Effects of Seawater on the Strength of Compacted Soils

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OBJECTIVE

To investigate the effect of seawater on the strength of compacted soils.

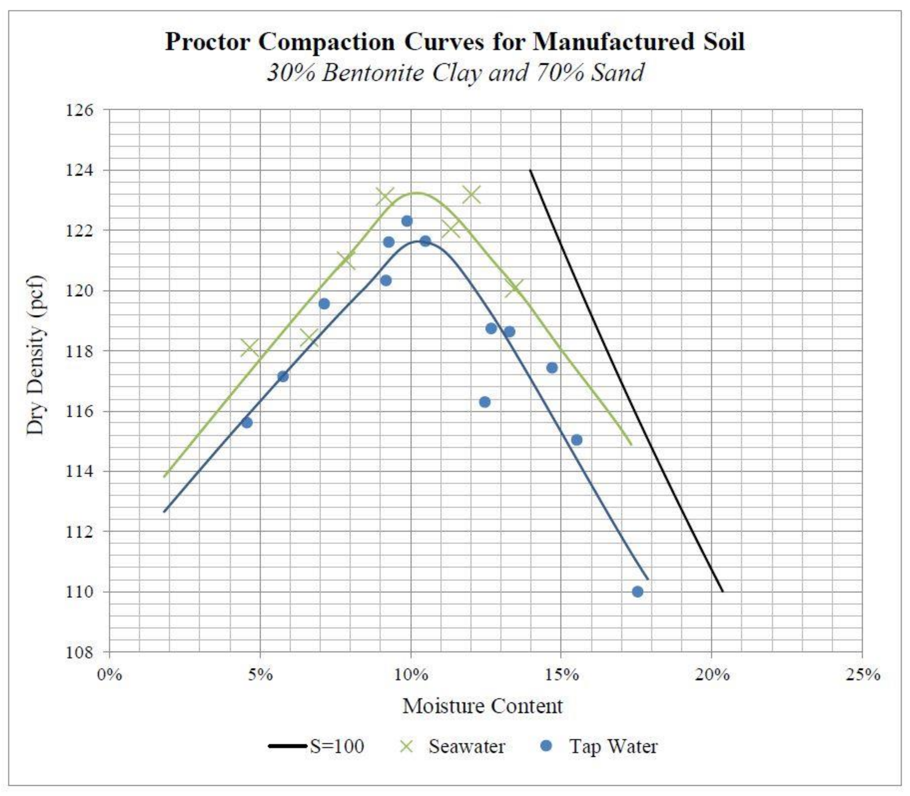
INTRODUCTION

The use of seawater for moisture conditioning during soil compaction instead of the use of freshwater could provide a cost effective alternative for many arid regions of the world where seawater supplies are abundant and freshwater supplies are limited. However, due to limited research on the behavior of soils that have been compacted with a seawater source, geotechnical engineers generally prohibit the use of seawater for moisture conditioning during compaction. The limited literature available on the behavior of soils compacted with seawater indicates that the use of seawater instead of freshwater for moisture conditioning during soil compaction results in a higher dry density and lower optimum moisture content. However, research regarding the effect of seawater on the strength of compacted soils is still lacking. This investigation aims to provide data on the unconfined compressive strength (q_u) of a manufactured soil sample which has been moisture conditioned with seawater prior to compaction. Control specimens that were moisture conditioned with tap water were also tested to provide a comparison. The manufactured soil consisted of 30% bentonite clay and 70% washed concrete sand based on dry masses.

TESTING PROCEDURE AND RESULTS

Preliminary Testing – Modified Proctor Compaction Test

The Modified Proctor Compaction Test, in accordance with ASTM D1557-09 Method A, was performed at various moisture contents on the manufactured soil sample moisture conditioned with both tap water and seawater in order to produce a Proctor Compaction Curve for both tap water and sea water samples. These two curves were used to select a target dry density for the unconfined compressive strength (UC) test specimens and are shown on the figure below. The target dry density for all UC test specimens was selected as slightly less than the maximum dry density of the tap water moisture conditioned sample. The optimum moisture content of the tap water sample was selected as one of the moisture content values at which to test the UC samples. The other two target moisture contents for the UC tests were ± 2.5% of this optimum moisture content.



Unconfined Compressive Strength Test

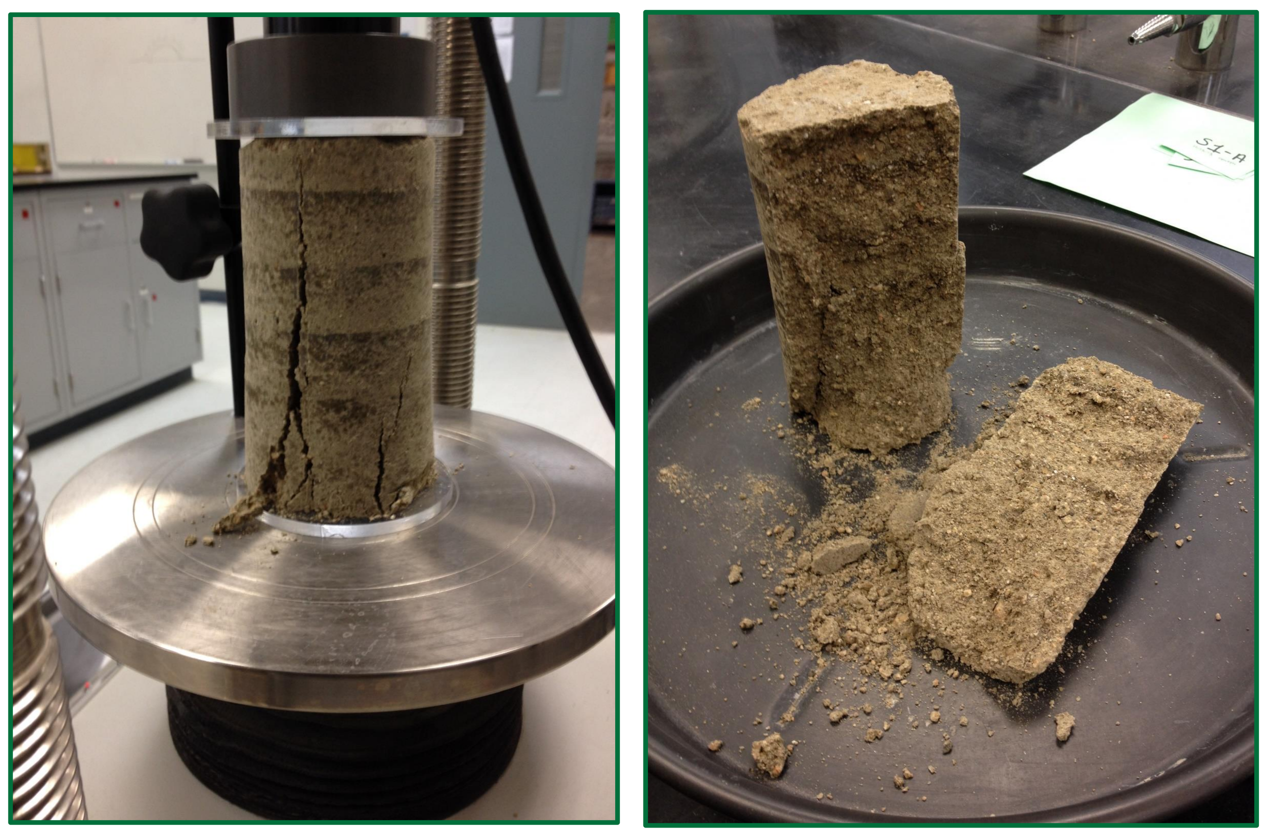
This investigation collected a total of six data points from the unconfined compressive strength (UC) tests, which were performed in accordance with ASTM D2166-06. The image to the right shows the equipment set-up for the UC tests. Six different samples were tested. Table 1 summarizes the target moisture contents, target dry densities, and type of water used for moisture conditioning of the six samples. Three specimens were prepared and tested for each sample to increase the accuracy of the data points. The parameters collected for each data point from the UC test include: unconfined compressive strength (q_u), strain at failure (%), moisture content (%), and dry density (lb/ft^3).

Image 1: UC Test Set-Up

Table 1: Summary of Variables for Six UC Test Data Points

Data Point	1	2	3	4	5	6
Sample Name	T1	T2	T3	S1	S2	S3
Target Dry Density (lb/ft^3)	121					
Target Moisture Content (%)	8.0	10.5	13.0	8.0	10.5	13.0

The unconfined compressive strength (q_u) is the compressive stress at which the unconfined cylindrical soil specimens failed; it is equal to the maximum load that was attained per unit area of the specimen. The cylindrical soil specimens tested in this investigation were on average 2.90" in diameter and 5.75" in height. This complies with the 2-2.5 height-to-diameter ratio range required by ASTM D2166-06. The UC test applied an axial load to the test specimens which was strain controlled at a rate of 0.5% ε/min. The testing software logged readings at intervals of approximately every 0.1% strain (ε). Table 2 shows the results obtained for all 18 test specimens as well as the average values which will be used to compare the six data points. The images below show the failure of test specimen S1-A.

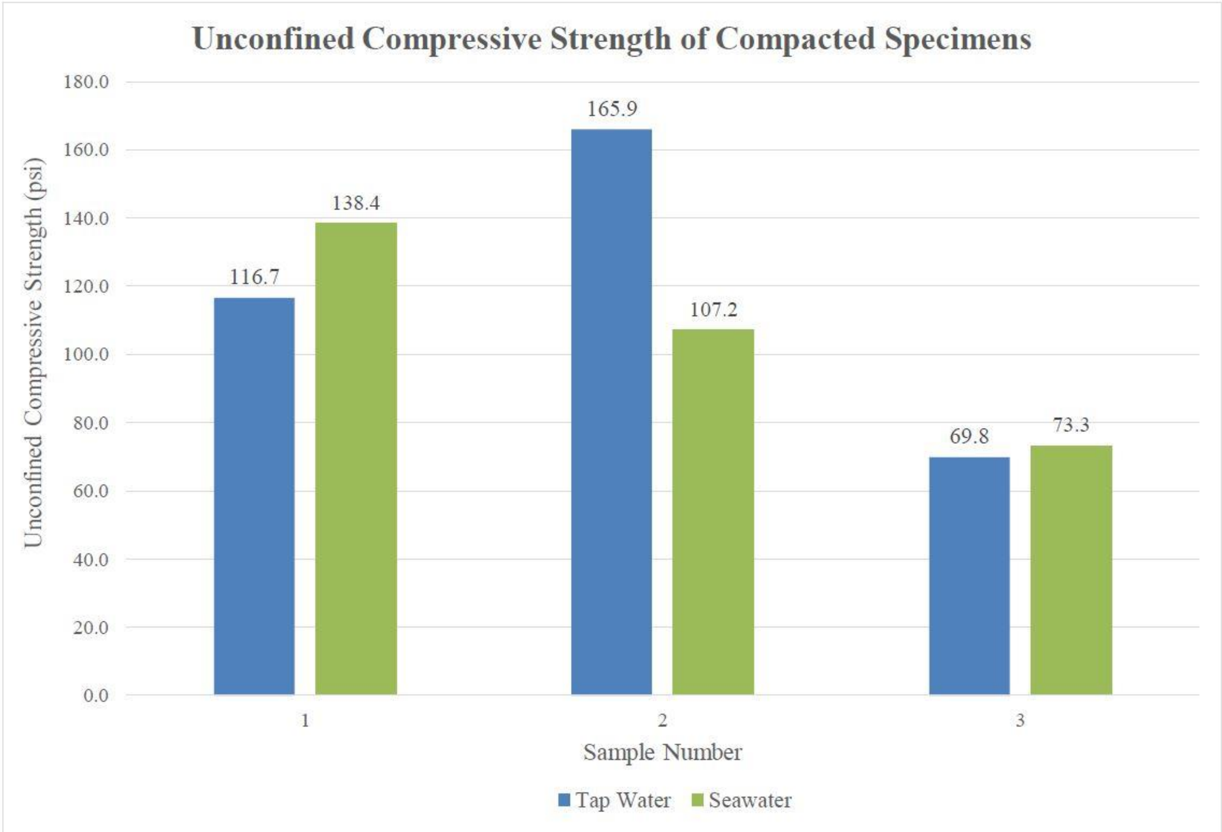


Images 2 & 3: Test Specimen S1-A during and after failure.

Table 2: Results of UC Test Specimens

Target Moisture Content (%)		Tap Water: Unconfined Compressive Strength (psi)	Tap Water: Strain at Failure (%)	Tap Water: Moisture Content (%)	Tap Water: Dry Density (lb/ft^3)	Seawater: Unconfined Compressive Strength (psi)	Seawater: Strain at Failure (%)	Seawater: Moisture Content (%)	Seawater: Dry Density (lb/ft^3)
8.0	Specimen A	119.1	1.7	7.8	117.8	130.1	2.3	8.1	117.9
	Specimen B	123.0	2.3	8.3	120.2	135.2	1.7	8.3	119.5
	Specimen C	108.0	2.0	8.5	116.9	149.8	1.5	8.2	119.4
	Average	**116.7**	**2.0**	**8.2**	**118.3**	**138.4**	**1.8**	**8.2**	**118.9**
10.5	Specimen A	154.9	2.5	10.5	119.6	110.4	1.9	10.1	120.8
	Specimen B	168.6	3.1	11.0	120.1	100.9	2.2	10.1	120.4
	Specimen C	174.2	2.5	10.3	120.4	110.1	1.8	10.1	120.0
	Average	**165.9**	**2.7**	**10.6**	**120.0**	**107.2**	**2.0**	**10.1**	**120.4**
13.0	Specimen A	65.2	3.9	12.9	119.7	77.8	4.2	12.5	120.3
	Specimen B	74.5	3.9	12.4	121.4	71.4	3.2	12.7	119.2
	Specimen C	69.7	4.2	12.6	120.9	70.7	2.8	12.7	117.3
	Average	**69.8**	**4.0**	**12.7**	**120.7**	**73.3**	**3.4**	**12.6**	**118.9**

The figure below shows a comparison of unconfined compressive strengths of compacted specimens that were moisture conditioned with tap and seawater at similar moisture contents and compacted to similar dry densities.



DISCUSSION AND CONCLUSIONS

Preliminary Testing - Proctor Compaction Test

The results of the proctor compaction tests performed as part of this investigation agree with the findings of previous literature on the effect of seawater in soil compaction on maximum dry density and optimum moisture content; however, the trend is not as significant as it has been for other studies. The seawater sample did yield a higher dry density than the water sample but by only 1.6 lb/ft^3. The optimum moisture content was also lower for the seawater sample compared to the tap water sample but by only 0.5%. These differences are small and could be considered insignificant. Thus, the results of these proctor compaction neither confirm nor contradict the common trend found from other studies that seawater in soil compaction results in a higher maximum dry density and lower optimum moisture content.

Unconfined Compressive Strength Test

The results for the tap water and seawater samples were compared at each of the three target moisture contents to evaluate the effect of seawater on the strength of compacted soils.

The target moisture content for data point 1 for both the tap water and seawater samples was 8.0% which is equal to 2.5% below the optimum moisture content of the tap water sample when compacted in accordance with ASTM D1557-09. The samples had a moisture content of 8.2% and average dry unit weight varied from 118.3-118.9 lb/ft^3. The seawater sample for this target moisture content case was slightly denser than the tap water sample. As summarized in figure 2, found on page 6, the tap water sample has an unconfined compressive strength of 116.7 psi whereas the seawater sample has an unconfined compressive strength of 138.4 psi. This target moisture content case suggests that the use of seawater yields a higher unconfined compressive strength; however, it should also be noted that the seawater sample was slightly denser than the tap water sample which could contribute to the higher unconfined compressive strength.

The target moisture content for data point 2 for both the tap water and seawater samples was 10.5% which is equal to the optimum moisture content of the tap water sample when compacted in accordance with ASTM D1557-09. The tap water and seawater samples had a moisture content of 10.6% and 10.1% respectively. Their average dry unit weight varied from 120.0-120.4 lb/ft^3. The seawater sample for this target moisture content case was slightly denser than the tap water sample. As summarized in figure 2, found on page 6, the tap water sample has an unconfined compressive strength of 165.9 psi and the seawater sample has an unconfined compressive strength of 107.2 psi. This target moisture content case suggests that the use of seawater does not yield a higher unconfined compressive strength. The difference in unconfined compressive strength for this target moisture content case is also much larger than the other 2 cases.

The target moisture content for data point 3 for both the tap water and seawater samples was 13.0% which is equal to 2.5% above the optimum moisture content of the tap water sample when compacted in accordance with ASTM D1557-09. The tap water and seawater samples had a moisture content of 12.7% and 12.6% respectively. The average dry unit weight varied from 118.9-120.7lb/ft^3. The seawater sample for this target moisture content case was much less dense than the tap water sample. As summarized in figure 2, found on page 6, the tap water sample has an unconfined compressive strength of 69.8 psi whereas the seawater sample has an unconfined compressive strength of 73.3 psi. This target moisture content case suggests that the use of seawater yields a slightly higher unconfined compressive strength; however, it should also be noted that the seawater sample was less dense than the tap water sample which could suggest that the difference is unconfined compressive strength is greater than this data depicts.

Overall, no conclusive statement can be asserted from the results of this investigation. In two out of the 3 cases, it appears that seawater does yield a higher unconfined compressive strength than tap water; however, the third case suggests that tap water yields a significantly larger unconfined compressive strength than the seawater sample. More data points are needed before a definite trend can be observed. Also, the testing procedure needs improvement to ensure greater accuracy for obtaining the target dry density. Lowering the target dry density to 119 or 120 lb/ft^3 could help minimize damage to the split mold and also increase accuracy of the test specimens' dry density values. Minimizing the difference in moisture content and dry density between the tap water and seawater sample, as well as between the 3 specimens for each sample, is important to increase the reliability of the comparison of unconfined compressive strength values obtained from the UC tests.

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