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Use of Granular Blast Furnace Slag in Embankment Construction

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Abstract

Huge quantities of blast furnace slag, is being generated in the steel plants during the extraction of iron from iron ores, and they are normally dumped in and around the plant occupying a large land area apart from causing significant environmental problems. Granular Blast Furnace Slag (GBFS) resembles to cohesion less granular material and is observed to contain mostly the sand-size particles. Therefore, the industrial wastes like Granular Blast Furnace Slag (GBFS) if used as a substitute to good quality borrow soils for base/ sub-base course in flexible pavements or as an embankment material, it may significantly decrease the construction cost apart from increasing the sustainable development. This study is carried out to utilize the slag in embankment construction. Being cohesion less material, it is mixed with local soil collect from Suvali near Eassar steel Ltd. As, the embankment/subgrade having high strength, can resist to deformation and increase the stability of the pavement. If the parent soil does not have good engineering properties can achieved with the use of additives/stabilizer. This additives/stabilizer is mixed with the soil materials to get desired improvement. This study focus on mechanical stabilization of parent soil (CH type) using GBFS. The CBR tests are conducted to check the four day soak strength of the soil mixed with the GBFS in different range (10 %, 15 % and 20 % by mass). The results of these tests are comparing with soil stabilized with lime (3, 4 and 5 % by mass) and cement (0.5, 1 and 1.5 % by mass) with different proportion.

Keyword- Granular Blast Furnace Slag, Embankment, Mechanical stabilization, Soil stabilization

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I. INTRODUCTION

The iron and steel slag that is generated as a byproduct of iron and steel manufacturing processes can be broadly categorized into blast furnace slag and steel making slag. Blast furnace slag is recovered by melting separation from blast furnaces that produce molten pig iron. It consists of non-ferrous components contained in the iron ore together with limestone as an auxiliary materials and ash from coke. Depending on the cooling method used, it is classified either as air-cooled slag or granulated slag. Steel making slag consists of converter slag (Basic oxygen furnace slag) that is generated by converter and electric arc furnace slag that is generated during the electric arc furnace steel making process that uses steel-scrap as the raw material. In the present study, solid waste which is generated as a by-product, during the melting process of mixed materials viz. steel scrap, sponge iron, pig iron, ferro-silicon, silico-manganese and Al-shots is termed as granulated blast furnace slag. The waste material is neutral and nonhazardous in nature as per chemical analysis report of Goa Pollution Control Board (Hazardous waste rules, 2008). The quantity of generation of this slag is around 24 lacs MT per year from different steel industries in Goa (CRRI, 2010). Steel slag may be used as a land fill cover liner (Inga, 2010). Pazhani and Jeyaraj (2010) studied feasibility of Granulated Blast Furnace slag (GBFS) for production of high performance concrete. Use of steel slag in asphaltic concrete minimizes potential expansion and takes advantage of the positive features in giving high stability, stripping resistant asphalt mixes with excellent skid resistance (Emery, 1994 and Mullick, 2005).

Presently, this granulated blast furnace slag is not utilized and is dumped on the costly land available near the plants. The main objectives of the present study were to investigate mix proportion of soil stabilized with Lime (3, 4 and 5 %), cement (0.5, 1.0 and 1.5 %) and with GBFS (10, 15 and 20%) for the construction of embankment and to estimate the optimum mix for road embankment. The industrial wastes can be utilized as construction material. The study is conducted to check the potential of the GBFS as a highway construction material in embankment and subgrade to increase the stability of parent soil. The CBR tests are conducted to check the effect of adding slag on the strength of the soil. The different content of slag are added in the soil to check performance of the soil with slag (GBFS) and same results are compared with lime and cement stabilization.

II. MATERIAL

Soil in south Gujarat region mainly consists of intermediate to highly compressible clay. For study, soil was collected from Suvali near to Surat city. The soil sample were taken from the different chainage of 3 Km road stretch.

The collected sample was tested in the laboratory for the investigation of engineering properties like specific gravity of soil solids, grain size distribution, Atterberg's limits, Swelling potential, soil classification, compaction characteristics and CBR, a summary of which is presented in Table 1. The grain size analysis shows that there silt and clay content are maximum in the sample. The soil classification results shows that the majority of the sample were CH type except at the chainage 1+100 (R) having SM type of soil. The soil having CBR value below 2 expect SM having CBR value of 4.85.

Properties	
coarser % 4.75 mm & above	*0*
sand % 0.075 mm to 4.75 mm	*5*
silt and clay content < 0.075 mm	*95*
LL %	*61*
PI %	*41*
IS classification	*CH*
FSI	*75*
Specific Gravity	*2.55*
MDD gm/cc	*1.66*
OM C %	*17.5*
CBR (soaked) %	*1.86*

Table 1: Engineering properties of soil

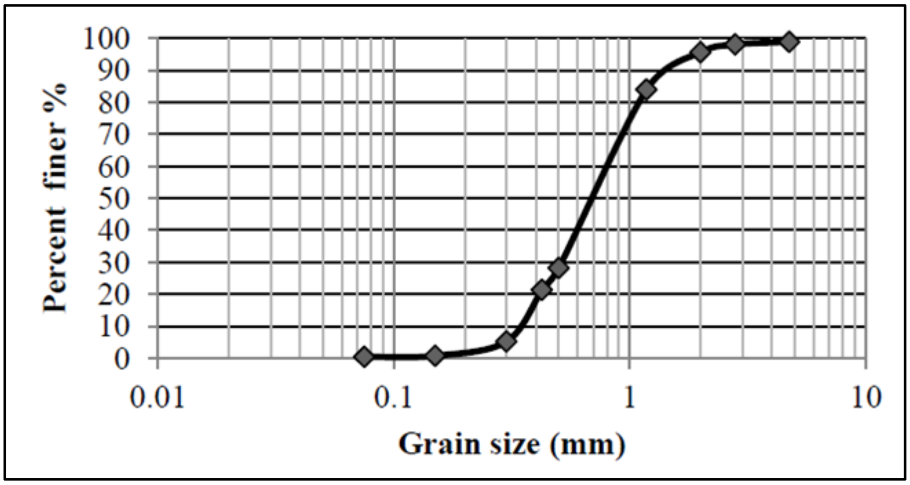

Fig. 1: Grain size distribution

The soil properties do not match with the minimum requirement of IRC 36. Most of the soil are of CH type having CBR less than 2, so engineering properties of the soil need to be improved.

Granular Blast Furnace Slag (GBFS) is collected from Essar steel Ltd. Hazira, Surat. The GBFS production is approximately 45,000 tonnes/month. The huge amount of steel slag is produce in the Essar steel. In laboratory the various test are performed to check the suitability of the GBFS as a stabilizer material mixed with soil. The sieve analysis and specific gravity of GBFS was carried out in the laboratory. The materials are non-plastic in nature.

In fig. 1, the result of sieve analysis are drawn for GBFS. This shows it is uniformly graded material and falls under Grading Zone II of fine aggregates (IS: 383-1970). The specific gravity is 2.28 of GBFS. This material is used in mechanical stabilization with CH soil to increase its engineering property for embankment construction.

The chemical composition of GBFS is shown in table 2. The result of chemical composition shows it contain 12.74% silica and 32.29 % CaO content. It is found that aluminium content is maximum in the GBFS i.e. 42.44%.

Oxide	*Composition, %*
Aluminium oxide Al2O3	*42.44*
Calcium oxide CaO	*32.29*
Silica SiO2	*12.74*
Calcium Sulphate CaSO4	*11.88*
Magnesium Oxide MgO	*7.95*
Ferric oxide Fe2O3	*1.934*
Titanium Oxide TiO2	*0.012*
Free lime	*0.0812*
Ferrous Oxide	*902mg/kg*

Table 2: Chemical composition of GBFS

III. LABORATORY INVESTIGATIONS

Construction of road embankment using slag alone would not be feasible as it is cohesion less material. Such embankments would be highly erodible. Therefore, it was mixed with local soil in the range of 10 %, 15 % and 20 % by mass and the CBR test are performed on the these mixes. The modified proctor tests were performing to find the OMC and MDD for particular mix.

Along with this mechanical stabilization, the soil is also stabilized with lime and cement. While stabilizing with lime, it is added 3, 4 and 5 % by mass. For cement the adding proportion is 0.5 %, 1 % and 1.5 % by mass is taken.

The lime and cement are collected from local market. Ordinary Portland cement is used in the project work. The chemical compost of the lime and cement are investigated. The chemical comports are shown in the table 3 and 4 for lime and cement respectively.

The modified proctor tests were performing to find the OMC and MMD for the preparation of CBR mould for all mixes. The CBR tests are performed according to the IS 2720 part 16. The soak CBR test is performed as it gives result of worst condition for material under loading.

All results with different stabilizer are compared. The results of all tests can see in table 5 below. The graph showing the comparison of different CBR values of the different stabilizer is prepared and can see in fig 2. The OMC is increased with increase in percentage of GBFG in the soil. The MDD is having liner relation with. As the percentage of GBFS, lime and cement is increase the MDD is also increases. This can be seen in Fig 3.5.The OMC is decreases with increase in percentage of the lime and give good MDD with incremental CBR result. The CBR is increased as increase in percentage of GBFS. However, the CBR value is lower as compare to the lime and similar to cement due to less binding properties. They give higher results as the percentage of is increase. The CBR value is 8.54 for Soil +GBFS 20%, 9.52 for Soil + lime 5 % and it is 7.88 for Soil + cement 1.5 %.

Compound	*Composition %*
Calcium Hydroxide Ca(OH)2	*72.88*
Calcium Carbone CaCO3	*10.215*
Calcium Sulphate CaSO4	*2.96*
Magnesium Oxide MgO	*3.21*
Aluminium Oxide Al2O3	*9.49*
Ferric oxide Fe2O3	*0.382*
Silica SiO2	*0.861*
Excess moisture H2O	*0.002*

Table 3: Chemical composition of lime

Compound	*Composition %*
Insoluble residual	*70.24*
Loss on ignition	*3.06*
Ratio of % aluminium to that of iron oxide	*1.50*
Total sulphur content calculated as sulphuric anhydride SO3	*2.247*
Magnesia	*0.231*

Table 4: Chemical compound of cement

Sample	*MDD g/cc*	*OMC%*	*CBR%*
Soil+GBFS 10%	*1.718*	*17.6*	*3.21*
Soil+GBFS 15%	*1.751*	*18.3*	*4.76*
Soil+GBFS 20%	*1.786*	*19*	*8.54*
Soil+lime 3%	*1.787*	*16.7*	*5.14*
soil+lime 4%	*1.826*	*16.6*	*7.32*
Soil+lime 5%	*1.864*	*13.2*	*9.52*
Soil+cement 0.50%	*1.797*	*13.9*	*4.38*
soil+cement 1%	*1.838*	*14.7*	*5.26*
soil+cement1.5%	*1.902*	*14.3*	*7.88*

Table 5: Result of different mix

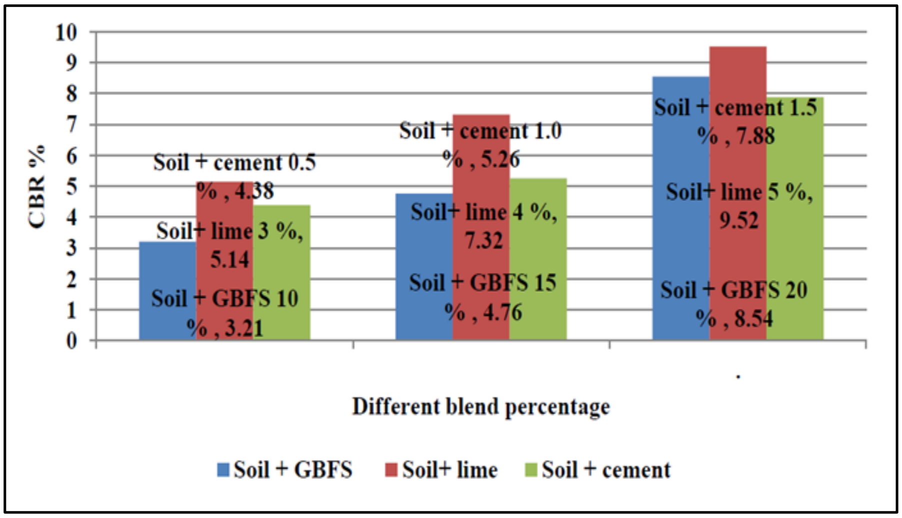

Fig. 2: CBR for different mix

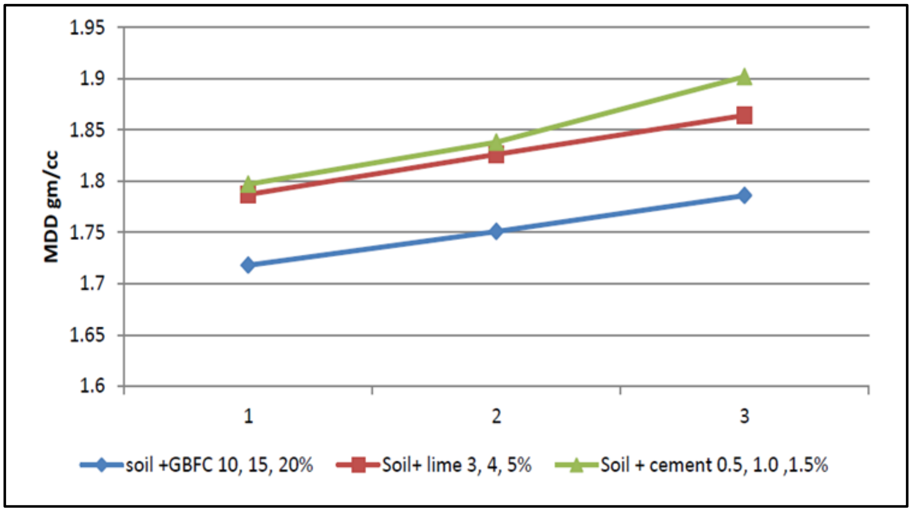

Fig. 3: MDD for different mix

IV. CONCLUSIONS

Soil + GBFS (10, 15 and 20 %), Soil + lime (3, 4, and 5 %) and Soil +cement (0.5, 1 and 1.5 %) are evaluated for their engineering characteristics by laboratory investigations for embankment construction. Different laboratory tests carried out included: grain size analysis, Atterberg limit test, Proctor compaction test, CBR test, aggregate impact value test, Abrasion test and moisture absorption test. The brief conclusions are given below:

- The soil is CH type of soil having CBR value lower than 2 except one chainage having SM soil with 4.85.
- The soil having swelling more than 50 % so it's required to stabilized.
- GBFS give more than 17 gm/cc MDD and up to 8.54 CBR value when mixed with soil.
- The lime is stabilizer as it reduces OMC and gives better MDD then cement and GBFS. The 9.52 CBR value is obtained when adding 5 % lime in soil.
- The GBFS mix gives comparative results with lime and cement. Its can be used as a stabilizer with soil having disagreeable properties for construction.

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