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Study on the Effect of Baking Soda on Workability, Water Absorption and Compressive Strength of Concrete

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Abstract: Baking soda is a valuable element for development because it not only helps in the food industry but can directly help in the construction industry. To make it, the alkaline component of sodium bicarbonate is combined with acid salts and corn starch. Baking powder is a chemical substance with the formula $NaHCO3$ that is used in baking. This compound is a member of the salt group and has been used for a very long time. The main retarder additives are divided into several categories according to their chemical composition, including Lignosulphonic Acid and Hydrocarboxylic acid and their salts. In this experiment, baking soda was used as a cement replacement in concrete. The purpose of this study is to determine the workability, water absorption and compressive strength of concrete with variations in the cement replacement with the baking soda of 0%, 3%, 6%, and 9% of the weight of cement. This is an experiment in the study of upgrading building materials on construction sites. Porosity and compressive strength samples in the form of a concrete cube are used to test for water absorption and strength. The outcomes from this research are the result of slump value for 3%, 6%, and 9% are 31mm, 35mm, and 43mm respectively. For water absorption test, the highest percentage of water absorbed is 9% of baking soda followed with 6% and 3%. The highest compressive strength obtained from this research is the concrete cube that contained 3% of baking soda followed by 6% and 9%. Based on the results obtained, it is proved that baking soda can increase the workability of concrete. When baking soda content is increased, the percentage of water absorption will increase.

Keywords: Baking soda, workability, water absorption, compressive strength

1. Introduction

Baking soda is created by combining sodium bicarbonate with other ingredients that are somewhat acidic. According to the recommendations for the use of chemical additives in concrete outlined in building materials and civil engineering No.22/SE/M/2015, baking powder ($NaHCO3$) is a chemical that contains salt, which is Sodium (Na). As a

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result, it makes it possible to be utilized as supplementary Khairul Azli et al., Recent Trends in Civil Engineering and Built Environment Vol. 3 No. 3 (2022) p. 1-8 2 material in concrete, given that the Na component contains, for instance, lignosulfonic acid. By reacting with sodium bicarbonate, potassium bitartate creates what is commonly known as baking soda. Sodium potassium bitartate salt, also known as a rochelle salt of class A, can be produced in this process under laboratory circumstances [1].

Among the studies that were conducted on the amount of time it takes for concrete to set, one of the most notable findings was that the incorporation of sodium silicate slowed down the hydration of tricalcium aluminate, which in turn prolonged the process of setting oil-well cement [2]. On cement mortar, polymer latexes have a good influence on reducing the amount of water present and a delayed setting behavior [3]. The initial setting time can be sped up or slowed down by triethanolamine depending on the concentration of ettringite produced, which is controlled by the amount of the chemical added to the mixture. The significance of triethanolamine and ettringite production in the original context is elucidated by these results [4].

In this study, we experimentally verified the possibility of controlling workability by adding baking soda to concrete mixing. The purpose is to examine the behavior the effect of baking soda on workability, water absorption and compressive strength in concrete.

2. Materials and Methods

The raw material used in the production of baking soda concrete are Ordinary Portland cement (OPC), coarse aggregate, fine aggregate, and water. Meanwhile, baking soda was used as cement replacement material in this study.

2.1 Material Preparation

In this experiment, Portland cement is substituted with baking soda, also known as sodium bicarbonate. Baking soda, often known as sodium hydrogen carbonate, is a substance having the formula $NaHCO3$. It is a salt made up of the cation sodium and the anion bicarbonate. Sodium bicarbonate can be found in crystalline white form, but more commonly takes the form of a fine powder. It tastes somewhat salty and alkaline, like washing soda (sodium carbonate). Nahcolite is the name of the mineral that occurs in nature. A component of natron, it can be found in solution in many natural springs. Only pure baking soda was used.

2.2 Mix Design

The quantities of concrete mix components are determined by the DOE Method. This project will utilize a cube measuring 150mm x 150mm x 150mm. Consequently, the volume of one cube of concrete is $0.003m^3$. For this project, each percentage of Baking Soda utilized 24 cubes of sample, resulting in a trial mix volume of $0.0204m^3$. Table 1 demonstrates the quantities of materials required by the British Standard Method for Concrete Mix Design (DOE Method), while Table 2 demonstrates the total weight of baking soda as a substitution for cement in the concrete mix for each trial mix of $0.0204m^3$.

Table 1 - The required material quantities according to British Standard Method for Concrete Mix Design (DOE Method)

Quantities	Cement (kg)	Water (kg or L)	Fine Aggregate (kg)	Coarse Aggregate (kg)		
				10mm	20mm	40mm
Per m^3 to nearest 5kg	380	190	546	-	1274	-
Per trial mix of $0.0204m^3$	7.76	3.88	11.14	-	25.99	-

Table 2 - The overall amount of baking soda used as cement substitution material per trial mix

Specimen	Cement (kg)	Baking Soda (kg)	Water (kg or liters)	Fine Aggregate (kg)	20 mm Coarse Aggregate (kg)
0%	7.76	0.00	3.88	11.14	25.99
3%	7.53	0.23	3.88	11.14	25.99
6%	7.29	0.47	3.88	11.14	25.99
9%	7.06	0.70	3.88	11.14	25.99

According to Table 3, 24 cubes of baking soda will be used to replace cement in the concrete mix. This includes 0%, 3%, 6% and 9%. The water-cement ratio used is 0.5. The total amount of baking soda used in this project is 1.4kg, with 3% being 0.23kg, 6% being 0.47kg, and 9% being 0.70kg. The cement will weight a total of 29.64kg.

2.3 Preparation of Sample

Sample preparation will be done after the design of the concrete mix using British Standard Concrete Mix (DOE Method). The DOE Method is used to figure out how much material is needed. For this project, a total of 24 concrete cube samples were used. There are 24 cubes for water absorption and compressive strength test. Both the water absorption test and the compressive strength test will use the same concrete cube. After the sample is ready, the concrete will be placed in a curing tank for 7 to 28 days to cure.

2.4 Slump Test

The freshness of concrete is tested using the slump method. After all the concrete ingredients have been combined, it must be put to the test. This procedure ensures that the freshly poured concrete will continue to look the same. The slump test is used to determine how easily a certain concrete may be shaped. Each batch of concrete undergoes a slump test to ensure consistency in quality. In terms of cost and turnaround time, the slump test is the gold standard for evaluating concrete workability. The slump test follows BS EN 12390-3: 2009.

2.5 Water Absorption Test

The curing process is completed, an evaluation of water absorption will be undertaken for 7 days and 28 days cube. The absorption of water is performed in accordance with BS1881: Part 122: 1983.

2.6 Compressive Strength Test

The hardened concrete will be tested for compressive strength afterwards 7 days and 28 days of cure. This test will assess the hardened concrete's compressive strength. The main goal of this test is to determine the concrete's crushing strength, which is expressed in Megapascals (MPa) or Newtons per square millimeter (N/mm^2). Compressive strength is the measure of a material's ability to withstand failure under compression. An essential factor in assessing how well a material performs under service is its compressive strength. The concrete mix can be designed or proportioned to meet the design engineer's needs for engineering and durability. The concrete cube will be tested in accordance with BS EN 1992-1-1:2004.

3. Results and Discussion

The results and discussion section presents data and analysis of the study. This section can be organized based on the stated objectives, the chronological timeline, different case groupings, different experimental configurations, or any logical order as deemed appropriate.

3.1 Slump Test

The slump test was performed in accordance with the procedures outlined in BS EN 12390-3: 2009 (Testing Fresh Concrete: Slump Test), which is used to evaluate the workability of freshly mixed concrete. Table 3 displays the results of the slump test.

Table 3 - Slump test results acquired

Specimen	Slump Value (mm)			Average Slump Value (mm)	Type of Collapse	Degree of Workability
	1	2	3			
0%	28	32	31	30	True	Medium
3%	31	32	30	31	True	Medium
6%	30	36	39	35	True	Medium
9%	46	41	42	43	True	Medium

According to the results, all the specimens in concrete mix were within the required slump vary of 30mm to 60mm. According to the findings, all the percentage of baking soda in the concrete mix were compatible with the specified cement/water ratio.

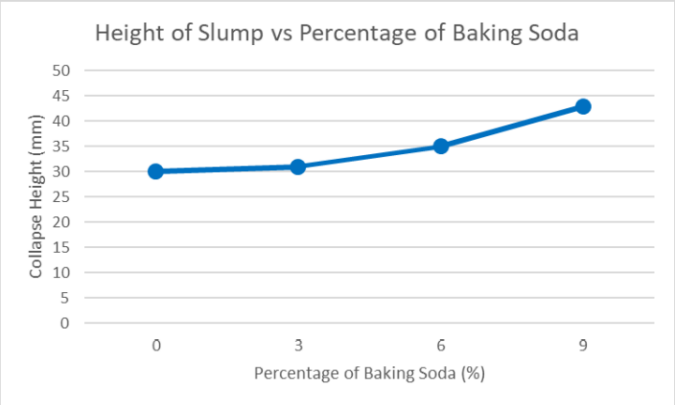

Fig. 3 - Graph comparing slump height versus percentage of baking soda in concrete mix

According to Figure 3, the workability of the concrete increased when the percentage of baking soda in concrete increased. Concrete with replacement of 0% cement has the lowest value of slump while concrete with replacement of 9% has the highest value of slump. The replacement of cement with baking soda in concrete increased the workability of the fresh concrete. This is due to baking soda which also named as sodium bicarbonate react with silicon dioxide that contained in cement. This reaction produced sodium silicate that can delay the hydration of Portland cement in concrete based on the previous research. As a result, the higher percentage of baking soda used to replace cement in concrete, the more workable the concrete will be.

3.2 Water Absorption Test

The water absorption test was performed in accordance with the procedures outlined in BS 1881: Part 122: 1983, which is used to evaluate the percentage of water absorbed in the concrete cube. Each concrete cube was soaked in water for 7 and 28 days and then weighted by using weighting scale. After 24 hours in room temperature, each cube will be dried in the oven for 3 days. After completely dried, the cubes will be weighted to obtain the data. Table 4 and Table 5 display the results of the water absorption test.

Table 4 - Water absorption test results for 7 days cubes

Specimen	Wet Weight (kg)			Dry Weight (kg)			Water Absorbed (%)			Average Water Absorbed (%)
	1	2	3	1	2	3	1	2	3	
0%	7.78	7.56	7.71	7.52	7.31	7.45	3.46	3.42	3.49	3.46
3%	7.41	7.61	7.55	7.08	7.34	7.25	4.66	3.68	4.14	4.16
6%	7.36	7.64	7.61	7.04	7.35	7.28	4.54	3.95	4.53	4.34
9%	7.83	7.67	7.67	7.48	7.32	7.35	4.67	4.78	4.35	4.60

Table 5 - Water absorption test results for 28 days cubes

Specimen	Wet Weight (kg)			Dry Weight (kg)			Water Absorbed (%)			Average Water Absorbed (%)
	1	2	3	1	2	3	1	2	3	
0%	7.86	7.85	7.80	7.60	7.60	7.47	3.42	3.29	4.41	3.71
3%	7.92	8.01	7.86	7.62	7.69	7.52	3.94	4.16	4.52	4.21
6%	7.71	7.88	7.82	7.37	7.60	7.44	4.61	3.68	5.11	4.46
9%	7.82	7.91	7.87	7.47	7.55	7.48	4.69	4.77	5.21	4.89

According to Table 4 and Table 5 0% baking soda cube has the lowest value of average percentage of water absorption, whereas 9% baking soda cube has the maximum value of percentage of water absorption for 7 and 28 days. The addition of baking in the concrete mixture increases the absorption of water. This is due to baking soda or sodium

bicarbonate can absorb moisture. Consequently, water absorption increases as the percentage of baking soda increases. Figure 4 shows the graph of percentage of water absorption over the percentage of baking soda at 7 and 28 days.

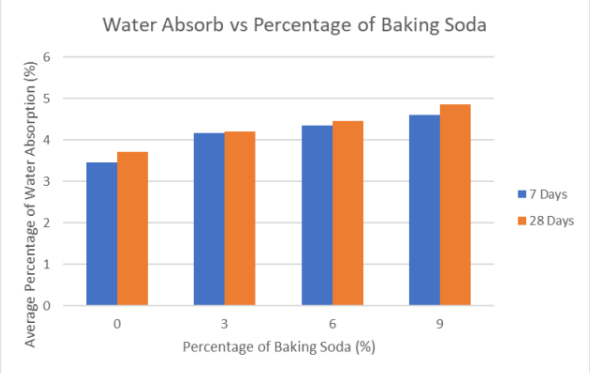

Fig. 4 - Graph of average percentage of water absorption over the percentage of baking Soda at 7 and 28 days

Figure 4 shows that concrete with a greater proportion of baking soda has a greater water absorption value. This indicates that sample with a greater proportion of baking soda are more absorbent. Due to pores and movement of water in the concrete, concrete absorb water. As the age of concrete and percentage of baking soda increase, the percentage of water absorption also increases. This is because baking soda can absorb surrounding moisture. The absorption of water is highly influenced by the moisture level of the concrete. Moisture content of concrete have a significant impact on water absorption which can cause erroneous evaluations of the performance of concrete.

3.3 Compressive Strength Test

The compressive strength of hardened concrete was tested using the procedures outlined in BS EN 1992-1-1:2004. (Determination of compressive strength of concrete cubes). The average strength of concrete was calculated using all of the data acquired from the compression test for three samples of each percentage of baking soda in concrete mix. Table 6 and Figure 5 show the average compressive strength test results for concrete samples aged 7 and 28 days.

Table 6 - Compressive strength at 7 days and 28 days cubes

Specimen	Maximum Strength (MPa)							
	7 Days				28 Days			
	1	2	3	**Average**	1	2	3	**Average**
0%	21.4	19.8	20.1	**20.4**	30.9	32.3	30.5	**31.2**
3%	18.7	16.5	18.2	**17.8**	20.4	20.9	21.5	**20.9**
6%	6.3	7.5	6.4	**6.7**	8.3	6.7	7.9	**7.6**
9%	4.3	5.4	5.9	**5.2**	4.4	6.7	6.1	**5.7**

According to Table 6, only average strength of 0% baking soda concrete cube at 28 days achieve the minimum concrete strength which is 31.2MPa. The other cubes did not achieve the minimum concrete strength for grade M30. For concrete cube of 0% baking soda at 7 days, this cube did not achieve the minimum concrete strength because the concrete is not fully hardened. Concrete needs 28 days of curing to gain its maximum strength before it can be tested. For the other specimen, all of them failed to achieve minimum concrete strength for grade M30. It is because the quantity of binding factor which is cement is not enough in each mix after been replaced by baking soda. From this result, it can conclude that the higher the percentage of cement replaced by baking soda, the lower the maximum strength of the concrete cube.

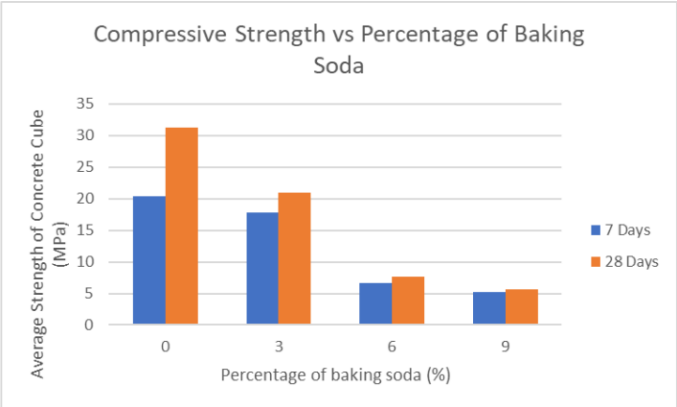

Fig. 5 - Graph of compressive strength over baking soda percentage at 7 and 28 days

According to Figure 5, the compressive strength of concrete increased as the age of the concrete grew. As we can see, the compressive strength of concrete at 7 days of every percentage of baking soda increased when they reached 28 days. This is due to concrete is fully hardened when they reached the age of 28 days. According to this finding, the highest compressive strength that can achieve by the baking soda concrete cube is 20.9Mpa for concrete containing 3 percent of baking soda as cement replacement material.

4. Conclusion

The addition of baking soda into concrete mix had increased the workability of the mixture. This indicates that the presence of baking soda will slow the hydration process that occur in concrete. This is because baking that also known as sodium bicarbonate will react with silicon dioxide that found in cement. This reaction will produce sodium silicate that can retard the hydration of cement. Based on the results obtained, it is proved that baking soda can increase the workability of concrete.

When baking soda content is increased, the percentage of water absorption will increase. The 9% of baking soda content has the maximum water absorption which is 4.89% while the 0% of baking soda content has the lowest water absorption which is 3.71% at 28 days. The higher the water absorption in concrete, the lower the durability of the concrete. Therefore, 3% of baking soda content is the most optimum content compared to other concrete that contain baking soda.

The final objective in this research is to investigate the compressive strength of concrete after cement replaced with baking soda. Based on the data obtained, the best compressive strength is 3% of Khairul Azli et al., Recent Trends in Civil Engineering and Built Environment Vol. 3 No. 3 (2022) p. 1-8 8 cement replacement with baking soda. However, the compressive strength of the concrete did not achieve the grade that is used in this research which is M30. This study is focused on cement replacement, that will be the reason why the concrete failed to achieve the strength required because lack of binding factor which is cement.

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