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HYDRAULIC CONDUCTIVITY OF GCL WITH BENTONITE – SILICA FUME MATRIX

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Abstract: This paper presents the influence of partial replacement of bentonite by silica fume which is used in the manufacture of Geosynthetic Clay Liner (GCL). Geosynthetic Clay Liners consist bentonite (Sodium Based) sandwiched between two geotextile. Benotinite, having low permeability imparts better hydraulic performance to the GCL to act as liner. In this investigation, an attempt has been made to study the hydraulic conductivity of GCL with modified Bentonite. The bentonite is partially replaced by silica fume, a waste product of ferroalloy industries. Silica fume reduces the cracking characteristics of bentonite on desiccation. The replacement levels varied from 0% to 50% at a gradual increment of 5%. The test results indicated that partial replacement of bentonite by silica fume did not affected the permeability of bentonite even at 30%. Beyond 45% replacement levels the bentonite- silica fume mixtures showed increased permeability. This increased permeability also well within permeability limits of liners 1×10^{-9}m/sec.

Keywords: Geosynthetic clay liners; permeability; waste management

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INTRODUCTION

Clay liners of large thickness (about 1.2 m) can be replaced by composite liners such as Geosynthetic Clay Liners of few centimetres thickness. GCL is a liner containing bentonite sand witched between two geo-textiles. Bentonite acts as a good barrier as its hydraulic conductivity is very less, while the geotextile holds the bentonite intact. Geotextile also provides shear strength to the composite to withstand shearing stresses that develop when it is laid along the slopes. As smectite has a stronger thermodynamic affinity for divalent cations (primarily calcium and magnesium) than for sodium, the bentonite of GCL may exchange its sodium for other cations if they are present in the fluids with which the GCL comes into contact.

Easy transportation and installation of GCL made them popular over the other liners. Non availability of bentonite in some places makes the GCL costly. Partial replacement of bentonite by silica fume makes the GCL more economical, as silica fume is an industrial waste product. Moreover the silica fume reduces the cracking of bentonite on desiccation. Silica fume being finer (specific surface area 10 000 cm^2/gram) do not much effect the hydraulic performance to the liner. Very scant literature is reported on the behaviour of Geosynthetic Clay Liners, with modified bentonite. The modification in bentonite is to make the material more economical without sacrificing the hydraulic properties like diffusion and hydraulic conductivity. An investigation in this regard has been planned to estimate the hydraulic conductivity of GCL with modified bentonite.

Review of Literature

Hewitt & Daniel (1997) conducted studies on estimating the hydraulic properties of geo-synthetic clay liners after freeze and thaw cycles. The compressive stress applied to the samples are in the range of 7.6–12.4 kPa which simulate the final cover systems of landfills. All the geotextiles withstood the freeze thaw cycles without a significant change in hydraulic conductivity. It was showed that geotextiles can withstand at least three freeze thaw cycles without significant changes in hydraulic conductivity.

Beddoe *et al.* (2011) studied the water retention behaviour of GCLs and concluded that GCL products showed significant variation between their wetting and drying curves indicating that both needle punching and thermal treatment have a significant effect on the swelling behaviour of the GCL and its water retention capacity.

Wong & Haug (1991) found that the hydraulic conductivity of compacted sand-bentonite mixtures did not increase after five freeze-thaw cycles.

Kalkan (2009) studied the effects of freezing and thawing cycles on the strength and permeability of modify the fine-grained soils. The soils are modified with silica fume. The natural fine-grained soils and soil–silica fume mixtures have been compacted at the optimum moisture content and subjected to the laboratory tests. The test results show that the stabilized fine-grained soil samples containing silica fume exhibit high resistance to the freezing and thawing effects as compared to natural fine-grained soil samples. The silica fume decreases the effects of freezing and thawing cycles on the unconfined compressive strength and permeability.

Kalkan (2009) studied the influence of silica fume on the desiccation cracks of compacted clayey soils and reported that silica fume decreases the development of desiccation cracks on the surface of compacted samples. Also suggested that silica fume waste material can be successfully used to reduce the development of desiccation cracks in compacted clayey liner and cover systems.

Experimental Programme

Experimental programme consists of compactions tests and permeability tests to assess the compaction and hydraulic conductivity characteristics of bentonite silica fume mixture, which is used as stuff in Geosynthetic clay liners. Proctors' compaction test is adopted to estimate the optimum moisture content and maximum dry density. Rigid wall falling head permeability tests are conducted on the bentonite – silica fume mixes for different percentage replacements of bentonite by silica fume. Bentonite adopted in this investigation is sodium based bentonite. Silica fume used in this investigation is obtained from Nava Bharat Ferro alloys Limited, Paloncha of Andhra Pradesh. The characteristics of silica fume and bentonite are presented in **Table 1**. The different percentage replacement levels of bentonite with Silica fume considered in this investigation ranged from 0% to 50% at regular intervals of 5%. The different geotechnical properties of silica fume and bentonite mixtures are presented in **Table 2**. Silica fume – bentonite mix is prepared at optimum moisture content to obtain maximum dry density for the preparation GCL in the laboratory. The compacted mixture of bentonite and Silica fume was placed between the non woven geotextiles and the composite was stitched to form GCL. Thus prepared GCL samples are immersed in water for 48 hours for complete saturation of bentonite and silica fume. The test setup used for conducting the permeability tests is presented in **Fig.1**.

Table1. Characteristics of Bentonite and Silica fume

Parameter	Bentonite	Silica fume
Specific Gravity	2.75	2.44
Bulk density (kN/m³)	13.95	11.48
Liquid Limit	265%	15%
Plastic Limit	52%	Not Plastic
Free swell index	430%	No free swell
Optimum Moisture Content	26%	56%

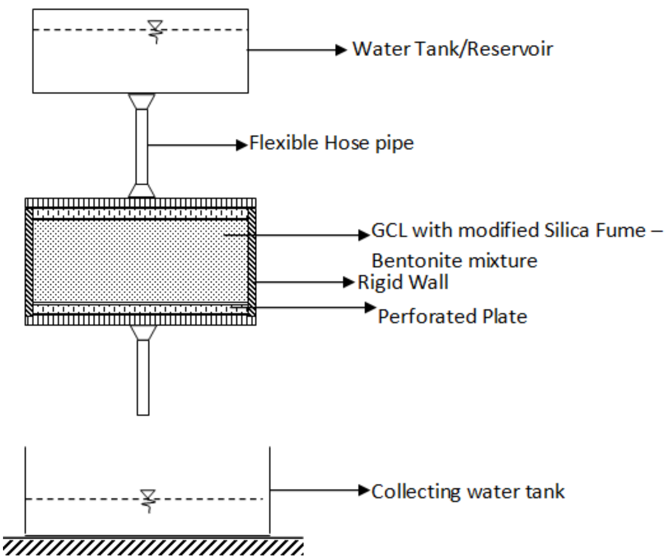

Fig. 1 Falling head permeability test setup.

RESULTS AND DISCUSSION

The permeability test results are presented in **Table 3** and **Fig. 2**. From these test results it can be understood that replacement of bentonite by Silica fume increases the permeability, however the increase in this value do not cross the stipulation of permeability as liner 1×10^{-9} m/s. The increase in permeability with the replacement of bentonite by Silica fume is due to the fact that bentonite under saturated conditions forms a double layer which makes it strong in resisting permeation of water. Silica fume particles present in the matrix (bentonite and Silica fume) being inert disturb the double layer. The broken micro particles of Silica fume also try to break the double layer. However the increase in the permeability of bentonite Silica fume mixture is not significant up to 40% replacement of bentonite by Silica fume. The variation of optimum moisture content of different mixtures considered in this investigation was presented in **Table 3** and **Fig.3**. From these variations, it is clear that when bentonite is partially replaced by Silica fume, there is an increase in the Optimum moisture content. From economy view, replacement of bentonite by Silica fume up to 40% can be advocated as the permeability of the resulting GCL is less than 1×10^{-9} m/s.

Table 2. Characteristics of Bentonite and Silica fume mixes

Mixture	Specific Gravity	Bulk density (kN/m^3)	Liquid Limit	Plastic Limit	Free swell index
95% Bentonite + 5% Silica fume	2.72	14.0	265	50	400
90% Bentonite + 10% Silica fume	2.70	13.8	260	45	390
85% Bentonite + 15% Silica fume	2.68	13.8	258	43	380
80% Bentonite + 20% Silica fume	2.65	13.5	253	41	340
75% Bentonite + 25% Silica fume	2.61	13.6	240	40	310
70% Bentonite + 30% Silica fume	2.59	13.5	235	38	250
65% Bentonite + 35% Silica fume	2.55	13.5	225	35	220
60% Bentonite + 40% Silica fume	2.5	13.4	215	32	110
55% Bentonite + 45% Silica fume	2.48	13.3	200	26	60
50% Bentonite + 50% Silica fume	2.43	13.0	180	22	80

Table 3. Permeability and OMC of Silica fume-bentonite mixes

Mixture	Permeability (m/s)	Optimum Moisture Content
100% Bentonite + 0% Silica fume	1.82E-10	26
95% Bentonite + 5% Silica fume	1.88E-10	30
90% Bentonite + 10% Silica fume	1.92E-10	33
85% Bentonite + 15% Silica fume	2.15E-10	36
80% Bentonite + 20% Silica fume	3.12E-10	38
75% Bentonite + 25% Silica fume	4.54E-10	40
70% Bentonite + 30% Silica fume	5.39E-10	41
65% Bentonite + 35% Silica fume	6.64E-10	44
60% Bentonite + 40% Silica fume	7.12E-10	45
55% Bentonite + 45% Silica fume	9.32E-10	49
50% Bentonite + 50% Silica fume	1.25E-09	50

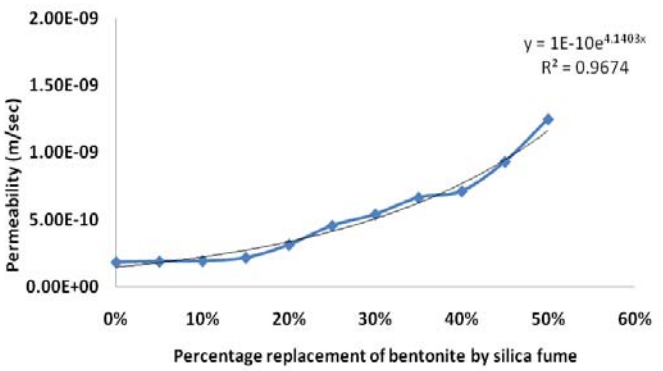

Fig. 2 Variation of Permeability of GCL for different replacement levels of bentonite with Silica fume.

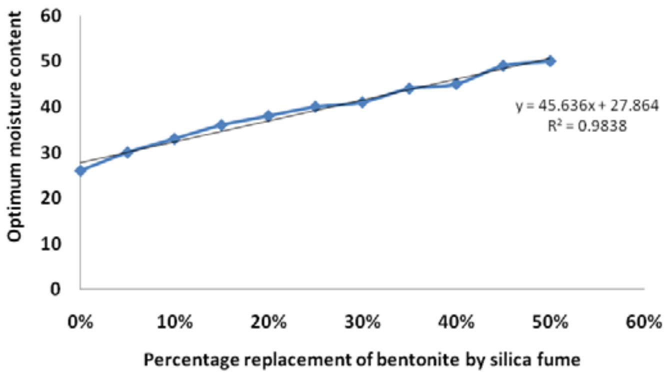

Fig. 3 Variation of OMC bentonite- Silica fume mix.

CONCLUSION

Based on the laboratory experimental study conducted on the behaviour GCL with partially replacing bentonite by Silica fume, the following conclusions were drawn.

1. The bentonite in GCL can be partially replaced by Silica fume to the tune of 40%. Increase in the permeability of the resulting modified GCL would be well within the allowable permeability limit of 1×10^{-9} m/s.

2. Partial replacement of bentonite by Silica fume increases the optimum moisture content and decreases the bulk density of the matrix.

3. Diffusion studies on GCL, in this direction are required to further promote the use of Silica fume in the manufacture of geosynthetic clay liners.

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REFERENCES

Beddoe, R., Take, W. & Rowe, R. (2011) Water-Retention Behavior of Geosynthetic Clay Liners. *J. Geotech. Geoenviron. Eng.* **137**(11), 1028–1038.

Hewitt, R.D. & Daniel, D.E. (1997) Hydraulic Conductivity of Geosynthetic Clay Liners after Freeze-Thaw. *J. Geotechnical & Geoenviron. Eng.* **123**(4), 305−313.

Kalkan, E. (2009) Influence of silica fume on the desiccation cracks of compacted clayey soils. *Appl. Clay Sci.* **43**(3−4), 296−302.

Kalkan, E. (2009) Effects of silica fume on the geotechnical properties of fine-grained soils exposed to freeze and thaw. *Cold Regions Sci. Technol.* **58**(3), 130−135.

Koerner, R.M. (1994) *Designing with Geosynthetics*, Prentice−Hall, inc., 1994.

Wong, L.C. & Haug, M.D. (1991) Cyclical closed−system freeze-thaw permeability testing of soil liner and cover materials. *Can. Geotech. J.* **28**(6), 784−793.