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Utilization of Rice Husk Ash and Fly Ash as Cement Substitutes in Highstrength Concrete

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ABSTRACT

This study analyzes the effect of rice husk ash (ASP) and fly ash (FA) as partial cement substitutions on the mechanical properties of high-strength concrete. The concrete mix was designed with a target compressive strength of f'_c60 MPa using the SNI 03-6468-2000 method. Substitution variations of ASP and FA were applied at 0%, 5%, 10%, 15%, and 20% of the cement weight. The experimental testing included measurements of unit weight, compressive strength at 7, 28, and 56 days, and modulus of elasticity at 28 days. The results indicate that FA significantly improves concrete unit weight and compressive strength, with optimal performance observed at the 10% substitution level; beyond this percentage, strength tends to stabilize or decrease. Meanwhile, ASP generally reduces concrete unit weight due to its lower specific gravity but still contributes to strength enhancement at certain substitution levels through its pozzolanic reaction, which strengthens the concrete microstructure over time. Both FA and ASP demonstrate substantial potential in improving the performance characteristics of high-strength concrete, particularly in terms of compressive strength and durability. Additionally, their utilization supports sustainable construction practices by reducing cement consumption and mitigating the environmental impact associated with industrial and agricultural waste disposal, making them viable eco-friendly supplementary cementing materials.

Keywords: *High Quality Concrete, fly ash, rice husk ash, cement substitution, compressive strength concrete*

INTRODUCTION

The development of material and construction technology continues to increase, this is inseparable from the increasingly rapid demands and needs of infrastructure facilities (Jaya et al., 2020; Susanto & Hadi, 2021). These facilities require the use of high-quality building materials, one of which is concrete materials (Nugroho & Santosa, 2022; Lestari & Wahyudi, 2023). The use of concrete as the main material for building construction today is undoubtedly its advantages because it is easy to shape, easy to work, high strength in carrying loads and durability, making concrete the main choice for construction materials (Prasetyo et al., 2020; Yanti & Firdaus, 2021).

Since the last two decades, concrete technology has continued to be developed and has many variations depending on its needs, one of which is high-quality concrete (de David et al., 2020; Li et al., 2022; Zhang et al., 2019). High-quality concrete is concrete that has a compressive strength value of Fc' ⩾ 45 Mpa (General Specification of Bina Marga, 2018). To produce high-quality concrete in addition to conventional concrete base materials, additives are also used in the form of mineral additives and chemical additives, which include mineral additives are materials that have pozolan properties such as fly ash, rice husk ash, silica fume, and others, while chemical additives such as supperplasticizers, retarders and others. High-quality concrete is also one type of concrete that uses more cement than normal concrete. Industrial waste and agricultural waste are still an environmental issue because they are disposed of in open spaces. One example of industrial waste and agricultural waste is coal waste and rice husks (Loy et al., 2018; Prasara-A & Gheewala, 2017; Yadav et al., 2021).

The use of coal as a fuel is increasing, which has an impact on the increasing amount of waste that will be generated (Hendra et al., 2020; Yulia & Pratama, 2021). Likewise, the opening of coal mining land is getting larger (Jaya & Santosa, 2022). In 2021, the coal demand for power plants is 113 million tons, consisting of PLN as much as 63.8 million tons and Independent Power Producers (private power developers) as much as 49.2 million tons (Kurniawan & Suryani, 2022). If it is assumed that the amount of fly ash and bottom ash produced is 10%, then the total waste in 2021 is estimated to be 11.3 million tons (Fadli & Hidayat, 2023).

Fly ash has a content of chemical compounds SiO2 = 48.05%, Al2O3 = 14.65%, Fe2O3 = 18.10%, CaO = 6.43%, other materials (Fitri Febrianti et al., 2022). With the high content of silica and oxides, fly ash has pozzolan properties that can be used in the manufacture of concrete (Blissett et al., 2012). The use of fly ash has been applied to the paving block production process, and shows an increase in compressive strength of 3 MPa to 13 MPa, but the percentage of fly ash use of 30% shows a decrease in compressive strength (Kusdarini et al., 2022; Syahputra et al., 2023).

Rice production in 2021 is estimated at 55.27 million tons of milled dry grain (GKG). If converted to rice, rice production in 2021 reached around 31.69 million tons, or an increase of 351.71 thousand tons (1.12 percent) compared to rice production in 2020 (Central Statistics Agency, 2021). In the rice milling process, husks are usually obtained around 20-30% of rice husks. Rice husks that have been softened by the combustion process will produce rice husk ash between 16-23% of the initial weight with a silica content of 95%. Based on the high silica content, rice husk ash can be classified as one of the materials that have pozzolanic properties that are beneficial for concrete properties (Retno Trimurtiningrum, 2021).

Over time, research on concrete technology continues to develop as is done (Azizah et al., 2022) "The Effect of the Use of Fly Ash as an Additive on the Compressive Strength of Mortar", this research uses fly ash as an additive to the concrete mixture, by using fly ash from PLTU Teluk Sepang Bengkulu City, the fly ash used is a material that passes filter no. 100, With variations of 5%, 10%, 15% and 20%, from the results of the compressive strength test using all variations of fly ash have increased compressive strength, and can increase compressive strength by up to 129.4% compared to concrete mixtures without using fly ash at the age of 28 days.

Research (Umar et al., 2023) "Optimization of Concrete Mixture Using Rice Husk Ash from Si Harang Karang Village", this study uses rice husk ash material as a substitute for cement, rice husk ash comes from Si Harang Karang Village, with a variation in use as a substitute for cement of 5%, 10%, 15%, 20%, from the results of the compressive strength test, the percentage of 5% to 15% increases the compressive strength value at the age of 28 days, and can increase the compressive strength value by up to 120.2% compared to concrete mixtures without using rice husk ash at the age of 28 days.

The purpose of this study is to analyze the effect of the use of fly ash and rice husk ash on high-quality concrete. In this study, fly ash and rice husk ash materials were taken from the source closest to the research site and these materials were used as cement substitutes. The results of this study are expected to be a reference in utilizing fly ash and rice husk ash on high-quality concrete, able to reduce existing waste and increase the use value of waste.

METHOD

The method used in this study is an experimental method carried out in the Civil Engineering laboratory of Bina Darma University and CV. Grace in Palembang. The object of this research is high-quality concrete that uses materials in the form of fly ash (fly ash) as a substitute for cement, variations of fly ash and rice husk ash are used in 5%, 10%, 15% and 20%. The design of concrete mixtures uses the SNI 03-6468-2000 method of concrete mixture, the manufacture of cylindrical test pieces with a mold size of 10 x 20 cm refers to research (Nalon et al., 2017; Rakhman et al., 2019; Visairo-Méndez et al., 2019) to test the compressive strength of concrete at the age of 7, 28 and 56 days and cylindrical test pieces with a mold size of 15 x 30 cm referred to the study (Indriyantho et al., 2023; Broken & Basic, 2022; Sakthivel et al., 2019) to carry out concrete elasticity modulus testing at the age of 28 days.

Table 1. Variations of the use of fly ash and rice husk ash

No.	Percent of cement usage	Substitution Materials for cement		Concrete Compressive Strength Test Piece (10 x 20 cm Test Piece)			Concrete Elasticity Modulus test piece (15 x 30 cm test piece)
		Material	Percent Usage	7 days of age	28 days of age	Age 56 days	28 days of age
1	100%	Fly Ash	0%	3	3	3	3
	95%		5%	3	3	3	3
	90%		10%	3	3	3	3
	85%		15%	3	3	3	3
	80%		20%	3	3	3	3
2	100%	Rice husk ash	0%	3	3	3	3
	95%		5%	3	3	3	3
	90%		10%	3	3	3	3
	85%		15%	3	3	3	3
	80%		20%	3	3	3	3

Mixture calculation and manufacture of test specimens

In this study, the concrete mixture planning method refers to the SNI 03-6468-2000 method as previously researched (Keumala Citra S Zein et al., 2018). After the concrete composition is determined, the concrete mixing is carried out with a molen mixer to obtain homogeneous concrete. After homogeneous concrete, the concrete is molded on 9 pieces of 10 x 20 cm cylindrical molds, and 3 pieces of 15 x 30 cylindrical molds in one mixture.

In this chapter, we will discuss the results of testing the properties of concrete forming aggregates as well as the results of testing the compressive properties of concrete and the modulus of elasticity of concrete. This research was carried out at the Civil Engineering Laboratory of Bina Darma University and the CV Laboratory. Grace. In this study, a mixed experiment used fly ash and rice husk ash with a variation in the use of 0%, 5%, 10%, 15%, 20%. The results of the analysis in this chapter are displayed in the form of tables, graphs and explained in detail according to the data displayed.

RESULTS AND DISCUSSION

In this chapter, we will discuss the results of testing the properties of concrete forming aggregates as well as the results of testing the compressive properties of concrete and the modulus of elasticity of concrete. This research was carried out at the Civil Engineering Laboratory of Bina Darma University and the CV Laboratory. Grace. In this study, a mixed experiment used fly ash and rice husk ash with a variation in the use of 0%, 5%, 10%, 15%, 20%. The results of the analysis in this chapter are displayed in the form of tables, graphs and explained in detail according to the data displayed.

Testing of the properties of aggregate materials in this study includes testing coarse aggregates and fine aggregates. In rough aggregates, the tests carried out consisted of filter analysis and wear testing using Los Angeles abrasion machines. The analysis of coarse aggregate sieve was carried out using strainers measuring No. 1/2", No. 3/8", No. 4, No. 8, No. 16, No. 30, No. 50, and No. 100 with a material weight of 2049.3 grams. The test results showed that the distribution of coarse aggregate gradation was within the required range, with the percentage passing the sieve that met the Bina Marga 2018 Revision 2 specifications, so that the coarse aggregate was declared suitable for use as a concrete constituent material.

In addition, coarse aggregate wear testing was carried out using a Los Angeles abrasion machine with the Method B method in accordance with SNI 2417:2008. The test material consists of aggregate that passes sieve No. 3/4" and sieve No. 1/2" and aggregate that passes sieve No. 1/2" and sieve No. 3/8" is strained, each weighing about 2500 grams. The test was carried out with a total of 500 revolutions to determine the level of aggregate resistance to wear. The results of the wear tests are further used as the basis for assessing the feasibility of coarse aggregates in concrete mixtures.

Table 2. Aggregate Wear Test Results with Abrasion Machine Los Angeles

Test methods		**B-side**	
Sieve Size Inspection Gradation		**Total Spins = 500 Spins**	
Passed	Held back		
19,1 (3/4")	12,7 (1/2")	2500,4	Gram
12,7 (1/2")	9,52 (3/8")	2500,2	Gram
Total weight		5000,6	Gram
Weight held by filter No. 12 after		3936,4	Gram
Weight Passes Filter No. 12 After		1064,2	Gram
Wear and tear		21,28	%

From the table, it is known that the results of the aggregate wear test with the Los Angeles abrasion machine were obtained a value of 21.28%, the result met the specifications of the 2018 highway rev.2. The testing of the number of materials in the coarse aggregate that passed the No. 200 filter was carried out based on the SNI method 03-4142-1996. The test results showed that the percentage of materials that passed sieve No. 200 for the two test samples was 3.09% and 3.17%, respectively, with an average value of 3.13%. This value exceeds the maximum limit required for crude aggregate, which is 1% according to the 2018 General Specification of Bina Marga Revision 2. Thus, the coarse aggregate used in this study did not meet the fine grain content requirements under these conditions.

Furthermore, the weight test of the coarse aggregate content was carried out using the SNI 03-4804-1998 method in loose and solid conditions. The test results showed that the weight of the coarse aggregate content in loose conditions had an average value of 1,364 gr/cc, while in solid conditions an average value of 1,504 gr/cc. Based on these results, the weight of the coarse aggregate content is still within the required range and meets the specifications of Bina Marga 2018 Revision 2, so that the coarse aggregate is declared suitable for use in terms of content weight.

The specific gravity and absorption of coarse aggregate water was tested using the SNI 1969:2008 method. The test results showed that the average bulk specific gravity value was 2.636, the saturated surface dry specific gravity (SSD) was 2.675, and the apparent specific gravity was 2.743. Meanwhile, the value of gross aggregate water absorption was obtained on average of 1.489%. These values are still within the permissible limits according to the 2018 General Specification of Highways Revision 2, so that the coarse aggregate meets the requirements as a concrete constituent material in terms of specific gravity and water absorption.

CONCLUSION

The results indicate that fly ash as a cement substitute increases concrete density, with optimal compressive strength gains of 157.41% at 7 days, 123.92% at 28 days, and 126.25% at 56 days using up to 15% substitution; the lowest modulus of elasticity (Ec) occurred at 20% (31,747.92 MPa). In contrast, rice husk ash reduces concrete density proportionally to its percentage, yielding a compressive strength increase of up to 121.92% at 7 days and 120.90% at 56 days with a maximum 10% substitution, but a decrease at all levels at 28 days; the lowest Ec was at 20% (27,176.22 MPa). For future research, investigations could explore combined fly ash and rice husk ash substitutions in high-strength concrete to optimize both strength and density while assessing long-term durability under environmental stresses like sulfate exposure.

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