The analysis of mechanical properties of non autoclaved aerated concrete with the substitution of fly ash and bottom ash

R Karolina* and F Muhammad
Civil Engineering Department, Universitas Sumatera Utara (USU)
Jl. Perpustakaan, Kampus USU Medan 20155 Indonesia
*E-mail: rachmie_caroline@yahoo.co.id

Abstract. Based on PP. No.85 of 1999 on the management of hazardous and toxic (B3), fly ash and bottom ash wastes are categorized into B3 waste because there are heavy metal oxide contents that can pollute the environment. One form of environmental rescue that can be applied is to utilize waste fly ash and bottom ash in the manufacture of concrete. In this research, fly ash and bottom ash waste are used as substitution of cement and fine aggregate to make lightweight concrete. The purpose of this research is to know the mechanical properties of non-autoclaved aerated lightweight concrete (NAAC) with FA and BA substitution to cement and fine aggregate which is expected to improve the quality of concrete. The NAAC lightweight concrete in this study is divided into 4 categories: normal NAAC lightweight concrete, FA substituted NAAC, BA substituted NAAC, and FA and BA combined lightweight concrete with variations of 10%, 20%, and 30%. The test specimen used in cylindrical shape, which was tested at the age of 28 days, amounted to 90 pieces and consisted of 10 variations. Each variation amounted to 9 samples. Based on the test results with FA and BA substitutions of 10%, 20%, and 30%, the highest compressive strength was achieved in samples with FA 30% of 12.687 MPa, maximum tensile strength achieved in samples with FA 30% of 1,540 MPa, The highest absorption was achieved in normal NAAC of 5.66%. Based on the weight of the contents of all samples, samples can be categorized in lightweight concrete, since the weight of the contents is less than 1900 kg / m3.

1. Introduction

With the rapid growth of knowledge and technology in the field of construction, then we are encouraged to pay more attention to quality standards and work productivity to be able to participate in improving construction for better quality. Therefore, we need a building material that has a better advantage than existing building materials. Concrete is one of the most widely used building materials and also its development of innovation and technology continues to run rapidly. One of the innovative developments is (Lightweight Concrete).

According to (SNI 3402-2008) Lightweight concrete has lighter density than concrete in general. Ordinary concrete has a high specific gravity (about 2400 kg / m3), where as lightweight concrete has a unit weight of not more than 1900 kg / m3. Lightweight concrete manufacture in principle is by providing a light mixture of stuffing, the mixture can be Styrofoam, pumice stone, foam agent, and fly ash. In this study, it is planned a non-autoclaved aerated concrete (NAAC) lightweight concrete using foaming agent, gravel as coarse aggregate, and fly ash and bottom ash as substitution of cement and sand. Fly ash and bottom ash are waste from coal obtained from industry.

Fly ash is the result obtained from coal combustion and is a very fine granular material whose component is 72.2% Silica based on test result from Balai Penelitian dan Standarisasi Industri Medan. The nature of fly ash is similar to that of cement that serves as a good adhesive, so it is considered able
to reduce the use of cement in order to reduce costs incurred. While bottom ash is a material that does not burn completely from coal combustion. Bottom ash has a larger and heavier particle size than fly ash with dark gray pore-shaped gray characteristics that are considered capable of reducing the use of fine aggregates.

Fly ash and bottom ash used in this research comes from PT. SOCI MAS. Therefore, the use of fly ash and bottom ash as substitution in the manufacture of non-autoclaved aerated concrete (NAAC) lightweight concrete is expected to improve the quality of concrete, as well as support the environmentally friendly movement, because we can utilize waste from unused coal in order not to pollute the environment.

![Fly Ash and Bottom Ash from PT. SOCI MAS](image)

Figure 1. Fly ash and bottom ash from PT. SOCI MAS

**Fly Ash**

Class F fly ash is produced from anthracite or bituminous coal combustion, has a pozzolanic nature and to obtain cementitious properties, quick lime, hydrated lime, or cement should be added. Fly ash grade F has a low lime content (CaO <10%). Class C Fly ash class is produced from lignite or sub-bituminous coal combustion in addition to having pozolanic properties also has self-cementing properties (the ability to harden and add strength when reacted with water) and these properties arise without the addition of lime. Fly ash class C contains lime greater than fly ash class F (CaO > 20%). So fly ash from PT. SOCI MAS used in this research is classified into fly ash class F, because lime content in the fly ash is 4.79% (CaO <10%).

**Bottom Ash**

Bottom ash is a material that does not burn completely from coal combustion. Bottom ash has a larger particle size and heavier than fly ash with a dark gray colored in the shape of pivot grains characteristics that are considered capable of reducing the use of sand.
2. Method

![Flowchart Diagram]

**Figure 2.** Fly ash and bottom ash from PT. SOCI MAS
3. Result and discussion

Absorption of Concrete Cylinder

Absorption is the ability of a material to absorb water. The absorption value is closely related to the specific gravity or porosity of a material, since large absorption values indicate the number of cavities present in the material. The amount of absorption can also cause a decrease in the strength of concrete, because the pores that exist cause the bonding between particles in a material is reduce.

Table 1. The test results of the sample test absorption using fly ash and bottom ash substitution

| No. | NAAC Lightweight Concrete Fly Ash and Bottom Ash Substitution | Wet Weight (kg) | Dry Weight (kg) | Absorption (%) | Average Absorption (%) |
|-----|-------------------------------------------------------------|-----------------|----------------|----------------|-------------------------|
| 1.  | FABA 10%                                                    | Sample I: 8,769 | Sample II: 8,397 | 4,43           | 4,60                    |
|     | Sample III: 8,653                                         | Sample I: 8,779 | Sample II: 8,450 | 3,89           | 3,92                    |
|     | Sample III: 8,646                                         | Sample I: 8,693 | Sample II: 8,356 | 4,03           | 5,17                    |
|     | Sample II: 8,646                                          | Sample I: 8,863 | Sample II: 8,389 | 5,65           |
|     | Sample III: 8,653                                         | Sample I: 8,969 | Sample III: 8,467 | 4,90           |
|     | Sample III: 8,887                                         | Sample I: 8,863 | Sample II: 8,550 | 4,90           |
|     | Sample III: 8,863                                         |

From all absorption test results, it showed that the use of fly ash and bottom ash as substitution of fine aggregate and cement can decrease the absorption value of concrete, this is caused by finer grains of fly ash and bottom ash are able to fill the smaller pore, thus the concrete produced is more dense and solid, the largest absorption value at every test is in normal NAAC lightweight concrete with absorption value of 5.66% and the smallest absorption value is in 30% of fly ash substitution with absorption value of 2.76%.

Compressive Strength of Concrete Cylinder

The tests are performed at age 28 days. The result of compressive strength test for concrete variation can be seen in the table below.

Table 2. The test result of weight and compressive strength of test sample by using fly ash and bottom ash substitution

| No. | NAAC Lightweight Concrete with Fly Ash and Bottom Ash Substitution | Concrete Weight (kg) | Weight of Content (kg/m³) | Average Weight of Content (kg/m³) | Age (days) | Compressive Strength kN | Average Compressive Strength (MPa) |
|-----|------------------------------------------------------------------|----------------------|--------------------------|----------------------------------|------------|------------------------|----------------------------------|
| 1.  | FABA 10%                                                         | Sample I: 8,197      | 1546,604                 | 1548,239                         | 28         | 141                    | 9,618                            |
|     | Sample II: 8,257                                                 |                      |                          |                                  |            | 122                    | 8,322                            |
|     | Sample III: 8,163                                                |                      |                          |                                  |            | 137                    | 9,345                            |
|     | Sample I: 8,350                                                  | 1575,472             | 1574,654                 | 28                               | 140        | 135                    | 9,594                            |
|     | Sample II: 8,392                                                 |                      | 1583,396                 |                                  |            | 144                    | 9,822                            |
|     | Sample III: 8,295                                                |                      | 1565,094                 |                                  |            | 138                    | 9,413                            |
|     | Sample I: 8,489                                                  | 1601,698             | 1597,925                 | 28                               | 135        | 128                    | 9,072                            |
|     | Sample II: 8,450                                                 |                      |                          |                                  |            | 133                    | 9,003                            |
|     | Sample III: 8,468                                                |                      |                          |                                  |            |                        |                                  |
Table 3. Classification Control of Lightweight Concrete Quality

| No. | Variation | Average Compressive Strength (MPa) | Average Weight of Content (kg/m³) | Weight of Content according to non structural lightweight concrete quality (Young, J. Francis.1972) | Compressive Strength according to non structural lightweight concrete quality (Young, J. Francis.1972) | Non structural lightweight concrete quality (Young, J. Francis.1972) |
|-----|-----------|------------------------------------|----------------------------------|------------------------------------------------------------------------------------------------|-----------------------------------------------------------------|---------------------------------------------------------------|
| 1   | Normal    | 8.891                              | 1522,704                         | 1100-1600 kg/m³                                                                                     | 7-14 MPa                                                        | Qualified                                                     |
| 2   | 10 % FA   | 11,505                             | 1590,252                         | 1100-1600 kg/m³                                                                                     | 7-14 MPa                                                        | Qualified                                                     |
| 3   | 20 % FA   | 12,232                             | 1614,340                         | 1100-1600 kg/m³                                                                                     | 7-14 MPa                                                        | Unqualified                                                   |
| 4   | 30 % FA   | 12,687                             | 1630,440                         | 1100-1600 kg/m³                                                                                     | 7-14 MPa                                                        | Unqualified                                                   |
| 5   | 10 % BA   | 9,686                              | 1583,396                         | 1100-1600 kg/m³                                                                                     | 7-14 MPa                                                        | Qualified                                                     |
| 6   | 20 % BA   | 9,776                              | 1600,252                         | 1100-1600 kg/m³                                                                                     | 7-14 MPa                                                        | Unqualified                                                   |
| 7   | 30 % BA   | 9,026                              | 1640,252                         | 1100-1600 kg/m³                                                                                     | 7-14 MPa                                                        | Unqualified                                                   |
| 8   | 10 % FABA | 9,095                              | 1548,239                         | 1100-1600 kg/m³                                                                                     | 7-14 MPa                                                        | Qualified                                                     |
| 9   | 20 % FABA | 9,594                              | 1574,654                         | 1100-1600 kg/m³                                                                                     | 7-14 MPa                                                        | Qualified                                                     |
| 10  | 30 % FABA | 9,003                              | 1597,925                         | 1100-1600 kg/m³                                                                                     | 7-14 MPa                                                        | Qualified                                                     |

From the data on every figure, it can be seen that the compressive strength of the sample obtained that can meet the requirement of non-structural lightweight concrete compressive strength is 7-14 MPa with the weight of concrete content of 1100-1600 kg / m³³ (Young, J. Francis.1972). From the compressive strength test of the sample, it is obtained that the highest compressive strength on NAAC lightweight concrete with 30% of fly ash substitution with a compressive strength is reaching 12,687 MPa with the weight of 1630,440 kg / m³. The increase in compressive strength is due to the high silica content found in fly ash and bottom ash, the finer grain of fly ash and bottom ash is able to fill the smaller pores, thus the concrete produced is denser and solid. Similarly, the addition of superplasticizer also improves the workability of the concrete, the addition of this admixture resulting a workability.
Tensile Strength of Concrete Cylinder

The tests are performed at age 28 days. The tensile strength test results for concrete variation can be seen in the table below.

| No. | NAAC Lightweight Concrete with *Fly Ash* and *Bottom Ash* Substitution | Age (days) | Tensile Strength | Average Tensile Strength (MPa) |
|-----|----------------------------------------------------------------------|------------|-----------------|--------------------------------|
|     |                                                                       |            | kN              | MPa                            |
| 1.  | FABA 10%                                                             | 28         | 60              | 1,023                          |
|     | Sample I                                                              |            | 73              | 1,244                          |
|     | Sample II                                                             |            | 65              | 1,108                          |
|     | Sample III                                                            |            | 73              | 1,244                          |
|     | FABA 20%                                                             |            | 72              | 1,227                          |
|     | Sample I                                                              |            | 79              | 1,347                          |
|     | Sample II                                                             |            | 80              | 1,364                          |
|     | Sample III                                                            |            | 80              | 1,364                          |
|     | FABA 30%                                                             | 53         | 53              | 0,903                          |
|     | Sample I                                                              |            | 61              | 1,040                          |
|     | Sample II                                                             |            | 63              | 1,074                          |
|     | Sample III                                                            |            | 63              | 1,074                          |

From the data on all figures it can be seen that the tensile strength of the sample has increased with the substitution of fly ash and bottom ash. The increase in tensile strength occurs due to the high silica content contained in fly ash and bottom ash, the finer ash grains and the finer bottom ash are able to fill smaller pores, thus the concrete produced is denser and solid. Similarly, the addition of superplasticizer also improves the workability of the concrete, the addition of this admixture resulting a workability. In certain proportions the superplasticizer will disperse the cement more evenly, resulting in a more perfect hydration reaction. This reaction will make the mixture more compact and solid so that the binding strength of the mixture becomes stronger and increases the strength of the resulting concrete. From the sample of tensile strength test, the highest tensile strength in NAAC lightweight concrete with 30% of fly ash substitution with tensile strength reaches 1,540 MPa and the smallest tensile strength is found in normal NAAC light concrete with the value of 0,801 MPa.

4. Conclusion

From the results of the research that has been done, there are some conclusions that can be taken as follows:

1. Fly ash and Bottom Ash can be substituted for fine aggregate ie cement and sand in the manufacture of lightweight concrete Non Autoclaved Aerated Concrete.
2. The largest absorbtion in this study is found in normal NAAC lightweight concrete that is 5.66% while the smallest absorption of water in this research is the substitution of fly ash 30% that is equal to 2.76%.
3. The largest compressive strength of this research is found in the fly ash substitution of 30% that is 12,687 MPa while the smallest compressive strength in this research is on normal NAAC lightweight concrete that is equal to 8,891 MPa.
4. The largest tensile strength in this research is found in 30% of fly ash mixture that is 1,540 MPa while the smallest tensile strength in this research is on normal NAAC lightweight concrete that is equal to 0,801 MPa.
5. From the maximum compressive strength and the resulted weight of contents, the concrete can be categorized as non-structural lightweight concrete with a weight of 1100-1600 kg / m³ with a compressive strength in the range of 7-14 MPa (Young, J. Francis 1972).

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