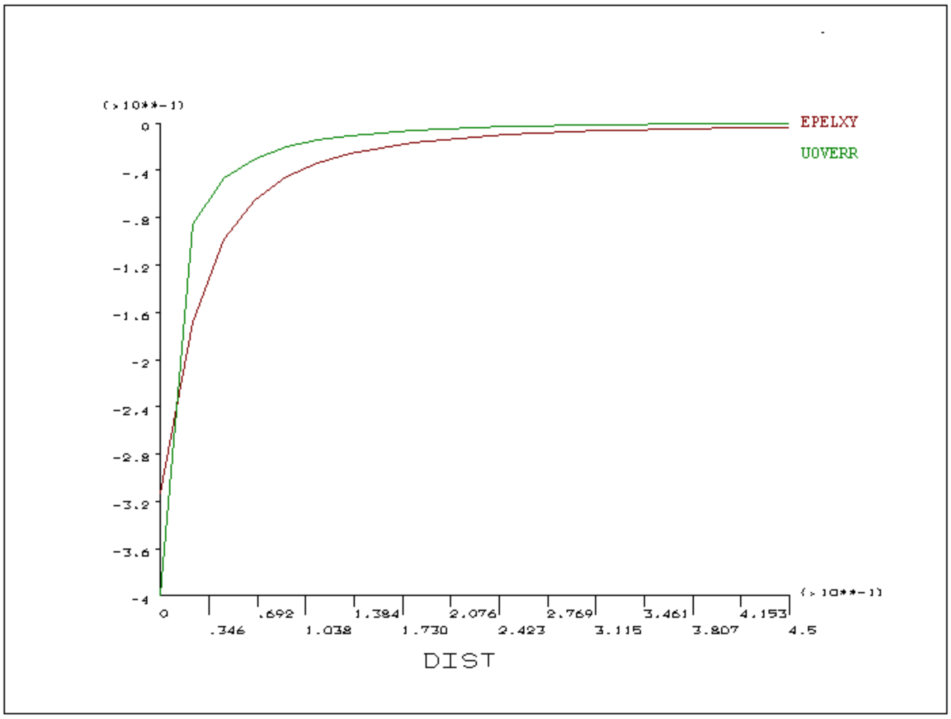

Figure 5. The distribution of the plastic shear strain and the circumferential displacement.

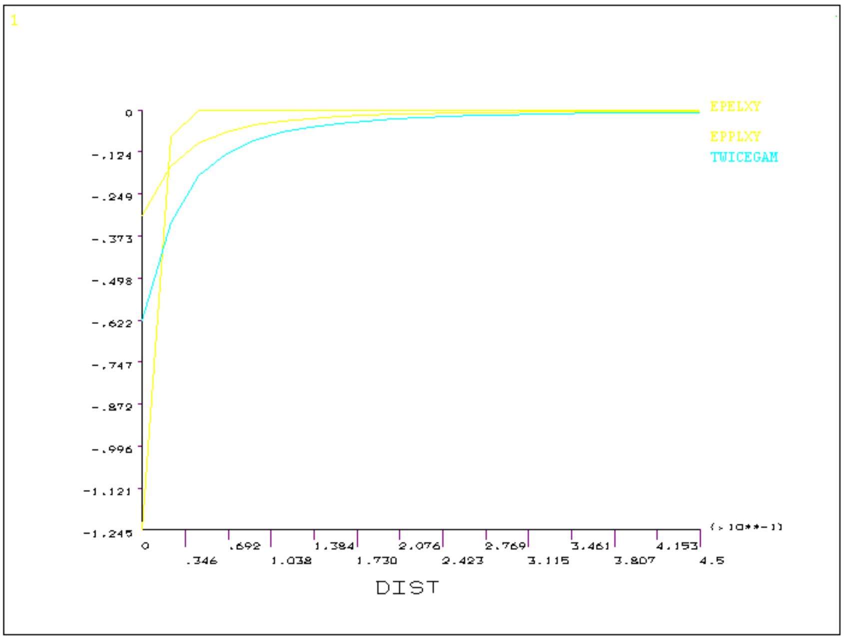

Figure 6. The distribution of the plastic , elastic and twice the v/r in the soil.

The plastic , elastic strain and twice v/r where v is the circumferential displacement are shown on figure 6. Again it can be seen that the plastic shear strain is concentrated near the tube boundary. Furthermore the theoretical result that the shear strain is half of v/r is fairly shown in the numerical model.

Figure 7 shows the vector diagram of the displacements. As can be seen form the figure, the soil is acting in a drained behaviour since volume of the soil is changing locally in the figure (the displacement vector has an outward component.) If the soil was acting in an undrained condition then the vectors of the displacement could not have an outward component. In other words in undrained condition u is zero and in drained condition u is different from zero (u is the radial displacement). Naturally at the soil boundary u is zero..

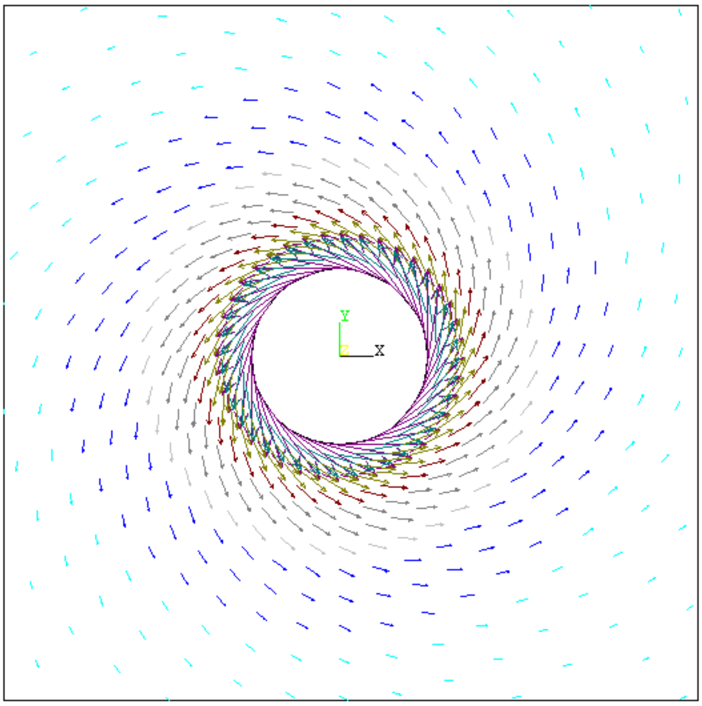

Figure 7. The vector diagram of the displacements around the SPT tube.

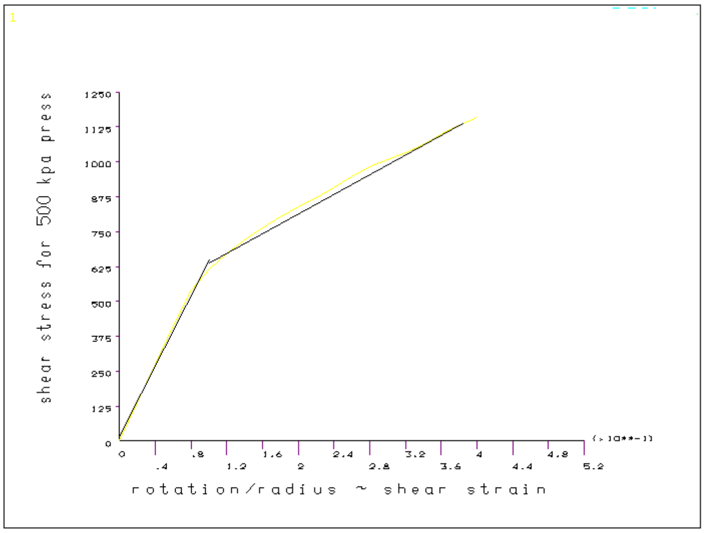

Figure 8. The shear stress versus v/r in the soil contact with the SPT tube.

Figure 8 shows the shear stress versus v/r in the soil contact with SPT tube. It can be seen that the shear stress keeps increasing after yield with the further increase of shear strain. This increasing behaviour is the pattern that separates the dilative soil behaviour from contractive soil behaviour and can be used for liquefaction potential evaluation. It also signifies that the theoretical result that for elastic shear strain the following formula applies is correct as predicted by Dehghani et al (99).

$$v / r = \delta / 2 = exy \quad (1)$$

This means that the circumferential displacement divided over radial distance is half of the engineering shear strain and almost equal to continuum mechanics shear strain.

Furthermore the results of distinct pattern of field shear as presented in Figure 9 can be used for liquefaction potential.

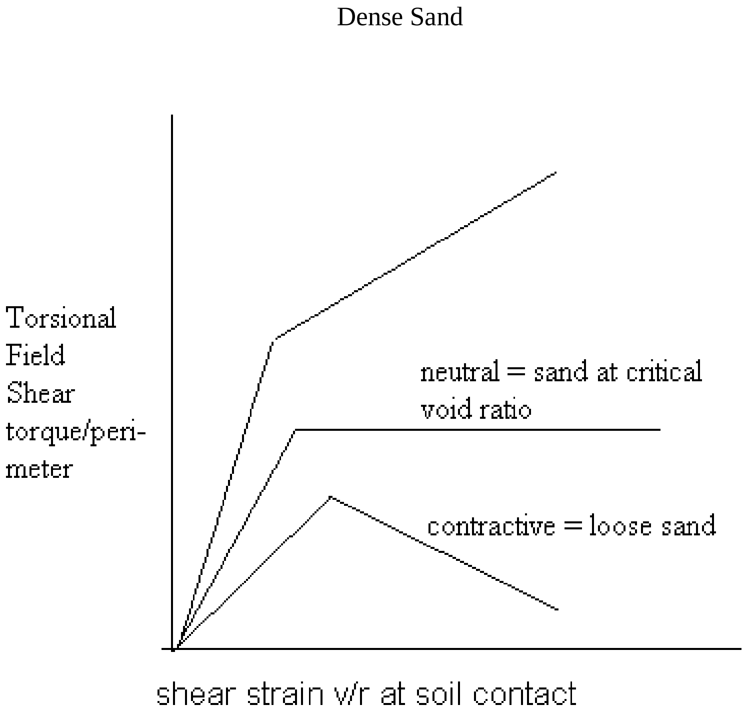

Figure 8 The field torsional shear test pattern for liquefaction potential evaluation.

CONCLUSIONS

The results of the field shear tests as well as the numerical simulation has shown that during the field shear, the dilative sand (dense sand) shows increasing shear stress even after yield as shear rotation is increased. The contractive sand (loose sand) achieves a peak and then after yield the shear stress starts to decrease as rotation is continued. The neutral sand does not show any increase of shear stress after yield. The above distinct pattern of behaviour can be used as a criterion for liquefaction potential. The SPT test can be simply modified for torsional field shear test .

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REFERENCES

Atkinson, J. H. and Jessett, J. H. (1990), Measurement of relative density of saturated sand using the piezovane, Field testing in engineering Geology, Engineering Geology Special Publication 6, pp. 229-233, London: Geological Society of London

Dehghani, M. (1998). Liquefaction potential of sand by torsional Shear test. PhD thesis, Shiraz University, Shiraz, Iran.

Charlie, W. A., Scott, C. El, Siller, T. J., Butler, L. W. and Doehring D. O. (1995). Estimating liquefaction potential of sand using the Piezovane, Geotechnique, 45, No. 1, 55-67

Dehghani, M. , Habibaghai, G. , Ghahramani, A. and Berrill, j. (1999). Liquefaction of sands by torsional shear test. Second International Conference in Earthquake Geotechnical Engineering, Lisbon , Portugal.