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Effect of Water Content on Hardened Properties of the Bentonite Mix

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ABSTRACT: Depending on the particular application and the required properties the ideal water to bentonite ratio will vary depending on the type of bentonite used. The characteristics of the nearby soil or rock, and the particular building application, the appropriate ratio may change. When planning and executing construction projects with bentonite mixes, it's crucial to pay close attention to the water to bentonite ratio to achieve the best possible behaviour, workability, and durability. In this study, the water content in the bentonite mixture is examined as a percentage of bentonite, and its impact on the characteristics of the hardened bentonite mixtures is examined. According to the test results the ideal bentonite mix ratios according to the used mixes was 1 bentonite to 2.5 water to 3 cement to 9 sand that shows a good compressive strength with suitable workability.

KEY WORDS: Bentonite; Water Content; Compressive Strength, Tensile Strength.

I.INTRODUCTION

Bentonite is a type of clay composed primarily of montmorillonite, a soft, porous, and highly absorbent mineral. The chemistry of bentonite is essential in understanding its properties and applications in various industries, including construction[1]. The chemical composition of bentonite varies depending on the source and location from which it is extracted. Typically, it is composed of various minerals, including silica, alumina, iron oxide, calcium, magnesium, and sodium. However, the primary mineral that gives bentonite its unique properties is montmorillonite, which makes up approximately 60-80% of the clay[2].

The structure of montmorillonite is composed of layers of aluminium, silicon, and oxygen atoms arranged in a crystalline lattice. These layers are held together by weak bonds, allowing water and other molecules to enter and exit the spaces between the layers[3]. When montmorillonite comes into contact with water, it swells and forms a gel-like substance due to the absorption of water molecules between the layers. The unique chemistry of bentonite makes it a highly versatile material for various applications in industries such as construction, oil and gas, and waste management. Its ability to absorb water and other molecules, swell, and form a gel-like substance makes it an excellent material for waterproofing, sealing, and stabilizing soil and rock formations[4].

In the construction industry, bentonite is used in the creation of borehole walls, also known as pilling. Bentonite is used as a drilling fluid that supports the excavation process, by stabilizing the borehole walls, keeping them from collapsing or caving in[5, 6].

One application of bentonite in pilling is the creation of secant piles. Secant piles are constructed by drilling primary piles and then creating secondary piles that intersect with the primary piles. The secondary piles are then reinforced with steel bars and concrete to create a stable foundation. Bentonite is used to stabilize the primary piles during excavation and the construction of the secondary piles[7, 8].

In secant piling, bentonite is used in two primary ways. First, it is used as a drilling fluid to support the excavation process and prevent borehole collapse. The drilling fluid is pumped into the borehole under high pressure, and as it circulates, it

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stabilizes the borehole walls and prevents soil from collapsing into the borehole. Second, bentonite is used to create a seal around the primary piles. A slurry made with bentonite is injected into the primary pile, creating a water-tight seal between the primary and secondary piles. This seal prevents water from entering the excavation area and helps to ensure that the secant piles remain stable[9-11].

Overall, the use of bentonite in secant piling is essential to creating a stable foundation for construction projects. Its unique properties make it an excellent material for stabilizing borehole walls and creating water-tight seals, ensuring that construction projects are completed safely and efficiently[12, 13].

As stated by many codes, bentonite mix is a commonly used material in the construction industry for various applications, such as drilling fluids, grouting, soil stabilization, waterproofing, and landfill construction[14]. Different codes of practice, such as ASTM, BS, and the Egyptian code of practice, provide guidelines and standards for the use of bentonite in construction.

The American Society for Testing and Materials (ASTM) provides various standards for the use of bentonite in construction, including ASTM D5084, which outlines the standard test methods for measurement of hydraulic conductivity of saturated porous materials using a flexible wall permeameter. This standard provides guidance on the use of bentonite in the construction of landfill liners and covers, as well as in the construction of clay liners for wastewater treatment facilities[15].

Similarly, the British Standards (BS) provides guidelines for the use of bentonite in construction, such as BS EN 13286-47, which outlines the test methods for the determination of the swelling properties of bentonite. This standard provides guidance on the use of bentonite in the construction of waterproofing systems for tunnels and underground structures[16].

The Egyptian code of practice for soil mechanics and foundation engineering provides guidance on the use of bentonite in construction, specifically for the construction of cut-off walls in dams and embankments. The code outlines the specifications for the use of bentonite in grouting, including the type of bentonite to be used, the required properties of the mix, and the methods for testing the mix[17].

Overall, the use of bentonite mix in construction is governed by various codes of practice that provide guidelines and standards for its use. These codes provide guidance on the selection of the appropriate type of bentonite, the required properties of the mix, and the testing methods to ensure the proper use of bentonite in construction projects. The actual proportions may vary depending on the specific application, such as the strength requirement, the type of cement, the aggregate gradation, and the environmental conditions. These codes provide detailed guidelines for determining the appropriate mix proportions based on these factors. It is recommended to consult these codes and work with a qualified engineer or concrete supplier to determine the optimal mix proportions for your specific project.

The water to bentonite ratio is an important factor that can affect the behavior, workability, and durability of bentonite in various construction applications. Generally, the water to bentonite ratio refers to the amount of water required to hydrate and activate the bentonite particles[18].

The behavior of bentonite is affected by its water content, which determines its viscosity, plasticity, and compressibility. Higher water to bentonite ratios results in a more fluid mixture, which may be easier to pump or pour, but may also result in reduced strength and stability. Lower water to bentonite ratios, on the other hand, may result in a more difficult to work with mixture, but can lead to higher strength and stability[19, 20].

Workability is an important characteristic of bentonite mixes, particularly in applications such as drilling fluids and grouting. The water to bentonite ratio can affect the workability of the mixture, with higher ratios resulting in more fluid mixes that are easier to work with, and lower ratios resulting in more viscous mixes that are harder to pump or pour[21, 22].

The durability of bentonite mixes is also affected by the water to bentonite ratio. A higher water to bentonite ratio may result in a weaker and less stable mixture, which may be more susceptible to erosion or displacement over time. A lower

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water to bentonite ratio, on the other hand, may result in a stronger and more stable mixture that can resist erosion and displacement[23, 24].

II. SIGNIFICANCE OF THE SYSTEM

The optimal water to bentonite ratio depends on the specific application and the desired characteristics of the mixture. The ideal ratio may vary depending on the type of bentonite used, the properties of the surrounding soil or rock, and the specific construction application. It is important to carefully consider the water to bentonite ratio when designing and implementing construction projects that involve bentonite mixes, to ensure optimal behavior, workability, and durability. This research presents a study of the water content in the bentonite mixture as a percentage of bentonite and introduce a study of its effect on the properties of the hardened mixture properties.

III. MATERIALS AND EXPERIMENTAL PROGRAM

a) Experimental Program Procedures and Equipment

Six bentonite mixtures have been cast as the experimental program was carried out to investigate the effect of water content on the bentonite mix properties. The compressive strength was tested at the ages of 3,7,28,56,90,180 and 360 days age for the tested samples. Cubes of dimensions 100x100x100 mm where used for sampling the tested mixes for measuring the compressive strength. The indirect tensile strength was tested at 7 and 28 days age for the tested samples. A 100 mm diameter and 200 mm height cylinders where used for measuring the indirect tensile strength of the tested mixes. All the testes were carried according to E.C.P. 203[25].

b) Materials

In the mix design, cement used was ordinary Portland cement CEM I 52.5N with chemical and physical properties that satisfies the Egyptian Standard of Specifications (E.S.S. 4756-1/2013) requirements [26]. Natural and clean sand with a specific gravity 2.68 t/m^3 and fines modulus 2.9. Sand satisfies the Egyptian standard of specifications for aggregate[27]. The used bentonite has chemical composition as shown in Table 1.

Table -1: Chemical Composition of the Used Bentonite

SiO_2 (%)	Al_2O_3 (%)	Fe_2O_3 (%)	CaO (%)	Na_2O (%)	MgO (%)	K_2O (%)
64.38	14.94	5.32	7.53	3.18	2.26	2.39

c) Mix proportions

The mix design of the tested mixes was shown in Table 2. Table 2 shows the mixture proportions considering the bentonite content as the measured unit and the values of the rest of ingredients were measured as a multiple number that multiplied with the bentonite content. The mix proportions were chosen according to the general requirement of different codes that were mentioned in the introduction section.

Table -2: Tested mixes proportions

Mix Code	Cement	Bentonite	Fine aggregate	Water
B1.5	3	1	9	1.5
B2.0	3	1	9	2.0
B2.5	3	1	9	2.5
B3.0	3	1	9	3.0

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B3.5	3	1	9	3.5
B4.0	3	1	9	4.0

IV. TEST RESULTS

a) Compressive strength test results

The compressive strength test was carried out on cubes of dimensions 100x100x100 mm. Tests were carried out on samples at the ages of 3,7,28,56,90,180 and 360 days age for the tested samples. Table 3 shows the compressive strength test results for different mixes.

Table -3: Tested mixes proportions

Code	Compressive Strength (MPa)							
	3 days	7 days	14 days	28 days	56 days	90 days	180 days	365 days
B1.5	11	15	24	33	44	49	59	69
B2.0	15	20	45	65	75	88	102	118
B2.5	14	18	42	62	73	86	101	115
B3.0	8	13	21	30	40	44	49	52
B3.5	5	9	16	25	35	42	49	61
B4.0	4	7	12	21	32	38	44	53

According to the test results shown in Table 3 the compressive strength for all the tested mix shows increasing with time but with varied increasing criteria. The compressive strength at the age of 28 days shown in Fig. 1 shows that B2.0 and B2.5 was very close in the compressive strength but when comparing these mixes according to its workability the B2.0 mix was very sticky and need more compaction. While in the case of B2.5, the workability was better than B2.5 and need less effort in compaction.

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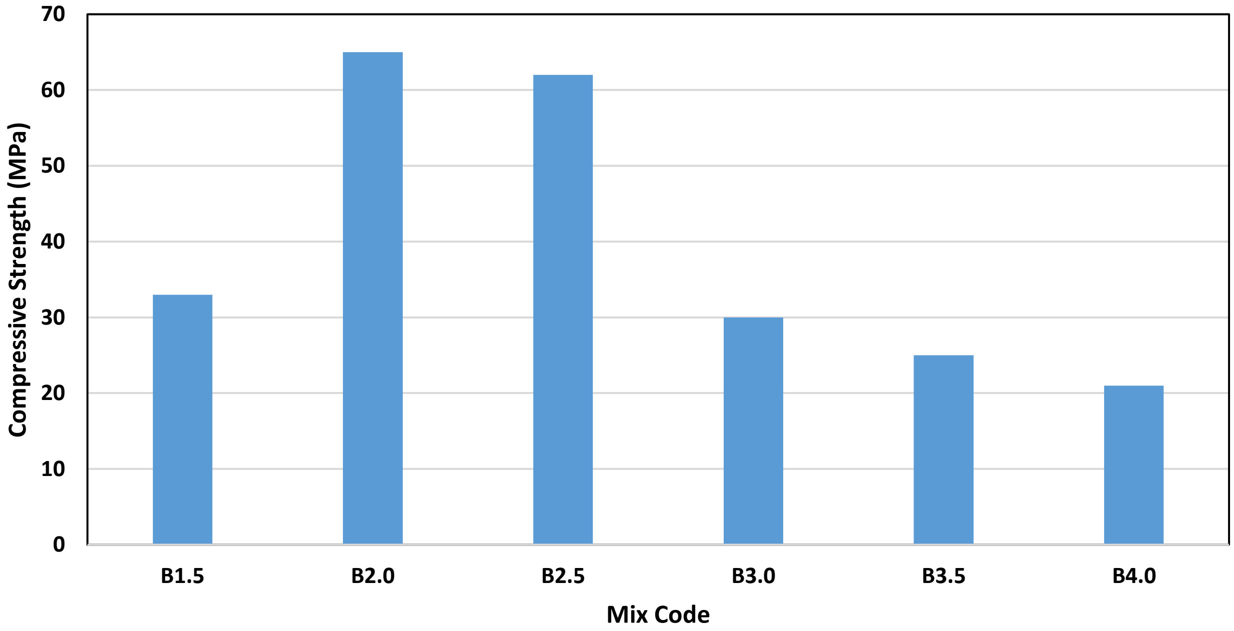

Fig. 1: 28 days compressive strength for the tested samples

b) Tensile strength test results

The Tensile strength test was carried out on 100 mm diameter and 200 mm height cylinders. Tests were carried out on samples at the ages of 7 and 28 days age for the tested samples. Figure 2 shows the tensile strength test results for different mixes. The tensile strength follows the same criteria as the compressive strength with the same ages.

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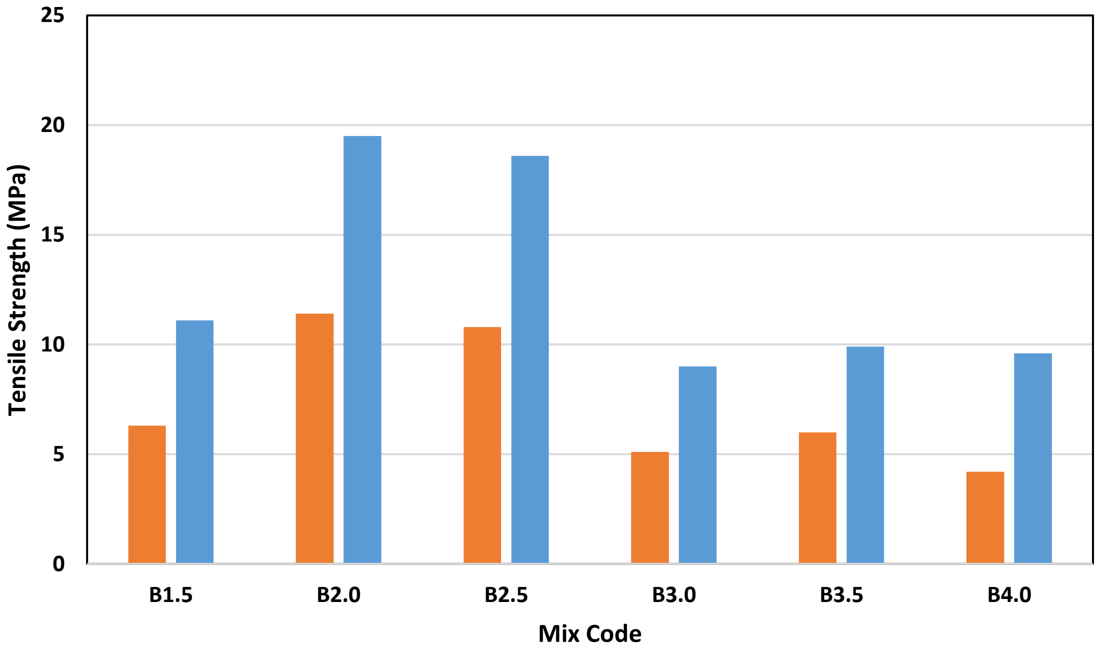

Fig.2: Tensile strength for the tested samples

V. CONCLUSION

According to the test results for the chosen mix proportions the following conclusions could be summarized:

- The highest 28 days compressive strength was 65 Mpa for B2.0 mix while B2.5 mix has 62 Mpa compressive strength.
- B2.5 mix has a better workability than B2.0.
- The highest 28 days compressive strength was 19.5 Mpa for B2.0 mix.
- The compressive and tensile strengths for all the tested mixes were increased with time.

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