Utilization of fly ash waste power plant Bosowa energy Jeneponto South Sulawesi as concrete mixed material

Nurdin¹, M Zakir² and E B Demmallino³

¹Environmental Management Study Program, Graduate School of Hasanuddin University
²Department of Chemistry, Faculty of Mathematics and Natural Sciences, Hasanuddin University
³Environmental Management Study Program, Graduate School of Hasanuddin University

Email: nurdin_tompo@yahoo.co.id

Abstract. Flyash waste is a result of coal combustion which can pollute the environment. The research aims to determine (1) how the effect of the variation of the percentage of Flyash as a partial substitute for cement on the weight of the concrete load, (2) how the variation in the percentage of Flyash as a partial cement substitute for the compressive strength of concrete, and (3) how does curing variation effect (treatment) on the value of compressive strength of concrete with Flyash as a substitute for partial cement. The research was conducted in the Laboratory of Building Materials, Structures, and Construction, Faculty of Architectural Engineering, University of Hasanuddin, Gowa Regency, South Sulawesi Province. The method used in this study was an experiment by making concrete from Flyash class F waste from PT. Bosowa Energi Jeneponto Regency, South Sulawesi Province. Concrete samples were made in a total of 120 pieces for two types of curing, namely dry curing and water curing, four sample variations namely 0%, 30%, 50%, and 70% Flyash, weight testing and compressive strength of the samples carried out each of the three age of 3, 7, 14, 21 and 28 days respectively. The results showed that the average weight of the lowest concrete samples was in the variation of 30% Flyash for dry curing, which was 3.45 kg, and water curing was 3.61 kg, while the highest was in the 70% variation of Flyash for dry curing, which is 4.47 kg, and water curing is 4.61 kg. Based on variations of 0%, 30%, 50%, and 70% the compressive strength of concrete declined, namely 24.84 MPa, 22.16 MPa, 11.97 MPa, and 4.20 MPa, for dry curing, and 25.73 MPa, 22.93 MPa, 12.87 MPa, and 4.97 MPa for water curing. The effect of curing variations on the compressive strength of concrete is also increasing as the curing period increases, for dry curing 3, 7, 14, 21, and 28 days, respectively 12.73 MPa, 13.33 MPa, 13.63 MPa, 15.07 MPa, and 22.16 MPa, for water curing, respectively 13.50 MPa, 14.09 MPa, 14.56 MPa, 15.84 MPa, and 22.93 MPa.

1. Introduction
Flyash is the majority of the waste products from the Steam Power Plant (PLTU). Compared with a variety of other wastes released in the form of liquid, gas or solid material, the Flyash is visibly fine-sized that comes out with flue gas and is given an Electro Static Precipitator (ESP) trap, so it does not pass out into the environment. Flyash is a material that comes from unused coal combustion. Flyash is a material that is inevitable and cannot be avoided during the activities carried out using coal.
combustion is mostly used in power plants, and it generates Flyash waste products up to an average of one million tons per year [1]. Jeneponto PLTU PT. Bosowa Energi uses coal as its fuel and the use of coal per day is uncertain depending on the quality of the coal used. Specifically in the September 2016 period, coal consumption amounted to 3,190,604,000 kg/month or an average of 106,354,000 kg/day and produced Flyash waste sent to PT. Semen Bosowa in Maros Regency as a recovery uses a Truck Capsule of 2,033,440 kg/month or an average of 67,780 kg/day for the two power plant units observed; having a composition of unburned carbon (LOI) as much as 13,420 kg/month, Silica (SiO₂) as much as 829,030 kg/month, Aluminum Oxide (Al₂O₃) as much as 319,040 kg/month, Iron (III) Oxide (Fe₂O₃) as much as 351,780 kg/month, Magnesium Oxide (MgO) as much as 143,150 kg/month, Calcium Oxide (CaO) as much as 297,280 kg/month, Sodium Oxide (Na₂O) as much as 17,890 kg/month, Sulfur Trioxide (SO₃) as much as 17,890 kg/month [2].

The chemicals contained in the Flyash are hazardous if discharged directly into the environment so that one alternative in overcoming them is to be used as one of the materials for making concrete. Until now, concrete is still popular to be used as a building or as a material to support buildings, such as the manufacture of electrical cable installation poles, bridge supports or building foundation poles [3]. Coal fly ash has the potential to be a concrete aggregate material because it is economical, so it can make the environment remain sustainable and maintained. The Flyash mixture used as a concrete binder is Portland cement. The chemical composition of Portland cement commonly used is almost the same as the chemical composition of Flyash above which generally contains CaO (calcium oxide), SiO₂ (silica sand), Al₂O₃ (alumina), Fe₂O₃ (iron oxide), and CaSO₄·2H₂O (gypsum) as adjuvants and regulate binding [4].

Therefore, this study aims to determine how the influence of the use of Flyash as a partial replacement of Portland cement to obtain economical (low-cost) and environmentally friendly concrete. The addition of Flyash waste to the concrete mix is pozzolanic so that it can be a useful mineral adding material for concrete. Pozzolan is a material that contains silica or silica and aluminum that reacts chemically with calcium hydroxide at ordinary temperatures to form cementitious compounds. To overcome the impact of excessive use of cement, Flyash usage arrangements are varied to replace the use of regular concrete to be one of the right solutions. By reducing this critical use of cement, it can reduce construction costs from simple types of construction [5].

Based on the description above, this research is carried out to utilize waste that can pollute the air environment if allowed to be carried by the wind or enter waters that can disturb aquatic biota and if it seeps into the soil which can reduce soil fertility. This utilization of waste, which is carried out by making concrete, can be more economical and is expected to be environmentally friendly.

2. Method

2.1. Research location and design

The study was conducted from June 2018 to February 2019. The research location was in the Materials, Structure, and Building Construction Laboratory of the Faculty of Architecture Engineering, Hasanuddin University, Gowa Regency, South Sulawesi Province. Fly ash sample was taken from the landfill of PT. Bosowa Energi, Jeneponto Regency, South Sulawesi Province. The reason for choosing this location is because of the increasing number of existing power generation units so that the waste generated is also increasing as well.

This type of research is an experimental study by making cylindrical concrete samples with a diameter of 100 mm, height 200 mm, which going through weight and compressive strength tests of each concrete sample after dry and wet curing for 3, 7, 14, 21, and 28 days consecutively. Besides that, the sample is made based on the desired variation according to the percentage of Flyash waste used, i.e., 0%, 30%, 50%, and 70%.
2.2. Population and Sample
The population used in this study is the power plant industry of PT. Bosowa Energy Units I and II Jeneponto Regency, South Sulawesi Province. The authors do not use Flyash waste from coal combustion from other regional power plants. The sampling technique is done by taking Flyash directly in the landfill (representativeness), without doing sample preparation from the source, to be used experimentally in the Laboratory. The research sample is a concrete specimen made in the Laboratory, as explained in the variations of the specimen previously.

2.3. Research Implementation Stage
Material that has been prepared weighed following the results of the calculation of the composition of the mixture that has been calculated by taking into account the number of molds available. The tools have been prepared. To anticipate the shortage of concrete mixes due to the stirring quality factor wasted during compaction and leveling of the concrete surface, the weight of each material used in mixing is 1.20 times the weight of each material calculated. Mix cement in advance with Flyash with a particular concentration that has been prepared in advance manually by using a tool in a bucket/pan evenly. Insert the crushed stone and prepared sand into molen first, then start the engine for about 5 minutes. Then turn off the engine and enter the substituted cement according to the Flyash percentage (0%, 30%, 50%, 70%). Turn on the molen machine again for about 5 minutes so that the mixture is entirely and evenly mixed. Pour water gradually and occasionally turn off the machine to check the dilution level; or mix manually with the mixer on the parts that have not been mixed evenly. After mixing for about 5 minutes, the concrete’s slump level is ready to be measured then printed. The slump level is maintained in the study so that the amount of water used varies.

2.4. Data analysis
The equation used in analyzing this data is straightforward, but what is complicated is a large number of samples for processing the data. Also, the data variation is huge, and they are divided into two kinds of curing. After that, the unit of measuring instrument used first should be matched into the equation. The equation is as follows: $F'c = P/Ao$, where $F'c$: concrete compressive strength (Mpa), $P$: compressive load (N), $Ao$: cross-sectional area of test specimens (mm$^2$). The excellent nature of concrete is if the concrete has compressive strength (between 20-50 MPa at 28 days), it can be assumed that the quality of concrete is reviewed only from its compressive strength.

3. Results
3.1. Concrete Weight Due to Use of Flyash
Table 1 shows the average weight for air curing in each successive variation of 3.38 kg, 3.45 kg, 3.47 kg, and 4.47 kg; and for water curing respectively 3.54 kg, 3, 61kg, 3.61 kg, and 4.61 kg. Based on table 1, the average weight graph of the two types of curing can be seen in figure 1.
Table 1. Concrete Weight for air and water curing

| No | Flyash Variation (%) | Curing | Flyash Variation (%) | Curing |
|----|----------------------|--------|----------------------|--------|
|    | 0% (Kg) 30% (Kg) 50% (Kg) 70% (Kg) | 0% (Kg) 30% (Kg) 50% (Kg) 70% (Kg) |        |
| 1  | 3.45 3.52 3.46 4.46   | 3.53 3.60 3.63 4.63   |
| 2  | 3.47 3.54 3.48 4.48   | 3.57 3.64 3.59 4.59   |
| 3  | 3.49 3.56 3.50 4.50   | 3.58 3.65 3.62 4.62   |
| 4  | 3.37 3.44 3.50 4.50   | 3.58 3.65 3.62 4.62   |
| 5  | 3.36 3.43 3.55 4.55   | 3.57 3.64 3.62 4.62   |
| 6  | 3.32 3.39 3.57 4.57   | 3.55 3.62 3.61 4.61   |
| 7  | 3.35 3.42 3.46 4.46   | 3.57 3.64 3.63 4.63   |
| 8  | 3.36 3.43 3.50 4.50   | 3.58 3.65 3.64 4.64   |
| 9  | 3.33 3.40 3.29 4.29   | 3.58 3.65 3.64 4.64   |
| 10 | 3.35 3.42 3.49 4.49   | 3.54 3.61 3.62 4.62   |
| 11 | 3.34 3.41 3.42 4.42   | 3.52 3.59 3.63 4.63   |
| 12 | 3.38 3.45 3.43 4.43   | 3.50 3.57 3.61 4.61   |
| 13 | 3.39 3.46 3.46 4.46   | 3.52 3.59 3.57 4.57   |
| 14 | 3.38 3.45 3.48 4.48   | 3.52 3.59 3.59 4.59   |
| 15 | 3.41 3.48 3.50 4.50   | 3.50 3.57 3.64 4.64   |
| Rata-Rata | 3.38 3.45 3.47 4.47 | 3.54 3.61 3.61 4.61 |

Figure 1. Graphic of Sample Weight Increment for Air and Water Curing

3.2. Concrete compressive strength due to the use of Flyash

Table 2 shows the increase in compressive strength of air and water curing concrete based on the age of each test specimen i.e., 3, 7, 14, 21, and 28 days, while the compressive strength based on the variation of Flyash used, respectively 0%, 30%, 50%, and 70% have decreased. Based on table 2, a graph of the increase in compressive strength can be seen in figure 2 for air curing, and figure 3 for water curing.
Table 2. Recapitulation of Concrete Compressive Strength for Air and Water Curing in MPa

| Flyash (%) | Air Curing Length (Days) | Water Curing Length (Days) |
|------------|--------------------------|---------------------------|
|            | 3 | 7 | 14 | 21 | 28 | 3 | 7 | 14 | 21 | 28 |
| 0          | 14.65 | 15.07 | 16.85 | 19.02 | 24.84 | 15.54 | 15.96 | 17.74 | 19.91 | 25.73 |
| 30         | 12.73 | 13.33 | 13.63 | 15.07 | 22.16 | 13.50 | 14.09 | 14.56 | 15.84 | 22.93 |
| 50         | 5.73 | 6.62 | 7.26 | 8.78 | 11.97 | 6.62 | 7.52 | 8.15 | 9.72 | 12.87 |
| 70         | 2.25 | 2.97 | 3.69 | 3.94 | 4.20 | 3.01 | 3.74 | 4.46 | 4.71 | 4.97 |

Figure 2. Graphic of Concrete Compressive Increment for Air Curing

Figure 3. Graphic of Concrete Compressive Increment for Water Curing

4. Discussion
This study shows the process of making concrete samples as test objects, by firstly weighing the material used to determine the proportion of the number of samples to be made. After perceiving the weight of each ingredient, samples are placed in a particular container, each accompanied by a label to make it easier to retrieve while mixing the material is in progress. Do not forget to rely on concrete targets that will be made is based on the planned or mix design that has been previously planned as a standard concrete produced. In this case, based on SK. SNI T-15-1990.

The next step is to clean and prepare the equipment that will be used when mixing, especially concrete cylindrical molds with the specific size as mentioned earlier. Pay attention to each equipment so that nothing is wet, or vice versa, that it must be saturated with water by soaking it immediately. This is in order to the cement water does not seep into the tool when mixing. The mold should be
greased with lubricating oil first, or the purpose of oil is to make it easier to remove; to avoid the concrete sample becomes adhesive when removing it from the mold. Another important tool that should be prepared is an iron stick; to pound a concrete mixture into a mold while filling the mold and to tighten and strengthen the mixture inside the mold while determining the number of collisions each time the mold is filled.

For the use of waste as in this study, there are still many other alternatives as considerations for its use are as follows: preparation of concrete for roads and dams, landfills for mining, recovery magnetic, chemosphere, raw materials for ceramics, glass, bricks, and refractories, polisher, asphalt fillers, plastics, and paper, additives in waste stabilization, conversion to zeolites, and adsorbents [6].

Flyash mineralogy is very diverse; the main phase faced is the glass phase together with quartz, multi and hematite, magnetite, and/or maghemite iron oxides. Other phases often identified are cristobalite, anhydrite, lime, periclase, calcite sylvite, halite, portlandite, rutile, and anatase. Mineral anorthite, gehlenite, acermanite which have Ca as well as various calcium silicates and calcium aluminate identical to those found in portland cement can be identified in Fly Ash rich in Ca or calcium elements [7].

The comparison between the chemical properties of fly ash waste and Portland cement is very close, so it is a reference in this study to make a mixture in making concrete. The chemical properties which are based on where the coal is formed as well as the age of the coal formation affect the type of coal produced. The type of waste from combustion also influences the chemical properties it causes. The concentration of other tracking elements varies according to the type of coal burned to form it. Even in the case of bituminous coal with the exception of boron, trace element concentrations are generally the same as concentrations in pollution-free soils [8].

Concrete produced from fly ash waste still needs to be studied further, especially its effects on the environment. Is the waste classified as toxic and dangerous material which is often called B3 waste? B3 waste is the residue of a business and/or activity containing hazardous and/or toxic material due to its nature and/or concentration and/or quantity both directly and indirectly that can pollute and/or damage the environment and/or endanger the environment, the health of the survival of humans and others living creatures [9].

The results of this study are to obtain concrete samples as planned, especially considering the use of Flyash waste which can provide economic value to the concrete and be an environmental-friendly product. Furthermore, the results to be achieved are how much the weight of concrete that is close to regular concrete in the use of a varied composition of waste, in the results of this study that the variation of 30% waste is the most effective to use. On the other hand, it means that the utilization of waste is only a small amount from the available waste in the field, which can pollute the environment if not handled professionally. Besides, this study also proves that the compressive strength of concrete decreases with the increasing amount of waste variation used, although the compressive strength increases based on the age of curing of the two types of treatment carried out; water curing has a higher compressive strength when compared to air curing.

The results of the calculation are also discussed by the authors; that the measuring instrument used in the Laboratory uses units that are not the same as the equation used to calculate the compressive strength of concrete samples. Therefore, the first obtained value must be found the same as the equation, in this case the compressive strength unit recorded the available tool is kilonewton (KN) so that it is first equated to a newton unit (N) and then the next step is to get a megapascal (MPa) value as expected from the equation used.

5. Conclusions and Suggestions
Based on the results of research and testing, it shows that the lowest average weight of concrete samples is in the variation of 30% Flyash for air curing, which is 3.45 kg, and water curing is 3.61 kg, while the highest is in the variation of 70% Flyash for air curing, which is 4.47 kg, and water curing which is 4.61 kg. Based on variations of 0%, 30%, 50%, and 70% the compressive strength of concrete decreases; respectively 24.84 MPa, 22.16 MPa, 11.97 MPa, and 4.20 MPa for air curing; and
25.73 MPa, 22.93 MPa, 12.87 MPa and 4.97 MPa for water curing. The effect of curing variations on the compressive strength of concrete is also increasing with increasing curing, for air curing 3, 7, 14, 21, and 28 days, respectively 12.73 MPa, 13.33 MPa, 13.63 MPa, 15.07 MPa, and 22.16 MPa, for water curing, respectively 13.50 MPa, 14.09 MPa, 14.56 MPa, 15.84 MPa, and 22.93 MPa. Based on the results of the study it is recommended the use of large volumes of Flyash waste in the manufacture of lightweight concrete, the aim of reducing pollution and producing economically valuable concrete and lighter weight of concrete.

References

[1] Nugraha P 2007 Teknologi Beton dari Material, Pembuatan, ke Beton Kinerja Tinggi Univ. Kristen Indones. Andi Offset, Yogjakarta

[2] Madiali S 2016 Telusuri Jejak Limbah B3 Pada Flyash PLTU Jeneponto PT. Bosowa Energi Kabupaten Jeneponto Provinsi Sulawesi Selatan (Universitas Muslim Indonesia)

[3] Mudjanarko S W, Rasidi N, Utomo W M, Alimudin A and Su- D 2018 The Concrete Quality Testing for Trapezoidal Model of the Prefabricated Foundation 7 311–5

[4] Krebs R D and Walker R D 1971 *Highway materials* vol 332 (McGraw-Hill New York)

[5] Umboh A H, Sumajouw M D J and Windah R S 2014 Pengaruh Pemanfaatan Abu Terbang (Fly Ash) dari PLTU II Sulawesi Utara Sebagai Substitusi Parsial Semen Terhadap Kuat Tekan Beton J. Sipil Statik 2

[6] Hwang J Y 1999 Beneficial use of fly ash *Inst. Mater. Process. Michigan Technol. Univ.* 1–23

[7] Snellings R, Mertens G and Elsen J 2012 Supplementary cementitious materials *Rev. Mineral. Geochemistry* 74 211–78

[8] Ladwig K 2010 Comparison of Coal Combustion Products to Other Common Materials. Chemical Characteristics. Final Report 2010 *Electr. Power Res. Institute, Palo Alto, USA*

[9] Yuliani E 2011 Pengelolaan Limbah Bahan Berbahaya Beracun (B3) Di PT. Bayer Indonesia-Bayer Cropscience Surabaya Plant