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Uses of Steel Slag in Landfill Cover Liners

Shipra Chaubey Department of Civil Engineering,Madan Mohan Malviya University of Technology, Gorakhpur

Avinash Mishra Department of Civil Engineering,Madan Mohan Malviya University of Technology, Gorakhpur

ABSTRACT

Local soil of Gorakhpur is not suitable for landfill cover liners due to low strength and high permeability. In order to enhance the soil strength, steel slag is added to soil in various proportions and checked for optimum moisture content, maximum dry density, CBR and permeability. Improvement in maximum dry density and CBR is found with increase in slag content, and at 25% required strength is achieved but permeability of soil is increased due to increase in slag content. Therefore, bentonite is added to soil with 25% of slag in different proportion and at 7% we have got the required permeability of order 10-9. Hence, slag can be used as a stabilizer but requires mixing of some admixture, in order to reduce its hydraulic conductivity.

KEYWORDS : steel slag, hydraulic conductivity, maximum dry density, California bearing ratio

INTRODUCTION

With the increase in population, waste generation has also been increased. Solid waste management (SWM) is a growing concern now days. It is an organized process of storage, collection, transportation, processing and disposal of solid refuse residuals in an engineered sanitary landfill. It is an integrated process comprising several collection methods, varied transportation equipment, storage, recovery mechanisms for recyclable material, reduction of waste volume and quantity by methods such as composting, waste-to-power and disposal in a designated engineered sanitary landfill. In Gorakhpur, waste generated amounts to 350 tones per day approximately and Gorakhpur Municipal Corporation (GMC) supposed to collect 420 tones of waste generated in a week. GMC is also dependent on contract labors, hence, due to lack of management most of the waste is being disposed either road sides or being dumped in an open ground. There are more than 230 nursing homes and hospitals running in the city and non-biodegradable waste generated have no disposal points. There is no permanent dumping ground in the city and the old landfills continuously contaminating ground water. Thus, solid waste management is one of the serious issues to be considered in the city. There are various solid waste management techniques, such as, incineration, landfilling, chemical recycling etc. but there is lack of initiative. Although landfills are one of the simplest methods of solid waste management but it generates leachate which deteriorates quality of under ground water. Therefore, it needs low permeability liners.

This research work involves the computation of geotechnical properties of soil and slag separately and then mixing it in variable proportion and checking out the resulting mixture for least hydraulic conductivity and maximum strength. Addition of slag in different proportion shows positive result for maximum dry density and CBR, it increases with increase in slag content, but permeability also increases, which is against our requirement. At 25% of slag, we got the required strength but permeability of the sample is increased and for this, we have added Bentonite. And with addition of Bentonite in different proportion, we have got the required permeability of the order 10-9cm/sec.

Rapid rise in steel production has resulted in India becoming 4th largest producer of steel. Total production of steel in 2014-15 is estimated around 65.197 million tones. Therefore, expansion of steel industry leads to increase in volume of residues and steel produced. Beneficial properties of slag such as strength, durability etc. makes it suitable for engineering applications. It can be used in road construction, soil stabilization and low permeability barrier liners.

MATERIALS USED

A national highway is passing through Narhi Village near in Suba Bazaar, Gorakhpur which has a low CBR value/strength. Thus, it was decided to enhance the bearing strength of soil by using soil stabilization techniques. For stabilization we have used steel slag as secondary construction material, since it is available locally and thus, can be obtained easily. The geotechnical properties of soil used are given in Table 1.

After completion of tests, particle size distribution of soil sample covers the range between sand, silt and also clay. From liquid and plastic limit test, IP (plasticity index) is found to be 16.57 %. Hence, from plasticity chart it can be said that soil is MI i.e. inorganic silt or clayey silts of medium plasticity. CBR value is very less and permeability is of the order 10-5. Therefore, it needs to be stabilized using some admixture.

Table 1: Geotechnical properties of soil

S.NO.	Properties	Values
1	Specific gravity	2.65
2	Grain size analysis Gravel (>4.5mm) Sand (0.075mm-4.5mm) Silt (0.002-0.075) Clay (<.0.002)	 0% 15% 77.06 7.94
3	Liquid limit Plastic limit	42.708% 27.662%
4	Optimum moisture content	17.50%
5	Maximum dry density	1.72g/cc
6	CBR value	2.246%
7	permeability	1.43×10^{-5}cm/s

For this research, iron slag was obtained from gallant industries, Gorakhpur. Slag is the granular material formed when molten iron blast furnace slag is rapidly chilled by immersion in water. It is a granular product with very limited crystal formation and is highly cementitious in nature. Physical properties of slag are computed and tabulated as under:

Table II: Geotechnical properties of slag

S.NO	Properties	Values
1	Specific gravity	3.03
2	Grain size analysis Gravel (>4.5mm) Coarse sand (2.00mm-4.75mm) Medium sand (0.425mm-2.00mm) Fine sand (0.075mm-0.425mm) Fines (silt and clay) (<0.075)	 0% 0% 4.6% 70.2% 25.2%
3	Liquid limit Plastic limit	Not obtainable Not obtainable
4	Optimum moisture content	19.80%
5	Maximum dry density	2.425g/cc
6	CBR test	12.35%
7	permeability	1.53×10^{-2} cm/s

From the test results obtained, slag is found to be non plastic and particle size distribution (PSD) of slag covers the whole range between silt and sand. The laboratory test has also shown hydraulic conductivity of slag is 1.53 ×10-2 cm/s. Angle of internal friction, ⍉= 41 and °Cohesion, c = 1.44 and hence, it can be said that slag is cohesive-friction in nature.

METHODOLOGY ADOPTED

After computation of properties of soil and slag separately, samples are mixed in various proportion. Preliminary test were conducted on 9 soil samples with 0%, 3%, 7%, 11%, 18%, 21%, 25% and 30% slag added to it and variation of maximum dry density, optimum moisture content, California bearing ratio, and hydraulic conductivity with slag are checked out and are listed:

Table III: Properties of sample prepared

S. No	Sample	OMC, (%)	MDD, (gm/ cc)	CBR, (%)	Hydraulic conductivity, (cm/sec)
1	Natural soil	17.50	1.70	2.25	7.32×10^{-5}
2	Natural soil +3%slag	14.30	1.656	2.43	7.42×10^{-5}
3	Natural soil +7%slag	14.450	1.765	2.62	1.26×10^{-4}
4	Natural soil +11%slag	15.05	1.773	3.37	1.82×10^{-3}
5	Natural soil +15%slag	15.50	1.783	3.556	2.4×10^{-3}
6	Natural soil +18%slag	16.50	1.835	3.650	2.8×10^{-3}
7	Natural soil +21%slag	17.00	1.935	3.930	3.2×10^{-3}
8	Natural soil +25%slag	17.9	1.950	4.211	3.8×10^{-3}
9	Natural soil+30%slag	18.73	1.912	2.246	4.6×10^{-3}

After conducting laboratory tests over samples prepared using slag and soil, we have found that, properties of soil have increased considerably but permeability, which is our main concern, has also increased, when we are intending to reduce it.

Therefore, suitable and easily available admixture i.e. Bentonite clay has been added in order to get the required permeability of order 10-9. Hence, keeping slag and soil ratio constant at 25%, on which we have got maximum CBR value. Bentonite is added in 3%, 5% and 7% respectively and checked again for OMC, MDD, CBR and hydraulic conductivity.

Table IV: properties of sample prepared after addition of bentonite clay

S.No	Sample	OMC, %	MDD, gm/cc	CBR, %	Hydraulic conductiviy, cm/sec
1	Natural soil	17.5	1.70	2.24	$7.32x10^{-5}$
2	Soil+25% slag +3% Bentonite	18.2	1.78	5.23	$6.23x10^{-6}$
3	Soil+25% slag +5% Bentonite	19.9	1.83	5.67	$7.85x10^{-7}$
4	Soil+25% slag +7% Bentonite	20.4	1.89	6.02	$6.02x10^{-9}$

RESULT AND DISCUSSION

From the laboratory results obtained, following graphs can be plotted, indicating various changes in properties

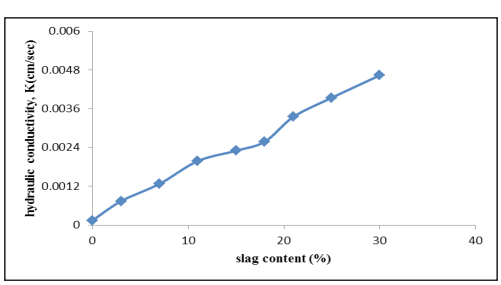

Figure I: variation of hydraulic conductivity vs slag content

With addition of slag alone, permeability which is an important property for landfill cover liners, increased proportionately due to high permeability of slag. In order to reduce that Bentonite clay has been added.

After addition of Bentonite, considerable improvement in properties of soil has been noted down. Increase in maximum dry density, optimum moisture content and California bearing ratio have been observed and decrease in hydvraulic conductivity is seen, which can be easily seen with help of graphs plotted between various properties and the percentage of addition of Bentonite content.

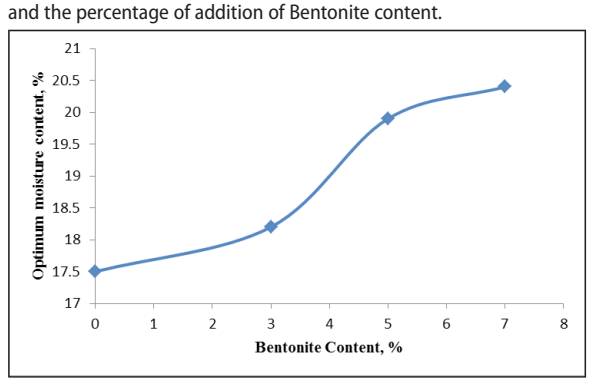

Figure II: Variation of OMC vs Bentonite content

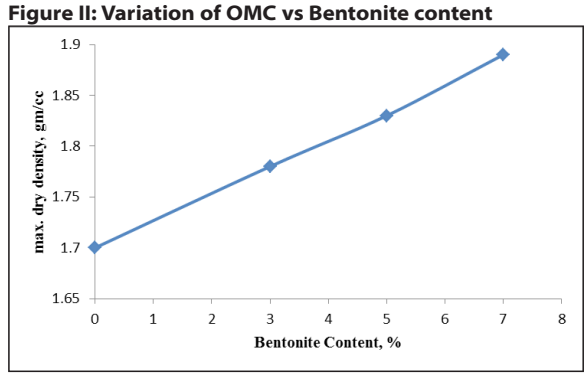

Figure V: Variation of MDD vs Bentonite Content

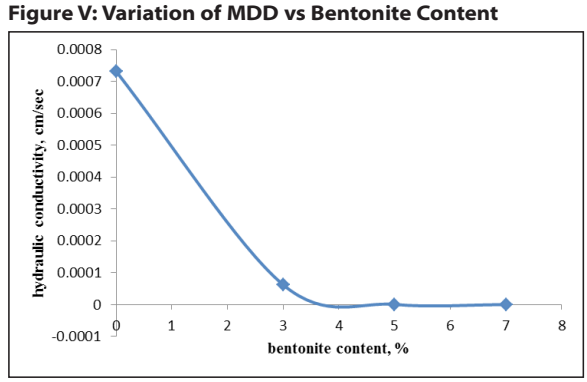

Figure V: Variation of hydraulic conductivity vs Bentonite Content

From the graph plotted above, it can be seen clearly that with the addition of Bentonite, soil properties improved considerably and permeability is decreased. At 7%, we get the required permeability of order 10-9.

CONCLUSION

1. There is not much effect on optimum moisture content of soil.it increases from 17.50% to 18.73 and with addition of Bentonite it increases up to 20.4%.
2. Maximum dry density of soil increases with increase in slag content and Bentonite making it a well packed structure.
3. CBR value of soil increases with increase slag content and therefore increasing its strength up to 25% mix and with further addition of Bentonite, it increases up to 6.02%.
4. Hydraulic conductivity of soil increases with increase in slag content, and in order to reduce it, Bentonite is added as admi-

ture, which reduces permeability up to desirable limit.

RECOMMENDATIONS

Natural soil with 25% slag is considered as ratio for optimum stabilization of soil and can be used for sub grade preparation etc. but slag can't be used solely as cover liners in landfill. Some admixture, such as Bentonite clay needs to mix in order to reduce its hydraulic conductivity.

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