Comparison addition of rice husk ash and roof tile ash on fly ash-based geopolymer cement with portland cement

Comparación de la adición de cenizas de cascarilla de arroz y cenizas de tejas a cemento de geopolímero a base de cenizas volantes con cemento Portland

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Fecha de Recepción: 20/04/2020
Fecha de Aceptación: 22/10/2020
PAG 287-294

Abstract

The use of Portland cement is considered a very good material for making concrete. This is because many are found in building shops and it's high performance in making concrete. Research on alternative Portland cement is a worldwide priority for reducing CO emissions to the atmosphere. Alternative Portland cement is a material containing aluminosilicate which is dissolved with an alkaline solution to produce strong pozzolanic properties and replace the function of Portland cement. Natural aluminosilicates can be found in agricultural and industrial wastes. For example fly ash (FA), roof tile ash (RTA), rice husk ash (RHA), sugar cane bagasse ash (SCBA). This method estimates the development of mechanical properties of concrete with alternative portland cement with concrete with portland cement throughout the treatment process. The mechanical properties that will be seen are setting time and compressive strength. Alternative Portland cement uses the basic ingredients of fly ash aluminosilicate with an alkaline activator solution (NaOH, Na2SiO3) of 12 Molar. This study is based on experimental studies by replacing FA by 5% and 10% with RHA and RTA where the development of several mechanical properties will be investigated. The results show that several alternative portland cement mixes have similar mechanical properties to portland cement.

Keywords: *Fly Ash; Rice Husk Ash; Roof Tile Ash; Setting Time; Compressive Strength*

Resumen

El cemento Portland se considera un excelente material para la fabricación de hormigón. Por su alto rendimiento en esta elaboración se encuentra mucho en tiendas de construcción. La investigación acerca de cementos Portland alternativos tiene prioridad a nivel mundial para reducir las emisiones de CO a la atmósfera. El cemento Portland alternativo es un material que contiene aluminosilicatos disueltos en una solución alcalina para producir propiedades puzolánicas suficientemente sólidas que reemplacen la función del cemento Portland. Los aluminosilicatos naturales se pueden encontrar en desechos agrícolas e industriales. Por ejemplo, en cenizas volantes (CV), cenizas de tejas (CT), cenizas de cascarilla de arroz (CCAr), cenizas de caña de azúcar (CCAZ). Este método compara el desarrollo de propiedades mecánicas del concreto con cemento Portland alternativo con las del concreto con cemento Portland normal, durante todo el proceso de su empleo. Las propiedades mecánicas que se revisarán son el tiempo de fraguado y la resistencia a la compresión. El cemento Portland alternativo utiliza una base de aluminosilicato de cenizas volantes con una solución alcalina activadora (NaOH, Na2SiO3) 12 molar. Este estudio se basa en ensayos experimentales de reemplazo de CV al 5% y 10% con CCAR y CT, en los que se investigó el desarrollo de varias propiedades mecánicas. Los resultados muestran que varias mezclas alternativas de cemento Portland tienen propiedades mecánicas similares al cemento Portland normal.

Palabras clave: Cenizas volantes; cenizas de cáscara de arroz; cenizas de azulejos; gestión del tiempo; resistencia a la compresión

1. Introduction

Cement is one of the main ingredients to make concrete, which serves as a binder with fine aggregate, coarse aggregate, and water with or without additional mixed materials. Increased use of cement can be seen with the increasing needs of concrete annually, of course, it is an adverse impact on the environment due to any cement manufacturing generated CO_2 released in the atmosphere when calcium carbonate is heated and produces lime (Amran et al., 2020)(Stafford et al., 2015).

The cement industry is a cause of one of the contributors to air pollution and other environmental pollution, one of the impacts that can be caused is the greenhouse effect that can increase global warming (Reza et al., 2013)(Hasanbeigi et al., 2012). Therefore, the use of alternative Portland cement with new cement needs to be developed. So that in the process of cement production reduces greenhouse gas emissions and energy efficiency occurs. Among these alternative materials are materials that contain many elements of silica (Si) and alumina (Al)(Torres-Carrasco and Puertas, 2017), both natural materials (clay)(Chen et al., 2016)(Yanguatin et al., 2017) or industrial waste products, such as fly ash(Yacob et al., 2019)(Gülşan et al., 2019)(Pavithra et al., 2016)(Pasupathy et al., 2017)(Muhammad et al., 2019) , rice husk ash (Nuaklong et al., 2020)(Akasaki et al., 2016), sugar cane bagasse ash (Mello et al., 2020)(Fairbairn et al., 2010)(Bahurudeen et al.; 2015) (Nugroho et al.; 2017), roof tile ash (Reggiani, 2019) (Bui et al., 2017)(Rachman, 2015).

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The fly-ash material, rice husk ash, and dust tile press powder in the manufacture of geopolymer cement can react with the help of alkaline substances (catalysts and activators) that act as activation of polymerization processes and the release of small molecules such as H2O to form more monomer chain bonds long. To get polymerization reactions required a reactant of the alkaline groups of Sodium Hydroxide (NaOH) and Sodium Silicate (Na_2SiO_3) which can release unnecessary ions(Torres-Carrasco and Puertas, 2017)(Zhang et al.; 2014) (Bajpai et al.; 2020). In a previous study the influence of NaOH on the setting time of the concrete that is the higher the value activators NaOH is given, then the faster its finish setting time (Risdanareni et al., 2015) (Kanaan and Soliman, 2019)(Gupta et al., 2017)(Aliabdo et al,. 2016). The purpose of this research is to experimentally test the setting time performance and compressive strength of fly ash-based geopolymer concrete compared to portland cement concrete.

2. Materials and Methods

2.1 Material

Cement:

The types of cement that will be compared in this experiment are portland cement types I, II, III, IV and V. Its characteristics are following Indonesian national standards (SNI) (Badan Stadandarisasi Nasional-BSN, 2004). The main physical requirements of Portland cement can be seen in (Table 1).

Table 1. *Major Physical Requirements of Portland Cement*

Description	**Types of Portland Cement**				
	I	II	III	IV	V
Setting Time (alternative method) with Vicat tool 1. Initial Time, minute, Minimum 2. Final Time, minute, Maximum	45 375	45 375	45 375	45 375	45 375
Compressive Strength : 1. 1 Day, kg/cm^2, Minimum 2. 3 Day, kg/cm^2, Minimum 3. 7 Day, kg/cm^2, Minimum 4. 28 Day, kg/cm^2, Minimum	- 135 215 300	- 100 175 -	120 240 -	- - 70 170	- 80 150 210

Aggregate:

The aggregates used are Ottawa sand with a specific gravity of 2.664 g/cm^3, water absorption rate of 0.267%, modulus of fineness of 2,427 and mud content of 0.352%.

Fly Ash (FA):

Fly ash is obtained from coal combustion waste at the Paiton power plant, (PLTU Paiton) Probolinggo, East Java, Indonesia. Fly ash is included in class F according to the standards given by ASTM C 618 (American Society for Testing and Materials –ASTM, 2014). The chemical composition of fly ash can be seen in (Table 2).

Table 2. *The Chemical Composite of Fly Ash (FA)*

Chemical ingredients	Percentage (%)
SiO_2	52,35
Al_2O_3	12,11
Fe_2O_3	12,35
CaO	6,79
MgO	10,63
Na_2O	2,15
SO_3	2,27
H_2O	0,12
LOI	0,40
$SiO_2 + Al_2O_3 + Fe_2O_3$	76,84

Rice husk ash (RHA):

Rice husks come from the Sumber Jeruk rice mill, Jember, East Java, Indonesia. To get good pozzolanic characteristics, rice husk must be burned in the range of 600^0C to 850^0C (Barbosa et al., 2013). In this study,rice husk was burned at ± 650^0C for 24 hours. Chemical characteristics can be seen in (Table 3).

Table 3. *The Chemical Composite of Rice husk ash (RHA)*

Chemical ingredients	Percentage (%)
SiO_2	79,7
Al_2O_3	0,42
Fe_2O_3	0,38
CaO	3,99
LOI	13,67
$SiO_2 + Al_2O_3 + Fe_2O_3$	80,5

Roof Tile Ash:

Tile powder is obtained from a tile factory waste in the village of Kunir, Lumajang, East Java. Roof tile ash obtained from burning tile powder at a temperature of ± 900^0C for 24 hours. Chemical characteristics can be seen in (Table 4).

Table 4. *The Chemical Composite of Roof tile ash (RTA)*

Chemical ingredients	Percentage (%)
SiO_2	24,5
Al_2O_3	17,8
Fe_2O_3	4,52
CaO	7,58
LOI	15,28
$SiO_2 + Al_2O_3 + Fe_2O_3$	46,82

2.2 Mixing method

The methodology used in this study is experimental research, which is an experiment and an error about previous research in the laboratory. The best NaOH solution is obtained for 12M. Before mixing with sodium silicate (Na_2SiO_3), NaOH solution is left for 24 hours. The ratio of the mixture between Na_2SiO_3 to NaOH is 2. (Table 5) and (Table 6) show the mixture of pasta and mortar. FA was replaced by RHA and RTA at 0%, 5% and 10%.

Table 5. The Composition for one geopolymer paste binder

Geopolymer Paste Binder Code	FA (gr)	RHA (gr)	RTA (gr)	NaOH (gr)	Na_2SiO_3 (gr)
P1	300	-	-	48.5	97
P2	285	15	-	48.5	97
P3	270	30	-	48.5	97
P4	285	-	15	48.5	97
P5	270	-	30	48.5	97

Table 6. The Composition of Mortar Geopolymer (kg/m3)

Mortar Geopolimer	Sand Ottawa	FA	RHA	RTA	NaOH	Na_2SiO_3
M1	1808,88	657,76	-	-	106,4	212,72
M2	1808,88	624,88	32,88	-	106,4	212,72
M3	1808,88	591,92	65,84	-	106,4	212,72
M4	1808,88	624,88	-	32,88	106,4	212,72
M5	1808,88	591,92	-	65,84	106,4	212,72

Figure 1. *Specimens (a) pasta binder; (b) mortar binder*

2.3. Casting and curing

Fresh geopolymer paste is cast in a conical cone-shaped mould, top diameter 60 mm, bottom diameter 70 mm and height 40 mm. The test specimens were kept in a humid cabinet for 30 minutes. The geopolymer mortar consists of geopolymer paste and Ottawa sand. Binder pasta, Ottawa sand and alkaline activators are mixed in a mixer until a homogeneous geopolymer mortar is obtained. Homogeneity testing of the mixture on the flow table with a flow rate requirement of 110 + 5 mm following SNI standards (Badan Stadandarisasi Nasional-BSN, 2014). The geopolymer mortar was printed in a 50 mm x 50 mm x 50 mm cube and allowed to stand for 24 hours at room temperature. The mould is opened and maintained in average roomtemperature, 260C, until the test day.

2.4. Testing

Setting time tests are carried out on geopolymer paste according to SNI standards by enabling mechanical testing. Insert the test specimen in the Vicat device, touch the tip of the Vicat needle in the middle of the surface of the test specimen and tighten the position of the Vicat needle, place the scale reading at zero or note the starting number, and immediately remove the Vicat needle. Read the penetration of the Vicat needle into the test specimen after 30 seconds. Repeat this test every five minutes. every time a penetration attempt is made, the Vicat needle must be cleaned and in a straight condition, free from vibrations. Geopolymer mortarcompressive strength test according to SNI standards (Badan Standardisasi Nasional-BSN, 2002). Before testing, the mortar is removed from the treatment area and allowed to stand for 15 minutes. Flatten the surface of the mortar so that it is flat and level with the sandpaper. Mortar compressive strength was tested at 1,3,7 and 28 days.

3. Result and discussion

3.1. Setting Time

In (Figure 2) it can be concluded that 5 proportions of geopolymer cement have a faster binding time than Portland cement, this is influenced by Sodium Hydroxide (NaOH) because the higher the activator value is given, the faster the binding time (Akasaki et al., 2016)(Pavithra et al., 2016). Pasta with 100% fly ash content (P1) has the fastest binding time. Replacing FA with RHA and RTA will slow downtime. This is influenced by the shape of the particles and their silica content (Nuaklong et al., 2020) (Pinasang et al., 2016). The spherical shape of the FA particles will increase the binding reaction, thereby reducing water usage, easily binding to each other and reducing the space between the mixed ingredients(Manjunath and Ranganath, 2019). The shape of RHA particles with holes like a sponge will require high water requirements so it is slow to react (Barbosa et al., 2013) . The silica content in the RTA is smaller than the FA so the reaction is also slower (Okoye et al., 2017).

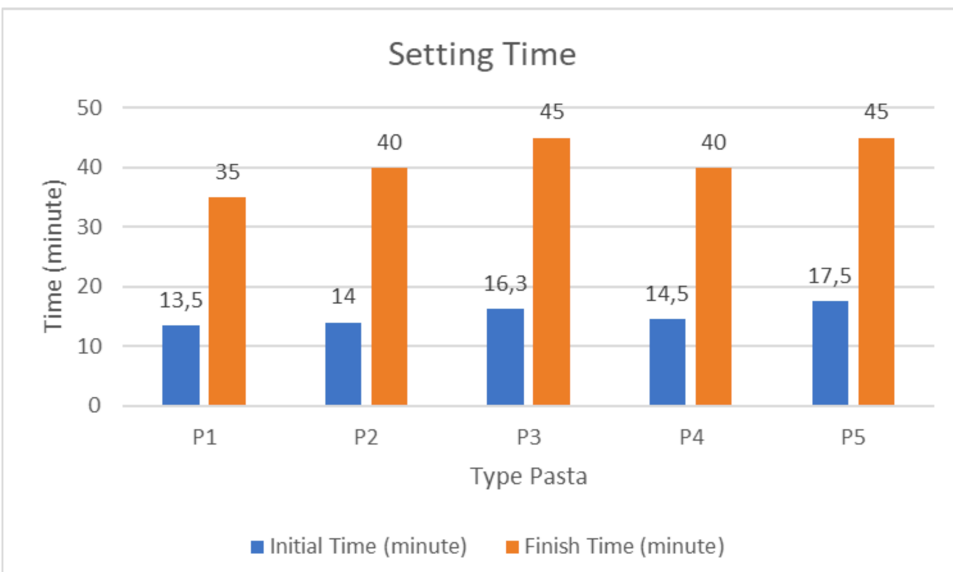

Figure 2. *Setting Time*

3.2. Compressive strength

In (Figure 3), for the age of 1 day the compressive strength of geopolymer cement types M1, M2, M3 and M4 according to the compressive strength for portland cement; at the age of 3 days the compressive strength of cement geopolymers, all proportions according to the compressive strength of Portland cement except portland type III cement; at 7 days the compressive strength of geopolymer cement types M1, M4 and M5, is according for portland cement; At 28 days the compressive strength of geopolymer cement, all proportions according to the Portland cement compressive strength.

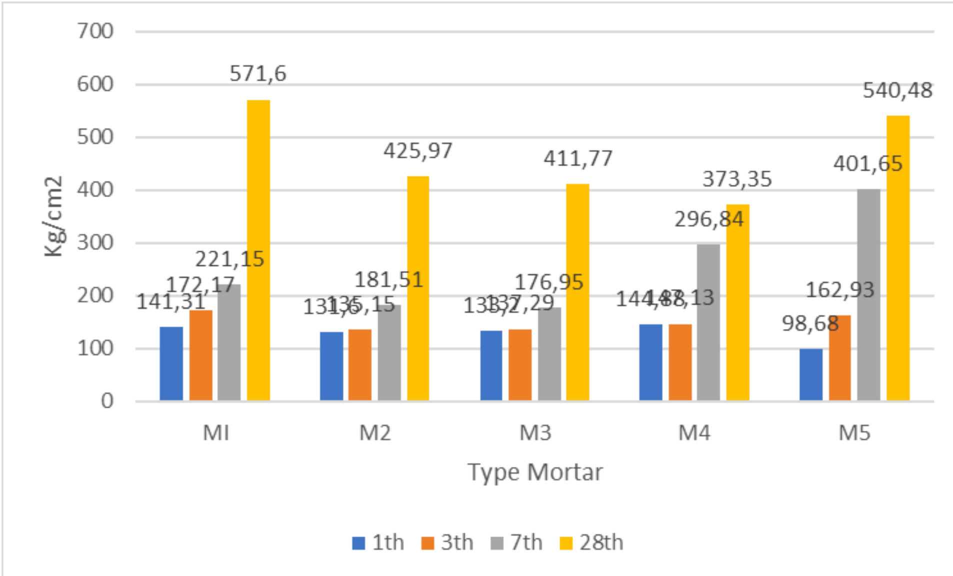

Figure 3. *Compressive Strength*

The determination of optimal proportion in this study was taken at the age of 28 days, which from each proportion got the best result 100% fly ash. The addition of rice husk ash and press tile powder has a strong press effect that is not too far against 100% fly ash. The addition of such ingredients sometimes gives increased and decreased compressive strength in certain ages such as at 1, 3, 7 and 28 days. At 1 day, the addition of roof tile ash (5%) gave a compressive strength higher than 100% fly ash. At 7 days old, the addition of roof tile ash of 5%, 10% powder gave a higher compressive strength than 100% fly ash. At the age of 28 days the addition of rice husk ash and roof tile ash, as well as both materials do not provide a compressive strength higher than 100% fly ash. The addition of rice husk ash to fly ash always provides a compressive strength lower than 100% fly ash. The determination of superior proportion is taken at the age of 28 days because at that age the value of compressive strength is considered stable (Badan Standardisasi Nasional-BSN, 2013). (Figure 3) shows that the superior proportion of proportion that gives high compressive strength is found 100% fly ash proportion.

4. Conclusions

In this section, in general, from the results presented in this work, we can compare the addition of rice husk ash and tile ash to geopolymer-based cement fly ash with portland cement. This research can be concluded as follows:

a. *From the results of making all types of geopolymer paste and mortar paste, the mixture and homogeneous flow rate meet SNI requirements for the production of geopolymer mortar.*
b. *Geopolymer cement has a faster binding time than Portland cement. In geopolymer cement, the substitution of fly ash with rice husk ash or tile ash, the binding time is slower.*
c. *The compressive strength test results show that geopolymer cement containing 100% fly ash can be an alternative use for Portland type I, II, IV, V; for substitution of fly ash with rice husk ash can be an alternative use for Portland type II, IV, V; for the substitution of fly ash with roof tile ash can be an alternative use for Portland types I, II, IV, and V.*
d. *Superior geopolymer cement composition at 28 days was obtained with 100% fly ash.*

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