Talk on Dynamic Analysis of Open-Ended Pipe Piles

By: Ir. Liew Shaw Shong

IT was the honour of Geotechnical Engineering Technical Division of IEM having the speaker, Prof. Samuel G. Paikowsky to deliver an evening talk at Tan Sri Prof. Chin Fung Kee Auditorium, Wisma IEM on 26 April 2010. The talk was chaired by Ir. Liew Shaw Shong, the deputy chairman of the technical division. The talk was attended by 45 participants.

The presentation was started by demonstrating an open ended plugged pipe pile after sufficient frictional resistance is developed by the inner soil cylinder within the pile (soil plug), thereby partially or completely preventing further intrusion of the soil into the pile. When plugging occurs in an impact driven pipe pile, a complex interaction between the pile and the soil plug takes place, causing the propagating stress wave to undergo an abrupt change. Current dynamic analyses of piles are based on the one-dimensional wave equation. Although the wave equation has the capability to indirectly (accommodate) the inner soil cylinder, it does not accurately simulate the physical phenomena when the pile is plugged, causing the predicted capacity of plugged piles based on the analyses utilizing that formulation to differ from actual field observations. A review of the pile plugging phenomenon was presented describing its identification, plugging mechanism (arching in sand materials), and its effects on pile performance when driven in predominantly cohesive or granular subsurface. The influence of artificially plugged piles on pile resistance and performance is demonstrated via large scale case histories. The need for correct, physical modelling of the stress wave propagation in plugged piles is established.

A different approach is presented in which the spatial stress transformation within the soil plug is modelled using an axis-symmetric wave propagation formulation. A two-dimensional finite difference solution was developed for that formulation. This numerical solution was implemented in a computer program called PWAP (Plug Wave Analysis Program). A case study was then used to examine the applicability of the solution and to determine if the static capacity of the pile could be predicted more accurately. The PWAP analysis was performed on a pipe pile driven in Empire Clay using dynamic records taken from a well documented case study.

The results of PWAP were compared to the results of programs based on one-dimensional wave equation (TEPWAP and CAPWAP), which do not simulate the effects of soil plugging. The PWAP analysis resulted in a better force match than the conventional analyses and predicted the pile capacity to 87% of the load test value, compared to about 30% for the conventional method predictions. PWAP was recently examined in a large bridge project (Sakonnet River Bridge Replacement Project) where plugging in 1828.8mm (72inch) diameter open piles was enhanced by artificial means. The piles were statically tested to 3MN and the dynamic analyses verified again the validity of the PWAP analysis.

The presented was ended at 6:50pm with the following conclusions:

a. While driven unplugged, the inner and outer soil resistances can be combined and the dynamic pile penetration can be simulated by one-dimensional wave equation.

b. When driven plugged or partially plugged , the inner soil plug-pile interaction violates the underlying assumptions of the one-dimensional wave equation leading to erroneous results even when a close match is observed between the measured and the calculated signals.

c. A more rigorous formulation of the plug's equation of motion accounting for both, the shear and longitudinal wave propagations seems to correctly capture the physical phenomenon.

d. Analysis using a numerical solution for the formulation of PWAP was proven to provide realistic capacity evaluation differing significantly from the one-dimensional wave modelling for the same case though both presented similar quality signal matching.