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# OPTIMIZATION OF THE USE OF FLY ASH IN PRECAST CONCRETE FOR RIGID PAVEMENT AND ITS RELATIONSHIP WITH $CO_2$ EMISSIONS

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**ABSTRACT**

*The application of the use of precast concrete road construction has an impact on the environment due to the use of cement which is quite high. The use of cement is the part of the construction world that contributes the most carbon dioxide emissions. Therefore, reducing the use of cement in construction materials is very important in supporting the sustainable development of building construction materials in its development considering two important aspects, both economic and environmental. Electrical energy in the cement industry is generally produced from coal-fired power plants, which in the combustion process produce waste (fly ash) which is puzzolanic and classified as B3 waste and Fly Ash waste cause environmental damage and pollution. The use of fly ash is expected to improve the performance of precast concrete for rigid pavements. This research is in the form of laboratory experimental research by substituting fly ash with cement in normal concrete mixtures. The test was carried out by varying the substitution of fly ash for normal concrete as a variable. Where the variation of fly ash substitution is 0%, 5%, 10%, 15%, and 20% of the concrete volume. For each fly ash variation test, 5 test objects were made, the tests included testing compressive strength, split tensile strength, and flexural strength. The purpose of this study was to determine the optimal value of using Fly Ash in precast concrete for pavement layers and its relationship to $CO_2$ emissions.*

*The results of testing in the laboratory at the age of 28 days with variations of Fly ash Substitution of 0%, 5%, 10%, 15%, and 20%. From the results of polynomial regression analysis on environmentally friendly precast concrete for rigid pavement applications, the optimum compressive strength is 36.35 MPa, the optimum split tensile strength is 3.96 MPa and the optimum flexural strength is 4.17 MPa with an optimum fly ash content of 13.3 %. The results of the analysis of the relationship between compressive strength and flexural strength using exponential regression analysis found that precast concrete with the use of fly ash can be applied to rigid pavements (fr = 4.17 Mpa). From the optimization results in this study, the optimum fly ash content was obtained at 13.3% with a maximum compressive strength of 36.35 MPa, so that in 1 m3 of concrete mixture it can reduce the amount of cement by 76.79 kg and at the same time reduce CO2 emissions by 162.79 Kg.* $CO_2$

**Keyword head**: Fly Ash, Precast Concrete, Rigid Pavement, Compressive Strength, Split Tensile Strength, Flexural Strength, $CO_2$ Emissions.

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## 1. INTRODUCTION

The application of cement concrete as road pavement in Indonesia began in 2003 and its development continues to increase to date. This can be seen on toll roads, national/provincial roads, and district/city roads that have used concrete cement pavement. Cement concrete pavement has several advantages, including being suitable for heavy traffic, more resistant to hot weather and not occur deformation as in flexible pavement, resistant to the effects of water, and the amount of material needed (aggregate) for pavement is lower (± 50%) compared to flexible pavements, under the same subgrade conditions and traffic loads. The current problem of asphalt availability is also driving the need to use cement as a road pavement material. Considering so far Indonesia needs 1.2 million tons per year (Department of General Work, 2008) and still imports about 50% - 60% of the national need for asphalt every year.

The concrete pavement layer does not only act as a surface layer, like a flexible asphalt pavement layer, but acts as a single structural element, namely individual pavement interlock blocks and acts as a barrier to centralized loading. The use of precast concrete road construction, to minimize deficiencies in manual concrete road construction. Precast concrete road construction is made using sheet-shaped concrete frames arranged in such a way that they have a strong bond. However, when considered in the long term, precast concrete construction is more profitable because it does not require maintenance for at least 20 (twenty years), whereas asphalt concrete construction requires routine maintenance every year and requires road improvements every 3 years.

The application of the use of precast concrete road construction has an impact on the environment due to the use of cement which is quite high. The use of cement is the part of the construction world that contributes the most carbon dioxide emissions. Therefore, reducing the use of cement in construction materials is very important in supporting the sustainable development of building construction materials in its development considering two important aspects, both economic and environmental. In terms of economy, green materials must consider the construction cost savings that can be achieved. While environmental considerations in green materials tend to focus on efforts to utilize waste which not only has economic value but also has environmental preservation efforts.

Along with environmental problems, it is necessary to think about ways to utilize industrial waste materials for purposes that bring benefits and reduce the creation of pollution due to these waste materials. The utilization of industrial waste materials in this case is specifically used as a substitute or replacement material in concrete technology.

One of the wastes that can be used as a substitute for concrete is waste from burning coal (fly ash) from the Steam Power Plant. According to the Environmental Impact Control Bureau, the cement factory can be categorized as hazardous waste (B3). Data from the cement factory Semen Tonasa Enterprise, Pangkep, South Sulawesi, obtained that the amount of fly ash produced was 0.59 million tons/year. Utilizing fly ash can have a good effect on the environment because it can reduce CO2 gas emissions. Which will cause global warming. So research is an alternative that can be done from the use of fly ash (fly ash), namely by making it a substitution material for environmentally friendly precast concrete for rigid pavements.

Several previous studies related to this research include: Flow behavior and strength of cement paste mixed with fly ash and mortal[2], the Development of fly ash-based geo-polymer concrete with the construction and demolition of waste as an aggregate in an acoustic barrier[3], The effect of reducing emissions $CO_2$ from innovative composite precast[4], Early age carbonization of precast reinforced concrete[5], Effect of cast-in-place concrete topping on the flexural response of precast hollow-core concrete slabs[6], Carbon reduction of precast concrete under marine environment[7], Durability performance of sustainable self-compacting concrete in precast products due to heat hardening process[8], Use of Recycled Concrete Aggregates in Precast/Prestressed Concrete[2], Mechanical properties and durability performance of reinforced concrete containing fly ash[9]. The objective of this study is to analyze the use of fly ash in precast concrete for rigid pavement and its relationship to $CO_2$ Emissions

## 2. RESEARCH METHODS

### 2.1. Research design

This research was carried out experimentally with seven research stages, namely the initial stage of examining the characteristics of the concrete forming material to determine the physical and mechanical properties of the materials that meet the terms and conditions based on material specification standards. The final stage is testing the characteristics of precast concrete to determine the physical and mechanical properties produced based on the planned concrete quality standards and guidelines for testing implementation for precast concrete types.

### 2.2. Research Stages

The stages of this research are described as follows:

Stage I: Called the preparatory stage. At this stage, all materials and equipment needed for the research are prepared in advance so that the research can run smoothly.

Stage II: Called the material test stage. At this stage, research was carried out on precast concrete constituent materials. This is done to determine the properties and characteristics of these materials. In addition to knowing whether the material meets the requirements or not.

Stage III: Called the design stage of the Fly Ash Substitute Material Composition. At this stage the following work is carried out:

(1) Determination of mixed design (mix design) of precast concrete mix.

(2) Preparation of precast concrete mix.

(3) Checking the slump value.

Stage IV: Called the Manufacturing and maintenance (curing) stage. At this stage, the manufacture of test objects is carried out in accordance with the third stage. Treatment is carried out by immersing the specimen after being removed from the mold.

Stage V: Called the testing phase. At this stage testing includes Compressive Strength, Split Tensile, Flexure and Deflection.

Stage VI: Called the analysis and discussion stage. At this stage, the analysis and discussion obtained from the test results are carried out.

Stage VII: Called the stage of drawing conclusions and suggestions. At this stage, conclusions are made related to the aims and objectives of the research along with providing suggestions and input regarding the research being conducted.

## 2.3. Calculation of CO2 Gas Emissions

Calculation of CO2 emissions can be done using one or a combination of the calculation-based and measurement-based approaches. Generator companies can choose the type of method depending on the availability of data in the field. To be able to improve the accuracy of GHG emission data, power companies are encouraged to use the highest method.

Generation units that have fuel consumption data but do not have fuel quality data (proximate analysis and carbon content), and post-combustion analysis data can calculate total CO2 emissions per type of fuel using Method 1.

1) CO2 Emissions

The formula for calculating CO2 emissions using Method 1 is as follows:

ECO2 = DA × FE

where:

ECO2: Total CO2 emission (ton CO2) DA: Activity Data (TJ)

FE: Emission Factor (tons/TJ)

Activity data is consumption data per type of fuel that has been converted to energy units. The formula for consuming fuel from mass units (tons) to energy units (Tj) is as follows:

DAbb = Fbb . NCV. 10-3

Where :

DAbb = Coal activity data (Tj).

Fbb = Coal consumption per year (tons)

NCV = Net calorific value of coal (Tj/Gj), NCV value of coal

2) CH4 and N2O emission

Calculation of CH4 and N2O emissions from fuel combustion using Method-1, the IPCC default emission factor. This was determined due to the unavailability of national CH4 and N2O emission factors and to determine national CH4 and N2O emission factors and/or according to combustion conditions in the Generating Unit requires certain laboratory tests which are limited in number and require a lot of money.

ECH4, N2O = (Fbb x NCV) x FE x 10

Where :

ECH4, N2O = Total Emissions of CH4 and N2O (tons)

FE = Emission Factor (Kg/TJ or Kg N2O/TJ)

Fbb = Coal consumption in a year (tons)

NCV = Net calorific value of coal (weighted average) TJ/Gg 10-6 = Multiplier Factor

# 3. RESEARCH RESULTS AND DISCUSSION

## 3.1. Fine aggregate characteristics

It can be seen from table 1 that all the results of examining the fine aggregate parameters from the sieve analysis for organic content meet the required specifications, so it can be concluded that the fine aggregate that has been tested is suitable for use in the concrete mixing process (Table 1).

**Table 1.** Fine aggregate characteristics

| NO | Parameters | Result | Qualification |
|---|---|---|---|
| 1 | Sieve Analysis | 2.99 | Meet the requirement |
| 2 | Water content | 6.56 % | Meet the requirement |
| 3 | Solid Volume Weight | 1.548 kg/L | Meet the requirement |
| | Loose Volume Weight | 1.459 kg/L | Meet the requirement |
| 4 | Specific gravity | 2.63 | Meet the requirement |
| | Absorption | 0.71 % | Meet the requirement |
| 5 | Sludge levels | 3 % | Meet the requirement |
| 6 | Organic Content | Clear yellow | Meet the requirement |

## 3.2. Coarse aggregate characteristics

It can be seen from table 2 that all the results of examining the coarse aggregate parameters from the sieve analysis for organic content meet the required specifications, so it can be concluded that the fine aggregate that has been tested is suitable for use in the concrete mixing process (Table 2).

**Table 2.** Fine aggregate characteristics

| NO | Parameters | Result | Qualification |
|---|---|---|---|
| 1 | Sieve Analysis | 6.786 | Meet the requirement |
| 2 | Water content | 2.25 % | Meet the requirement |
| 3 | Solid Volume Weight | 1.602 kg/ltr | Meet the requirement |
| | Loose Volume Weight | 1.481 kg/ltr | Meet the requirement |
| 4 | Specific gravity | 2.62 | Meet the requirement |
| | Absorption | 0.56 % | Meet the requirement |
| 5 | Sludge levels | 0.74 % | Meet the requirement |
| 6 | Coarse Aggregate Wear | 20.2 % | Meet the requirement |

## 3.3. Cement characteristics

It can be seen from table 3 that all cement inspection results meet the required specifications, so it can be concluded that the cement that has been tested is suitable for use in the concrete mixing process.

**Table 3.** Cement measure results

| NO | Parameters | Result | Qualification |
|---|---|---|---|
| 1 | Specific Gravity of Cement | 3.15 | Meet the requirement |
| 2 | Cement Fineness #100 | 100 % | Meet the requirement |
| | Cement Fineness #200 | 91 % | Meet the requirement |
| 3 | Normal Consistency | 23 % | Meet the requirement |
| 4 | Initial Tie Time | 150 menit | Meet the requirement |
| | End Time | 225 menit | Meet the requirement |
| 5 | Solid Cement Volume Weight | 1.199 kg/L | Meet the requirement |
| | Loose Cement Volume Weight | 1.127 kg/L | Meet the requirement |

### 3.4. Fly Ash Analysis

The results of the fly ash test showed that the binding time was longer with increasing fly ash concentration. The initial binding time without fly ash is 3 minutes and the end is 105 minutes; whereas at a concentration of 20%, the binding time increased to 65 minutes early and 185 minutes late (Table 4).

**Table 4**

| Fly ash content (%) | Time (minutes) | |
|---|---|---|
| | Begin | Finish |
| 0 | 30 | 105 |
| 5 | 35 | 120 |
| 10 | 45 | 135 |
| 15 | 60 | 165 |
| 20 | 65 | 185 |

The results of measurements in the laboratory show that the total content of $SiO_2$+$Al_2O_3$+$Fe_2O_3$ is 65% referring to the chemical requirements for the Fly Ash class, so this Fly Ash is included in class C with a minimum $SiO_2$+$Al_2O_3$+$Fe_2O_3$ content of 50% (Table 5).

**Table 5.** Chemical content of fly ash

| No. | Parameter | Hasil (%) |
|---|---|---|
| 1 | Calcium Oxide (CaO) | 27.15 |
| 2 | Magnesium Oxide MgO) | 9.04 |
| 3 | Silica (SiO2) | 32.02 |
| 4 | Aluminum Oxide (Al2O3) | 16.70 |
| 5 | Ferroxide (Fe2O3) | 16.28 |
| 6 | Alkali (Na2O+K2O) | 0.19 |
| 7 | Sulfur (SO3) | 0.0186 |
| 8 | Phosphorus (P2O5) | 0.0672 |

### 3.5. Result of job mix formula

The results of the job mix formula indicated that the formula required 208.75 kg of water, 577.40 kg of cement, 982.75 kg of fine aggregate and 497.09 kg of coarse aggregate (Table 6).

**Table 6.** The need for each concrete mix material per m$^3$

| No | Materials | Weight (kg) |
|---|---|---|
| 1 | Water | 208.75 |
| 2 | Cement | 577.40 |
| 3 | Coarse Aggregate | 982.75 |
| 4 | Fine Aggregate | 497.09 |

### 3.6. Concrete material requirements for trial mix loss

The need for cement and fly ash for concrete materials for the Trial Mix 10% loss factor varies frequently with an increase in fly ash concentration. At a fly ash concentration of 0%, the cement requirement is 12.099 kg; while at a concentration of 20% the need for cement is 9.679 kg and fly ash is 2.420 (Table 7)

**Table 7.** Concrete material requirements for trial mix loss factor 10%

| No | Fly Ash (%) | Materials | | | | |
|---|---|---|---|---|---|---|
| | | Cement ( Kg) | *Fly Ash* ( Kg ) | Coarse aggregate (Kg ) | Fine aggregate (Kg) | Water (Kg) |
| 1 | 0 | 12.099 | 0 | 26.879 | 22.243 | 5.244 |
| 2 | 5 | 11.494 | 0.605 | 26.879 | 22.243 | 5.244 |
| 3 | 10 | 10.889 | 1.210 | 26.879 | 22.243 | 5.244 |
| 4 | 15 | 10.284 | 1.815 | 26.879 | 22.243 | 5.244 |
| 5 | 20 | 9.679 | 2.420 | 26.879 | 22.243 | 5.244 |

### 3.7. Compression strength

In this study, the compressed strength test of concrete was carried out with five replicates. Concrete compressive strength testing was carried out at 28 days of age using cylindrical specimens measuring 150 mm x 300 mm, as many as 25 cylinders with variations of mineral supplements 0%, 5%, 10%, 15%, and 20% where each variation was made of 5 objects test. The graph of the compressive strength test can be seen in Figure 1. The graph of the relationship between the variation of mineral supplements (%) and the compressive strength of concrete (MPa) follows. The highest compression strength was obtained at a concentration of 10% fly ash (36.55 Mpa) while the lowest was obtained at a concentration of 0% (31.29 Mpa) (Figure 1).

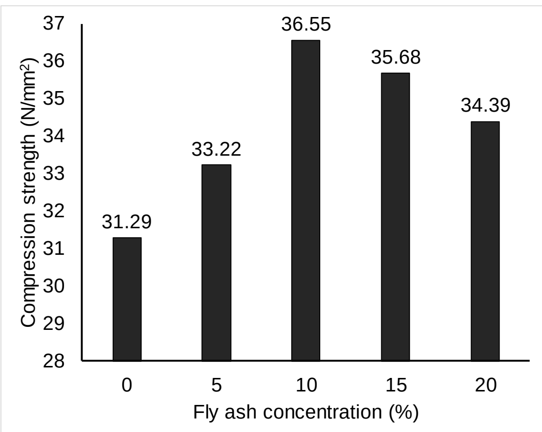


**Figure 1.** Average of concrete compression strength (N/mm$^2$ or MPa)

After carrying out the regression analysis, the maximum compressive strength was obtained at a fly ash concentration of 13.3%, with a score of 36.352 Mpa with an $R^2$ correlation of 0.9046. The following is a graph of the optimum Fly Ash content with polynomial regression formula of $-0.0059 X^2 + 0.1569 X + 33{,}222$ (Figure 2).

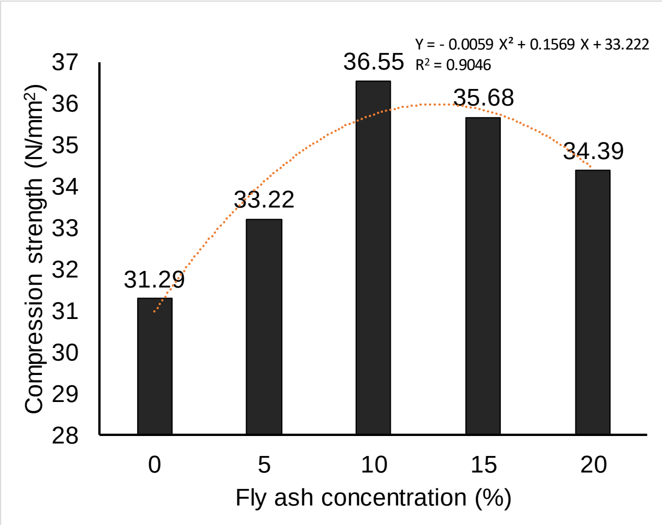


**Figure 2.** Optimum fly ash concentration for the highest compression strength

### 3.9. Tensile strength

In this study, tensile strength was measured. The scores were varied. The highest tensile strength was obtained at a concentration of 10% fly ash (3.02 Mpa) while the lowest was obtained at a concentration of 0% (2.80 Mpa) (Figure 3).

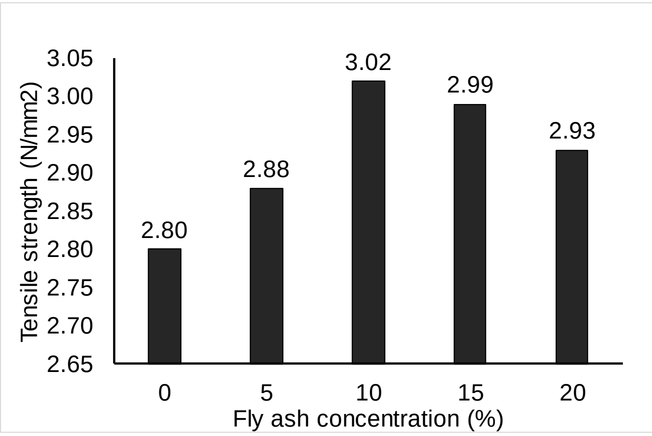


**Figure 3.** Average of concrete tensile strength ($N/mm^2$ or MPa)

After carrying out the regression analysis, the maximum tensile strength was obtained at a fly ash concentration of 13.17%, with a score of 3.0312 Mpa. The following was a graph of the optimum Fly Ash content with the polynomial regression formula $Y = -0.0003 X^2 + 0.0079 X + 2.8752$, $R^2$ correlation of 0.9253 (Figure 4).

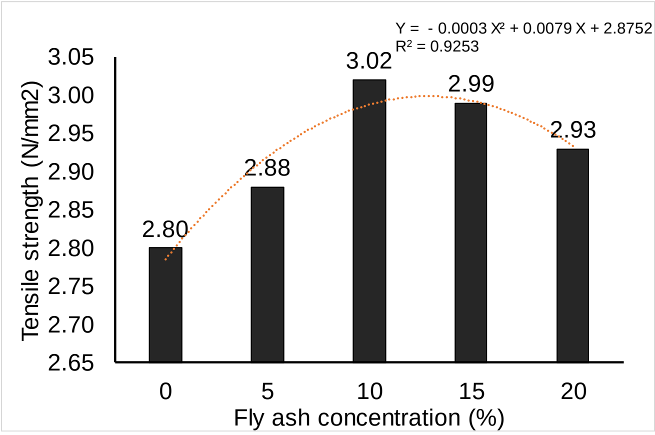


**Figure 4.** Optimum fly ash concentration for maximum tensile strength

### 3.10. Flexible strength

In this study, flexible strength was measured. The scores were varied. The highest tensile strength was obtained at a concentration of 10% fly ash (3.98 Mpa) while the lowest was obtained at a concentration of 0% (3.36 Mpa) (Figure 5).

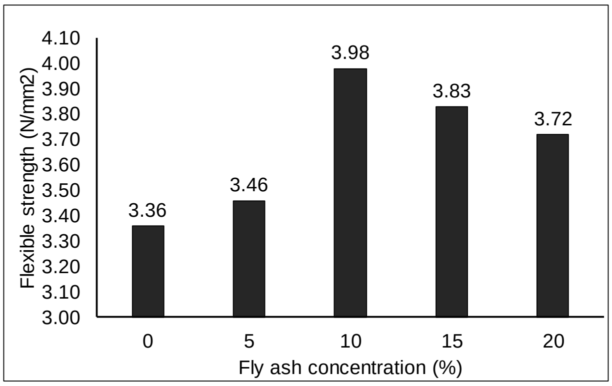


**Figure 5.** Average of concrete flexible strength (N/mm$^2$ or MPa)

After carrying out the regression analysis, the maximum flexible strength was obtained at a fly ash concentration of 13.88%, with a score of 3.7925 MPa. The following was a graph of the optimum Fly Ash content with polynomial regression formula Y = - 0.0004 X² + 0.0111 X + 3.5615, $R^2$ correlation of 0.8009 (Figure 6).

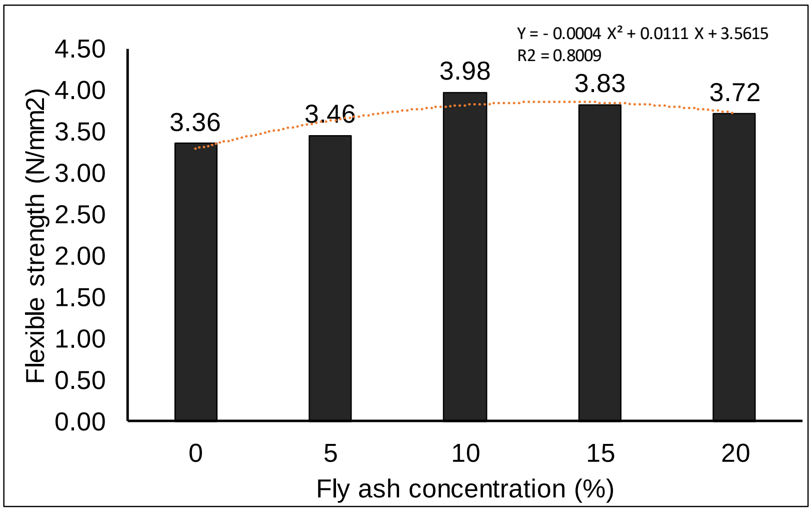


**Figure 6.** Optimum fly ash concentration for maximum flexible strength

### 3.11. The optimal value of using fly ash in precast concrete

The optimal value of using fly ash as a substitute for cement in precast concrete was 13.45% (Table 8). As is known, calcium-silicate (C, S and C, S) was the main component of cement. When mixed with water, calcium-silicate will hydrolyze with the following reaction:

$2(3CaO\ SiO_2) + 6H_2O \rightarrow 2(2CaO.SiO,) + 4H_2O$

$3CaO.2SiO,.3H_2O + 3Ca(OH),\ 3CaO.2SiO,.3H_2O + Ca(OH)_2$

**Table 8.** The optimal value of using fly ash in precast concrete aged 28 days

| Fly Ash (%) | | Precast concrete strength (N/mm$^2$) | | |
|---|---|---|---|---|
| Substitution | Average optimum | Compression strength | Tensile strength | Flexible strength |
| 0 | | 31.29 | 2.80 | 3.36 |
| 5 | | 33.22 | 2.88 | 3.46 |
| 10 | | 36.55 | 3.02 | 3.98 |
| 13.3 | 13.45 | 36.35 | 3.03 | 3.79 |
| 15 | | 35.68 | 2.99 | 3.83 |
| 20 | | 34.39 | 2.93 | 3.72 |

The main products of hydration are calcium-silicate-hydrate, which is a solid element in the form of a rigid gel (which is often also referred to as tobermorite gel), and calcium-hydroxide.

Calcium-silicate-hydrate ($3CaO.2SiO$, $3H_2O$) or often abbreviated as CSH gel is a gel of the crystalline type with short crystal spacing. The morphology of its formation can vary, it can be in the form of thin fibers that give a fibrillar or honeycomb structure at a young age, but in other conditions, it can be a more compact solid structure.

CSH gel is the main component of the strength of cement paste (and thus also the main source of strength of concrete). The function of the gel is to substitute the space within the cement grains and fill the spaces between the cement grains, as well as the bridge between them, which in turn causes the hardening and strength of the cement paste.

The cement paste hardening process will continue for quite a long time, whereas in the subsequent formation process, CSH gels will slowly fill the capillary pores so that the porosity of the paste will decrease and the strength will increase. This was seen when Fly ash (0%), the compressive strength increased to 31.29 MPa from the design compressive strength.

The strength of cement paste is determined by various factors, namely mainly by the amount of adhesive gel per unit volume of cement paste, its adhesion strength, and the strength of the gel particles themselves. The amount of adhesive gel per unit volume produced will depend on the concentration of the cement hydration product and the size of the CSH gel particles, where the concentration of the hydration product will depend on the success rate of hydration and the porosity of the cement paste.

The structure of the CSH gel is generally not fixed in space and time dimensions. The average value of the C/S ratio was around 1.75 with local variation between 1.2 to 2.3 over the age of several years, with the silicate ions being more of a chain consisting of several tetrahedra. With increasing age, the local variations in the value of the C/S ratio will decrease, with the chain length increasing to form a more stable structure.

However, in terms of reaction rates, the hydration of the two calcium-silicate elements C, S and $C_2S$ has unequal reaction rates, where the C, S reaction takes place relatively quickly (the hardening can be in hours), whereas $C_2S$ proceeds much more slowly (the setting can be deep weeks to months).

By substituting Fly ash for Portland cement, the following reaction is obtained:

Ca (OH )2 + H2O + SiO2 → CSH Ca ( OH )2 + H2O + Al2O3 → CAH

The binding between the silica content (from mineral additives) and calcium-hydroxide (which is contained from the hydration of the cement), will produce a CSH gel that is identical to that which occurs in the hydration of portland cement, so in principle, the addition of mineral additives will increase the strength of the cement paste (because CSH gel is an element of cement paste strength), and at the same time reduces the weakness of concrete (because it has reduced calcium-hydroxide). In this case, the C/S ratio values will tend to be 1.4 to 1.6 with fly ash, and 1.0 to 1.2 with micro silica. It has been observed that the length of the main chain also becomes longer, especially in the case of the addition of micro silica, resulting in polymerization in the cement paste.

The hydration process itself will consist of several stages, starting from the first meeting of cement with water until the hydration process is complete. As stated earlier, these stages can be referred to as the pre-induction stage, induction (or sleep stage), intermediate stage, and final stage. In this case, based on microstructural observations, cement hydration products can be described as divided into "outer" hydration products (outer CSH) and "inner" hydration products (inner CSH). The so-called "outer" hydration products are for gels that form or grow in locations previously occupied by water around the outside of the cement granules, while the "inside" hydration products are for gels that form inside the cement grains themselves. Under normal conditions, the total volume of fully hydrated semen is about 2.25 times the unit volume of anhydrate cement.

The results showed that the "outer" hydration product had a lower C/S ratio value than the "inner" hydration product at a young age, because the "outer" hydration product C/S only grew "normally" at the age of mature pasta.

The results also noted that the circumference of the cement granules that produce "outer" hydration will determine the strength of the cement paste. Therefore, the addition of very fine and reactive granules such as micro silica will increase the circumferential volume of the "outer" hydration product (outer CSH), which in turn will increase the density and strength of the cement paste.

In that case, calcium-hydroxide is the only hydration product with a clear (hexagonal) crystalline structure. However, calcium-hydroxide is often a weak element in concrete and can be a source of corrosion in concrete due to sulfate, which is caused by the formation of ettringite or C.A.3CaSO.32$H_2O$ by a reaction of calcium-sulfate with C, A and water, which in turn can lead to volume expansion and damage to concrete. This is what causes the addition of Fly ash into the concrete up to a certain limit (optimum) will increase strength and more than that will reduce strength.

## 3.12. Reduction of CO2 Gas Emissions

### *1) CO2 Emissions*

The formula for calculating CO2 emissions using Method 1 is as follows:

ECO2 = DA × FE

where:

ECO2: Total CO2 emission (ton CO2) DA: Activity Data (TJ)

FE: Emission Factor (tons/TJ)

Semen Tonasa Enterprise, which has an installed capacity of 7.4 million tons of cement per year, has four factory units, namely Tonasa II, III, IV and V plants and 2 power plant units.

Steam Power Plant, namely: BTG 1 with a capacity of 2 x 25 MW and BTG 2 generator with a capacity of 2x 35 MW. Cement production is 6.7 million tons/year and consumes coal of 0.804 million tons/year with calories ≤ 5100 Kg GRK/TJ.

Activity data is consumption data per type of fuel that has been converted to energy units. The formula for consuming fuel from mass units (tons) to energy units (Tj) is as follows:

DAbb = Fbb . NCV . 10-3

Where :

DAbb = Coal activity data (Tj).

Fbb = Coal consumption per year (tons)

NCV = Net calorific value of coal (Tj/Gj), NCV value of coal Default national, NCV = 14.8%

DAbb = 0.804. 14.8 . 0.001

= 0.0118992 ( Tj )

ECO2 = 0.012 . 106.478 = 1.28 million tons/year. So in 1 million tons of coal, 1.59 million tons of CO2 is produced. Or in 1 kg of coal, 1.59 kg of CO2 is produced.

***2) CH4 and N2O emission***

Calculation of CH4 and N2O emissions from fuel combustion using Method-1, the IPCC default emission factor. This was determined due to the unavailability of national CH4 and N2O emission factors and to determine national CH4 and N2O emission factors and/or according to combustion conditions in the Generating Unit requires certain laboratory tests which are limited in number and require a lot of money.

ECH4, N2O = ( Fbb x NCV ) x FE x 10

Where :

ECH4, N2O = Total Emissions of CH4 and N2O ( tons )

FE = Emission Factor ( Kg/TJ or Kg N2O/TJ )

Fbb = Coal consumption in a year (tons)

NCV = Net calorific value of coal (weighted average) TJ/Gg 10-6 = Multiplier Factor

ECH4,N2O = ( 0.804 x 14.8 ) 106.476 x 10-6

= 0.0013 Million tons of CO2

CO2 Equivalent CH2 = 0.0013 x 21 = 0.0273 million tons CO2 CO2 Equivalent N2O = 0.0013 x 310 = 0.4030 million tons CO2

Total CO2,e = 0.0273 + 0.4030 = 0.4303 million ton CO2

So 1 million tons of coal = 0.5012 million tons of CO2,e (CH2,N2O).

Or in 1 kg of coal it produces 0.5012 kg of CO2,e (CH2, N2O). So in 1 Kg of Coal will produce = 1.59 + 0.53 = 2.12 Kg CO2

From the results of the Mix Design, it is obtained that 1 m3 of precast concrete consists of: Water = 208.75 Kg; Cement = 577.40 Kg; Coarse Aggregate = 982.75 Kg; and Fine Aggregate = 497.09 Kg.

And from the results of the study obtained Optimum average Fly Ash Levels of 13.3% (76.79 Kg

) with a Maximum Compressive Strength of 36.352 Mpa.

1) Determination of CO2 Gas Emission Value.

The Cement Industry releases carbon dioxide in 2 (two) processes:

(1) Burning of fossil fuels which contributes around 30% of the total CO2 produced overall. The majority of cement factories use coal as fuel, so does the Semen Tonasa Cement Factory

(2) Decomposition of limestone which contributes 70% of the total CO2 produced overall. Heated limestone will produce calcium oxide and carbon dioxide gas.

1 Kg Cement = 0.12 Kg Coal

1 Kg Coal (combustion) = 2.12 Kg CO2 Coal burning process:

1 Kg Cement = 0.12 Kg Coal

= 0.12 (2.12 Kg CO2)

= 0.2549 Kg CO2

Lime Calcination Process:

1 Kg Cement = 0.70 Kg CO2

So that in 1 Kg Cement = 0.2549 + 0.70 = 0.9549 Kg CO2. So the CO2 Gas Emission Value per Kg of Cement at the PT Semen Tonasa Cement Factory is 0.9549

2) Reduction of CO2 Gas Emissions.

In 1 m3 Precast concrete with fly ash will reduce:

The amount of reduced use of Fly Ash = 76.79 Kg

Total amount of CO2 = 76.79 Kg (2.12 Kg CO2) = 162.79 Kg CO2

## 4. CONCLUSION

Optimization of the use of fly ash as a cement substitution material in precast concrete is as follows:

1) This research is the use of Fly As as a substitute for cement in environmentally friendly precast concrete and its relationship to CO2 gas emissions, where the optimum Fly Ash is obtained as a substitute for cement in precast concrete of 13.30% to produce concrete compressive strength, tensile strength split and Flexural Strength of 4.17 Mpa,

2) with the optimum fly ash of 13.30% as a substitute for cement, it can reduce the use of cement by 76.79 kg from the cement requirement of 577.40 kg in 1 m3 of precast concrete, which means it can also reduce CO2 emissions by 162.79 kg per 1 m3 of precast concrete.

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