The effect of Ground Granulated Blast Furnace Slag (GGBFS) on Portland cement type II to compressive strength of high quality concrete

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Abstract. Failure of concrete in the environment which containing sulphate causes damage to the cement bonds. One of environment that contains sulphate is peatlands. Peat water has a low acidity (pH) that it can damage the concrete slowly from the edges and corners with release of granules and becomes a porous. On this research, Ground Granulated Blast Furnace Slag (GGBFS) is a mineral additive that used as an additive to reduce the damage. The purpose of this research was to determine the effect of using variations of GGBFS and the optimum percentage of using GGBFS on Portland cement type II. This research outline divided into several stages, i.e. material testing, manufacturing cylindrical specimens with addition 0 %, 2%, 4%, and 6% of GGBFS and concrete age 7, 14, 28 days, testing of specimens and analysing test result. Also, the treatment of specimens carried out using peat water. The result show that GGBFS increased compressive strength of the concrete, however it decreased at addition 2% and 6% of GGBFS on 7 days with amounting to -14.62% and -3.47%. The optimum percentage is concrete with variation of 4 % GGBFS and the minimum percentage is concrete with a variation of 0 % GGBFS.

1. Introduction
Concrete is a necessity that can’t be avoided by Infrastructure Development in Indonesia. More than 60% projects from the simplest to projects with complex technology use concrete. Therefore, concrete is one of the construction supply chains that must be considered [1]. As one of the supply chain of construction, material availability is the most important factor that affected by the quality of the material. For high quality concrete, added ingredients are usually used to improve the quality of concrete, the added material can be either admixtures or additives. From research that has been done a lot, it showed that admixtures and additives can improve the quality of concrete [2,3].

Peatlands are one of the acidic environments which are of particular concern in the world of concrete construction. The type of acid found in this field is ferric sulfate (Fe3SO4). Peat water has a low acidity (pH). The acidic environment will slowly damage the concrete starting from the edges and corners of the concrete by releasing the grains of concrete particles until concrete becomes porous. If the concrete is porous, the bonds between the concrete paste and the aggregate will decrease and decrease the compressive strength of the concrete too. This occurs due to the disintegration of concrete constituent materials due to the cement hydration compounds namely calcium hydroxide (Ca(OH)2) and CSH (Calcium Silicate Hydrate) compounds. Calcium hydroxide (Ca (OH)2) which reacts with an acidic
environment will cause volume expansion to cause cracking. According to previous research showed that concrete on peat water has decreased compressive strength [4-6].

In this research, to reduce the impact on environmental conditions, the use of type II Portland cement and mineral additives in the form of GGBFS is carried out. GGBFS (Ground Granulated Blast Furnace Slag) is a refined GBFS (Granulated Blast Furnace Slag) which has cementitious properties that function as aggregate adhesives. While GBFS (Granulated Blast Furnace Slag) is the combustion residue in the furnace of the steel refining process. Based on previous research, The Effect of Used Portland Type II Cement on Sulfate Resistance shows that sulfate attack in the short term causes a decrease in concrete strength [7]. And in addition, research on the performance of Ground Granulated Blast Furnace Slag (GGBFS) shows that GGBFS can increase a compressive strength on concrete, however the strength of the concrete at an early age has slow process than the compressive strength of concrete with cement alone [8-10].

2. Research methods
The methodology of this research is shown in Figure 1.

Figure 1. Procedure of research.

2.1. Identifying problem statement
The issues related about concrete especially on sulphate environment were identified.

2.2. Preliminary study
Study literature about concept of high quality concrete, sulphate effect on concrete, additives on concrete, and the rules about concrete.
2.3. Preparation of tools and materials
Prepare tools and materials that will be used for conducting research on laboratory, such as GGBFS, fine aggregates, coarse aggregates, Portland cement type II, peat water, cylindrical mold, scales, one set of aggregate inspection tools, mixer, slump tools, compressive strength machine, etc.

2.4. Testing of materials
Material inspection is carried out on fine and coarse aggregates, which consist of:

- Mud content level on fine and coarse aggregates [11,12].
- Specific Gravity and Water Absorption on fine aggregates [13].
- Specific Gravity and Water Absorption on coarse aggregates [14,15].
- Fine and coarse aggregates filter analysis [16].

2.5. Planning of mix design
Make a planning of mix design from the result of testing material for the implementation of specimens [17].

2.6. Manufacture of specimens with GGBFS variation
Making a cylindrical specimen with additive variation 0%, 2%, 4%, and 6% of GGBFS by the weight of cement, and concrete age of concrete are 7, 14, and 28 days each of 3 specimens.

2.7. Treatment with peat water
The specimens that have been hardened are treated by immersing them in peat water’s

2.8. Compressive strength testing
The specimens which have been reached their age are tested to know the amount of compressive strength obtained.

2.9. Analysing data of testing result
The testing result were analyzing to saw the concrete developments, its analyses compressive strength by the age of concrete and compressive strength by the additive variation, and peat water content that used on treatment.

2.10. Conclusions
From the analysis, will be drawn a conclusion about the effect of GGBFS on type II cements, the optimum percentage of GGBFS variation, and the effect of peat water treatment.

3. Results and discussions

3.1. Peat water content
The results of peat water content which comes from Kenten Laut, Banyuasin. The samples from peat water were analyzed and results showed that peat water contained high levels of sulfate (SO\textsubscript{4}) and Iron (Fe). The results of the analysis can be seen in table 1.

| Table 1. Peat water content. |
|-----------------------------|
| Characteristics            | Unit | Result  |
| A. Physical                |      |         |
| Temperature                | °C   | 24.5    |
| Total Dissolved Solid (TDS) | mg/L | 3810    |
| Turbidity                  | NTU  | 137.9   |
| Color                      | TCU  | 20      |
### Table 1. Cont.

#### B. Chemical

|                |            |          |
|----------------|------------|----------|
| **pH**         | -          | 3.72     |
| Sulfate (SO$_4$) | mg/L      | 13200    |
| Chloride (Cl)  | mg/L      | 29.78    |
| Calcium (Ca)   | mg/L      | 34.50    |
| Magnesium (Mg) | mg/L      | 3.77     |
| Iron (Fe)      | mg/L      | 1962.53  |
| Manganese (Mn) | mg/L      | 0.027    |

3.2. **Compressive strength analysis by the age of concrete**

Concrete compressive strength test results with a variation 0 % (normal concrete), 2 %, 4 %, and 6 % of GGBFS in type II cement to the concrete age of 7, 14, and 28 days can be seen in the table 2 and figure 2.

### Table 2. Compressive strength recapitulation by the age of concrete.

| Type of mixed     | Age (days) | Average of Compressive Strength (MPa) |
|-------------------|------------|---------------------------------------|
| Normal of concrete| 7          | 27.58                                 |
|                   | 14         | 30.61                                 |
|                   | 28         | 33.82                                 |
| Concrete + 2 % GGBFS | 7      | 23.55                                 |
|                   | 14         | 30.78                                 |
|                   | 28         | 34.06                                 |
| Concrete + 4 % GGBFS | 7      | 30.26                                 |
|                   | 14         | 34.95                                 |
|                   | 28         | 40.90                                 |
| Concrete + 6 % GGBFS | 7      | 26.62                                 |
|                   | 14         | 33.64                                 |
|                   | 28         | 35.39                                 |

![Figure 2. Compressive strength recapitulation against age of concrete.](image)
From table 2 and figure 2 shows that the addition of GGBFS in Type II cement causes an increase in the compressive strength of concrete. However, the addition of 2 % and 6 % GGBFS caused a decrease in the compressive strength of the average concrete to normal concrete at 7 days of each of -14.62 % and -3.47 %.

3.3. Compressive strength analysis by the additive variation

Concrete compressive strength test results at 7, 14, and 28 days with additive variation 0 % (normal concrete), 2 %, 4 %, and 6 % of GGBFS in type II cement to the additive variation can be seen in the table 3 and figure 3.

| Age (days) | Type of mixed               | Average of Compressive Strength (MPa) |
|------------|-----------------------------|--------------------------------------|
| 7 Days     | Normal of concrete          | 27.58                                |
|            | Concrete + 2 % GGBFS       | 23.55                                |
| 14 Days    | Concrete + 4 % GGBFS       | 30.26                                |
|            | Concrete + 6 % GGBFS       | 26.62                                |
| 28 Days    | Normal of concrete          | 30.61                                |
|            | Concrete + 2 % GGBFS       | 30.78                                |
|            | Concrete + 4 % GGBFS       | 34.95                                |
|            | Concrete + 6 % GGBFS       | 33.64                                |
|            | Normal of concrete          | 33.82                                |
|            | Concrete + 2 % GGBFS       | 34.06                                |
|            | Concrete + 4 % GGBFS       | 40.90                                |
|            | Concrete + 6 % GGBFS       | 35.39                                |

Figure 3. Recapitulation of concrete compressive strength using cement type II by the additive variations.

From table 3 and figure 3 above shows that the addition of variations of GGBFS in Type II cement causes an increase in concrete compressive strength. However, the addition of variations of 2% and 6% caused a decrease in compressive strength to the compressive strength of normal concrete at the age of 7 days and increased at 14 and 28 days. Percentage reduction of normal concrete compressive strength with concrete compressive strength + GGBFS 2 % and concrete compressive strength + GGBFS 6 % at the age of 7 days respectively - 14.62 % and - 3.47 %.

4. Conclusion

Based on the results of research showed that the effect of GGBFS as an additive to type II cement causes an increase in the average compressive strength of the concrete. However, type II cement decreased with
the addition of 2% and 6% GGBFS at 7 days cause an inorganic material in the cement which has a slow process. The optimum percentage of variation GGBFS to type II cement at 28 days was produced concrete with the addition of 4% GGBFS of 40.90 MPa. And, the effect of treatment with peat water in type II cement causes the development of concrete to be hampered by sulfate attack, causing damage to the cement bonds and causing sizable cavities in the concrete. It caused peat water contains high level of sulphate (SO$_4^{2-}$) and Iron (Fe).

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