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Microstructure Characteristics of Self Compacting Concrete using Sea Water

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Abstract

In the cycle of life, the needs of fresh water more and more. Infrastructure development is increasing. On the concrete industry, several billion tones of water used in earth as mixing water, treatment water (curing) and cleaner water every year, where using of sea water is obstructed. For that, the using of sea water which consists of 97% of the total water on earth is absolutely necessary.Self-compacting concrete (SCC) has dense microstructure. Knowledge about the microstructure and properties of each component a concrete and their relationship is useful to control the behavior. This research aims to know the relationship between compressive strength and microstructure characteristics of Self Compacting Concrete which using sea water up to the age of 90 days. The results of this study were the compressive strength of SCC using sea water is higher than the SCC using fresh water. Sea water does not reduce the strength of SCC concrete until the age of 90 days, but instead of Seawater is accelerating the development of SCC concrete strength at early age. Compressive strength of concrete SCC is influenced by the phase microstructure (especially with tobermorite and portladite) formed in the concrete.

Paper Code:

Keywords: Sea water, SelfCompacting Concrete (SCC), Compressive strength, Tobermorite, Portlandite

Introduction

In the cycle of life, the needs of fresh water more and more. Infrastructure development is increasing. On the concrete industry, several billion tones of water used in earth as mixing water, treatment water (curing) and cleaner water every year, where using of sea water is obstructed. For that, the using of sea water which consists of 97% of the total water on earth is absolutely necessary.

Microstructure of concrete is the type, number, size, shape, and distribution of solid phase in the concrete. Harsh elements of the material microstructure can be seen from the cross section of the material, while the subtle elements of the microstructure can usually be seen with the aid of a microscope. Material properties and microstructure relationships are the core of modern materials science. Concrete is a material that heterogeneous and complex microstructure. Material properties and microstructure relationships are the core of modern materials science. Concrete is a material that heterogeneous and complex microstructure. Therefore, it is very difficult to establish realistic models for microstructure while the material behavior can be predicted perfectly. However, knowledge about the microstructure and properties of each component a concrete and their relationship is useful to control the behavior. One component of the microstructure a concrete is cement paste that formed. The main phases of the paste are hydrated calcium silicate, calcium hydroxide, and anhydrates clinker grains [1].

Research about the using of sea water as mixing water in the concrete is still lacking. Concrete research using sea water as mixing water with the use of various types of cement and concrete over the age of 20 years exposure test was performed by Otsuki, N et al. [2], and they have concluded that it is safe to use sea water as mixing water in the concrete, and sea water has little effect on the strength and corrosion in concrete. Furthermore, by Tjaronge[3], have researched the use of sea water as mixing water, concrete without curing/cured in air has poor hydration process so many pores and cracks that occur in concrete. Besides, by Falah M. W [4], Aburawy, MM and Swamy, RN [5], have researched concrete using sea water as mixing water and cured in sea water. They concluded that sea water has accelerated the development of quality concrete early age up to 14 days.

One of the concepts of innovative concrete technology that is effective and efficient is the self compacting concrete (SCC). Fresh SCC has high fluidity that can flow and fill the space in the mold with little or no vibration process [6].

SCC has done a lot of research, among others, by Dinakar, P. et al. [7], examined the SCC with normal concrete. The result is that the SCC has a permeable voids and water absorption is higher than normal concrete with the same strength. However, the diffusion of chloride and acid attacks on high volume fly ash SCC had significantly more weight lower and chloride ion diffusion. Furthermore, the study by Furuya, D et al.[8]. using the Blast-Furnace Slag (BFS) cement by mixing sea water causes a reaction ratio of BFS up, Friedel's salt and ettringite products increased, and the micro-pore total pore volume decreased compared to the mixing water flute. The results of compressive strength test specimens were stronger mixing of sea water mixing distilled water specimens. By Heikal, M. et al. [9], have researched SCC and concluded that the presence of SCC Super plasticizer in concrete, becomes more solid microcrystalline tobermorite (3CaO. $2SiO_2$. $3H_2O$ or CSH) as the main product with hydration sheet portlandite ($Ca(OH)_2$ or CH).

Materials and methods

Cement

This study has used the type of Portland Composite Cement (PCC). The chemical composition of cement used can be seen in Table 1.

Table 1 The Chemical composition of PCC (%)

SiO_2	Al_2O_3	Fe_2O_3	CaO	MgO	SO_3	LOI
19.53	5.24	3.50	66.77	0.88	2.28	6.84

Sea water

This study used seawater to mix water and cure. The chemical composition of sea water used can be seen in Table 2.

Table 2 The chemical composition seawater

Specific gravity	PH	Chemical composition (mg/L)					
		Cl	SO4	Ca	Mg	Na	CO3
1.01	8	20415.3	355.9	85.2	1.4	0.2	10560

Aggregates

The aggregates used in SCC mixture were collected form Jeneberang River, south Sulawesi province in Indonesia. The physical properties of coarse aggregate and fine aggregate are summarized in Table 3.

Table 3. Physical Properties of Aggregate

Parameter	Value
Coarse Aggregate (crushed river stone)	
Maximum size (mm)	20
Abrasion (%)	34.07
Density (SSD)	2.62
Absorption	2.31
Fine aggregate (river sand)	
Density (SSD)	2.57
Absorption	1.37

Admixture

Superplasticizer used A-3115 ViscoCrete. A ViscoCrete-3115 is a third-generation superpasticizer. Density of A-3115 ViscoCrete is 1.04 kg/liter

Method of Experiment

Compressive strength testing method follows the ASTM test standard 39/C 39M – 99, with 10 mm x 20 mm cylinders specimens. Equipment of Universal Testing Machine (UTM) was used to test the compressive strength. This test has done of concrete age in 1day, 3 days, 7 days, 28 days and 90 days.

Calcium silicate hydrate ($3CaO.2SiO_2.3H_2O$) or tobermorite is main hydration product from the cement constituents and minerals react, and calcium hydrate ($Ca(OH)_2$) or portlandite is a byproduct when tobermorite is formed. Increasing and decreasing amounts of tobermorite and portlandite and other cement hydrate were observed. In this paper just explain about tobermorite and portlandite. Equipment of X-ray diffraction (XRD) was used to analysis of concrete microstructure in 1day, 3 days, 7 days, 28 days and 90 days.

This study has two variations of mixing i.e. 1) Self-compacting concrete using fresh water as mixing water and water immersion, it was named SCC-FF; 2) Self-compacting concrete using sea water as mixing water and water immersion, it was named SCC-SS. The amount and types of testing each sample can be seen in Table 4.

Table 4. The types and amount of testing

No.	Name of sample	Types of testing	Age (day) and Amount of sample				
			1	3	7	28	90
1	SCC-FF	- Compressive strength	3	3	3	3	3
		- Microstructure SEM and XRD	2	2	2	2	2
2	SCC-SS	- Compressive strength	3	3	3	3	3
		- Microstructure SEM and XRD	2	2	2	2	2

Mix Design of SCC

Design of materials proportion SCC used method The European Federation of Specialist Chemicals and Concrete Constructions Systems (EFNARC, 2002; 2005). The design of SCC used 1.1 ratio volume of water/cement. The materials proportion of mix design both SCC-FF and SCC-SS in detail can be seen in Table 5.

Table 5 Mix design concrete both SCC-FF and SCC -SS

Materials	SCC-freshwater (SCC-FF)		SCC-sea water (SCC-SS)	
	volume (litre/m^3)	weight (kg/m^3)	volume (litre/m^3)	weight (kg/m^3)
Fresh water	204.01	204.01	-	-
Sea water	-	-	204.01	206.11
Cement	190.91	601.36	190.91	601.36
Sand	299.57	770.12	299.57	770.12
Crushed stone	299.51	785.11	299.51	785.11
Superplasticizer	5.78	6.01	5.78	6.01

Result

Compressive strength test has done at the age of 1 day, 3 days, 7 days, 28 days and 90 days. This testing conducted to determine the compressive strength development of the concrete up to 90 days. The results of compressive strength test both SCC-FF and SCC-FF can be seen in Table 6.

Table 6. The Compressive strength result of SCC FF and SCC-SS

Age (day)	SCC fresh water (SCC-FF)	SCC sea water (SCC-SS)
	Compressive strength, fc (MPa)	Compressive strength, fc (MPa)
1	9.11	14.97
3	25.55	31.27
7	35.22	38.02
28	50.58	51.92
90	52.69	53.74

The results of microstructure on the hardening concrete that has been done by X-ray power diffraction (XRD) analysis at the age of 1 day, 3 days, 7 days, 28 days and 90 days that can be seen in Table 7 for SCC-FF and SCC-SS.

Table 7 The microstructure testing results on concreteSCC-FF and SCC-SS

Test Sample	**Microstructure phase (%)**	**Age (day)**				
		1	**3**	**7**	**28**	**90**
SCC-FF	Portlandite, ($Ca(OH)_2$) : CH	12.35	13.69	16.61	19.71	22.92
	Tobermorite($3CaO.2SiO_2.3H_2O$): CSH	24.69	26.32	34.27	39.42	45.83
SCC-SS	Portlandite, (Ca(OH)2) : CH	10.53	12.63	13.90	15.08	15.70
	Tobermorite ($3CaO.2SiO_2.3H_2O$): CSH	29.47	31.58	36.36	43.24	46.74

Discussion

The compressive strength development of SCC

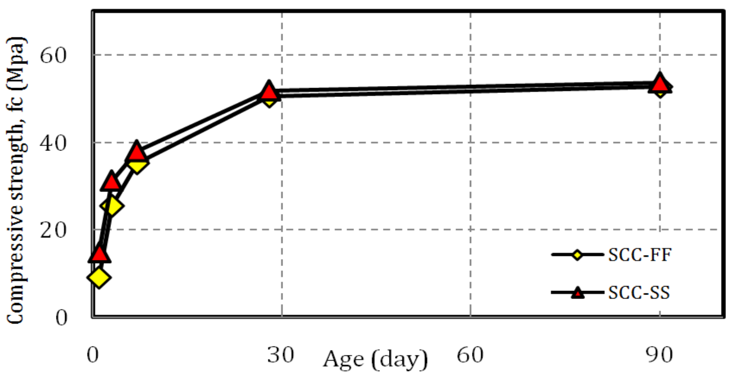

Figure 1. Compressive strength developments on both SCC-FF and SCC-SS

Figure 1 shows the development of concrete compressive strength on both SCC-FF and SCC-FF-SS at the age of 1 day, 3 days, 7 days, 28 days, and 90 days. SCC-SS compressive strength is higher than the compressive strength of SCC-FF. Compressive strength differences of SCC -FF with SCC-SS at the age of 1 day, 3 days, 7 days, 28 days and 90 days were 5.87 MPa (39.19%), 5.71 (18.27%), 2.81 MPa (7.38%), 1.34 MPa (2.58%), 1.05 MPa (1.95%), respectively.

The difference of concrete compressive strength between SCC-SS and SCC-FF-SS is high in an early age of concrete at the age of 1 day and 3 days. Thus, the effect of sea water on concrete was accelerating the development of concrete strength at an early age. Compressive strength improvement of concrete at an early age caused by sea water also occurs in the studied by Erniati (2013) have examined the mortar using distilled water and sea water as mixing water, compressive strength of mortar using sea water is higher than mortar using distilled water, besides the sea water has accelerated the development of mortar of early age strength. Furthermore, I agree with previous studies by Falah M. W (2010), Aburawy, MM and Swamy, RN (2008) have examined the concrete using sea water as mixing water and cured in sea water. They gave the conclusion that sea water has accelerated the development of early age strength of concrete up to 14 days.

The microstructure of SCC-FF and SCC-SS

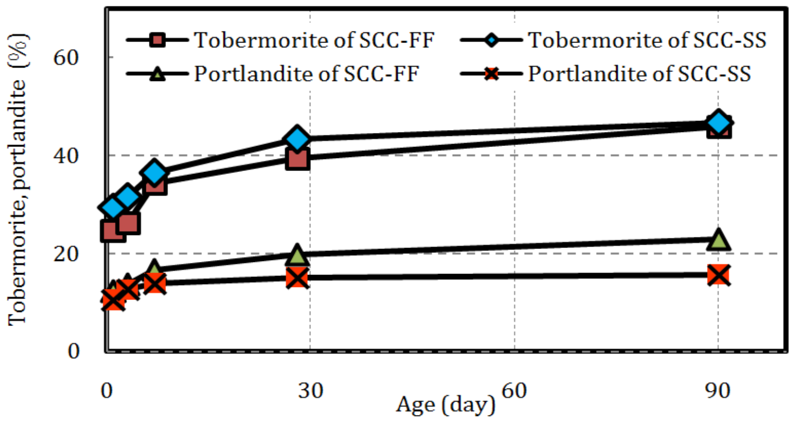

Figure 2. Microstructure developments on both SCC-FF and SCC-SS

Figure 2 show the development of microstructure (tobermorite and portlandite) on both SCC-FF and SCC-SS at the age of 1 day, 3 days, 7 days, 28 days, and 90 days. Tobermorite percentage in SCC-SS is higher than tobermorite in SCC-FF, otherwise portlandite percentage of SCC-SS is smaller than portlandite percentage of SCC-FF.

Figure 3a shows the non-linear regression relationship compressive strength and tobermorite of SCC-FF. compressive strength and tobermorite relationship equation is $y = 66.08 \ln(x) - 196.7$ with correlation value, $r = 0.958$ and the coefficient of determination, $R^2 = 0.917$. Correlation values showed a positive correlation is very strong, this means that increasing levels of tobermorite also increase the compressive strength. The determination coefficient value means tobermorite affects 91.7% on compressive strength. Furthermore, Figure 3b shows the non-linear regression relationship fc and tobermorite of SCC-SS. compressive strength and tobermorite relationship equation is y = 77.89 ln(x) – 243 with correlation value, r = 0.964 and the coefficient of determination, R^2 =0.93. Correlation values showed a positive correlation is very strong, this means that increasing levels of tobermorite also increase the compressive strength. The determination coefficient value means tobermorite affects 93% on compressive strength.

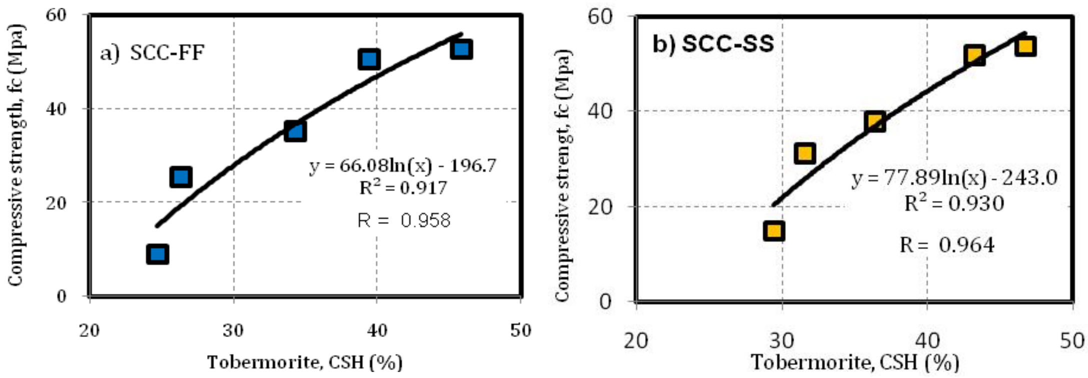

Figure 3. Relationship about compressive strength versus tobermorite

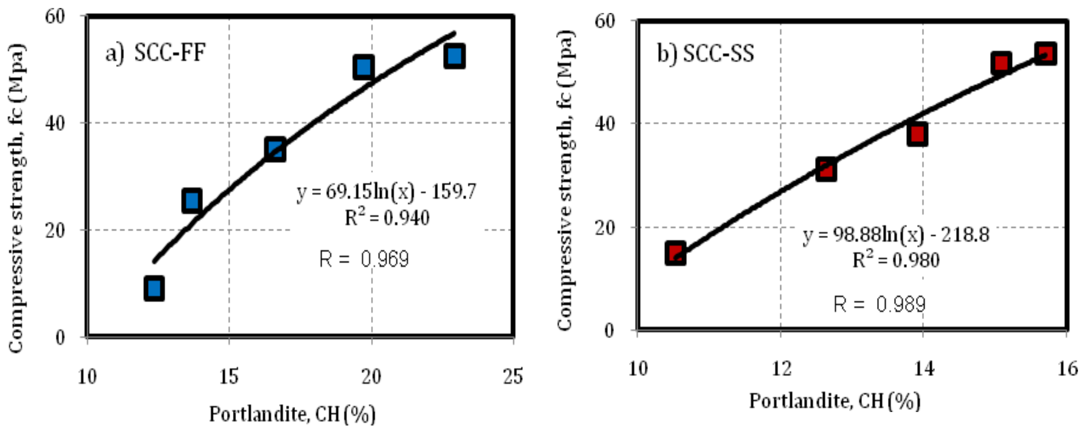

Figure 4. Relationship about compressive strength versus portlandite

Figure 4a shows the non-linear regression relationship compressive strength and portlandite of SCC-FF. compressive strength and portlandite relationship equation is y = 66.08 ln(x) – 196.7 with correlation value, r = 0.969 and the coefficient of determination, R2 =0.94. Correlation values (r) showed a positive correlation is very strong, this means that increasing levels of portlandite also increase the compressive strength. The determination coefficient value means portlandite affects 94% on compressive strength.

Figure 4b shows the non-linear regression relationship fc and portlandite of SCC-

SS. compressive strength and tobermorite relationship equation is y = 77.89 ln(x) – 243 with correlation value, r = 0.989 and the coefficient of determination, R2 =0.98. Correlation values (r) showed a positive correlation is very strong, this means that increasing levels of portlandite also increase the compressive strength. The determination coefficient value means portlandite affects 98% on compressive strength.

Conclusion

The compressive strength of SCC using sea water as mixing water and immersion water is higher than SCC using fresh water up to the age of 90 days. Furthermore, sea water does not reduce the strength of SCC concrete up to the age of 90 days, but rather of seawater is accelerating the development of SCC concrete strength at early age. Tobermorite of SCC using sea water as mixing water and immersion water is higher than SCC using fresh water, otherwise portlandite of SCC using sea water as mixing water and immersion water is smaller than SCC using fresh water. Compressive strength of concrete SCC is influenced by the phase microstructure (especially with tobermorite and portlandite) formed in the concrete. So, from the discussion of compressive strength and microstructure of SCC concrete using sea water until the age of 90 days, the possibility of sea water can be used in concrete construction.

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