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INFLUENCE OF SOIL ANISOTROPY ON SOIL LIQUEFACTION

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INTRODUCTION

Soil liquefaction can be triggered by large scale earthquakes and it can result in disastrous effects to the built environment. Extensive studies on the hazard were conducted, and recent experimental evidences show that soil anisotropy has a significant influence on liquefaction of sand. A new plasticity model was modified recently to account for the effect of anisotropy on the simulated soil behaviour. This project focuses on evaluating the simulative potential of the modified model on problems involving liquefaction. Imperial College Finite Element Program was employed for all simulations in the project (Potts & Zdravkovic, 1999).

MODIFICATIONS

Williams (2014) introduced two major modifications to the boundary surface plasticity model developed by Taborda (2011). These include:

(a) a new hardening parameter scalar to relate material anisotropy and hardening modulus (Loukidis & Salgado, 2009), and

$$h_A = e^{\left[\left(\frac{A_c - A}{A_c - A_e}\right)^{1.25} \ln(k_A)\right]}$$

(b) a pseudo critical state line that evolves with direction of principal stresses and deviatoric distance to the critical state surface (Williams, 2014).

$$e_{cs} = (e_{cs})_{ref} . e^{V_A \frac{\langle d^c \rangle}{d^c_{ref}} \langle A_c - A \rangle} - \lambda \left(\frac{p'}{p'_{ref}}\right)^{\xi}$$

The modifications allows the effects of fabric anisotropy and direction of major principal stress, α, on soil behaviour to be modelled, as shown in Figure 1.

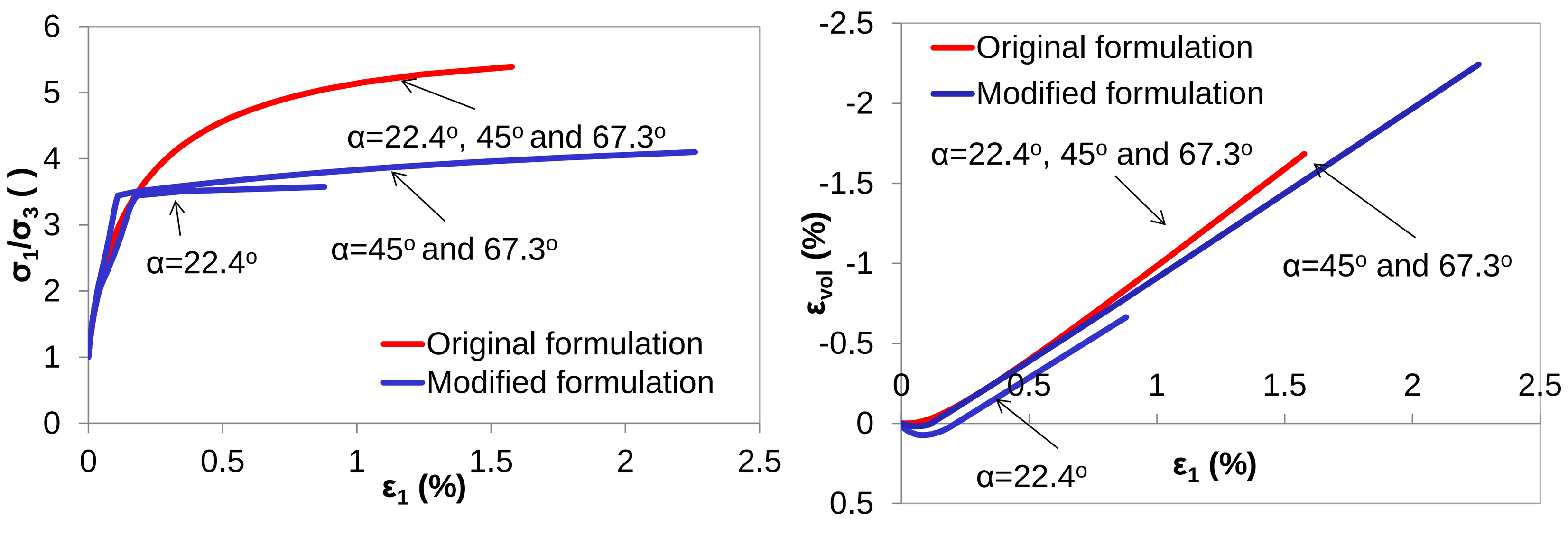

Figure 1: Hollow Cylinder Simulations

CALIBRATION

A total of 32 parameters were calibrated by use of available laboratory test data of Nevada sand. The final calibrated model can reproduce the laboratory tests with an adequate degree of accuracy. It should be noted that large discrepancies are observed when simulating the axial strain variation in cyclic triaxial test, particularly after the onset of liquefaction.

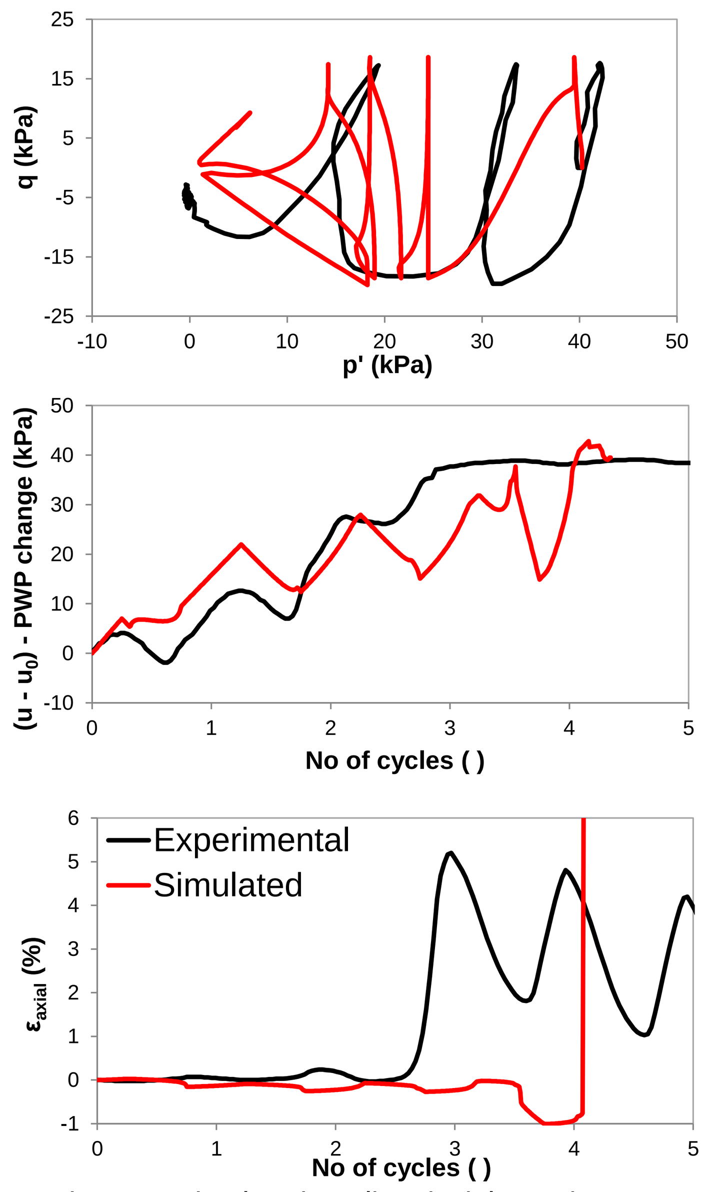

Figure 2: Simulated Cyclic Triaxial Test (CY 40-115)

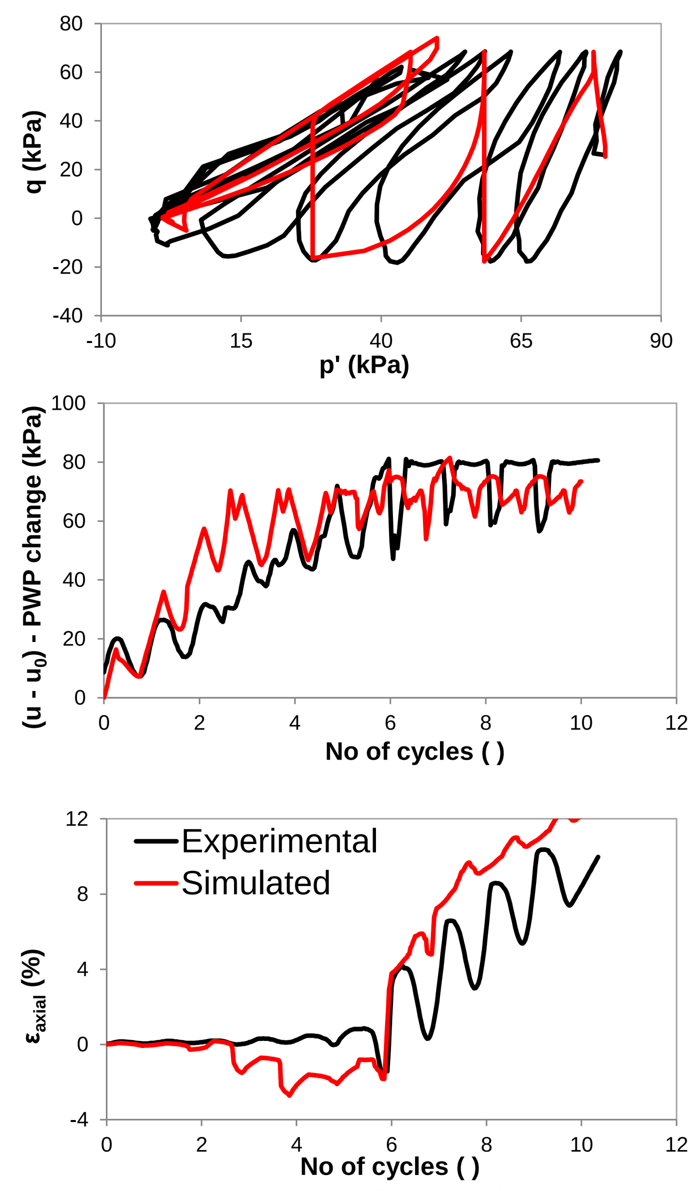

Figure 3: Simulated Cyclic Triaxial Test (CY 40-73)

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APPLICATION

A centrifuge test replicating a 10m-thick horizontal liquefiable soil deposit under dynamic excitation was simulated by use of a 100-element mesh and the calibrated constitutive model. The simulated results were compared with the test data (Taboada & Dobry, 1993).

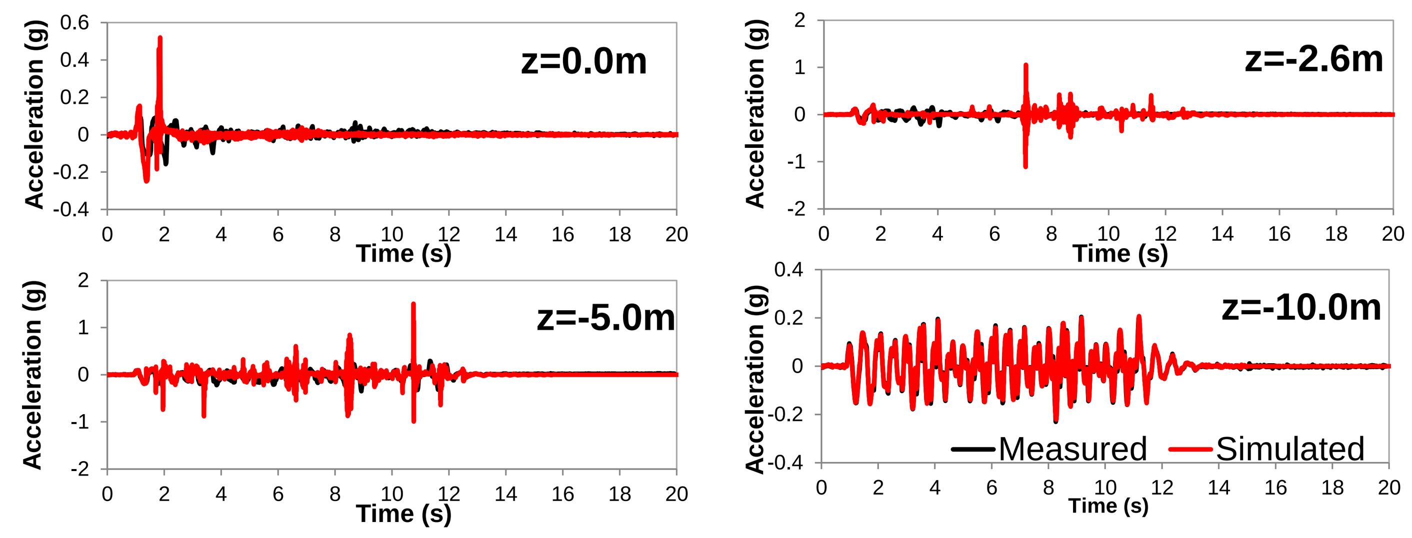

Figure 4: Measured and simulated acceleration time-histories at different levels

The simulated and measured acceleration time-histories are in good agreement. However, spikes are recorded and premature solidification is observed at z≈-2.6m.

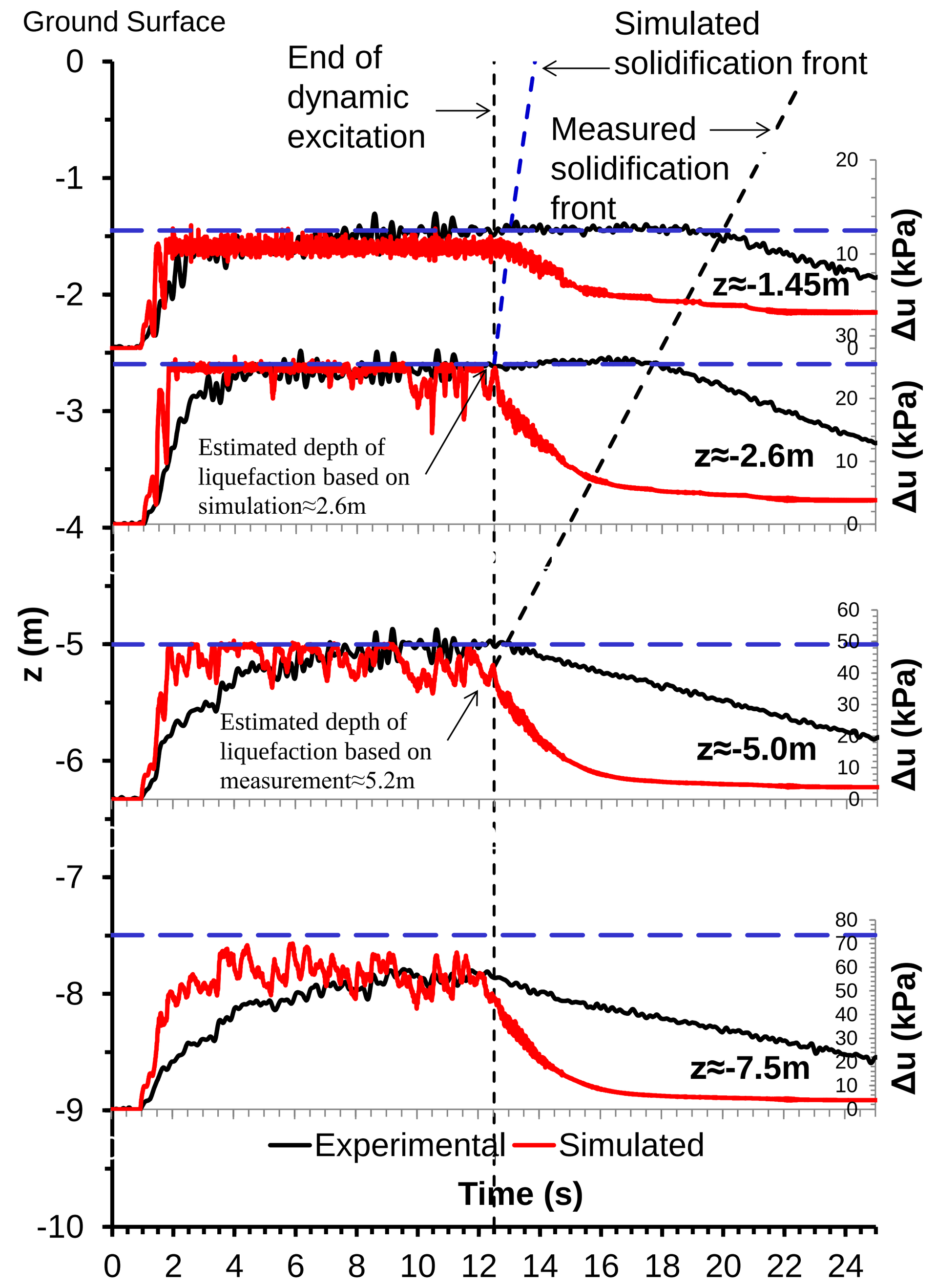

Figure 5: Measured and simulated excess pore water pressures with solidification fronts

The rates of pore pressure build-up are overestimated by the model. This issue can be improved by re-calibrating the Fabric index.

The rates of dissipation are also overestimated by the model.

It is also observed that the approximate depth of liquefied layer is underestimated by the model by 50%.

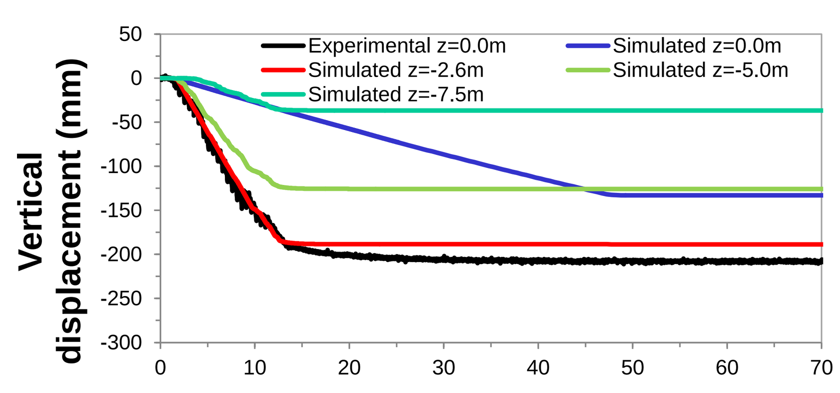

Figure 6: Measured and simulated vertical displacement at different levels

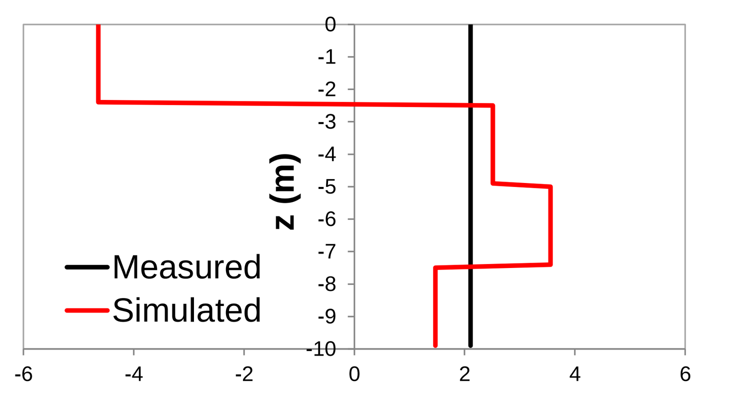

Figure 7: Measured and simulated volumetric strains at t=25.0s

A significant vertical displacement was simulated at z=-2.5m where the soil is liquefied during dynamic excitation. However, dilatant behaviour was simulated for soil near the surface, which is presumably due to constant upflow of water from deeper level. Therefore the simulated surface settlement was reduced.

CONCLUSION

The modified model is capable to simulate both the results of laboratory tests and the boundary value problem to a reasonable degree of accuracy. However it is difficult to conclude whether the modified model has improved the soil response under liquefaction. Further studies on the simulative potential of the model are suggested.

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