A REVIEW ON UTILIZATION OF MINE WASTE ON BLACK COTTON SOIL

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Abstract

Mine wastes are one of the chronic waste concerns. The volume of solid waste generated during mining process, is one of the main pollution concern. The presence of high concentration of heavy metals and acid producing mineral phases can endanger the environment if management of these wastes are not addressed properly. Mine wastes have numerous ecological effects viz Air, Land and Water. There is a great difficulty in finding space for the storage of wastes generated in enormous quantity. The review of past studies indicated that 50 to 60% of mine waste by volume can be used as coarse grained particle and 10 to 15% by volume as fine aggregate. Despite quite a lot of attempts to diminish the amount of waste, mine waste remains one of world's largest waste streams. Black cotton soil on the other hand is problematic due to the presence of momtmorillonite that imparts high swell-shrink potentials. These soils are very hard when dry but loose strength completely when wet. Pavement surface on poor soil subgrade show early distress causing pavement failure. The present study examines the utilization of these wastes as stabilizers for black cotton soil for unpaved road construction.

Keywords: *Mine Waste, slag aggregate, Solid Waste Materials, Iron Ore slag*

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1. INTRODUCTION

Mining in India meets the mineral requirement of various industries. India is highly potential to produce large quantity of Iron ore, moderate to high quality for domestic use and export. Waste from extractive operation is one among the largest waste streams. It entails materials that must be removed to get admittance to the mineral resource, such as overburden, topsoil and waste rock, as well as tailings left over post extraction of minerals from the ore. The type, amount, and properties of mine waste produced at different mines vary depending on the resource being mined, process technology used, and geology at the mine site. These mining operations produce waste materials which currently has modest or no economic value. [1] The soil and rock which is removed to gain access to buried ore, and the material (water, solids, and gases) left behind after the ore has been processed to remove the valuable commodities, are considered to be waste materials. However mineral content between ore and waste rock can differ depending on market conditions and available extraction technology.

There are numerous cases where material that was once considered waste has become a resource for modern mining operations. [2]. Overburden that includes soil and rock is removed to gain access to the ore deposits at open pit mines. It is usually piled on the surface at mine sites which does not impede further expansion of the mining operation.

These mining operations comprises of removal of overburden to entrée the ore contribute to major problems in storage and reclamation. 2:1 to 5:1 waste to ore ratio is generated depending on local condition. 16 to 20 million tons of ore produce 40 to 50 million tons of waste per year with waste ratio of 3:1 for present condition [1]. To dump the waste mining companies had to acquire private land exterior to the lease area due to exhaustion of the present land. Mining has a number of widespread activities, each of which has potentially-adverse effect on the natural environment, society and cultural heritage. It also affects the health and safety of mine workers, and communities located near the mining operation sites. The requirement of extra land will increase every year unless there is a proper technique for the use of these wastes.

The presence of heavy metals also causes erosion and dust. The impacts can have long lasting socio-economic and environmental effect. It may lead to tremendously difficult consequences and may prove expensive to handle through remedial measures. Management of Wastes from the extractive industries plays a vital role in ensuring the long-term stability of disposal unit and to prevent water and soil pollution that is arising from acid or alkaline drainage and heavy metal leaching.

1.1 World outlook on Mine Waste Usage

Mine waste consists of unmodified natural material other than crushing. Overburden and Top soils classified as wastes are used as raw material as additive in building materials and for recuperating extroverted material such as Aluminum.

In recent years countries contributing the production of minerals have come across problems on improved utilization of mine waste of its gathering and lack of suitable storage space. The utilization of mining waste has been done as a construction material in road construction, railway, river and dam. It's use has widely increased in 20 years. An example for direct of Mine waste as bulk fill in the Mining Industry, Ruhr has been mentioned in the table below [1].

Table 1.1: Usage of Mine waste as Construction materials

Construction	Quantities (MillionTon)
Dykes and dams	2.62
Earth and road construction	6.61
Filling in sand pit and gravel	3.0
Mine waste discharge in to rivers	3.55
Total Usage	15.78

1.2 Black Cotton Soil

The black cotton soil of India covers an area of at least 200,000 sq.miles and ranks as the second most important of our Indian soils. It is the largest proportion of our Indian cotton crop is grown.

Black cotton soils are the most problematic clays due to their strange swell shrink behaviour with abrupt variations in moisture content. Most of the world nation has surface area covered by the Black cotton soil and huge damages caused by them have been reported. It has been investigated that the presence of clay minerals like montomorillonite induces the swell-shrink behavior to these soils. For any country, transport and communication are the major influential factors for the development of countries. Importantly for highly populated countries like India, road transport is the major dependent feature for connectivity and accessibility of different locations. During the process of network development, the road alignment may have to be fixed, though the soils en-route may not be suitable to bear the traffic loads with adequate strength. It has been established that the stability and performance of pavement is reflected by soil sub grade, Pavements constructed on expansive soils are bound to fail resulting in poor performance and increased maintenance cost. Past studies have shown that the stabilization of black cotton soil with lime, flyash, GGBS etc have resulted in to enormous advantages like improvement the soil strength. Reduction in soil volume changes due to moisture and temperature, improved soil workability and durability. It has also brought economy in the cost of road. An attempt can therefore be made to use mine waste for the stabilization of black cotton soil.

Table 2.1: Utilization of Mine waste as construction material and stabilizer with Black Cotton Soil

Alteration Agent	Test Carried out	Remarks	References
Mine waste	Particle size distribution UCS	50-60% of the Mine waste can be used as Coarse aggregate and 10-15% by volume as fine aggregate. This material had resulted in higher UCS value for a concrete mix of 1:2:6 as compared to the conventional aggregate for the same mix.	Mohan Yellishetty, et al. (2008)
Aggregate + Iron ore slag Aggregates	Life cycle inventory assessment`	For every 1% replacement of Iron ore slag aggregate, there was a reduction in 8tonnes of mine waste.	Sathyanarayanan Rajendran et al. (2007)
Aggregate + Iron ore slag Aggregates (mine waste)	Particle size distribution	30% to 40% of the waste generated from the mining process was found suitable to be used for road construction and manufacture of bricks	Asokan Pappu et al.(2006)
Black cotton soil + Copper slag	Compaction CBR	For the combination of 72% of BC soil and 28% of copper slag soaked CBR value increased from 1.64% to 5.43%. High value of MDD 1.9 g/cc and OMC 18% was obtained for 68% BC soil with 32% copper slag as compared to the conventional mix of MDD 1.64g/cc for the same optimum moisture content.	Tushal Baraskar S K Ahirwar
Black cotton soil + Copper slag	Atterburg limits, CBR, Compaction, Swelling Index, Direct shear, UCS, Permeablity	Copper slag - black cotton soil mix (30:70) has a low free swell index of 38%. By utilizing this mix we can avoid the problems of swelling and shrinkage of expansive soil. The coefficient of permeability of copper slag was found to be 2.8×10 -6 m/ that indicates its potentiality for its use as a drainage layer in road base. The coefficient of permeability of copper slag local soil mix (30:70) was found to be 5.7 ×10 -9 m/s, thus proving its impervious nature and thus it's suitability as a subgrade in road pavement. For the same mix soaked CBR value increased considerably.	Yogendra K Tandel Jignesh B Patel
Black cotton soil + Copper slag	Grain size distribution, CBR, UCS	30% to 60% of the copper slag can be stabilized with Black Cotton soil to improve the soil characteristics. It can hence be recommended for construction of embankment, improvement of subgrade soil condition and reclamation of land.	Prof. Jinka Chandrshekhar et al.

Alteration Agent	**Test Carried out**	**Remarks**	**References**
Soil + Copper slag + Cement	Load settlement characteristics	There was a remarkable improvement in the ultimate load of copper slag cushion – expansive soil bed when admixed with cement and lime. It was also noticed that ultimate load is 1.7 times when 4% lime was added to copper slag and it was increased three times when 6% lime was added to copper slag. For the same percentage of admixture added, it was noticed that the increase the ultimate load is more for cement when compared to that lime.	C Lavanya et al.
Soil + Copper slag +Cement	Atterburg limits, CBR, Compaction, FSI	Soil stabilization with copper slag for an optimum mix of 30% proved to be more efficient reducing plasticity index by 40%. 2% of cement was added to stabilized mix resulting in decrease in FSI. Higher MDD and a lower OMC were achieved for the same mix. CBR value got increased, thus making it suitable to use as subgrade material.	C Lavanya A Sreerama Rao N Darga Kumar
Flyash + Copper slag + Lime	UCS,Triaxial Shear, Durability	Compacted soil-flyash-copper slag mix and compacted soil-fly ash-lime/cement mix have shown improved geotechnical characteristics.	Ghosh and Subbarao (2007)
Copper slag + Fly Ash + dolime	Compaction UCS FEA	Optimum Moisture Content increased constantly for various copper slag and fly ash mixes, whereas MDD increased for an optimum value of 10%. Based on UCS test results 80% copper slag + 20% fly ash + 15% dolime was found to be the optimum mixes.	J.T Shahu et al (December 2013)
Aggregate + slag aggregarte	UCS	The compressive strength of the concrete with tailings aggregates at 28 days was 36.95 MPa which shows an improvement of 11.56% over the concrete with conventional aggregates.	Francis Atta Kuranchie (August 2015)

Table 2.2: Soil Stabilization using Ground Granulated Blast Furnace Slag and Granulated Blast Furnace Slag

Alteration Agent	**Test Carried out**	**Remarks**	**References**
Soil + Lime +GGBS	UCS	Addition of Lime content up to 8% to attain a 1:1 ratio of substitute with GGBS at 23% moisture content showed higher strength even under soaked condition. UCS gained high rate of strength of 4000 kN/m^2 at 56 days curing, which later slowed down till 90 days resulting a strength higher than 4500 kN/m^2	G.N. Obuzor J.M. Kinuthia, R.B. Robinson
Soil + GBFS	Atterburg limits, Compaction Swelling Index	The GBFS obtained from the Iskenderun iron-steel plant were incorporated into low plasticity Kolsuz clay and high-plasticity bentonite clay in various rates (5%, 10%, 20%, 30%, and 50%). The stabilization turned out to be positive and the improvement in bentonite clay is greater than that in Kolsuz clay.	Osman Sivrikaya, Selman Yavascan and Emre Cecen
Soil + GGBS	Atterburg limits, Compaction Swelling Index, CBR	By blending with GGBS there is a substantial improvement in compaction parameters while considerable improvement was also seen in CBR value up to 10%. There was a reduction of 5% in liquid limit and Plasticity Index.	K Uppaiah, G V Prasad Raju (2013)
Soil + GGBS + Road Cem	UCS Free swell Percentage,	Unconfined Compressive Strength of soil increased with 65% of OPC by GGBS. With addition of lime up to 12% there was a further gain in UCS value. Free swell Index was inversely proportional to increase in stabilizer.	M. S. Ouf (20 13)

Alteration Agent	Test Carried out	Remarks	References
Soil + GBFS + Waste rubber tyres	Compaction CBR	The influence of Granulated blast furnace slag and waste rubber tyre chips is marginal on MDD and high for OMC. The OMC is found to increase by 1.9 times with GBFS and 2.3 times with WRT as compared with unmodified aggregate. An optimum filler content of 5% with GBFS and 2% with WRT is recommended for best results. 3. It is concluded that the efficacy of GBFS is higher to that of WRT. At optimum conditions CBR increase with GGBS from 40.78% and 46.60% at 20% GBFS content is very high to that with WRT i.e from 4.71% to 7.7% at 2% . 4.	K.V.Subrahmanyam V.K.Chakravarthi U.Arun Kumar
Soil + Lime + GBFS	Grain size distribution Compaction CBR, UCS	There was a pronounced increase in the soaked CBR When lime-stabilized GBS cushion was placed over the expansive soil. Lime content of 10% resulted in to increase in shear strength corresponding to unit normal stress.	G Sridevi Shreerama Rao (2011)
Soil + GGBS	Atterburg limits, CBR UCS	With the addition of 15% of GGGBS there was 37% increment in CBR and 15% increment in UCS value. There was also considerable decrease in Liquid limit and Plasticity Index.	D Neeraja A.V Narashimha Rao
Soil + GGBS	CBR, UCS	25% GGBS has shown higher UCS values compared to other Percentage and at 28 days it has shown maximum values than other curing periods. A higher value of CBR i.e, 35% was obtained for 25%GGBS at 28 days curing period. Hence Redmud stabilized with GGBS can be used as subbase, base course and also subgrade material for road construction.	CH.V.Hanumanth et.al (August 2011)
Soil + GBFS	Compaction CBR	Addition of GGBS to soil increased the maximum dry density up to 10%. CBR increased with an increase in GGBS percentage up to 10% GGBS content, and then started to decrease. Partial substitution of lime by GGBS could significantly reduce swelling and heave in the presence of sulphates.	Mohamad Nidam Rahmat1 and Norsalisma Ismail
Soil + GBFS + Fly ash	Compaction CBR	Fly ash and GBS when mixed with soft soil primly effected the reduction of clay content and frictional resistance. This resulted in an increased OMC and MDD value. 3.3% of fly ash and 6% of GBS were the optimum percentage since CBR test reached the optimum value for both unsoaked and soaked condition.	Laxmikant Yadu Dr. R.K. Tripathi (2001)
Soil + GBFS + Lime	Free swell Undrained Shear strength	It is found that when 20% slag & 4 % lime (5:1 slag to lime ratio) is added to soil, undrained shear strength (Su) increased phenomenally almost by 16 times and with 40% slag & 4 % lime (10:1 slag to lime ratio) Su increased by 18 times. It is also observed that the free swell of Black cotton soil which was reduced with 40% slag & 2 % lime along with BCS. Thus, we could achieve volume stability also.	K.V Manjunath L Govindaraju P.V Shivapullaih
Soil + Cement Slag	Atterburg limits, UCS, Free swell, Swell pressure, Compaction	Soil treated with cement slag resulted in decrease of Liquid limit and Plasticity Index from 67.3% to 50% and 32% to 25% respectively. Free swell also decreased from 91% to 85%. Unconfined compressive strength was increased from 57.6 to 77 KN/m^3.	Y. Keerthi, et al.
Soil + GBFS + GBFS-Cement	Atterburg limits, Swell Index CBR	Soil stabilization with GBFSC and GBFC decreased the swell index percentage. These additives also contributed in the alteration of grain size distribution of the soil sample. Swell Inxed value of 6% also satisfied the Irrigation water standard. The addition of 15% GBFSC and 20% GBFS to soil reduced the swell percent from 29.4 to 10.9% and 3.1%, respectively.	Erdal Cokca Veysel Yazici Vehbi Ozaydin

Alteration Agent	Test Carried out	Remarks	References
Soil + GBFS	Compaction CBR	Addition of GGBS to soil increased the maximum dry density up to 10% GGBS addition, above which the MDD decreased. CBR increased with an increase in GGBS percentage up to 10% GGBS content, and then started to decrease. Partial substitution of lime by GGBS could significantly reduce swelling and heave in the presence of sulphates.	Mohamad Nidam Rahmat1 and Norsalisma Ismail

2. CONCLUSION

- The waste material obtained from iron ore mining was used as an aggregate in road construction. Particle size distribution test result indicated that 50-60% by volume of mine waste can be used as coarse aggregate and 10-15% by volume can be used as fine aggregate.
- Soaked CBR value increased from 1.64% to 5.43% for the combination of 72% of BC soil and 28% of copper slag.
- Copper slag of 80%, 20% of fly ash was found to be the optimum mix based on the Unconfined Compression Test.
- By blending soil with GGBS CBR strength increased up to 10%. There was also reduction of Liquid limit up to 5%.
- The Maximum Dry Density and CBR value increased considerably with the addition of GGBS up to 10%.
- The Unconfined Compression Test, Split Tensile Test has increased at 28 days curing up to the addition of 25% of GGBS.

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