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## The effect of w/c ratio on microstructure of self-compacting concrete (SCC) with sugarcane bagasse ash (SCBA)

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SHOW ABSTRACT

# The Behavior of Self-Compacting Concrete (SCC) with Bagasse Ash

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**Abstract.** Self-Compacting Concrete (SCC) has the ability to flow and self-compacting. One of the benefit of SCC can reduced the construction time and labor cost. The materials to be used for see slightly different with the conventional concrete. Less coarse aggregate to be used up to 50%. The maximum size of coarse aggregate was also limited e.g. 10 mm. Other material was quartz sand with grain size of 50-650 μm. For reducing the around of cement, bagasse ash was used as partial replacement of cement. In this research, the variations of w/c to be used, e.g. 0.275, 0.300, 0.325 and the percentage of bagasse ash substitution were 10%, 15%, and 20%. EFNARC standard was conducted for slump flow test following the V-funnel test and L-box shape test. The maximum value of slump flow test was 75.75 cm, V-funnel test was 4.95 second, and L-box test was 1.000 yielded by mixture with w/c = 0.325 and 0% of bagasse ash. The minimum value of slump flow test was 61.50 cm, V-funnel test is 21.05 second, and L-box test was 0.743 yielded by mixture with w/c = 0.275 and 20% of bagasse ash. The maximum value of compressive strength was 67.239 MPa yielded by mixture with w/c = 0.275 and 15% of bagasse ash. And the minimum value of compressive strength was 41.813 MPa yielded by mixture with w/c = 0.325 and 20% bagasse ash.

## INTRODUCTION

Self-Compacting Concrete (SCC) is a new generation of concrete that has ultra-high compressive strength. SCC is made to reduce time efficiency and help the minimum labor in concrete work because SCC is a concrete that can flow and compact by itself. In general, the materials used as SCC constituents are cement, water, fine aggregate, coarse aggregate, and admixtures.

The research about SCC is still being done until now with many aspects of the study, such as durability, permeability, and compressive strength. Hardened concrete compressive strength > 300 MPa is achievable due to the use of superplasticizer admixture which allows decrease of water-cement ratio (w/c) to w/c ratio = 0.3 or smaller [1].

The difference between SCC and conventional concrete is in the composition of coarse aggregate, in conventional concrete the coarse aggregate is about 70 – 75% of the total volume of concrete, whereas in SCC the coarse aggregate is limited to approximately 50% of the total volume of concrete [2]. The limitation of coarse aggregate aims to allow the concrete can flow and compact by itself without a compactor [3]. Sugarcane bagasse ash (SCBA) is a by-product of the sugar industry that is burned at the sugar mill to produce the resources required for different activities. The burning of sugarcane bagasse produces sugarcane bagasse ash as waste, which has Pozzolan that is potential to be used as a substitution for cement or as a substitution material into cement. It is known that the total worldwide sugarcane production is over 1,500 million tons. Sugarcane consists of about 30% sugarcane bagasse while white sugar is about 10%, and about 8% sugarcane bagasse ash as waste, the waste disposal of sugarcane bagasse ash becomes a serious concern. This bagasse ash has been tested in several parts of the world for use as a cement substitution. Bagasse ash is found to enhance some properties of paste, mortar, and concrete including compressive strength. The higher of the silica content in bagasse ash, the better its use in cement [4].

*Proceedings of the 3rd International Conference on Construction and Building Engineering (ICONBUILD) 2017*
AIP Conf. Proc. 1903, 050005-1–050005-10; https://doi.org/10.1063/1.5011544
Published by AIP Publishing. 978-0-7354-1591-1/$30.00

The bagasse ash is the ash obtained from the bagasse which has been squeezed and has gone through a combustion process on the boiler where the bagasse is used as fuel for the boiler at the sugar mill. Steam boilers are the sources of power to move the sugarcane mills [5]. Water cement ratio is the control of water use in the concrete mixture. W/C can also be associated with workability or ease of work. In SCC, the w/c used is quite low and can be up to 0.3, but there is an additional material used to make the concrete as liquid. The variations of w/c value to produce SCC were 0.8 – 0.29 and the compressive strength results obtained from 15 – 75 MPa with EFNARC standard. The higher w/c ratio is used, the lower quality of the concrete is obtained and the lower w/c ratio is used, the higher quality of the concrete is obtained [6]. The finer size of fine aggregate is used, the larger slump flow diameter is obtained. It can be concluded that the finer size used in the concrete mixture, the higher compressive strength is obtained [7].

The composition of SCC is different from conventional concrete. Conventional concrete has a large amount of coarse aggregate about 70 – 75% from the volume, while SCC has no more than 50% [8]. The composition of mixture can be seen in Table 1.

**TABLE 1.** Mixture composition [8]

| Constituents | Mass range (kg/m$^3$) | Volume range (L/m$^3$) |
|---|---|---|
| Powder | 380 – 600 | - |
| Paste | - | 300 – 380 |
| Water | 150 – 210 | 150 – 210 |
| Coarse aggregate | 750 – 1000 | 270 – 360 |
| Fine aggregate | The content balances other constituents, usually about 48 – 55% from total aggregate | |
| Water/powder ratio from volume | - | 0.85 – 1.10 |

The composition of SCC mixture is different with conventional concrete. There are some requirements that can be seen in Table 2 [9].

**TABLE 2.** The composition requirements of SCC concrete [9]

| Parameters | Value |
|---|---|
| Coarse aggregate volume | 28 – 32% (maximum size >12 mm)<br>50% (maximum size 10 mm) |
| Paste fraction | 34 – 40% (total volume of mixture) |
| Mortar fraction | 68 – 72% (total volume of mixture) |
| w/c | 0.32 – 0.45 |
| Cement | 386 – 475 kg/m$^3$ (lower with VMA) |

## MATERIALS AND METHODS

The method that used in this study was experimental method. The mechanical property that has been done was compressive strength test. In this study, the percentages of sugarcane bagasse ash were 0%, 10%, 15%, and 20% and substituted into cement and the quartz use in SCC mixture. In this study, the variations of w/c were 0.275, 0.3, and 0.325 to find out the effect of w/c on concrete compressive strength. The compressive strength test used the cylinder specimens with dimensions of 10 cm x 20 cm and done at age 3 days, 7 days, 14 days, and 28 days. The tests of fresh concrete were slump flow test (Fig. 1), V-funnel test (Fig. 2), and L-box test (Fig. 3).

**FIGURE 1.** Slump flow

**FIGURE 2.** V-funnel

**FIGURE 3.** L-box

## Materials

The cement type that used for this study was Ordinary Portland Cement (OPC) type I according to ASTM C 150-02a standard. The water that used for the concrete mixture must be clean, no oil, and no impurities which can damage the concrete. The sugarcane bagasse ash that used was from Gula Putih Mataram Inc., Lampung. Sugarcane bagasse ash was sieved with No.200 sieve. The test of the contents of SCBA was based on SNI 15-2049-2004 and done at Semen Baturaja Laboratory, Palembang. The result of the SCBA contents can be seen in Table 3. The SEM test was done at Centre of Geology Survey Laboratory, Bandung with 500 times of magnifying. The result of SEM test of SCBA can be seen in Fig. 4. There were two kinds of fine aggregates that used in this study, the sugarcane baggase ash with the size of 0.125 – 4 mm and sand with the size of 50 – 650 μm. Coarse aggregate that used in this study was the aggregate with maximum size of 10 mm. Chemical admixtures that used was the superplasticizer type F. The use of superplasticizer was for increasing the compressive strength and reducing the water per cement ratio (w/c).

**TABLE 3.** The contents of SCBA

| Contents | Weight (%) |
|---|---|
| Silicon Dioxide ($SiO_2$) | 83.40 |
| Aluminum Oxide ($Al_2O_3$) | 0.00 |
| Iron (III) Oxide ($Fe_2O_3$) | 5.00 |
| Calcium Oxide (CaO) | 2.38 |
| Magnesium Oxide (MgO) | 0.00 |
| Sulfur Trioxide ($SO_3$) | 8.36 |
| LOI | 83.40 |

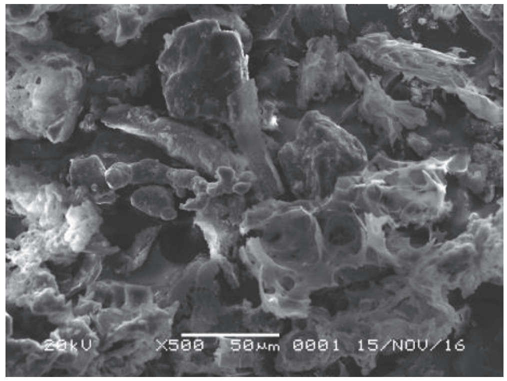


**FIGURE 4.** SEM test of SCBA

## Mixture Composition

The composition of SCC was arranged with the collection of some journals, EFNARC standard, and ACI standard. The material that used were OPC type I cement, the fine aggregate (FA) with the size of 50 – 650 µm as the first fine aggregate and the size of 0.125 – 4 mm as the second fine aggregate, the maximum size of coarse aggregate (CA) was 10 mm, water, and superplasticizer (SP) 1,500 ml per 100 kg of cement. The composition of SCC mixture that used can be seen in Table 4.

**TABLE 4.** The composition of 1 $m^3$ SCC

| Label | 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 | 570 | 60 | 246 | 540 | 823 | 165 |
| SCC-5-0.300 | 570 | 60 | 246 | 540 | 823 | 180 |
| SCC-5-0.325 | 570 | 60 | 246 | 540 | 823 | 195 |
| SCC-10-0.275 | 540 | 120 | 246 | 540 | 823 | 165 |
| SCC-10-0.300 | 540 | 120 | 246 | 540 | 823 | 180 |
| SCC-10-0.325 | 540 | 120 | 246 | 540 | 823 | 195 |
| SCC-15-0.275 | 510 | 180 | 246 | 540 | 823 | 165 |
| SCC-15-0.300 | 510 | 180 | 246 | 540 | 823 | 180 |
| SCC-15-0.325 | 510 | 180 | 246 | 540 | 823 | 195 |

# RESULT AND DISCUSION

## The Result of Fresh Concrete Test

### *Slump flow*

The result of slump flow can be seen Fig. 5 and Fig. 6. The value of the slump flow was from four directions and then averaged. Based on Fig. 5, it can be seen w/c = 0.325 has the largest slump flow diameter of 75.75 cm from SCC-0-0.325 and w/c = 0.275 has the smallest diameter slump flow diameter of 61.50 cm from SCC-20-0.275. The variations of w/c affected slump flow diameter, the lower w/c used in the mixture caused the smaller the slump flow diameter. Based on Fig. 6, the largest slump flow diameter is on SCBA 0% from cement weight of 75.75 cm and the smallest slump diameter is SCBA 20% from cement weight of 61.50 cm.

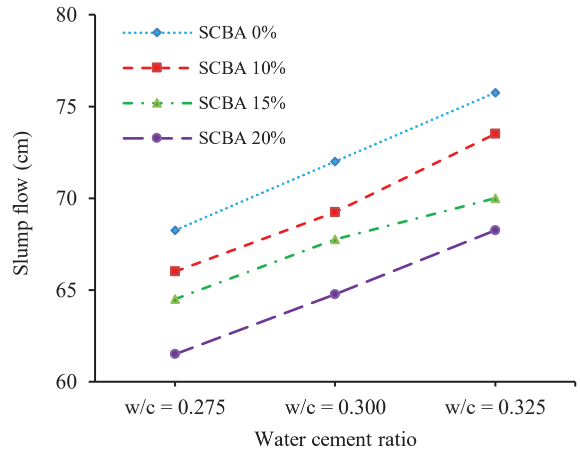


**FIGURE 5.** The effect of water cement ratio on slump flow

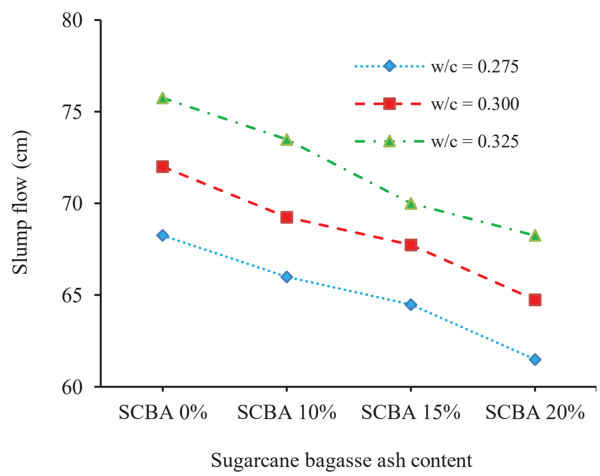


**FIGURE 6.** The effect of sugarcane bagasse ash on slump flow

### *V-funnel*

The V-funnel test can be seen in Fig. 7 and Fig. 8. The value of V-funnel was the stopwatch reading for counting the concrete flow time from V-funnel. The result of V-funnel test from SCBA 20% was faster than SCBA 0% with each time of 21.05 seconds and 4.95 seconds. The finer grain size of sugarcane bagasse ash caused the material more reactive and faster to absorb water, the more sugarcane bagasse ash used causes the higher of the viscosity value. Therefore, the use of sugarcane bagasse ash in large amount can cause the concrete mixture more viscous and longer to flow. The result of V-funnel with w/c = 0.325 was faster than w/c = 0.275 with each time of 21.05 seconds and 4.95 seconds. The higher w/c used in the mixture, it took the faster time for concrete to flow on the V-funnel.

### *L-shape box*

The result of L-box test can be seen in Fig. 9 and Fig. 10. The value of L-box test was obtained from the high measurement $H_2$ and $H_1$, then the data were compared (passing ratio). The L-box result from w/c = 0.275 was lower than w/c = 0.325 with each passing ratio 0.743 and 1.000. The lower w/c used in the mixture, the ability of SCC to pass through the reinforcement gaps became hampered. The higher w/c used in the mixture, the ability of SCC to pass through the reinforcement gaps became not hampered.

The L-box test result from the mixture of SCBA 20% was lower than SCBA 0% with each passing ratio of 0.743 and 1.000. The finer grain size of SCBA made the material thicker and faster to absorb water. The higher of SCBA used in the mixture, the ability of SCC to pass through the reinforcement gaps became hampered. The lower SCBA used in the mixture, the ability of SCC to pass through the reinforcement gaps became not hampered.

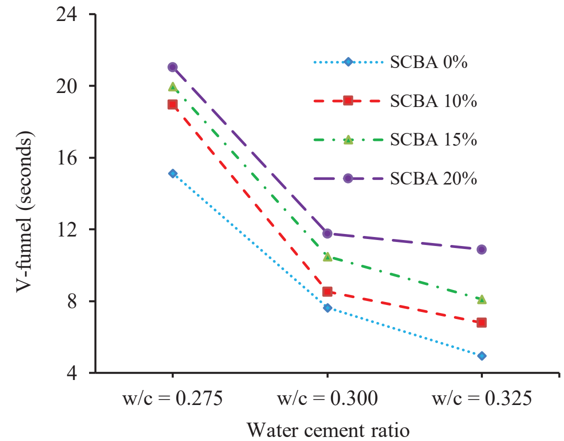


**FIGURE 7.** The effect of water cement ratio on V-funnel

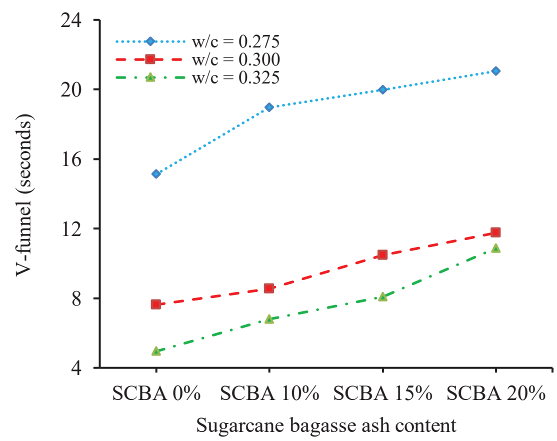


**FIGURE 8.** The effect of sugarcane bagasse ash content on V-funnel

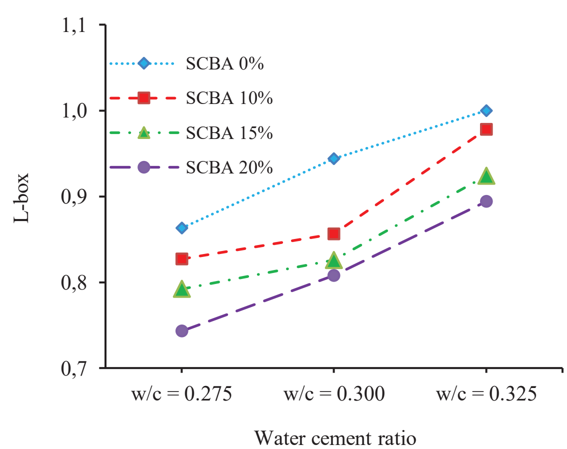


**FIGURE 9.** The effect of water cement ratio on L-box

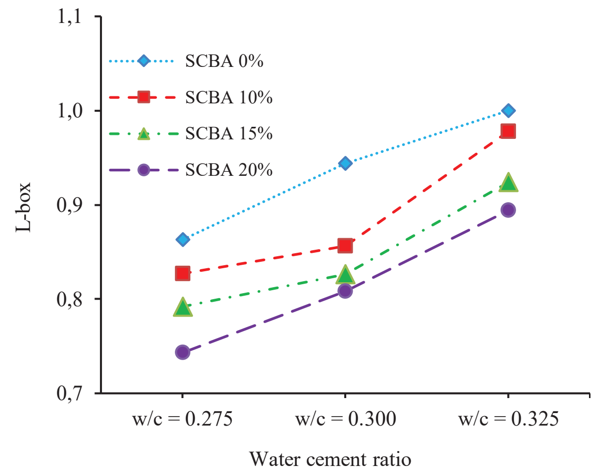


**FIGURE 10.** The effect of water cement ratio on L-box

## The Test Results of Hardened Concrete

The results of the compressive strength and the percentage change of hardened concrete for age 3, 7, 14, and 28 days of concrete can be seen in Fig. 11 for SCBA 0%, Fig. 12 for SCBA 10%, Fig. 13 for SCBA 15%, Figure 14 for SCBA 20%, Fig. 15 for the correlation between compressive strength of age 28 days of compressive strength and w/c, and Figure 16 for the correlation between compressive strength of age 28 days and SCBA content.

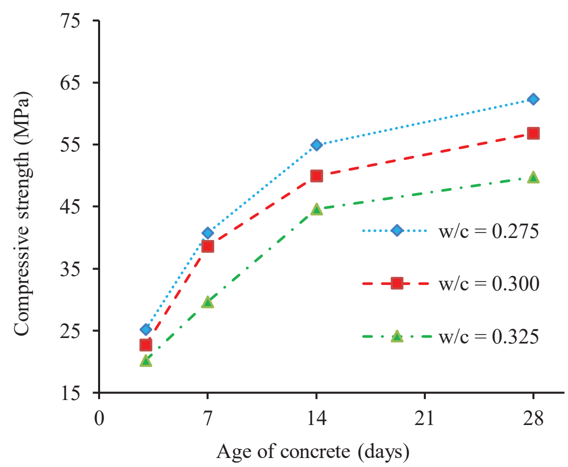


**FIGURE 11.** The effect of age of concrete on SCBA 0% compressive strength

The result of compressive strength SCBA 0% with w/c = 0.275 and w/c = 0.300 showed the increase of compressive strength from age 3, 7, 14, and 28 days significantly. While with w/c = 0.325 showed a not significant increase from age 3 and 7 days and at age 14 days showed the increase significantly the same as w/c = 0.275 and w/c = 0.300. The result of compressive strength SCBA 10% showed a significant increase from age 3, 7, 14, and 28 days with w/c = 0.325. The concrete of w/c = 0.300 and w/c = 0.325 at age 7 days showed almost the same results. After 14 days, the compressive strength showed the significant increase for each w/c ratio. The result of compressive strength SCBA 15% with w/c = 0.275 and w/c = 0.300 showed a significant increase at age 3, 7, 14, and 28 days. The concrete of w/c = 0.325 at age 7 and 14 days showed the increase that almost the same with w/c = 0.300 at age 14 days. Age 28 days did not show any significant increase with w/c = 0.325. The result of compressive strength SCBA 20% with w/c = 0.275 and w/c = 0.300 showed the increase of compressive strength from age 3-28 days significantly.

While with w/c = 0.325 showed a not significant increase at 7 days, almost the same with age 3 days, and after age 14 days showed the increase significantly. Age 28 days showed the significant increase of compressive strength.

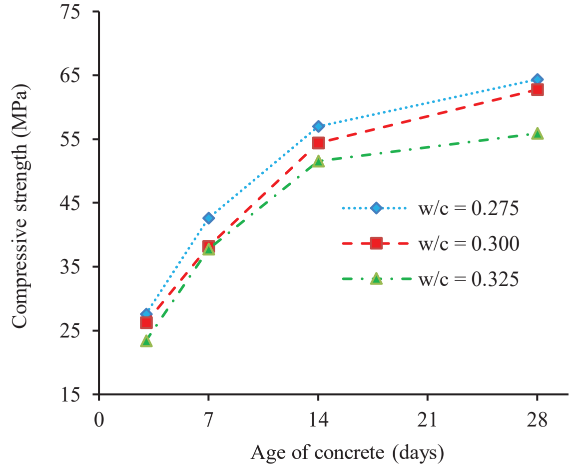


**FIGURE 12.** The effect of age of concrete on SCBA 10% compressive strength

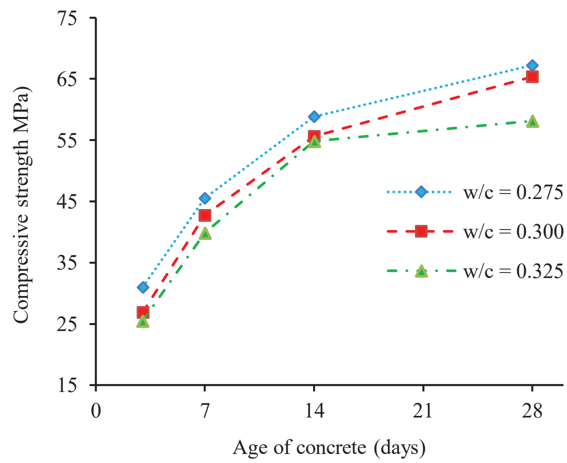


**FIGURE 13.** The effect of age of concrete on SCBA 15% compressive strength

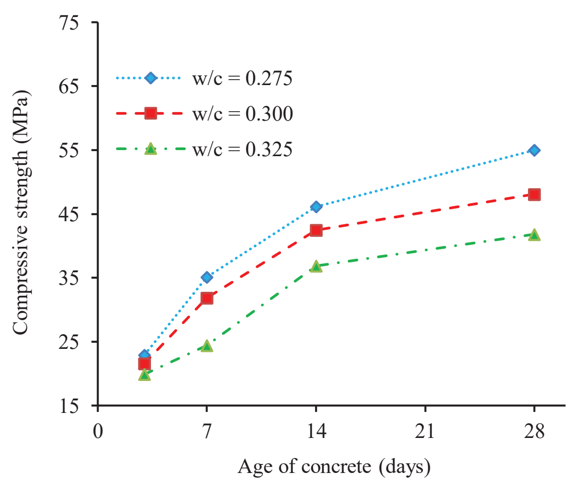


**FIGURE 14.** The effect of age of concrete on SCBA 20% compressive strength

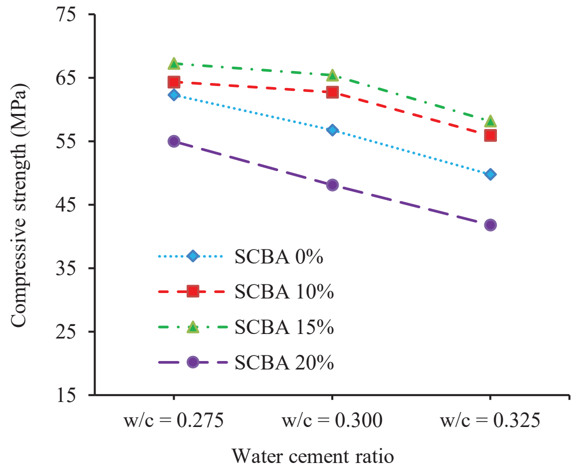


**FIGURE 15.** The effect of water cement ratio on on compressive strength result of age 28 days

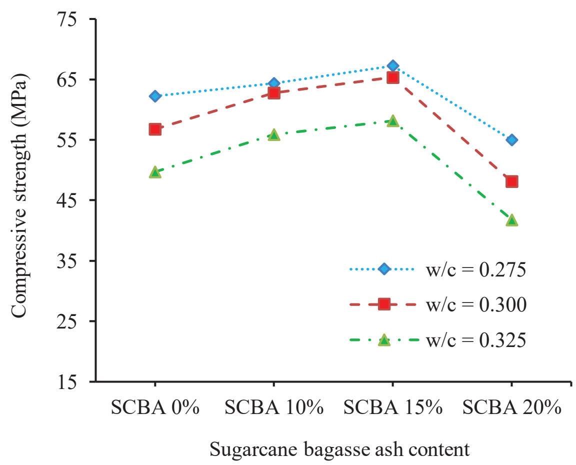


**FIGURE 16.** The effect of sugarcane baggase ash content on compressive strength result of age 28 days

The result of compressive strength at age 28 days was obtained for the highest result with w/c = 0.275 and the lowest result w/c = 0.300 which were 67.239 MPa on SCC-15-0.275 and 41.813 MPa on SCC-20-0.325. This obtained result was because the higher of w/c ratio used in the mixture caused the decrease of compressive strength.

The result of compressive strength at age 28 days was obtained for the optimum compressive strength on SCBA 15% from cement weight and the lowest on SCBA 20% and each result was 67.239 MPa and 41.813 MPa. The compressive strength test shows that the optimum addition of SCBA is 15% from cement weight. It was because the sugarcane bagasse ash (SCBA) had a high $SiO_2$ content that cause the forming of CSH, so it can increase the compressive strength. SCBA also had finer size than cement so that it became the filler for minimizing concrete pores which made concrete more solid and dense. The addition of SCBA 20% caused the decrease of compressive strength because the excessive addition of SCBA can cause the damage for chemical reactions in concrete.

## CONCLUSIONS

The conclusions obtained from the study results are as follows:

- The effects of w/c ratio and SCBA content on fresh concrete tests (workability):
  - The higher of w/c ratio caused the larger slump diameter. The more amount of SCBA content in the concrete mixture caused the smaller slump diameter.
  - The higher of w/c ratio caused the less time for concrete to flow on the V-funnel. The more amount of SCBA content in the concrete mixture caused the longer time for concrete to flow on the V-funnel.

- The higher of w/c ratio caused the greater value of passing ratio**.** The more amount of SCBA content in the concrete mixture caused the smaller value of passing ratio and the ability of the concrete to pass through the reinforcement was increasingly hampered.

- The effects of w/c ratio and SCBA content on SCC mechanical properties:
  - The results of the compressive strength test indicate that the compressive strength of w/c = 0.275 was greater than w/c = 0.325. The w/c ratio in concrete was very influential on the compressive strength of concrete; the greater w/c ratio caused decrease in compressive strength.
  - The result of the highest compressive strength test was obtained at SCC-15-0.275 that is 67.239 MPa. SCBA content was also influential in the compressive strength of concrete. In this study, the optimum SCBA content to achieve a high compressive strength was 15% of the weight of cement. If the SCBA content exceeds 15%, it will cause decrease in compressive strength. This happened because an excessive SCBA content can damage chemical reactions in concrete.

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*Penulis :* **Dr. Ir. Hanafiah, MS**

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