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The Effect of Fly Ash Mixture on Concrete Compressive Strength

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Abstract

Fly ash is a waste from the steam power plant industry that can be used as added material in making concrete. This is because the chemical compounds in fly ash are almost the same as cement. The purpose of this study was to determine the compressive strength of concrete with partial replacement of cement with fly ash. The composition of partial replacement of cement with fly ash is 0%, 20%, 25%, 30%, and 35%. The planned concrete quality is fc' 30 MPa and tested at the age of 7 days and 28 days. The test results show the average compressive strength of the concrete for all variations of both 7-day and 28-day replacement is less than 30 MPa. The greater composition of fly ash used, the smaller the compressive strength value of the concrete. This is caused by the slow hydration process because fly ash is pozzolans which delay the hydration process. In addition, the reduction of cement content will also result in a decrease in compressive strength, this is because the bonding capacity of the aggregate decreases. However, when viewed based on the density of the concrete, the fine fly ash grains can make the concrete denser.

Keywords: concrete, fly ash, cement, compressive strength

Abstrak

Fly ash merupakan limbah dari industri pembangkit listrik tenaga uap yang dapat digunakan sebagai bahan tambah dalam pembuatan beton. Hal ini dikarenakan senyawa kimia pada fly ash hampir sama dengan semen. Tujuan dari penelitian ini adalah untuk mengetahui kuat tekan beton dengan penggantian sebagian semen dengan fly ash. Komposisi penggantian sebagian semen dengan fly ash adalah 0%, 20%, 25%, 30%, dan 35%. Mutu beton yang direncanakan adalah fc' 30 MPa dan diuji pada umur 7 hari dan 28 hari. Hasil pengujian menunjukkan kuat tekan rata-rata beton untuk semua variasi baik penggantian 7 hari maupun 28 hari kurang dari 30 MPa. Semakin besar komposisi fly ash yang digunakan maka nilai kuat tekan beton semakin kecil. Hal ini disebabkan lambatnya proses hidrasi karena fly ash merupakan pozzolan yang menunda proses hidrasi. Selain itu, penurunan kadar semen juga akan mengakibatkan penurunan kuat tekan, hal ini dikarenakan daya rekat agregat menurun. Namun jika dilihat berdasarkan berat jenis beton, butiran fly ash yang halus dapat membuat beton menjadi lebih padat.

Kata kunci: *beton, fly ash, semen, kuat tekan*

I. INTRODUCTION

In general, construction buildings in Indonesia use concrete as the main structural material. This is because concrete has several beneficial properties including raw materials that are easy to obtain, relatively inexpensive prices, easily formed according to needs, and do not require maintenance costs that are too expensive. In making concrete, the selection of materials used is very important, especially to obtain the quality of concrete with the desired special properties. In the practice of making concrete, additives, and admixture are considered important materials. The use of these materials is intended to improve and add concrete properties as desired. An alternative additive material that can be used is to utilize industrial waste, one of which is fly ash waste. Fly ash is a waste of industrial steam power plants with coal fuel. The chemical composition contained in fly ash is Silicon Dioxide (SiO_2), Aluminum (Al_2O_3), and Ferrum Oxide (Fe_2O_3). Chemical compounds in these wastes

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have similarities with chemical compounds in cement.

Research on the use of fly ash as an added material in the manufacture of concrete has been done before. One of them was carried out by [1]. The experimental results showed that concrete with a 28-day compressive strength of 80 MPa could be obtained with a fly ash content of 45%. Research carried out by [2] replaced 40%, 45%, and 50% of Portland cement with fly ash. The results showed a reduction in 28 days compressive strength, splitting tensile, flexural strength, modulus of elasticity, and abrasion resistance. However, the strength properties and abrasion resistance show a continuous and significant improvement at the ages of 91 and 365 days. Research [3] conducted a study using fly ash from Western Australia as a partial replacement for cement. The concrete mixtures with fly ash as 30% and 40% of total binders were used to make the test specimens. The 28-day compressive strength of the concrete mixtures varies from 65 to 85 MPa. In general, the incorporation of fly ash as a partial replacement of cement improved the durability properties of concrete. Research also conducted by [4] uses fly ash in concrete to reduce the consumption of natural resources and also reduce the effects of pollutants in the environment in India. In this study, cement has been replaced by fly ash with variations of 0% (without fly ash), 10%, 20%, 30%, 40%, 50%, and 60% by weight of cement for the M-25 mixture. It was observed that cement replacement up to 30% with fly ash had compressive strength almost the same as the reference concrete after 56 days.

In some studies, fly ash is mixed with silica fume or lime powder to replace a portion of cement in concrete. Research by [5] investigated the effects of replacing cement with fly ash and silica fume on the strength, compressive stress-strain relationship, and fracture behavior of concrete. Research by [6] involves three types of mixes, the first consisting of different percentages of fly ash, the second using different percentages of silica fume, and the third using a mixture of fly ash and silica fume. The results show that concrete with 15% of silica fume gives higher values of compressive strength than those with 30% of fly ash. A study from [7] replaced the proportion of cement with fly ash and lime powder in highly flowable-consolidating concrete (SCC). This type of concrete is widely used for complex concrete construction, such as in dams and thick foundations. The results showed that concrete with 55% weight replacement of cement with fly ash and lime powder had sufficient strength to be used at 28 days and 365 days. In terms of cost and compressive strength, concrete with 10% fly ash has a compressive strength of 42.83 MPa and a cost savings of Rp. 9,571,725. This type of concrete is used to hold Cobalt-60 ionizing radiation at 1.25 Mev [8].

Based on several previous studies, it can be concluded that fly ash can be used as a replacement for cement. The purpose of this study was to determine the compressive strength of concrete with partial replacement of cement with fly ash. The fly ash used in this study came from the waste of the steam power plant industry in Pelabuhanratu, Sukabumi. Therefore, it is expected that the fly ash from the Pelabuhanratu steam power plant waste can be reduced and has economic value as a material for making concrete.

II. RESEARCH METHOD

In this study, variations in the addition of fly ash as a partial replacement for cement were 0% (without fly ash), 20%, 25%, 30%, and 35%. For each variation, 3 concrete cylinders (150 mm diameter, 300 mm height) were made. Therefore, there are 15 concrete cylinders made. The steps taken include preparation materials and tools, aggregate material testing, mix design, making test specimens, fresh concrete testing (slump test), curing test specimens, and hard concrete testing (compressive strength test). The flowchart of this study is illustrated in Figure 1.

A. Preparation Materials and Tools

Materials used in the process of making test specimens include Portland cement type I, fine and coarse aggregates in the form of sand and gravel, water, and fly ash from the Pelabuhan Ratu steam power plant industry, Sukabumi. The tools used include a scale, concrete mixer, Abrams cone, and cylinder mold.

B. Aggregate Material Testing

The aggregate test consists of specific gravity (dry surface), water absorption (%), and moisture content (%). The test was conducted at PT Prima Mixindo Utama Laboratory. The results of aggregate material testing are shown in Table 1. Aggregate test results will affect the calculation of mix design.

C. Mix Design

In this study, the proportion of concrete mixing is calculated based on the procedures outlined in SNI 03-2834-2000 [9]. In the mix design calculation, the compressive strength value is

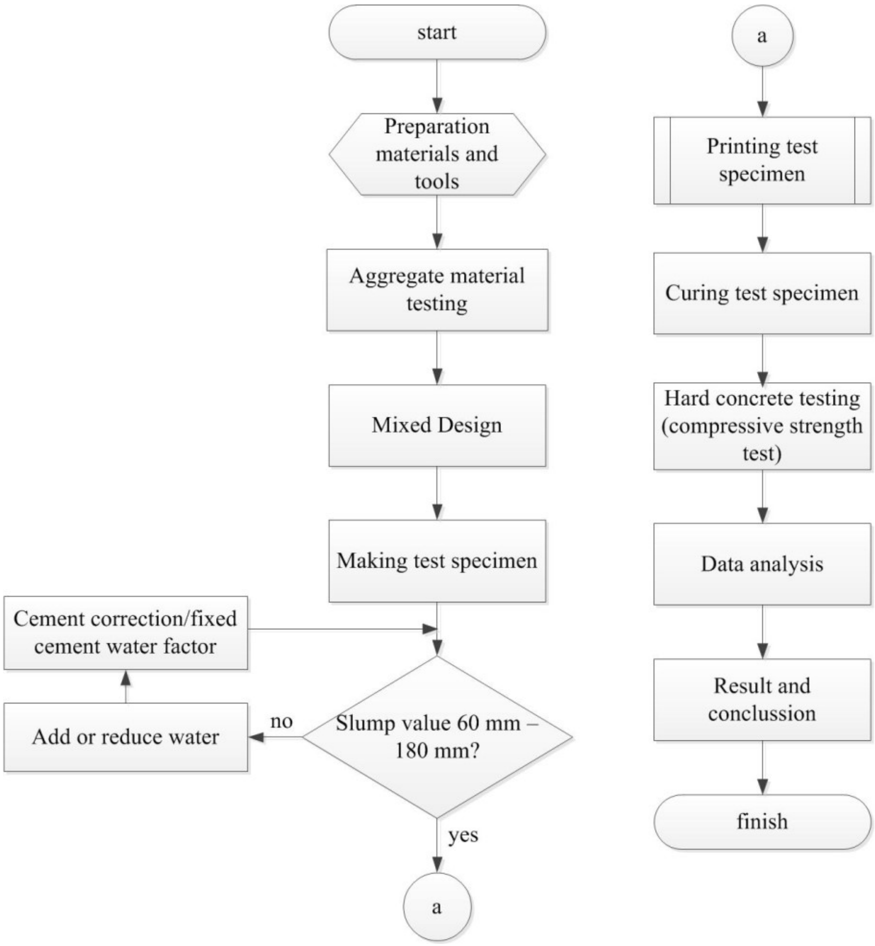

Figure 1. Flowchart of the study

Table 1. Results of aggregate material test

Aggregate Properties	Fine Aggregate	Coarse Aggregate
Specific Gravity (Dry Surface)	2.631	2.583
Water Absorption (%)	3.092	2.944
Moisture Content (%)	8.13	1.56

Table 2. Material requirements based on mix design SNI 03-2834-2000

Fly Ash Replacement	Portland Cement (Kg)	Fine Aggregate (Kg)	Coarse Aggregate (Kg)	Water (Kg)	Fly Ash (Kg)
0%	2.36	3.05	5.82	1.02	0.00
20%	1.89	3.05	5.82	1.02	0.47
25%	1.77	3.05	5.82	1.02	0.59
30%	1.65	3.05	5.82	1.02	0.71
35%	1.38	3.05	5.82	1.02	0.82

required at 30 MPa for the 28-day concrete. For testing fresh concrete, a slump value of 60 mm – 180 mm is determined. The maximum cement water factor is set at 0.60, so a free cement water factor is obtained at 0.46. In addition to these values, several parameters are also determined based on aggregate test results. The results of the mix design calculation can be seen in Table 2. These results are the material requirements for one test specimen.

D. Making Test Specimen

The process of making test specimens starts with preparing the materials needed. The material is then weighed according to the mix design results. After that, the material is mixed with a concrete mixer.

The material pouring sequence starts with some water, gravel, sand, cement, and fly ash. If the mixture is well mixed, then the remaining water can be added little by little until the concrete mixture is mixed homogeneously.

E. Fresh Concrete Testing (Slump Test)

Good fresh concrete is fresh concrete that can be stirred, transported, poured, and compacted. In addition, there is no tendency to separate gravel from the mixture (segregation) or the separation of water and cement from the mixture (bleeding). Based on SNI-1972-1990 fresh concrete testing is done by slump test [10]. The purpose of the slump test is to determine the workability of a concrete mixture.

Slump testing is carried out using the Abrams cone, which is a cone with a bottom diameter of 20cm, a top of 10 cm, and a height of 30 cm. The testing procedure begins by inserting concrete into three layers into the Abrams cone. Each layer is compacted with a compactor 25 times. The top surface is flattened by sliding the compactor rod horizontally. After that, the Abrams cone is lifted vertically upward slowly. Slump value is the difference between the height of the mold with the height of the concrete. If the value meets the reference slump value, then the next step is to print the concrete mixture into a cylindrical mold.

F. Curing Test Specimen

The cylindrical specimens were cured by immersing them in the soaking tub for 7 days and 28 days. The purpose of the immersion is to keep the concrete condition moist so that rapid evaporation of water in the concrete can be avoided. This is due to the use of Portland cement which has a high enough hydration heat.

G. Hard Concrete Testing (Compressive Strength Test)

Hard concrete testing consists of concrete compressive strength, modulus of elasticity, permeability, and density. However, due to the unavailability of tools, only compressive strength tests are carried out. A concrete compressive strength test is carried out to compare the compressive strength of the test results with the compressive strength of the plan. The concrete compressive strength test refers to SNI 03-1974-2011 [11].

Concrete compressive strength values were obtained through standard testing procedures using a testing machine. The method of testing is carried out by providing multilevel compressive loads with a certain speed increase. The test object is pressed until it breaks. The formula (1) is used for calculating the compressive strength of concrete. The tests were carried out on 7-days and 28-days concretes.

$$f'c = \frac{P}{A} \tag{1}$$

where:
$f'c$ = concrete compressive strength,
P = maximum load,
A = cross-sectional area of the test specimen.

III. RESULT AND DISCUSSION

A. Fresh Concrete Testing (Slump Test)

The slump value is a workability parameter of concrete. The higher the slump value, the higher workability of the concrete. Physically, concrete workability can be seen from the level of mixture viscosity. The slump test results are shown in Table 3.

From Table 3, it can be seen that the slump value for all variations of fly ash has met the planned target, which is 80 mm - 180 mm. The lowest slump value of 82 mm is obtained from 0% fly ash and the highest is 108 mm from 35% fly ash. Replacement of 20%, 25%, 30%, and 35% cement with fly ash can increase the value of slumps respectively by 11%, 19.5%, 25%, and 32%. Therefore, the more percentage of fly ash used, the greater value of slump in fresh concrete. This is because the shape of fly ash grains is very fine and almost the same as cement so it can reduce the occurrence of bleeding and segregation. The round shape of the fly ash can also improve concrete workability.

B. Hard Concrete Testing (Compressive Strength Test)

The concrete compressive strength test was carried out at the age of 7 days and 28 days with a planned compressive strength of 30 MPa. By using Formula (1), the average concrete compressive strength results are shown in Figure 2.

Table 3. Slump value of fly ash concrete

Fly Ash Replacement	Slump Value (mm)	Slump Value Increase (%)
0%	82	-
20%	91	11
25%	98	19.5
30%	103	25
35%	108	32

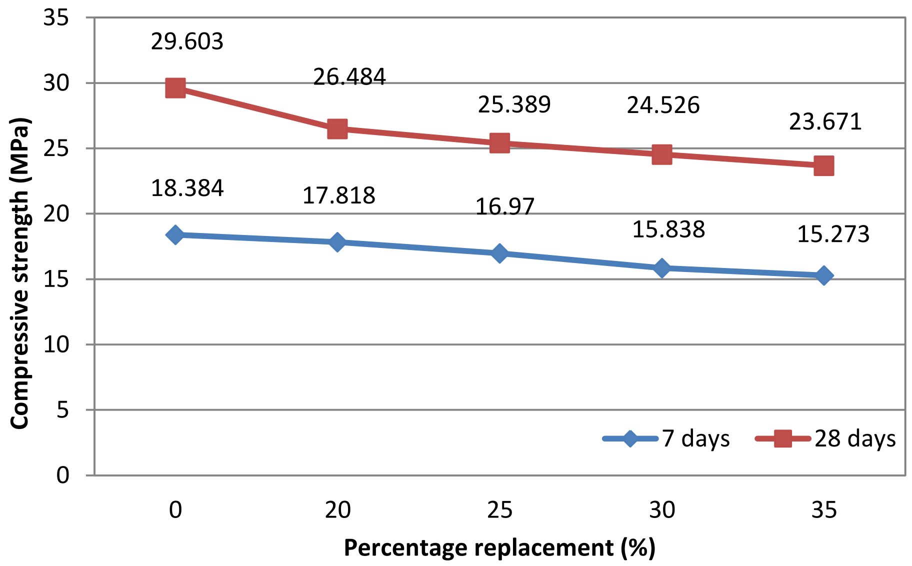

Figure 2. Average compressive strength of fly ash concrete

From Figure 2, it can be seen that 28 days of concrete with 0% fly ash has the highest average concrete compressive strength value and close to the planned strength value. It was observed that cement replacement up to 30% with fly ash had compressive strength almost the same as the reference concrete after 56 days. For 7 days of concrete, the highest average compressive strength value is also found in concrete with 0% fly ash. The lowest average compressive strength values for 7 days and 28 days of concrete are found in concrete with 35% fly ash. The greater composition of the replacement for fly ash used, the lower the compressive strength of the concrete. This is similar to the results of research conducted by [2] and [4], where 28 days of concrete with the replacement of fly ash will experience a decrease in compressive strength.

According to [2] and [4] the decrease in strength may be due to a slow hydration process since fly ash is a slow reactive pozzolan which delays the hydration process. This makes the compressive strength of the concrete increase with time. The reduction in cement content will also result in a decrease in compressive strength, this is due to the decreased binding power between aggregates. Even though the composition of fly ash resembles cement, its function is not the same as cement. When viewed from the density of the concrete, the fine fly ash grains can make the concrete denser. This is because the porous between the aggregates are filled with fly ash so that the concrete surface is smoother and less porous.

IV. Conclusion

Analysis of the effect of fly ash as a partial substitute for cement on the compressive strength quality of concrete has been successfully carried out in this study. Testing the compressive strength value of concrete is carried out at the age of 14 days and the age of 28 days. The results show that the concrete age of 7 days and 28 days with the addition of 0% fly ash has the highest concrete compressive strength value. The lowest concrete compressive strength values at 7 days and 28 days of concrete are shown by the concrete with the most additional fly ash, which is 30%. This is due to the slow hydration process since fly ash is a slow reactive pozzolan which delays the hydration process. However, when viewed based on the density of the concrete, the fine fly ash grains can make the concrete denser. This is because the porous between the aggregates are filled with fly ash so that the concrete surface is smoother and less porous.

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