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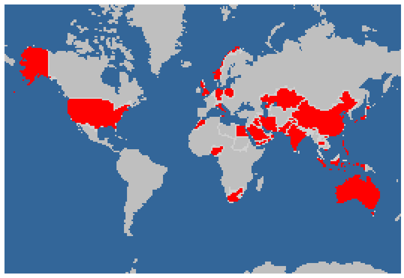

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The Effect of Water-Cement Ratio on Sulfate Resistance of Self-Compacting Concrete with Bagasse Ash

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***Abstract*— Previous study showed so many factors will contribute to the durability of concrete, such as cement content, water cement ratio, admixtures to be used, compaction dan curing methods. Two types of admixtures for concrete mixture can be used, e.g. chemical admixture and mineral admixture. Materials can be categoried as mineral admixture such as fly ash, silica fume, risk husk ash, and bagasse ash. Sulfate resistance of concrete is one of the examples of chemical durability of concrete. Self-Compacting Concrete (SCC) known as concrete which can flow within its self-weight and without forming honeycombing, segregation and bleeding, even with no compaction. In this experimental work, bagasse ash was used in concrete mixture as partial replacement of cement with the percentage of 10%, 15% and 20%. The variation of w/b were used e.g 0.275, 0.300 and 0.325. For the purpose to stipulate the sulfate attack on concrete, the cylinder specimen with size of 100 x 200 mm and magnesium sulfate solution with 5% and 7% molarity were used. To observe the percentage of concrete weight loss, all the specimen were immersed in this solution within 28 days. The result showed that the value of compressive strength for the specimen with w/b = 0.275 and 15% bagasse ash was up to 67.240 MPa for 28 days and 68.096 MPa for 56 days without immersion in magnesium sulfate solution. The highest percentage of concrete weight loss is 3.030% yielded from the specimen with w/b = 0.325 and 0% bagasse ash which was immersed in 7% molarity of magnesium sulfate solution.**

***Keywords*— self-compacting concrete; magnesium sulfate; bagasse ash.**

I. INTRODUCTION

Self-Compacting Concrete (SCC) is defined as a new concrete innovation that does not require compaction. This concrete can flow with its weight and fill the formwork. This concrete is hardened, homogeneous, and also has the same properties and durability as conventional concrete, which is vibrated [1]-[3].

Experimental work [4] was about the permeability of SCC compared to conventional concrete. In the study, they used pozzolanic fly ash (PFA) and limestone powder as additional binder and admixture, then divided into two types of SCC concrete which are medium and high strength. Air permeability test results in Hadlow or better permeability results than conventional concrete. For water permeability test results, only SCC concrete containing PFA and limestone powder had a low resistance or permeability compared to conventional concrete which is vibrated. The production of SCC is through testing its durability against sulfuric acid on the compressive strength of concrete [2], [5]-[7]. SCC concrete was made using limestone as filler. Besides that, the researchers also used coarse and fine aggregates, silica, and limestone. The test results that obtained for compressive strength of concrete at 28 days before immersion with sulfuric acid was SCC concrete with LA-LS-20LF2 mix design of 60.2 MPa.

The definition of workability is the properties of the fresh concrete that determines the ease of work and homogeneity properties of concrete that can be stirred, transported, compacted, and completed [8]-[10]. The criteria of w/c have been defined from existing literature such as [8], [11]-[14]. Some w/c criteria for fresh concrete SCC can be seen in Table 1.

TABLE I
THE CRITERIA OF W/C FOR FRESH CONCRETE OF SCC

Criteria	Slump flow test (mm)		T_{500} test (s)		V-funnel test (s)	
	Min	Max	Min	Max	Min	Max
EFNARC	650	800	2	5	6	12
JSCE	500	750	3	25	7	20

II. MATERIALS AND METHODS

The method of study used was the experimental method. Experimental that conducted was in the form of testing of fresh concrete and hardened concrete. This study was conducted by using variations of sugarcane bagasse ash (SCBA) of 0%, 10%, 15%, and 20% of the amount of cement used. Variation w/c were w/c = 0.275, w/c = 0.300, and w/c = 0.325. Fresh concrete tests include slump flow test, V-funnel, and L-box, while hardened concrete tests include the durability of concrete by immersing the samples into water mixed with $MgSO_4$ with two variations of 5% and 7%. Immersion was done for 28 days after the concrete age was 28 days, the compressive strength test was conducted using cylindrical test samples of 100 mm x 200 mm. After the compressive strength test, the microstructure test of concrete was conducted by SEM.

A. *Material*

This study used Ordinary Portland Cement (OPC) type I with a fineness of $340m^2/kg$. The water used for the concrete mixture must be clean, no oil, and no impurities which can damage the concrete. This study used distilled water because distilled water is free from organic impurities or other impurities. The sugarcane bagasse ash that used was from PT. Sugar Group Companies (Persero) Lampung. The SCBA was sieved with No.200 sieve. The test of chemical contents was done at PT. Semen Baturaja Laboratory. The results of the test are shown in Table 2. SEM test was done at the Centre of Research and Development Marine Geology Laboratory, Bandung; the test results can be seen in Figure 1.

The fine aggregate sizes used in this study were two sizes that less than 4 mm and quartz sand with the size of 50-650 µm. The coarse aggregate size used in this study was the maximum of 10 mm. The coarse aggregate used was Merak split stone. Chemical admixture used in this study was superplasticizer type F. Superplasticizer type F has the density of 1.04 kg/Liter and were used to reduce water usage and accelerate the binding process of concrete. The durability test was done by immersing the samples into a tub containing distilled water mixed with magnesium sulfate (MgSO4) with 5% and 7% concentration.

TABLE II
SCBA CONTENT TEST RESULTS

No.	Content	Weight (%)
1.	Silicon Dioxide (SiO_2)	83.40
2.	Aluminum Oxide (Al_2O_3)	0.00
3.	Iron (III) Oxide (Fe_2O_3)	5.00
4.	Calcium Oxide (CaO)	2.38
5.	Magnesium Oxide (MgO)	0.00
6.	Sulfur Trioxide (SO_3)	0.61
7.	LOI	8.36

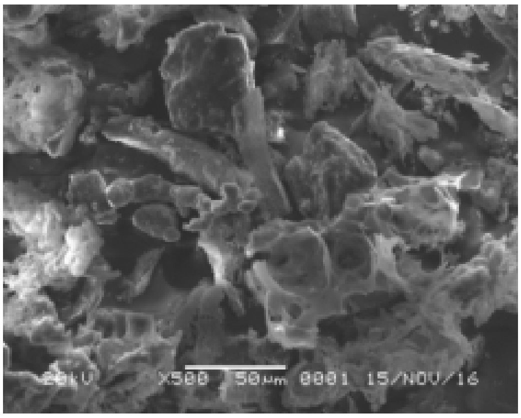


Fig. 1 SEM microstructure of SCBA

B. *Mixture proportion*

The mixture compositions of SCC were arranged by collecting data from journals and standards of EFNARC and ACI. The mixture compositions in this study consisted of 16 mixture variations. The mixed composition of SCC used can be seen in Table 3.

TABLE III
MIXTURE PROPORTION OF $1M^3$ SCC MIXES

Mix	OPC (kg)	SCBA (kg)	FA (kg)		CA (kg)	Water (kg)
			1	2		
SCC-0-0.275	600	0	246	540	823	165
SCC-0-0.300	600	0	246	540	823	180
SCC-0-0.325	600	0	246	540	823	195
SCC-5-0.275	540	60	246	540	823	165
SCC-5-0.300	540	60	246	540	823	180
SCC-5-0.325	540	60	246	540	823	195
SCC-10-0.275	510	90	246	540	823	165
SCC-10-0.300	510	90	246	540	823	180
SCC-10-0.325	510	90	246	540	823	195
SCC-15-0.275	480	120	246	540	823	165
SCC-15-0.300	480	120	246	540	823	180
SCC-15-0.325	480	120	246	540	823	195

III. RESULTS AND DISCUSSION

A. *Slump flow*

The results of the slump flow test were obtained from four directions, and then the data were averaged. Slump flow test results can be seen in Figure 2. In Figure 2, the addition of sugarcane bagasse ash (SCBA) to the composition of the mixture affects the slump flow value. The more SCBA is used, the lower slump flow value is obtained. The decrease result of the slump flow based on SCBA content can be seen in Table 4.

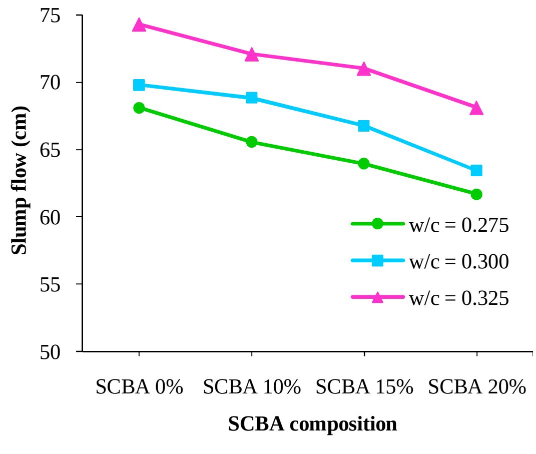


Fig. 2 The effect of SCBA on slump flow

Table 4 shows that the highest and lowest slump flow was found in w/c = 0.275 with 20% SCBA mixture and in w/c = 0.325 with 10% SCBA mixture with values of 9.43% and 1.39%. Figure 3 indicates that based on the effect of w/c ratio there is an increase in slump flow. The highest slump flow was found in w/c = 0.325 with 0% SCBA mixture, while the lowest slump flow was in w/c = 0.275 with 20% SCBA mixture.

TABLE IV
THE DECREASE PERCENTAGE OF SLUMP FLOW VALUE BASED ON SCBA COMPOSITION

w/c	AAT (%)	Slump flow (cm)	Change Percentage (%)
0.275	0	68.10	0.00
	10	65.56	-3.73
	15	63.94	-6.11
	20	61.68	-9.43
0.300	0	69.80	0.00
	10	68.83	-1.39
	15	66.76	-4.36
	20	63.44	-9.11
0.325	0	74.30	0.00
	10	72.10	-2.96
	15	71.03	-4.40
	20	68.10	-8.34

B. V-funnel

Figure 3 of the test results shows that the increase of sugarcane bagasse ash, the flow time becomes longer. This is because the sugarcane bagasse ash has a high absorbency ability so that the viscosity of concrete increases.

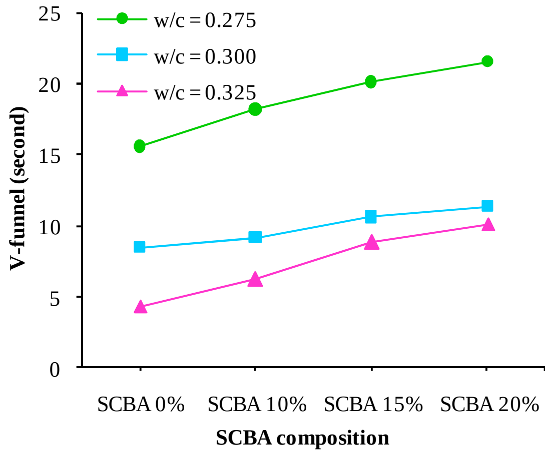


Fig. 3 The effect of SCBA on V-*funnel*

Table 4 explains that the V-funnel value is greater as the addition of SCBA, so the greater value or time obtained in V-funnel test. The highest and lowest increase percentage of V-funnel value is in w/c = 0.325 with 20% SCBA mixture and w/c = 0.300 with 10% SCBA mixture with each value of 134.03% and 8.06%.

TABLE V
THE INCREASE PERCENTAGE OF V-FUNNEL VALUE BASED ON SCBA COMPOSITION

w/c	SCBA (%)	Duration (sec)	Increase percentage (%)
0.275	0	15.15	0.00
	10	18.13	16.59
	15	20.09	29.20
	20	21.49	38.20
0.300	0	8.44	0.00
	10	9.12	8.06
	15	10.58	25.36
	20	11.34	34.36
0.325	0	4.32	0.00
	10	6.22	43.98
	15	8.79	103.47
	20	10.11	134.03

C. L-box

The tests were performed on four mixture compositions with each mixture composition consisting of three variations of w/c ratio. The L-box test results can be seen in Figure 4.

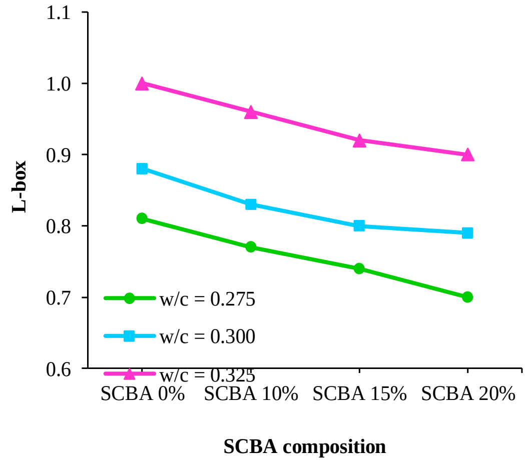


Fig. 4 The effect of SCBA on L-box

Figure 4 and Table 4 shows the results obtained in the L-box test indicates that the higher w/c ratio causes the higher L-box test value. The addition of SCBA also affects the result of the L-box value, the more significant addition of SCBA causes the smaller obtained test results.

TABLE VI
THE DECREASE PERCENTAGE OF L-BOX BASED ON SCBA COMPOSITION

w/c	SCBA (%)	H_2/H_1	Decrease percentage (%)
0.275	0	0.81	0.00
	10	0.77	-4.94
	15	0.74	-8.64
	20	0.70	-13.58
0.300	0	0.88	0.00
	10	0.83	-5.68
	15	0.82	-6.82
	20	0.79	-10.23
0.325	0	1.00	0.00
	10	0.96	-4.00
	15	0.92	-8.00
	20	0.90	-10.00

D. Mass Change

Mass testing is the ratio of the mass of samples before immersion and after immersion in $MgSO_4$ for 28 days. Figure 5 shows the mass test was performed by measuring the weight of the samples before and after being immersed in 5% $MgSO_4$.

Figure 6 shows that there was a decrease in the concrete mass with w/c = 0.300. The highest decrease of concrete mass was found in the mixture composition with SCBA 20% of 45 grams.

Based on Figure 7, it shows that the highest concrete mass decrease occurred in concrete with w/c = 0.325 and SCBA content of 10% with a decrease value of 50 grams, while the lowest decrease was in the mixture composition with w/c = 0.325 and SCBA content of 15%. The sulfate resistance test was also performed on the $MgSO_4$ solution with 7% concentration.

Figure 8 shows there was a mass decrease in SCC with SCBA content with w/c = 0.275. The highest decrease was found in SCBA 10% concrete of 70 grams, while the lowest decrease was found in SCBA 20% concrete with 40 grams.

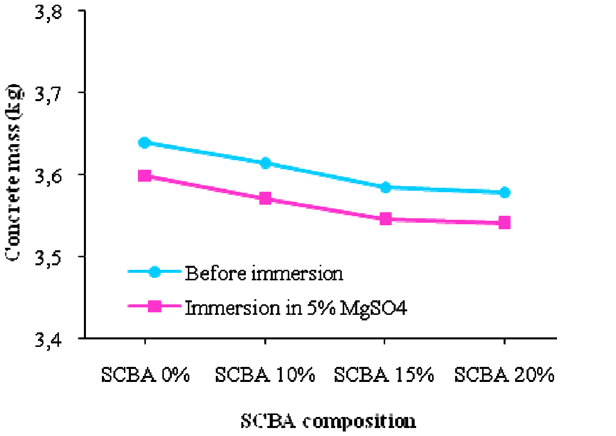


Fig. 5 The effect of SCBA content on concrete mass with w/c = 0.275 ($MgSO_4$ = 5%)

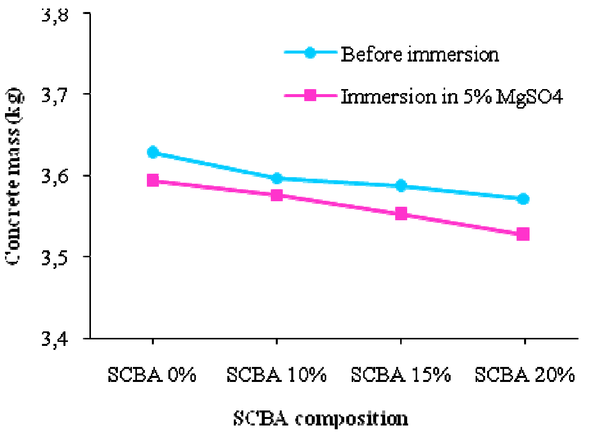


Fig. 6 The effect of SCBA content on concrete mass with w/c =0.300 (MgSO4 = 5%)

Based on Figure 9 shows that the highest decrease of concrete mass was in the mixture composition with SCBA0% by 55 grams, while the lowest decrease was in the mixture composition with SCBA15% by 30 grams.

Based on Figure 10, it shows that the highest and lowest concrete mass decrease was found in SCBA20% and SCBA15% concrete with a mass decrease value of 85 grams and 35 grams. The result of concrete mass measurement conducted by immersing in 5% of MgSO4 found that the mass decrease ranged between 20 grams up to 50 grams. The highest decrease in mass with a decrease of 45 grams occurred in the mixture composition of the SSC-10-0.325. The lowest decrease in mass with a 20 grams decrease occurred in the mixture composition of SSC-20-0.275.

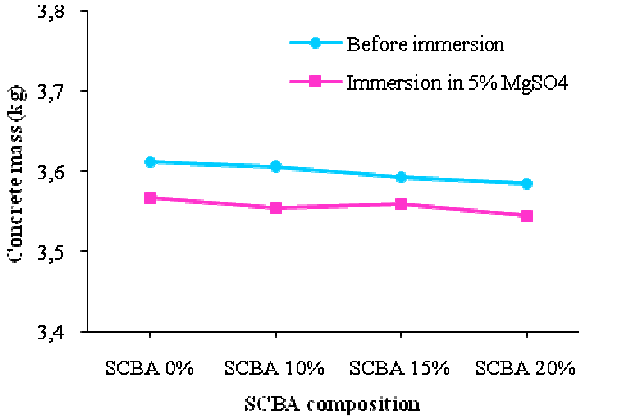


Fig. 7 The effect of SCBA content on concrete mass with w/c =0.325 ($MgSO_4$ = 5%)

The decreased range of concrete mass in the 7% $MgSO_4$ sulfate resistance test between 35 grams up to 100 grams. The highest decrease in mass with a decrease of 100 grams occurred in the mixture composition of SSC-0-0.325, while the lowest mass decrease with a 35 grams decreases occurred in the composition of the SSC-15-0.325 mixture.

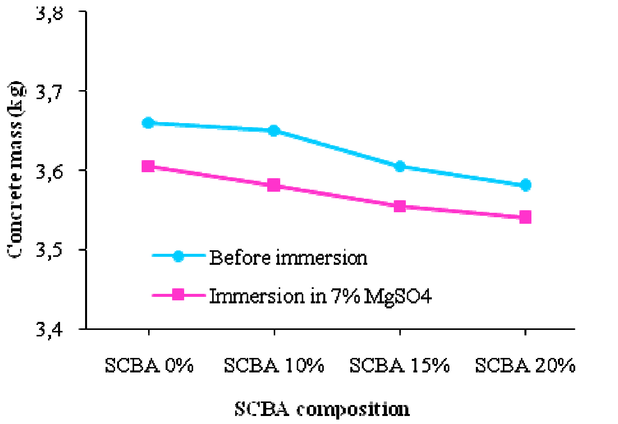


Fig. 8 The effect of SCBA content on concrete mass with w/c = 0.275 ($MgSO_4$ = 7%)

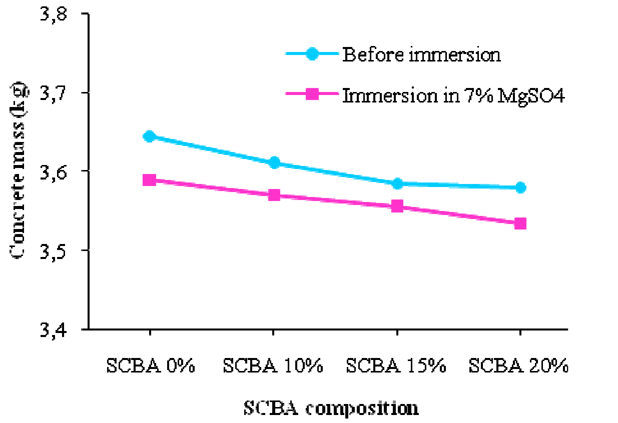


Fig. 9 The effect of SCBA content on concrete mass with w/c = 0.300 ($MgSO_4$ = 7%)

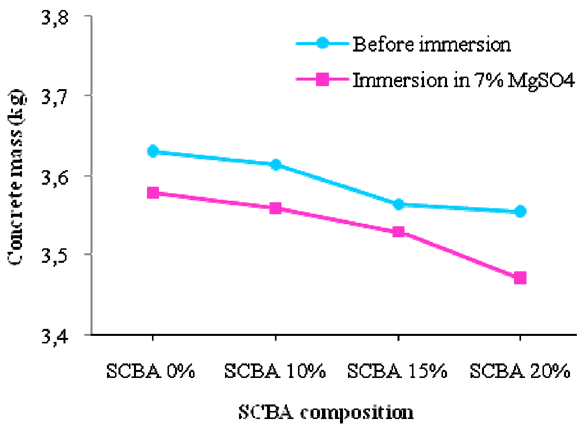


Fig. 10 The effect of SCBA content on concrete mass with w/c = 0,325 ($MgSO_4$ = 7%)

The recapitulation of the effect of 5% and 7% $MgSO_4$ on the mass of concrete can be seen in Table 7 and Table 8. Based on Table 7, the sulfate resistance test in 5% $MgSO_4$ solution was obtained the result of the percentage with the highest mass decrease occurred in the composition of the SSC-10-0.325 with a value of 1.399%, while the lowest percentage occurred in the composition of the mixture SCC-20-0.275 with a value of 0.557%, so the percentage range of concrete mass decreases was between 0.557% to 1.399%.

Table 8 shows the sulfate resistance test in the 7% $MgSO_4$ solution was obtained a percentage with the highest compressive strength decrease occurred in SCC concrete with a value of 2.770% in the mixture composition of SCC-0-0.325. The lowest percentage occurred in the mixture composition of SCC-15-0.275 with a value of 1.113 %/ The percentage range of SCC concrete mass decreases that occurred in the test of 7% sulfate resistance $MgSO_4$ was 1.113% up to 2.770%.

TABLE VII
THE RESULT OF SCC CONCRETE MASS AFTER SULFATE RESISTANCE TEST IN 5% $MGSO_4$ DURING 28 DAYS

Mix design	**Mass (kg)**		**Decrease percentage**
	Before immersion	**$MgSO_4$ 5%**	
SSC-0-0.275	3.640	3.600	1.099
SSC-0-0.300	3.628	3.593	0.965
SSC-0-0.325	3.612	3.567	1.246
SSC-10-0.275	3.615	3.570	1.245
SSC-10-0.300	3.597	3.557	1.112
SSC-10-0.325	3.575	3.525	1.399
SSC-15-0.275	3.585	3.545	1.116
SSC-15-0.300	3.577	3.542	0.979
SSC-15-0.325	3.553	3.523	0.844
SSC-20-0.275	3.588	3.568	0.557
SSC-20-0.300	3.582	3.557	0.698
SSC-20-0.325	3.570	3.535	0.980

TABLE VIII
THE RESULT OF SCC CONCRETE MASS AFTER SULFATE RESISTANCE TEST IN 5% $MGSO_4$ DURING 28 DAYS

Mix design	**Mass (kg)**		**Decrease percentage**
	Before immersion	**$MgSO_4$ 7%**	
SSC-0-0.275	3.660	3.605	1.503
SSC-0-0.300	3.645	3.555	2.469
SSC-0-0.325	3.610	3.510	2.770
SSC-10-0.275	3.650	3.580	1.918
SSC-10-0.300	3.630	3.570	1.653
SSC-10-0.325	3.605	3.560	1.248
SSC-15-0.275	3.595	3.555	1.113
SSC-15-0.300	3.585	3.535	1.395
SSC-15-0.325	3.565	3.530	0.982
SSC-20-0.275	3.580	3.540	1.117
SSC-20-0.300	3.580	3.535	1.257
SSC-20-0.325	3.555	3.470	2.391

E. Compressive Strength Change

The compressive strength test was performed when the concrete had been immersed for 28 days. The test samples performed by compressive strength test were the non-immersed concrete and immersed concrete into 5% and 7% $MgSO_4$. Figure 11 shows the difference in compressive strength results in SCC concrete due to the different composition of mineral additives although with the same w/c of 0.275. The result of compressive strength of 5% $MgSO_4$ concrete had decreased the compressive strength compared with the non-immersed concrete.

Based on Figure 12, SCC compressive strength results in variations of SCBA with w/c = 0.300. The highest compressive strength was found in the composition of SSC-15-0.300 mixture. The result of compressive strength before immersion was 66.237 MPa and after immersion5% $MgSO_4$ was 62.932 MPa.

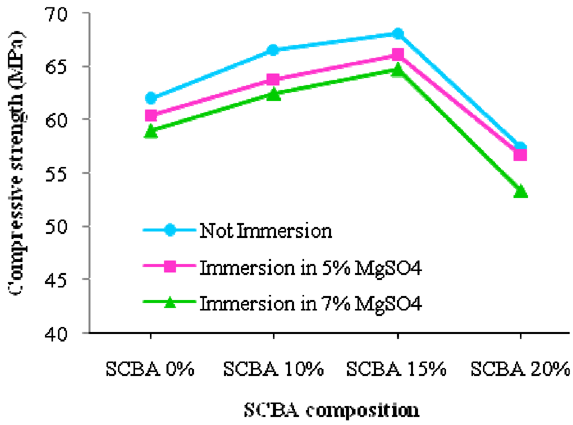


Fig. 11 The effect of SCBA composition on concrete mass with w/c = 0.275

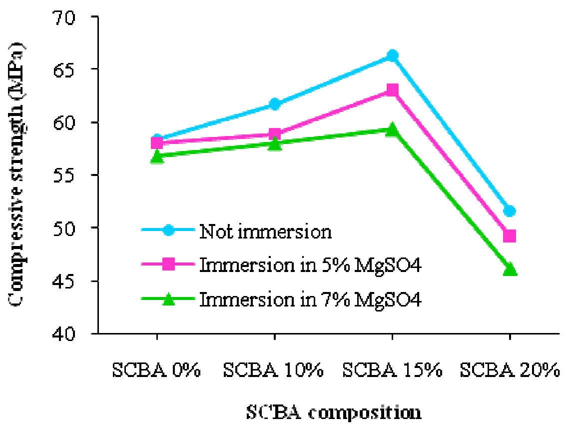


Fig. 12 The effect of SCBA composition on concrete mass with w/c = 0.300

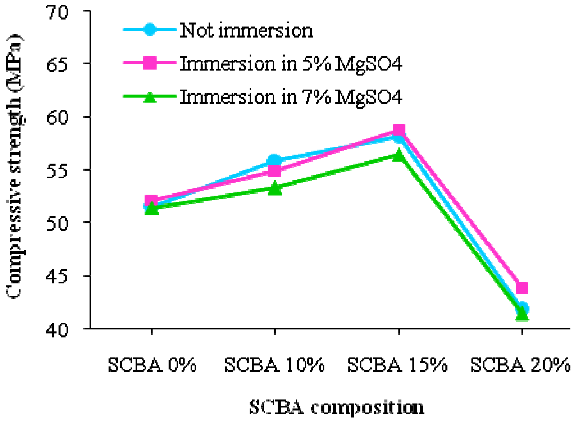


Fig. 13 The effect of SCBA composition on concrete mass with w/c = 0.325

Figure 13 shows the compressive strength of SCC for w/c = 0.325 with variations in the use of SCBA. The concrete compressive strength results of SCC showed that the mixture composition of SSC-15-0.325 had the highest compressive strength of non-immersed or immersed concrete in 5% MgSO4 with each value of 60.553 MPa and 58.786 MPa. The recapitulation of the effect of MgSO4 on the compressive strength of SCC concrete can be seen in Table 9.

Based on Table 9 and 10, the highest compressive strength was found in the mixture composition of SSC-15-0.275 with 68.096 MPa, while the lowest compressive strength was found in in the mixture composition of SSC-20-0.325 with 45.598 MPa. The highest percentage of compressive strength decrease in SCC concrete immersed at 5% MgSO4 occurred in the mixture composition of SSC-15-0.300 with a value of 4.990%, while the lowest percentage occurred in the composition of the mixture SCC-0-0.300 with value 0.531%. The concrete immersed at 7% MgSO4 had the highest decrease of compressive strength with a value of 10.469% in the mixture composition of SCC-20-0.300, while the lowest percentage occurred in the mixture composition of the SCC-0-0.300 mixture with a value of 2.742%.

TABLE IX
THE RESULT OF SCC COMPRESSIVE STRENGTH AFTER SULFATE RESISTANCE TEST IN 5% $MgSO_4$ DURING 28 DAYS

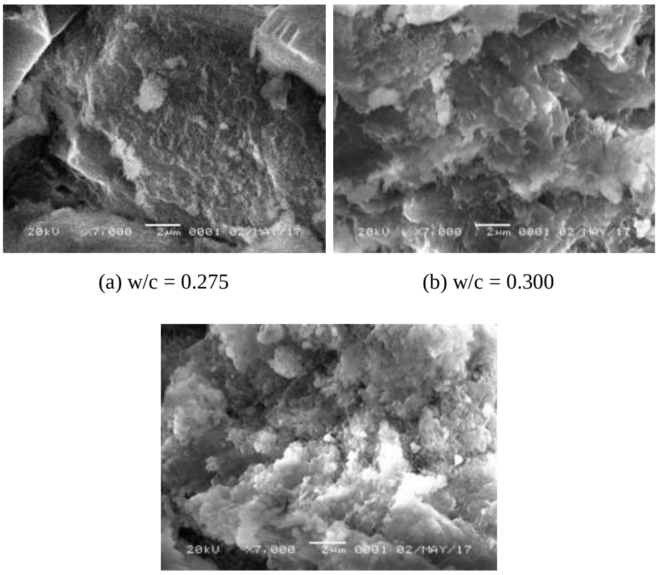
Mix design	Compressive strength(MPa)		Decrease percentage
	Not immersion	Immersion in $MgSO_4$ 5%	$MgSO_4$ 5%
SSC-0-0.275	61.926	60.408	2.451
SSC-0-0.300	58.389	58.079	0.531
SSC-0-0.325	53.845	52.182	3.088
SSC-10-0.275	66.591	63.821	4.160
SSC-10-0.300	61.604	58.889	4.407
SSC-10-0.325	55.890	54.900	3.469
SSC-15-0.275	68.096	66.011	3.062
SSC-15-0.300	66.237	62.932	4.990
SSC-15-0.325	60.553	58.786	2.918
SSC-20-0.275	57.470	56.738	1.274
SSC-20-0,300	51.627	49.149	4.800
SSC-20-0,325	45.598	43.920	3.680

TABLE X
THE RESULT OF SCC COMPRESSIVE STRENGTH AFTER SULFATE RESISTANCE TEST IN 7% $MgSO_4$ DURING 28 DAYS

Mix design	Compressive Strength (MPa)		Decrease percentage
	Not immersion	Immersion in $MgSO_4$ 7%	$MgSO_4$ 7%
SSC-0-0.275	61.926	58.933	2.451
SSC-0-0.300	58.389	56.788	0.531
SSC-0-0.325	53.845	51.442	3.088
SSC-10-0.275	66.591	62.490	4.160
SSC-10-0.300	61.604	58.014	4.407
SSC-10-0.325	55.890	53.295	3.469
SSC-15-0.275	68.096	64.728	3.062
SSC-15-0.300	66.237	59.311	4.990
SSC-15-0.325	60.553	56.472	2.918
SSC-20-0.275	57.470	53.384	1.274
SSC-20-0.300	51.627	46.222	4.800
SSC-20-0.325	45.598	41.446	3.680

F. *Microstructure Test*

Microstructure test done was a SEM test. The SEM test results were with the magnification of 7000 x can be seen in Figures 14. SEM samples were obtained after 28 days of sulfate resistance test at 56 days of concrete age.

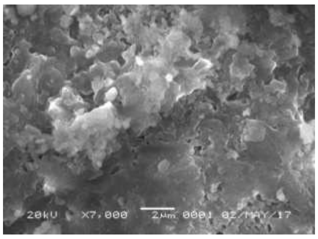


(a) w/c = 0.275 (b) w/c = 0.300

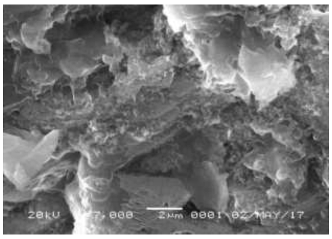
(c) w/c = 0.325

Fig. 14 Photo of SEM SCC 15% SCBA not immersion

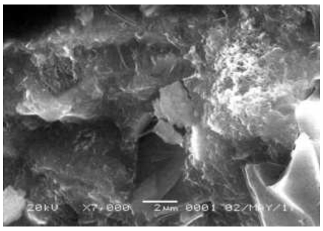
Figure 14 (a) is a SEM photo of SCC-15-0.275 indicating that almost all parts had formed CSH. SCC-15-0.275 showed the most solid SEM photo compared to mixture compositions with different w/c, and there was a small amount of CH. Figure 14 (b) is a SEM photo of SCC-15-0.300, indicating that CSH had formed solidly and formed pore with a tiny scale of 2 µm. Figure 14 (c) is a SEM photo of SCC-15-0.325 indicating that CSH had formed, but it is not denser than other w/c mixture compositions, and there were many pores that less than 1 µm in size. The less dense CSH causes a decrease of the concrete compressive strength.



(a) w/c = 0.275



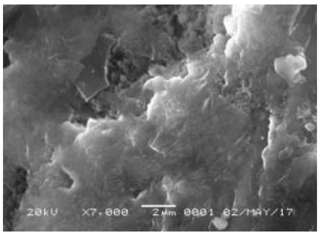
(b) w/c = 0.300



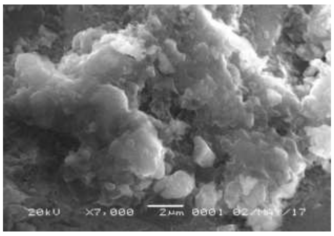
(c) w/c = 0.325

Fig. 15 Photo of SEM SCC 15% SCBA immersion in 5% $MgSO_4$

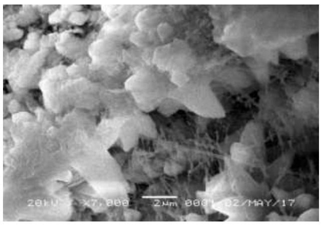
Figure 15 is a SEM photo with 15% SCBA immersed in $MgSO_4$ with 5% concentration. Figure 15 (a) is a SEM photo of SCC-15-0.275 indicating that it had very solid CSH compared to other w/c and there was no CH. Figure 15 (b) is a SEM photo of SCC-15-0.300 indicating that CSH had formed quite dense and there was CH as the residual reaction of cement hydration. Figure 15 (c) shows a SEM photo of SCC-15-0.325 indicating that CSH formed less dense and there were many CH. The formed CH causes a compressive strength decrease due to the absence of the cement matrix bond.



(a) w/c = 0.275



(b) w/c = 0.300



(c) w/c = 0.325

Fig. 16 Photo of SEM SCC 15% SCBA immersion in 7% $MgSO_4$

Figure 16 is a SEM photo with 15% SCBA immersed in $MgSO_4$ with 7% concentration. Figure 16 (a) is SEM photo of SCC-15-0.275 indicating that there was the most denser CSH than the other w/c CSH and there was only a small amount of CH. Figure 16 (b) is a SEM photo of SCC-15-0.300, the CSH had been very solid, but not denser than w/c = 0.275. Figure 16 (c) is a SEM photo of SCC-15-0.32 indicating that the CSH had formed quite solid. At the bottom of CSH, CH was formed where the ettringite was also formed. The formation of ettringite on hardened concrete should be avoided because it causes expansion that creates micro crack in the concrete that makes the decrease of concrete strength.

IV. Conclusions

The result of the concrete mass change test in the 5% $_{MgSO4}$ solution, the highest and lowest mass decreases were 45 grams and 20 grams. In the 7% $MgSO_4$ solution, the highest and lowest mass decreases were 110 grams and 35 grams. The highest percentage mass decrease or mass reduction was 3.030% in the compositions of SCC-0-0.325 mixture immersed in a 7% $MgSO_4$ solution.

The highest and lowest compressive strengths obtained after immersion in a 5% $MgSO_4$ solution were 66.011 MPa and 43.920 MPa. The highest percentage of compressive strength decrease was found in the composition of the SCC-15-0.300 mixture of 4.990%. The highest and lowest compressive strength obtained after immersion in a 7% $MgSO_4$ solution were 64.728 MPa and 41.446 MPa. The highest percentage of compressive strength decrease was found in the composition of the SCC-20-0.300 mixture of 10.469%.

The effects of SCBA content on the durability of SCC are as follows: The results 56 days compressive strength test shows the use of 15% SCBA substitution on cement resulted in the highest compressive strength. The highest compressive strength of 56 days on the compositions of SCC-15-0.275 mixture is 68.096 MPa. The durability test result was an immersion in $MgSO_4$ solution, 15% SCBA use resulted in the highest compressive strength, while 20% SCBA use resulted in the lowest compressive strength.

The effect of w/c ratio variations durability of SCC are as follows: The results of the compressive strength test 56 days with w/c = 0.275 resulted in the highest compressive strength, the higher value of w/c ratio causes the decrease of concrete compressive strength. The highest percentage decrease of 28 days was found in the mixture of SCC-20-0.325 which was 23.932% to the mixture SCC-20-0.275. The results of durability test with immersion in $MgSO_4$ solution of w/c ratio = 0.275 resulted in the highest compressive strength, while w/c ratio = 0.325 resulted in the lowest compressive strength. The result of the SCC microstructure test shows that w/c = 0.275 gives more solid CSH and less amount of CH than other w/c mixtures.

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