Effect of GGBFS on Compressive Strength, Porosity, and Absorption in Mortars

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Abstract. This research aims to determine the influence of Granulated Blast Furnace Slag (GGBFS) as an ingredient partially added cement in the making of mortar against compressive strength, porosity, and absorption of mortar. This method of research uses experimental methods. The Mortar mixture used is 1 PC: 2 PS and 0.5 cement factor. GGBFS variations are used at 0%, 10%, 20%, 30%, 40%, and 50% of the weight of cement. This research used cubes with a size 5 cm × 5 cm × 5 cm with a sample amount of 36 pieces with a test age of 7 days. The research results gained compressive strength mortar than mortar control, but at a percentage of 30%, GGBFS bagasse ash in a portion of cement has decreased in strength. Compressive strength at the age of 7 days obtained 10.93 MPa; 11.73 MPa; 17.33 MPa; 10.8 MPa; 16.27 MPa, and 16.8 MPa. The compressive strength the maximum average found in the variation of 20% and a variation of 20% GGBFS is a variation that meets the Type M Mortar plan's compressive strength of 17.2 MPa.

1. Introduction
Industrial development in Indonesia in the last 10 years has increased, especially the construction industry. Indonesia as a developing country still needs to build a lot of physical infrastructure [1]. Therefore, the domestic industry improves its quality [2] so that it is not less competitive. Indonesia contractors are demanded to increase their competitiveness [3]. Indonesia’s construction industry will grow into one of the largest in the world in the coming decades [4]. As it is developing, it certainly increases the number of productions, and this emerges the impacts of the productions process, either good impacts or bad ones. The construction industry is well-known for producing waste detrimental to the environment, and its impacts have increased with the development process of cities [5]. Bad impact that arises from this production process is the waste that pollutes the environment. The waste produced from production process will badly impact the environment unless managed properly, which will affect community’s health. Therefore, it is required to have a good waste management to reduce the bad impacts.

The industry in the steel-material management sector is one of the industrial sectors that is rapidly growing. According to Ministry of Industry’s data on the first 9 months this year, steel production grows 10.74%. As the steel productions grows in Indonesia, it is required to have planned strategy to get around and manage environmental problems that are affected by the steel industry waste. This waste is steel slag. Steel slag is an industrial waste from the steel production process, and it is estimated that over 400 million tons are produced annually [6]. Steel slags are industrial by-products of metal manufacturing, characterized as fantastically calcareous, siliceous and ferrous. They can be classified into simple oxygen furnace (BOF) slag, electric arc furnace (EAF) slag, and ladle furnace (LF) slag [7]. Steel slag
is the residu from the steel processing that is included in the category of hazardous, according to government regulation number 85/1999. Becasue of this categorized as B3 waste, it is neccessary to make efforts to manage the steel slag waste into useful material. Steel slag, unless properly managed, will have negative impacts for the environment [8].

PT. Krakatau Steel Indonesia is the biggest steel producer with 3,15 tons production capacity per year and produces slag waste up to 750 million tons per year [9]. In 2013, PT Krakatau Semen Indonesia was formed based on the cooperation between two large companies, PT Krakatau Steel and PT Semen Indonesia. PT Krakatau Semen is intended to reduce the environmental pollution which is caused by slag waste from steel production at PT Krakatau [10]. This slag waste is GBFS (Granulated Blast Furnace Slag). GBFS is a grain/granular produced from combustion in a steel refining furnace. To produce cement-like material, GBFS is finely ground so that it becomes fine particles similar to the size of cement particles in general. This finely-ground GBFS is called GGBFS. Beside its similar size to cement particles in general, GGBFS also shows the same adhesive quality with portland cement [11].

Granulated blast furnace slag should contain calcium oxide (CaO), magnesium oxide (MgO), and silicon dioxide (SiO₂), the sum of which should account for at least two-thirds of the mass [12]. In the process of making the concrete mixture or mortar, calcium oxide can react with water during hydration process to form Ca(OH)₂, and this reaction will make the concrete expand. Whereas silicone dioxide in the concrete mixture or mortar will react with Ca(OH)₂ to form CSH, and this reaction will reduce the number of pores on the concrete or mortar [13]. This will make the concrete more solid and is expected that it will have an influence on compressive strength and reduce water absorption in concrete or plaster so it is appropriate to be applied to trasmram wall plastering.

GGBFS reduces workability and setting time on recycled aggregate [14]. However the addition of GGBFS to geopolymer concrete enhances the setting time, fast energy improvement is observed and carbon footprint is extensively reduced [15], [16]. GGBFS can be one of the synthesizers for the manufacture of Alkali-Activated Concrete (AAC) [17]. In this research, GGBFS is used as added cement material in mortar to increase the quality of compressive strength, porosity and absorption in mortar. Mortar is intended for trasmram-wall platering work, which has good watertight quality with a mixture ration of 1 cement : 2 sand. In this research, mortar is expected to have a good compressive strength and also good quality of porosity and water absorption.

2. Methodology

The method used in this research is an experiment carried out in a laboratory by conducting a direct experiment to obtain data or results that connect all variables examined. The test object to be used is the mortar for trasram (water resistant properties)-wall plastering (1 cement : 2 sand) in the form of a 5 x 5 x 5 cube, with the addition of GGBFS with a percentage of 0,10,20,30,40 and 50 of the weight of the cement and cement water factor of 0,5. The examination begins with a preliminary test of the material that makes up the mortar, the creation of the test object, the treatment process; the test of compressive strength, porosity, and absorption is carried out in Laboratorium Uji Bahan Teknik Sipil, Universitas Negeri Jakarta.

3. Result and discussion

3.1. Absorption Testing on Mortar

According to Figure 1, absorption value in mortars will decrease as GGBFS increase in mortars. The results of the absorption value test on the mortar in this study meet the requirements for the water absorption in mortars, which is ≤ 20% in accordance with Indonesian National Standard (SNI) number 15-2000. The level of addition of GGBFS to the mortar significantly affects the ability of the mortar to absorb water, because GGBFS has fine physical properties and can fill the empty cavity particles in the mortar so that the mortar mixture becomes denser, so it can make the water absorption in the mortar become smaller.
3.2. Porosity Testing on Mortar

Figure 1. Absorption testing on mortar

Porosity value in mortars from variation 0% to 50% experiences a downward trend. Theoretically, the lower porosity value contained in mortars, the lower the absorption value [18]. This shows that mortars with lower water absorption will surely have low pores content because this content will impact the absorption level.

This experiment of porosity level in mortars with additional GGBFS shows that the more GGBFS levels, the lower the mortar’s porosity level. This indicates that GGBFS can affect the density of the mortar mixture so that mortars can be more solid or denser compared to mortars without additional GGBFS. This is caused by the fact that GGBFS has high level of silicon dioxide which will react with Ca(OH)$_2$ to form CSH (Calcium Silicate Hydrate) and this reaction will reduce the number of pores in concretes or mortars [19].
3.3. Compressive Strength Testing

From the Figure 3, it is shown that mortars with 7 days of age with additional GGBFS results relatively stronger compression strength compared to the ones without additional GGBFS. Control mortar, which is mortar with 0% GGBFS, can receive an average compressive strength of 10.93 MPa, mortars with 10% GGBFS experience an increase in compressive strength of 7.32% from control mortar which is 11.73 MPa, mortars with 20% GGBFS experience a significant increase in compressive strength against control mortar, which is 58.55% with a strength of 17.33 MPa, mortars with 30% GGBFS experience a decrease in compressive strength by 1.19% against control mortar with a strength of 10.8 MPa, the mortars with 40% GGBFS increase by 48.86% against the control mortar with the strength of 16.27 MPa, while the mortars with the largest addition of 50% GGBFS also experience an increase in compressive strength against the control mortar which is 53.71% with compressive strength of 16.8 MPa.

According to the determination of the compressive strength of type M mortars at the age of 7 days, it is found that the compressive strength limit is 9.18 MPa. With the results of the compressive strength level of mortars with added GGBFS with a percentage of 0, 10, 20, 30, 40, and 50, compressive strength level of type-M mortars has been reached, shown from the results of the conversion of compressive strength level at the age of 7 days.

At the variation in the percentage of GGBFS 10, 20, 40, and 50, there is a significant increase in compressive strength compared to control mortars. This is because GGBFS has physical properties in the form of fine particles so that it can fill the cavities in the mortar more solid and denser. GGBFS can also help increase the compressive strength of the mortar because the primary composition of GGBFS is silicon dioxide (SiO2), calcium oxide (CaO) and magnesium oxide (MgO) [20]. Calcium oxide contained in GGBFS can react with water during the hydration process to form Ca(OH)2 to make mortars expand, while the silicon dioxide in the concrete or mortar mixture will react with Ca(OH)2 to form CSH which will reduce the number of pores in concrete and mortar. This smooth physical properties of GGBFS and the chemical properties of GGBFS can react with cement and water in the mortar mixture so that the mortar will become solid and dense and will certainly affect the mechanical properties of the mortar to have a better compressive strength than mortar without GGBFS.

In the percentage variation of 30% GGBFS, based on the results of the experiment, there is a decrease in compressive strength of 1.19% compared to the control mortar which is 10.8 MPa. This is presumably because the process of making the specimens in this variation is less optimal, so that the constituent materials in the mixing process not properly mixed, and also at the time of molding the specimens, it is suspected that there is a lack of more thorough compaction that makes the mortar less solid and the surface is uneven.
4. Conclusions
Based on the results of the data and descriptions that have been explained regarding the effect of GGBFS as an added material for cement on compressive strength, porosity and absorption in mortars, it can be concluded that: 1) The addition of GGBFS to the mortar mixture can cause the consistency level of the mortar to decrease but this consistency level will be still categorized as good because it is in accordance with the standards. 2) The content weight of the mortar tends to increase with the increase of the use of GGBFS in the mortar mixture. 3) Based on the research results, the absorption value and porosity of the mortar decrease compared to the control mortar which indicates that the use of GGBFS in mortar can have an effect on the water absorption level in mortars and pores content of the mortar. Mortar with the best absorption and porosity level is found in the mortar with a mixture of 50% GGBFS, which are 8.6% absorption level and 16.81 porosity level. 4) The results of this experiment show that the optimum compressive strength level is 17.33 MPa in mortar with 20% GGBFS variation at the age of 7 days. This result makes it the right variation to use on type-M mortar trasram plastering with the strength of 17.2 MPa. 5) The results show that the minimum compressive strength level is found in the 30% GGBFS variation with a compressive strength of 10.8 MPa. Mortars with a variation of 30% GGBFS decrease the level of compressive strength control mortar. 6) The use of GGBFS as an added material for cement with various variations can affect the consistency level of the mortar, the weight of the mortar, the absorption level, the porosity level, and the compressive strength.

5. References

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