RESEARCH UTILIZATION RICE HUSK ASH AS SUBSTITUTE FOR FIREPROOF CONCRETE

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Abstract - Desire to get fireproof concrete but still strong, durable, and economical is still an expectation for developers and building owners, because then will be obtained a building that meets technical requirements at low cost. Based on Law no. 28 of 2002 concerning Building, it mandates that each building must meet the requirements of safety, health, comfort, and convenience. Safety aspects include aspects of load, fire, lightning, electrical installations, and explosives. This is why until now the problem of refractory concrete is still an interesting topic, for various reasons such as the demands of laws and regulations, technical requirements, risk reduction, and so on. Theoretically, main parameter that can determine fire resistance is conductivity and integrity materials, but for certain cases that also need attention is the use of raw materials that have insulating properties against fire, because it will determine nature concrete that produced. At present national rice production reaches 57.16 million tons / year, and will produce about 20 % of rice husk or 11.43 million tons / year. This amount will increase along with government's plan through Ministry Agriculture which will open 1,000,000 ha rice fields. Utilization husk currently limited to mixing materials in manufacture bricks and fuel in burning bricks with field stoves. From burning the husk it can produce husk ash by 20 % from weight husk with large enough silica content and includes cementitious materials and insulators. With potential and characteristics as above, it is necessary to continue to improve its use, among others, as substitute for manufacture refractory concrete. Research utilization rice husk ash for refractory concrete is an effort to create buildings that meet safety and comfort requirements because it will inhibit thermal propagation so the room becomes cool and prevent heat radiation that can cause fires. From research results, it was obtained data that rice husk ash can be used as substitute for making concrete and increasing value of thermal conductivity of concrete produced. Based on its compressive strength optimal rice husk ash content obtained at 20 % aggregate, with thermal conductivity value is very good (below maximum limit specified). Thus it can be concluded that rice husk ash can be used as substitute in manufacture refractory concrete, to improve safety and comfort buildings.

Keywords - Rice Husk Ash, Refractory Concrete, Conductivity, Building Safety.

I. INTRODUCTION

Until now, fire disasters still occur even increasing from year to year which hit various types of buildings, especially housing. Fire is one of the most frightening disasters because in addition to causing frequent casualties, the social impact caused is very wide, including loss of housing and property, work process, and business stagnation, environmental damage, and so on. Theoretically, there are three important factors that cause fires, namely the existence of source fire (heat), the presence of combustible material (fuel), and the availability of sufficient oxygen supply in the room. If we can eliminate one of these three things, then the occurrence of fire will be prevented, but this is very difficult because each one is very close to life. One of the factors that cause frequent fires and why fires occur is always fatal because there has not been total protection system that includes passive protection, active protection, and the implementation of fire management in buildings so that fires cannot be extinguished early because the installed components are flammable with fast and unprepared for building users so the fire is difficult to control.

To improve the resilience of buildings against fire hazards, better protection system needs to be applied which includes passive protection systems that include the use of fire-resistant materials and components, compartmentalization and separation and protection of openings. The use or application of NSPM scope materials and building components in passive protection systems includes specifications of materials, coating methods or methods of fire retardant materials, and other technical instructions relating to implementation in field.

With the issuance of UUBG no. 28/2002, it is our obligation to comply with and implement so that efforts to protect safety against users of buildings can be guaranteed, because one of important aspects regulated in the UUBG is the requirement for reliability buildings.

Furthermore, in detail the technical requirements regarding safeguards against fire hazards in buildings and environment are contained in Decree Minister of Public Works no. 10/KPTS/2000 and Minister of Public Works Regulation no. 29/PRT/M/2006, concerning Guidelines Technical Requirements for Building, which can be used as references in implementation to produce buildings that are safe from fire.

One of the important requirements contained in Laws of Buildings (UUBG) no. 28/2002 is Building Reliability Requirements which include:

- Safety.
- Health.
- Comfort.
- Ease.

Passive protection systems include the level of resistance of building materials and components to fire, compartmentalization systems, protection of openings, providing access to evacuation and building site arrangement. Active protection systems include detection system and alarm fire, fire suppression system, and smoke control system. To determine the level of fire resistance of building materials and components, it is necessary to conduct fire testing in laboratory and observe three aspects, which is stability, integrity, and conductivity of the material. Tests can be carried out on materials and structural components, such as walls, columns, beams, or floor slabs. Specifically for wall components, specimen can use small scale or large scale according to the type of furnace to be used. From this test will obtained fire resistance properties of these structural components which include stability, integrity, and conductivity, all of which can provide description of fire resistance.
Especially in the safety requirements mentioned above, can be described in several aspects:

- Safety against loads / structural reliability,
- Safety against fire hazards,
- Safety against the danger of lightning.

Furthermore, the safety aspects of fire hazards can be described in several systems:

- Passive protection system.
- Active protection system.
- Application of fire safety management.

This research activity was carried out to obtain an overview the possibility of using rice husk ash as substitute in the manufacture of concrete in order to improve insulating properties of thermal. This is related to the technical requirements of buildings, especially the safety aspects of fire hazards. By increasing the value of thermal insolation that can fulfill a material that can meet requirements as construction material is obtained as an effort to form passive protection system. Rice husk ash is the outer part of rice grain which is by-product after drying and rice milling process with amount about 20 % of weight of rice. Rice husk ash is obtained as product from grain grinding process into rice. The use of rice husk ash through technological intervention has not attracted many investors, for example for building materials and electricity. In addition to increase the added value of production, the use of rice husk ash is a form of technological intervention, in line with zero waste concepts that is environmentally friendly. Based on the distribution of rice producing regions, Java Island is still the largest producing region of 28.6 million tons (55.6 %). It was followed by Sumatra island around 11.5 million tons (22.4 %) and Sulawesi island 5.4 million tons (0.6 %) and from other regions.

With national production level 57.16 million tons, the potential of rice husk ash that produced is 11.43 million tons/year. The value of direct economic benefits from the production of rice husk ash is currently widely used in Java Island for burning in the process of burning brick/tile. Rice husk ash burning can produce about 20 % rice husk ash containing silica which can be used as good quality concrete mixture.

1.1 Purpose, Goals, and Target

The purpose of this study is to use rice husk ash for substitution in manufacture of concrete, with goals to obtaining materials that have better fire resistance level. While the target to be achieved is the availability of building components that have fire resistance and good insulating properties so that they can be used for passive protection, in an effort to improve building safety against fire.

1.2 Outputs

The product of this activity is the value of thermal insulation of concrete with substitute material for rice husk ash which is better than normal concrete.

1.3 Benefits

The results of this study are expected to be used as basis in the development of refractory concrete with substitutes for rice husk ash to reduce the risk of fire and improve the reliability of buildings.

1.4 Scope of activities

In order to achieve the objectives of this study, the following restrictions are needed:

- Conduct literature review to obtain secondary data.
- Conduct field studies to obtain primary data,
- Tested the manufacture of concrete panel specimens and fire resistance test in laboratory.
- Conduct analysis fire resistance test data from concrete with various levels of rice husk ash.

II. STUDY LITERATURE

2.1 Fire Hazard Prevention Concept

To prevent and cope with fire hazards in buildings, basic concept is needed as reference material. There are three main aspects in building security against fire hazards, namely the application of passive protection systems, active protection systems, and the application of fire safety management (FSM). These three aspects will interact with each other in fire prevention so that each will help or contribute positively in preventing the development of fire during fire.
In accordance with Regulatory Ministry of Public Works no. 29/PRT/M/2006 concerning Guidelines

Technical Requirements for Building, which are included in passive protection system, are fire resistance from materials and building components installed, compartmentalization systems and separation between rooms and protection of openings that allow fire to spread. While active protection system is detection system and fire alarm, manual extinguishing system, smoke control system, automatic outage system, fire lift installations, emergency prevention and direction signs, emergency power system, and fire control centers. The scope of FSM includes carrying out checks and maintenance fire protection equipment, conducting human resource training, providing fire emergency plan procedures, conducting fire training, conducting fire safety audit, make fire safety house, and provide brochures and porters about fire safety.

Basically, purpose fire protection includes:

- Protection life safety.
- Protection property safety.
- Protection environmental safety.

In practice, these preventative measures can be described as follows:

a. Prevention ignition.

Monitoring of ignition sources such as electrical installations, cooking utensils, cigarettes, machinery and equipment, etc.

b. Fire growth control.

- Controlling fire sources (good houskeeping).
- Determination specifications suitable fire cover material.
- Installation hydrants and provision lightweight fire extinguishers.
- Installation sprinkler automatic.
- Inspection water source capacity on field.

c. Control spread of fire.

- Installation smoke barrier.
- Doors must be closed.
- Seal installation on penetrations.
- Installation smoke ventilation system.
- Installation smoke detectors in ducts.
- Provision automatic control devices on HVAC systems.
- Provision pressurized wells.

d. Restricting spread of fire in buildings.

- Application compartmentation system.
- Protection in ceiling and confined spaces.
- Limitation size and dimensions outer wall.

e. Prevention spread of fire to other buildings.

- Determination window size and type of glass.
- There is a safe separation distance.
- Fire resistance level outer wall elements.
- Provision facilities exit.
- Installation detection systems and fire alarms.
- Supply sufficient number rescue paths.
- Size / width of rescue line that meets.
- Restrictions on the length of dead-end corridors.
- Provision emergency lights and signs.
- Provision evacuation procedures.
- Training evacuation procedures.
- Maintenance regular evacuation routes.

f. Provision facilities for operation of Fire Service.

- Providing direct connections to Fire Service.
- Provision fire location signs.
- Provision fire car entrances.
- Providing access that safe to space / buildings.
- Inspection water sources.
- Supply fire hydrants and upright pipes in sufficient quantities.

g. Prevention structural collapse.

- Fire resistance level of structural elements meets the requirements.
- Application compartmentalization to prevent spread of fire.

2.2 Classification Building Materials for Prevention of Fire Hazards

Prevention of fire hazards needs to be started from selection building materials which must have fire resistance properties as classified in SKBI 4.4.53.1987 concerning Specifications Building Materials for Prevention Fire Hazards in Houses and Buildings.

Based on its nature if fire test (combustion properties) building materials are classified into 5 levels, that is quality level 1 (M-1) to quality level 5 (M-5) which can be described as follows:

2.2.1 Material Quality Level 1 (M-1)

To be able to meet material quality level 1, material must be able to meet requirements of fire test and fire propagation test on surface, with following conditions:

a. For fire test, when testing the temperature rise in furnace does not exceed 50 ºC.

b. For fire propagation test on surface must meet :

- Area curve temperature - time (t dΘ) = 0 density of smoke (CA) < 30.
- No melting exceeds size of thickness.
- Depth of crack on back surface of specimen must be less than 1/10 the thickness.
- There is no flame more than 30 seconds after combustion has stopped.
- No deformation occurs which endangers and or does not emit toxic gases.

2.2.2 Material Quality Level 2 (M-2)

To be able to meet materials quality level 2, material must be able to meet requirements of fire propagation test on surface for materials that are difficult to burn with following conditions:

a. Area curve temperature - time (t dΘ) is not more than 100 and density of smoke (CA) < 60.

b. No melting exceeds size of thickness.

c. Depth of crack on back surface of specimen must be less than 1/10 the thickness.
d. There is no flame more than 30 seconds after combustion has stopped.
e. No deformation occurs which endangers and or does not emit toxic gases.

2.2.3 Material Quality Level 3 (M-3)
To be able to meet provisions material quality level 3, material must be able to meet requirements of fire propagation test on surface for materials fire retardant level, in accordance with following conditions:
a. Area curve temperature - time (t dΘ) is not more than 350 and density of smoke (CA) < 120.
b. No melting exceeds size of thickness.
c. Depth of crack on back surface of specimen must be less than 1/10 the thickness
d. There is no flame more than 30 seconds after combustion has stopped.
e. No deformation occurs which endangers and or does not emit toxic gases.

2.2.4 Material Quality Level 4 (M-4)
To be able to meet material quality level 4, material must be able to meet the requirements of fire propagation test on surface for materials somewhat inhibit fire, in accordance with the following provisions:
a. Area curve temperature - time (t dΘ) is not more than 350 and density of smoke (CA) is not limited.
b. No melting exceeds size of thickness.
c. Depth of crack on back surface of specimen must be less than 1/10 the thickness.
d. There is no flame more than 30 seconds after combustion has stopped.
e. No deformation occurs which endangers and or does not emit toxic gases.

2.2.5 Material Quality Level 5 (M-5)
To be able to meet materials quality level 5, all materials that cannot meet requirements both fire test and fire propagation test on surface, or materials that cannot meet requirements for materials quality level 4.

2.3 Concrete and Fire Resistance
Concrete is material obtained by mixing several raw materials such as cement, aggregate, water, and or without other additives, formed in such a way so it is obtained a compact mass, solid, strong, and stable. In general, concrete is material that is resistant to fire and includes quality M1, but at temperature above 400ºC with long enough time it will experience physical changes characterized by changes in color on surface, shrinkage, and cracked hair although it has not affected to concrete strength. But if temperature reaches above 600 ºC it will have a lot of influence on stability, integrity, and insulating concrete where heat will penetrate to reinforcement steel and can cause collapse in building. Therefore, insulating properties are one important parameter in preventing occurrence these critical conditions where in addition to preventing propagation fire to reinforcement also prevents other spatial heat radiation. What is meant by heat insulating concrete is a component of concrete that functions as coating material or prevent heat propagation (thermal) from one side to other side or from one room to another room. The use of this insulating material with the intention to protect from the influence of heat or thermal sources from the fire.

III. MATERIALS AND RESEARCH METHODS

The research method used was experimental by making specimen concrete panel plus rice husk ash as substitute for fire resistance test with several measured parameters that is stability, integrity, and insulation. Furthermore, the results were analyzed and compared with normal concrete so will obtained the value of effectiveness of adding rice husk ash to fire resistance.

3.1 Materials and Tools
The material of rice husk ash was taken from brick kiln in Jatiwangi Majalengka District - West Java, in the form of fine granules gray blackish, then refined with fineness level approaching portland cement (PC) before being used as mixture in making specimen concrete panel.

IV. EXPERIMENTAL DESIGN

Manufacturing and testing of specimens is intended to determine quality concrete and its conductivity, which includes compressive strength test, stability, integrity, and insulation of concrete panel, with various proportions of mixtures which can be described in table 1 and table 2.

Table 1 Design of Mortar Mixture Composition

Code	Mixture Composition		Aggregate Composition (%)	
	Cement	Sand	Sand	Rice Husk Ash
1	1	4	100	0
2			80	20
3			60	40
4			40	60
5			20	80
I-1	1	5	100	0

Code	Mixture Composition		Aggregate Composition (%)	
	Cement	Sand	Sand	Rice Husk Ash
I-2			80	20
I-3			60	40
I-4			40	60
I-5			20	80
II-1			100	0
II-2			80	20
II-3	1	6	60	40
II-4			40	60
II-5			20	80

Table 2 Design of Concrete Mixture Composition

Code	Mixture Composition				
	Cement	Sand	Coarse	Rice Husk Ash	Water
I	340	720	1.080	0 (0 %)	204
II	340	576	1.080	144 (20 %)	204
III	340	432	1.080	288 (40 %)	204

Note : Rice husk ash content to sand (fine ggregat)

4.1 Equipment and Specimen

Equipment used is stirring machine (mixer), cube mortar molding, mortar beam, and mortar panel, as well as concrete panel molding, 200 tons UTM (Universal Testing Machine), furnace, and auxiliary devices such as calipers, scales, meter, and specimen treatment room.

4.2 Combustion Method

Combustion is done after specimen installed in furnace, and the placement of thermocouple to measure temperature in furnace and temperature behind specimen.
Combustion temperature follows curve temperature standard, as in table 3.

Table 3 Curve Time - Temperature Standard

No.	Time Interval (Minute)	Temperature Standard ($^{\circ}$C)
1	0	20
2	10	705
3	20	795
4	30	840
5	40	880
6	50	905
7	60	925
8	70	945
9	80	965
10	90	980
11	100	990
12	110	1000
13	120	1010
14	130	1015
15	140	1025
16	150	1030
17	160	1040
18	170	1045
19	180	1050

Temperature observation:

a. Furnace temperature was observed through thermoduct to control temperature in furnace according to standard temperature.

b. The rear temperature of specimen includes 5 points, in middle, right upper side, left upper side, right lower side, and left lower side.

Damage observation:

a. Observation of damage visually observed during combustion process which includes changes in shape, occurrence of cracks, deflections, changes in color on surface concrete and other damage in accordance with development rising temperature.

b. Next the observation is continued after the specimen is removed from furnace, both during

transportation (unloading) and after being placed on ground floor.

V. RESULTS AND DISCUSSION

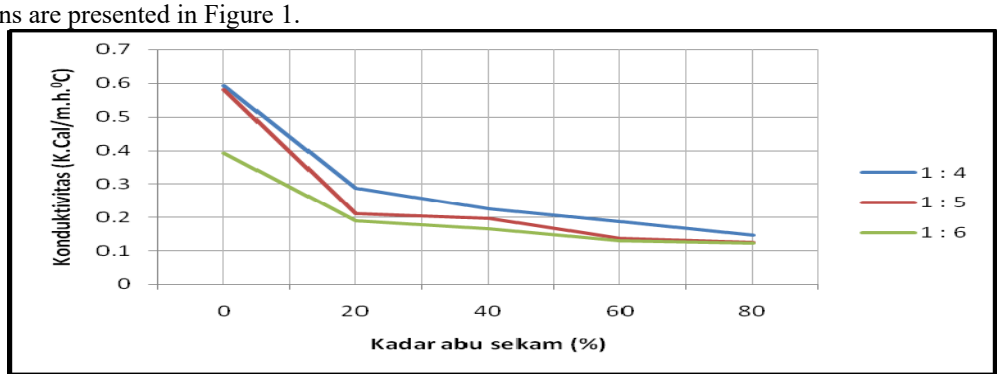
5.1 Rice Husk Ash as Substitute for Mortar

As first step and to determine the effectiveness of rice husk ash on physical and mechanical properties, and thermal conductivity, then made preliminary study in the form of cube and panel mortar. The results of physical and mechanical properties, fire resistance, and conductivity, are presented in table 4.

Table 4 Test Results Compressive Strength and Combustion Properties Mortar

No	Mixture PC : Sand	Rice Husk Ash Content (%)	Compressive Strength (kg/cm^2)	Flexural Strength (kg/cm^2)	Combustion Properties	Conductivity (K.Cal/m.h.^{0}C)
1	1 : 4	0	242,1	42,8	M-1	0,593
2		20	167,4	19,0	M-1	0,288
3		40	98,6	12,2	M-1	0,226
4		60	68,0	6,4	M-1	0,188
5		80	38,7	4,2	M-1	0,147
1	1 : 5	0	237,3	33,8	M-1	0,580
2		20	122,7	14,5	M-1	0,210
3		40	76,3	4,8	M-1	0,195
4		60	49,3	2,6	M-1	0,136
5		80	30,2	2,1	M-1	0,124
1	1 : 6	0	202,6	26,4	M-1	0,393
2		20	108,6	13,5	M-1	0,188
3		40	56,8	3,2	M-1	0,164
4		60	34,9	1,9	M-1	0,128
5		80	26,2	1,6	M-1	0,122

In the form of picture relationship between rice husk ash content and conductivity value various mixture proportions are presented in Figure 1.



Material rice husk ash in the form of fine particles and contains a lot of silica is very well used as filler in mortar, because can increase the ease of workmanship, density, and stability mortar because the material contains pozolanik which is very reactive to cement.

Mortar with addition rice husk ash has good conductivity, this can be seen from test results above that the higher content rice husk ash produces the lower conductivity, so can inhibit thermal propagation rate / heat from one medium to another and can be used as insulator material. From test results combustion properties, all specimens include in classification fire resistance M-1 or include non-flammable material; this indicates that the material is very well used as coating material on components that are required to be resistant to fire. With the value of conductivity and combustion properties indicate that this material can be used as coating material (passive protection) according to building function and risk level to fire damage.

While addition rice husk ash in mortar does not contribute to strength, this is because the content of fine particles in mixture has optimal limit so when excessive it is not effective enough to increase strength, but in application can be selected suitable proportion based on compressive strength resulted, both for structural and non structural.

5.2 Rice Husk Ash as Substitute for Concrete

Fire resistance test was carried out on specimen concrete panel measuring 106 cm x 105 cm x 12 cm using small scale fire test furnace, with variations rice husk ash content 0 %, 20 %, and 40 % of weight sand. So the function of rice husk ash is as substitute a portion of sand or fine aggregate so can function as filler material which can increase density and ease concrete workmanship. Test results fire resistance and conductivity are presented in table 5.

Table 5 Test Results Fire Resistance Conrete Panel

No	Combustion Time (minute)	Temperature Standard (ºC)	Furnace Temperature (ºC)			Temperatur Behind Test Specimen (ºC)		
			1	2	3	1	2	3
1	0	0	0	0	0	0	0	0
2	10	705	613	346	325	32	24	24
3	20	795	795	698	655	91	25	24
4	30	840	815	763	746	94	26	25
5	40	880	878	810	799	106	32	30
6	50	905	905	851	831	138	48	43
7	60	925	928	880	869	264	65	62
8	70	945	933	899	890	270	79	77
9	80	965	-	973	961		90	88
10	90	980		984	980		96	92
11	100	990		989	979		98	95
12	110	1000		992	988		100	96
13	120	1010		999	994		103	98
14	130	1015		1009	1009		104	99
15	140	1025		1013	1010		105	101
16	150	1030		1016	1011		107	102
17	160	1040		1019	1016		109	104
18	170	1045		1036	1034		110	105
19	180	1050		1040	1037		112	106

Specimen 1 = rice husk ash content 0 %
Specimen 2 = rice husk ash content 20 %
Specimen 3 = rice husk ash content 40 %
In the form of picture relationship between combustion time and furnace temperature, temperature standard and temperature behind test specimens of various rice husk ash content are presented in figure 2, figure 3, and figure 4.

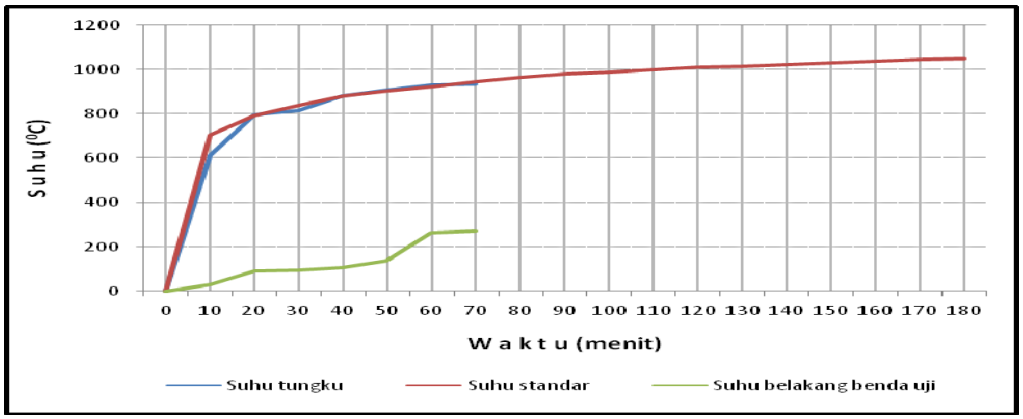


Figure-2 Graph relationship between combustion time and temperature produced from concrete panel with rice husk ash content 0 %

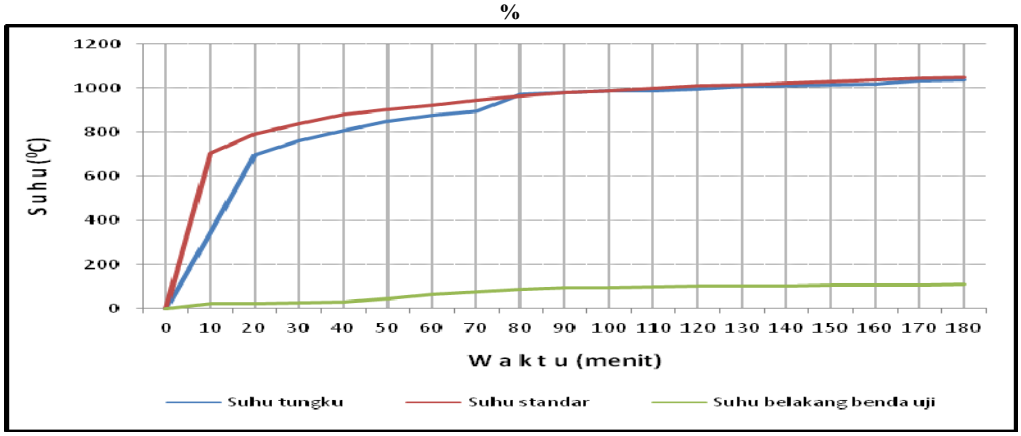


Figure-3 Graph relationship between combustion time and temperature produced from concrete panel with rice husk ash content 20 %

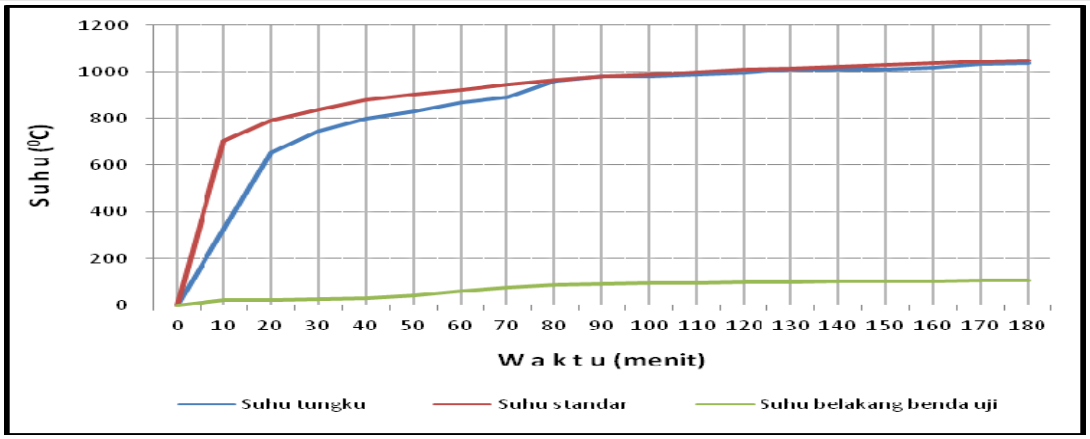


Figure-4 Graph relationship between combustion time and temperature produced from concrete panel with rice husk ash content 40 %

Concrete panel with rice husk ash content 0 % only have fire resistance for 1 hour, where after burned for 1 hour temperature behind specimen has reached 270 ºC above limit maximum requirement 140 ºC, and has deformed and cracked on surface panel. While panel with rice husk ash content 20 % and 40 % have fire resistance for 3 hours with temperature behind specimen reach 112 ºC and 106 ºC. Besides temperature behind specimen, visually the two specimens have excellent stability and integrity because there are no physical changes and cracks that can transmit thermal radiation.

From the results of fire resistance test above, it can be seen that addition rice husk ash in concrete mixture can increase the value of fire resistance, both visually (stability and integrity) and insulation properties (conductivity), so can inhibit thermal propagation rate / heat from one side to other side. With these results can illustrated that addition rice husk ash to concrete can increase fire resistance and can inhibit heat propagation rate so in practice can be applied in manufacture concrete, especially in building components which are classified as passive protection.

CONCLUSION

1. The higher level rice husk ash on mortar the better resistance to fire and its conductivity value, so the material is very well used as mixture / substitution material in manufacture fire resistant components.
2. Testing the combustion properties of all mixtures with rice husk ash content from 0 % to 80 % all mixtures meet M-1 quality classification or including non-flammable materials.
3. From fire resistance test to panel with rice husk ash content 0 %, it can only meet class 1 hour where temperature behind specimen has reached above 140 ºC. But for concrete panel with rice husk ash content 20 % and 40 % can meet requirement class 3 hours with temperature behind new specimen reach 112 ºC and 106 ºC, this means addition rice husk ash can increase fire resistance and can used as passive protection material in buildings to prevent or inhibit flame propagation / thermal.

SUGGESTION

1. In development utilization rice husk ash as concrete substitute, needs to be considered its quality considering quality the material depends on level perfection combustion and silica contained.
2. For the purpose, needs to quality control before rice husk ash used, by carrying out chemical analysis or physical tests in laboratory;
3. In order to obtain balanced quality between strength and resistance to fire, need to choose an appropriate proportion based on properties possessed from test results.

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