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White Cement and Concrete Compressive Strength in Sea Water Curing

Syahrul Sariman[1*], Abd. Rahim Nurdin[2], Riswanto M[3]

[1,2]Association Professor of Civil Engineering Dept, Bosowa University, Makassar, 90231, South Sulawesi Indonesia
[3]Post Graduate of Civil Engineering, Bosowa University, Makassar, 90231, South Sulawesi Indonesia
* Corresponding Author

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Abstract— *Concrete is the most widely used construction material in the world, including in areas around the sea. Several previous studies have shown that sea water can reduce the strength of concrete. Therefore, research is needed to overcome this. This study aims to obtain the compressive strength of concrete treated in seawater by substituting portland cement with white cement, which is 10%, 20% and 30%. The results showed that the substitution of White Cement could increase the compressive strength of the concrete, both cured with fresh water and cured with seawater. The decrease in compressive strength of concrete that does not contain white cement is 11.28% greater than that of concrete containing white cement which is only around 4% on average.*

I. INTRODUCTION

Concrete is a popular material for many construction applications, and it is widely used because of its strength, durability, reflectivity, and versatility [1] {2]..

However, the strength of concrete can be reduced due to the influence of sea water. The high chloride (Cl) content in seawater is a salt that is aggressive towards other materials, including concrete. Damage can occur in concrete due to the reaction between aggressive seawater that penetrates into the concrete with compounds in the concrete which causes the concrete to lose some mass, lose strength and stiffness and accelerate the weathering process. Sodium salts contained in seawater can become hazardous elements in combination with reactive alkaline aggregates, as in combination with alkaline cement. Salts such as Calcium Chloride and Magnesium Chloride will chemically react with cement thereby reducing setting time, increasing early strength but decreasing final strength and sulfate concentrations in seawater can also cause damage to the paste. In addition to chemical reactions, the crystallization of salt in the concrete cavity can cause destruction due to the crystallization pressure. Since crystallization occurs at the point of evaporation of water, the only if water can be absorbed in the concrete (3).

Research by The Construction civil.org shows that seawater contains about 3.50 per cent of dissolved salts. The approximate percentages of various salts are 78 percent of sodium chloride, 15 per cent of magnesium chloride and magnesium sulphate and the rest 7 per cent of calcium sulphate, potassium sulphate, etc. Now all chlorides tend to accelerate the setting of cement and to improve the strength of concrete in early stages. On the other hand, the sulphates tend to retard the setting of cement and to discourage the strength of concrete in early stages. It is found that the net effect of these two contradictory actions is the fall in strength of concrete to the tune of about 8 to 20 per cent. **[4]**. Several studies have been carried out to overcome concrete damage due to the use of seawater as a mixing material and as a curing medium. **Nagabhushanaet al, in 2017,** In this research work, the effect of salt water and fresh water on the compressive strength of concrete is investigated. For this, the concrete cubes were casted for a mix design of M-40, 1:1.30:2.63 by weight and 0.50 water-cement ratio was considered. The salt of various proportions like (25, 30, 35, 40, 45) grams/ litre of water was mixed and cured with fresh water. Some of the cubes were casted and cured with fresh water and other cubes were casted and cured using sea water.

The concrete cubes were cured for 3 and 7 days. The average compressive strength results obtained for 3 and 7 days using fresh water are 24.96 – 27.88 N/mm2 and for sea water are 22.43 – 27.31 N/mm2. The results obtained for various salt contents which were used for casting shows that there is increase in the compressive strength of concrete for low levels of salt content and there is decrease in compressive strength for high levels of salt content [5].

B.Sathish kumar et.al in 2018, The investigation aimed to use sea water in thondi region both for mixing and curing of concrete as the potable water is a scarce commodity on the planet. At least sea water can be adopted in the construction industry as an alternative ingredient to potable water particularly in the coastal region. In this research work, the effect of sea water and fresh water on the concrete is going to be investigated. Totally 27 specimen (9 cubes, 9 cylinders, 9 beams) were casted and cured with fresh water and other 27 specimens (9 cubes, 9 cylinders, 9 beams) were casted and cured using sea water. The concrete cubes were going to be cured for 7, 14 and 28 days There is lower in the strength of concrete specimen cast & cured with salt water as compared to those of cast & cured in fresh water. From the above research, we can conclude that if the water contains fewer amounts of hardness, PH and salts then there is no reduction in strength. Hence, this water can be used for casting. If reinforcement is needed to be provided, then the structures should be provided with proper admixtures to protect it from corrosion **[6]**. Therefore, to reduce the losses caused by the influence of chlorides and sulfates on this concrete, high-strength concrete is used. **Aditya Kumar Saini**'s research, et al in 2021, provides an overview of the use of waste material as a partial replacement of cement. The overall aim of this research is to find a waste material that has desired qualities when mixed with concrete Industrial by-products such as Ground granulated blast furnace slag, Silica Fume, glass powder, rice husk ash, Metakaolin, and fly-ash provide excellent. This aims to obtain high-strength concrete so that the penetration of seawater into the concrete becomes increasingly difficult due to the high density of concrete. **[7]**. One of the materials that can be used to increase the density of concrete is white cement. Because the price is more expensive than ordinary Portland cement, some cement can be substituted with white cement. Research by **Ahmed Shaban Abdel-Hay Gabr**, et al in 2015 used white cement to replace a certain amount of Sulphate Resisting Portland Cement (SRPC) which was used to testing fresh properties (slump), mass transport properties (Isat- sorptivity) and mechanical properties (compressive- splitting tensile). The thermal gravimetric analysis (TGA) of cement paste containing various blending of white cement with SRPC is also investigated. Concrete specimens were prepared with SRPC, water, sand and dolomite of 10 mm maximum nominal size. The blending of white cement with SRPC were 0, 10, 20,30,40,50 and 100% at w/c = 0.50. The effect of 10% SF on compressive strength of concrete made with various percentage of white cement to SRPC is also considered. The results indicated that, 30 % percentage of white cement to SRPC exhibited peak slump, the maximum compressive and splitting strength were observed at 30 % percentage of white cement to SRPC . Also, the lowest values of Isat and sorptivity were occurred at 30 % percentage of white cement to SRPC which agree with the results of compressive and splitting strength. 10 % SF has an adverse effect on

compressive strength of concrete containing various percentage of white cement [8].

compressive strength of concrete containing various percentage of white cement [8].

In accordance with the statement above, this study aims to answer the research questions: (1). Whether the white cement used to partially replace portland cement can increase the compressive strength of the concrete, (2). How is the difference in the compressive strength of concrete using white cement when preserved with fresh water and sea water.

II. LITERATURE REVIEW

A. White cement.

White cement is a type of portland cement that does not contain calcium oxide (CaO) so it does not cause pollution White cement is usually used for artistic and decorative buildings and for installing ceramics. The function of cement in general is to glue aggregate grains to form a compact mass, even though cement only fills about 10% - 30% of the volume of concrete. The advantage of white cement compared to other types of portland cement is that white cement hardens faster because it contains more silicon dioxide (SiO_2) and can be colored if desired. **[9]**.

B. Chemical Composition of Seawater

Salt content in seawater (salinity), measured from the amount of dissolved material in each kilogram of seawater; or the equivalent of parts per thousand (1/1000). Salinity describes the amount of dissolved material in seawater; according to Vicat generally ranged from 3.4-3.5%. [10] . Table 4 is an estimate of the salinity of some of the world's famous seas. The ability of water to dissolve salt tends to vary and depends on where the sea is located, but the ratio of the main components contained in it is relatively constant. The main components are calculated to identify weaknesses and possible collapse of buildings in areas affected by seawater. The physical characteristics and chemical composition of seawater in general can be seen in table 4. [11}

Table 4. Physical characteristics and chemical composition of seawater

Spesific Gravity	1,022
pH	7,77
Na	9,290 part per thousand
K	0,346 part per thousand
Ca	0,356 part per thousand
Mg	1,167 part per thousand
Cl	17,087 part per thousand
SO_4	2,378 part per thousand
CO_3	0,11 part per thousand

Sumber : Widianto, 2017

C. **Fine and Coarse Aggregate**

Parameters of Fine Aggregate (Sand) and Coarse Aggregate (crush Stone) :

- **Sive analiysis** Sieve Analysis Test of fine and coarse aggregate is done to check the gradation of aggregate particles. Aggregate particle distribution in aggregate volume is important **for** good quality concrete. In this test, the aggregate sample is passed through a series of IS sieve sizes ordered from bigger to smaller sizes at the bottom. A sand particle having a respective size is retained on a sieve and then the weight of sand retained on each IS Sieve is taken Then % of aggregate retained on each IS Sieve is calculated which shows the particle size distribution in the aggregate sample. [12][13][14]
- Water content. Water content in the aggregate is strongly influenced by the amount of water contained in the aggregate. The greater the difference between the weight of the original aggregate and the weight of the aggregate after drying the oven, the more water contained by the aggregate and vice versa. Tolerance of water content in fine aggregates is 3% -5% and coarse aggregate is 0.5% -2%N .**[15]**
- The volume weight is the ratio between the weight of the aggregate in the dry state and its volume. The purpose of the test is to determine the fine or coarse aggregate content weight. Volume weight tolerance for fine aggregate is 1.4 kg / ltr-1.9 kg / ltr and for coarse aggregate of 1.6 kg / ltr-1.9 kg / ltr. [**16],**
- Specific gravity is the ratio between the weight of dry aggregate and the weight of distilled water whose contents are the same as the aggregate content in a saturated state at a certain temperature. Specific gravity for fine aggregate is 1.6% -3.3% and for coarse aggregate is 1.6% -3.2%. Absorption is the percentage of the weight of water that can be absorbed by the material against the weight of dry aggregate. The tolerance of observation for fine aggregates is 0.2% -2% and for coarse aggregate of 0.2% -4%. [**17], [18]**

III. METHOD AND MATERIALS

A. *Research Design*

This research is an experimental test through laboratory testing to obtain test results data. The data is processed quantitatively to obtain a result in accordance with the research objectives. The research was carried out at the Laboratory of Concrete Materials and Structures, Department of Civil Engineering, Faculty of Engineering, Bosowa University using a cylindrical test object with dimensions of 15 cm x 30 cm. The study began by doing a mix design of concrete using Portland cement, sand, crushed stone and water as much as 20 samples soaked in fresh water for 28 days, then testing the compressive strength with a target compressive strength of f'c = 20 MPa. This concrete mixture is used as a control concrete mixture. Furthermore, 3 cylinders of control concrete mixture were cured in seawater for 28 days to determine the effect of the immersion media on the compressive strength of the concrete. Furthermore, white cement was used to replace some of the Portland cement as such as 10%, 20% and 30% then the variations of the mixture were immersed in fresh water and sea water.

Each variation consisted of 3 samples with fresh water and sea water immersion media, so a total of 18 specimens

B. *Test Method* .

- Slump Test

Concrete Slump Test is a measurement of concrete's workability, or fluidity. It's an indirect measurement of concrete consistency or stiffness. A slump test is a method used to determine the consistency of concrete. The consistency, or stiffness, indicates how much water has been used in the mix. The stiffness of the concrete mix should be matched to the requirements for the finished product quality

The slump test result is a measure of the behavior of a compacted inverted cone of concrete under the action of gravity. It measures the consistency or the wetness of concrete which then gives an idea about the workability condition of concrete mix **[19]**

Fig.1. Slump test Apparatus

- Concrete Compressive test

The concrete compressive strength is determined as the value of the acceptable axial load divided by the surface area of the concrete specimen under test. The compressive strength of concrete was determined at the age of 28 days. after cured. The required compressive strength of concrete is in accordance with the structural design requirements and local conditions. [20]. Calculation of compressive strength is carried out by the formula :

$$f'c = P / A$$

where :

f'c = concrete compressive strength (MPa)

P = axial Load (N)

A = Surface area of specimen (cyilinder) (mm2)

Fig.2. Concrete Compressive Test Machine

IV. RESULT OF TEST

A. *Testing of Aggregate Characteristics*

Aggregate testing consists of sieving analysis, material passes # 200, water content, unit weight, and specific gravity

1) Fine Aggregate (Sand):

Table 1,. Test result properties of Sand

NO.	Description	Code	Test Result
1	Sieve Analysis	*ASTM 136 -95A*	
2	Material Less than #200	*ASTM C 117 - 95*	3.15%
3	Moisture Content	*ASTM D.2216-98*	4.45%
4	Volume Weight	*SNI 1973 - 2008*	
	- loose		1.15%
	- Congested		1.76%
5	Spesific Gravity	*ASTM C 128 – 04*	
	- Bulk		2.62%
	- SSD		2.64%
	-- Apparent		2.67%
	Absorption		1/92%

2) Coarse Aggregate

Table 2,. Test result properties of Crushed coarse ¾"

NO.	Description	Code	Test Result
1	Sieve analysis	*ASTM 136 -95A*	
2	Material Less than #200	*ASTM C 117 - 95*	0.79%
3	Moisture Content	*ASTM D.2216-98*	0.56%
4	Volume Weight	*SNI 1973 - 2008*	
	- loose		1.48%
	- Congested		1.52%
5	Spesific Gravity	ASTM C127 – 07	
	- Bulk		2.48%
	- SSD		2.54%
	- Apparent		2.64%
	Absorption		2.34%

Base of sieve analysis of fine and coarse aggregate to find a aggregate combination grading consist of 60 % Coarse Agregate pass ¾" and 40 % sand, as followsc ;

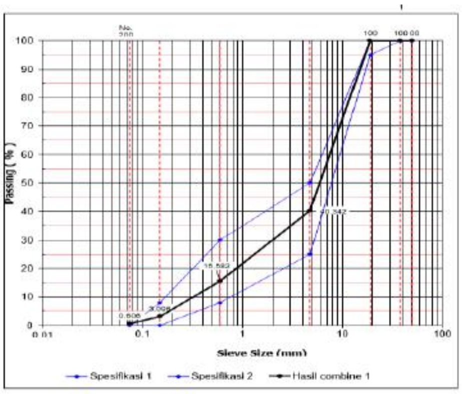

Fig.3. Aggregate combined grading

B. Mix Design

In this study, the mix design method of the Indonesian National Standard (SNI) No. M 03-2834-2000 was used and the composition for control concrete was obtained, as follows

Table 3. Batch proportion of concrete mix

Raw material	Weight (kg) of m3 concrete	Volume of cylinder (m^3).	Weight (kg) of 1 specimen
Water	192,06	**0.0053**	**1.017**
Sand	730,82		**3.873**
Crush Agg. 1- 2	1047,5		**5.551**
Portland Cement	**379,63**		**2.012**

Based on this composition, a mixture was made by controlling workability through slump testing and formed in a cylindrical mold with a diameter of 15 cm and a height of 30 cm, then curing in clean water for 28 days. Then the compressive strength test was carried out.

The results of the control concrete compressive strength test are presented in table 4.

Table 4. Compressive strength test results of control concrete

Specimen No.	Slump	Weight	f'c
	(cm)	(Gram)	(N / mm²)
1	7.5	12240	20.67
2	7.7	12259	21.51
3	7.2	12063	21.51
4	7.5	12199	21.23
5	8.0	12173	22.93
6	7.9	12162	22.36
7	7.8	12153	21.80
8	7.7	12103	21.51
9	7.7	12075	23.21
10	7.6	12978	22.65
11	7.5	12188	22.08
12	8.1	12118	20.95
13	7.3	12098	21.51
14	7.2	12188	22.93
15	8.1	11941	22.65
16	7.6	12008	22.08
17	7.2	11990	20.67
18	7.2	12121	20.95
19	7.4	11998	21.51
20	7.5	12130	22.08

f'c Avarage : f'cr = 21.84 MPa

Deviation standard : sd = 0.79 MPa

f'c = f'cr – 1.34 sd = 20.78 MPa

f'c = f'cr – 2.33 sd + 3.5 = 23.50 MPa

Choose a larger value

Correction factor for 20 samples; 1.08, so that

f'c = 23.50 / 1.08 = 21.75 MPa > 20 Mpa

Thus the mixture qualifies as f'c = 20 MPa

C. Making test samples and testing the compressive strength of variation concrete

1) Variation of concrete mix composition

Composition of water, Sand and Coarse Agregate for weigth of 1 specimen same of the Mix design. While ratio of Portland cement and white cxement was variation 95 % : 5%, 90% : 10 % and 85 : 15 % respectively. Composition of mixture can be seen at table 5

Table 5 Proportion of Portland Cement (PC) and White Cement (WC)

No	Weight (gr) of 1 specimen		Media of curing	Notation
	PC	WC		
1	2012.0	0	Sea water	**BN L**
2	1810.8	100.6	Fresh Water	**BV90 T**
			Sea water	**BV90 L**

3	1609.6	201.2	Fresh Water	**BV80 T**
			Sea water	**BV80 L**
4	**1408.4**	**301.8**	Fresh Water	**BV70 T**
			Sea water	**BV70 L**

Each variation consists of three pesimen.

After curing among 28 days, the all specimen tested by compressive strength test and result of test can be seen at table 6

Table 6 Result of compressive strength test of all specimen

Notation	Slump (cm)	Weight of Specimen (gram)	f'c (MPa)	Average f'c (MPa)
BN.L	8,0	189.25]	18.68	18.485
	7.8	12240	19,25	
	7,8	12259	18.29	
BV5T	7.6	12063	21.51	22.533
	7.7	12199	22.88	
	7.8	12173	23.21	
BV5L	7.6	12162	21.88	21.595
	7.8	12153	21.31	
	7.5	12103	20.38'	
BV10T	7.5	12075	23.78	23.590
	7.5	12978	24.91	
	7.4	12188	22.08	
BV10L	7.6	12118	22,65	22.635
	7.7	12098	22.51	
	7.5	12188	22.76	
BV15T	7.3	11641	26.04	24.533
	7.4	11699	22.08	
	7.4	11660	25.48	
BV15L	7.4	11679	23.78	23.590
	7.2	11714	22.98	
	7.5	11660	24.01	

V. DISCUSSION

A, Effect of sea water curing

The test results show the comparison between normal concrete treated in fresh water and sea water as shown in the graph in Figure 3 as follows

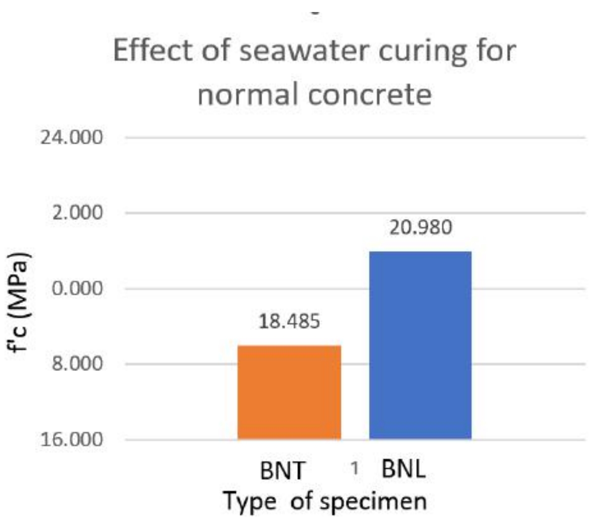

Fig.4. Effect of seawater for normal concrete

Table 7 Effect of sea water curing on normal concrete

No	Notation	f'c (Mpa)	Different (Mpa)	Percentage (%)
1	BN T	20.980	2.495	11.89%
	BN L	18.485		

The test results showed a decrease in the compressive strength of concrete immersed in seawater compared to the compressive strength of concrete treated in fresh water. The data shows that the decrease in compressive strength reached 11.89%.

5.2. Effect of Reducing Portland Cement with White Cement

The test results show the effect of substitution of Portland cement with white cement according to the graph in Figure 4 and Table 8 a and 8b

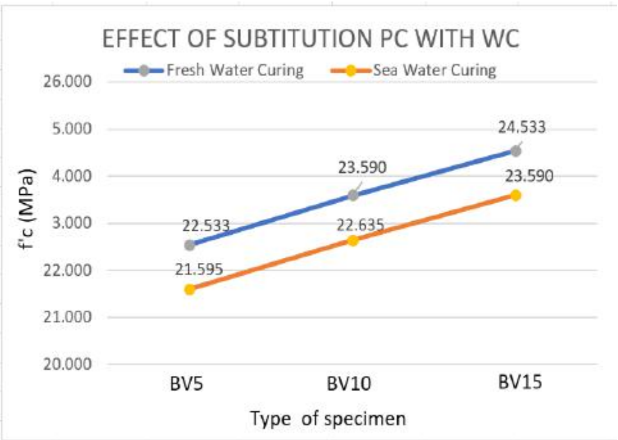

Fig.5. Effect of substitution Portland cement with white cement to concrete compressive strength

Table 8a Effect of substitution of Portland cement with white cement on the compressive strength of fresh water cured concrete

No	Notation	f'c (Mpa)	Difference	
			MPa	%
1	BV5T	22.533		
			1.057	4.69%
2	BV10T	23.590		
			0.943	4.00%
3	BV15T	24.533		

Table 8b Effect of substitution of Portland cement with white cement on the compressive strength of sea water cured concrete

No	Notation	f'c (Mpa)	Difference (Mpa)	(%)
2	BV5L	21.595		
			1.040	4.82%
3	BV10L	22.635		
			0.955	4.22%
4	BV15L	23.590		

From Figure 5 and Tables 8a and 8b, the results show that the effect of substituting Portland cement with white cement will increase the compressive strength of concrete by 4.40% for every 5 % increase in reduction of Portland cement with white cement.

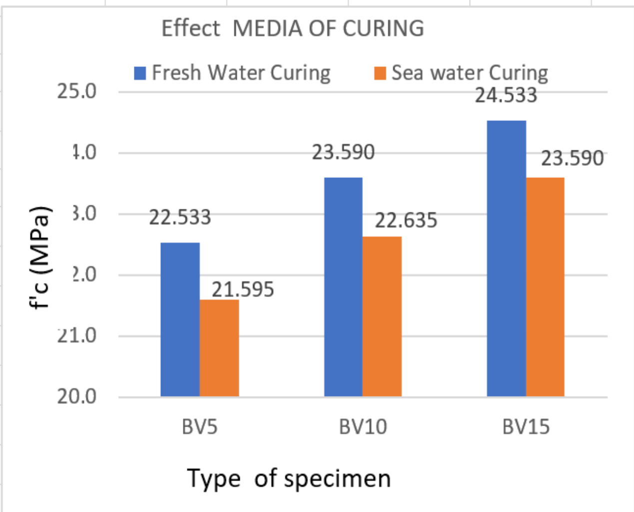

Fig.6. The effect of curing media on the compressive strength of concrete with variations in the white cement content

2. Comparison of the concrete compressive strength due to differences in curing media

The test results show the effect of the curing medium on the concrete, which has partially replaced portland cement with white cement according to the graphs in Figure 6 and Table 9.

Table 9. The compressive strength of concrete that has been substituted with white cement with different media of curing.

No	Notation	f'c (MPa)	Difference	
			MPa	(%)
1	BV5T	22.533	0.938	4.16%
	BV5L	21.595		
2	BV10T	23.590	0.955	4.05%
	BV10L	22.635		
3	BV15T	24.533	0.943	3.85%
	BV15L	23.590		

Figure 6 and table 9 show the difference in the concrete compressive strength where Portland cement has been partially replaced with white cement and then curing in a different cured medium.

The test results show that the compressive strength of each addition of white cement substitution in Portland cement is 5 %, then curing is done in fresh water and sea water. The compressive strength decreases in specimens cured in seawater.

Each addition of white cement substitution in Portland cement is 5%. there is a difference in the average compressive strength of 4.02% of specimens cured in fresh water compared to specimens cured in sea water. When compared to concrete that does not contain white cement or to control concrete which has a decrease in compressive strength of 11.89%, this shows quite good results in the use of white cement as an effort to reduce the effect of seawater immersion on the compressive strength of concrete.

The replacement of 5 % Portland cement with white cement has also been able to increase the compressive strength of concrete cured in seawater to exceed the targeted concrete compressive strength of 20 MPa.

VI. CONCLUSIONS

Based on the results of the testing and discussion above, it can be concluded:

1. White cement can be used to partially replace Portland cement to increase the compressive strength of concrete

2. The decrease in the compressive strength of concrete containing white cement due to cured in seawater is smaller than the decrease in the compressive strength of normal concrete

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