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The Effect of Rice Husk Ash as Cement Substitution on the Compressive Strength of Self-Compacting Concrete

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ABSTRACT

Self-Compacting Concrete (SCC) is an innovative solution in today's world of concrete technology. Unlike traditional concrete, it does not require a vibrator for compaction, which makes concrete work easier. One of the key features of SCC is its high workability, which is achieved through the use of chemical admixtures and mineral additives. Rice husk ash is one such additive that can be used as a pozzolanic material for concrete mixtures, which is important as rice husk waste can cause environmental problems. The objective of this study was to investigate the effect of rice husk ash on SCC concrete. The study involved using Rice Husk Ash (RHA) as a partial replacement for cement in SCC concrete at varying percentages (0%, 5%, 10%, and 15% of cement weight). The results of the slump flow test showed that the highest value of 775 mm was achieved at 15% RHA, meeting the specifications of SCC concrete. In terms of compressive strength, the results showed that the SCC mixture without rice husk ash (0% RHA) had the highest average compressive strength, which was 30.56 MPa at 14 days and 31.66 MPa at 28 days of concrete. On the other hand, the average compressive strength of SCC concrete with rice husk ash mixture was highest at 5% RHA, with 25.04 MPa at 14 days and 28.81 MPa at 28 days. Overall, the study found that the use of rice husk ash in SCC concrete had a significant effect on its compressive strength, with the highest compressive strength being achieved at 5% RHA.

Keywords: *Self Compacting Concrete; Rice Husk Ash; Compressive Strength; Slump Flow.*

INTRODUCTION

Compaction or vibration of concrete is crucial in conventional reinforced concrete structure work, especially in parts of concrete structural elements that are difficult to compact perfectly with a vibrator. This is because imperfect compaction can cause gaps in tight reinforcement and voids in the mold room, leading to a reduction in concrete compressive strength and impermeability [1]. Air must be expelled during the mixing process to obtain a uniform solid mass. To overcome the problem of difficult compaction, self-compacting concrete (SCC) technology can be used.

Self-compacting concrete (SCC) is a type of fresh concrete that was first developed in Japan in the mid-1980s. It began to be used in concrete construction in the early 1990s. Unlike traditional concrete, SCC can flow through reinforcement and fill all the space in the mold densely without the need for compaction, either manually or by mechanical vibration[2]. To achieve this, SCC requires a higher paste content, aggregate size setting, aggregate portion, and superplasticizer admixture to achieve a special viscosity that allows it to flow on its own [3].

SCC technology is now widely used in various construction projects. It offers several advantages over conventional concrete, including improved workability, which can reduce the time and labor costs needed, making it easier to fill solid molded parts, improving the bond between cement paste and aggregate/reinforcement, and improving the durability and quality of concrete [4]. Several ways can be used to improve the quality of high concrete and workability in SCC concrete, including paying attention to the constituent components by using mineral additives such as pozzolan from waste materials either as additives or as a substitute for cement in the concrete mixture.

The reuse of waste materials in concrete is an attempt to solve environmental problems and enhance concrete performance by incorporating mineral-based materials in industrial construction. Rice Husk Ash (RHA) is a byproduct of rice husk combustion that is often used as fuel to make red bricks. RHA is widely available in many parts of the world, including Indonesia, and it is a major contributor to air, river, sea, and groundwater pollution. According to National BPS data [5], national rice production reached 54.42 million tons of GKG (dry milled grain) in 2021, while rice production between January and April 2022 reached 25.4 million tons of GKG, a 7.7% increase from the same period in 2021. This leads to an increase in rice husk waste production, where every kilogram of rice yields 280 grams of husk [6]. The use of RHA in concrete is expected to alleviate part of the environmental issues. RHA contains a high percentage of silica compounds (SiO_2) of 89.64% [7], making it a pozzolanic material that can enhance concrete performance.

This study investigates the impact of incorporating RHA as a partial substitute for cement in Self-Compacting Concrete (SCC). The study will consider the compressive strength and workability of the SCC mixture.

METHOD

Research Approach

The methodology used in this study is an experimental method, specifically laboratory testing. It aims to determine the cause-and-effect relationship between different factors and compare them. In this study, several tests were conducted, including material testing, SCC (Slump Flow) fresh concrete testing, and SCC hard concrete (Compressive Strength) testing by creating test samples. The goal of this research was to investigate the impact of using rice husk ash as a substitute for some cement in Self Compacting Concrete.

Research sites

This research was conducted at the Laboratory of Materials and Soil Mechanics, Civil Engineering Department of Padang State University. The laboratory is located at Jl. Prof. Dr. Hamka in West Fresh Water, North Padang District, Padang City, West Sumatra. The planning phase for this concrete research activity took approximately four months, starting in August 2022 until December 2022.

Research Test Materials and Samples

The materials used in this final project research consist of several types. Portland cement with the brand Semen Padang is obtained by ordering from cement producers. Fine and coarse aggregate are obtained from suppliers producing materials. Fine aggregate comes from Batang Air Pauh, Nagari Kurai Taji, and Kota Pariaman and coarse aggregate comes from the crushed

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stone factory in Kalumbuk, Kuranji District, Padang City. The coarse aggregate used has a maximum size of 10 mm. The water used is found in the Laboratory of Soil Materials & Mechanics, Civil Engineering, Padang State University. Mineral-added materials in the form of rice husk ash are obtained from combustion waste at a red brick manufacturing plant in Kanagarian Piladang, Lima Puluh Kota Regency, West Sumatra. Rice husk ash is sifted using sieve no.200.

To get the SCC-type concrete mixture, additional chemicals are used in the form of superplasticizers with the brand SikaCim Concrete Additive. 1% of the weight of cement is used. The test sample made in this study was in the form of cylindrical concrete measuring 15 cm x 30 cm using added materials in the form of rice husk ash in the SCC technology concrete mixture. This hard concrete testing is carried out at 14 and 28 days of concrete life. The planned manufacture of SCC concrete test samples is as many as 24 cylindrical concrete samples with the percentage of using rice husk ash as a substitute for cement, namely 0%, 5%, 10%, and 15%.

Mix *Design*

When planning the mixture for concrete, the data used are based on the test results of the basic materials of the concrete components. These materials have been previously calculated as per the standard technical specifications for concrete design. During the planning stage, the mixture design for Self-Compacting Concrete (SCC) refers to SNI 03-2834-2000 [8] to determine the appropriate proportion of cement, fine aggregate, coarse aggregate, and water. A trial mix is carried out to adjust the characteristics of SCC as per the specifications of EFNARC Specifications & Guidelines for Self-Compacting Concrete (2002) [9]. The table below shows the calculation results of mix planning and the amount of material composition required for the SCC concrete mixture.

Table 1. Composition of SCC for 1m³ of Concrete Mixture

Percentage of RHA (%)	Weight (kg/m³)					
	Water	**PCC**	**Fine Aggregate**	**Coarse Aggregate**	**RHA**	**SP**
0	233,33	530,30	638,12	918,27	-	5,83
5	233,33	503,79	638,12	918,27	26,52	5,83
10	233,33	477,27	638,12	918,27	53,03	5,83
15	233,33	450,76	638,12	918,27	79,55	5,83

Table 2. Composition of the mixture for 6 pieces of specimens (0.03174 m³)

Percentage of RHA (%)	Weight (kg/m³)					
	Water	**PCC**	**Fine Aggregate**	**Coarse Aggregate**	**RHA**	**SP**
0	**7,41**	**16,83**	**20,25**	**29,14**	**-**	**0,19**
5	7,41	15,99	20,25	29,14	0,84	0,19
10	7,41	15,15	20,25	29,14	1,68	0,19
15	7,41	14,31	20,25	29,14	2,52	0,19
Total	29,62	62,28	81,01	116,56	5,05	0,74

RESULTS AND DISCUSSION

Material Testing

In order to ensure that the concrete mixture meets the necessary quality standards, it is imperative to subject all the materials that will be used in the mixture to comprehensive testing. This involves examining the characteristics of the aggregate to determine if they meet the required specifications. The testing process is vital because any material that fails to meet the requirements cannot be used in the concrete mixture.

Consequently, the aggregate characteristics have been meticulously examined using various testing methods to ensure that they meet the necessary standards. The tests conducted include analyzing the size, shape, and texture of the aggregate, as well as determining its strength, durability, and water absorption capacity. The testing results have been compiled below to provide an accurate representation of the aggregate's characteristics.

Table 3. Aggregates properties

Material Testing	Fine Aggregate	Coarse Aggregate
Water content (%)	10,53	0,535
Mud content (%)	2,07	0,209
SSD Specific Gravity	2,523	2,686
Absorption (%)	3,79	1,31
Loose Bulk Density (gr/ml)	1,243	1,365
Compacted Bulk Density (gr/ml)	1,480	1,513
Fineness Modulus	3,284	7,18
Organic Impurities	No. 2	-
Aggregate Abrasion (%)	-	18,8

SCC *Slump Flow* Testing

In the context of construction, the workability and speed of Self-Compacting Concrete (SCC) are determined by the concrete slump flow value. This value is of great significance, as it affects the overall quality of the concrete. To ensure that the SCC concrete meets the standards set by EFNARC, a slump flow value of 650 mm is required. In this study, we have adhered to these standards and conducted a slump flow test to determine the value of SCC concrete. The results of this test are presented in Table 4, Figure 1, and Figure 2, which provide a comprehensive overview of the SCC concrete slump flow value.

Table 4. *SCC* Slump Flow Test Results

SCC Mixed Variants	D1 (cm)	D2 (cm)	Average (cm)
Normal SCC	68	68	68
RHA 5%	73	74	73,5
RHA 10%	74	75	74,5
RHA 15%	77	78	77,5

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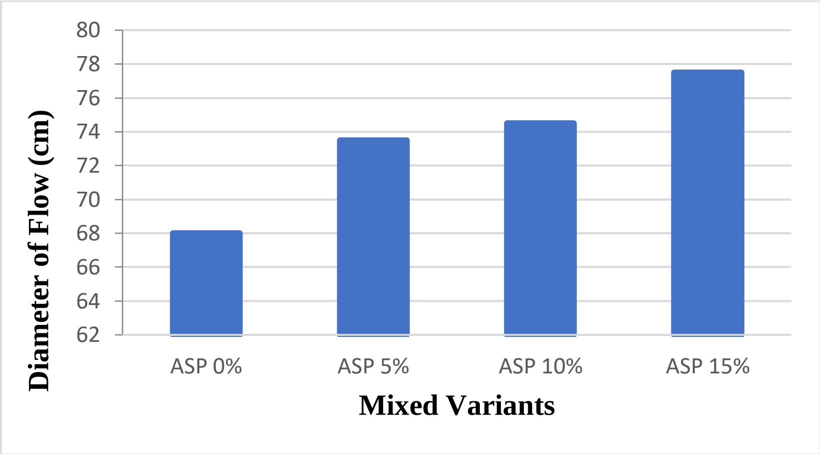

Figure 1. *Slump Flow Test Results Graph*

Figure 2. *Slump Flow Examination Results*

Based on the results of slump flow testing, it is evident that the inclusion of rice husk ash in the SCC concrete mixture has an impact on the distribution diameter. The test results indicate an increase in distribution diameter as the amount of rice husk ash in the SCC concrete mixture increases. The flow diameter of SCC concrete with rice husk ash mixture is as follows: 680 mm at ASP 0%, 735 mm at ASP 5%, 745 mm at ASP 10%, and 775 mm at ASP 15%. These slump flow results meet the requirements for SCC distribution diameter.

SCC Compressive Strength Testing

The objective of this test is to assess the compressive strength of Self-Compacting Concrete (SCC) and determine the impact of substituting cement with rice husk ash partially. To conduct this test, specimens have been created as per the mixed design and will be examined after 14 and 28 days from casting. The results of the compressive strength test will be analyzed for each percentage of rice husk ash used and will be presented in Table 5.

The following data presents a comprehensive analysis of the compressive strength of self-compacting concrete (SCC) with and without rice husk ash (RHA) at two stages of its life,

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namely after 14 and 28 days. The average compressive strength of SCC concrete without RHA was found to be 30.56 MPa at 14 days and 31.66 MPa at 28 days. Conversely, the SCC concrete with 5% RHA had an average compressive strength of 25.04 MPa at 14 days and 28.81 MPa at 28 days. Similarly, the SCC concrete with 10% RHA had an average compressive strength of 23.72 MPa at 14 days and 25.88 MPa at 28 days. Finally, the SCC concrete with 15% RHA showed an average compressive strength of 20.78 MPa at 14 days and 22.43 MPa at 28 days.

It is worth noting that the compressive strength of SCC concrete decreases as the percentage of RHA increases. The chart below provides a clear overview of the compressive strength yield of SCC concrete across both 14 and 28 days of its life. These findings can be utilized to determine the optimal amount of RHA required for the production of SCC concrete, ultimately enhancing its strength and durability.

Table 5. Compressive Strength of SCC Concrete with Variation of RHA

Variations of Rice Husk Ash".	**Age (days)**	**Surface area (cm^2)**	**Max Load (kg)**	**Compressive Strength (MPa)**	**Average (MPa)**
SCC RHA 0%	14	176,625	60510	34,25	30,56
			50760	28,73	
			50690	28,69	
	28	176,625	53560	30,32	31,66
			58580	33,16	
			55670	31,51	
SCC RHA 5%	14	176,625	42650	24,15	25,04
			44420	25,15	
			45630	25,83	
	28	176,625	53190	30,11	28,81
			50810	28,76	
			48680	27,56	
SCC RHA 10%	14	176,625	43940	24,87	23,72
			40170	22,74	
			41570	23,54	
	28	176,625	45080	25,52	25,88
			45326	25,66	
			46750	26,46	
SCC RHA 15%	14	176,625	36640	20,75	20,78
			36700	20,78	
			36770	20,82	
	28	176,625	39680	22,47	22,43
			39910	22,59	
			39270	22,23	

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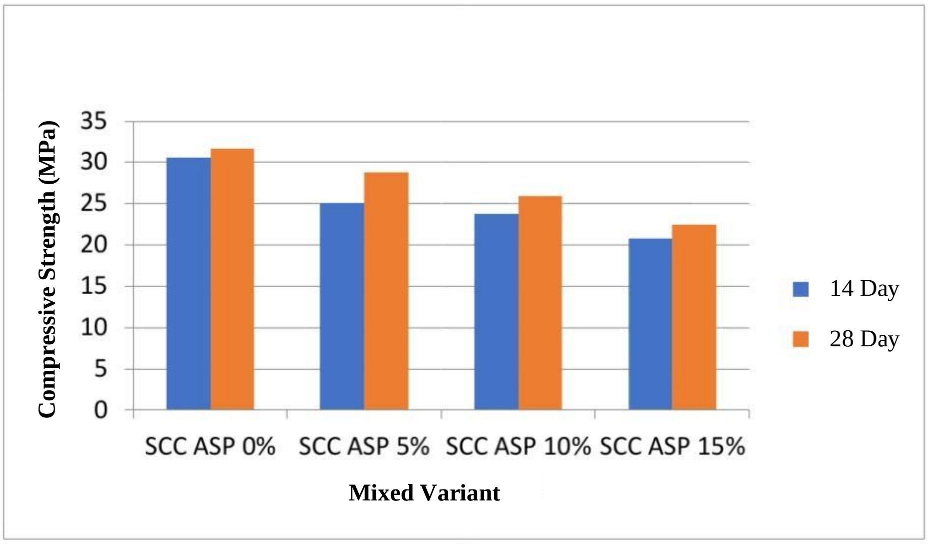

Figure 3. SCC compressive strength test result graph

It has been observed that the quality of concrete increases significantly from 14 days to 28 days. However, it is also found that the compressive strength of self-compacting concrete (SCC) decreases as the percentage of rice husk ash (RHA) increases in the mixture. The compressive strength of SCC concrete is highest in the mixture without RHA (0%) at 30.56 MPa for 14 days and 31.66 MPa for 28 days. On the other hand, the lowest compressive strength value is found in the mixture with 15% RHA, which is 20.78 MPa for 14 days and 22.43 MPa for 28 days.

The graph clearly shows that self-compacting concrete (SCC) with a certain amount of rice husk ash (RHA) has the highest compressive strength value in the 5% RHA mixture variant. After 14 days, the value is measured at 25.04 MPa, and after 28 days, it increases to 28.81 MPa. However, it's important to note that increasing the RHA percentage can lead to a higher distribution value of fresh concrete, which can result in a thinner and less cohesive mixture due to poor bonding between RHA and water. Additionally, the low calcium oxide content of RHA (only 0.50%) makes it unsuitable as a partial cement substitute, which can also impact the compressive strength yield.

CONCLUSION

After conducting research and calculations, the following conclusions were drawn:

1. All test results for fresh Self-Compacting Concrete (SCC) containing Rice Husk Ash (RHA) at 0%, 5%, 10%, and 15% met the required standards for SCC.
2. The test results for SCC's slump flow showed an increase in the diameter of the distribution as the amount of rice husk ash in the SCC mixture increased. At 15% RHA, the highest flow value was recorded at 775 mm.
3. The SCC studied in this research facilitated the work process without requiring compaction like conventional concrete. It also resulted in fewer cavities than usual concrete, making it a more efficient option.
4. The highest average compressive strength value was recorded at 0% RHA, which was 31.66 MPa at the age of 28 days. However, SCC concrete with a mixture of RHA had the highest compressive strength value at 5%, which was 28.81 MPa at the age of 28 days.

5. The percentage of compressive strength obtained from RHA decreased with each addition. Therefore, using rice husk ash is not recommended to replace some cement in SCC concrete, as it can negatively affect the mixture's quality.

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