Utilization of Sea Water to Production of Concrete in Terms of Mechanical Behavior

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Utilization of Sea Water to Production of Concrete in Terms of Mechanical Behavior

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Abstract. Supplies of fresh water in everyday life has increased, but the smaller the potential sources of water so we need to think of alternative uses of water for concrete construction work. This study aims to compare the compressive strength of concrete using sea water and fresh water with water cement ratio of 0.37. An experimental research was conducted by making specimens of concrete cylinder with a diameter of 150 mm and height of 300 mm. The study used specimens of concrete using sea water and fresh water. There were 32 specimens for each kind of concrete. The treatment of each specimen used sea water and fresh water in accordance with the type of mixing water. The immersion periods were 1, 3, 7 and 28 days. Mechanical testing of concrete was conducted by testing the compressive strength and elasticity, while the testing of concrete microstructure was conducted by using X-Ray Diffraction (XRD) and Scan Electron Microscopy (SEM). The results revealed that in the 28-day immersion period. The compressive strength values of the sea water concrete and fresh water concrete were 44.88 MPa and 44.03 Mpa respectively. The difference of compressive strength in the two types of concrete was not significant. The result of microstructure test in the 28-day period revealed that in the sea water concrete, there was a formation of Friedel's salt ($3CaO.Al_2O_3.CaCl_2.10H_2O$) of 7.71%, tobemorite ($3CaO.2SiO_2.3H_2O$) of 58.66% and calcium hydroxide ($Ca(OH)_2$) of 6.18%. In the fresh water concrete, there was a formation of tobermorite ($3CaO.2SiO_2.3H_2O$) of 51.35%, and calcium hydroxide ($Ca(OH)_2$) of 22%. There was no formation of Friedel's salt in the fresh water concrete because there was no mutual reaction between chloride and calcium hydroxide elements. From the regression analysis, showed that the difference of microstructure compressive strength differences caused by differences in the microstructure of the content of the two types of concrete.

1. Introduction

One of the building blocks of concrete is water, one of which is potable water. In the current phenomenon, the need for water that meets the requirements for its use has begun to become deficient, especially in big cities or in developed countries where clean water is only prioritized on primary needs. In this life cycle, the world of civil engineering, especially in developed countries, has thought about the future challenges of reducing the potential for tap water (fresh water) which can be used as a material for mixing concrete, moreover, infrastructure development is increasing along with the use of clean water that is needed Lots. Data from the United Nations and the World Meteorological Organization predict that around 5 billion people will lack of clean water and even for potable water. The conference also said that by 2025 half of humanity will live in areas that lack of clean water (freshwater) [1].

Various studies have been conducted on mixing concrete using sea water, a study on the performance of concrete mixtures using sea water in tidal environments. In this study, observing the behavior of compressive strength, chloride penetration and steel corrosion in concrete with a mixing pattern using sea water and tap water (fresh water). The results showed that the concrete mixture with sea water showed an advantage at high initial strength. After 20 years of exposure, there is no significant difference in the compressive strength in mixing the concrete using sea water and tap water [2].

Research on the possibility of using sea water as mixing water in concrete. In this study using OPC (*Ordinary Portland Cement*) and BFS cement (*Blast Furnace Slag*) mixed with fresh water and sea water in order to compare the durability of concrete. In this study, it was also found that mixing with sea water decreased the number of pores which increased the compressive strength of BFS cement compared to using fresh water [1]

For hollow concrete, there is a study examined the effect of sea water on the strength of hollow concrete using Portland composite cement and *polypropylene micro monofilament* fibers. The hollow concrete specimens were immersed in sea water for up to 28 days. Compressive strength tests and flexural strength tests were carried out at 3, 7 and 28 days in order to investigate the strength development. The results show that the strength of porous concrete can develop in sea water. It was revealed that there was not a sufficient effect of sea water on the hydration process when porous concrete was immersed in sea water. Good bonding occurs between cement paste and coarse aggregate, so that it can withstand compressive and bending loads having a good capacity in hollow concrete [3].

Research on the binding of chlorides to various types of cement on the contribution of C-S-H and AFm hydration. This study examines the isothermal chloride binding of various types of cement primarily to determine the contribution of C-S-H and AFm hydrates to the binding of *isotherms* chloride. The cements used are *Ordinary Portland Cement* (OPC), *Modified Cement* (MC), *Fast-Cement Portland Cement* (RHC) and *Low-Heat Portland Cement* (LHC). Total chloride content and free chloride content were analyzed by ASTM. The C-S-H content, AFm hydrate and salt were *Friedel's* determined by X-ray diffraction analysis *Rietveld* (XRD *Rietveld*). The results showed that OPC had the highest chloride binding capacity, and, LHC had the lowest chloride ion binding capacity [4].

Indonesia is also an archipelagic country in the sense that at every point of location, there are buildings located in the coastal area such as the building of the Harbor Pier, Talut, and other buildings that we often find according to the needs of community activities. In such conditions, it is possible that the need for clean water is very difficult to reach and there are even some areas that are isolated from clean water. Nowadays, there are several areas in the archipelago that often use contaminated water with high chloride (seawater) and even use beach sand for mixing concrete. From this phenomenon, by looking at the abundant potential of sea water sources, there is an idea to use sea water as a mixing material for concrete, especially on buildings that are located near the seawater, and often interact with sea water. In this study, the microstructure content of sea water concrete and freshwater concrete will be examined on the effect of the compressive strength of the two types of concrete.

2. Materials and Method

2.1. Location and Type of Research

This research was conducted at the Eco-Materials Laboratory at the Civil Engineering Department of Hasanuddin University using experimental methods, namely mechanical testing which includes testing the compressive strength of cylindrical concrete. Meanwhile, for microstructure testing using XRD and SEM test equipment.

2.2. Population and Sample

Compressive strength testing is carried out at the age of 1, 3, 7 and 28 days which refers to SNI number 1974 (2011). The formula for compressive strength is given by $\sigma = \frac{P}{A}$, where P = Maximum load, and A = Surface area of cylindrical concrete. Apart from the concrete mechanical test, concrete microstructure testing was also carried out at each age of 1, 3, 7 and 28 days.

The materials and equipment used in the manufacture of cylindrical concrete are the Tonasa brand composite Portland cement, gravel from the Bili-Bili river, sand from the Jeneberang river and Barombong sand as well as seawater and fresh water. The equipment used includes capacity testing machines 1500 kN, mold cylinder size 150 mm in diameter and 300 mm in height, mixing machine /*mixer* concrete, shovel, bucket, balance and other attachments.

This research was conducted for 28 days in a laboratory with two types of cylindrical concrete items made. Seawater concrete is made with a composition of materials consisting of the Portland cement composite of the Tonasa brand, gravel from the Bili-Bili river, sand from Barombong beach, and Barombong sea water. Meanwhile, freshwater concrete has a material composition consisting of the cement *Portland* composite of the Tonasa brand, gravel from the Bili-Bili river, sand from the Jeneberang river, and freshwater (tapwater) taken from the Civil Engineering Laboratory of Hasanuddin University. The composition of seawater concrete and freshwater concrete were each made in the form of a cylinder mold. The amount made of each was 32 pieces divided into four immersion items for 1, 3, 7 and 28 days. From the water-cement factor 0.37 gives the composition of the design mix for seawater concrete in 32 cylindrical concrete pieces giving the proportion of 32.98 kg of water, 93.15 kg of cement, 90.57 kg of sand and 187.06 kg of gravel. While the composition of the mix design for freshwater concrete for 32 samples was 33.79 kg of water, 93.99 kg of cement, 71.62 kg of sand and 203.51 kg of gravel.

At the end of each immersion time, a cylinder compressive strength test is carried out using a concrete compressive strength equipment. Microstructure testing is also carried out according to the immersion age so that any changes in mechanical behavior can be followed by analyzing changes in microstructural behavior. In microstructural research, there are two types of equipment used, namely molecular microstructure testing using *X-Ray Diffraction (X-Ray Diffraction)* and detecting chemical elements using *Scan Electron Microscopy (SEM)*. The data obtained from mechanical testing and microstructural testing will be analyzed in relation to using regression analysis where mechanical testing is the dependent variable and the microstructure is the independent variable.

3. Results and Discussion

3.1. Concrete Mechanical Test

The compressive strength test was carried out based on the immersion age which can then be seen the comparison of the results of the compressive strength in the attachment of Table 1 and. The compressive strength of seawater concrete has a higher value than the compressive strength of freshwater concrete which can be seen visually in Figure 1.

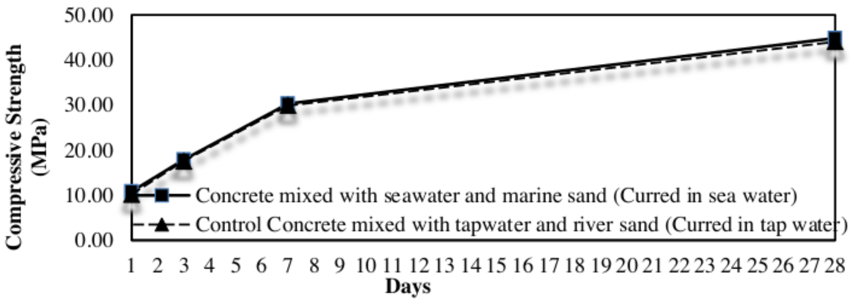

Figure 1. The increase in compressive strength of the seawater concrete and freshwater concrete

3.2. Microstructure Test

X-Ray Diffraction done by entering a sample of each type of concrete and then analyzed based on the intensity with the magnitude of the 2-theta angle. Likewise, analysis was *Scan Electron Microscopy* carried out using the tool *Vega3SB Analytical Tescan.* The results of these two microstructural tests can be seen in Table 1.

Table 1. Results of compressive and microstructural strength testing on seawater and freshwater concrete

Specimens	Compressive strength f'c (MPa)				Sea water microstructure											
					Tobermorite (%)				Calcium hydroxide (%)				Friedel salt (%)			
	1 Day	3 Days	7 Days	28 Days	1 Day	3 Days	7 Days	28 Days	1 Day	3 Days	7 Days	28 Days	1 Day	3 Days	7 Days	28 Days
Seawater concrete	11.31	19.23	31.11	45.25	30.77	34.72	43.63	58.66	10.23	9.37	7.58	6.18	0.3	1.39	3.25	7.71
	10.75	16.97	29.70	44.40												
	10.56	17.54	29.98	44.97												
Average	**10.84**	**17.91**	**30.26**	**44.88**												
Freshwate concrete	10.46	18.67	30.55	42.42	29.97	31.58	39.20	51.35	11.09	12.28	16.80	22.00	-	-	-	-
	10.18	15.84	29.41	44.69												
	9.90	18.10	29.70	44.97												
Average	**10.18**	**17.54**	**29.89**	**44.03**												

3.3. Data Analysis

Data that been obtained were analyzed using linear regression method which aims to find the relationship between existing data. The compressive strength of the concrete is used as the dependent variable object, while the concrete microstructure is the independent variable. In relation to this data, it will look for the causes of an increase in the compressive strength of sea water concrete. Along with these facts, the microstructure behavior will be analyzed between the two types of concrete. The relationship between *tobermorite* $(3CaO.2SiO_2.3H_2O)$ (x) and the compressive strength of seawater concrete (y) can be seen in the attachment of Figure 2.

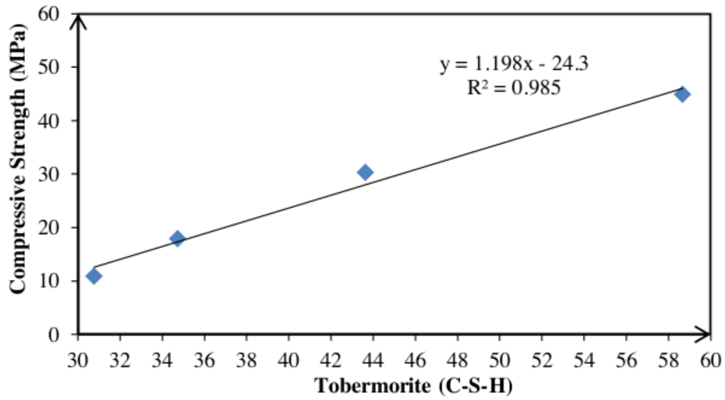

Figure 2. Linear regression tobermorite relationship with the compressive strength

From the regression analysis, it gives the equation y = 1.198x - 24.3 with a coefficient of determination r^2= 0.985 and the correlation coefficient r = 0.992. From this equation provides a very strong relationship between the two variables. The coefficient of determination r^2= 0.985 means that tobermorite has an effect on 98.5% of compressive strength. When viewed from the effect of calcium hydroxide (Ca $(OH)_2$) (x) with an increase in compressive strength (y) in Figure 3.

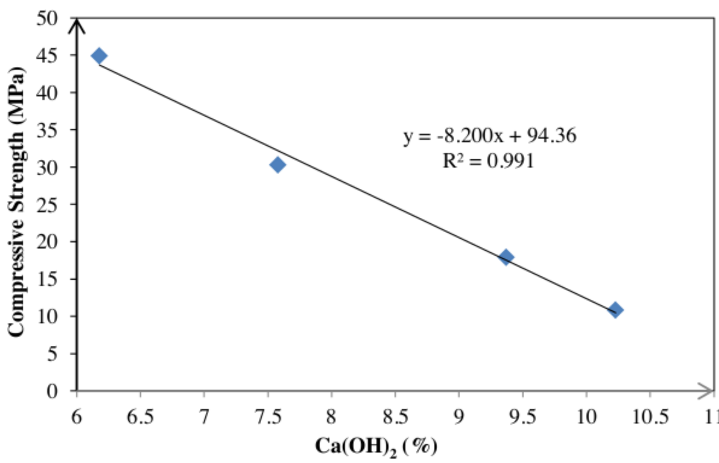

Figure 3. Linear regression models with strong ties calcium hydroxide press

Regression analysis gives the equation y = -8.2x + 94.36. The resulting relation coefficient is r = 0.995, which means that it has a very strong correlation with the increase in compressive strength. The coefficient of determination r^2 = 0.991 makes it clear that calcium hydroxide has a 99.1% effect on the increase in compressive strength. While the effect of *Friedel's* salt (x) to the increase in the compressive strength of concrete (y) can be seen in Figure 4.

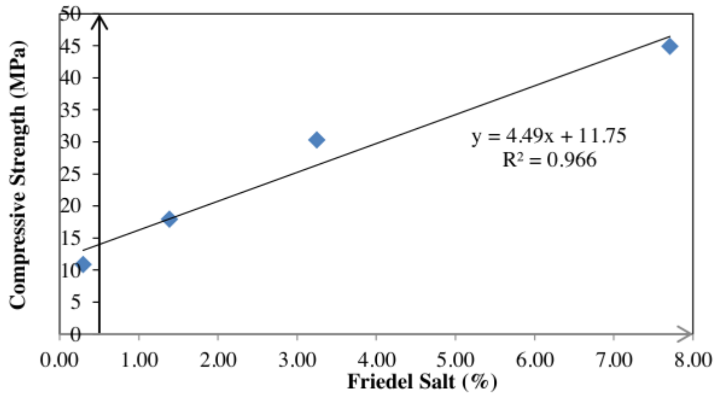

Figure 4. Linear regression model relationships *Friedel's* salt with compressive strength

From the regression analysis obtained the equation y = 4.494x + 11.75, where r^2 = 0.996 and r = 0.998. At the value of the coefficient of the relationship, it provides a very strong relationship to the two variables, while the value of r^2 = 0.996 means that *Friedel's* salt has an effect on 99.6% of the increase in the compressive strength of sea water concrete.

From the results of the data analysis above, it shows that the relationship between the characteristics of the concrete microstructure is very influential on its compressive strength behavior.

This study shows that the microstructure characteristics of the concrete give a very high effect on the compressive strength of the concrete produced. The difference in the content of *tobermorite, Friedel's* salt, and calcium hydroxide in the two types of concrete results in different compressive strength. From the results of the regression analysis, it also shows that the characteristics of the concrete microstructure strongly indicate the difference in the compressive strength of the two types of concrete.

The higher the content *tobermorite* in the concrete, the higher the compressive strength produced. This is caused by the role of *tobermorite* in concrete which functions to form the strength of the concrete. Another case with calcium hydroxide which is inversely proportional to the compressive strength that occurs. In terms of function, calcium hydroxide means that the compound has multiple functions. On the one hand, calcium hydroxide is able to protect concrete reinforcing steel from corrosion because it is able to maintain the pH of the concrete. However, on the other hand, calcium hydroxide is also very soluble, soft and reacts with any compound so that the reduced levels of calcium hydroxide can increase the compressive strength of concrete. Meanwhile, *Friedel's* salt plays a role in filling the pores in concrete, thereby increasing the compressive strength of concrete based on the quantity it contains [4]. *Friedel's* salt is a formation of the reaction process between calcium hydroxide and sodium chloride in concrete to form calcium chloride. This calcium chloride re-reacts with tricalcium aluminate to form *Friedel's* salt.

Sea water that contains NaCl contributes to fresh concrete which will form *Friedel's* salt crystals which can increase the pH higher, increase the alkalinity so that it will activate the hydration of the cement and provide a denser paste structure with smaller pores [5]. If the chloride ions contained in water react with cement, some of the cement hydration products will bind chloride ions in the concrete either through chemical bonding or through physical adsorption. Chloride ions that are not bound by hydration products will explore through the pores of the concrete and penetrate into the galvanized layer of steel [6]. Where the amount of bound chloride has reached its maximum point, meaning that there are no more elements or compounds from cement that can bind chloride [7].

The process of chloride attack on concrete can be explained by the following chemical reaction. NaCl and MgCl after reacting with $Ca(OH)_2$ and becoming calcium chloride [8].

$$Ca(OH)_2 + 2NaCl \longrightarrow CaCl_2 + 2NaOH$$
$$CaCl + (3CaO)\ Al_2O_3 + 10H_2O \longrightarrow (3CaO)\ Al_2O_3.CaCl_2.10H_2O$$

Calcium Chloroaluminate/*Friedel's* salt

In marine environments, chloride penetrates into concrete which comes from seawater to form *Friedel*'s salt. *Friedel's* salt occupies the pores in the concrete. In the conditions studied, up to the age of 28 days, it turns out that the chemical elements of cement are still sufficient and the chloride content is almost completely bound by the chemical elements of cement. In the sense that it allows for a very long time to wait for the penetration of chloride from outside through the pores of the concrete so that it can still protect itself from the corrosion process. A study that provides a statement on research conducted for 30 years which examined chloride penetration and corrosion of cylindrical concrete reinforcement. One of the conclusions given is that the type of concrete made using cement slag still shows a high level of reinforcement in the reinforcement. This means that it can still protect the corrosion of steel reinforcement in concrete exposed for 30 years in an environment that contains high chlorides [9].

4. Conclusion

From the results of this study it can be concluded that the presence of the element NaCl in the seawater content can bind calcium hydroxide compounds in concrete so that the calcium hydroxide content in seawater concrete is less. This can cause the compressive strength of the concrete to increase. With the continuous reaction between NaCl and $Ca(OH)_2$, it is able to form *Friedel's* salt which directly fills the pores in the concrete so that it also affects the addition of the compressive strength value of the concrete. This is what causes the compressive strength of concrete mixed with sea water to be different from the compressive strength of concrete mixed with fresh water. From the microstructure review, the difference of tobermorite is 7.31%, calcium hydroxide is -15.82%, and is *Friedel's* salt 7.71%, which can cause a difference in compressive strength of 1.93% between sea water concrete and freshwater concrete.

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