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Improvement in CBR Characteristics of Red Mud using Single Geogrid Layer

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Abstract— **In India millions of tons of red mud are produced from alumina industries. Its property is similar to sandy clay and it mainly comprises of oxides of aluminum, iron and silicon. Its storage has created enormous problems. To solve this problem alternate uses of red mud should be investigated. Improvement of load bearing characteristics of red mud with the help of geogrid is presented in this paper. This reinforced red mud will be useful as pavement materials for roads, particularly in areas nearer to alumina industries. This paper presents laboratory test, particularly soaked California Bearing Ratio test conducted on unreinforced and red mud reinforced with single geogrid layer. CBR test results are compared for reinforced red mud by varying the embedment depth of geogrid layer. Consequently, it is concluded that according to load bearing criteria optimum embedment depth of geogrid is equal to diameter of CBR loading plunger.**

Keywords— Embedment ratio, CBR, CBRI, Subgrade modulus, Pavement thickness.

I.INTRODUCTION

Red mud is a waste byproduct generated during the production of alumina from bauxite by the Bayer process. During the production of 1 ton of alumina 0.8 to 1.5 tons of red mud is produced (Liu and Zhang. 2011). In country like India, where land resource is scarce storage and disposal of red mud have created a great disaster. Therefore, researches are going on to find alternate uses of red mud. Literatures are available on alternate uses of red mud, like production of geopolymer(He et al. 2013; Kumar and Kumar 2013) (cement ((Singh et al. 1996; Tsakiridis et al. 2004)), brick (Kavas 2006; Yang and Xiao 2008), Red mud have also been used as a road construction material(Jianzhao 2005; Kehagia 2008) .
Red mud have properties similar to clay and sand; even if it does not contains any quartz or clay minerals. Similarity in properties is may be due to presence of hydroxysodalite, goethite, and hematite in red mud. Frictional behavior of red mud is similar to sand and compression behavior similar to clay(Newson et al. 2006). Due to the similarity in properties with soil red mud can be used as substitute of soil, which can solve disposal and storage problem associated with it.

In the present study attempts are made to illustrate effective use of geogrid to reinforce red mud to improve its load carrying capacity. Geogrids are reinforcing elements which is used to increase strength of soil subgrade. Polypropylene geogrids are preferred over jute geogrid for important projects because of its high strength and durability(Choudhary et al. 2012). In this experimental work, load bearing characteristics of unreinforced and reinforced red mud were studied by conducting soaked CBR tests on both type of samples. The main objective of paper is to study the effect of embedment depth of geogrid reinforcement on load carrying capacity of red mud so that red mud can be used as road construction material in areas nearer to alumina industries. To accomplish this objective soaked CBR tests on red mud reinforced by single geogrid layer having different embedment depths of 0.25d, 0.5d, 0.75d, 1.00d. 1.50d were conducted and test results are analyzed to investigate the effect of embedment depth of reinforcement on soaked CBR characteristics.

II.MATERIALS

Red mud taken for study had been collected from HINDALCO, Muri. Grain size distribution curve of red mud is shown in figure 1. Geogrid had collected from local market.

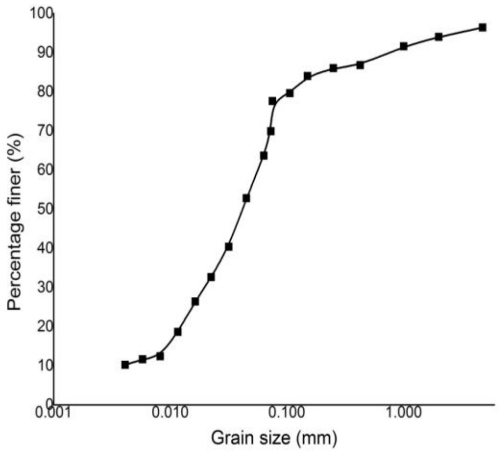

Figure 1 Grain size distribution curve of red mud

The physical properties of red mud and geogrid are presented in table-1 and table-2 respectively.

Table 1 Properties of red mud

PARAMETERS	VALUE
Specific gravity	2.8
Grain Size Distribution :	
% Gravel size	3.60
% Sand size	18.80
% Silt and clay size	77.60
Coefficient of Uniformity (C_u) =	14.97
Coefficient of Curvature (C_c)=	1.81
Atterberg Limits:	
Liquid limit in percentage	43.2
Plastic limit in percentage	31.55
Plasticity Index in percentage	11.65
Standard Proctor compaction result :	
Maximum dry density (in kN/m^3)	16.48
Optimum moisture content in percentage	24.75
Void ratio at maximum dry density and OMC	0.66
Classification:	
Indian Standard Classification	MI (Inorganic silts of medium compressibility)
AASHTO Classification	A-7-5 (9)

Table 2 Properties of Geogrid

Parameters	Geogrid
Material	Polypropylene
Type	Biaxial
Aperture Size in mm	2.5
Thickness in mm	0.5
Average Tensile strength in kN/m	5.0

III. SAMPLE PREPARATION

Geogrid layers were cut into circular shape of 14.5 cm diameter, which is slightly lower than CBR mould's internal dia(ie. 15 cm) so that it does not separate out from red mud specimen during testing. Red mud was oven dried and passed through 4.75 mm sieve prior to testing.

IV. EXPERIMENTAL PROCEDURE

Soaked CBR test was performed on both reinforced and unreinforced red mud compacted by standard proctor compaction. For testing on reinforced red mud, required quantity of oven dried red mud and water to required to fill up to the depth of reinforcement layer (embedment depth) and above it was calculated form maximum dry density and optimum moisture content result obtained from standard compaction test. Red mud was mixed thoroughly with required amount of water. Red mud required to fill portion below geogrid reinforcement layer is compacted in CBR mould by light compaction to get required maximum dry density. Then surface of red mud was leveled and geogrid layer was placed over it. After that remaining red mud mixed thoroughly with water was filled in layers and compacted as per standard proctor compaction. The top level of red mud was leveled, filter paper and perforated metals disc were placed over it. An annular surcharge load of 25 N is applied over it. The whole assembly was placed inside a water tub for a soaking period of 96 hrs. After 96 hrs whole assembly was transferred to strain controlled loading frame. Loading plunger was placed at the center of the specimen passing through the annular surcharge. A seating load of 40 N was applied by the loading plunger. Fig 2 shows the whole assembly. Load was then applied at a strain rate of 1.20 mm/min. Loads corresponding to different penetration were noted up to a maximum penetration of 12.5 mm. This experimental procedure is repeated for geogrid embedment depth of 0.25d, 0.5d, 0.75d, 1.0d, 1.5d.

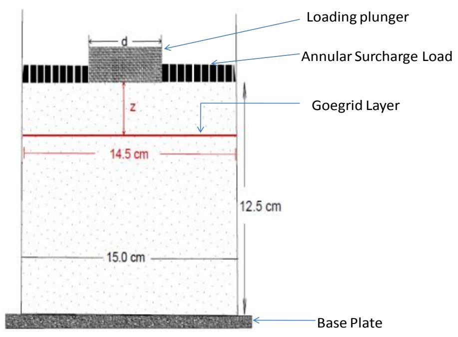

Figure 2 Schematics of CBR test assembly of geogrid reinforced red mud

V.RESULTS

Load penetration curve obtained from CBR tests for unreinforced and red mud reinforced by geogrid for different embedment ratios are presented in fig-3. From load penetration curve it is observed that with increase in embedment ratio(z/d) of geoggrid layer the plunger load at a given penetration increases up to embedment ratio reaches 1. For z/d > 1 the plunger load starts decreasing. As the curves don't have any initial upward convexity so there was no need for applying correction on curves.

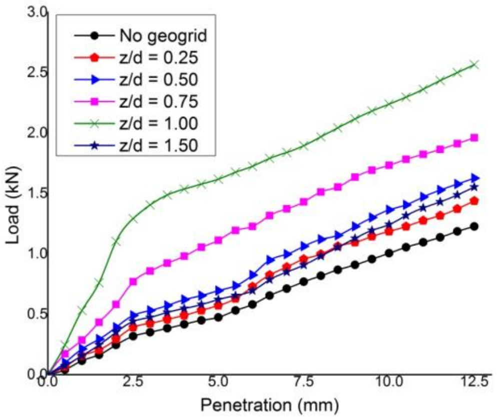

Figure 3 Load-Penetraion Curve

Variation of CBR with embedment ratio is plotted in fig 4. From load penetration data that it was observed that CBR value at 2.5mm penetration was higher than 5mm penetration. From fig 5 it is observed that CBR values of reinforced red mud are higher than unreinforced specimen. With increase in embedment depth(z) of geogrid, CBR value increases but up to embedment depth(z) equals to diameter of loading plunger(d). When z>d there is decrease in CBR value. For reinforced red mud at embedment depth z=d, the increase in CBR value is by 305% as compared to unreinforced red mud specimen.

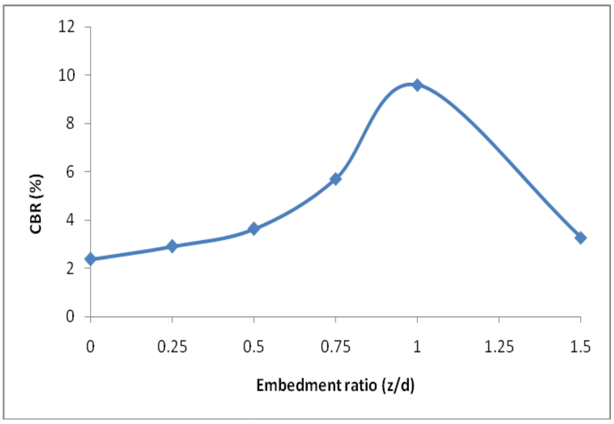

Figure 4 Variation of CBR with embedment ratio (z/d)

Improvement of CBR value of reinforced red mud is represented by a dimensionless parameter California Bearing Ratio Index (CBRI). CBRI is defined as ratio of CBR value of reinforced specimen (CBR_r) to unreinforced specimen(CBR_u)(Choudhary et al. 2012).

$$CBRI = \frac{CBR_r}{CBR_u} \quad \text{Eq(1)}$$

Fig 5 presents variation of CBRI with embedment ratio$\left(\frac{z}{d}\right)$. CBRI value increases with increase in embedment ratio of geogrid. At $\frac{z}{d} = 1$ maximum CBRI achieved is 4.05, but when $\frac{z}{d} > 1$ CBRI value decreases and reaches a value of 1.38 at $\frac{z}{d} = 1.5$.

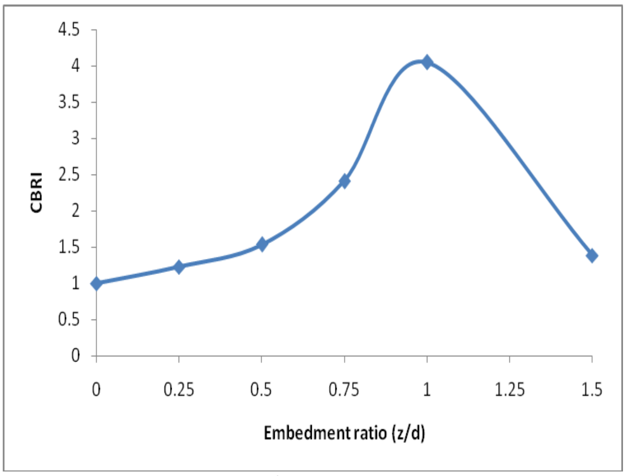

Figure 5 Variation of CBRI with embedment ratio

Fig 6 shows variation of plunger load corresponding to 12.5mm penetration($P_{12.5}$) w.r.t. variation of embedment ratio$\left(\frac{z}{d}\right)$. Incase of unreinforced red mud specimen $P_{12.5}$ is 1.23 kN. $P_{12.5}$ value increases with increase in embedment ratio$\left(\frac{z}{d}\right)$ and it reaches a value of 2.56 kN at $\frac{z}{d} = 1$, then it start decreasing when $\frac{z}{d} > 1$ and reaches a value of 1.55 kN at $\frac{z}{d} = 1.5$.

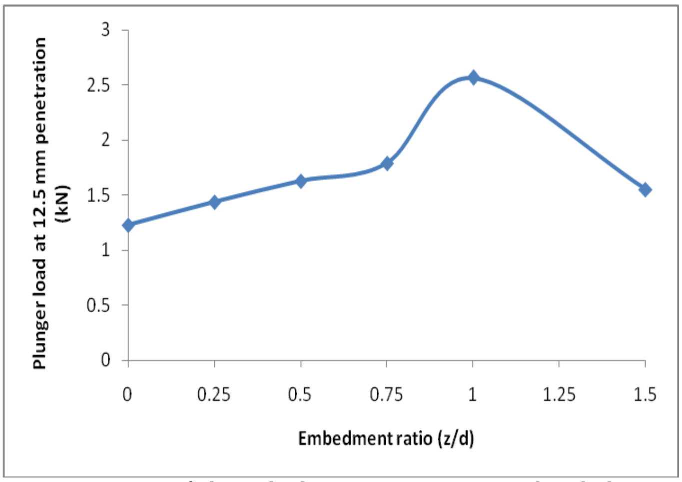

Figure 6 Variation of Plunger load at 12.5mm penetration with Embedment ratio

Strength of red mud subgrade can be represented by a parameter, subgrade modulus(K). It is the ratio of load (in kN) corresponding to penetration 2.5mm ($P_{2.5}$) to the penetration of 2.5mm.

$$Subgrade\ modulus(K) in \frac{kN}{mm} = \frac{P_{2.5}}{2.5}$$

Eq(2)

Fig 7 represents variation of sugrade modulus(k) with embedment ratio$(\frac{z}{d})$. Subgrade modulus value of geogrid reinforced red mud is greater than unreinforced specimen. Subgrade modulus value of unreinforced red mud is 0.127 kN/mm. Sugrade modulus variation shows same variation as that of CBR. Maximum subgrade modulus value is 0.516 kN/mm at embedment ratio$(\frac{z}{d})$ = 1.

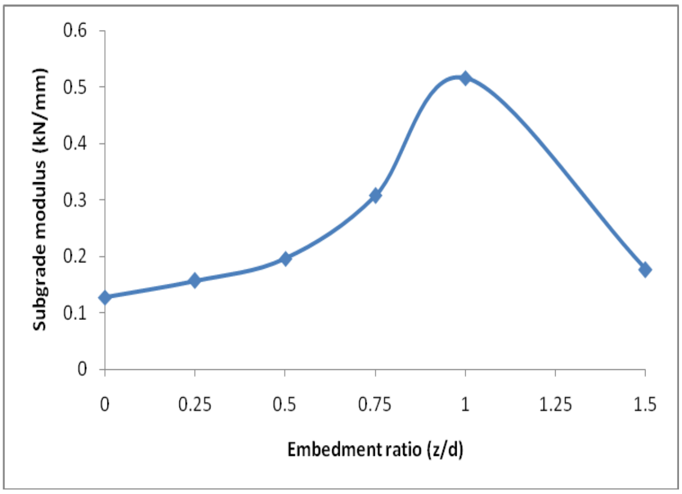

Figure 7 Variation of subgrade modulus with embedment ratio

Fig 8 shows variation of total pavement thickness with embedment ratio$(\frac{z}{d})$ of geogrid. Total pavement thickness is estimated from design chart given in IRC:37-2001 for different traffic loadings of 1, 5 and 10 million standard axles (msa). For different traffic loadings minimum pavement thickness is obtained when z=d. The percentage of total pavement thickness reduced at optimum embedment ratio$(\frac{z}{d} = 1)$ with respect to unreinforced specimen is 39.44%, 37.18% and 33.88% for traffic loadings of 1, 5 and 10 msa respectively.

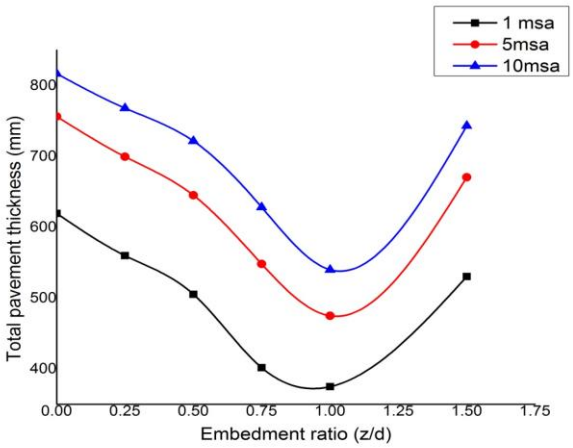

Figure 8 Variation of total pavement thickness with embedment ratio

VI. DISCUSSION

From the experimental analysis it is known that the red mud taken for study have very low bearing strength. Use of geogrid increases its strength. As the aperture of geogrid is very small, it get clogged by fine red mud material and act like geosynthetic sheet. Geogrid increases the bearing capacity by increasing the lateral spreading of stress(Gulhati and Datta, 2012). This lateral spreading of stress is equal in both the directions because the geogrid taken for study is of biaxial type. Lateral spreading os stress is mainly due to mobilisation of friction geogrid and red mud at their interface. This mobilisation of friction depends on propertie of red mud, geogrid and embedment depth of reinforcement. Effect of embedment depth(z) of geogrid on strength of reinforced red mud specimen can be explained by following mechanism(Choudhary et al. 2012).

When $z < d$ Boussinesq's stress due to loading plunger is very high but overburden load due to red mud on geogrid is low, so the geogrid does not get sufficient confinement for mobilizing friction and transferring stress in lateral directions. When $z > d$ overburden pressure on geogrid is high so the geogrid gets sufficient confinement but Boussinesq's stress due to plunger load developed at the level of geogrid is low, so the frictional resistance developed between the geogrid-red mud interface is vary low. Optimum embedment depth gives adequate conditions for getting sufficient confinement on geogrid and Boussinesq's stress is also enough for development of high frictional resistance between red mud reinforcement interface. Hence, maximum bearing strength is achieved at $z = d$. CBR, CBRI, $P_{12.5}$, K values are highest when geogrid depth is equal to diameter of loading plunger. Subgrade modulus is the indication of stiffness of the reinforced and unreinforced re mud. Which is the loading resistance for a specific penetration. Reinforced red mud have higher subgrade modulus then unreinforced specimen due to load spreading in lateral direction by geogrid.

Pavement thickness is a function of CBR value and traffic loading. Higher is the CBR value of subgrade material lesser will be the total pavement thickness. At optimum embedment depth of geogrid ($z = d$) CBR value is high so the pavement thickness required for different cumulative traffic (in msa) minimum. cost of pavement construction is a function of pavement construction. When geogrid is placed at optimum depth cost of pavement construction is minimum.

VII. CONCLUSION

The laboratory investigations based on CBR test leads to following conclusions.

- Red mud, waste product of alumina industry which creates enormous problems of disposal and storage can be used as pavement material after reinforcing it by geogrid.
- CBR characteristics of geogrid reinforced red mud depends on the embedment depth of reinforcement.
- Optimum embedment depth(z) obtained from experimental study is equal to diameter of loading plunger(d).
- Insertion of geogrid increases the stiffness of red mud.
- At optimum embedment depth of geogrid total pavement thickness obtained is minimum so it is more economical.

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