Piping Resistance of Sand Filters

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1. Introduction

Piping phenomena can occur at a soil filter used in an embankment dam; a case study from Ochoco Dam (Park, Youngjin, 2003) has shown this piping problem. Thus, it is important to determine the piping resistance of soils used for filters, especially when subjected to the high hydraulic gradients.

The objective of this study is to investigate the effect of gradation and the compaction efforts on the piping resistance characteristic of sand filters.

2. Design of filter gradation

The gradation of soil filter must fulfill two main conditions (Das, 1983): (1) The size of the voids in the filter material should be small enough to hold the larger particles of the protected material (*base soil*) in place; (2) The filter material should have a high permeability to prevent buildup of large seepage forces and hydrostatic pressures in the filters. The assessment of eligible soil gradation as filter material has been proposed, such as by Terzaghi and Bertram (1940), US Army Corps of Engineers (1955), and USBR (1994).

3. Sample and Test Procedure

Based on USCS method, base soil material was MH soil (Liquid Limit = 63.23%, Plasticity Index = 19.62%). The sand filter material was river sand, which modeled as well-graded ($Cu = 6.42$, $Cc = 1.27$), uniformly graded ($Cu = 3.05$, $Cc = 0.99$) and gap-graded ($Cu = 5.47$, $Cc = 0.55$). The Modified, Standard and Reduced Proctor compactive efforts were taken to investigate the effect of gradation and density on the piping resistance of sand filters. Reduced Proctor (US Army Corps of Engineers, 1970) was similar as Standard Proctor, only it has 15 number of blows at each layer and represent a poor condition of compaction in the field. Finally, the permeability test proposed by Furumoto et al (2002) was conducted to investigate the piping resistance of the sand filter materials.

4. Results and Discussions

The determination of filter gradation as proposed by USBR (1994) based on the base soil is shown in Figure 1. The modeling filter gradations: well graded filter (Filter A), uniformly-graded filter (Filter B) and gap-graded filter (Filter C) are also plotted in this figure, and all of these filters were satisfied to USBR gradation criteria.

The characteristic of piping resistance followed the permeability test proposed by Furumoto et al (2002) on well-graded filter (Filter A), uniformly-graded filter (Filter B), and gap-graded filter (Filter C) are shown in Figure 2, Figure 3 and Figure 4, respectively. It is seen that the density characteristic affect the piping resistance of the filter; filter material compacted with higher compactive effort (Modified Proctor) has higher resistance to piping. The critical hydraulic gradient (the hydraulic gradient which almost reach piping condition) for the densest material are higher than the sample with less compaction. Also, gradation affect the piping resistance of the filter material; well-graded filter (Filter A) has higher resistance to piping.

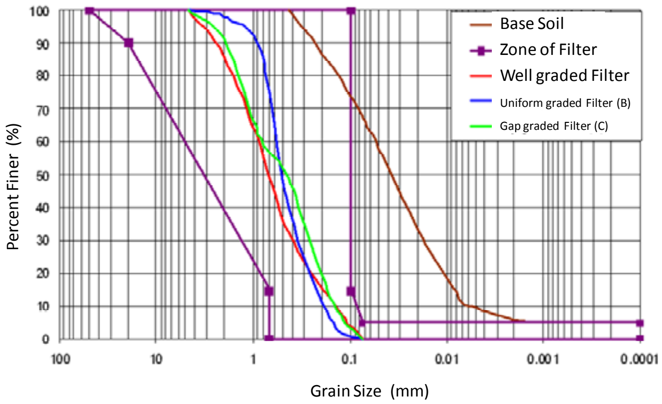

Figure 1 Zone of filter gradation based on USBR criteria.

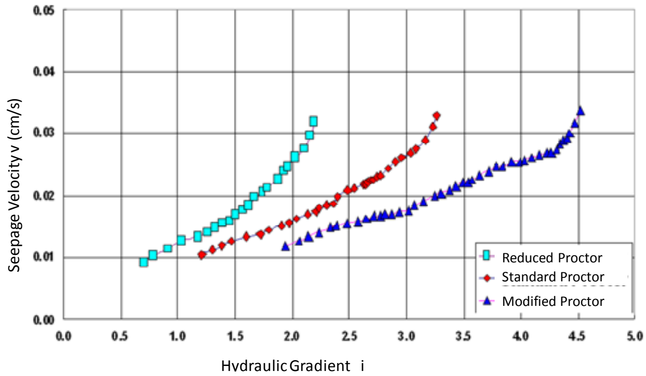

Figure 2 Piping resistance of Filter A.

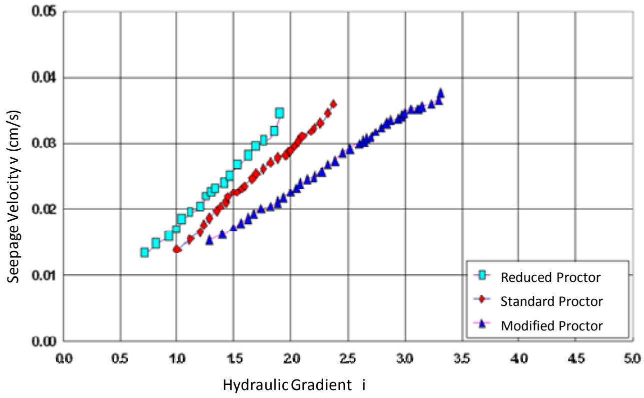

Figure 3 Piping resistance of Filter B.

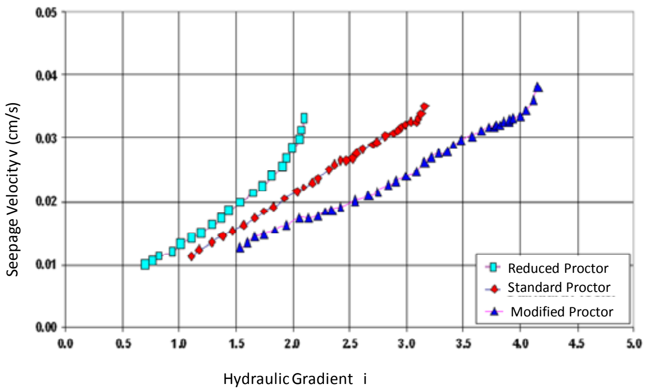

Figure 4 Piping resistance of Filter C.

The increasing hydraulic gradient for all of these filters are shown in Figure 5. From the figure, filters compacted with Modified compaction efforts shows a higher hydraulic gradient and longer time to reach piping condition; so, this means a better resistance to piping.

5. Conclusions

From the results of this study, the main conclusions are summarized as follows:

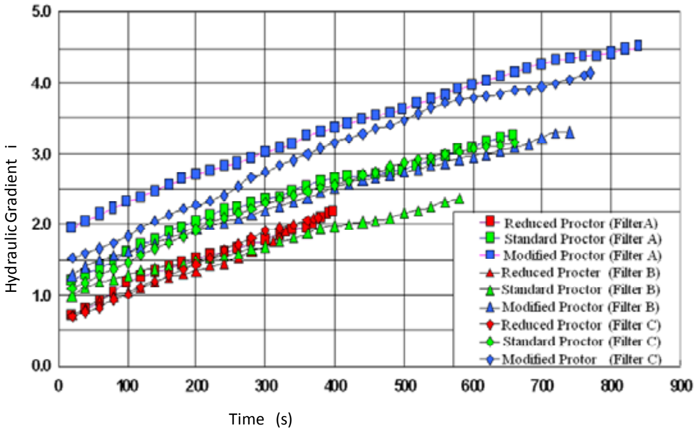

Figure 5 Increasing gradient hydraulics of filters.

1. Density characteristic affects the piping resistance of the filter; filter material compacted with higher compaction effort has higher resistance to piping.
2. Gradation affect the piping resistance of the filter material; well-graded filter has higher resistance to piping.

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