



# SPLITTING TENSILE OF CONCRETE WITH POND ASH AS REPLACEMENT OF FINE AGGREGATE

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**Abstract**— Handling of coal burning waste of thermal power plant in Lati, Berau district, East Kalimantan Province, is to dispose the coal ash into pools flowed water so that coal ash did not fly and cause air pollution. As known that coal ash waste is included hazardous and toxic waste, therefore managing it carefully is a necessity. Sediment or heap of coal ash in the sedimentation pond that is flowing with water is called Pond Ash. This study is conducted by utilizing the pond ash as a replacement material in the concrete mix. The effect of the use of pond ash as partial replacement of sand, fine aggregate in the concrete mix, is studied using cylindrical specimen with a diameter of 100 mm and a height of 200 mm. Specimens were made by taking the ratio of the percentage of pond ash of 0%, 5%, 10%, 15% and 20% of the mixture of concrete with the constant water cement ratio 0.49 which is based on the results of normal concrete mix design. The splitting tensile test of concrete was conducted at ages 1, 3, 7, 14, 28 and 90 days. The test results of splitting tensile of concrete obtained showed an increase in splitting tensile in accordance with the addition of pond ash in the mix. The adding of pond ash in the mix affected the increasing in the splitting tensile of concrete, and the optimum splitting tensile is obtained in the ratio of 16.9% pond ash, which increased to 2,659 MPa from 2,459 MPa for concrete with and without pond ash mixes respectively, or increased by 8,15%. This increase is not significant and cannot be used as a reference, however, by the results of this study it can be concluded that the pond ash waste can be utilized for the manufacture of concrete as a partial replacement of fine aggregate/sand.

**Keywords**— Splitting tensile, concrete, coal ash waste, pond ash.

## I. INTRODUCTION

Concrete is one of the materials which is the most widely used in construction, therefore the development of the material continues to be done to obtain better quality of concrete. Moreover, concrete is still considered as the most economical, readily available, and easy to use for structural components. This is because the reinforced concrete has a high compressive strength and high durability, and it does not need additional treatment for standard applications and located in the normal environmental without aggressive exposures. The disadvantage of concrete is it has low tensile strength, so the reinforcement is needed for the purposes withstand tensile stresses [1].

Operation of steam power plant using coal material resulted in solid waste such as coal ash. Based on the form of granules the coal ash is classified to soft granulated such as dust and it's called coal dust/coal fly ash, it flies when hit by wind, the dimension is very small that equivalent to sieve #200. It contains  $\text{SiO}_2$ ,  $\text{Al}_2\text{O}_3$ ,  $\text{P}_2\text{O}_5$ , and  $\text{Fe}_2\text{O}_4$ . The silica content ( $\text{SiO}_2$ ) is sufficient with a high  $\pm 70$  percent [2], allowing the coal ash to qualify as a material that has properties of cement/pozzolan. Other coal ash has coarse grained, it's called coal bottom ash, grains such as black sand to grayish-not shiny. Fly ash and bottom ash is a coal combustion waste, non plastic, non cohesion and granular.

The process of coal ash waste management plant in East Kalimantan, based on the recommendation of the Environment Agency (BLH) of East Kalimantan Province it is conducted by soaking the coal ash mix of fly ash and bottom ash stacked/disposed of in a large pool or beach. The main purpose of the pool in order to flush/soak/wash coal ash, so that does not fly. A mixture of fly ash and bottom ash in a pond termed the pond ash. Considering these conditions, this study tried to find a solution by utilizing the pond ash as a replacement material for the manufacture of concrete. Based on the gradation, pond ash meets the requirements of fine aggregate zone 3, it was attempted utilizing the pond ash to replace partially the sand in the concrete mix materials.

The commonly main purpose of concrete mix design is to get a high compressive strength of concrete. Due to the compressive strength of concrete properties is the main requirement in the calculation in designing structures. The compressive strength is directly related to the ability of the material to support under the applied loads. Moreover the compressive strength of concrete is affected by the constituent material so that the quality control of these materials as well as composition in the concrete mix must be composed carefully in order to obtain concrete according to the desired strength.

Result of research about the using of coal ash waste (fly ash and/or bottom ash) as mixing in the concrete is among others : Effect of coal bottom ash on the properties of concrete such as workability, bleeding, setting times, compressive strength, split tensile strength, flexural strength, shrinkage, and durability [3], Upgraded incinerator bottom ash can replace up to 20 % sand and/or gravel in reinforced concrete and up to 50 % in plain concrete [4], It was observed that up to 30% replacement the results of compressive, flexural, split and water permeability test are approximately same as that of the controlled concrete [5], The strength development for various percentages (0-50%) replacement of fine aggregates with bottom ash can easily be equated to the strength development of normal concrete at various ages [6], indicate significant improvement in the strength properties of plain concrete by the addition of fly ash as partial replacement of fine aggregate (sand), and can be effectively used in structural concrete [7].

The aim of this study is to determine the compressive strength of concrete with the concrete mix made from pond ash as a substitute for sand/fine aggregate. To make concrete in accordance with the planned quality, the concrete composition determined by an analysis of the concrete mix design is required. In Indonesia, the standard SNI 03-2834-2000 is used for concrete mix design that provides tables and curves for concrete and use a normal type of Portland cement, the title of this standard is Procedures of Mix Concrete Manufacturing Plan for Normal Concrete. Due to Ordinary Portland Cement is no longer produced in Indonesia except on special request. While in many productions and on the market are Portland Pozzolan Cement and Portland Composite Cement which certainly have different characteristics with Ordinary Portland Cement, consequently the Portland Composite Cement is used in this study.

## II. MATERIAL AND EXPERIMENT METHODS

**Materials.** The material used for normal concrete mix consist of cement, water, fine aggregate and coarse aggregate. Portland Composite Cement of Tonasa South Sulawesi is used as the hydraulic cement binder. Water for concrete mix is taken from the laboratory of construction materials, Polytechnic State of Samarinda. The fine aggregate used is river sand originating from Palu, while the coarse aggregate such as crushed stone coming from Palu, Central Sulawesi.

**Cement.** As mentioned before, recently an Ordinary Portland Cement (OPC) is no longer produced in Indonesia except on special request, while most construction uses Portland Composite Cement (PCC) or Portland Pozzolan Cement (PPC). In this study Portland Composite Cement is used. Criteria cement used to refer to the technical specifications of the Portland composite cement that is used for general purpose of construction (SNI 15-7064-2004). Inorganic material in the PCC includes furnace slag, silicate compounds of pozzolan, limestone, with a total content of inorganic materials is around 6% - 35% of the mass of Portland Composite Cement. Additional requirements for chemical content of  $\text{SO}_3$  in Portland Composite Cement is a maximum 4.0%.

**Aggregates.** Sand and crushed stone for construction materials in East Kalimantan is not originating from local products, instead they are imported from Palu district, Central Sulawesi, because the local sand and crushed stone do not meet the technical requirements. Consequently to reduce dependence on imports of concrete materials an utilizing coal ash waste produced from the local area such as Lati Berau is conducted in this research. Aggregate is one of the concrete filler material, and the role of aggregate in the concrete is very important. The content of aggregates in the concrete is approximately 60% -75% of the volume of concrete. The aggregate influence on the properties of concrete, so the selection of aggregates is an important part in making the concrete mix.

**Pond Ash.** Utilizing of pond ash in concrete can reduce pond ash waste, conserve natural resources and reduce environmental impact on human health and living things. Because of many steam power plants in East Kalimantan operates coal, raw material and dispose of wastes as pond ash. Pond ash used for this study was taken from the power plant PT. Berau Coal in Lati Berau Regency, East Kalimantan.

**Splitting tensile of Concrete.** Splitting tensile of concrete is the second parameter that must be known and can give a description of almost all the other mechanical properties of concrete. The value of indirect tensile strength of cylindrical concrete specimen obtained from the compression load of the test specimen is placed horizontally parallel to the surface of the table compression testing machine called a splitting tensile strength of concrete. The tensile strength of concrete is commonly ranging from 10% to 15% of the compressive strength of concrete.

### III. RESULTS AND DISCUSSION

#### Cement.

The cement used in this study was a Portland Composite Cement (PCC) produced by Tonasa. In Indonesian standard, SNI 15-7064-2004 set the physical requirements of cement, including requirements concerning setting time with a Vicat test defined as follows.

TABLE I - TERMS PHYSICS AS LISTED BELOW

| No | Description  | Unit             | Terms     | Result |
|----|--|------------------|-----------|--------|
| 1  | Setting time with the vicat:<br>- initial setting time<br>- final setting time | minute<br>minute | 45<br>375 | 110    |

The PCC oxide component is shown in Table 2.

TABLE III - THE OXIDES COMPONENT OF PCC

| No | Oxide                                    | (%)   |
|----|--|-------|
| 1  | SiO <sub>2</sub> (Silica)                | 19.44 |
| 2  | Al <sub>2</sub> O <sub>3</sub> (Alumina) | 0.52  |
| 3  | Fe <sub>2</sub> O <sub>3</sub> (Iron)    | 2.36  |
| 4  | CaO (Lime)                               | 64.25 |
| 5  | MgO (Magnesia)                           | 0.48  |
| 6  | SO <sub>3</sub> (Sulfuric anhydride)     | 0.35  |

#### Aggregates

The testing methods of density and water absorption of aggregate use Indonesian national standards, 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 Standard specification for concrete mixed. The physical properties of sand and crushed stone are listed in Table 3. Based on the results of the analysis of the specific gravity and absorption testing of all the aggregates used in this study were obtained the following results.

TABLE IIIII - THE OXIDES COMPONENT OF PCC

| No | Physical properties      | Sand  | Crushed stone |
|----|--------------------------|-------|---------------|
| 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 Aggregates

The results of sieve analysis for fine aggregate, coarse aggregate and pond ash are plotted in the graph. According to grading zone specifications (B.S. 882/1944 concreting sands) [8], obtained results for the gradation of sand is categorized as zone 1, while the pond ash in the category zone 3. Based on the results of sieve analysis of the concrete mix consisting of sand, crushed stone and pond ash, the combined variations of materials is designed in accordance with the composition based on the specifications defined in SNI 03-2834-2000. Variation of mixed composition is initially calculated by the percentage of trial combined gradation between crushed stone and sand without adding the pond ash. Finally, the ratio of sand and crushed stone is obtained, that is 37.5% and 62.5%. The combined results were plotted on a combined graph of aggregate gradation as shown in Figure 1.

The next composition variation is specified by the percentage of crushed stone 62.5%, while the percentage of sand is reduced in accordance with the addition of pond ash. The total combined percentage of these three ingredients is still 100%, the results are plotted in the combined gradation graph of three materials (sand, crushed stone and pond ash). The graph shows that all four of these variations meet the requirements of combined gradation with the maximum diameter of 20 mm.

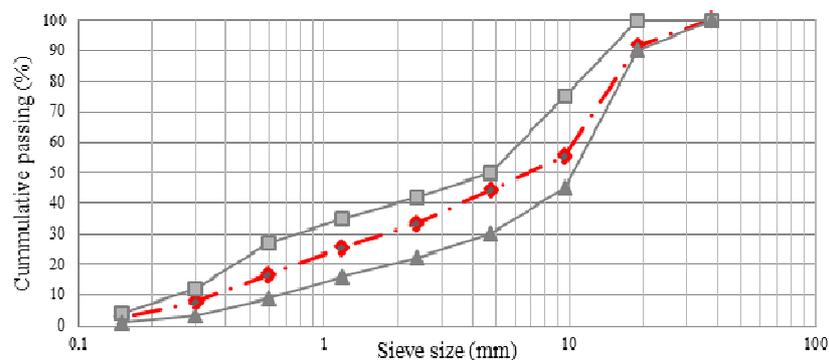


Fig. 1 Grading curve for combined sand 37,5% : crushed stone 62,5%.

### Mix Design

Concrete designed using the effective compressive strength of  $f_c = 25$  MPa with water cement ratio value is set at 0,49 corresponding concrete mix design based on SNI 03-2834-2000. The characteristics of each variation of concrete with five variations are provided in Table 4. Mixing concrete is conducted by the mixer. Prior mixing concrete the aggregates were prepared under Saturated Surface Dry (SSD) conditions. Five variations of mixture composition are made to determine the compressive strength of concrete. Concrete samples are made from pond ash waste with the variation set at 0%, 5%, 10%, 15% and 20% of the combined aggregate weight and a normal concrete without a replacement pond ash as a control sample. Variations in pond ash content of 0% are the compressive strength control. For any kind of variation, the test specimens of concrete are cylinders with a diameter of 100 mm, a height of 200 mm.

TABLE IVV -MIX PROPORTIONS

| No. | Mixture          | Unit                 | NC       | PAC5     | PAC10    | PAC15    | PAC20    |
|-----|------------------|----------------------|----------|----------|----------|----------|----------|
| 1   | Cement           | (kg/m <sup>3</sup> ) | 404.08   | 404.08   | 404.08   | 404.08   | 404.08   |
| 2   | Water            | (liters)             | 200.88   | 240.96   | 281.03   | 321.10   | 361.18   |
| 3   | Pond ash         | (%)                  | 0.00     | 5.00     | 10.00    | 15.00    | 20.00    |
| 4   | Pond ash         | (kg/m <sup>3</sup> ) | 0.00     | 48.84    | 97.69    | 146.53   | 195.37   |
| 5   | Sand             | (kg/m <sup>3</sup> ) | 666.89   | 577.97   | 489.05   | 400.14   | 311.22   |
| 6   | Stone Crushed    | (kg/m <sup>3</sup> ) | 1,128.15 | 1,128.15 | 1,128.15 | 1,128.15 | 1,128.15 |
| 7   | Concrete Density | (kg/m <sup>3</sup> ) | 2,400.00 | 2,400.00 | 2,400.00 | 2,400.00 | 2,400.00 |

The moulded test specimen is left in the mold for 24 hours and then opened from the mold to be further treated. Treatment is done by soaking the specimen in water as long as the determined time for compressive strength testing of the age of 1, 3, 7, 14, 28 and 90 days, with each variation consisted of two samples. The number of the total specimens made entirely with 5 variations of composition of pond ash as a substitution material of sand (fine aggregate) by 60 (sixty) pieces. Information about generating splitting tensile for the various age test, carried out an analysis to find the relationship between the various ages and resulted splitting tensile. This is done on concrete made from a variety of pond ash percentage.

In this analysis, the average value is obtained from the test of the specified sample. The development of splitting tensile of each concrete made using pond ash as replacement of fine aggregate by hydration time is given in Figure 2.

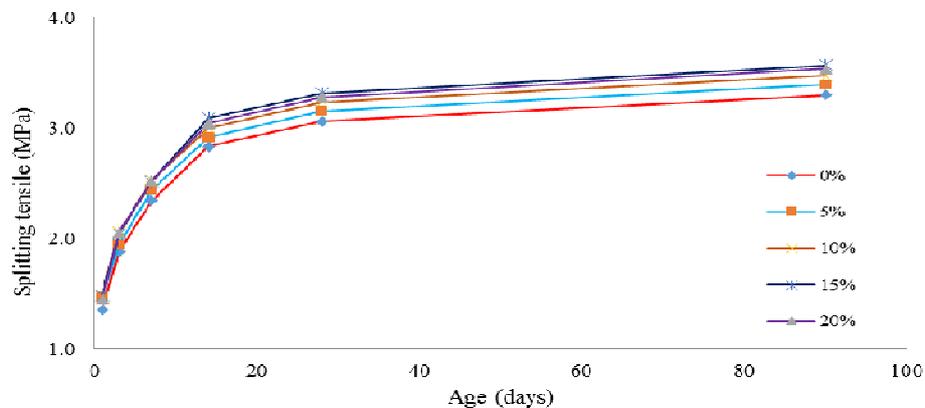


Fig. 2 Graph of increasing in splitting tensile.

Based on the Figure 2, it can be seen that the splitting tensile, for all types of concrete, increased in accordance with the increasing in hydration age. Increased splitting tensile of concrete appear faster on the initial hydration age, up to 28 days, and a further increase is likely to be slower and even the development of splitting tensile began to stabilize with a small improvement. Concrete made using pond ash as replacement of fine aggregate develop a higher splitting tensile when compared to normal concrete/control made without substitutes pond ash at the hydration age after 28 days. Before reaching the age of 28 days, concrete with increasing variety of fine aggregate replacement shows higher growth for a higher percentage of pond ash when compared to concrete with aggregate replacement fewer. However, by increasing hydration age the differences of tensile strength development have become increasingly apparent. Based on the Figure 2 can be stated that the splitting tensile of the concrete pond ash has characteristics increase the splitting tensile of the same at various ages compared with the characteristics of an increase in splitting tensile of normal concrete. Furthermore, based on Figure 2 the increase in the splitting tensile of concrete for each variation of pond ash, compiled by calculating the splitting tensile of the average of each composition variations in the materials used after converting to splitting tensile 28 days. Produced splitting tensile of concrete with variation pond ash as a substitute for sand, obtained a graph of the splitting tensile of the concrete pond ash to variations in the levels of pond ash is used. The results are as shown in the graph, Figure 3 with an average splitting tensile of the variations in the levels of pond ash of 2,549 MPa; 2,626 MPa; 2,666 MPa and 2,645 MPa when compared to normal/control with the average value of 2,459 MPa. As a result, by utilizing the pond ash in the concrete mix the comparison of splitting tensile of concrete is found, which their strength higher than the normal concrete, that is 3,67%; 6,80%; 8,41% and 7,55% of the normal concrete respectively.

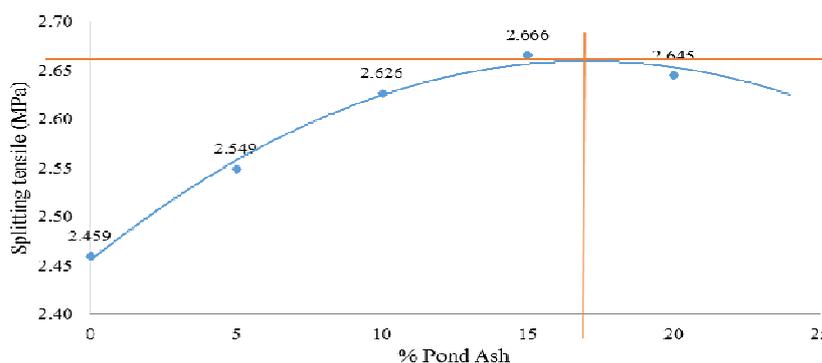


Fig. 3 Graphs of optimum splitting tensile.

Based on the analysis of optimum splitting tensile of each composition and with the help of polynomial graphs, the optimum splitting tensile is obtained in 2,659 MPa or achieve an increase in the splitting tensile of 8,15% of the splitting tensile of normal/control concrete which has 2,459 MPa, which occurred on the replacement of pond ash of 16.9%.

#### IV. CONCLUSIONS AND RECOMMENDATIONS

Based on the description of analysis above, it can be argued that the use of pond ash from power plants in Lati Berau District of East Kalimantan as a substitute material for sand in sand ratio of 20.6%: 16.9% of pond ash: 62.5% of the crushed stone increased splitting tensile of the concrete compared to the normal/control concrete of 2,459 MPa to 2,659 MPa or an increase of 8,15%. Because of the pond ash material is waste material that can be utilized and can reduce dependence on imports of sand, then the use of pond ash as a substitute of sand is still profitable economically and recycling of waste materials. Further research can be conducted to determine the contained chemical composition in the concrete mix with pond ash as substitute materials to ensure the behavior of mechanical strength of concrete. Other tests also need to be carried out, such as modulus elasticity and the flexural strength.

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