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COMPRESSION STRENGTH OF CONCRETE WITH POND ASH AS REPLACEMENT OF FINE AGGREGATE

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ABSTRACT

A residue of coal incineration of the thermal power plants which is not well managed, resulting in the buildup to the final disposal site into pond ash. The pond ash waste is categorized as a hazardous material that requires a change in its management from friable materials into solid materials. Preliminary study of utilizing the pond ash as replacement materials of concrete, at the early stage, it is used as a partial replacement of fine aggregate in the concrete mixes and investigated by analyzing the effect of the use of the pond ash to the strength of concrete. The cylindrical specimens of concrete with 100 mm in diameter and 200 mm in height are used. The fine aggregate replacement is made with the weight of the pond ash in the sand ratio of 0%, 12.5%, 25%, 37.5% and 50%, with a constant water-cement ratio of 0.49 based on the normal concrete mix design. Compressive strength test of concrete is conducted at the age of 1, 3, 7, 14, 28 and 90 days. The result shows that by partially replacing sand with pond ash, a noticeable decrease in compressive strength is found in accordance with the increasing of a percentage of the pond ash. Effect of addition of pond ash in the concrete mixture causes a decrease in the compressive strength of concrete, and the smallest compressive strength occurred in the ratio of 50% pond ash with a decreasing compressive strength from 31.73 MPa to 25.97 MPa (18, 13%), for normal concrete and 50% pond ash concrete respectively.

Keywords: concrete, coal ash waste, pond ash, fine aggregate replacement, compressive strength.

INTRODUCTION

Kalimantan is one of the islands having rich natural resources of coal. To support the manufacturing activity, the electric power is required by making a coal-based thermal power plant due to the abundance of coal available in nature.

Thermal power plants generated by coal have been thought is not environmentally friendly because resulting coal ash waste that is divided into two groups, namely soft granulated and coarse granulated. The soft granulated form as dust is called as coal dust / coal fly ash. It is easily flown by gusts of wind with very smooth dimension equivalent to sieve #200 size. This type contains SiO_2, Al_2O_3, P_2O_5 and Fe_2O_3; however, the percentage of SiO_2 is higher than others and even reaches ± 70 percent. The coarse granulated is called bottom ash coal, its grain is comparable to the sand, its colour is greyish-black (ash with glossy black colour means coal dust has not been ignited yet, and it has different characteristics). Fly ash and bottom ash are residual from coal combustion with the characteristics of non-plastic, not-cohesive and granular form.

The amount of coal ash waste produced in a thermal power plant in East Kalimantan is very high and dumped in a mixed state between fly ash and bottom ash. The coal ash waste is not well managed because the sites between the production and disposal process of power plant are not separated, so it accumulates and requires a larger final disposal area.

Coal ash mixtures of fly ash and bottom ash that accumulate into one because of the process of disposal of power plant can be termed as pond ash. By these conditions, in this study we try to find a solution by utilizing pond ash materials for the concrete manufacturing. Based on the gradation, pond ash meets the requirements of zone 4 of fine aggregate. So, it was attempted to utilize pond ash as partially replacement materials of sand in the concrete mix.

Aggregate in making concrete mixture serves as a filler material. In East Kalimantan, the aggregate must be imported from other areas, because the local aggregate and the local rock do not meet the technical requirements of materials for manufacturing of the concrete mix.

One of the criteria that is commonly used in the concrete structure design is the compressive strength of concrete. The compressive strength is a parameter of the concrete that is the most highly considered in the structural design calculations related directly to the material's ability to support the working loads.

Compressive strength of concrete is influenced by its material constituent, thus the quality control of the ingredients and composition in the concrete mix must be carefully considered in order to obtain the desired strength of concrete.

The composition of the concrete mixtures determined through analysis in concrete technology is required to make a concrete in accordance to the planned quality. In Indonesia, the standard of concrete mix design that provides curves for concrete using the ordinary Portland cement type is commonly used [8].

However, recently the ordinary Portland cement has been no longer manufactured in Indonesia except upon special request. To date, the cements that are still produced are Portland pozzolan cement and Portland composite cement, which certainly has different characteristics compare to that of ordinary Portland cement. In this study, the Portland composite cement is used.

The purpose of this study is to determine the compressive strength of concrete with pond ash as sand replacement material.

MATERIALS AND EXPERIMENTAL METHODS

MATERIALS

The materials for normal concrete mix consisting of cement, water, fine aggregate and coarse aggregate are used in this study. The Portland composite cement produced by Tonasa, South Sulawesi is used as a hydraulic cement binder. Water for material's mixing of concrete is taken from the laboratory Polytechnic of Samarinda. Fine aggregate used is river sand, and coarse aggregate used is crushed stone that all are imported from Palu, Central Sulawesi.

CEMENT

Recently the type-I of cement or Ordinary Portland Cement (OPC) is no longer produced in Indonesia except upon special request. So, all the constructions were built by using Portland Composite Cement (PCC) or Portland Pozzolan Cement (PPC). Criteria of cement used to refer to the technical specifications of Portland composite cement that is used for general construction (SNI 15-7064-2004). Inorganic materials in the PCC including furnace slag, silicate pozzolan compounds and limestone are relatively high with a total content of inorganic materials 6% - 35% of the mass of Portland composite cement. Additional requirements for the chemical constituents of Portland composite cement, SO_3 maximum is 4.0%.

SNI 15-7064-2004 also set the standard physical requirements, including the requirements of the binding time by using the vicat as follows:

Table-1. Terms physics as listed below.

No	Description	Unit	Terms
1	Binding time by the vicat: - beginning binding - final binding	 minute minute	 45 375

AGGREGATES

Aggregate, such as sand and crushed stone, for construction materials in East Kalimantan cannot be produced from local natural resources, thus they are imported from Palu, Central Sulawesi. It is because the local sand and crushed stone material in East Kalimantan do not meet the technical requirements. So, in order to reduce the dependence on imported materials for concrete, we try to utilize the local existing coal ash waste for aggregate replacement in concrete.

Aggregate is one of the concrete filler materials, and its role in the concrete is very important. The proportion of aggregate in the concrete reaches approximately 60% -75% of the total volume of concrete. Aggregate affects the properties of concrete, so the selection of aggregates is an important part in the making of the concrete mix. Fine aggregate is generally considered to be small / escaped from sieve No. 4 (4.75 mm) while the coarse aggregate is the larger one which retained on sieve No. 4 (4.75 mm).

The testing method of specific gravity and water absorption of aggregates refers to Indonesian National Standard SNI 03-1969-1990 and SNI 03-1970-1990 for coarse aggregate and fine aggregate, respectively. The technical specifications of aggregate refer to ASTM C 33-90, a standard specification for concrete aggregates.

SIEVE TEST ANALYSIS

Figure 1-3 show the gradation of crushed stone, sand and pond ash, respectively. Gradation of sand is satisfied and meet the category zone 1, while for coarse aggregate distribution designed with a maximum diameter of 20 mm according to ISO standards 03-2834-2000.

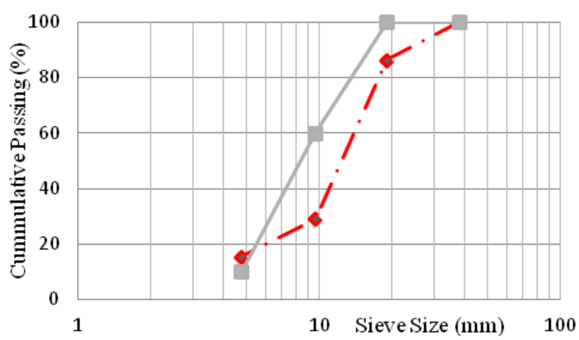

Figure-1. Grading curve for stone crushed.

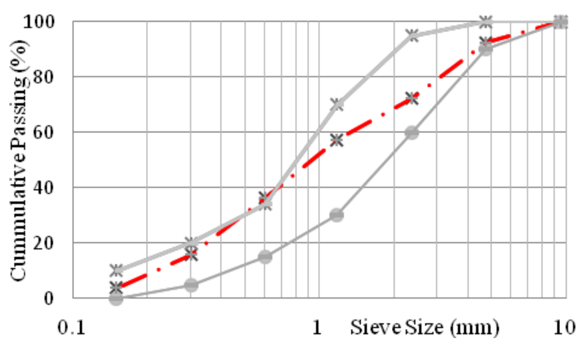

Figure-2. Grading curve for sand at Zona 1.

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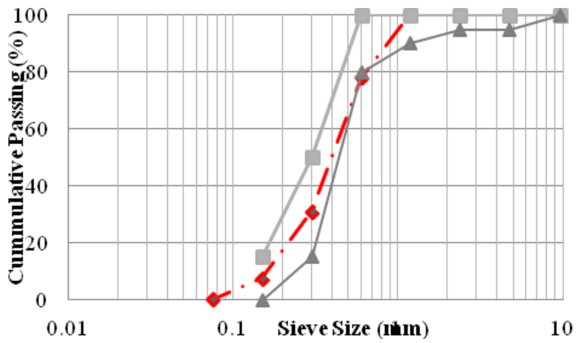

Figure-3. Grading curve for pond ash at Zona 4.

MIX DESIGN

Each variation of the concrete mix is made of a concrete specimen cylinder with a diameter of 100 mm and height of 200 mm. Concrete is designed according to Indonesian National standard (SNI). Mixing of concrete is done by using a concrete mixer, and aggregates are prepared in a saturated surface dry condition (SSD) prior to mixing.

Test specimens that have been molded are kept in the mold for 24 hours. Then, the specimens are opened from the mold and cured by immersing them in water during certain age. Compressive strength test is conducted after 1, 3, 7, 14, 28 and 56 days, with two specimens for each test day.

Compressive strength results for various age tests are analyzed to find the relationship between various ages and compressive strength. This is also done in concrete made from at various percentages of pond ash. In this analysis, the average value obtained from the test object specified is used.

TEST RESULTS AND DISCUSSIONS

POND ASH

The use of pond ash in concrete was found to have some effects such as reducing the production of coal ash waste (pond ash), conserving the natural resources as well as reduce the negative environmental impact to the human health and ecosystem. Because in Indonesia many thermal power plant use coal as energy, pond ash produced is dumped as waste into the landfill.

Pond ashes used in this study are from the coal ash waste at the power plant PT. Kalimanis in Samarinda, East Kalimantan.

CEMENT

The cement used in this study is a type of Portland cement composite (PCC) EXS Tonasa. The PCC oxide component is shown in Table-2.

Table-2. Component oxides of PCC.

No	Oxide	(%)
1	SiO_2 (Silica)	19.44
2	Al_2O_3 (Alumina)	0.52
3	Fe_2O_3 (Iron)	2.36
4	CaO (Lime)	64.25
5	MgO (Magnesia)	0.48
6	SO_3 (Sulfuric anhydride)	0.35

AGGREGATES

Some physical properties of sand and crushed stones are listed in Table-3. From specific gravity and absorption tests for all aggregates used in this study, the following results are obtained.

Table-3. Physical Properties of sand and stone crushed.

No.	Physical properties	Sand	Stone crused
1	Unit weight (kg /l)	1,362	1,522
2	SSD Density	2,547	2,718
3	Absorption (%)	1,40	0,80
4	Abrasion Los Angeles (%)	---	16,6

GRADING COMBINED AGGREGATES

Based on the results of sieve analysis of materials, such as sand, crushed stone and pond ash, the variation of the combined material is designed in accordance with the composition based on the specifications defined in SNI 03-2834-2000.

A variation of the composition of the mixture was initially calculated by the percentage of trials combined gradation of the crushed stone and sand without adding pond ash; it is obtained a ratio 37.5%: 62.5% of sand and crushed stone percentage respectively. The result is plotted on a graph of combined gradation of aggregate as shown in Figure-4.

Variation of composition by specifying the percentage of crushed stone 62.5%, while the percentage of sand decreases in accordance with the addition of pond ash. The total percentages of the combined with all materials remain 100%, and the results are plotted in the graph of a gradation combination of three materials (sand, crushed stone and pond ash). The results show that those four variations meets the requirements of the fourth variation of the combined gradation are shown in Figure-5 to Figure-8.

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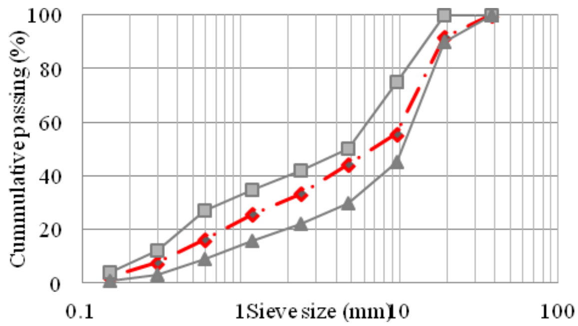

Figure-4. Grading curve for combined sand 100%: pond ash 0%.

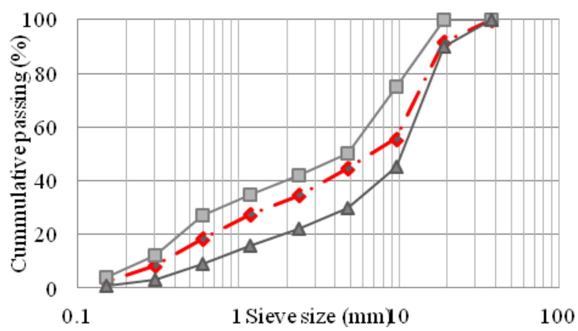

Figure-5. Grading curve for combined sand 87, 5%: pond ash 12, 5%.

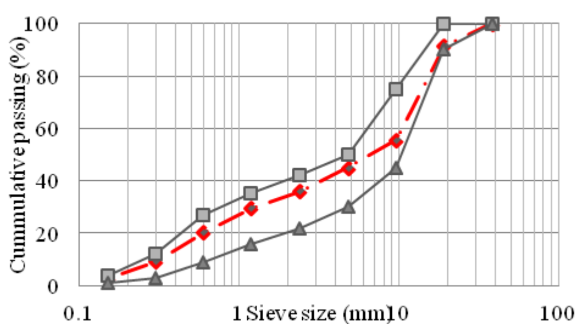

Figure-6. Grading curve for combined sand 75%: pond ash 25%.

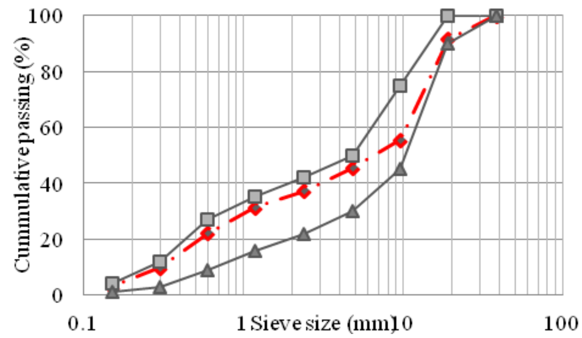

Figure-7. Grading curve for combined sand 62, 5%: pond ash 37, 5%.

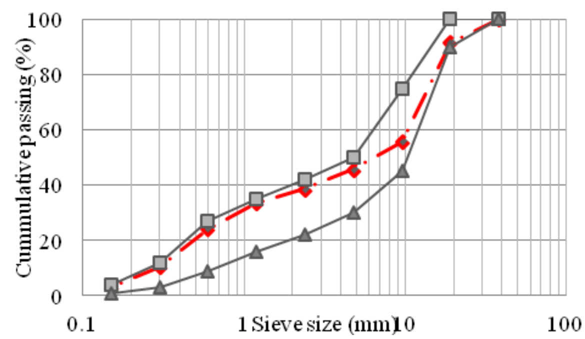

Figure-8. Grading curve for combined sand 50%: pond ash 50%.

PROPORTION COMPOSISIONS

Five variations of composition in the mixture were made to determine the compressive strength of concrete made from pond ash with the variation set of 0%, 12.5%, 25%, 37.5% and 50% by weight of fine aggregate (sand) and the normal concrete without replacement of coal ash as compared. The normal concrete without pond ash content (0% pond ash) is used as reference. For every variation, cylindrical concrete is made with a diameter of 100 mm and height 200 mm.

Concrete strength is designed by using the effective compressive strength (f'_c) 25 MPa with a water cement ratio 0.49 corresponding concrete mix design based on SK.SNI 03-2847-2002. The characteristics of each of the five types of concrete variations are shown in Table-4.

Table-4. Mix proportions.

No.	Mixture	Unit	CA0	CA1	CA2	CA3	CA4
1	Cement	(kg/m^3)	404,08	404,08	404,08	404,08	404,08
2	Water	(ltr)	200,88	200,88	200,88	200,88	200,88
3	Pond ash	(%)	0	12,5	25	37,5	50
4	Pond ash	(kg/m^3)	0	83,36	166,72	250,08	333,45
5	Sand	(kg/m^3)	666,89	583,53	500,17	416,81	333,45
6	Stone Crushed	(kg/m^3)	1.128,15	1.128,15	1.128,15	1.128,15	1.128,15
7	Concrete Density	(kg/m^3)	2.400,00	2.400,00	2.400,00	2.400,00	2.400,00

Figure-9. The process of mixing and sample preparation.

The number of tests specimens was adjusted according to the number of variations in the composition of the mixture used, the age of the test and the number of test specimens. Compressive strength testing is carried out at the age of 1, 3, 7, 14, 28 and 90 days using 2 specimens for each test age. Thus, the total specimens made of the whole composition with 5 variations of pond ash as fine aggregate replacement material is 60 specimens.

The development of compressive strength of each concrete made using pond ash as a fine aggregate replacement based on hydration time is shown in Figure-10.

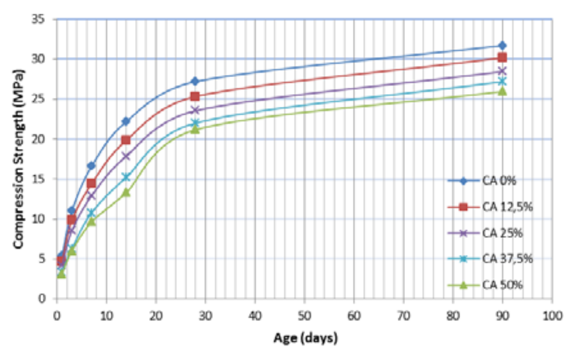

Figure-10. Graph of increasing in compressive strength.

Figure-10 shows that the compressive strength, for all types of concrete, increased corresponding with increasing the hydration age. The increasing in compressive strength of concrete can be clearly identified to be more rapid in the early hydration age until 28 days. However, after 28 days the development of compressive strength increased slowly even began to tend to be stable. Concrete made using coal ash as a fine aggregate replacement develops a lower compressive strength when compared to normal concrete as a reference for each hydration age. At the age under 28 days, the concrete with a higher percentage of fine aggregate replacement variance shows slowness in the development of compressive strength compared to concrete with the fewer replacement. However, by increasing the hydration age, the differences of compressive strength development noticeably reduced. And finally, at the age of 90 days, the compressive strength of the concrete with a various of fine aggregate replacement, such as 12.5%, 25%, 37.5% and 50% can achieve 95.13%, 89.73%, 85.74% and 81.87%, respectively of the compressive strength of normal concrete as reference with the strength 31.73 MPa.

CONCLUSIONS AND RECOMMENDATIONS

Based on the analysis, it can be concluded that the use of pond ash as a fine aggregate replacement with the ratio of 50% pond ash has decreased the compressive strength of 18.13%, from 31.73 MPa of normal concrete without pond ash to be 25.97 MPa. However, the coal ash waste material can be utilized and can reduce dependence on imported sand material. The use of coal ash as sand replacement materials still gives economically benefit and can increase the recycling of waste materials.

It is recommended that the use of waste coal ash mixed with sand for the manufacture of concrete is not used on a large construction or heavy loading structures.

Further research can be conducted to determine the chemical composition of the concrete mix contained pond ash to ensure the behavior of concrete compressive strength. For further study, the behavior of the other strengths of pond ash concrete should be also evaluated, such as tensile strength, elastic modulus, flexural strength to get a brief understanding.

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