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The Effect of Using Rice Husk Ash as a Cement Substitution on the Binding Time of Cement Paste

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ABSTRACT: The utilization of agricultural waste as an alternative construction material is one of the efforts to support sustainable development. One type of waste with potential for use is rice husk ash, which has a high silica content. This study aims to analyze the effect of using rice husk ash as a partial substitute for cement on the setting time of cement paste. This research was conducted experimentally in a laboratory with variations in rice husk ash content of 0%, 2.5%, 5%, 7.5%, 10%, 12.5%, and 15% by weight of cement. The tests included determining normal consistency as well as initial and final setting times using the Vicat apparatus in accordance with SNI 03-6827-2002 standards. The research results show that the addition of rice husk ash has a significant effect on the setting time of cement paste. The silica content in rice husk ash plays a role in the hydration process. At percentages of 2.5%, 5%, and 7.5%, rice husk ash can improve the efficiency of cement usage without exceeding the setting time limits specified by the standards. At higher proportions, a considerable change in setting time occurs, so its use needs to be carefully considered.

KEYWORDS: rice husk ash, setting time, cement paste

1. INTRODUCTION

Waste management is a major challenge for the government, and little progress has been made in managing the resulting agricultural waste. However, agricultural waste can cause severe environmental pollution if not managed properly. One type of agricultural waste is rice husks, which are separated from the rice grains during the rice milling process and become waste or milling residue. The chemical elements contained in this waste include a large amount of silica, reaching 93%, equivalent to the microsilica produced by factories (Swamy, 1986). Burning rice husks at a temperature of 600–900°C produces 16–25% rice husk ash, which contains a high silica content of around 87–97%. Rice husk ash, which has a high silica content, can be used as an admixture for making concrete.

The addition of rice husk ash as an additive is believed to affect the setting time of cement because its chemical composition, such as high silica and carbon content, and the fine physical structure of rice husk ash can extend or modify the cement hydration process. The setting time determines the start and end of cement paste setting. The setting time is influenced by the composition of minerals and water used. In addition to hydrating cement, water also functions to provide mobility for the cement paste. The setting of cement in the cement mixture with water is a symptom of the occurrence of stiffness or freezing of cement which is usually expressed as the setting time (setting time), which begins from the formation of the cement mixture until the cement begins to stiffen, while hardening is the state where the cement begins to harden and provides strength. (SNI 15-2049-2004).

Based on the background described above, the following problem is formulated:

1. What is the best substitute for rice husk ash for cement paste to obtain the right mixture based on the resulting setting time?
2. What is the composition of the rice husk ash mixture in cement paste that is still permitted by the SNI (SNI 03-6827-2002) standard regarding setting time?

2. LITERATURE REVIEW

2.1 Cement

Cement comes from the Latin word caementum, meaning adhesive. Simply put, cement is a glue or adhesive that can bind other materials, such as bricks and cobblestone, to form a building. In general, cement is defined as an adhesive capable of binding solid materials into a compact and strong whole. (B. A. Putra, 2013).

Raw Materials for Cement Production

The raw materials for cement manufacture are divided into several groups which provide an indication of the components contributed by the group (Hewlett, 2004), the raw material groups are:

- Calcareous group for lime components
- Siliceous group for silica components
- Argillaceous group for alumina components
- Ferriferous group for iron components

2.1.2 Types of Cement

Several types of cement according to Indonesian national standards (SNI) include:

A. White Portland Cement

B. Portland Pozzolan Cement (PPC)
C. Mixed Portland Cement
D. Cement Masonry
E. Portland Cement / Ordinary Portland Cement (OPC)
F. Composite Portland Cement (PCC)

The primary function of cement is to bind aggregate particles together to form a strong unit. The main compounds in cement include:

A. Tricalcium Silicate (C_3S) or $3CaO.SiO_2$

Its properties are similar to those of cement; when water is added, it stiffens and hardens within a few hours. C_3S supports the initial strength of cement and generates a heat of hydration of approximately 58 calories/gram after 3 days.

B. Dicalcium Silicate (C_2S) or $2CaO.SiO_2$

When water is added after the reaction, the paste hardens and generates 12 calories/gram of heat after 3 days. The paste hardens, developing a stable and slow strength over several weeks, then reaches a final compressive strength almost equal to that of C_3S.

C. Tricalcium Aluminate (C_3A) or $3CaO.Al2O_3$

This element, when reacting with water, generates a high heat of hydration of 212 calories/gram after 3 days. Strength development occurs in one to two days but is very low.

D. Tetracalcium Aluminoferrite (C_4AF) or $4CaO.Al_2O_3.Fe_2O_3$

This element reacts with water very rapidly, and a paste forms within minutes, generating a heat of hydration of 68 calories/gram.

2.2 Water

Cement cannot become a paste without water. Water must always be present in liquid concrete, not only for hydration of the cement, but also to transform it into a paste, making the concrete workable. The amount of bound water in concrete with a water-cement ratio of 0.65 is approximately 20% of the cement weight at 4 weeks of age. Calculated from the mineral composition of the cement, the amount of water required for hydration is theoretically 35-37% of the cement weight. In practice, an estimate of chemically bound water is obtained by drying the sample to 100°C, removing any free water that may evaporate in the capillary pores. The weight loss due to decomposition of the dry sample at 100°C is considered the non-evaporable amount. Full hydration is achieved by hydration of the cement slurry (with a water/cement ratio above 1.00) in a ball mill. This process removes the hydrated layer from the surface of the cement grains. The entire process can take several months to achieve full hydration. (Zulkarnain, 2021)

Rice Husk Ash

Rice husk ash is the result of the combustion of rice husks. During the process of converting rice husks into ash, combustion removes organic matter and leaves behind a residue rich in silica (SiO2). Heat treatment of rice husks results in structural changes that affect two things, namely the level of pozzolanic activity and the fineness of the ash grains. (Tjokrodimuljo, 1996).

2.4 Cement Paste

Cement paste is a mixture of cement and water in specific proportions. If left to stand for a certain period of time, the mixture will stiffen and harden. This hardening process occurs through a hydration reaction, in which water reacts with the compounds in the cement to form products that provide strength and stability. (Mulyono, 2004).

2.5 Hydration Reaction

When cement comes into contact with water, it reacts to form a sticky, glue-like substance (bonding agent), eventually hardening. This process is called hydration. The reaction of the compounds mentioned above is exothermic. This indicates that heat is released during the cement's binding and hardening. The amount of heat released by the cement is the heat of hydration. (Nugraha, 1989)

Cement and water are combined in certain proportions. For Portland cement I, one part by weight of cement requires about 0.25 parts by weight of water for hydration. (Murdock & Brook, 1991)

2.6 Hydration Heat

The heat of hydration is the amount of heat (in joules) per gram of unhydrated cement released until complete hydration occurs at a given temperature. Hydration of cement compounds is exothermic. (Wibowo & Wahyuni, n.d.)

For ordinary Portland cement:

1. ½ of the total heat is released between 1-3 days
2. ¼ of the total heat is released within 7 days
3. And reaches 90% within 1 month

The heat of hydration depends on the chemical composition of the cement and is approximately equal to the sum of the heats of hydration of each individual compound when proportioned in the hydration period itself. By reducing the amount of C_3A and C_3S compounds, the heat of hydration (and its rate) of cement can be reduced. The cement compound that releases the most heat is C_3A, then C_3S, C_4AF, and the lowest is C_2S.

2.7 Normal Consistency

The normal consistency of cement is the viscosity between the cement mixture and water in kneading the dough, which is expressed as a percentage of the amount of water to the weight of the mixture used as an experimental intuition. The amount of water for normal cement consistency, as a control variable for type 1 cement (ASTM International C187-04, 2004) ranges from 25% - 30%. This is to determine the level of fast stiffening development of the cement paste to determine whether the mixture meets the fast stiffening specification limits or not. The purpose and use of this test method is to determine the amount of water needed to prepare hydraulic cement paste for testing.

Setting time

The setting time process is the change of cement paste in a plastic state to become solid, immediately after setting time the cement paste is not strong and the compressive strength becomes small. As time passes and along with the hydration process, the cement paste becomes hard and its compressive strength automatically increases. (Mulyono, 2004).

Setting time is the period that occurs between the beginning of the cement becoming stiff and the moment the cement turns into a hard or solid state. During this period the cement becomes hard but not strong enough. After that the hardening continues, at first quickly then slowly over a long time. The binding continues to occur slowly, otherwise the concrete mixture will be difficult to work with. (Wibowo & Wahyuni, n.d.)

3. RESEARCH METHODS

General

This research is experimental research by making a paste mixture using cement and rice husk ash. Where rice husk ash is used as a cement substitution material. The vicat and compressive strength tests will be carried out on the mixed materials.

Research Location

This research will be carried out at the Concrete Laboratory of the Muhammadiyah University of Palembang which is located at Jln. Talang Banten, Campus B, 13 Ulu Palembang, Palembang City, South Sumatra 30263.

Tools and Materials

Some of the tools and materials used in this research are as follows:

Tools

Hand Drill

The hand drill used is a substitute for a mixing machine.

Digital Scales

Digital scales used to weigh ingredients for cement paste mixtures.

Leveling Spoon

Leveling Spoon is a tool used to even out the surface of the pasta after being put into the mold.

Stop Watch

A stop watch is used during normal consistency and setting time tests.

Measuring Cup

A measuring cup is used to measure water to be mixed with other ingredients with a capacity of 100 ml.

Sifter Machine (Sieve Shaker)

Facilitates the aggregate sieving process to ensure separation of particles of the desired size.

Vicat Tools

The Vicat apparatus was used in this study to determine normal setting time and consistency.

Rubber Gloves

Rubber Gloves were used to make pasta balls in normal setting time and consistency studies.

Sieve

This filter is used to specifically determine the gradation of rice husk ash.

Initial needle

The initial needle for testing the setting time is one of the important components in testing the setting time and is used in the Vicat tool to measure the duration of the cement paste starting to lose its plasticity.

Conical ring mold

A conical ring mold is a tapered ring-shaped tool used in Vicat testing to accommodate cement paste, which aims to measure the standard consistency, initial setting time and final setting time of cement.

Glass Plate

A glass plate for testing the setting time of cement is a flat, flat glass plate that is used as a base or foundation when placing a conical ring mold containing cement paste in testing the normal consistency and setting time of cement.

Material Testing

This test is carried out to determine the properties and characteristics of the material that will be used to mix cement paste. Material testing is carried out in the laboratory. Data on material test results is attached. Materials tested include:

Test the silica content in rice husk ash

Testing the silica content of rice husk ash is a laboratory analysis that aims to find out what percentage of silica (SiO_2) is contained in the ash resulting from burning rice husks. By knowing the percentage of silica contained, the suitability of the ash can be determined as a raw material for industry and research. Apart from that, the test results can also be a basis for optimizing the rice husk burning process to obtain ash with a high silica content and a structure that meets requirements.

Test the fineness of rice husk ash

The rice husk ash experiment must meet the cement fineness requirements, so other efforts are made with the following procedure:

The filters are arranged, cover the filter in the top position, then filter No. 200, and in the bottom arrangement, place PAN.

The filter is shaken manually for approximately 10 minutes.

The rice husk ash in the PAN is also placed in another container.

To use Rice Husk Ash as a cement substitute in paste, use Rice Husk Ash that passes through the No. 200 sieve.

3.5 Mixture Design of Test Objects

The test objects consisted of six variations in the percentage of rice husk ash content and several variations in observation time. Variations in the percentage of rice husk ash added to the cement paste were 0%, 2.5%, 5%, 7.5%, 10%, 12.5% 15% and 0% as a control.

Preparation of Test Objects

Weigh the cement material and rice husk ash according to the planned proportions according to the mold capacity of the test object.

Place the dry mixer and bowl in the mixing position on the mixer.

Add the mixed water according to the planned FAS into the bowl.

Then put the ingredients according to the order of the planning table into the bowl and wait for 30 seconds for the mixed water to be absorbed.
Run the mixer and mix at low speed
Stop the mixer for 15 seconds and during this time collect the paste that sticks to the walls of the bowl.
Run the mixer at medium speed until the ingredients are mixed.
Making and testing Paste Test Objects
Normal Consistency Testing
Based on the ASTM C 187 standard which is commonly used for testing the normal consistency of cement using the Vicat tool, the variation in water content for testing is usually around 25% to 30% of the cement weight. Normal consistency of the paste is achieved if the launch rod penetrates to a limit of (10 ± 1) mm below the surface of the paste within 30 seconds after release.
Intended to obtain the percentage of water content required in the cement paste in the initial cement bond test. Normal consistency testing procedures include the following:
Preparation of a set of vicat tools
Preparation of cement paste
Mix 300 grams of cement with varying water content starting from 25%, 27.5%, 30% of the cement weight.
Print the sample. Shape the cement paste like a ball using both hands and throw it 6 times from one hand to the other with a throwing distance of 15 cm. During work, avoid pressing on the cement paste.
Determine the consistency by placing the cement paste into the vicat tool, attaching the vicat launcher rod to the surface of the paste and locking the screw, writing the beginning of the launcher rod designation, writing the designation occurs when the launcher rod penetrates at a limit of 10 mm below the surface of the paste within 30 seconds after being launched.

4. RESULTS AND DISCUSSION

XRF test results for Rice Husk Ash
The chemical composition of rice husk ash was obtained using the X-Ray Fluorescence (XRF) test.

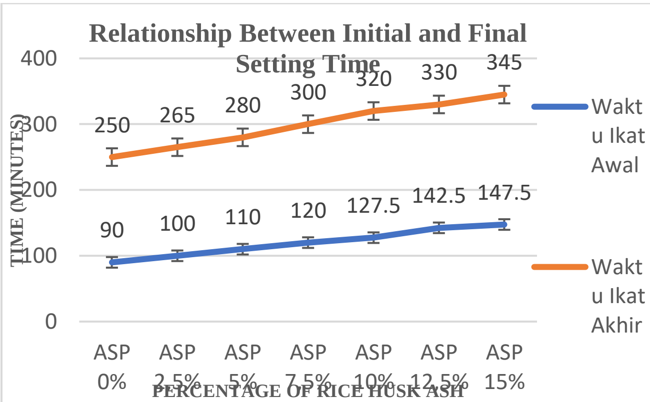
Table 4.1 Xrf Results of Rice Husk Ash

No	Parameter	Unit	Analysis results
1	Al_2O_3	%	33,449 ± 0,225%
2	SiO_2	%	26,716 ± 0,201%
3	SO_3	%	16,983 ± 0,108%
4	TiO_2	%	15,353 ± 0,078%
5	Fe_2O_3	%	3,280 ± 0,027%
6	CaO	%	1,626 ± 0,031%
7	Na_2O	%	1,293 ± 0,598%
8	MgO	%	0,685 ± 0,157%
9	Mn_3O_4	%	0,461 ± 0,019%
10	P_2O_5	%	0,154 ± 0,039%
11	K_2O	%	< 0,037%

Sources: Research Results, 2025

Based on the results of the X-Ray Fluorescence (XRF) test, rice husk ash has the main content of Al_2O_3 of 33.449%, SiO_2 of 26.716%, SO_3 of 16.983%, and TiO_2 of 15.353%. These figures show that rice husk ash is rich in alumina and silica oxides, and contains quite large amounts of sulfate. Apart from that, there are also other oxides but in smaller levels, namely Fe_2O_3 (3.280%), CaO (1.626%), Na_2O (1.293%), MgO (0.685%), Mn_3O_4 (0.461%), and P_2O_5 (0.154%), while K_2O is almost non-existent because its value is very low (<0.037%).
Normal Consistency Test Results
Based on the ASTM C 187 standard for normal consistency testing using a vicat tool, consistency determination aims to determine the amount of water needed for the paste to be used for the setting time test. Normal consistency of the paste is achieved if the launch rod penetrates to a limit of (10 ± 1) mm below the surface of the paste within 30 seconds after release.

4.3 Setting Time Test Results



Based on the graph of the relationship between initial setting time and final setting time, it can be seen that there are similarities in the increase in time. The value of the initial setting time and final setting time continuously increased from the sample using 0% rice husk ash with an initial setting time value of 90 minutes and a final setting time of 250 minutes, on the 2.5% rice husk ash test object, the test value increased with an initial setting time value of 100 minutes and a final setting time of 265 minutes, then the value increased in 5% rice husk ash with an initial setting time of 110 minutes and a final setting time of 280 minutes, the test value continued to increase in test specimen with 7.5% rice husk ash, where the initial setting time value was 120 minutes and final setting time 300 minutes, then the value increased again in the test object with 10% rice husk ash with an initial setting time of 127.5 minutes and final setting time of 320 minutes, the test value increased further on the test object with 12.5% rice husk ash with an initial setting time value of 142.5 minutes and a final setting time of 330 minutes. The test with 15% rice husk ash was the point with the highest results, namely with an initial setting time of 147.5 minutes and a final setting time of 345 minutes. The use of 2.5%, 5% and 7.5% rice husk ash was concluded as the optimum point in the setting time test, because the optimum binding time occurred between 60 - 120 minutes.

5. CONCLUSION

Based on the analysis of the data that has been obtained, it can be concluded as follows: The setting time of cement paste with the substitution of Rice Husk Ash with variations of 2.5%, 5%, 7.5%, 10%, 12.5% and 15% experienced a slowdown in hardening time. The optimal mixture varies between 2.5%, 5% and 7.5% because the initial setting time and final setting time do not exceed the specified time limit, meaning it does not harden too quickly or takes too long to harden.

Rice Husk Ash (%)	Water (%)	Cement (gr)	Rice Husk Ash (gr)	Test Objects	Water (ml)	Drop (mm)
0	25%	300	0	1	75	9
	27,5%	300	0	1	83	15
	30%	300	0	1	90	25
2,5%	25%	292,5	7,5	1	75	6
	27,5%	292,5	7,5	1	83	10
	30%	292,5	7,5	1	90	28
5%	25%	285	15	1	75	6
	27,5%	285	15	1	83	9
	30%	285	15	1	90	18
7,5%	25%	277,5	22,5	1	75	5
	27,5%	277,5	22,5	1	83	9
	30%	277,5	22,5	1	90	14
10%	25%	270	30	1	75	4
	27,5%	270	30	1	83	7
	30%	270	30	1	90	11
12,5%	25%	262,5	37,5	1	75	3
	27,5%	262,5	37,5	1	83	5
	30%	262,5	37,5	1	90	9
15%	25%	255	45	1	75	3
	27,5%	255	45	1	83	5
	30%	255	45	1	90	9
	Amount	5828	473	21	1733	

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