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Use of Fly Ash as a Partial Supplement of Sand in Road Sub-grade

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Abstract: Fly ash is a byproduct causes environmental pollution. Every year remarcable amount of ferming land is used for it's disposal. But it has some geotechnical properties which we can use for civil engineering pueposes. The present study aims at development of specifications for use fly ash in road construction and their suitability in improved sub-grade of a road pavement. Laboratory proctor Test for MDD and CBR Test for CBR values were performed at first for fly ash and sand sample alone and then for fly ash with sand in different proportions. Then the result is compared with LGED, Bangladesh requirements to find out the suitable samples for road sub-grade. According to ROAD DESIGN STANDARDS, RURAL ROAD (2005) published by LGED and JICA- required CBR for improved sub-grade material for low and medium traffic road construction is 8%. In this study it is found that, upto 40% fly ash mixed with sand gives more than 8% CBR. So, at most 40% fly ash may be used as a supplement of sand for improved subgrade.

Keywords: Fly Ash, Environmental Pollution, Improved Subgrade

1. Introduction

The Barapukuria Coal Power Plant is an existing 250 megawatt (MW) coal-fired power station which is owned and operated by the Bangladesh Power Development Board (BPDB) at Parbatipur in Dinajpur, Bangladesh. Currently the plant has two 125 MW units, but operators are seeking to add an additional 250 MW unit.

The plant was commissioned in 2006 and consumes approximately 450,000 tons of coal a year which is supplied by the nearby Barapukuria coal mine.

As there is used a huge amount of coal to produce power, there is also a huge amounto f fly ash is produced as a by-product. This coal burnt ash is not generally used for an engineering purposes, rather these wastes mostly are stored as heaps temporarily and later on sold to the cement manufacturing companies.

The liquid fly ash are drained out of the coal power plant using open drainage system. The liquid wastes flow through the drainage and get mixed with pond water outside the coal plant area. Various research studies on fly ash have been conducted in recent years to analyze the possibility of utilization of these ash, how these ash can be stored safely without causing any pollution and also how these ash can be used to prevent various kinds of environmental pollution.

In recent years, a number of researches have been conducted to determine and compare the geotechnical properties of fly ash and to analyze the feasibility of using it for engineering purposes.

Carpenter (1952) determined that fly ash had an excellent effect on the retained compressive strength for asphalt concrete specimens immersed in water.

Churchill and Amirkhanian (1999) showed that fly ash has been used extensively in concrete production; however, there are limited applications in which fly ash has been used in asphalt pavement.

Kumar *et al.* (2011) observed that, the utilization of fly ash in concrete as partial replacement of cement is gaining immense importance today, mainly on account of the improvement of the long term durability of concrete combined with ecological benefits. Technological improvements in thermal power plants operation and fly ash collection systems have resulted in improving the consistency of fly ash. To study the effect partial replacement of cement by fly ash, studies have been conducted on concrete mixes with 300 to 500 kg/cum cementing material sat 20%, 30%, 40% and 50% replacement level. In their work the effect of fly ash on workability, setting time, density, air content, compressive strength, modulus of elasticity, shrinkage and permeability by Rapid Chloride Permeability Test (RCPT) are studied.

Liu *et al.* (2007) investigated the accumulation of selenium in tree rings from a high selenium producing coal combustion area in China. They noted that selenium is one of the most toxic and volatile trace elements emitted during coal production and that selenium present in scrubber stock piles poses an environmental hazard to the health of humans as well as plants and animals. For this study, Liu *et al.* chose trees as bio- indicators of enhanced selenium deposition. Two sites were sampled (YV and YM) where high-selenium coal was known to be the primary fuel source both for energy production, cooking and heating.

Long *et al.* (1999) examined growth variations of white oak (Quercusalba L.) trees that were subjected to historic levels of fluctuating air pollution from a coal-fired power plant in Pennsylvania that began operations in 1954. Growth variations in white oak were compared between 3 in- close sites and 3 control sites located 10–50 km away from the power plant. They noted that stack height sat the plant varied through time and hypothesized that differ in gastack heights influenced ground pollution levels, primarily SO_2. Results indicated that when the stacks were at the lowest height, pollution was the greatest. White oak at two in-close sites showed a growth reduction during this time, while the third site showed no impact. In 1976, taller stacks were constructed, reducing ground-level contaminants. Increased growth response sat two in-close affected sites were noted from 1976–1985. Growth rates after 1976 for white oak, at all three in-close sites, were comparable to growth rates of white oak growing at the control sites. Long *et al.* Noted that the mid-1960s drought could have been anointer acting factor that contributed to suppressed radial growth.

SankaranandRao (1973) found that, additions of fly ash provided higher stability for asphalt mixtures.

Tapkin (2008) found that, addition of fly ash provided higher stability for asphalt mixtures.

2. Objectives and Scope of Study

There produces a huge amount of fly ash as a by-product in Barapukuria Coal Power Plant, which is being dumped to nearby open field, pond or open sewage. This open disposal system is injurious to human and animal health as well as to environment. To minimise this problem suitable engineering management system of these refuses is essential. The present study aims at development of specifications for use of these power plant fly ash in road construction and their suitability in sub-grade and improved sub-grade of a road pavement. All the laboratory tests were conducted in accordance with relevant codes. Fly ash from Barapukuria Coal Power Plant has been studied.

3. Methodology

The study was based on materials collection, laboratory test (Unit Weight Test, Specific Gravity Test, Fineness Modulus Test, Modified proctor Test, California Bearing Ratio Test) and compare the values with LGED standards.

Sand (Fineness Modulus = 2.30) was collected from Talaimari, Rajshahi, Bangladesh and Fly ash was collected from The Barapukuria Coal Power Plant, Dinajpur, Bangladesh. The following ingredients were found in fly ash

Table 1. *Ingredients of fly ash.*

No.	Items	Values (%)
1	SiO_2	54.4
2	Al_2O_3	35.6
3	Fe_2O_3	2.9
4	Mn_3O_4	0.11
5	CaO	0.56
6	MgO	0.18
7	K_2O	0.66
8	Na_2O	0.06
9	SO_3	0.13
10	TiO_2	3.2
11	P_2O3	0.46

The CBR is a measure of resistance of a material to penetrate of a standard plunger of 50 mm diameter under controlled density and moisture conditions.

It is the ratio of force per unit area required to penetrate a soil mass with standard circular piston at the rate of 1.25 mm/min. to that required for the corresponding penetration of a standard material. The test is conducted by causing a cylindrical plunger of some diameter to penetrate a pavement component material at 1.25 mm/minute. The loads, for 2.5 mm and 5mm are recorded. This load is expressed as a percentage of standard load value at a respective formation level to obtain CBR value. The values are given in the table below:

Table 2. *Unit load for different penetration level.*

Penetration(mm)	Standard load(kg)	Unit load(kg/cm²)
2.5	1370	70
5.0	2055	105
7.5	2630	134
10.0	3180	162
12.5	3600	183

In this study CBR (soaked) test was conducted according to ASTMD 1883-Standard test method for determination of California bearing ratio of soil.

The Proctor compaction test is a laboratory method of experimentally determining the optimal moisture content at which a given soil type will become most dense and achieve its maximum dry density. The term Proctor is in honor of R.R. Proctor, who in 1933 showed that, the dry density of a soil for a given compaction effort depends on the amount of water the soil contains during soil compaction. His original test is most commonly referred to as the standard Proctor compaction test; later on, his test was updated to create the modified Proctor compaction test.

In this study Modified Proctor Test was conducted according to Modified Proctor (ASTM D 1557)– Modified rammer using 5 layer sand 25 blows per layer.

4. Results

Proctor Test:

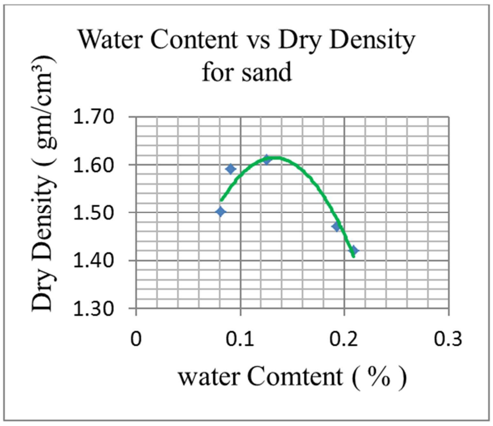

Figure 1. *Graph showing variation of Dry Density with WC for Sand.*

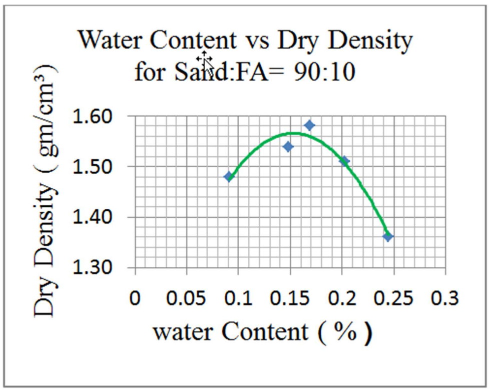

Figure 2. *Graph showing variation of Dry Density with water Content for sample (sand: fly ash = 90:10).*

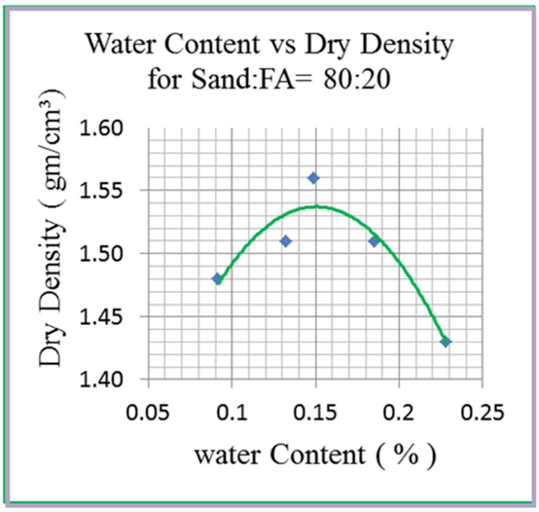

Figure 3. *Graph showing variation of Dry Density with water Content for sample (sand: fly ash= 80:20).*

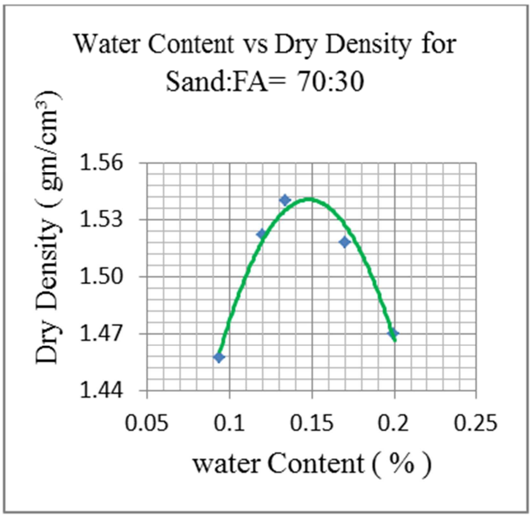

Figure 4. *Graph showing variation of Dry Density with water Content for sample (sand: fly ash=70:30).*

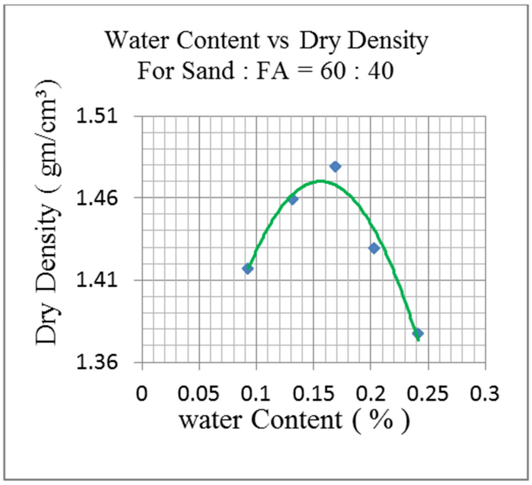

Figure 5. *Graph showing variation of Dry Density with water Content for sample (sand: fly ash=60:40).*

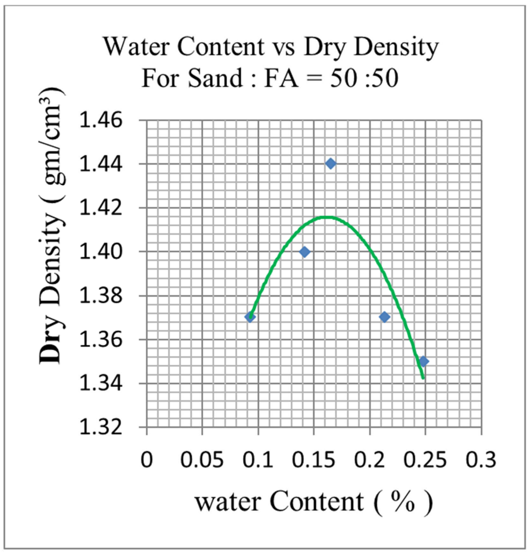

Figure 6. *Graph showing variation of Dry Density with water Content for sample (sand: fly ash=50:50).*

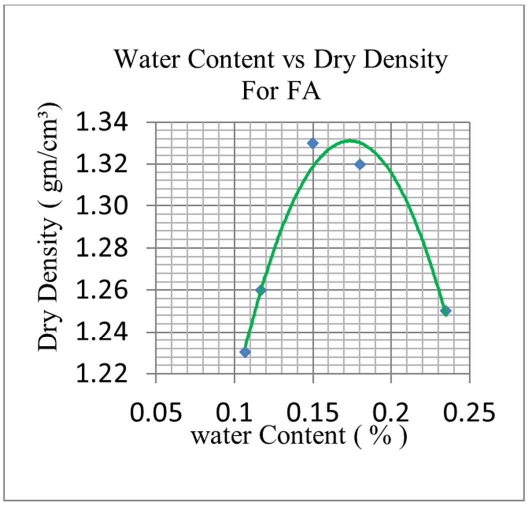

Figure 7. *Graph showing variation of Dry Density with water content for Fly Ash.*

CBRTest:

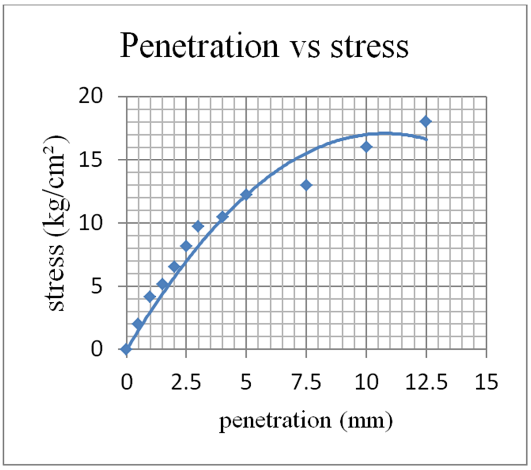

Figure 8. *Graph showing variation of stress with penetration for sand.*

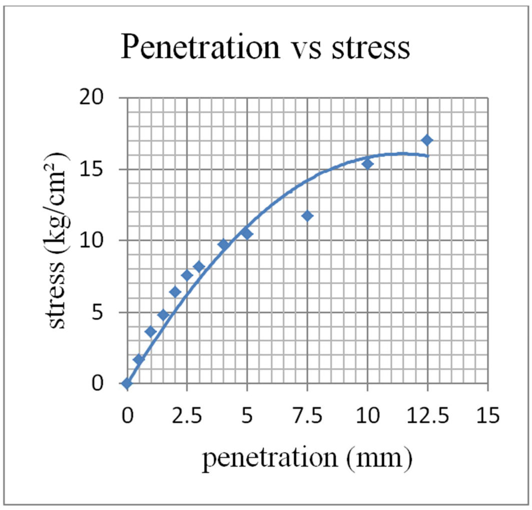

Figure 9. *Graph showing variation of stress with penetration for Sample (90% Sand:10% Fly Ash).*

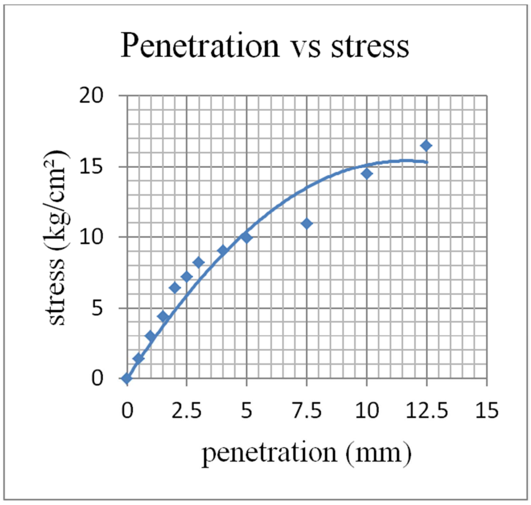

Figure 10. *Graph showing variation of stress with penetration for Sample (80% Sand: 20% Fly Ash).*

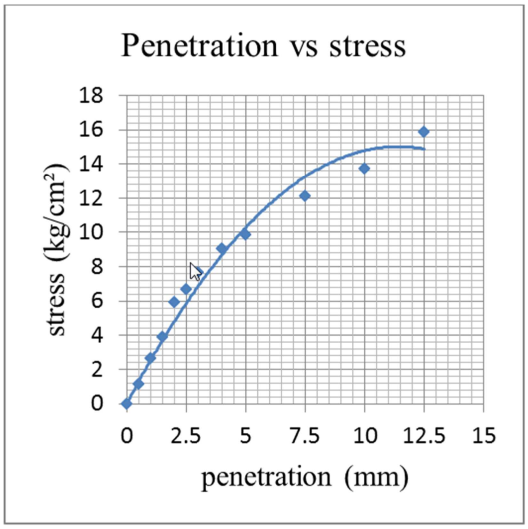

Figure 11. *Graph showing variation of stress with penetration for Sample (70% Sand: 30% Fly Ash).*

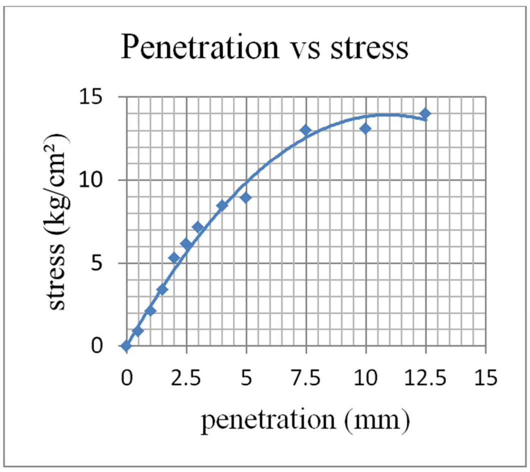

Figure 12. *Graph showing variation of stress with penetration for Sample (60% Sand: 40% Fly Ash).*

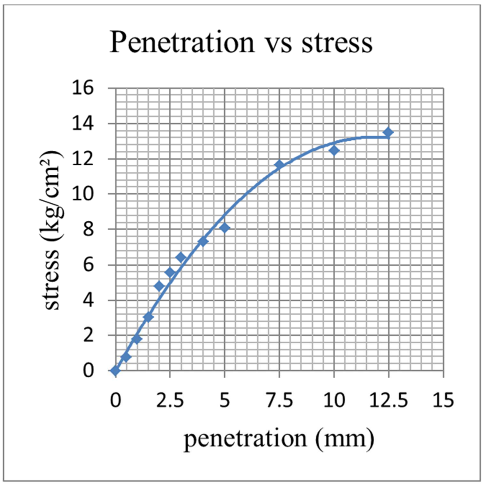

Figure 13. *Graph showing variation of stress with penetration for Sample (50% Sand: 50% Fly Ash).*

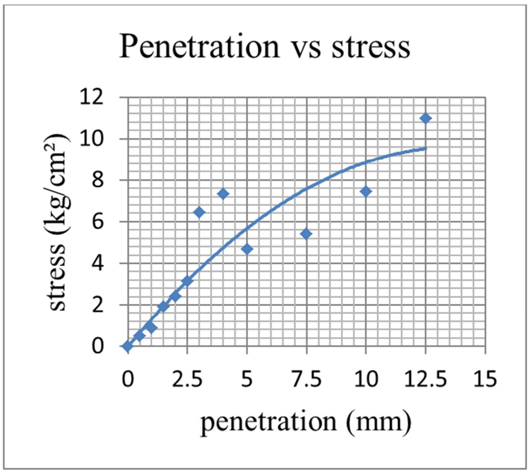

Figure 14. *Graph showing variation of stress with penetration for Fly Ash.*

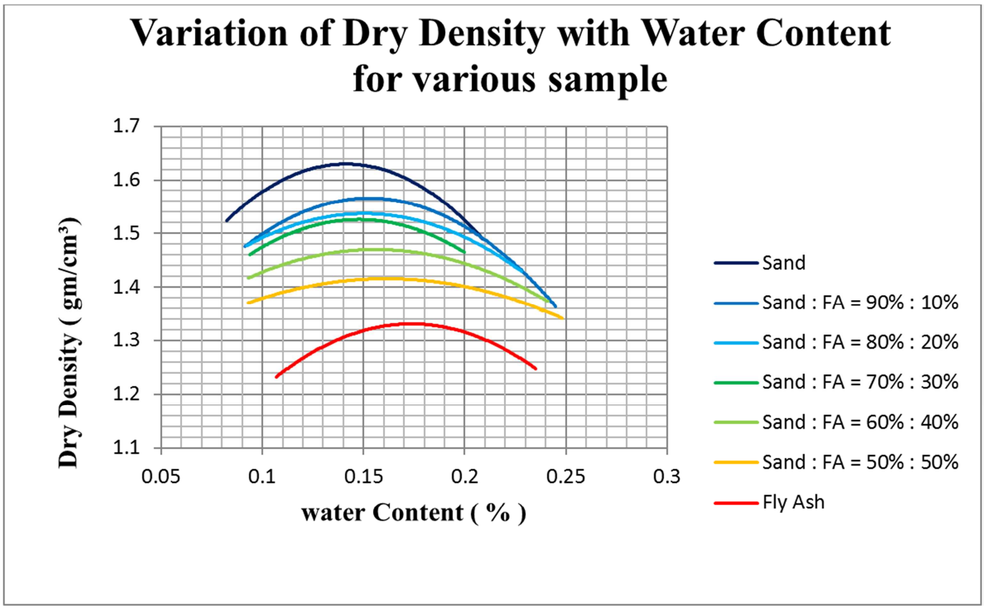

Figure 15. *Graph showing variation of Dry Density with water Content for various sample.*

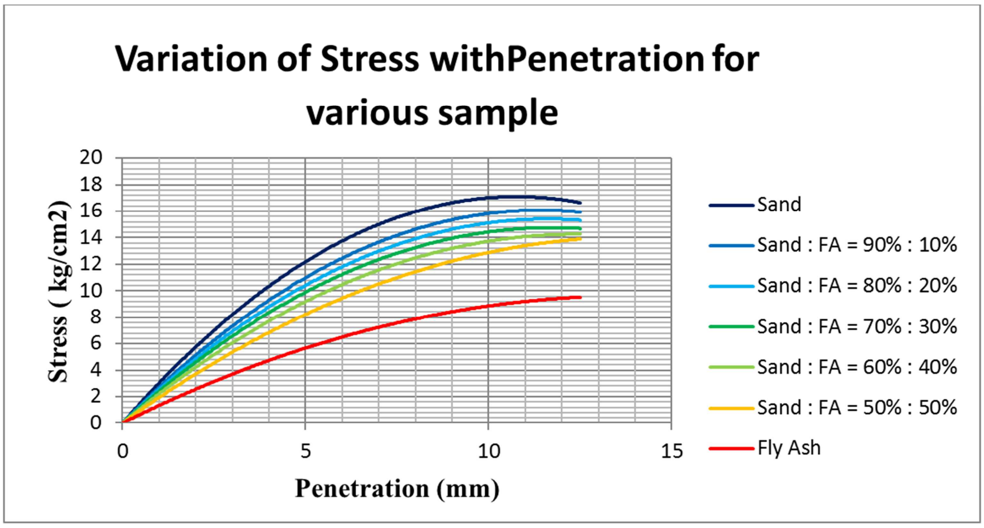

Figure 16. *Graph showing variation of stress with penetration for various Sample.*

Table 3. *Specific Gravity and Unit Weight of the samples.*

Sample	Specific Gravity	Unit Weight (gm/cm^3)	
		Loose	Compacted
Sand	2.46	1.24	1.46
Fly Ash	2.30	0.94	1.19

Table 4. *MDD and CBR % of various sample.*

Samples	MDD(gm/cm^3)	CBR(%)
Sand	1.61	11.69
90%sand:10%Flyash	1.58	10.79
80%sand:20%Flyash	1.56	10.25
70%sand:30%Flyash	1.54	9.54
60%sand:40%Flyash	1.47	8.81
50%sand:50%Flyash	1.44	7.92
Fly ash	1.33	4.50

It is obvious from the table that, with the increase of fly ash in the sample both the value of MDD and CBR percentage is decreasing. Now, According to ROAD DESIGN STANDARDS, RURAL ROAD (2005) published by LGED and JICA–

Table 5. *LGED requirement for road construction materials.*

Pavement layer	Minimum CBR (Lab. Test after 4 days soaking)	Typical materials likely to meet specification
Sub-base	30%	Brick, bricks and mixture, broken concrete etc
Improved Sub-grade	8%	Usually locally occuring fine sand
Sub-grade	4%	Natural soil of low plasticity

According to LGED requirement, minimum CBR required for improved sub-grade materials is 8%, and from the table it is seen that, up-to 40% fly ash mixed with sand has a CBR value more than 8%.

5. Conclusion

From the above study we can reach in the following decisions:

Specific gravity of sand and fly ash is 2.46 and 2.30 respectively and compacted unit weight 1.46 and 1.19 gm/cm^3 respectively.

With the increase of percentage of fly ash, value of maximum dry density is decreasing and, CBR value decreases with the increase of percentage of fly ash.

According to ROAD DESIGN STANDARDS, RURAL ROAD (2005) published by LGED and JICA, up-to 40% fly ash mixed with sand can be used as a improved sub-grade materials.

Abbreviation

MDD = Maximum Dry Density
CBR = Californiya Bearing Ratio
LGED = Local Government Engineering Department
JICA = Japan International Cooperation Agency

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