Piping Phenomena in an Open-end Pipe Pile of Offshore Structure

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Abstract

This research is conducted to study the piping phenomena occurs with cohesiessless soils below different levels of water with different grain size distribution, (i.e. fine, medium and coarse sand) and its effect when excavation process done within pipe pile through experimental model study. The sand was used as a natural soil in this study, poorly graded clean sand and most particles were rounded. The sandy soil was sieved to obtain different grain size distribution of fine, medium and coarse graded according to (ASTM D 422). Total number of (166) models of steel pipe piles test, involving four open-ended steel pipe piles models of 32 mm in diameter embedded to a depth of 500mm within different grain size distribution cohesionless soils prepared with a different relative densities of (35, 50 and 70)%, under various head of water of (20, 30 and 40) cm above soil surface. It was found that the water head increase the ultimate load capacity of piles but when excavate inside the pipe pile, piping phenomena will occur when reaching to a certain length of soil inside the pipe pile. Generally this phenomenon affected by many parameters such as soil density, water head and grain size distribution. The results appeared that the ratio of inside soil column length to the embedded pile length which cause that phenomena in fine sand about (9 – 27)%, while in medium sand piping occurs with percent about (6 – 24)% and for coarse sand the percent about (14 – 26)%.

Keywords: Open pipe pile, piping phenomena in pipe piles, cohesionless soils, grain size distribution

1. Introduction

Piping is often described using the term backward erosion. This is because piping is the erosion of soil particles at some seepage exit location due to forces imposed by water transport through a porous media. This process results in channels or pipes that progress in an upward gradient back towards the water source.

The phenomenon of piping or tunneling in the soil has been known for some years, particularly to engineers [Terzaghi, 1936]; yet piping has been generally overlooked by hydrologists. Engineers have been mainly concerned with piping failure in earth dams, and a considerable amount of research has been done on this aspect.

Many studies specialized with piping phenomena as Schmertmann (2000) developed a method which is depended on backward piping tests at University of Florida. Schmetmann’s results indicated a correlation between the gradients which initiated piping erosion, and the uniformity of the sand gradation measured using the coefficient of uniformity Cu and found that critical hydraulic gradient increase with increasing the coefficient of uniformity Cu. Tomlinson S.S and Vaid Y.P (2000) found that the confining pressure and the magnitude and rate of gradient increase may influence initiation of piping. Indraratna and Sujeewa (2002), investigate that the critical hydraulic gradient decreases with increasing the pore diameter in sandy soil. Jacobson (2013) made a relationship between critical gradient with the shearing angle and dry unit weight that explain the critical hydraulic gradient for most soils increase with increasing the angle of failure shear, so it increase with increasing dry unit weight. Chang and Zhang (2013), recently investigated the effects of stress state on critical hydraulic gradients at which suffusion occurs in gap-graded soils. Suffusion is the erosion of finer particles from a matrix of coarser particles as a result of seepage flow.

They performed tests under drained triaxial conditions, isotropic and triaxial extension conditions. They determined that the initiation of a critical hydraulic gradient is determined by the pore structure of the soil. Specifically as the stress ratio increases, porosity in the soil decreases. Therefore the gradient at which failure occurred was a function of the initial stress state of the soil, the applied seepage forces, and the shear strength of the soil with triaxial extension stress resulting in higher gradients for the initiation of piping.
2. Experimental work and tables

The grain size distribution of the sand used illustrated in figure (2.1), physical soil properties are shown in table (2.1). The pipe pile model used of 3.2 cm diameter having embedded length within cohesionless soil of different relative densities of (35,50 and 70) % and head of water above soil surface is (20, 30 and 40) cm.

The model steel container have dimensions of (60*60*1150) cm the container and set up of model tests with steel frame and load cell of testing explained as shown in plate (2.1) and it manufactured as Yu and Yang (2012) recommendation, the axial load testing for piles is according to ASTM D 1143 - 07. The ultimate bearing capacity of pipe piles model tests are shown in table 2.2.
3. Results

The effect of grain size distribution can be represented with respect to coefficient of uniformity on critical hydraulic gradient as shown in figure (3.1). The figure shows that coefficient of uniformity increases with increasing hydraulic.

![Fig 3.1: Effect of coefficient of uniformity on critical hydraulic gradient](image)

Figures (3.2) to figure (3.4) show critical length of soil column within the pipe piles caused piping phenomena and the behavior of pipe pile during piping phenomena.

![Fig 3.2: Critical length of soil column within the pipe pile cause the piping from model test in fine sand](image)

![Fig 3.3: Critical length of soil column within the pipe pile cause the piping from model test in medium sand](image)

![Fig 3.4: Critical length of soil column within the pipe pile cause the piping from model test in coarse sand](image)

Where:

Le : Embedded length of pile
hw : Head of water above soil level
Lc : Critical inside length where piping occur

Conclusions

The following conclusion can be drawn from the model tests:

1) The relationship between critical hydraulic gradient which is direct parameter select the occurring of piping phenomena and coefficient of uniformity (Cu) is positive relationship; it is increase steadily when coefficient of uniformity increase.

2) The Piping phenomena depended on grain size distribution where the medium sand had highest critical hydraulic gradient, it fail with minimum inside length of soil plug, while coarse sand has lowest value of critical hydraulic gradient and fine sand between of them.

3) Length of the soil column within the pipe pile used to resist the piping phenomena depends on the water head level outside the pipe pile.

4) The results appeared that the ratio of inside soil column length to the embedded pile length which cause that phenomena in fine sand about (9 – 27) %, while in medium sand piping occurs with percent about (6 – 24)% and for coarse sand the percent about (14 – 26)%.

References


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