CHAPTER II

LITERATURE REVIEW

Infrastructure construction is one of the main priorities of the government. One of the focus is the construction of new roads all over Indonesia. The construction of road needs a lot of material to create a high quality and long-lasting pavements. The thickness and the type of the pavement construction will control a large sum of the project cost. Hence, engineer have to take the condition of the soil below the pavements into account since the pavements will be supported by the subbase layer to carry the weight of the traffic loads, in addition to the pavement loads. The problem arises when high quality natural resources, such as soil, sand and gravel is not available. The constant needs of those materials also started to cause problems since it had to be mined first. Thus, civil engineers have begun their search to find alternatives as a substitute of the natural resources. One of the answer is to use blast furnace slag, a waste material from the production of molten pig iron.

The utilization of blast furnace slag has been studied several times in the past years. One of the study was done by Kumar in 2014. In the study, the blast furnace slag was used as replacement of coarse aggregate on subbase layer, and also used modified red soil as a filler material. The objective of the study was to investigate the possibility of using blast furnace slag with variety blended mixes of conventional aggregates in subbase layer, with different percentages. The material used was red soil, modified red soil (red soil plus 4% of Red Husk Ash), function of the pavement is to minimize stresses to the layers below so that there is only a small or no deformation in the soil layers. Consequently, the better the soil's ability to resist the deformation, the thinner the pavement will be, that will end up in lower cost for the construction.

However, pavement construction always requires a huge amount of natural resources, such as soil, sand and gravel. Those materials may not be available on-site, and need to be bought and brought to the construction site. Nowadays, there is a growing concern about the scarcity of those materials, since they have to be mined and could potentially harm the environment. Thus, civil engineers have begun to find alternatives as a substitution to the natural resources.

At the same time, the manufacturing process of iron in Indonesia also results in production of granulated blast furnace slag as a byproduct. Granulated blast furnace slag is one of the two type of ferrous slag, with the other one being steel slag. ground blast furnace slag is recovered by melting separation from blast furnaces that produce molten pig iron. It consists of non-ferrous components contained in the iron ore together with limestone as an auxiliary materials and ash from coke. On average, the production of one metric ton of crude iron will also produced 0.25 to 0.3 metric ton of granulated blast furnace slag. As of 2017, Indonesia produced more than 2 million tonnes of granulated blast furnace slag annually. Granulated blast furnace slag can be grounded to create Ground Granulated Blast Furnace Slag (GGBFS) with finer size than the GBFS. If granulated blast furnace slag or ground granulated blast furnace slag is not utilized, then the deposit of those materials might cause problems for the environment.

In this study, ground granulated blast furnace slag (GGBFS) is used as partial replacement of natural fine aggregate in subbase layer in different percentages. Then, the effect of the replacement on subbase properties is the main objective of this study. The output of this research will be the maximum dry density (MDD), optimum moisture content (OMC) and California Bearing Ratio (CBR) value on unsoaked condition from variations of subbase layer mixtures.

1.2 Problem Statement

Infrastructure construction is one of the main priorities of Indonesian government. The construction of pavement requires good soil layer below the surface layer, one of it is subbase layer. This layer will take and transfer the load from self weight of soil layers above it, and also traffic load to subgrade soil. If the subbase layer has good properties to resist the load, the thickness of the pavement can be reduced, thus saving cost of the construction. To create a good subbase layer, a big amount of natural aggregate is required. When the natural aggregate is scarce, it becomes a problem. Thus, engineers have started to search for alternative materials to construct subbase layer, but there is still no research that study about the possibility of using ground granulated blast furnace slag (GGBFS) as fine aggregate substitution to improve subbase course.

1.3 Objective

The objective of this research is to know about the influence of substitution of fine aggregate using ground granulated blast furnace slag (GGBFS) towards the

Optimum Moisture Content (OMC) and Maximum Dry Density (MDD) of the subbase mixture. Then, the influence of the substitution on the California Bearing Ratio (CBR) value on unsoaked condition will be investigated. The last objective will be finding the structural layer coefficient of the subbase layer (a_3).

1.4 Limitation

1. The soil that will be used is obtained from Berbah.
2. The coarse aggregate used is obtained from Clereng.
3. The natural fine aggregate used is obtained from Kali Progo.
4. The ground granulated blast furnace slag is obtained from PT. Krakatau Semen.
5. The base mixture of 10 : 50 : 40 (Soil : Coarse aggregate : Fine aggregate) will be used.
6. The variation of fine aggregate substitution with ground granulated blast furnace slag will be 0%, 15%, 30%, and 45%.
7. The CBR test on sub-base course is carried on unsoaked condition.

1.5 Research Benefit

The result of this final project is expected to help evaluate the utilization of ground granulated blast furnace slag (GGBFS) as fine aggregate substitution in the subbase course to the Optimum Moisture Content (OMC) and Maximum Dry Density (MDD). Furthermore, the California Bearing Ratio (CBR) tests will be done to investigate the effects of the utilization of GGBFS. From there, the structural layer coefficient (a_3) for the subbase will be calculated.

1.6 Originality of Final Project

Numerous studies on slag showed positive results when it is used as subbase layer material. A study was carried out by Ahmed Ebrahim Abu El-Maaty Behiry in 2013 about the effect of using steel slag combined with limestone aggregates as subbase layer material. The study investigated the effect of quantity of steel slag on the mechanical properties of blended mixes with crushed limestone aggregates. The study was also estimated the resistance for failure factor of subbase under overweight trucks load. Another study was carried out by M. Neeraja in 2018, about the utilization of ground granulated blast furnace slag (GGBFS) and fly ash in granular subbase layer. The study evaluated the compaction and California Bearing Ratio (CBR) tests of conventional material for strength parameters, and a comparative study is made to know the variation of strength by replacing a known percentage of conventional material with granulated blast furnace slag and fly ash under different proportions.

From all the researches and studies that have been done, none of them discussed about the evaluation of unsoaked California Bearing Ratio (CBR) value on subbase course that uses conventional material, and comparative study with variation of strength by replacement of natural fine aggregate material with ground granulated blast furnace slag (GGBFS) on different percentages.

quarry dust, natural aggregates of 20 mm sieve passing The test was done using 5 varieties of blast furnace slag percentage as an aggregate replacement, starting from 0%, 10%, 20%, 30%, and 40%. The value of Maximum Dry Density (MDD) and Optimum Moisture Content (OMC) for natural aggregate is the highest and the lowest, sequentially. The value of MDD is decreasing with the increase of Blast Furnace Slag, and the value of OMC is increasing with the increase of Blast Furnace Slag. This is caused by blast furnace slag's lower specific gravity compared to the natural aggregate's specific gravity (Kumar, 2014).

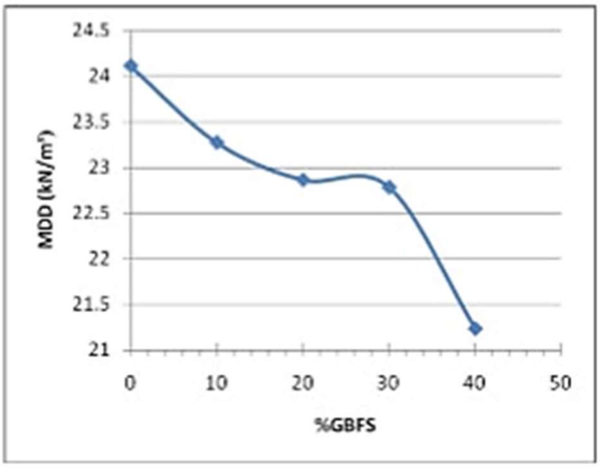

Fig. 2.1 Maximum Dry Density Value for Various (%) of GBFS. (Kumar, 2014)

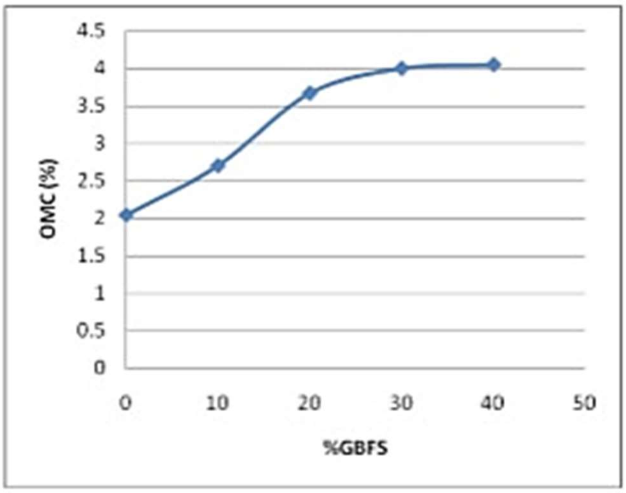

Fig. 2.2 Optimum Moisture Content for Various (%) of GBFS. (Kumar, 2014)

CBR test was also done to examine the strength of the Blast Furnace Slag mixes. The test was carried out in unsoaked condition and 4 days soaked condition. The addition of Blast Furnace Slag increased the CBR value, up to 20% addition of Blast Furnace Slag. The maximum unsoaked CBR value of 20% replacement with Blast Furnace Slag is increased by 40.78%, while the maximum 4-day soaked CBR value is increased by 46.60%. After 20%, the addition of blast furnace slag will decrease the CBR value, both in unsoaked and 4-day soaked conditions. The increase of CBR value is caused by cementitious properties possessed by blast furnace slag (Tripathi, 2013).

Table 2.1 CBR Value (Unsoaked and 4-day soaked) for Each Sub-base Blend. (Kumar, 2014)

Blend Sample Type	CBR (%)	
	Unsoaked	4-Day Soaked
Aggregate	74.20	66.90
Aggregate replacement with10%GBFS	81.96	71.77
Aggregate replacement with 20%GBFS	104.46	98.08
Aggregate replacement with 30%GBFS	95.49	89.41
Aggregate replacement with 40%GBFS	82.87	68.12

Another study was completed by Ruqayah Al-Khafaji and colleagues in 2017, where it tried to evaluate soft soil stabilization using Ground Granulated Blast Furnace Slag (GGBS). The study was caused by soft soil's poor shear strengths and high compressibility. Thus, GGBS was used to stabilize soft soil, because of its cementitious properties. In this research, GGBS was mixed with soft soil in a variety of proportions starting from 0%, 3%, 6%, 9% and 12% of the dry weight of the soft soil to obtain the optimum variety for soil stabilization. Then, the investigation of the physical and geotechnical characteristic of the soft soil stabilized with GGBSS were done by tests of Atterberg limits tests to obtain the Liquid Limit (LL), and Plasticity Index (PI), Standard Proctor Compaction test to determine the Maximum Dry Density (MDD) and Optimum Moisture Content (OMC), and Unconfined compressive strength (UCS) test to measure the shear strength. From the Atterberg limit result, the increase of GGBFS content caused the decreasing of liquid limit (LL) and an increase in Plasticity Index (PI).

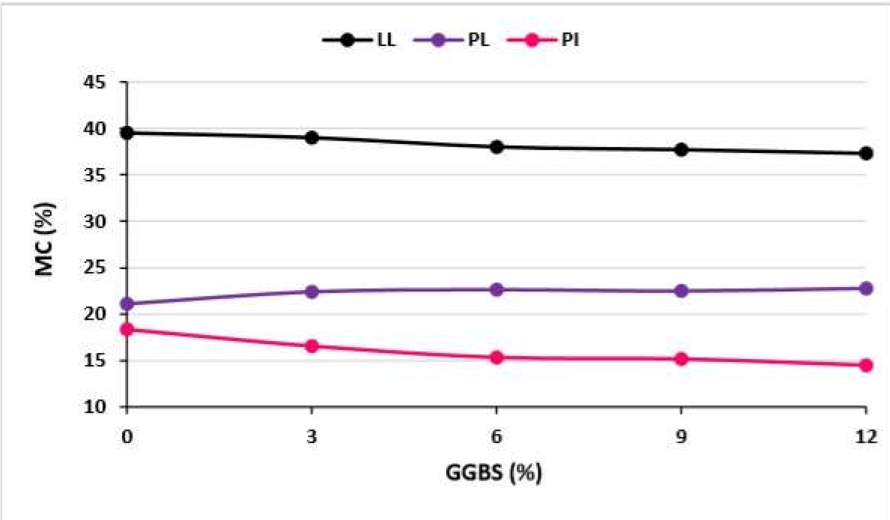

Fig. 2.3 Atterberg limits after GGBS treatment. (Al-Khafaji, 2017)

The compaction test is done to obtain the Maximum Dry Density (MDD) and the Optimum Moisture Content (OMC) for the untreated soil and soil mixed with various percentages of GGBS. The result showed that an increase in GGBS percentage will cause an increase in the MDD, while also decrease the OMC with the increase of GGBS content up to 9%. If the GGBS content is increased further, the MDD and OMC will be decreased and increased respectively.

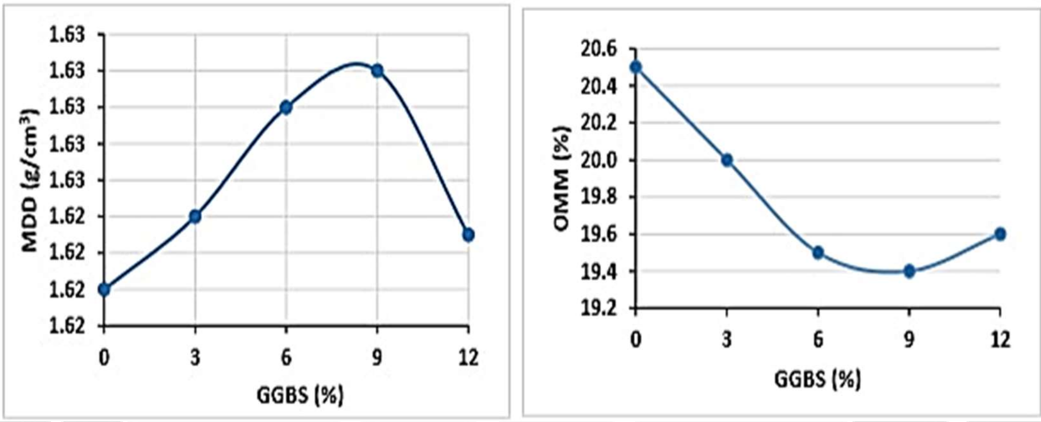

Fig. 2.4 (a) MDD value and (b) OMC value with various percentage of GGBS. (Al-Khafaji, 2017)

The increase in MDD is caused by the specific gravity of GGBS (2.89) which is higher than the specific gravity of the soil (2.67). The decrease in the OMC with the increase of GGBS content is caused by the decreasing of free silt and clay fraction quantity with the addition of GGBS, hence the smaller surface area required less water (Yadu & Tripathi, 2013).

From the Unconfined Compressive Strength (UCS) test in 7 days cured samples, the result showed that the addition of GGBS can increase the strength of the soil up to 6% content, further than that the strength will decrease gradually. The increase of strength can be caused by the development of a cementitious compound between the GGBS and the soil (Yadu & Tripathi, 2013). The gradual decrease of strength with 9% and 12% GGBS may have been resulted from excessive amount of GGBS to the soil, thus caused to the formation of weak bonds between the soil and the cementitious compounds obtained (Yadu & Tripathi, 2013).

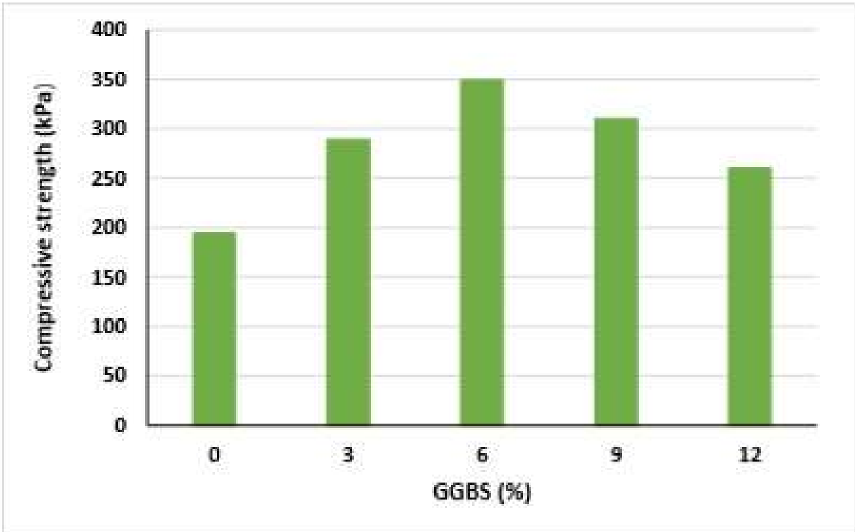

Fig. 2.5 Relation between UCS and Percentage of GGBS in 7 days curing period.

(Al-Khafaji, 2017)