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Laboratory Investigation of the Effects of Sheet Pile on Seepage Control and Sand Boiling through Alluvial Foundation of Hydraulic Structures

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ABSTRACT

The sheet piles are used below hydraulic structures to reduce seepage flow rate and hydraulic gradient at the outlet of such structures rested on permeable foundations. So far, for analysis of seepage flow under hydraulic structures much research work has been carried out in the form of numerical and analytical models. Nevertheless, less field and experimental works have been done to investigate boiling phenomena for evaluating of the numerical models. In the present research, a laboratory apparatus was built to simulate seepage and its controlling measures under sheet piles. The model consist of a flume 2.2 m long, 0.8 m deep and 0.4 m wide, in which vertical sheet pile were provided by Perspex sheets. The flume was made of steel frame and Perspex as well as thick glass sheets. The foundation material was made of clean, fine sand, compacted to a uniform density and covered the bottom 40 cm of flume. Perspex sheets were employed sheet pile variable depth. The piezometric heads at both downstream and upstream side of sheet pile were measured using small diameter clear plastic tubes. The effect of position and depth of the sheet pile on the seepage flow and exit gradient have been demonstrated in form of dimensionless curves. The results show that the depth of the sheet piles d/D=0.46 with the maximum upstream water level h/h_m=1.0 boiling phenomenon does not occur and the seepage rate and hydraulic gradient in the area are favorable.

KEYWORDS:

Sand Boiling Phenomena, Seepage, Sheet Pile, Laboratory Model, Exit Gradiant

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1- Brief Introduction

Investigation the behavior of saturated sandy soils has always been of interest to many researchers working in different areas of civil engineering.

The first studies about optimizing the seepage flow from soil dams have been done by Tarzaghi (1946). He presented his results by analyzing the seepage from body and soil dam foundations according to permeability coefficient of the materials. The result was that the less is the core permeability than foundation and shell, the more would decline the seepage. Considering the depths of sheet pile located in foundation dam, he analyzed the seepage from shell and foundation as well. His analysis was done based on flow network method illustrated for each condition [2]. During past decades many researchers have reviewed seepage issues analytically and numerically. In most researches the accuracy of numerical results with experimental data was evaluated by Sedghi Asl et al., (2010, 2012) [1-4].

Boiling causes when a small prism of soil at drilled surface doesn't have enough resistance to neutralize the uplift pressure. Terzaghi (1943) defined the critical hydraulic gradient (i_c) to control the boiling [1].

Sedghi-Asl et al. (2005) reviewed the effect of optimal position of sheet pile on seepage discharge and flow velocity decrease under hydraulic structures by using a numerical model and concluded that the best location for controlling the seepage and boiling phenomenon is at heel and toe of the dam [5].

Urban development makes it necessary to built constructions with high depth which may be used in constructing parking and urban transportation. Deep digging design is often followed by water flow around the sheet pile (Benmebarek et al., 2005).

Sedghi-Asl et al. (2012) studied the effective factors on seepage from costal foundation dikes. They built an experimental model that was 9 m long, the width and height of 1 m, with steel skeleton, glass and plexiglas walls and chosed coastal clean sand as foundation materials. Their results showed that the ratio of blanket optimal length and sheet pile depth to upstream water depth and foundation thickness in order to minimize the seepage and control the internal erosion, are 8 and 0.8, respectively [3].

Many researchers have already done studies on the seepage, weather from inside the body or from dam foundation. The previous studies have been mainly based on the mathematical and numerical analysis of seepage issues. Since the comparison between results of numerical models and field or experimental have not performed yet, therefore; the numerical results would be uncertain and it is not reasonable to solely rely on the numerical data.

2- Methodology

Laboratory experiments were conducted in a flume 2.2 m long, 0.40 m wide and 0.80 m deep with sidewalls made of a combination of Plexiglas and steel sheets. As mentioned before, non-cohesive fine clean sand exemplifying a material extremely sensitive to piping and boiling was used to establish the most potentially critical situation subject to erosion. The bottom of the flume was filled with this material to a depth of 40 cm. Fig. (1) shows the general view of the laboratory model and the schematic view is presented by Fig. (2). The flume consists of the following components: A water supply system, joints and connectors, sheet pile element, a tank for regulating upstream and downstream water surface levels, piezometer tubes, data registering panel and discharge measuring device. Totally, 24 piezometer tubes in 3 rows and at depths of 10, 20 and 30 cm from the bed of the flume were installed to measure piezometric pressure downstream and upstream sides of the sheet pile. Also, volumetric method was used to measure the flow discharge. For easy readings of the pressures, the piezometers were installed on a scaled piezometric board as shown in Fig. (1). In order to prevent the material from washing away from the outlet, a 150# wire mesh was provided at the end of the flume. The sheet pile depths were adjusted at various depths of 10, 15, 16, 17.5, 18, 20 and 30 cm from the bottom of the flume. Before conducting any experiment, it was necessary to fully saturate the foundation material. A vacuum pump was used to drain any air bubble inside the piezometer tubes. The measurements were initiated after steady state seepage was established and in total 24 hours time was spent for each experiment (reading piezometers and measuring the seepage discharge).

Upstream water level was set at the 7 levels 5, 10, 15, 20, 25, 30 and 35 cm from the surface of the foundation while downstream water level was set at zero level. The form Fig. (3) applied to coastal sandy grading curve shows follow laboratory.

3- Conclusions

Boiling is highly destructive phenomenon for hydraulic structures rested on alluvial foundations.

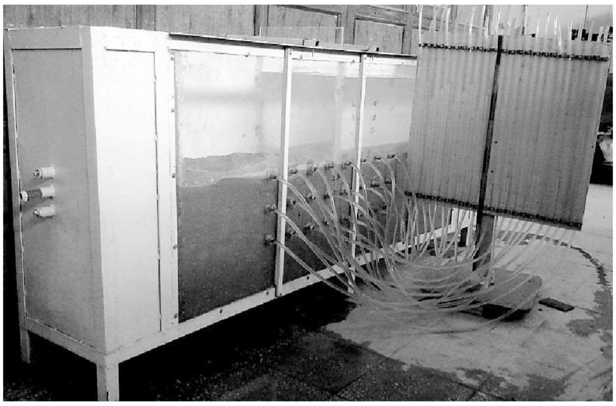

Fig. 1. General view of the laboratory model

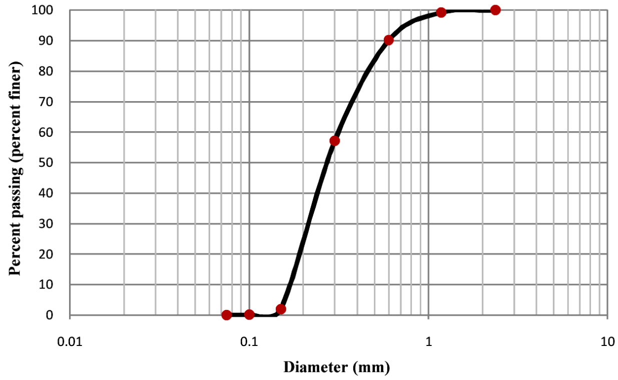

Fig. 3. Grading curves of sandy beach, following the model used in the laboratory

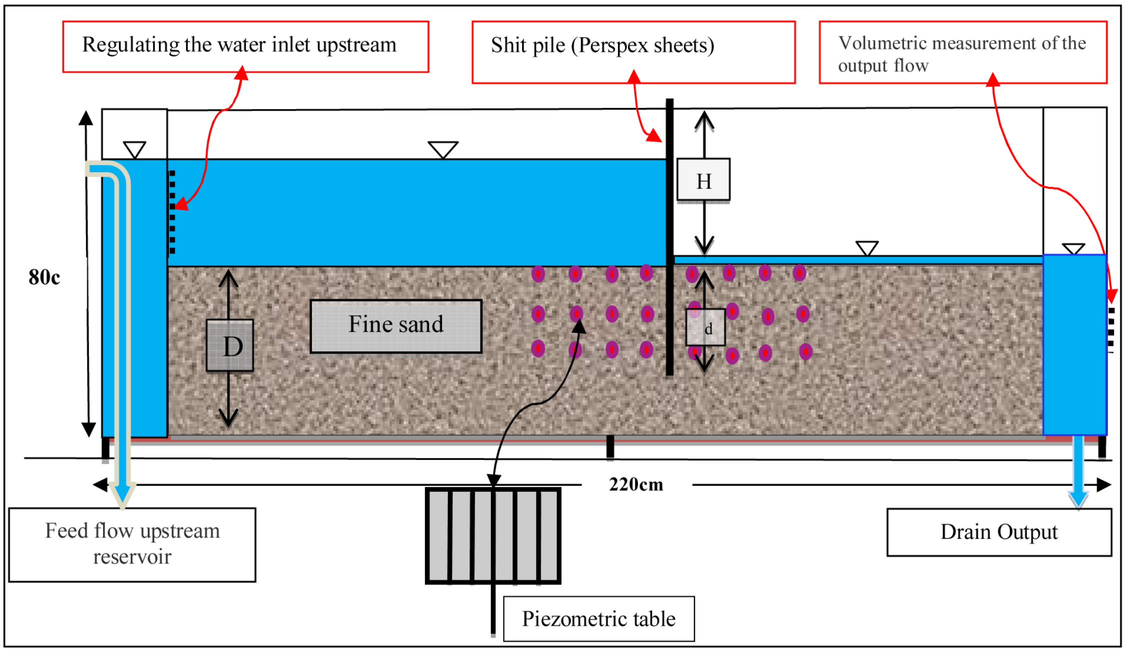

Fig. 2. Schematic design of the laboratory

Based on the experimental observations, it can be concluded the following remarks:

• The analysis indicates that the sheet pile dept ratio d/D=0.46 is the optimum value to effectively reduce the boiling phenomenon under hydraulic structures.

• Selection of a proper depth for sheet pile depends on the technical and economical factors and may not always be feasible to employ the deepest one.

The results presented in this study for coastal structures, diversion dams, and embankments rested on alluvial foundations are applicable to safely remove the boiling phenomenon.

4- References

[1] Terzaghi, K.; "Theoretical Soil Mechanics," New York: *Wiley*. 1943.

[2] Rahimi, H.; "Embankment Dams," *University of Tehran Press*, Tehran, Iran, 2003 (in Farsi).

[3] Sedghi-Asl, M.; Rahimi, H. and Khaleghi, H.; "Laboratory Investigation of the Seepage Control Measures under Coastal Dikes," *Experimental Techniques*, Vol. 36, No. 1, pp. 61–71, 2012.

[4] Sedghi-Asl, M.; Rahimi, H. and Khaleghi, H.; "Experimental Analysis of Seepage Flow under Coastal Dikes," *Experimental Techniques*, Vol. 34, No. 4, pp 49–54, 2010.

[5] Sedghi Asl, M.; Rahimi, H. and Khaleghi, H.; "Optimal Positioning of Vertical Sheet pile to Reduce Seepage and Flow Under Hydraulic Structures using Numerical Model," *5th Iranian Hydraulic Conference*, Kerman University, Kerman, Iran, 2005 (in Farsi).