Chapter 7. Sand Castle Tests[3]

7.1. Background

To prevent continuous erosion through cracks, filter materials must satisfy two conditions. The first is that the gradation of the filter material falls within the proper gradation limits, detailed in previous chapters. The second is that the filter material must be capable of collapsing and filling a crack, should one develop. Vaughan and Soares (1982) noted that including fines in a filter to enable it to retain small clay particles may give it cohesion, thereby reducing its ability to collapse and fill cracks. They suggested a simple test to examine the ability of filter material & collapse using a compaction mold or a small bucket, like a child's toy used to build sand castle. The test is performed by placing a sample (the "sand castle") a shallow tray and the tray is flooded with water. A cohesionless material will collapse immediately, showing its ability to collapse and fill cracks. A sample with cohesion will not collapse, or will collapse only after a long period of time, indicating that it would not be suitable for use as a filter.

7.2. Description of device and test procedure

A sand castle test is performed by placing a compacted soil sample in water and observing it for some time. In the tests described in this chapter, the behavior of the samples was recorded using a digital camera. Figure 7.1 shows the test apparatus developed for the Sand Castle Tests described here. A plastic sheet was first inserted into a 261 ml plastic cup. The plastic sheet prevents the soil from adhering to the cup. The soil sample was then compacted in the cup using a hand compactor. The compacted sample was inverted over a wire mesh, and was lowered into a one gallon glass container filled with distilled water using the steel rod with hooks

[3] Sand Castle Test (SCT): The name of test was coined by Vaughan and Soares (1982)

at their ends. The condition of the sample was recorded using a digital camera, and a recording of the test was saved as a movie file. After the test, pictures at elapsed times of 0, 1, 2, 4, 8, 16, 32, and 64 minutes were extracted from the movie file for presentation.

Figure 7.1 Devices for Sand Castle Test

Figure 7.2 shows the assembled apparatus ready for a sand castle test. White panels were placed behind the reservoir and in front of the camera to prevent glare during filming. The steel rod hooks were removed after the sample was placed under water. Time was measured by filming a digital clock. A description of the sample (test number, water content, fines content, types of fines, and sample weight) was posted on a card visible in the movie frame as shown in Figure 7.3.

Figure 7.2 Test configuration for Sand Castle Test

Figure 7.3 Front view of test setup

7.3. Test material

Sand castle tests were performed on the Horsetooth Dam filter material used in this research. The fine fraction of this material was separated from the coarse fraction by sieving through a #200 sieve. Samples were prepared for testing by mixing the coarse fraction of the Horsetooth Dam filter material with various percentages of highly plastic fines (HPF) or non-plastic fines (NPF). In this research, the plastic fines contents were 5%, 10% and 15%, and water contents were 5%, 7%, 10%, and 13%. All samples were stored for 24 hours in a plastic bag prior to testing. For highly plastic fines, CH material was used. The Liquid Limit was 72, the Plastic Limit was 32, resulting in a Plasticity Index of 40.

For tests with non-plastic fines, the original fines from the Horsetooth Dam filter material were remixed with the coarse fraction. This fine material cannot be rolled into a 1/8 inch thread at any water content; therefore it is classified as "non-plastic" by ASTM D2487. These non-plastic fines were combined with the coarse fraction to form test specimens having 15% fines.

Tests on samples containing highly plastic fines were conducted for various combinations of water and fines contents. Some samples containing non-plastic fines could not be tested because they slumped immediately after the samples were taken from mold, before immersion in water.

7.4. Test Results

As mentioned in the previous section, the Horsetooth Dam filter material was mixed to 5%, 10%, and 15% of HPF. For each fines content, water contents of 5%, 7%, 10%, and 13% were tested. Table 7.1 shows the results of tests at these four water contents with 5% HPF. The only test specimen which did not collapse completely in one minute or less was compacted at 13% water content.

Test results for the test specimens containing 10% HPF are shown in Table 7.2. The specimens formed at 5% and 7% water contents collapsed within 16 minutes. Test specimens compacted at higher water contents did not collapse in 64 minutes. This indicates that compaction water content is an important factor governing collapse behavior. This finding is substantiated by the results shown in Figure 7.4 and Figure 7.5.

Table 7.1 Sand Castle Test with 5% highly plastic fine

Time (min)	5% HPF, w=5%	5% HPF, w=7%	5% HPF, w=10%	5%HPF, w=13%
0				
1				
2	Complete collapse in 1 minute	Complete collapse in 1 minute	Complete collapse in 1 minute	
4				
8				
16				Complete collapse in 8 minute
32				
64				

Table 7.2 Sand Castle Test with 10% highly plastic fine

Time (min)	10% HPF, w=5%	10% HPF, w=7%	10% HPF, w=10%	10%HPF, w=13%
0				
1				
2	Complete collapse in 1 minute			
4				
8				
16				
32		Complete collapse in 16 minute		
64			Minor slumping after 64 minutes	Minor slumping after 64 minutes

Table 7.3 Sand Castle Test with 15% highly plastic fine

Time (min)	15% HPF, w=5%	15% HPF, w=7%	15% HPF, w=10%	15%HPF, w=13%
0				
1				
2	Complete collapse in 1 minute			
4				
8				
16		Complete collapse in 8 minute		
32				
64			Minor slumping after 64 minutes	Minor slumping after 64 minutes

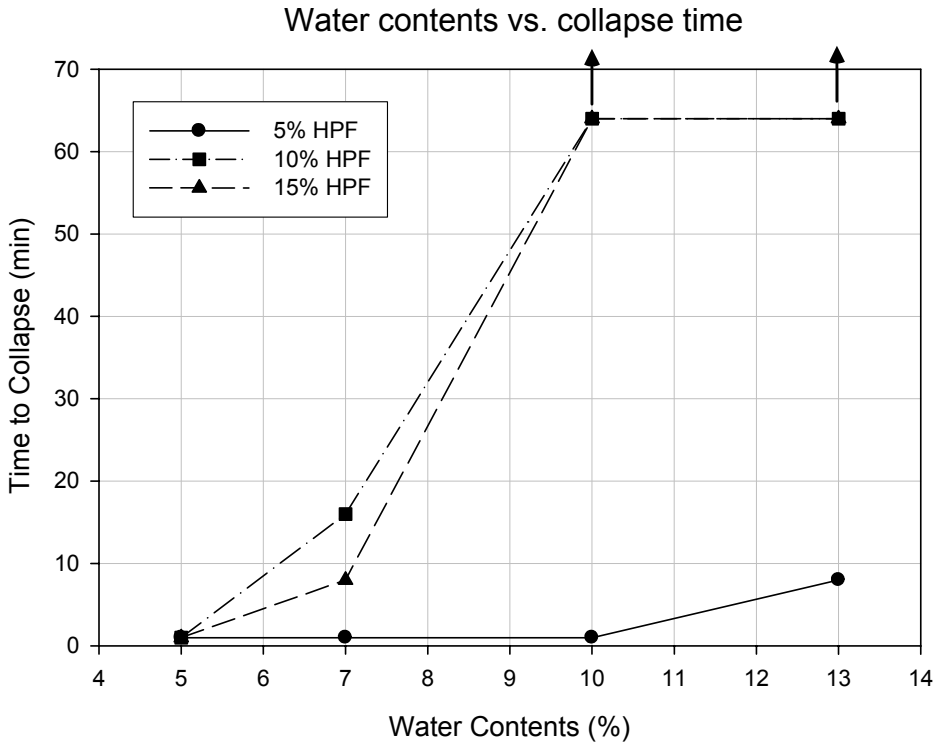

Figure 7.4 Water Contents vs. Time to Collapse from SCT

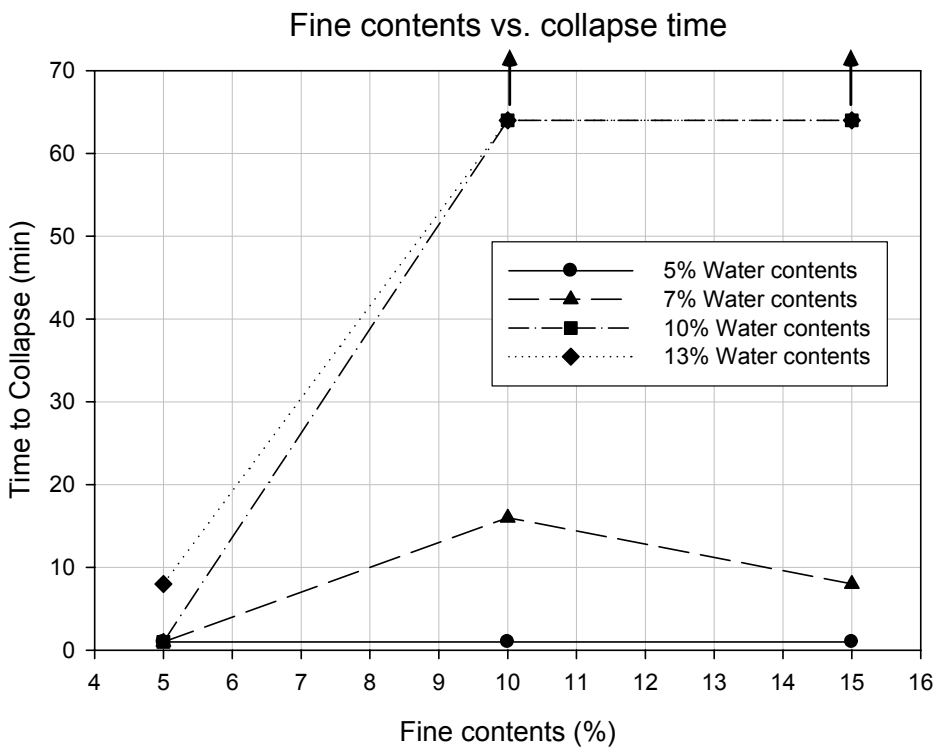

Figure 7.5 Fines Content vs. Time to Collapse from SCT

If a sample collapsed within one minute or less, it was described as "Collapsed Immediately." If sample collapsed after 1 to 64 minutes, it was described as "Collapsed in Time." If collapse did not occur within 64 minutes, "Did not collapse" was used to describe the result. Table 7.4 shows the results categorized in these terms.

All samples with non-plastic fines collapsed in less than one minute, even for 15% fines contents. Figure 7.6 shows the beginning of test 28. The sample has 15% NPF and 10% water content, as indicated by the test label. When the bottom of the sample touched the water, the clock indicated 3:53:26.

Figure 7.7 shows the test specimen 14 seconds later. The specimen immediately collapsed even before the sample base reached the bottom of tank. After 45 seconds, the sample was completely collapsed in Figure 7.8.

Since the test specimen with 15% NPF and 10% water content collapsed immediately, no more tests were performed on samples with non-plastic fines.

Table 7.4 Test results of HPF cases

		Water content (%)			
		5	7	10	13
Fine content (%)	5	Collapsed Immediately	Collapsed Immediately	Collapsed Immediately	Collapsed in Time
	10	Collapsed Immediately	Collapsed in Time	Did not collapse	Did not collapse
	15	Collapsed Immediately	Collapsed in Time	Did not collapse	Did not collapse

Figure 7.6 The beginning of Test 28 (w[4]=10%, fc[5]=15%, non-plastic fine)

Figure 7.7 Test 28 elapsed time of 14 seconds

[4] w: water content
[5] fc: fines content

Figure 7.8 Test 28 elapsed time of 45 seconds

7.5. Summary

The results of Sand Castle Tests are governed by:

- Plasticity of fines
- Fines content
- Compaction water content

Samples with non-plastic fines collapsed immediately, even when the fines content was as large as 15%. Some samples with highly plastic fines also collapsed immediately–samples with 5% HPF, and water contents less than 13% collapsed immediately.

All samples compacted at 5% water content also collapsed immediately, regardless of the percentage of highly plastic fines. Samples containing more than 5% highly plastic fines (which were compacted at water contents greater than 5%) did not collapse immediately.