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Utilization of coal fly ash to enhance the bearing capacity of road base

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Abstract. Coal is responsible for the generation of around 38 percent of the power that is used throughout the entire planet. In the last two decades, there has been a rise in the number of chances for recycling and usage of fly ash from coal combustion due to its hydrophobic and cementitious properties. However, there is still limited commercialization of coal fly ash (CFA) in road construction. The focus of this research is to determine the bearing capacity of a CFA-treated crusher run used as a road base course. In order to determine the appropriate percentage of CFA, the crusher run was mixed with various percentages of Class F CFA, including 10%, 15%, 20%, and 25%. The proctor Compaction test (PCT), soaked and unsoaked California Bearing Ratio (CBR) tests, and Unconfined Compressive Strength Test (UCST) were then used to evaluate the bearing capacity of the CFA-treated crusher. The result shows that as the percentage of CFA increased, the Optimum Moisture Content (OMC) and Maximum Dry Density (MDD) decreased compared with the control specimen. The soaked and unsoaked CBR of the CFA-treated crusher run with 20% CFA increased by approximately 32% and 26% respectively that of the control specimen. Therefore, it is proven that utilization of CFA up to 20% into crusher run could enhance the bearing capacity of the road base.

Keywords: Coal Fly Ash, CBR test, Crusher run, Bearing Capacity.

1. Introduction

After gas, coal is fast gaining favour as a power source for producing electricity, and the upward direction in coal consumption is expected to continue, owing to strong electricity demand. The rise in coal demand has led to an increase in the types of industrial waste generated [1][2]. where the annual output of coal ash worldwide has been over 600 million tonnes during the previous decade, with fly ash accounting for approximately 500 million tonnes, or 75-80% of total ash produced [3]. As civil

engineers, we believe that recycling or utilising these byproducts in civil engineering works is the best alternative for long-term development. However, there hasn't been much research into the usage of coal fly ash in road construction. where fly ash can improve the base course's performance, according to a small number of studies. According to Ashutosh & Sujit, adding more interfaces and layering soil stabilisation with CFA produced a robust material for the subgrade of roads and runways [4]. In addition, when used as a road subbase, fly ash can raise the soil's strength and bearing capacity while lowering some geotechnical properties like compressibility, permeability, and swelling capacity. [5]. According to Lakshmi et al (2020), found that adding FA enhanced the CBR value by 28 percent when compared with contral sample [6].
In this study, CFA was added to crusher run in various percentages to determine the bearing capacity of CFA-treated crusher run used as road base materials and compare performance to untreated crusher run. The laboratory tests performed were Proctor Compaction Test (PCT), California Bearing Ratio (CBR), and unconfined compressive strength Test (UCST).

2. Materials

2.1. Crushed Run

The crushed run was sourced from Hanson Quarry's inventory in Kulai, Malaysia. The crushed run properties and particle size distribution, as shown in table 1 and figure 1, met all of the Malaysia Public Work Department's specifications [7]. In Johor Malaysia, crushed run with a top size of 50.00 mm is most typically utilised as a base course in road construction.

2.2. Coal Fly Ash (CFA)

Tanjung Bin coal power thermal facility in Johor provided coal fly ash (CFA). As shown in table 2, the CFA used in this investigation was classified as type F according to ASTM C 618 [8], with a value greater than 70% of total elements 65.9% of SiO_2, 19.7% of Al_2O_3, and less than 5% of CaO (3.29%).

Table 1. The crushed run properties

Aggregate Testing	Standard Method	Results	Value
Specific Gravity	ASTM C 128	2.81	-
Aggregate Impact Value (%)	BS EN 1097-2	12.73	<30
Aggregate Crushing Value (%)	BS EN 1097-2	16.47	<30
Los Angeles Abrasion (%)	AASHTO T96	17.4	<45
Flakiness (%)	BS EN 933-3	19.4	<25
Elongation (%)	BS 812	23.18	<25

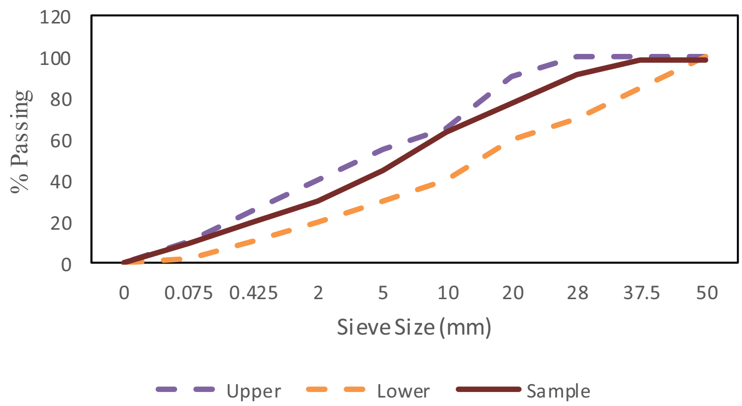

Figure 1. The crusher run gradation

Table 2. The chemical component of CFA

Component	% CFA
Al2O3	19.7
SiO2	65.9
Fe2O3	5.82
TiO2	1.21
Na2O	1.28
MgO	0.958
SO3	0.322
K2O	1.52
CaO	3.29

2.3. Preparation of Mixing Proportion
The crushed run was mixed with CFA in five different percentages in this study. Table 3 gives an explanation of the mix composition ratios.

Table 3. The mixture composition ratios

Specimens	CFA %
CR	0
CR-10CFA	10
CR-15CFA	15
CR-20CFA	20
CR-25CFA	25

3. Mixture Testing

3.1. Proctor Compaction Test (PCT).
The modified PCT was used to determine the optimum moisture content (OMC) and maximum dry density (MDD) in accordance with ASTM D 1557 [9]. Samples were compressed in a 152 mm mold in five layers with 56 blows each using a 4.5 kg rammer that was dropped from a height of 45.7 cm. The 19-mm sieve retains around 23% of the crushed run. Every material used for compaction must pass a 19 mm sieve according to ASTM D 1557 [5], so any sample material that remained on the sieve was removed before compaction. Table 4 shows the OMC and MDD values for the untreated crushed run and CR-CFA mixtures.

3.2. California Bearing Ratio (CBR).
CBR testing was conducted per ASTM D 1883 [10] on untreated crusher run and CFA-treated crusher specimens. Using the CBR testing machine, the samples were evaluated for CBR in both unsoaked and soaked conditions. After compacting, the untreated crusher run and CFA-treated crusher sample were soaked for four days in a drum of water under a 4.54 kg surcharge. During the CBR testing, the piston pushed 1.27 mm into the specimens each minute, and a calibrated load indicating the device was utilised to push the penetration piston with a diameter of 50 mm into the specimen, as required by ASTM D 1883 [6]. Due to technology limitations, the specimens' penetration resistance was determined up to a penetration of 7.50 mm.

3.3. Unconfined Compressive Strength Test (UCST).
ASTM D 1633 [11] was used to evaluate the unconfined compressive strength of untreated crusher specimens and the crusher specimens that had been treated with CFA. Standard-sized samples were

made accorden with ASTM D 1633 [7] for each of the CFA contents. CFA-treated crusher samples were compressed at a rate of 0.21 percent per minute until the samples failed.

4. Result and Discussion

4.1. Proctor Compaction Test (PCT).

Table 4 and figure 2 summarises the PCT of untreated crusher specimen and CFA-treated crusher specimens. OMC decreased from 8.9% to 7.2 percent and subsequently increased to 7.6% as the percentage of CFA increased from 0% to 25%, while MDD decreased from 2.064 gm/cm3 to 1.972 gm/cm3. The decrease in OMC that occurred initially as a result of increasing the percentage of CFA up to 20% could be due to the finer CFA particles filling the vacuum spaces that were previously filled with water molecules in CR, resulting in a maximum percentage decrease in OMC of 19.1% compared to RC. OMC was shown to rise as CFA was increased beyond 20%, which could be attributed to water retention within the soil mass for lubricating purposes. As in previous studies [6][12], increasing CFA concentration resulted in a drop in maximum dry density, which was attributed to clay particle agglomeration and flocculation via cation exchange reaction, resulting in larger space occupied and a lower weight to volume ratio. As a result, as compared to RC, MDD decreased by 4.45% in the current study. Samples for the CBR test and UCST were prepared using the OMC and MDD.

Table 4. PCT of untreated crusher specimens and CFA-treated crusher specimens

Spesments	CFA [%]	OMC [%]	Decreased of OMC	MDD [%]	Decreased of MDD
CR	0	8.9	-	2.064	-
CR-10CFA	10	8.2	7.86	2.015	2.37
CR-15CFA	15	7.8	12.36	1.998	3.19
CR-20CFA	20	7.2	19.10	1.976	4.26
CR-25CFA	25	7.6	14.61	1.972	4.45

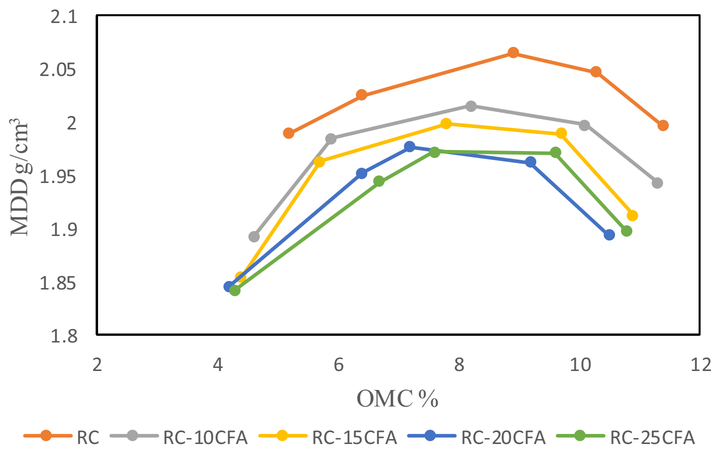

Figure 2. OMC vs MDD for all specimens

4.2. California Bearing Ratio (CBR).

Table 5 and figure 3 shows the maximum CBR and the increase for crusher specimens and CFA-treated crusher specimens. For untreated crusher specimens and CFA-treated crusher specimens, the Unsoaked CBR and Soaked CBR values are 95%, 127%, 131%, 140%, 128% and 83%, 102%, 117%, 124%, 115%, respectively. after adding the CFA. The bearing strength of CR was significantly increased. As the CFA percentage increased from 0% to 25%, the unsoaked CBR value of the untreated crusher sample was found to increase from 95% for RC to 140 with 20% CFA. In the same way, the soaked CBR value increased from 83% for RC to be 124% with 20% CFA. after which it decreased. untreated crusher with 20% CFA showed an increase in unsoaked CBR and soaked CBR values of 32% and 26%, As a result, the appropriate percentage of CFA to be blended with crushed was 20%. CFA has a low cementitious value, but in the presence of moisture, it interacts chemically and creates cementitious compounds, enhancing the specimen's strength and compressibility [5].

Table 5. CBR values of crusher specimens and CFA-treated crusher specimens

Spesments	CFA [%]	Unsoaked CBR [%]	Increased of Unsoaked CBR	Soaked CBR [%]	Increased of Soaked CBR
CR	0	95	-	83	-
CR-10CFA	10	127	25	102	19
CR-15CFA	15	131	27	117	22
CR-20CFA	20	140	32	124	26
CR-25CFA	25	128	26	115	24

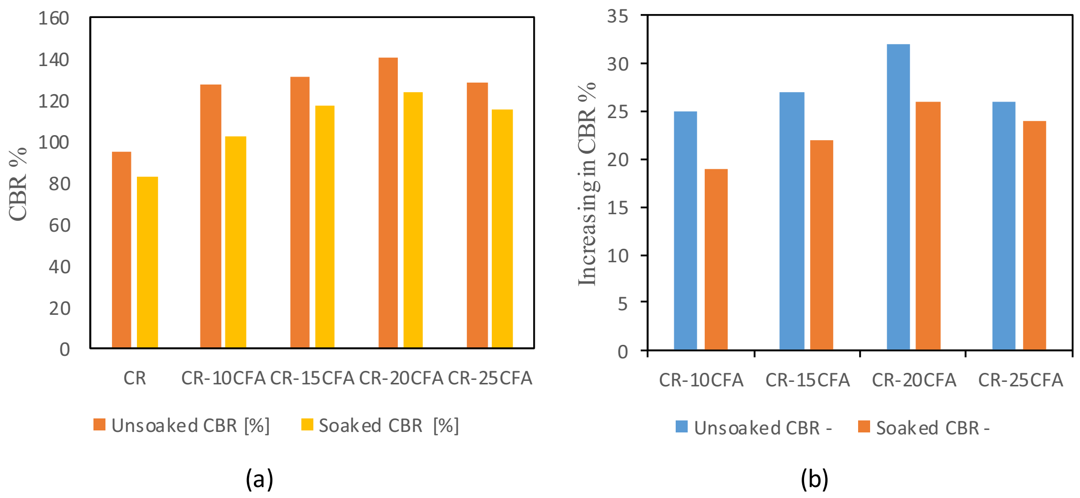

Figure 3. Graph of (a) Unsoaked & Soaked CBR, (b) Increasing in CBR values.

4.3. Unconfined Compressive Strength Test (UCST)

Table 6 and figure 4 show the findings of UCST conducted on untreated crusher specimens and CFA-treated crusher specimens and the corresponding percentage increase in strength, where The UCST increased with the increase of the CFA content: 1.36 MPa for CR-10CFA, 1.48 KPa for CR-15CFA, 1.67 KPa for CR-20CFA and 1.59 KPa for CR-25CFA respectively, and the untreated crusher specimen had 1.21 MPa. the size of CFA particles passing through the sieve 75mr was smaller compared to crushed run particles which led to voids filling and improved performance [6][13].

Table 6. UCST of untreated crushed run and CFA-treaded crusher run specimens.

Specimens	% CFA	UCST (KPa)	Increased of UCST %
CR	0	1.33	-
CR-10CFA	10	1.36	2.21
CR-15CFA	15	1.48	10.14
CR-20CFA	20	1.67	20.35
CR-25CFA	25	1.59	16.67

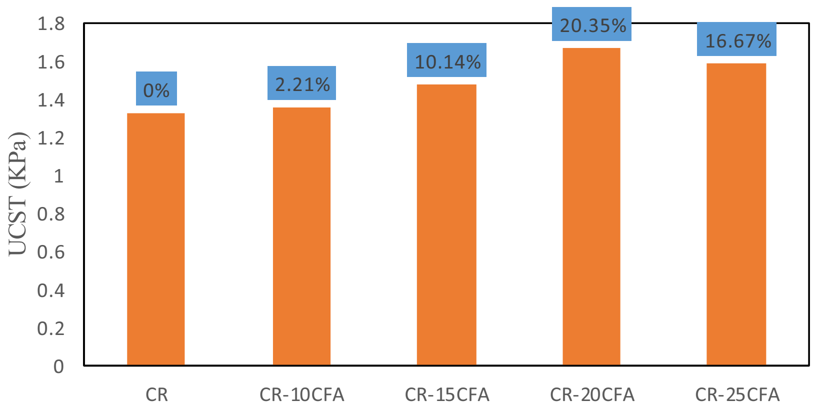

Figure 4, UCST of untreated crushed run and CFA-treaded crusher run specimens.

5. Conclusion

The tests used in this investigation comprised a proctor compaction test, unsoaked CBR and soaked CBR, and unconfined compressive strength tests on the untreated crushed run and CFA-treated crusher specimens in the laboratory to be used as road base course. OMC was found to initially reduce and then increase as the amount of CFA in CR was increased up to 25%, while MDD was found to decrease. The optimal proportion of CFA to add to CR was discovered to be 20%, with a maximum UCST of 1.67 KPa and maximum unsoaked and soaked CBR values of 140 % and 124 %, respectively.

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