International Journal of Science and Research Archive

eISSN: 2582-8185

Cross Ref DOI: 10.30574/ijsra

Journal homepage: https://ijsra.net/

(Research Article)

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Compressive strength of Cement-Bentonite grouting

Bassel M. Nassef *, Mohamed Kohail and Mohamed Y. Abdellatief

Department of Structural Engineering, Ain Shams University, Cairo, Egypt.

International Journal of Science and Research Archive, 2023, 09(01), 468–473

Publication history: Received on 03 May 2023; revised on 12 June 2023; accepted on 15 June 2023

Article DOI: https://doi.org/10.30574/ijsra.2023.9.1.0468

Abstract

Cement bentonite grouting is used to seal and stabilize soil or rock formations. This involves mixing cement, bentonite, and water to create a slurry that is pumped into the ground under pressure. The slurry fills voids and fractures in the soil or rock, creating a solid mass that can support the structures or prevent water from seeping through. Bentonite is a type of clay that swells when it meets water, making it an effective sealing material. Cement is added to the mixture to provide strength and stability. The ratio of cement to bentonite varies depending on the specific application. Different researchers have studied CB slurry properties over the long term. There is a lack of studies done to discover the early age strength of CB slurry with different cement percentages. The objective of this study is to investigate the compression resistance of CB slurry at early ages for different percentages of cement (10-15-20) percent at curing times of 3 and 7 days.

Keywords: Cement Bentonite slurry; Grouting; Unconfined compressive strength; Permeability

1. Introduction

Bentonite grouting is a process of injecting a slurry of bentonite clay and water into the ground to fill voids, stabilize soil, and prevent water infiltration [1]–[3]. Bentonite swells when mixed with water, making it an effective material for sealing and waterproofing, and the process of bentonite grouting involves drilling holes into the ground and injecting bentonite slurry under pressure[4]–[8]. The slurry fills any voids in the soil, creating a solid mass that can support the structures or prevent water from seeping through. Bentonite grouting is commonly used in construction projects such as foundation repair, tunneling, and dam construction [9], [10]. It can also be used to seal underground storage tanks or prevent contamination from leaking into groundwater. One advantage of bentonite grouting is that it is environment-friendly. It also has a long lifespan and can remain effective for decades. However, bentonite grouting has certain limitations. It may not be suitable for certain types of soil or rock formations, and it can be difficult to control the flow of slurry during injection. The addition of binders, such as cement, to bentonite slurry results in the production of cement-bentonite (CB) grout, which has improved mechanical properties and stability compared to pure bentonite slurry[11]–[14]. The technical results of adding cement to bentonite slurry include the following:

- Increased strength: The addition of cement increases the compressive strength and shear strength of CB grout, making it suitable for use in structural applications.
- Reduced permeability: CB grout has lower permeability than pure bentonite slurry, which makes it more effective in sealing underground structures such as tunnels and dams.
- Improved stability: CB grout has better stability and resistance to erosion than pure bentonite slurry, which makes it more suitable for use in soil stabilization applications.
- Reduced shrinkage: The addition of cement reduces the shrinkage of the CB grout during curing, which improves its overall performance

* Corresponding author: Bassel M. Nassef

- Increased viscosity: The addition of cement enhanced the viscosity behavior of the CB grout, which improved its ability to suspend solids and prevent settling [15]–[18]. Overall, the addition of cement to bentonite slurry improves its mechanical properties, stability, and performance in various applications. The aim of this study was to investigate the early compressive strength of CB slurry at curing times of 3 and 7 days using a laboratory experimental program with different dosages of cement (10, 15, and 20) percent of the total weight). In addition, a discussion and conclusions are presented. Moreover, giving a suggestion for further studies needed.

2. Material and methods

2.1. Materials

The raw materials used to form the CB slurry were bentonite clay, tap water and Portland cement type CEM I (42.5). The used bentonite was highly active and swelled. The bentonite-swelling index was determined to be greater than 22, and the liquid limit reached 285%. Table 1 lists the chemical compositions of the cement and bentonite used. The physical properties of bentonite are listed in Table 2.

Table 1 The Chemical Composition of raw materials

Chemical Properties	Cement	Bentonite
SiO_2	21.20	57.72
$Al_2 O_3$	5.60	22.57
$Fe_2 O_3$	3.19	5.63
CaO	63.20	0.45
MgO	0.65	1.95
MnO	-	<0.01
SO_3	2.38	0.13
Na_2O	0.10	0.87
K_2O	0.50	0.94
P_2O_5	-	<0.01
Cl	-	1.14
TiO_2	-	1.54
F.L	2.60	-
LOI	2.32	-

Table 2 Physical properties of Bentonite

Properties	Bentonite
Bulk Density	950 kg/m^3
Yield	24 m^3/ton
Dry screen analysis passing 100 us mesh	99.5%
Moisture content 105 Oc	10.3%
Filter loss (30 min.)	15 ml
PH of 5% of distilled water	9.4
Wet screen residue on 200 mesh	0.5%

Marsh funnel viscosity of 4%	45 sec
Swelling index	≥ 22 ml/2g
Liquid limit	285 %
Water content	≤ 13 %
P.I	2.51
Gs	2.74

2.2. Samples preparation:

Cement Bentonite slurry was prepared by mixing 5 percent of bentonite of the total weight of mixture for minimum five minutes, to be sure that the bentonite is fully hydrated and the mixture is homogenous. The mixture was then placed in buckets and hydrated for twenty-four hours. Subsequently, a certain amount of cement was added as a percentage of the total weight. Three percentages were selected for mixing (10, 15, and 20) with the Bentonite slurry. After mixing the cement with the bentonite slurry, the mixture was poured into UCS molds with a diameter-to-height ratio of 1:2, as shown in Fig. (1). the samples were cured for 3 and 7 d per group. On the test day, the samples were extruded from the molds and the surfaces were leveled before testing.

Figure 1 CB UCS samples

2.3. Experimental Methodology

2.4. Unconfined compressive strength (UCS)

Figure 2 Unconfined compressive strength apparatus

The laboratory experimental program for testing the samples in the UCS apparatus shown in Fig. 2 is shown in Table 3. Three groups of CB mixtures with binder percentages (10-15-20) to be for investigation. Each group was tested 2 times on curing days 3 and 7 in order to study the early strength of the CB samples, which were extruded from molds on the test day, in order to keep the sample in a saturated condition. The sample surfaces were leveled, maintaining a diameter-to-height ratio of 1:2. The test was performed at a displacement rate of 1 mm/min. results are presented herein.

Table 3 Illustrate the experimental laboratory program

X GROUP NO.	BINDER TYPE	TEST	BINDER (%) BY WEIGHT	BENTONITE (%) BY WEIGHT	CURING TIME	MARSH VISCOSITY (SEC)
C1	CEMENT	UCS	20%	5%	(3-7) days	70
C2			15%			66
C3			10%			64

3. Results

The CB samples were tested at curing times of three and seven days Fig. 2 shows the stress–strain curve for the UCS test for all samples. It was found that increasing the cement percentage increased the compressive strength. In addition, the compressive strength increased with an increase in curing time. As shown in the stress-strain curve, the samples with a cement percentage of 10% did not exceed 20 kPa after 7 days. Samples with 15% and 2% exceeded 100 kPa on day.

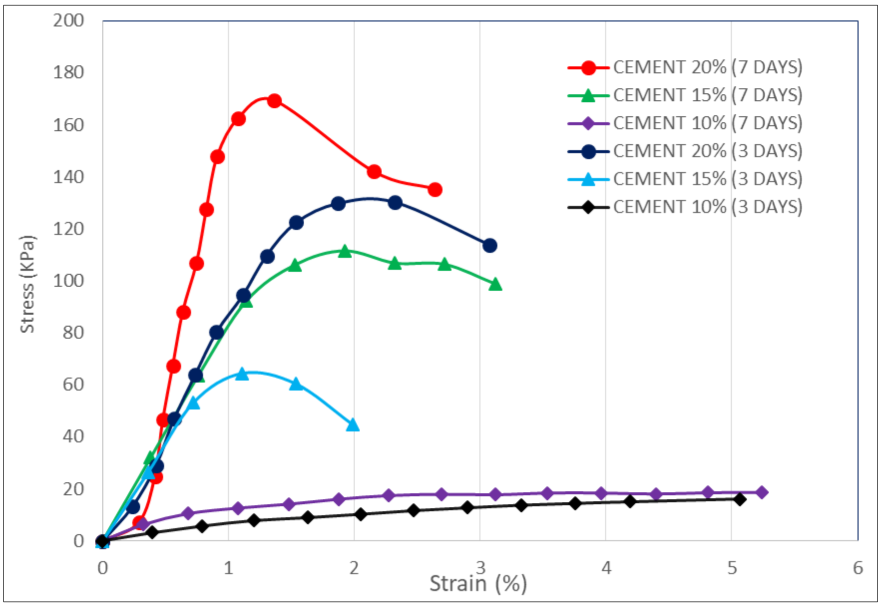

Figure 3 Unconfined compressive strength stress-strain curve

4. Discussion

Bentonite clay is classified as swelling soil; it is highly active when it meets water. Bentonite slurry is used in many geotechnical applications such as barriers to prevent the underground water seepage depending on its low permeability. Many researchers have studied the effect of adding cement to bentonite slurry, which contributes to the mechanical properties of the bentonite grout. In addition, it increases its compressive strength and durability and decreases its permeability. The addition of cement contributes to a decrease in the intermolecular spaces; hence, the compressive strength increases. The chemical reaction between cement and bentonite was described as it pass through two stages [19]–[21]. The first stage is the reaction between the cement and water, producing C-S-H gel and calcium hydroxide. In the second stage, the calcium hydroxide produced reacts with the silica oxide of bentonite, forming an additional C-S-H gel. This decreases the intermolecular space and subsequently increases the mechanical and rheological properties of the grout.

5. Conclusion

Cement bentonite grouting is one of the most common solutions for improving the soil properties. The addition of cement to bentonite enhances the mechanical properties of the slurry. A laboratory experimental program was carried out to study the early strength behavior of the slurry under compression. Three groups of cement bentonite mixtures were tested in UCS, with cement percentages (10-15-20) from the total weight of the mixture at curing times of 3 and 7 days.

It was concluded that by increasing the cement content in the mixture, the compressive strength increased, as shown in Fig.3, and the compressive strength increased with the curing time. Moreover, it was noticed that the mixture containing 10% cement had a very low compressive strength, which did not exceed 20 kPa in either three or seven days. For the CB samples with 15% cement on day 3, it reached 64 kPa, whereas on day 7 it reached 111 kPa. The samples containing 20 % cement performed better at both 3 and 7 d. The 20% cement samples on day 3 exceeded the compressive strength reached by the samples that contained 15% cement on day 7. Additionally, it reached a compressive strength of 129 kPa. It is not recommended to use cement with a percentage of 10% for early age strength up to 7 days. Samples with 20% are higher in compressive strength in both 3 and 7 days than samples with 15% and 10 %. Further studies are needed to investigate the permeability behavior of early age CB grouts.

Compliance with ethical standards

Acknowledgments

The authors acknowledge the Geotechnical Research Lab - Ain Shams University.

Disclosure of conflict of interest

The authors certify that they have No affiliations with or involvement in any organization or entity with any financial interest, or non-financial interest in the subject matter or materials discussed in this manuscript.

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