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EFFICACY OF DOLIME FINE STABILIZED RED MUD-FLY ASH MIXES AS SUBGRADE MATERIAL

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ABSTRACT

Red mud is an industrial solid waste produced during the production of alumina. The effects of dolime fine on compaction properties, unconfined compressive strength (UCS), soaked California bearing ratio (CBR) and durability of red mud stabilized with optimum percentage of fly ash have been discussed in this paper. Modified Proctor compaction and UCS tests were conducted on red mud -fly ash mixes to find the optimum percentage of fly ash (15%) for stabilization of red mud. Dolime fine was added to red mud stabilized with optimum percentage of fly ash from 0 to 12% at an increment of 2%. Modified Proctor compaction, UCS, and soaked CBR tests were conducted on dolime fine stabilized red mud-fly ash mixes. The optimum percentage of dolime fine obtained was 8%. Durability test was conducted on the sample, having optimum percentage of red mud, fly ash and dolime fine. It was observed that, the sample having optimum percentages of red mud, fly ash and dolime fine is durable. The economy of addition of fly ash and dolime fines was studied by designing a flexible pavement and found that there would be substantial savings in cost of construction if dolime fine stabilized red mud -fly ash mixes is used as subgrade in place of a low CBR soil.

Keywords: red mud, dolime fine, soaked California bearing ratio, fly ash.

1. INTRODUCTION

The cost of construction of flexible pavement in subgrade of low California bearing ratio (CBR) value is very high due to high thickness of the pavement. Removal and replacement is one of the techniques to increase the CBR of subgrade. The subgrade soil having low CBR value is removed, and replaced with soil of high CBR value, if it is available in the nearby areas economically. However it is not always possible to find soils of high CBR value to be used as subgrade over low CBR soil. Again bringing the soil from a locality where soil is used for agriculture purpose will reduce the agricultural product output. It will also create a number of depressions in the ground which may lead to land degradation, problem for communication, breeding site for mosquitoes etc. On the other hand disposal of huge amount of solid wastes produced due to different human activities create lot of geoenvironmental problems in the form of ground water, surface water and local air pollution, other than loss of valuable land near the plant site. Solid wastes can be combined to produce a composite material of high CBR value to be used as subgrade in place of soils of low CBR value.

Red mud is a solid waste produced from the aluminium industry during production of alumina from bauxite in Bayer process. The annual production of red mud in the world is 75 million tonnes [1]. Class-F fly ash is an industrial solid waste obtained from the combustion of coal in coal-fired power plants and is generally found to be a pozzolanic material. Dolime fine is another solid waste produced while crushing large dolomite stones to get dolomite chips for use in different industrial processes, it is rich in CaO content. Dolime fine has been recommended by IRC: 88-1984 [2] as a binding agent that can replace pure lime [3]. The disposal of these three solid wastes always creates problem. The CBR value of red mud is very low and it is dispersive in nature. Stabilization using solid wastes is one of the different methods of improving the engineering properties of soil. Similar techniques can be adopted for improving the strength and durability of red mud. Red mud can be combined with a pozzolanic material fly ash and a binder dolime fine to form a composite material red mud-fly ash-dolime fine to use it as a subgrade in place of soils of low CBR value.

Red mud has been stabilized using different materials by various researchers for geotechnical applications. Jain *et al*. [4] had studied the engineering properties of red mud-fly ash mixes and had found the optimum percentage of fly ash as 10%. Rao *et al.* [5] had also stabilized red mud with ground granulated blast furnace slag (GGBS) and lime and had found the optimum dose of lime as 6% and GGBS as 20%. Satayanarayana *et al.* [6] had stabilized red mud with lime to find its suitability in road construction and found 10% lime as optimum. Paramkusam *et al.* [7] had studied the effect of waste plastic on CBR of red mud and fly ash stabilized red mud (50% red mud +50% fly ash) and had found optimum percentage of waste plastic as 2%. Singh *et al.* [8] had stabilize red mud using cement kiln dust for finding its suitability for road construction and found that red mud stabilized with 8% cement kiln dust as optimum. Sahoo and Chowdhary [9] had increased the CBR of red mud using a single geogrid layer by varying the embedment

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depth and found the optimum depth equal to the diameter of CBR loading plunger. However very little efforts have been made to study the effects of dolime fines on engineering properties of fly ash stabilized red mud.

The objective of the present investigation is to study the effects of dolime fines on compaction, UCS, soaked CBR, and durability of red mud stabilized with optimum percentage of fly ash and evaluate efficacy of the mix as a subgrade material.

2. MATERIALS AND METHODS

2.1 Materials

The materials used in the test programme are Red mud, Fly ash, and Dolime fines.

Red mud

The red mud used in the experimental programme was collected from an aluminium plant located in Odisha, India.

The geotechnical properties of red mud are:

i) Specific gravity- 3.12
ii) Grain size analysis: Gravel size -0 %, Sand size - 6 %, silt and clay size -94 %
iii) Liquid limit- 29%
iv)Plastic limit-23 %
v)Plasticity index-6 %
vi) Compaction properties (Modified Proctor)- Optimum moisture content (OMC)-18.3%,maximum dry density (MDD)-21.2 kN/m^3
vii)Unconfined compressive strength(UCS) –137 kN/m^2
viii) Soaked CBR- 1.72 %.

Fly ash

The fly ash used in the experimental programme was collected from a power plant located in Odisha, India. It is a class-F fly ash, the major Chemical compositions of the fly ash are: CaO - 0.17%, Al_20_3 - 22.26%, SiO_2-75.39%, and Fe_2O_3 - 0.51%.

Dolime fine

Dolime fines (having CaO=52.31%) were made by crushing dolomite chips and fines passing 425 micron sieve is used in the experimental programme.

2.2 Methods

Fly ash was added to red mud from 0 to 25 % at an increment of 5%. Modified Proctor compaction tests were conducted on red mud-fly ash mixes to obtain OMC and MDD to prepare samples for UCS tests. UCS tests were conducted on red mud - fly ash mixes. The optimum percentage of red mud obtained was 15%. Dolime fines were added to red mud stabilized with optimum percentage of fly ash mixes, from 0 to 12% at increment of 2% by replacement of red mud with dolime fines. Modified Proctor compaction, UCS, soaked CBR, and durability tests were conducted on red mud-fly ash-dolime fine mixes. All tests were conducted after 7 days of curing except compaction tests. Compaction, UCS, and soaked CBR tests were conducted according to relevant Indian standard codes. Modified Proctor tests were conducted without curing of the samples.UCS tests were conducted after 7 days of curing and soaked CBR tests were conducted after 7days of curing and 96 hours of soaking under a surcharge of 5Kg. Compaction tests were conducted to find OMC and MDD to prepare samples for UCS and soaked CBR tests. The tests were conducted according to the procedures given in relevant Indian standard (IS) Codes. Durability tests were conducted on UCS samples having optimum percentages of red mud, fly ash and dolime fine and after 7 days of curing. The samples were subjected to 6 wet-dry cycles. The samples were submerged in water for 5 hours and then it was placed in oven for 42 hours at 70^0 C which constitutes one wet-dry cycle. After each wet-dry cycle the volumetric strains were measured. Samples were rejected having volumetric strain more than 10%. UCS tests were conducted on the samples after completion of each cycle. For each proportion of red mud, fly ash and dolime fine 3 samples were prepared and the average value of the three test results was recorded.

3. ANALYSIS OF TEST RESULTS

Figure-1 shows the variation of MDD of red mud with fly ash. From the figure it is found that the MDD goes on decreasing with increase in percentage addition of fly ash. The MDD decreases due to replacement of red mud particles having high specific gravity (3.12) with fly ash particles having low specific gravity (2.21).

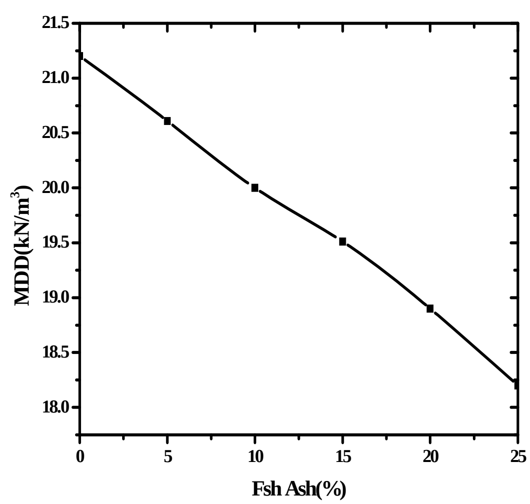

Figure-1. Variation of MDD with fly ash (%).

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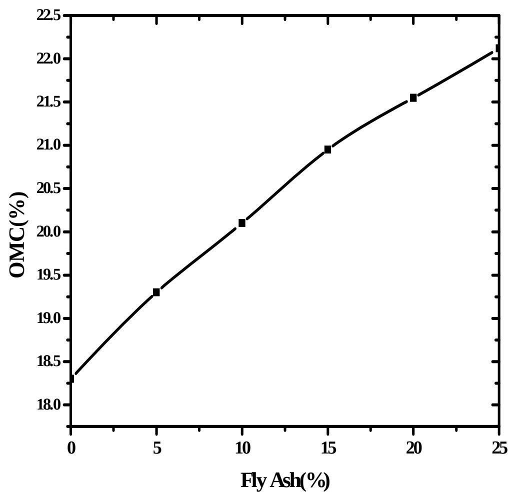

Figure-2. Variation of OMC with fly ash (%).

Figure-2 shows the variation of OMC of red mud with fly ash. From the figure it is found that the OMC goes on increasing with increase in percentage addition of fly ash. The OMC increases as fly ash absorbs more water than red mud.

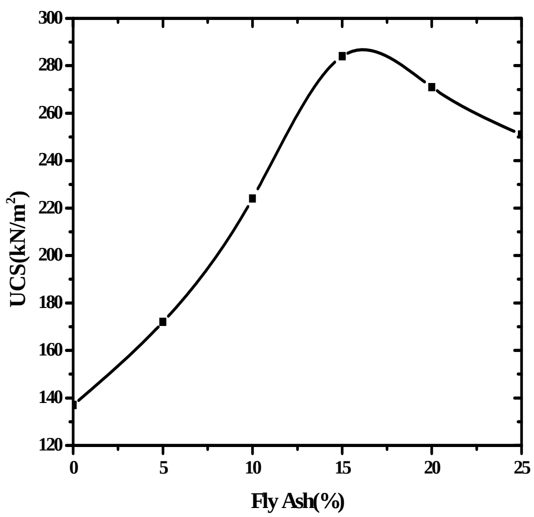

Figure-3. Variation of UCS with fly ash (%).

Figure-3 shows the variation of UCS of red mud with fly ash. From the figure it is found that the UCS goes on increasing up to 15% addition of fly ash thereafter it decreases. The UCS increases due to better packing of red mud -fly ash mixes.

From the UCS test results the optimum percentage of fly ash for stabilization of red mud is found to be 15%.

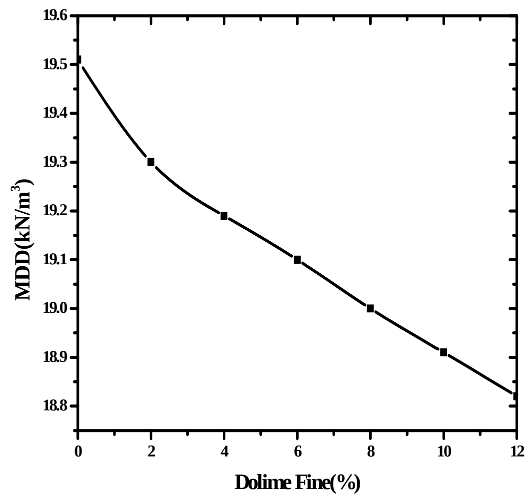

Figure-4. Variation of MDD of red mud-fly ash mixes with Dolime fine (%).

Figure-4 shows the variation of MDD of red mud - fly ash mixes with dolime fines. From the figure it is found that the MDD of red mud-fly ash mixes goes on decreasing with increase in percentage addition of dolime fines. The MDD decreases due to addition dolime fines, as it contains sufficient CaO it reacts with alumina and silica present in red mud-fly ash mixes, flocculation and agglomeration of red mud-fly ash particles occur and occupy large space leading to a decrease in dry density of red mud-fly ash mixes and MDD decreases.

Figure-5 shows the variation of OMC of red mud - fly ash mixes with dolime fines. From the figure it is found that the OMC of red mud-fly ash mixes goes on increasing with increase in percentage addition of dolime fines. The OMC increases due to addition of dolime fines, as more percentage of CaO is available more water is required for reactions to occur between alumina and silica of red mud-fly ash mixes with CaO of dolime fines.

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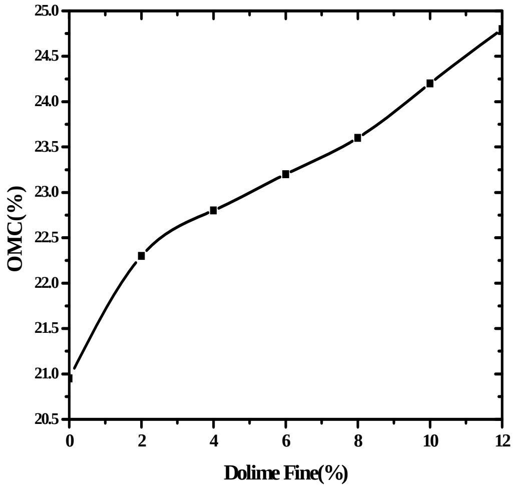

Figure-5. Variation of OMC of red mud-fly ash mixes with Dolime fine (%).

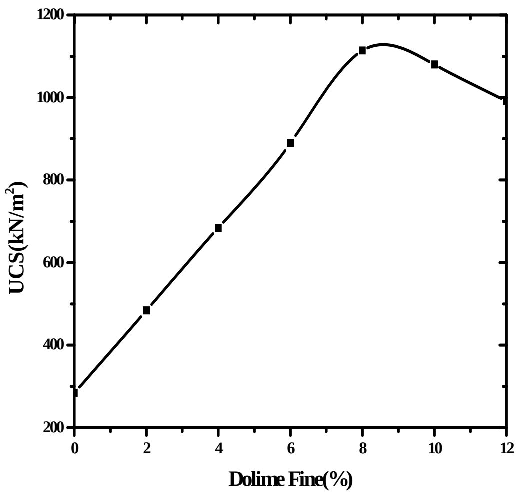

Figure-6. Variation of UCS of red mud-fly ash mixes with Dolime fine (%).

Figure-6 shows the variation of UCS of red mud - fly ash mixes with dolime fines. From the figure it is found that the UCS of red mud-fly ash mixes goes on increasing with increase in percentage addition of dolime fines up to 8% thereafter it decreases. At optimum the UCS has the value of 1114 kN/m^2 an increase of approximately 292% as compared to fly ash stabilized red mud and an increase of 713% as compared to virgin red mud. The UCS increases because of the development of pozzolanic reaction between the alumina and silica present in red mud-fly ash mixes with the CaO present in dolime fines, the UCS decreases due to excess addition of dolime fines resulting excess CaO to react with insufficient alumina and silica of red mud-fly ash mixes resulting carbonation reaction and the strength decreases.

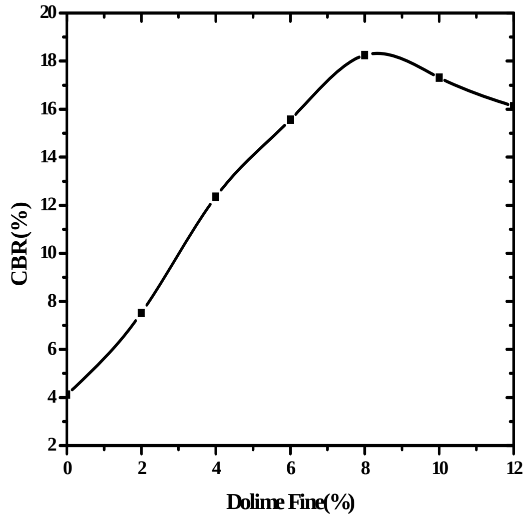

Figure-7. Variation of CBR of red mud-fly ash mixes with Dolime fine (%).

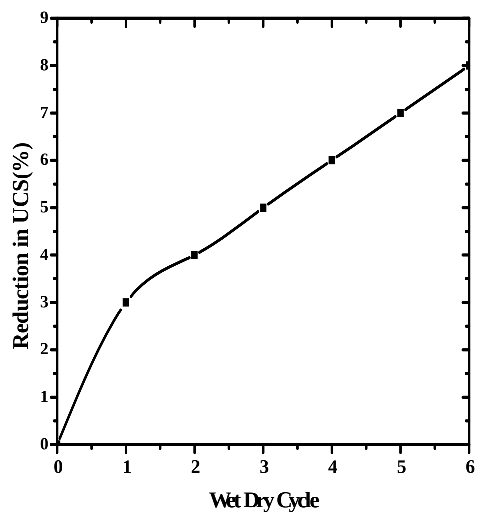

Figure-8. Reduction in UCS (%) of red mud-fly ash-dolime fine mix with Wet-Dry cycle.

Figure-7 shows the variation of soaked CBR red mud - fly ash mixes with dolime fines. From the figure it is found that the soaked CBR of red mud-fly ash mixes goes on increasing with increase in percentage addition of dolime fines up to 8% thereafter it decreases. At optimum the soaked CBR has the value of 18.25% an increase of 343% as compared to fly ash stabilized red mud and an increase of 961 % as compared to virgin red mud. The increase and decrease of soaked CBR occurs due to similar reasons as discussed in UCS test results.

The red mud-fly ash mix was unable to survive any wet-dry cycle due to lack of any binding material with it. However red mud-fly ash mix stabilized with 8%

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dolime fine and cured for 7 days was able to survive the wet-dry cycles. Figure-8 shows the percentage reduction in UCS of red mud- fly ash mix stabilized with 8% dolime fine and cured for 7 days, with wet-dry cycles. After 6 wet-dry cycles, the percentage reduction in UCS is 8%. Hence the dolime fine stabilized red mud fly ash mix is durable. The red mud fly ash mix after addition of optimum quantity of dolime fine becomes stronger and hence the wet-dry cycles had not reduced the UCS of soil substantially.

From the analysis of test results it is found that the optimum percentages of fly ash and dolime fine for stabilization of red mud are 15% and 8% respectively.

4. UTILIZATION OF RED MUD-FLY ASH-DOLIME FINE MIXES AS SUBGRADE MATERIAL

The red mud-fly ash- dolime fine mix at optimum proportion can be used as a subgrade of a flexible pavement in place of soil having low CBR value. If the red mud-fly ash- dolime fine mix at optimum proportion having soaked CBR value of 18.25% is used as subgrade of 500 mm thickness and the soil below the subgrade is having a soaked CBR value of 3%, then according to IRC: 37-2012, "Tentative guide lines of the Design of Flexible Pavements" [10] the effective soaked CBR is found to be 10%. The economy of using red mud-fly ash- dolime fine mix as subgrade has been studied by designing a flexible pavement for a traffic intensity of 5, 10, 20 and 30 Million Standard Axles(MSA) resting over soil having soaked CBR =3%, and red mud-fly ash- dolime fine mix subgrade. The design soaked CBR of red mud- fly ash-dolime fine subgrade has been taken as 10%, assuming the soil below it has soaked CBR value of 3% from IRC: 37-2012 [10].

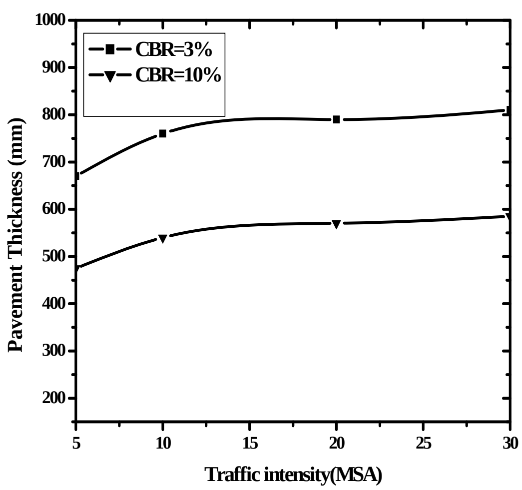

Figure-9. Thickness of the Pavement resting on Subgrade having CBR of 3% and CBR of 10%.

Figure-9 shows the thickness of flexible pavement resting over subgrade having soaked CBR=3% and pavement resting over red mud-fly ash-dolime fine subgrade.

Figure-10 shows the reduction in pavement thickness due to red mud-fly ash-dolime fine subgrade. The percentages reductions in thickness for traffic intensity of 5, 10, 20, 30 MSA are 195%, 220 %, 220% and 225 % respectively. Reduction in pavement thickness is saving in cost of construction of pavement.

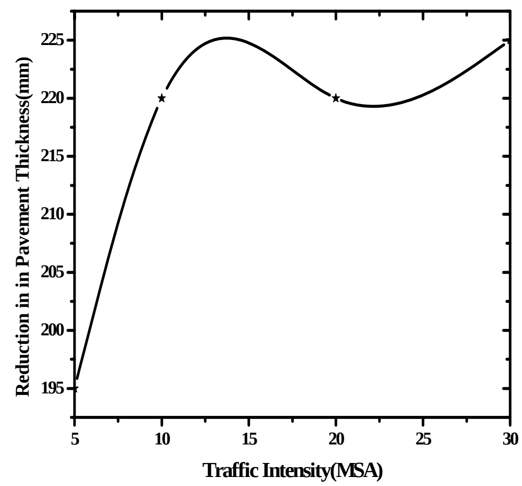

Figure-10. Reduction in thickness of the Pavement with Traffic intensity (MSA).

5. CONCLUSIONS

A series of laboratory tests were conducted to study the effect of dolime fine on compaction properties, UCS, soaked CBR and durability of red mud stabilized with optimum percentage of fly ash, and to study the potential utilization of red mud-fly ash-dolime fine mix as subgrade material in place of low CBR soil. The following conclusions are drawn from this study.

a) The optimum percentage of fly ash required for stabilization of red mud is found to be 15% based on compaction and UCS test results.
b) The addition of dolime fines to, red mud stabilized with optimum percentage of fly decreases the MDD and increases the OMC. MDD goes on decreasing and OMC goes on increasing irrespective of the increase in percentage addition of dolime fines.
c) The addition of dolime fines to red mud stabilized with optimum percentage of fly ash increases the UCS. The UCS reaches maximum value when the percentage addition of dolime fine is 8%; further addition of dolime fines decreases the UCS. There is 713 % increase in UCS value as compared to virgin

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red mud, and 292% increase in UCS value as compared to red mud stabilized with optimum percentage of fly ash.

d) The addition of dolime fines to red mud stabilized with optimum percentage of fly ash increases the soaked CBR. The soaked CBR reaches maximum value when the percentage addition of dolime fines is 8% further addition of dolime fines decreases the soaked CBR. There is 961% increase in soaked CBR value as compared to virgin red mud, and 343% increase in soaked CBR value as compared to red mud stabilized with optimum percentage of fly ash.

e) The optimum percentage of dolime fine for stabilization red mud-fly ash mixes is found to be 8%.

f) The red mud stabilized with 15% fly ash and 8% dolime fine and cured for 7 days is found to be durable.

g) There would be substantial savings in cost of construction if red mud-fly ash-dolime fine mix is used as subgrade over soil of low soaked CBR value.

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