REPUBLIK INDONESIA
KEMENTERIAN HUKUM DAN HAK ASASI MANUSIA

SURAT PENCATATAN
CIPTAAN

Dalam rangka pelindungan ciptaan di bidang ilmu pengetahuan, seni dan sastra berdasarkan Undang-Undang Nomor 28 Tahun 2014 tentang Hak Cipta, dengan ini menerangkan:

Nomor dan tanggal permohonan	:	EC00201979569, 3 November 2019
Pencipta		
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Kewarganegaraan	:	Indonesia
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Alamat	:	Villa Permata Hijau Cluster Garnet Blok C1 No. 2 Kelurahan Serdang Kec. Kramatwatu, Kab. Serang, 27, 42161
Kewarganegaraan	:	Indonesia
Jenis Ciptaan	:	**Karya Tulis**
Judul Ciptaan	:	**Utilization Of Steel Slag And Fly Ash In Soil Stabilization And Their Effect To California Bearing Ratio (CBR) Value. (Case Study: Kp. Kadusentar Road Medong Village Mekarjaya Subdistrict Pandeglang District)**
Tanggal dan tempat diumumkan untuk pertama kali di wilayah Indonesia atau di luar wilayah Indonesia	:	31 Oktober 2019, di Cilegon
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Nomor pencatatan	:	000164679

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Utilization of Steel Slag and Fly Ash in Soil stabilization and Their Effect to California Bearing Ratio (CBR) value. (Case study: Kp. Kadusentar road Medong village Mekarjaya Subdistrict Pandeglang District)

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Abstract. Road construction is not always on good subgrade, there is possibility being built on subgrade which has low soil bearing capacity which could cause damages such as holes and bumps on the pavement road. One of the parameters to determine soil bearing capacity is Californian Bearing Ratio(CBR) value. This study aims to determine the effect of steel slag and fly ash to soil CBR value and its effect on soil physical properties. Soil samples were taken from Kadusentar Village of Pandeglang District Banten. The method of soil stabilization used percentage variation admixture of 20% fly ash mixed with 0%, 10%, 20% and 30% of steel slag from soil total weight. The analysis results showed that original soil samples can be classified as non-organic clay soil with high plasticity. The CBR laboratory test result showed that variation of 20% fly ash and 20% steel slag with 7 days ripening give the optimum value of CBR increased from 3.524% became 26.14%. The highest CBR value of this mixture can be categorized as good classification of subgrade. Plasticity index value decreased became 4.57% which can be categorized as lowplasticity.

1. Introduction

Soil condition at Kp. Kadusentar road in Medong Village, Mekarjaya District, Pandeglang Banten is damaged. The road experiences many holes and bumps due to the low road strength that is often passed by vehicles between villages or districts in this area. Low bearing capacity soil can be one of the causes of that pavement failure. Based on the AASHTO soil classification, one type of subgrade soil which has low bearing capacity is type of clay soil. The CBR test method is usually used as a method to determine the subgrade capacity of the highway pavement planning which is expressed in CBR value. Subgrade soil which lacks the bearing capacity has a low CBR value. Before this research began, on site CBR testing was conducted using Dutch Cone Penetration (DCP) test which obtained the result of 2.9%. The PI value of the existing soil has a high value of 24.59%.

In order to improve the effectiveness of subgrade soil from initial bad conditions, then it is necessary to make soil improvement which is known as soil stabilization. One of soil stabilization method is adding additives materials that have chemical properties to strengthen the soil (chemical method). Steel slag and fly ash are additive materials that will be seen having an effect on soil strength in this study. Fly ash and steel slags have pozzolanic and self-cementing properties (the

ability to harden and increase strength when reacting). Beside its benefits, the use of slag and fly ash can also help the industrial waste utilization program for other applications, especially in Banten region.

Several previous studies in utilizing fly ash and steel slag have been carried out by Ardiayanti [1], Mina [2], Kusuma [3],Dayalan [8] and Padmaraj [9] . In her research Mina [2] concluded that by adding 20% fly ash to clay soil could increase the CBR value to 38.6% but could not reduce the soil plasticity index so that the soil was still in the high plasticity category. Utilization of steel slags was done by Ardianti [1] where a mixture of 10% steel slag with soil can increase CBR value. Based on several references, the use of fly ash alone has not been able to improve the physical properties of clay soil which is their plasticity index is still high. Therefore the use of a combination of fly ash and steel slag is expected to be a mixed alternative to see its effect on soil strength and also improve the physical properties of the soil. The plan for the stabilization method uses a mixture of 20% fly ash and steel slag with variations of 0%, 10 %, 20%, and 30% and to see the effect of curing time, samples were incubated with variations of 0 day, 3 days and 7 days. It is expected that from this study a combination of mixtures that can produce optimum soil strength (CBR) results for clay stabilization methods.

2. Literature Review

2.1. Soil Properties and Classification

Soil classification system is an integrated classification system of soil types that have same characteristics into groups and subgroups based on their use. There are two systems that are often used the USCS (Unified Soil Classification System) and AASHTO (Association of Highway State Officials and Transportation). These systems use simple soil index properties such as liquid limit, plastic limit, and grain size distribution.

Table 1. Classification of soil based on USCS System

Classification procedure		Symbol	Type
Fine-grained soil (more than 50% passes sieve No.200	Clayly Silt with liquid limit of less than 50%	ML	Non organic Silt with a small amount of fine sand, gravel or clayly fine sand with low plasticity
		CL	Clayly silt non organic with low to moderate plasticity, silt mixed with clayly fine sand
		OL	Organic silt or organic clayly silt with low to medium plasticity
		MH	Non organic clay, clay mixed with fine sand
	Silty Clay with liquid limit of more than 50%	CH	Non-organic clay with high plasticity, fat clay
		OH	Organic clay with medium to high plasticity
		PT	Peat and high organic soil

(Source : Hardiyatmo[6])

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2.2. Fly Ash

Fly ash is solid waste produced from burning stones in smelter companies. Fly ash has fine grain size, is grayish in color and is obtained from the coal combustion result. In essence, fly ash contains chemical elements including silica (SiO_2), alumina (Al_2O_3), ferrous oxide (Fe_2O_3) and calcium oxide (CaO), also contains in additional elements like magnesium oxide (MgO), titanium oxide (TiO_2), alkaline (Na_2O) and K_2O, sulfur trioxide (SO_3), phosphorus oxide (P_2O_5) and carbon. According to ASTM C618 fly ash is divided into two classes, namely class F and class C. The main difference from these two ash is the amount of calcium, silica, aluminum and iron content in the ash.

2.3. Steel Slag

Slag is steel or copper smelting waste, mostly containing iron oxide and silicate, has flat and pointed (sharp) shape. Slag can be used as a substitute for fine aggregates because it has stable chemical properties and almost the same physical properties as sand. Slag waste at PT. Krakatau Steel originating from the steel making process which is carried out using slag atomizing technology (SAT) technology and material recovery plant (MRP).

2.4. Soil Stabilization

Soil stabilization in principle is to improve poor soil quality. According to Ingles and Metcalf [7], stabilization can be proceed by several methods, which are:

1. Mechanical method

   soil improvement using mechanical way, where soil is improved without addition of other materials.
2. Physical Method

   Improvement soil by physical means is by utilizing -the physical changes.
3. Chemical method

   Chemical soil improvement is using addition of stabilization materials that can change the unfavorable properties of the soil.

2.5. California Bearing Ratio (CBR)

Bearing capacity of subgrade in   highway pavement design is stated by California Bearing Ratio value (CBR). In pavement design CBR test for a road or an airport is used to determine the ground strength. Whereby knowing the CBR value of subgrade, the thickness of the pavement layer can be determined. In the test it was found that there were various types of CBR, but for the laboratory CBR there were two types, namely, soaked laboratory CBR and unsoaked laboratory CBR.

3. Research Methodology

This study used experimental method, which is conducting research by conducting experiments on objects that are directly examined. The purpose of this experimental method is to investigate the effects additive material such as fly ash and steel slag to soil stabilization. Soil samples are taken from KP. Kedusentar road Medong Village Pandeglang Banten Indonesia, this location are shown in **Figure 1**. This study used 36 samples to examined their bearing capacity through laboratory CBR test based on variation of additive material adding in the soil. This Research was conducted through literature studies and laboratory experiments. The stages of research can be described as follows:

* The physical properties of soil samples without any admixtures such as water content, specific gravity, plasticity index is examined.
* Samples are made based on parameter of dry density and optimum water content from compaction test results.
* Made sample variation of admixture which using 20% of fly ash mixed with 0%, 10% , 20%, and 30% of steel slag.

- Every variation needed 12 samples for every ripening period of 0 days, 3 days, and 7 days which totally needed 36 samples.
- Determined the CBR value from CBR laboratory test for every variation of samples based on its ripening period. The results are then recorded and compared to see the effect of admixtures on bearing capacity of soil (CBR value).
- Examined the effect of admixtures on soil properties such as the plasticity index.

Figure 1. Research location map *(Source: Google Maps, 2018)*

4. Results and Discussions

4.1. Soil Properties and Classification

The original soil sample was examined for properties parameter and then the results were summarized. Table 1 shows the results of soil properties such as grain size analysis, liquid limit, plastic limit, and specific gravity of soil without material additive:

Table 2. Soil properties test results

| No.	Characteristics	Value(%)
1	% fine grain	78.30 %
2	Soil density	2.70
3	Liquid limit	61.50 %
4	Plastic limit	36.91 %
5	Plasticity index	24.59 %
6	Optimum water content	34.0%
7	Dry unit weight	1.27 gr/cm^3

(Source: Author, 2019)

Soil grain size analysis results in **Table 1** showed that the existing soil conditions on the Kp. Kedusentar Road Medong Village can be classified as fine-grained soil. Soil has plasticity index value 24.59% with a dry volume weight of 1.27 gr / cm^3. It showed that soil has high plasticity properties. Classification of soil was determined through USCS soil classification system table. Based on analysis results it can be concluded that the soil was classified as MH soil, which is non-organic clay that had high plasticity properties.

4.2. CBR (California Bearing Ratio) Test Results

CBR laboratory test results for every variation of percentage of steel slag and fly ash and ripening or curing days for 0 days, 3 days and 7 days are shown in **Figure 2**. Based on the results, it can be concluded that the addition of the percentage of steel slag and 20% fly ash to the soil will increase CBR value. At ripening 0 days without admixtures the CBR value of soil was 3.524%. CBR value increased as percentage of steel slag increased.   CBR value reach maximum at variation of percentage steel slag 20% and fly ash 20% to become 17.181%. After 3 days ripening, CBR value of soil without

adding admixtures reach 2.496% then increases when the percentage of steel slag 20% and fly ash 20% to became 20.853%. Furthermore, at 7 days of ripening with variation of 0% steel slag and 20% fly ash CBR value was 2.585% then reached optimum value at the percentage of steel slag 20% and fly ash 20% with CBR value became 26.14%. While at percentages of 30% steel slag and 20% fly ash CBR value decreased to 25.25%, the decreasing of CBR at this stage could probably due to the presence of excessive pozzolanic material on clay which could only have function as filler to pore space of soil particles and no longer functioned as binder of soil particles so that cementation processes do not occur.
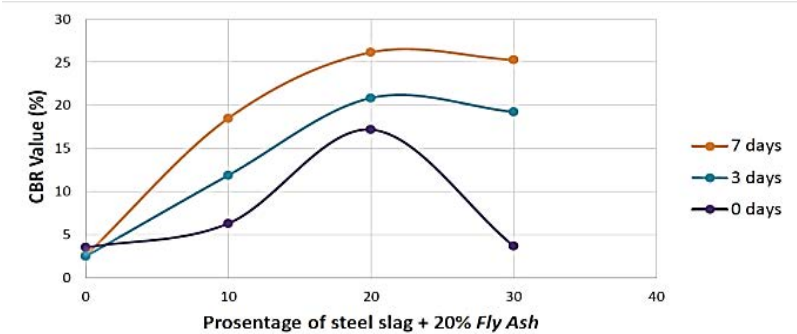
Figure 2. Graph of relation between CBR value and percentage of additive Materials
(Source: Author, 2019)
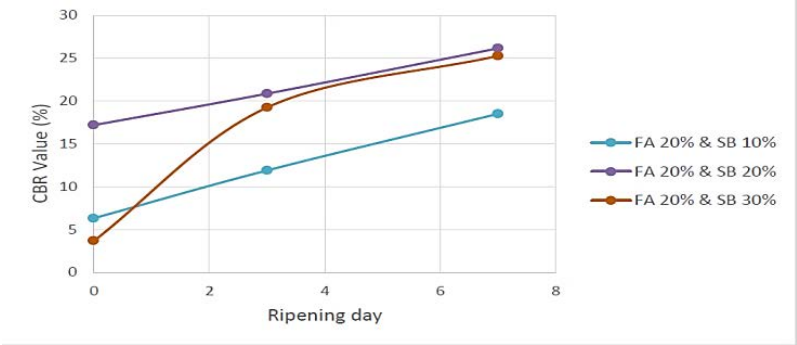
Figure 3. Graph of relation between CBR value to ripening day long
(Source: Author, 2019)

Ripening or curing gives influence to the bearing capacity of soil as shown in **Figure 3**. Based on each variation of 0%, 10%, 20%, 30% of steel slag and 20% fly ash it shows that the longer curing process time, the higher CBR value.

**Table 3.** Soil classification based on CBR value

CBR (%)	Level	Objective
0-3	*Very poor*	*Subgrade*
3-7	*Poor to fair*	*Subgrade*
7-20	*Fair*	*Subbase*
20-50	*Good*	*Base or Subbase*
>50	*Excellent*	*Base*

(Source: Bowles, 1992)

Sample soil from Kp. Kadusentar road Medong village without admixtures has CBR value 3.524% which is included in poor to fair category as described in **Table 2**. The CBR value of soil reaches maximum value at the variation admixtures 20% fly ash and 20% steel slag which increased to 26.14% which can be included as good category. Thus it can be concluded that addition of admixtures of steel slag and fly ash can increase the CBR value of soil. Variation of percentage of the admixtures reaches optimum CBR value at 20% fly ash and 20% steel slag.

*4.3. Properties of soil with admixtures Steel Slag and Fly Ash*
Soil liquid limit (LL) has decreased as percentage of material of admixture steel slag increased, this indicated that steel slag could affect the physical properties of the soil. The lowest liquid limit value is 27.50%. Soil plastic limit of soil also tended to decreased when percentage of steel slag increases which has lowest plastic limit (PL)value is 25.20%. **Figure 4** show the effect of percentage of steel slag with 20% fly ash to LL an PL value.
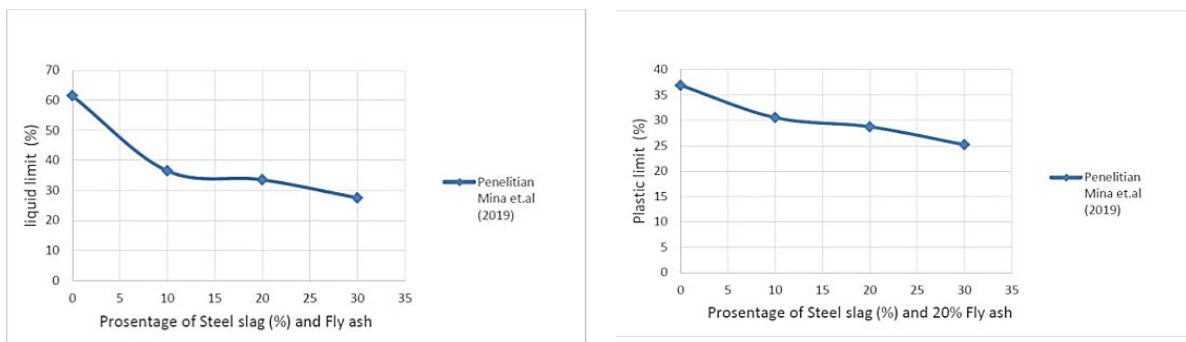
(a)   (b)
Figure 4. Graph of relation between (a) liquid limit and (b) plastic limit with percentage of additive materials *(Source: Author, 2019)*

Plasticity index as the results of the difference between liquid limit with plastic limit are shown in **Figure 5**. With the added material of fly ash and steel slag the plasticity index value decreases directly with the percentage of added material, with the lowest plasticity index value was 2,30% at variation of 20% fly ash and 30% steel slag.
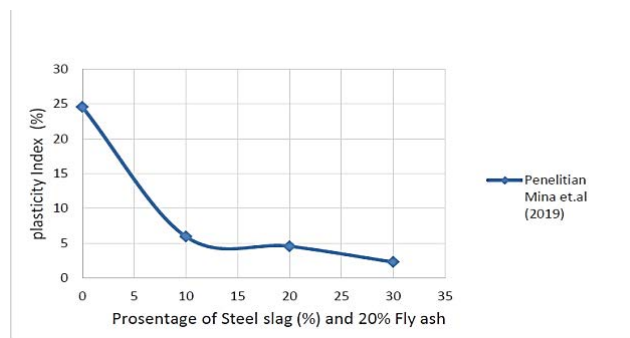
Figure 5. Graph of relation between plasticity index and Percentage of additive materials
(Source: Author, 2019)

4.4. Discussion
The results of this research regarding stabilization of soil from Kp. Kadusentar road, Medong Village, Pandeglang using fly ash and steel slag has the highest CBR value compared to two other previous studies is shown on **Table 3**. Previous research by Karimah [4] has the smallest CBR value compared to the other two studies. This proves that the more percentage of additives used, the more it will increase the CBR value. Thus also it can be concluded that the use of fly ash and steel slag besides being able to increase the CBR value is also able to improve the physical properties of clay by reducing the plasticity index value.

Table 4. Comparison with previous research based on percentage of material additives

Research	Fly Ash (%)	Steel slag (%)	CBR Optimum
Karimah [4]	3.75	1.25	7.283
Rahmadya [5]	7.5	2.5	8.316
Author	20	20	26.139

(Source: Author, 2019)

5. Conclusion and Suggestion

5.1. Conclusion
Based on the results of this study it can be concluded that based on the USCS classification system, original soil samples can be classified as MH class, non-organic clay which has high plasticity index 24.59%. Those are categorized as very poor soil. The initial CBR value of soil was 3.524% categorized as poor to fair base soil. The addition of fly ash and steel slag can increase CBR value which reach optimum value 26.14% at variation of 20% fly ash and 20% steel slag with 7 days ripening period. This soil can be categorized as good subbase. The addition of fly ash and steel slag also can decrease soil plasticity index where at the variation of 20% fly ash with 20% steel slag the plasticity index value become 4.57%.

5.2. Suggestions
This study can be developed using CBR for soaked condition to find out the maximum CBR value in saturated soil. The results can be applied when the area has flood risk. The development can be continued by adding admixture of other materials besides steel slag and fly ash, in the form of other mixtures such as salt, ceramic industrial waste, textile solid waste (sludge), chemical solutions (NaOH, H2SO4, H3PO4) and etc.

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