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Generation of *p-y curves* based on Decomposition Method for Pore Water Pressure

Baydaa Hussain Maula

Abstract: ***To highlight the importance and strengthen the prominent role of a pore pressure generation on p-y behavior under different vital parameters a numerical study will be conducted depending on previous research of shaking table tests. Accordingly, we recognize that the relationship and the mechanism of the dynamic factors is not easy to predict and explain. Estimating lateral resistance and displacement's demands on a soil-pile-structure in a liquefiable ground required an accurate measurements for PWP along the quake period. The decomposition method results explain the mechanical effect of PWP generation with time intervals on pile lateral deformation for cases the presence of a single pile or with a group.***

Keyword: Pile group foundation, Sand blow, OpenSeesPL, Generation of p-y, decomposition method.

I. INTRODUCTION

It is not a secret the impact of the huge damage of earthquake life facilities, building and foundations due to pore water pressure increased in the lands of hitting an area. Many research mimic on laboratory experiments and numerical analyzes, which simulates liquefaction has captured the attention of study the impact of the earthquake numerically using the program (OpenSeesPL). Responses of pore pressure, acceleration, soil pressure, pile-soil relative displacement and moment during liquefaction have been analyzed. It illustrates that time-history curves of that research demands varied seismic waves could be divided into four parts, (Lin Ji Cong and Ling Xian Chang, 2012).

II. COMPUTATIONAL FORMATIONS

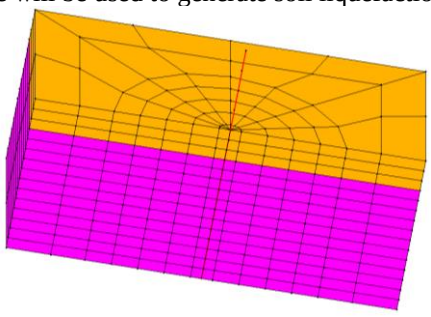
2.1 Characterization of a Previous Experiment

The theory of this study is to represent the model that was made by the researchers, Tang Liang etal 2014 and Tang,2010 numerically by the program OpenSeesPl, and in order to clarify the model assembly, a reinforced concrete pile with 0.2m in diameter was employed to simulate a bridge foundation lies into two soil layers. To simulate shaking table test numercillay set the software parameters as below :

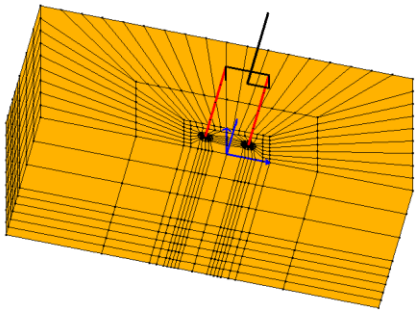
1- Define the boundary condition type as a rigid box.
2- Pile head connection considers as a fix restraint with a head mass of 240 kg is set as the superstructure.
3- Single pile with 0.2 m in diameter and 0.1 m for group model and 1.92m in length
4- The model soil parameters, will be consist of lower strata (liquefied soil) have 1.2m thickness is modeled to simulate a saturated sand, the upper one “clay soil” stratum with 0.3m thickness.

2.2 Numerical Meshing

Figure 1 showe the meshing and numerical model used for the simulation case for the foundation of the survey interested which was created with OpenSeesPL by using the prototype dimensions. The model dimensions are 2.5 m (longitudinal) x 2.5 m (transverse) x 1.92 m (vertical). Figure 1 (a) and (b) shows an isometric view of the model, respectively. The numerical model of pile group consider a group of two piles position in a square pattern, each 0.1m in diameter arranged in two rows. The suite of Sinusoidal shaking events of (0.1 and 0.15g) of 1 Hz and 0.15g 2 Hz will be will be used to generate soil liquefaction.



(a) Single



(b) Pile group

Fig. 1 Finite Element Modeling (a: Source Tang liang etal 2010)

2.2.1 Mechanism configuration of Liquefaction due to a quake

During the process of shaking and tremors occurring in the territory of the quake-prone or earthquake, the saturated sandy soils going to suffer from the loss of the strength of soil molecules and atoms, as a result of shaking, pressure will be generated from pore water.

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The pressure will be increased till its equal to the soil's weight affecting at the same depth in which it generates, the soils will behave as fluids and this is what is known scientifically by the phenomenon of liquefaction which in turns will produce a anther critical phenomenon found on ground surface known as sand blow as shown in Figure 2(http://mptuttle.com/newmadrid3.html).

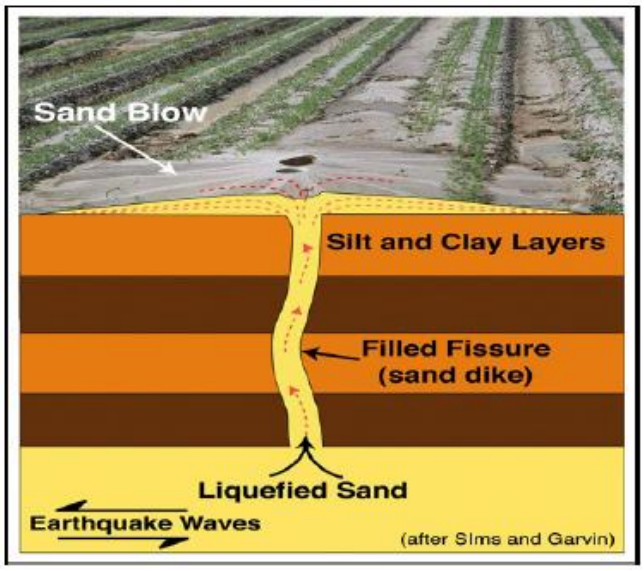


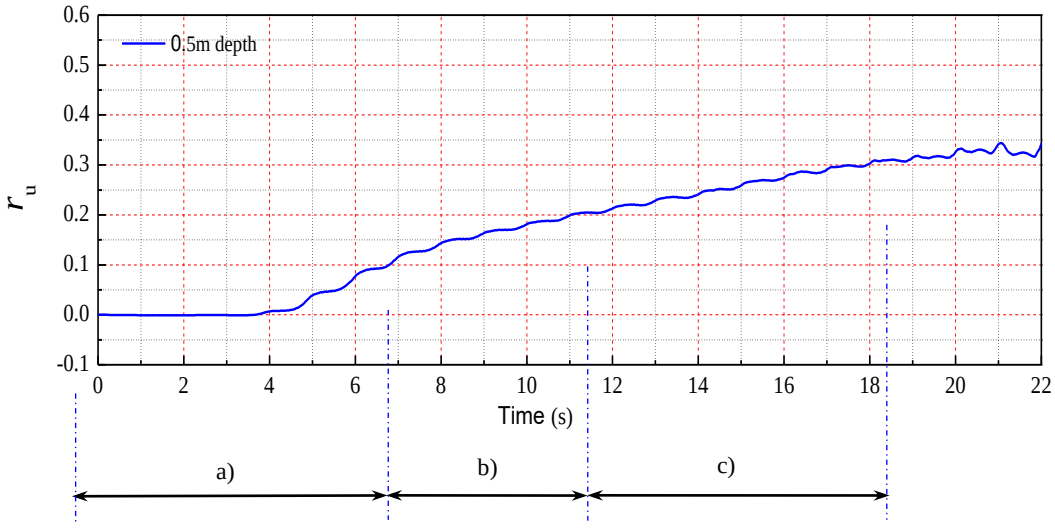
Fig 2. Sand blows formation due to earthquake-induced liquefaction.(Source : http://mptuttle.com/newmadrid3.html)

2.2.1 Effect of earthquake time duration based on Liang Decomposition methods

In 2010, Liang established a method to analyze the effect of pore water pressure generated as a result of shaking impact. The method had to hold the inspection and testing under different depths along the pile and the level of various shaking amplitudes and frequency. In order to make the comparison and see its validity, Tang Liang confirms the effect of pore pressure segments with shaking time (s) on p-y behavior. Figures 3-4, show the relationships of relative displacement (y) with a lateral resistance (p) and an average pore pressure ratio (r_u) at 0.5, 0.7, 0.9, and 1.2m depths in 0.15g and 1 Hz motion event as well as a 0.2m pile diameter size for three-time segments.

The p-y curves near time segments between 7, 11 and 18s are presented together in Fig.3 with curves near time segments between 7, 17 and 22s. The Figures showed the instability of lateral displacement (*y*) towards negative values and positive movement between the pile and the surrounding soil. Lateral resistance (p) of the shallower depth during shaking Fig 3 increases distinctly with relative displacements (y) incremental, while for the deeper depth Fig 4, in contrast, it becomes very small, which makes the p-y behavior stress softening. At 0.7 m, depth (Fig 3) shows action behavior in between the two. From the two figures, we can observe that the increase in lateral resistance (p) at any depth appears to occur in accordance with the decrease in average pore pressure.

On the other hand, according to the increased depth of soil strata is calculated as an indicator of the pile length & effect of the thickness of the liquefaction layer,"Positions of soil particles before and during liquefaction indicated decreasing soil density during liquefaction"(Abdoullah. N and Mehdi.K. 2009), to minimize the effect of pore water pressure in the liquefaction layer. Figure 3-4 show changing levels of pore water pressure at each depth are indicated.



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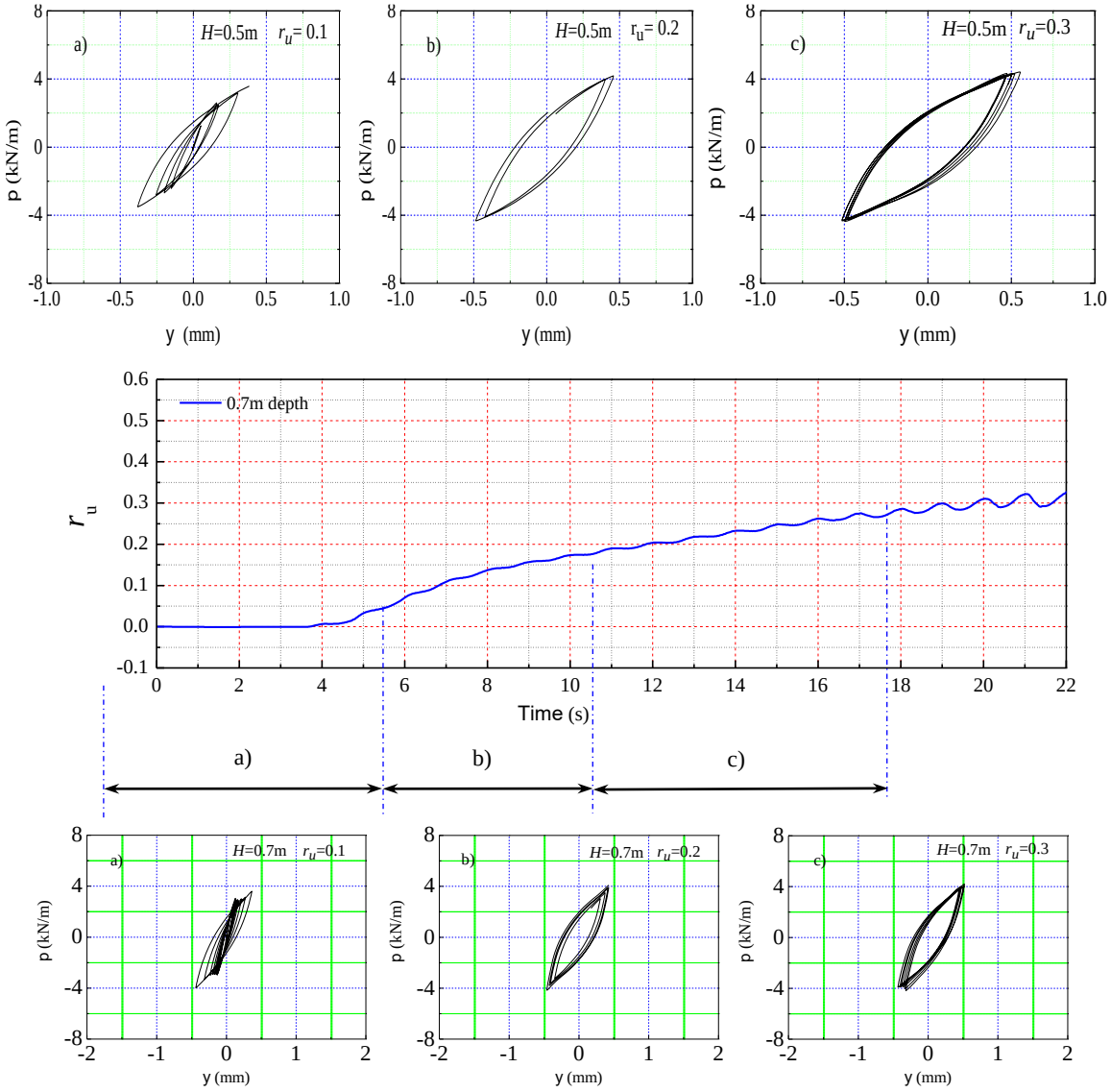
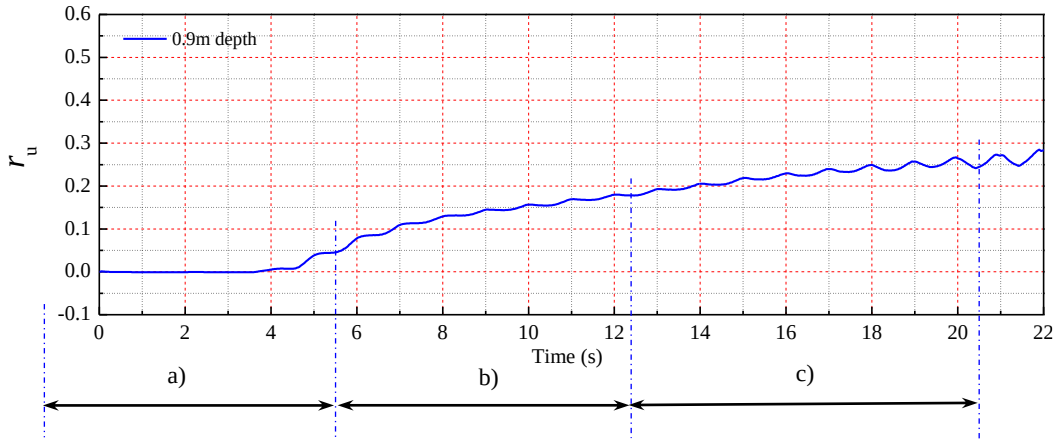


Fig 3 Decomposition of Dynamic *p-y* Curves of Medium-Dense Sand Based on Pore Pressure Ratios (Source Tang Liang 2010)



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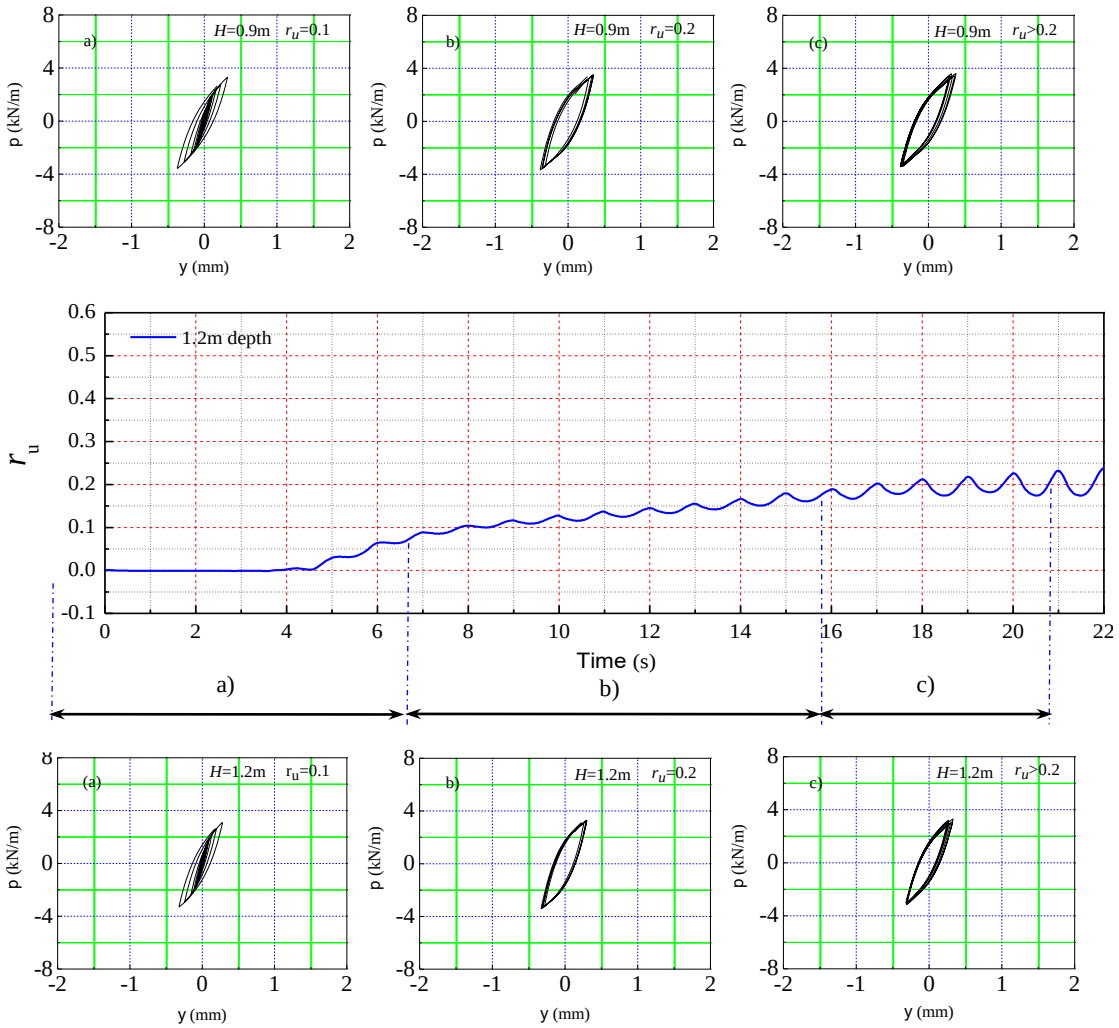

Fig 4 (Cont.) Decomposition of Dynamic *p-y* Curves of Medium-Dense sand based on Pore Pressure Ratios (Source Tang Liang 2010)

The highest p values was noticed at 7s and decreased during the remaines of shaking. At the same time, the y values showed several peaks of similar magnitude between 7 and 18 s. This degradation of p with same manner can be observed in the p-y time histories' behavior for depths 0.9m and 1.2 m, shown in Fig 4. The ratio of p to y remains almost constant until about 17 s into shaking. Then after 17 s, the p values incrementally decrease relative to y. This behavior after 17 s can be attributed to the values of r_u, which severely increased to relatively high levels at 17 s and continued to show the same behavior until the end of shaking this results was agreed with the study provide by Daniel W et al 2000.

2.2. 3 Effect of Liquefiable soil layer thickness on p-y Curve (Phanikanth et al 2013)

As mentioned earlier the function design of the pile in the liquefied ground through shaking depends on *soil and pile properties* (Mokhtar et al 2014).

Followed **Phanikanth et al 2013**, The presence of liquefaction layer the amount of its deepens on soil-pile response is conducted as a function of the embedded length to the depth of the pile which expressed in terms of (L_e / L_l). The pile bending response at depth 0.5 m is plotted in Figs 5-8. It can be seen that the maximum bending moment occurs at a position closed to 80% of the total embedded pile length. That's what has been presented according to the results obtained were in line with what Phanikanth et al 2013 had done of Research.

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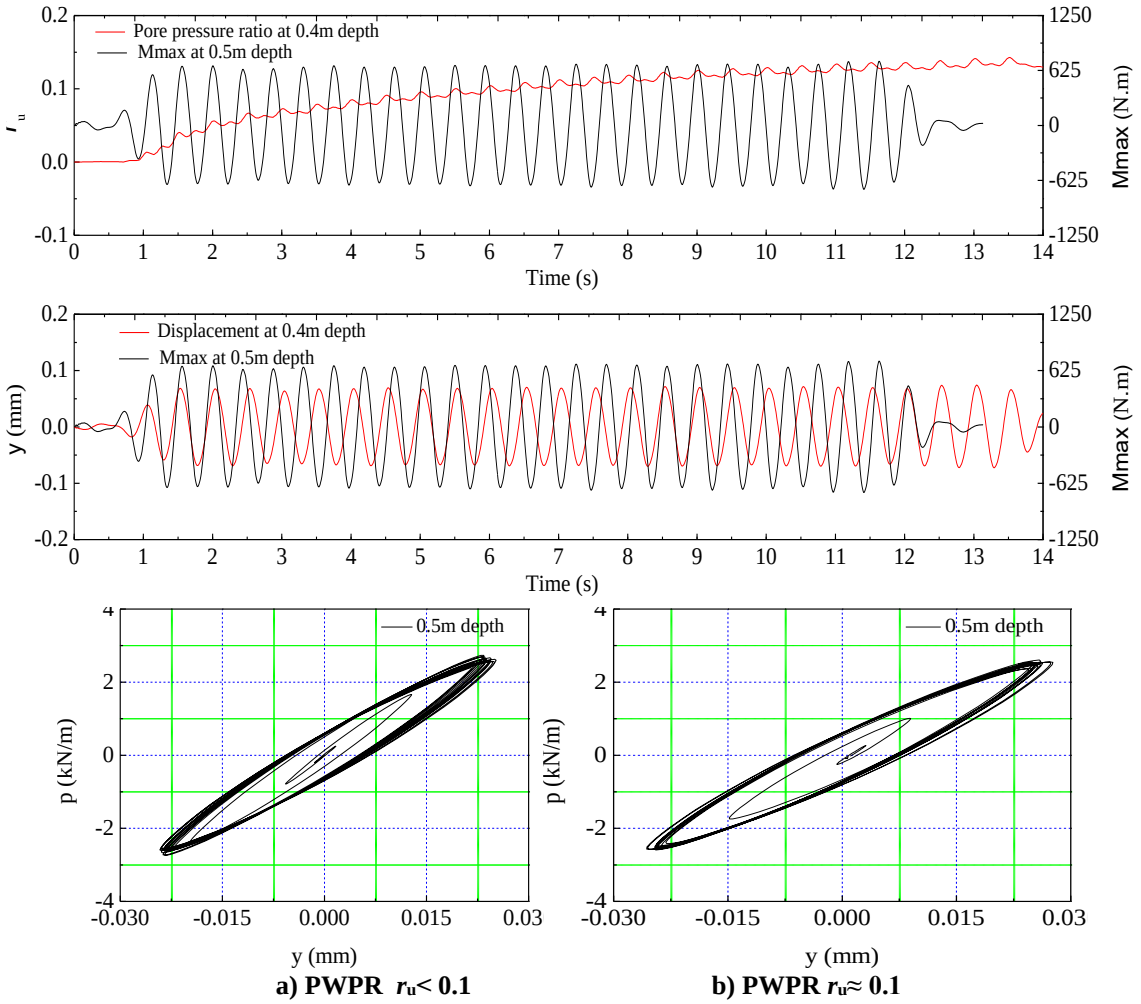
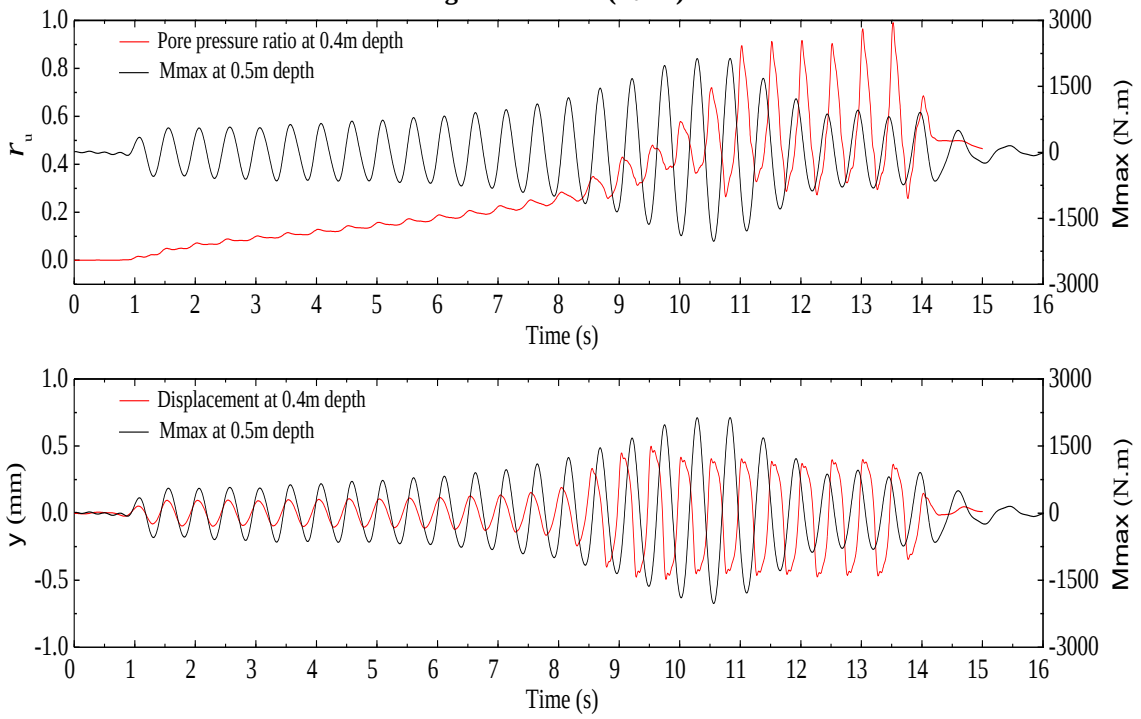


a) PWPR $r_u < 0.1$ **b) PWPR $r_u \approx 0.1$**

Fig 5 Pore Pressure, Displacement and Pile B moment Time Histories and Segmented Dynamic *p-y* Curves under 0.15g and 2Hz for (L_e/ L_l) = 0.4



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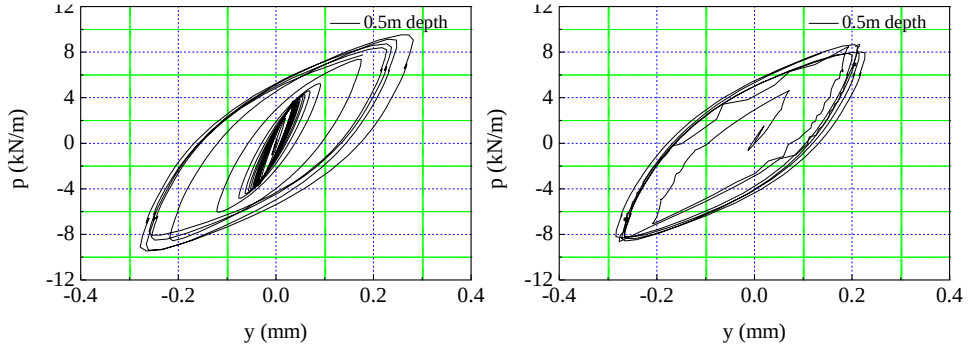
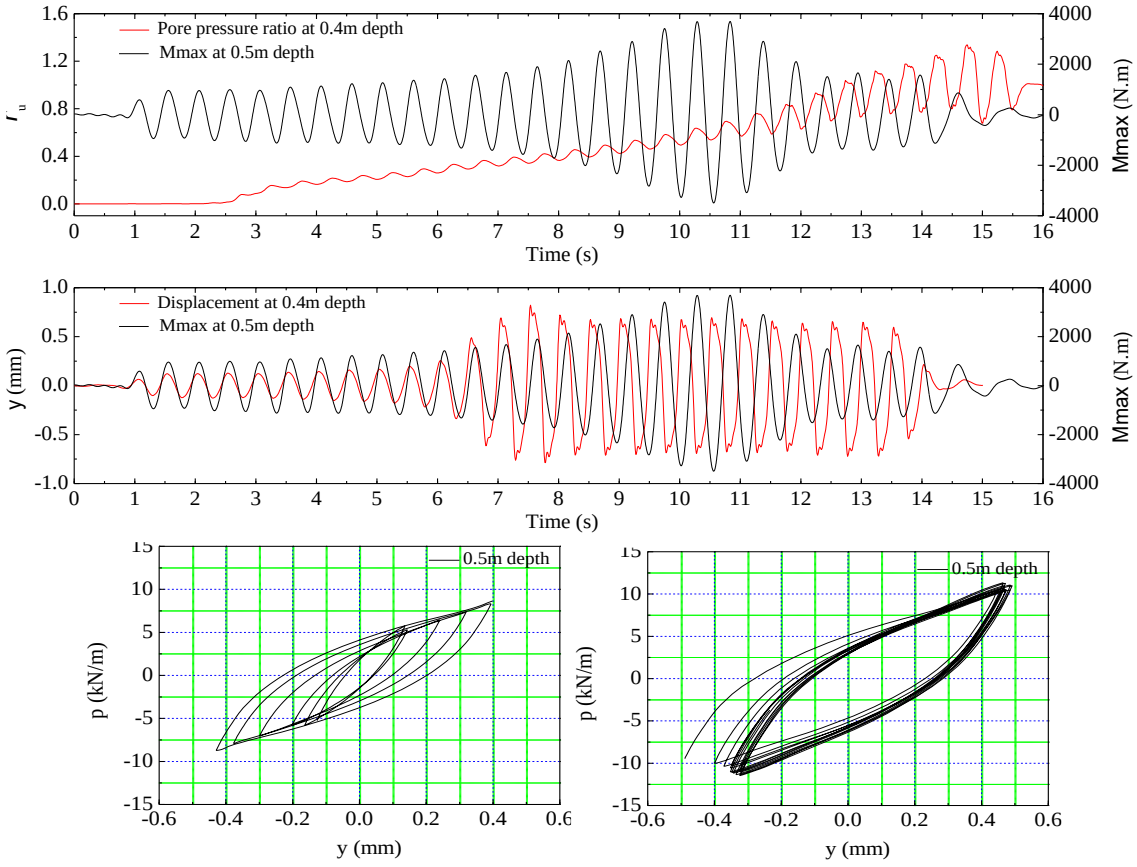


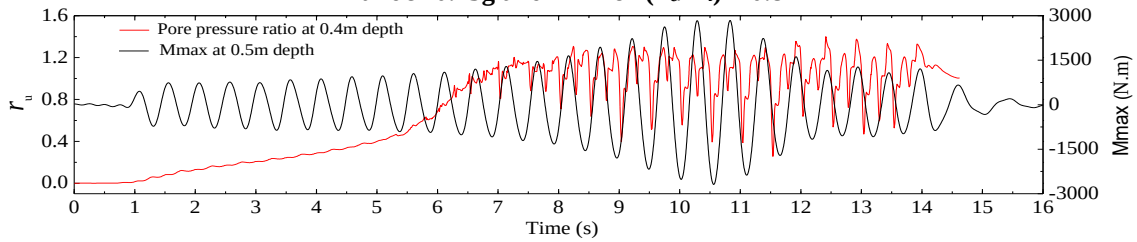
a)PWPR r_u< 0.6 b) PWPR r_u< 1.0

Fig 6 Pore Pressure, Displacement and Pile Bending Moment Time Histories and Segmented Dynamic *p-y* Curves under 0.15g and 2Hz for (L_e / L_l) = 0.6



a) PWPR r_u <1 **b) PWPR r_u >1**

Fig 7 Pore Pressure, Displacement, and Pile Bending Moment Time Histories and Segmented Dynamic *p-y* Curves under 0.15g and 2Hz for (L_e/ L_l) = 0.8



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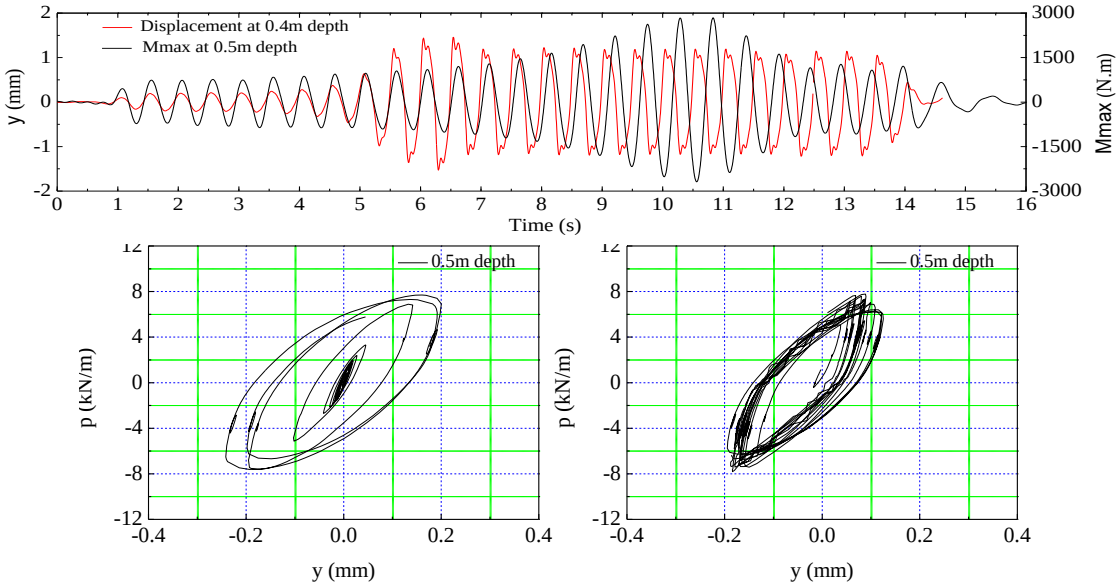


a) PWPR $r_u < 1$ **b) PWPR $r_u > 1$**

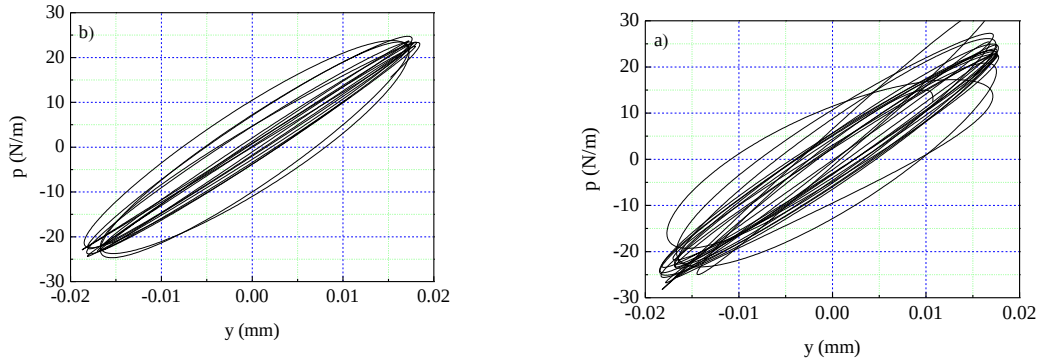
Fig 8 Pore Pressure, Displacement and Pile Bending Moment Time Histories and Segmented Dynamic *p-y* Curves under 0.15g and 2Hz for (L_e / L_l) = 1.0

Figs 5-8. show that the *p-y* curves are softer when the thickness of the liquefied layer is approximately 60 to 80% of the total embedded pile length. While for 40 % of the total length near upper clay layer, *p-y* curves show no apparent difference for *p* and *y*. Figs 5-8 show that the *p-y* curve yields at smaller pile displacement the liquefiable layer near upper clay layer.

2.2.4 Group Effect on p-y Curve

Due to the absence of providing data of a prototype of shaking table test to model groups and pile caps a numerical test was developed to simulate the model for the case shown in Figure 1 (b)

Fig. 9-10 shows a comparison of p-y curves for single and pile group, for single pile, with the pore pressure ratio increases, showing a gradual softening of the soil characteristics, showing the dynamic stiffness of p-y curves softened; For pile groups, dynamic p-y curves did not reflect this effect, with the pore pressure ratio increases, soil pressure did not show a significant softening trend, during shaking start state. Meanwhile, with the shaking time increases, soil reaction force and the relative displacement between pile and soil increased accordingly, but the curve increased stiffness is not obvious; the dynamic pile p-y curves with increasing number of cycles showed softening trend, while the pile group dynamic p-y softening curves characteristic is not obvious.



a) PWPR $r_u < 1$ **b) PWPR $r_u > 1$**

Fig 9 Decomposition of Dynamic *p-y* Curves of Medium-Dense Sand Based on Pore Pressure Ratios for the pile group at depth 0.9m

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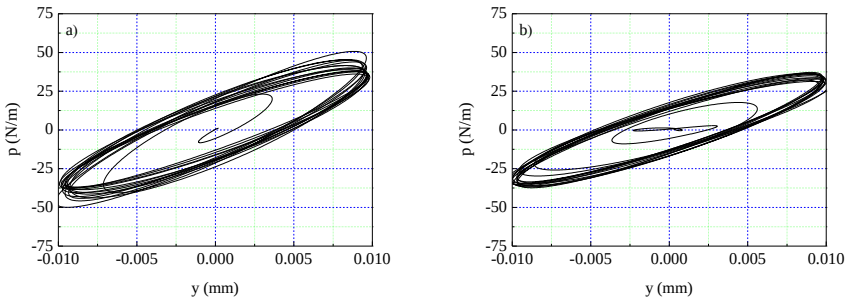

a) PWPR $r_u < 1$ **b) PWPR $r_u > 1$**

Fig 10Decomposition of Dynamic *p-y* Curves of Medium-Dense Sand Based on Pore Pressure Ratios for single pile at depth 0.9m

2.2.4 Pile diameter

Three trial pile diameters of 0.4, 0.5 and 0.65 of single pile diameters (0.2m), without change the dimension of the pile cap at its position or the other parameters. Thus, have different diameter ratio s/d. Figure 11 shows the peak bending moment on the pile; with the increasing pile diameter, pile soil reaction showed an increasing trend; near layers boundary, with the depth increases, the pile diameter causing peak bending moments gradually decreases over the layers. However, for the group of piles, the maximum bending moment occurs at the junction pile and pile cap. Seen, with the pile diameter increases, the peak bending moment showed a gradual increasing trend, but the rate of change was significantly notice for larger pile size; the pile moment is much larger near the soil boundary but it less for the cap, as the depth increases. Pile diameter under different dynamic p-y curve for single pile, with increasing diameter it will increase the soil reaction force and the relative displacement of the pile and soil are gradually increasing, and both relatively obvious increasing trend curve stiffness, but the increase is not obvious for the pile group, with the pile diameter increases, the soil reaction force increases more obvious, but the relative displacement between pile and soil increases is not obvious. Comparing different pile diameter, the group piles and its dynamic p-y curves change in stiffness, can be seen more obvious than the single pile.

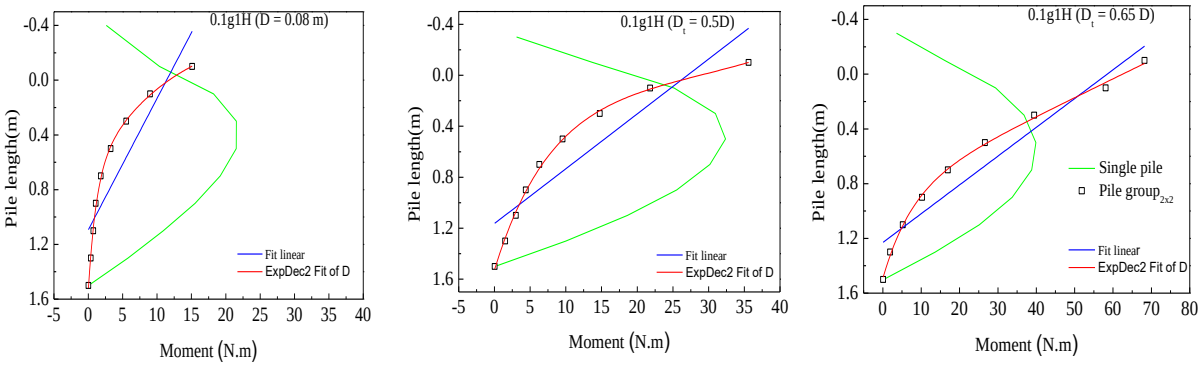

Fig.11 Comparison of peak bending moment from Single and pile group

III. CONCLUSIONS

This paper describes the result acquired on the basis of the numerical study of the dynamic behavior of deep foundations due to liquefaction. The Dynamic *p-y* behavior characteristics that lateral deformation related to the soil Liquefaction under a certain cases has been highlighted in this study. Based on the gained results, the key findings are as follows:

1. The relation between (p) and (r_u) is invert related
2. There is a correlation between the thickness of liquefaction layer and the pore water pressure and thus its effect on the pile and its disposal in response.
3. To draw more general guidelines**.** Resaech for the lateral resistance ratios in terms of stiffness and strength parameters are needed.
4. Further analyses are recommended to study the effect of the layering media for pile foundation, especially the cases belongs to pile group, pile spacing effect and internal friction angle
5. The bending moment for pile group closer to exponential more than linear behavior

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