DETERIORATION OF CONCRETE INCORPORATING RICE HUSK ASH WITHOUT PROCESSING UNDER SIMULATED ACID RAIN ENVIRONMENT

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ABSTRACT

Cement production was expressed as the second largest contributor of CO_2. Therefore nowadays, creature of environmentally friendly concrete is increased so that economy development does not have to stop for the sake of the environment. The acidity of rainfall in the majority of Indonesia has a pH value ranging from 3 to 5. This condition indicates that rainfalls at several cities were acid and would damage the concrete. The aim of this study is to use rice husk ash as a cement substitute in concrete mix in order to reduce damage caused by acid rain attack. This study is an experimental study using rice husk ash, as waste material from the burning husks in brick produce. Before using the ash in mixing, it was filtered with #100 sieve. It also examined its characteristics using scanning electron microscopy (SEM), energy dispersive X-ray (EDX) and X-ray diffraction (XRD). Specimens were cubes while to simulate acid rain; acid solution mixing H_2SO_4 and HNO_3 was used in this study with two pH values. The independent variables in this study consist of the rice husk ash percentage and pH values. Rice husk ash replacement levels of 0%, 5% and 10%, by weight of cement were used in this experiment. Immersion of specimens takes until 90 days. The experiment used two levels of pH which were 3 and 4. Furthermore, the dependent variable is the deterioration of concrete. Deterioration was measured by three parameters, namely compressive strength, CaO/SiO_2 ratio and percentage of SO_3. The data was collected by conducting a SEM test and compressive strength test on the specimen. The results of this study showed that rice husk ash could potentially be used as a cement substitute in the concrete to decrease the deterioration of concrete due to acid rain.

Keywords: Acid rain, concrete, rice husk ash, SEM analysis, compressive strength.

1. INTRODUCTION

The economy development is rapidly increasing growth of concrete buildings in many places. Because of that, concrete production increased in number significantly. Unfortunately concrete production is synonymous with environmental damage, such as limestone digging process, the process of combustion, or emissions. Cement production was expressed as the second largest contributor of CO_2. Therefore nowadays, creature of environmentally friendly concrete is increased so that economy development does not have to stop for the sake of the environment.

Previous studies have researched about the positive opportunities using rice husk ash (RHA) as a cement replacement material in concrete mix. Concrete mixture containing up to 25% RHA as a replacement of ordinary Portland cement (OPC) produced the same strength as the concrete containing 100% OPC. Higher proportions (40%) of RHA could be used for non-structural works where strength is not critical [4,5]. Due to the high specific surface area of the RHA, the dosage of superplasticizer had to be increased along with RHA fineness to maintain the desired workability. Increasing RHA fineness would enhance the strength of blended concrete; this due to the increased pozzolanic activity and that RHA will act as micro filler in the concrete matrix [3]. Concrete containing 10% and 20% of RHA replacements level showed excellent durability to chloride attack [1].

Based on those studies, the aim of this study is to use RHA as a cement substitute in concrete mix in order to reduce damage caused by acid rain attack. The acidity of rainfall in the majority of Indonesia has a pH value below the normal pH (pH 5.6) which was ranging from 3 to 5. On the other hand, acid condition that tolerated by concrete is pH 5 – 6. This condition indicates that rainfall would damage the concrete. H^+ in acid rain dissolves $Ca(OH)_2$ in the hardened cement paste and that SO_4^{2-} also corrodes it. The dissolution effect of H^+ will lead to the reduction of $Ca(OH)_2$ concentration in the concrete specimens [8].

2. METHODOLOGY

2.1. Materials

The RHA was collected from brick manufacturing that uses rice husk as fuel. Figure 1 presents the mineralogy of RHA was obtained with XRD, whereas the presentation composition of silicon dioxide was 95.08 by using SEM-EDX. XRD test of powdered RHA was performed using Rigaku MiniFlex II XRD. This analysis was carried out to ascertain the mineralogical phases (amorphous or crystalline) of the RHA. Figure 1 displayed the XRD pattern of RHA sample. It showed a peak, representing it as crystalline structures, which were identified as cristobalite low, making it a proper cement-replacement material due to its high pozzolanic activity [1,4,5,6,7].

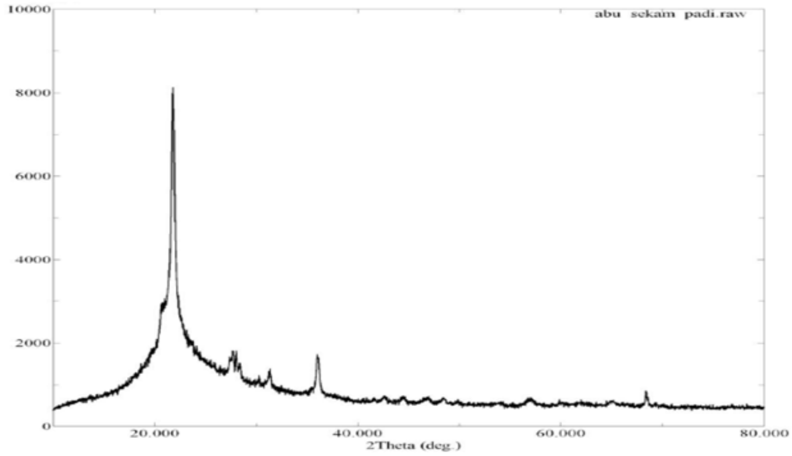

Figure 1. X-ray diffraction of RHA

Table 1. Chemical composition of PCC

Oxide compounds	Chemical composition (%)
CaO	60.33
SiO_2	21.50
Al_2O_3	8.60
FeO	3.17
SO_3	2.69
K_2O	1.80
Na_2O	0.99
MgO	0.58

In this study, natural siliceous river sand (fineness modulus of 2.6 and specific gravity of 2.42) is used as fine aggregate, crushed granite (maximum nominal size 20 mm and specific gravity of 2.3) as coarse aggregate. The Portland composite cement (PCC) was used as the major binder material in this study, to product 30 MPa of strength concrete. The chemical compositions of the PCC, which was carried out using SEM-EDX, are listed in Table 1. Utilization RHA with PCC reduced workability of the concrete mixture. In order to maintain its workability, a superplaticizer was used. The type of Sikamen-LN was used and its specific gravity was 1.20.

2.2. Methods

Cube concrete specimens that were 150 mm x 150 mm x 150 mm were prepared for tests. Table 2 shows the mixture proportion of concrete. The cement, sand and course aggregate content was 402 kg/m^3, 705 kg/m^3 and 1071 kg/m^3, respectively. The control mix was prepared using 100% of PCC. RHA replacement level of 5% and 10%, by weight of cement were used in this study. The experiment used two levels of pH which were 3 and 4.

The specimens were divided into three groups. The first group was immersed in water. The second and the third group were immersed in solution with pH value of 3 and 4, respectively. They were immersed for 1 day and then naturally dried them at room temperature for 1 day along 90 days.

Table 2. Mix proportions of concrete (kg/m^3)

Concrete	PCC	RHA	Sand	Course Aggregate	Water	Superplasticizer	Curing
N-W	402	0	705	1071	187	0	Water
RHA5-W	381.9	20.1	705	1071	187	3.8	Water
RHA10-W	361.8	40.2	705	1071	187	3.8	Water
N-A3	402	0	705	1071	187	0	Acid (pH3)
RHA5-A3	381.9	20.1	705	1071	187	3.8	Acid (pH3)
RHA10-A3	361.8	40.2	705	1071	187	3.8	Acid (pH3)
N-A4	402	0	705	1071	187	0	Acid (pH4)
RHA5-A4	381.9	20.1	705	1071	187	3.8	Acid (pH4)
RHA10-A4	361.8	40.2	705	1071	187	3.8	Acid (pH4)

Test carried out on concrete specimens with and without RHA after immersion in acid solution for 90 days. The first test was conducted to cube specimens to find compressive strength. To find CaO/SiO_2 ratio and percentage of SO_3, little hardened specimens were ground into powder for SEM-EDX analysis.

3. RESULTS AND DISCUSSIONS

3.1. Compressive Strength

Compression tests were performed at the age of 90 days on cube specimens to evaluate the evolution in compressive strength (fc'). Table 3 shows the compressive strengths which were calculated from five specimens each series. It shows that samples of RHA5 gave better result than those of RHA10.

Table 3. Compression tests

Concrete	fc' (MPa)
N-W	32.33
RHA5-W	34.52
RHA10-W	30.54
N-A4	27.51
RHA5-A4	30.20
RHA10-A4	28.15
N-A3	27.01
RHA5-A3	29.54
RHA10-A3	27.47

Specimens of RHA5 in an acid solution (value pH of 3 and 4), gave the highest compressive strength of 30.20 MPa and 29.54 MPa, respectively. While in normal immersion conditions, these specimens was able to provide enhanced compressive strength by 2.19 MPa compared to the control specimens. But in the acid immersion, it appears that there was a greater reduction than in water immersion. This can happen because of the nature of the RHA, which has longer initial setting time compare to cement [2], when the specimen was directly treated in an acid solution.

3.2. CaO/SiO_2 Ratio

The CaO and SiO_2 percentages of the concrete specimens with and without RHA were measured in different acid solutions. These compositions were found by SEM-EDX analysis. Table 4 shows the CaO and SiO_2 percentages formed after immersion in for 90 days.

It can be seen that when the specimens with RHA immersed in water, CaO/SiO_2 ratio tends to decrease when those without RHA. This is consistent with the theory that the silica in the RHA will react with $Ca(OH)_2$ and form new CSH. This led to a decline in CaO content in concrete, from 50.44% to 43.58% and 43.60%. Meanwhile, the condition of the concrete immersed in acid, showed both a decrease and an increase in the ratio as well. The ratio of RHA5 immersed in the acid solution with pH value of 4 decreased compared to the specimens without RHA. This phenomenon is caused by the fact that the content of $Ca(OH)_2$ will react either with silica from RHA or sulfuric acid as well, so it declined from 45.44% to 37.65%. It is not similar for the specimen of RHA10, the condition is opposite which it has an increase ratio. CaO content goes up to 54% is not the same of other specimens. There is the possibility of replacing

10% of cement with RHA causes the percentage of $Ca(OH)_2$ which reacts with sulfuric, is bigger than with silica. It also causes a decrease in the percentage of silica from 29.72% to 24.84%, because a percentage of new CSH compounds are little.

Based on the above description, it can be concluded that the ratio does not give a clear enough figure about CSH formation and reduction of $Ca(OH)_2$. Therefore, it is necessary to further study to find exact compound formed, for example by XRD test of concrete.

Table 4. CaO/SiO_2 ratio

Samples	Chemical composition (%)		CaO/SiO_2 Ratio
	CaO	SiO_2	
N-W	50.44	28.43	1.77
RHA5-W	43.58	31.79	1.37
RHA10-W	43.60	32.50	1.34
N-A4	45.44	29.72	1.53
RHA5-A4	37.65	35.48	1.06
RHA10-A4	54.00	24.84	2.17
N-A3	59.24	25.26	2.35
RHA5-A3	45.36	29.90	1.52
RHA10-A3	68.30	16.79	4.07

3.3. Percentage of SO_3

Table 5 shows the percentage of SO_3 which was found by SEM-EDX analysis. The percentages of SO_3 of the concrete specimens with and without RHA were measured in different acid solutions.

Table 5. Percentage of SO_3

Samples	SO_3 (%)
N-A4	2.23
RHA5-A4	0.57
RHA10-A4	1.65
N-A3	3.53
RHA5-A3	1.27
RHA10-A3	2.53

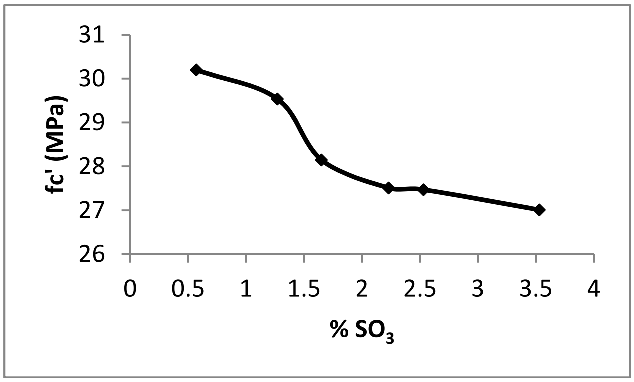

Figure 2. Relation between percentage of SO_3 and fc'

The decrease in strength is mainly caused by $Ca(OH)_2$ loss with caking property and the formation of $CaSO_4$ in volumes larger than Ca(OH)2 [8]. The percentage of SO_3 is represented as $CaSO_4$ content. Table 5 shows that the use of RHA can reduce the amount of SO_3 in concrete immersed in an acid solution.

Furthermore, Figure 2 shows the relationship between compressive strength and the amount of SO_3 in concrete. The relationship is inversely proportional, if the content of SO_3 goes up, the value of compressive strength actually decreased. But to make an equation model need for additional research with variety of compressive strength and value of acidity.

The presence of RHA, which contains high silica, has formed the new CSH compounds. The new CSH compounds and CASH have a more dense structure, thus making the concrete has low permeability. This led to a decline in the content of SO_3 in specimens using RHA. Compounds can withstand SO_3 infiltration into the concrete, it results a huge increase of SO_3 content in specimens without RHA.

4. CONCLUSION

This study is focused on the role of RHA in concrete to reduce the deterioration caused by acid rain. Deterioration is measured from the compressive strength, the CaO/SiO_2 ration and SO_3 content. The experimental results show that:

1. Compressive strength of concrete will reduce due to the attack of acid rain. However, the compressive strength of concrete using 5% RHA by weight as cement replacement is higher than concrete without RHA.
2. The ratio of CaO/SiO_2 cannot give a good understanding about the amounts of CSH and $Ca(OH)_2$.
3. The content of SO_3 in concrete immersed in acid solution could be reduced by using 5% RHA by weight as cement replacement.

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