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Compressive strength characteristics of cement treated sand prepared by static compaction method

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Abstract. An experimental program was conducted to investigate the effects of the static compaction pressure, cement content, water/cement ratio, and curing time on unconfined compressive strength (UCS) of the cement treated sand. UCS were conducted on samples prepared with 4 different cement/sand ratios and were compacted under the lowest and highest static pressures (8 MPa and 40 MPa). Each sample was cured for 7 and 28 days to observe the impact of curing time on UCS of cement treated samples. Results of the study showed the unconfined compressive strength of sand increased as the cement content (5% to 10%) of the cement-sand mixture and compaction pressure (8 MPa to 40 MPa) increased. UCS of sand soil increased 30% to 800% when cement content was increased from 2.5% to 10%. Impact of compaction pressure on UCS decreased with a reduction in cement contents. On the other hand, it was observed that as the water content the cement-sand mixture increased, the unconfined compressive strength showed tendency to decrease regardless of compaction pressure and cement content. When the curing time was extended from 7 days to 28 days, the unconfined compressive strengths of almost all the samples increased approximately by 2 or 3 times.

Keywords: static compaction; sand; cement; curing period; unconfined compressive strength

1. Introduction

Soil stabilization is the process of blending and mixing additives into the locally available soils to improve their geotechnical engineering properties. The process may include the blending of soil or aggregate to achieve a desired gradation or the mixing the additives to alter the gradation, texture, or plasticity of the soil or to bind soils particles (Su *et al*. 2014, Nakaraia and Yoshidab 2015). Portland cement, lime, Class C fly ash are the most common additives used for such applications. Portland cement is the most widely used chemical additives among these three additives. Stiffness, strength, durability, fatigue, shrinkage and erodibility resistance of soils can be altered significantly with cement stabilization (Park 2010, Wen *et al*. 2010, Consoli *et al*. 2011a).

Cement reacts with water and bonds with soil particles to generate a stronger and stiffer layer through cementation and hydration. This process can significantly improve the strength, stiffness, and durability of the host material. According to the Portland Cement Association (PCA) guideline

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(1992), the 7-day UCS of soil-cement falls between 2.1 and 5.5 MPa with cement content 3% to 10%. Numerous studies have shown that cement-treated base functions as a superior load-spreading layer in the pavement system (Walker 1995, Prusinski and Bhattacharya 1999, Lim and Zollinger 2003). Cement-stabilized pavement bases have been commonly used in areas that lack quality aggregates sources and in areas subject to heavy loads (Mohammad *et al*. 2000).

The main reason of cement to be the most common chemical stabilizer is due to its easy availability and high strength as compared to the other chemical components (Consoli *et al*. 2009, 2011b, Guettala and Mezghiche 2011). The strength of cement stabilized soils is highly dependent on the soil type and water/cement ratios (W/C). Inclusion of excessive or insufficient amount of water in the soil-cement mixture would affect the compressive strength significantly. Use of higher water/cement ratio results in low strength value while lower water /cement ratio results in high strength value (Barzegari Kahnemouei 2013).

Das and Dass (1995) investigated the unconfined compressive strength (UCS) of the mixture of poorly graded sand with silica and Portland cement (Type 1). Sandy soil is mixed with cement by 4%, 6%, and 8% at optimum water contents and compacted with Standard compaction energy. All samples were cured for 14 days and then they were subjected to unconfined compressive strength (UCS) tests. Results of this study indicated that UCS of sand increased consistently with cement content. Furthermore, unit deformation values, at which the peak strength occurred, decreased as the cement content increased.

Walker (1995) studied the influence of soil characteristics and cement content on the strength, durability and shrinkage characteristics of stabilized soil blocks. In this study, river sand was combined with different clay content and then stabilized with various cement contents. Average saturated compressive strength decreased with a reduction in cement content and increasing plasticity index. Similar to saturated compressive strength, performance was improved by increased cement content and reduced clay content during wet-dry cycling. Prusinski and Bhattacharya (1999) investigated the stabilizing mechanisms of cement and its effect on engineering properties and durability of the stabilized clays. The research indicated that a small amount of cement content in clay reduced the plasticity and shrinkage properties and improved the compressive strength significantly.

In order to determine stress, deformation and strength characteristics of soil stabilized with cement, Schnaid *et al*. (2001) carried out unconfined compression and permeability tests. Soil was mixed with cement ratios of 1%, 3%, and 5% by weight. Samples were cured for 7 days after compacted at their corresponding optimum moisture contents. After curing samples were subjected to UCS tests and results showed that as the cement content increased, UCS of soil increased linearly.

Ismail *et al*. (2002) examined the effects of Portland cement on shear strength of the soils containing limestone and sand. Cement/Sand ratios used in the preparation of samples were 8% and 15%, and the samples were cured for 7 days. According to the test results, there was a strong correlation (R^2 = 0.96) between the cement ratio and UCS.

In a study conducted by Bahar *et al*. (2004) on performance of the clay soils with compacted cement treated sand, the samples were compacted by using static and dynamic compaction methods. In the preparation of the samples by dynamic compaction method, the rammer weight was 12.5 kg and its drop height was 820 mm. In the static compaction method, the mixture was compacted by applying static pressures of 2.1 MPa, 4.2 MPa, 6.3 MPa, and 7.3 MPa. The prepared samples were cured for 7, 4, 21, and 28 days. It was observed that UCS of the cement-sand mixtures prepared by using static compaction method increased with an increase in cement content.

On the other hand, UCS values of the samples prepared by using dynamic compaction method showed that UCS of samples did not experience any increase with an increase in Cement content beyond 6% by weight. These results indicated that the samples prepared using the static compaction method were more homogenous than the samples prepared using the dynamic compaction method.

In a study conducted by Consoli *et al.* (2007) on the parameters controlling strength of the sands with artificial cement, sandstone and Portland cement (Type III) with high early strength as binding material were used in the preparations of the samples. The samples were compacted at 3 layers by applying static compaction and cured for 7 days. The samples were prepared in two groups; (1) dry density was variable, and water content was constant; and (2) dry density was constant, and water content was variable. In the samples with constant water content, the cement ratios were: 1%, 2%, 3%, 5% and 7%, whereas, in the samples with variable water content the cement ratios were: 2%, 9% and 12%. The samples were subjected to unconfined compression test and triaxial tests. According to the test results, the addition of the cement even in small amounts increased the strength of the soil considerably. As the cement content increased, UCS increased almost linearly; as the water content increased, the strength values reached to a maximum value and then started to decrease.

The stress–strain response and volume change behaviour of sands in shear and interface shear is mainly controlled by friction mechanism. It is well known that for granular materials, increasing confining stress (in triaxial test or overburden stress) or normal stress (in direct shear test or interface shear condition) increases both number of particles in contact and particle-to-particle contact area. In a similar manner, compaction pressure should have similar impact on the contact area between sand-to-sand and cement-to-sand interface for cement-water-sand mixtures.

As mentioned previously; when the existing literature is reviewed within scope of geo-technology, the effect of cement content and curing time on UCS have been studied comprehensively examined. However, there is no detailed study on investigating the effect of compaction pressures on UCS of cement treated granular soils with static compaction test method.

In this study, the effects of compaction pressure, cement/sand (C/S) ratio, and water/cement (W/C) ratio on unconfined compressive strengths (UCS) of cement treated sand soils were investigated. Samples were compacted at different static pressures and cured for 7 days and 28 days before conducting UCS tests. The stress-strain behaviour, unconfined compression strength of samples under different compaction pressures were observed.

2. Materials and methods

The sand passing through the sieve U.S. No. 16 (1.18 mm) and left on the sieve U.S. No. 30 (0.595 mm) was used in the study. Particle size distribution curve of the sand is shown in Fig. 1. The specific gravity (ASTM D854 2015), coefficient of uniformity, and coefficient of curvature the sand was 2.71, 1.25, and 1.01, respectively. In the study, the pozzolanic cement (CEM IV/B (P) 32.5 R) was used as the binder. Pozzolanic cement was used as the cementing agent with a specific gravity of 2.88 (Ulker 2010). According to the standard of BS EN 197-1 (2011), pozzolanic cement is a hydraulic binder obtained as a result of grinding Portland cement clinker (45-64% by mass) and pozzolanic substance (36-55% by mass) with some amount of gypsum. Table 1 illustrates chemical composition of this substance (Ulker 2010).

Triaxial strength tests are commonly used to determine strength parameters of soils, but due to

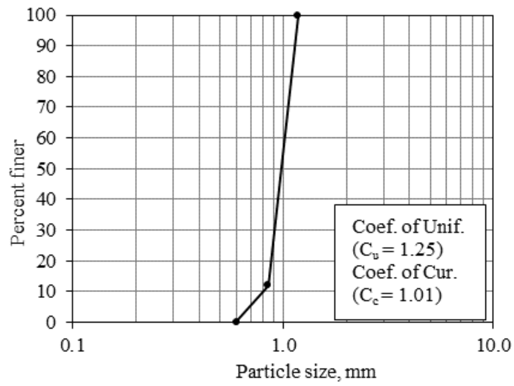


Fig. 1 Particle size distribution curve of the sand used in the study (modified from Barzegari Kahnemouei 2013)

Table 1 Quantities of the Oxides forming the pozzolanic cement (CEM IV / B (P) 32.5R) (Ulker 2010)

Oxide	Oxide quantitiy (%)
CaO	51.18
SiO_2	26.66
Al_2O_3	7.63
Fe_2O_3	3.43
MgO	1.81
Na_2O+K_2O	0.85
SO_3	1.83

yielding high strength values they are rarely used on cement-soil mixtures (Yilmaz and Ozaydin 2013). Unconfined compression test is the mostly used test to determine the strength characteristics of cement-soil mixtures.

In order to investigate the effect of cement ratio and compaction pressure on unconfined compressive strength (UCS), 4 different cement/sand (C/S) ratios (2.5%, 5.0%, 7.5% and 10.0%) and 6 different compaction pressures (4, 8, 16, 24, 32, and 40 MPa) were used, respectively. All mixtures were prepared at 3 different water/cement (W/C) ratios (1.0, 1.5, and 2.0). Totally 270 samples were prepared by compacting under different static pressures. All samples were cured for 7 and 28 days before being subjected to the unconfined compression test. Table 2 summarizes the cement-water-sand mixtures subjected to unconfined compression test.

Unconfined compression tests were performed on 192 samples in total. 3 replicates were prepared for each mixtures. Table 2 shows that among the samples prepared under the compaction pressure of 4 MPa are failed except the samples prepared with 10% C/S ratio and at 1 W/C ratio. All samples were cured for 7 and 28 days before being subjected to the unconfined compression tests.

Maximum and minimum dry densities of the sand and cement-sand mixtures were obtained by using the vibratory table with vertical vibration according to the standard of ASTM D4253 and ASTM D4254, respectively (Table 3).

Table 2 The details of the cement- water-sand mixture used in the study

Cement/Sand (C/S) (%)	Water/Cement (W/C) (%)	Axially applied static compression (MPa)											
		4		8		16		24		32		40	
		Curing period (day)											
		7	28	7	28	7	28	7	28	7	28	7	28
		Number of samples prepared for unconfined compression tests											
2.5	1.0	F*	F	F	F	This range was held outside of the experimental work						3	3
	1.5	F	F	F	F							3	3
	2.0	F	F	3	3							3	3
5.0	1.0	F	F	3	3							3	3
	1.5	F	F	3	3							3	3
	2.0	F	F	3	3							3	3
7.5	1.0	F	F	3	3							3	3
	1.5	F	F	3	3							3	3
	2.0	F	F	3	3							3	3
10.0	1.0	3	3	3	3	3	3	3	3	3	3	3	3
	1.5	F	F	3	3	3	3	3	3	3	3	3	3
	2.0	F	F	3	3	3	3	3	3	3	3	3	3

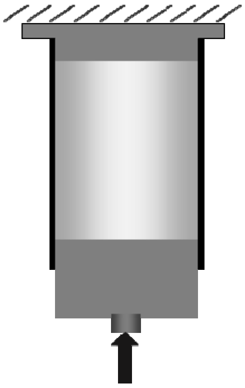
*F: Failed attempt (78 samples out of 270); non-cylindrical sample

Table 3 The maximum void ratio (or minimum dry density) and the minimum void ratio (or maximum dry density) of sand and cement-sand mixtures (Barzegari Kahnemouei 2013)

Cement/Sand (%)	Averege G_s	ρ_{maks} (Mg/m^3)	ρ_{min} (Mg/m^3)	e_{max}	e_{min}
0	2.710	1.540	1.316	1.058	0.759
2.5	2.713	1.619	1.336	1.030	0.676
5.0	2.718	1.650	1.390	0.954	0.647
7.5	2.722	1.687	1.400	0.944	0.613
10.0	2.726	1.757	1.409	0.936	0.551

The samples prepared for the unconfined compression test were obtained by compacting the cement-water-sand mixtures, filled into the compaction mold, in the axial direction. Compaction apparatus consisted of a cylindrical steel pipe, stopper, moveable piston and a hydraulic jack (Fig. 2). The moveable piston ensured compaction of the mixture by moving in the mold during compaction due to the applied load. Figs. 2(a) and (b) show schematically the details of the compaction mold. Diameter of the mold was 40 mm. Soil and soil-cement mixtures were placed into the compaction apparatus and compacted under the desired static axial compaction pressure (Fig. 2(c)).

Diameter/height ratio of the compacted samples were in the ranges of 2.0–2.20. After compaction samples were subjected to unconfined compressive strength (UCS) test. Each sample was kept for 1 minute under the applied corresponding static pressure during compaction. In order to take out the compacted samples from the mold without any damage, electrically operated



(a) 2-D Sketch of the compaction mold

(b) A sand-cement mixture under compaction

Fig. 2 Compaction mold and compaction apparatus (Barzegari Kahnemouei 2013)

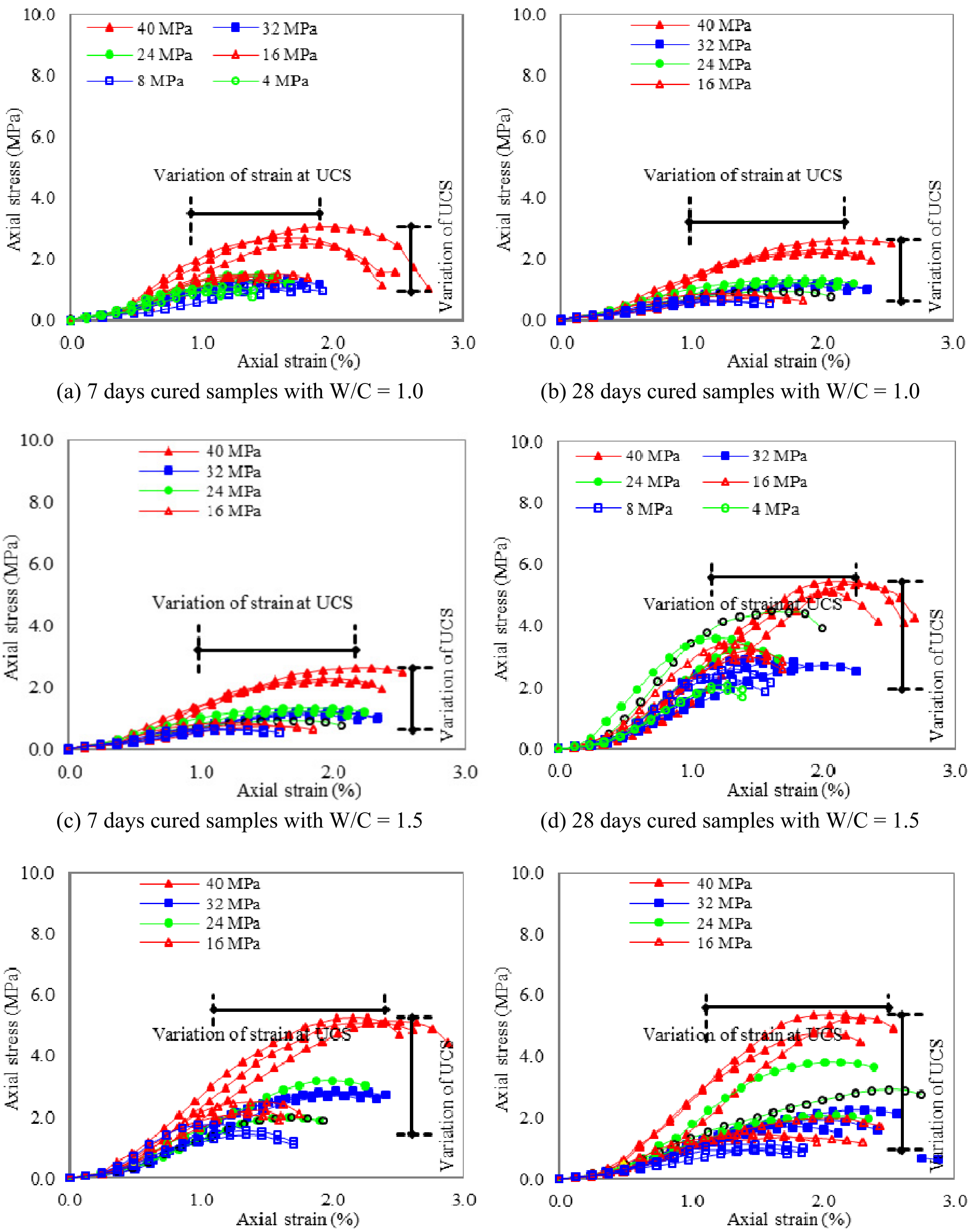
hydraulic jack was used. Compacted samples were transported in the curing room for 7 and 28 days at 24±2°C and 95±5% relative humidity.

3. Results

In order to investigate the effect of compaction pressure on unconfined compressive strength, only the sand-cement mixtures containing 10% cement by weight were used. The samples (C/S = 10%) were compacted at six different static pressures (4, 8, 16, 24, 32, and 40 MPa) and cured for 7 and 28 days and then they were subjected to unconfined compression tests. Two approaches were taken into consideration regarding choosing of the C/S ratio as 10%. The first one is the fact that cement is more homogenously distributed throughout the mixture at high cement ratios. Therefore, unconfined compression strengths to be obtained will show a more homogenous approach. As the C/S ratio decreases, the possibility of homogenous distribution of the cement throughout the mixture decreases. Small amounts of cement can accumulate: in the lower part of some samples, in the middle part of some samples, and in the upper part of some samples. According to the second approach: because it is known that UCS increases with increasing C/S ratio. UCS values of the samples, prepared under the similar conditions, (the same compaction pressure and the same W/C ratio) at lower C/S ratios can be estimated. Because UCS values of the mixtures with C/S = 10% will be higher than the UCS values of the samples with lower C/S ratio, it can be used as the threshold value. Here the test results of the samples subjected to unconfined compression test in two curing times will be examined by being grouped according to the curing time.

3.1 The effect of static compaction pressure on UCS

Fig. 3 shows axial unit deformation-axial stress curves of the samples with C/S = 10%, prepared under different static compaction pressures, in the unconfined compression test based on the curing time. According to the Fig. 3, deformation modules of all the samples were obtained almost at the same level from the beginning of the test to the 0.1% axial unit deformation level. It is thought that its cause is the failure of transferring the applied load to the sample homogenously because of the poor sand- cement interaction on lower and upper surfaces of the sample. Because



(a) 7 days cured samples with W/C = 1.0

(b) 28 days cured samples with W/C = 1.0

(c) 7 days cured samples with W/C = 1.5

(d) 28 days cured samples with W/C = 1.5

(e) 7 days cured samples with W/C = 2.0

(f) 28 days cured samples with W/C = 2.0

Fig. 3 Variation of axial stress-axial strain curves of the samples with C/S = 10.0%

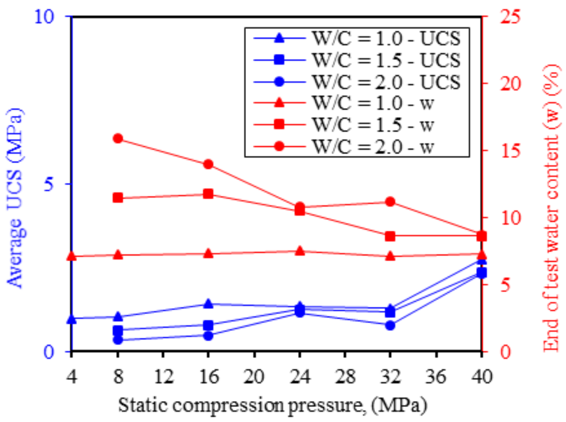
at the deformation levels higher than 0.1% the deformation modules showed significantly differences depending upon the cement content of the mixture and the compaction pressure (Fig. 3). Lower and upper bounds of UCS of the mixtures and their corresponding strain ranges at failure (UCS) were plotted in Fig. 3. It is observed that the stress-strain curves show no significant variations with respect to both W/C ratio and curing period (Fig. 3). Strain values at failure of the all samples are between 1% and 2.5% interval. On the other hand, UCS of the samples appear to be increasing wıth an increase in curing period.

Change of average UCS of the samples with the compaction pressure is shown in the left axis in Fig. 4. Change of average water contents of the samples at the end of the test with the compaction pressure is shown in the right axis in Fig. 4. Indication ranges of the left and right axes were arranged in consideration of readability (Interference of the average UCS curves and the average water content curves were avoided).

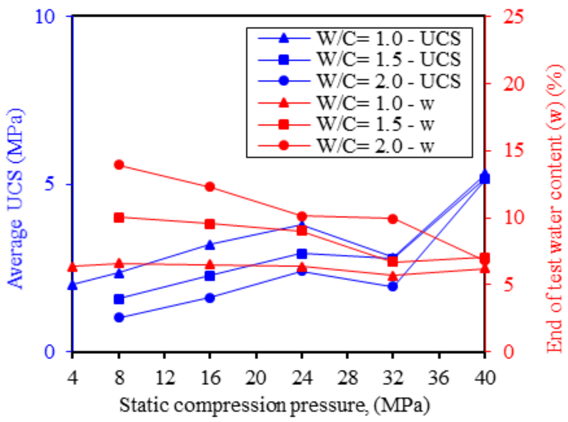
Average UCS values of the samples kept in the cure for 7 days showed a slow increase tendency when the compaction pressure was increased from 4 MPa to 32 MPa. On the other hand, when the compaction pressure was increased from 32 MPa to 40 MPa, the increase tendency of average UCS was higher (Fig. 4(a)). The effect of W/C ratio on the average UCS was observed less than 1.0 MPa for each compaction pressure level. As W/C ratio increased, average UCS showed a decrease tendency under all the compaction pressures (Fig. 4(a)).

In case of low compaction pressure, the effect of W/C ratio on average of final water content of samples was higher such as the samples prepared under the compaction pressures of 8 MPa and16 MPa. However, the effect of W/C ratio on average final water content of samples became insignificant under high compaction pressure.

When the change of the average water content with the increasing compaction pressure was examined on Fig. 4(a), it was observed that the increase in the compaction pressure did not affect the water contents of the samples with W/C ratio of 1.0. On the other hand, water contents of the samples prepared with W/C ratio of 1.5 and 2.0 decreased with increasing compaction pressure. Therefore, according to Fig. 5 it was thought that in the mixtures prepared with W/C = 1.5 and W/C = 2.0, the compaction pressure decreased the water content at the end of the test and the decreasing water content increased UCS.



(a) 7 days cured samples



(b) 28 days cured samples

Fig. 4 Variation of average UCS and end of test water content (average) with static compaction pressure

It was clearly seen that UCS - Static compaction pressure relations and water content at the end of test - static compaction pressure relations obtained for the mixtures kept in the cure for 28 days (Fig. 4(b)) and the relations obtained for the mixtures kept in the cure for 7 days (Fig. 4(a)) showed similar tendencies.

According to another important finding obtained from Figs. 4a and 4b; both of the water contents at the end of the test and the unconfined compressive strengths of the samples prepared under the high compaction pressure (40 MPa) and with high W/C ratios (W/C = 1.5 and 2.0) were obtained almost at the same level. Therefore, it can be asserted that the effect of W/C ratio on UCS decreased in the samples compacted under high compaction pressure. It is believed that increasing the static pressure level during compaction forces free water (water-cement suspension) to be squeezed out of sample which resulted all cement-water-sand mixtures to have similar final water content after tests regardless of W/C ratios.

When comparing average UCS values of the samples kept in the cure for 7 days with those of the samples kept in the cure for 28 days (UCS ratios in Figs. 4(a) and (b) based on the compaction pressure), it is seen that average UCS increase caused by the increase in curing time was about 1.9 – 3.4 times al all compaction pressures. When W/C ratio was taken as reference; with increasing curing time. UCS values in the samples with W/C ratios of 1.0, 1.5, and 2.0 increased as 2.8, 2.8, and 3.4 times respectively at most. Similarly, as the curing time increased, UCS values in the samples with W/C ratios of 1.0, 1.5, and 2.0 increased as 1.9, 2.1, and 2.1 times respectively at most. According these data, it was observed that as the W/C ratio increased, the increasing curing time and the increase in UCS were directly proportional.

Fig. 5 illustrates the change of relative density values of the samples with the C/S = 10% with compaction pressure. By using the sample sizes obtained before the unconfined compression test and wet weight values and the water content at the end of the test; void ratios of the mixtures before the test were obtained. In the calculations of relative density, only maximum and minimum void ratios obtained for the dry mixture with C/S = 10% by using related ASTM standards were used (Table 3). According to Fig. 5, relative density increased as static compaction pressure increased. In case that the compaction pressure was increased from 4 MPa to 40 MPa, relative density increased from the level of ~50% to the level of ~150%. According to Fig. 5, distinctive characteristic of the W/C ratio on relative density is not clear (when the effect of water on compatibility of the soils was taken into consideration). It is revealed from Fig. 5 that beyond 24 MPa static compression level the rate of increasing tendency of relative density decreases. But, it appears to be around after 40 MPa static compression level, that crushing of particles may start to increase the relative density of the samples.

3.2 Effect of C/S Ratio on UCS

It is previously mentioned that static compaction pressures used in the study were chosen in the range of 4 MPa–40 MPa (Table 1). Cylindrical samples having the conditions required for the unconfined compression test could not be taken from all the mixtures compacted under 4 MPa static pressure (mixtures with the C/S = 10% and W/C = 1 were excepted) (Table 1). The lowest effective compaction pressure used in the study was 8 MPa (for the unconfined compression test. cylindrical samples were obtained from all the mixtures except for the mixtures with C/S = 2.5% and W/C = 1 and 1.5). Therefore, the effect of C/S ratio on UCS was investigated on the samples prepared under the static compaction pressures of 8 MPa–40 MPa. Fig. 6 illustrates axial unit deformation – axial stress curves of the samples based on curing time.

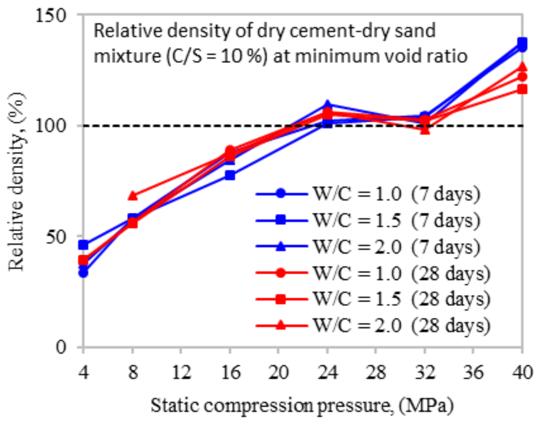
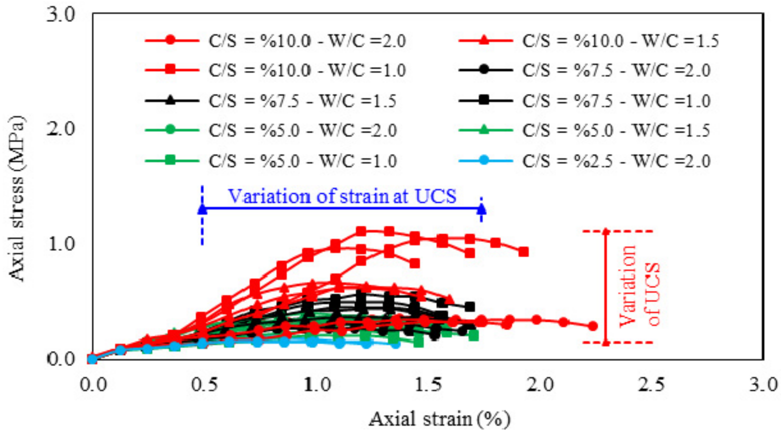
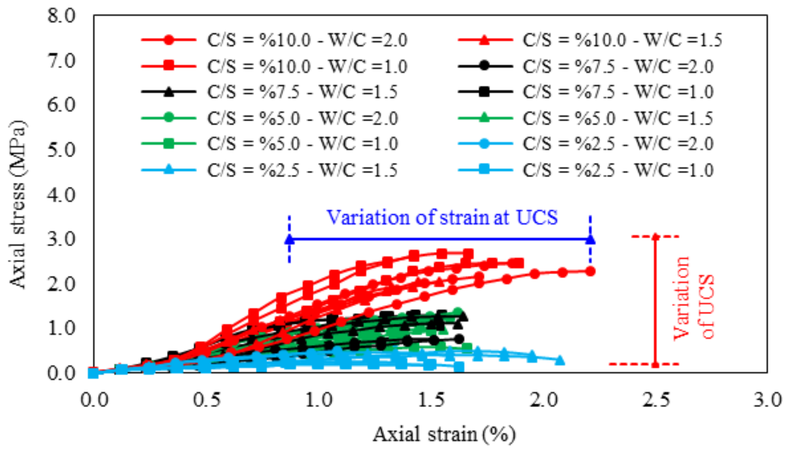


Fig. 5 Variation of relative density of the samples (C/S = 10%) with compaction pressure

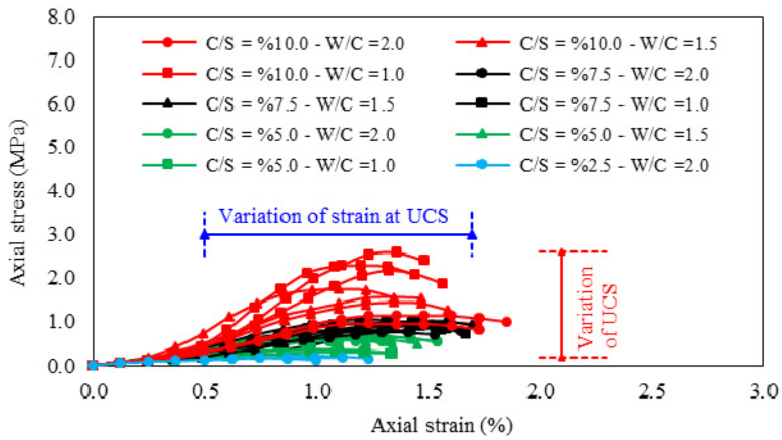


(a) Compacted with 8 MPa static pressure and cured for 7 days

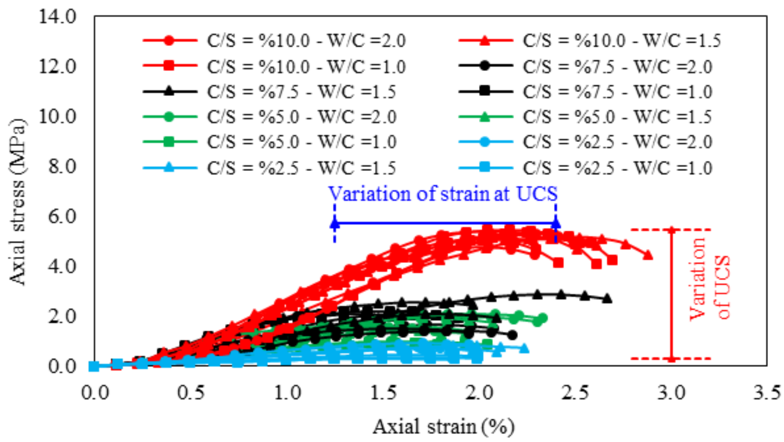


(b) Compacted with 40 MPa static pressure and cured for 7 days

Fig. 6 Variation of axial stress-axial strain curves of the sand-cement mixtures



(c) Compacted with 8 MPa static pressure and cured for 28 days

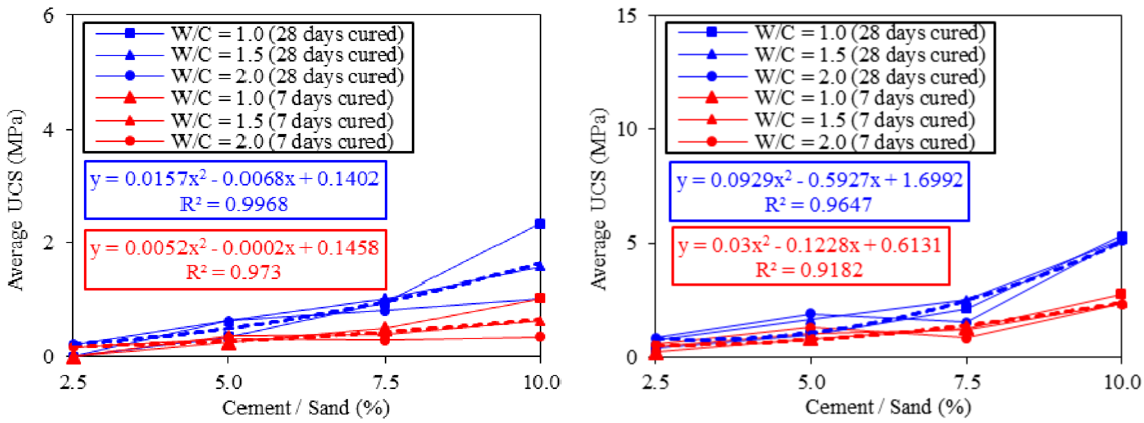


(d) Compacted with 40 MPa static pressure and cured for 28 days

Fig. 6 Continued

According to Fig. 6; as the curing time and compaction pressure increased, the deformation modulus increased. Peak strength values of the samples prepared under 8 MPa static compaction pressure were obtained within the axial unit deformation level range of 1.0%–1.5% (in both of the curing time). As the compaction pressure (40 MPa) increased, axial unit deformation levels shifted to the range of 1.5%–2.5%. Axial stress– axial unit deformation curves of the samples with C/S ratio of 10% were distinctive from curves of the samples with different C/S ratios. Lastly, it was seen that the effect of W/C ratio on stress–deformation curves was not characteristic (Fig. 6).

The effect of C/S ratio on average UCS was separately compared at 8 MPa and 40 MPa levels (Fig. 7). When Figs. 7(a) and (b) were compared, it was observed that UCS values of the samples compacted under 40 MPa were more sensitive to the curing time compared to the samples compacted under 8 MPa. UCS increase tendencies of the samples compacted under 40 MPa based on the C/S ratio increased with the curing time. In the samples prepared under high compaction pressures, the effect of W/C ratio on strength decreased with increasing C/S ratio. As it was mentioned before, 6 identical samples were prepared for all the mixtures (3 of them were kept in



(a) Compacted under 8 MPa (b) Compacted under 40 MPa

Fig. 7 Variation of average UCS with C/S ratio

the cure for 7 days and the other 3 were kept in the cure for 28 days). Therefore, UCS behaviour trends of the samples with the W/C = 2.0 kept for 7 days and 28 days were quite similar (Fig. 7(b)).

In the samples prepared independently from the W/C ratio (i.e., UCS of the samples at all the W/C ratios), compacted under the compaction pressure of 8 MPa and kept in the cure for 7 days; there was a relationship between UCS and C/S ratio as follows: UCS = $0.0052(C/S)^2 - 0.0002(C/S) + 0.1458$, where $R^2 = 0.973$. Whereas the relation for the samples kept in the cure for 28 days was as follows: UCS = $0.0157(C/S)^2 - 0.0068(C/S) + 0.1402$ where $R^2 = 0.9968$. In the equations, unit of UCS was MPa and C/S was used as percentage.

Similarly, R^2 value of the 2nd degree polynomial relation between UCS and C/S ratio of the samples compacted under 40 MPa and kept in the cure for 7 days was found as 0.9182, and R^2 value of the samples kept in the cure for 28 days was found as 0.9647. When R^2 values of the samples kept for 7 days and 28 days were compared, it was observed that R^2 value increased significantly as the curing time increased. Accordingly, the effect of W/C ratio on UCS was not distinctive for the samples compacted either under low static pressure (8 MPa) or high static pressure (40 MPa) (high R^2 value).

From Fig. 8, it is clearly seen that C/S ratio dominates the UCS of the samples (as the cement content in the mixture increases the rate of UCS increases in the order of 2nd degree polynomial). The effect of curing period on the UCS (at the same C/S ratio) also become more distinctive as the cement content in the mixture increases.

4. Conclusions

A series of unconfined compression tests were conducted to investigate the effects of compaction pressure and the cement/sand (C/S) ratio on unconfined compressive strengths (UCS) of the cement-sand mixtures. The effect of compaction pressure on UCS was examined on samples with C/S = 10%, and the effect of cement ratio on UCS was investigated under the compaction pressures of 8 MPa and 40 MPa. The observations and conclusions from this study can be summarized as follows:

- Results of the study showed that as the compaction pressure increased, average UCS increased. When the increase tendency of the average UCS was taken into consideration, two zones, where the compaction pressures were within the range of 4 MPa-32 MPa and 32 MPa-40 MPa, could be defined. Increase tendency of average UCS in the second zone (32 MPa-40 MPa) was higher compared to the first zone (4 MPa-32 MPa).
- When the W/C ratio increased, the average UCS showed a decrease tendency under all the compaction pressures. While the effect of W/C ratio on average UCS was higher in case of low compaction pressure; the effect of W/C ratio on average UCS became significant in case of high compaction pressure. In case that the compaction pressure increased from 4 MPa to 40 MPa, relative density increased from the level of ~50% to the level of ~150% (when the standards of ASTM D4253 and ASTM D4254 were taken as reference).
- It was shown on that sensitivity of UCS of soils dependent on the static compaction pressures. However, results indicated that UCS values of the samples were not highly sensitive to the curing times. Slight impact of curing time was only observed in UCS of samples that were compacted under 40 MPa and 8 MPa and it was found that samples compacted at 40 MPa were more sensitive to the curing time compared to the samples compacted under 8 MPa.
- Results showed that the effect of change in the C/S ratio on the UCS was the highest when soils were compacted at 40 MPa compaction pressure. It was observed that UCS of the samples compacted under 40 MPa increased drastically when the C/S ratio increased.
- In general, this study claims that C/S ratio is the dominant factor on soil strength when it is compacted at high static compaction pressure while soil strength is more sensitive to W/C ratio when compacted under lower static compaction pressure. It is also determined that curing time increases the soil strength significantly.

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