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Vaishali S. Gor
Mott Macdonald Pvt. Ltd., India

Liviu S. Thakur
ITM Universe, Baroda, India

K. R. Biyani
M. S. University, Baroda, India

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STUDY OF TYPICAL CHARACTERISTICS OF EXPANSIVE SUBGRADE WITH GEOTEXTILES AND CUSHION MATERIALS

Vaishali S. Gor
Geotechnical Engineer
Mott Macdonald Pvt. Ltd.

L. S. Thakur
Assitant Professor
ITM Universe, Baroda

Dr. K.R. Biyani
Retd. Professor
M. S. University, Baroda

ABSTRACT

Well-built and maintained roads play a major role in the development of a nation. Hence considerable attention is required towards the widening of roads, their stability and periodic repair works. Since the beginning of modern highways, engineers have strived continuously to produce better pavement at lower cost. Most state highways in the central part of India have problems of foundation due to presence of expansive soil i.e. black cotton soil. For the improvement of such problematic soil, conventional technique of soil stabilization, use of cushion, use of moisture barriers, etc. has been adopted.

The main objective of the research work was to study the typical characteristic of expansive soil and to control the swelling of expansive soil below flexible pavements. To achieve this aim work has been carried out with reinforcing geotextile overlain with cushion material. Effect of cushion material on swelling of expansive soil has been investigated alongwith the ability of geotextiles in locked and unlocked condition with cushion material was scrutinized. Better cushioning due to use of flyash can be attributed to pozzolanic activity forming stable compounds. It is observed that the use of flyash as cushion material provides better swelling control as compared to quarry dust. Unlocked geotextiles did not prove as effective as locked textiles with the use of either of the cushion materials. The unlocked textiles proved advantageous with quarry dust but did not prove as advantageous as only flyash. The most important two functions of geotextiles namely separating and reinforcement have been most effectively used in the locked condition.

The study was further extended to stabilize the expansive soil with metakaolin. Swell pressure test and UCS results on samples treated using 1% metakaolin provided its effectiveness in controlling the swelling characteristics of expansive soil as well as strength improvement.

INTRODUCTION

The discovery of high speed vehicles by mankind has put in immense pressure on the engineering fraternity to put in if not larger efforts at least equal efforts into building better roads on any given soil. Well-built and maintained roads play a major role in the development of the nation. Hence considerable attention is required towards the construction of new roads, modernization of existing roadways, their stability and periodic maintenance works. Since the beginning of modern highways, engineers have strived continuously to produce better pavement at lower cost. Modern developing society needs good trafficable roads and railways; and that to almost maintenance free and with longer service life. This need of strong and sound transportation way without any flaw has given importance to the ground improvement technique for pavement construction. In India, most state highways in the central part have problems of foundation due to presence of expansive soil i.e. black cotton soil. Black cotton soil when associated with engineering structures with moisture variation experiences either settlement or heave depending on the stress level and the soil swelling pressure. Design and construction of civil engineering structures on and with expansive soils is a challenging task for geotechnical engineers.

Conventionally, the expansive sub-grades are improved by soil stabilization techniques, checking the entry of moisture content into expansive sub-grade, using cushion materials to absorb the swelling of the expansive soil etc. These techniques have been found to be effective in improving their engineering properties, strength characteristics and CBR value but prove short duration improvement, cumbersome in execution, maintenance and/or costly.

Investigations for the present study have been divided in two sections essentially. The first section involved the use of geotextile at the interface of expansive soil and cushion material in locked and unlocked conditions, whereas the second section involved the stabilization of expansive soil with metakaolin.

TYPICAL CHARACTERISTICS OF EXPANSIVE SOIL

Expansive soils are those that when exposed to moisture, absorb it resulting in significant increase in volume of the soil. water and significantly increase in volume. The phenomenon of soil expansion under exposed moisture conditions is analogous to various metals expanding under exposure to elevated temperatures. Certain minerals in expansive clays have a remarkable ability to absorb water and to assimilate it into their microstructure. A picture of clay particles showing how they attract and “hold” polar water molecules is shown in Fig. 1. The larger the surface area of clay particles, higher is the charge density, higher is the capacity of the clay microstructure to assimilate water.

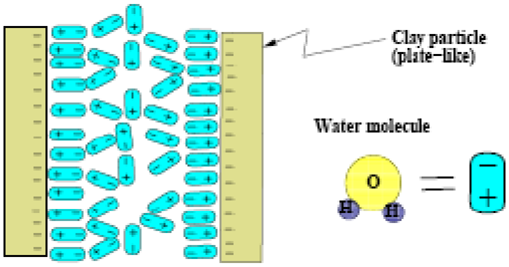

Fig. 1. Charged Clay Particles and Attracted Dipolar Water Molecules.

MATERIALS

Black cotton soil

Black cotton soil procured from Karjan; Gujarat was kept for air-drying and than pulverized. Geotechnical properties of the soil were found out using standard methods prescribed in relevant IS codes (IS 2720), and are summarized in Table 1. California bearing ratio (CBR) test has been conducted on black cotton soil in unsoaked as well as soaked condition. The CBR values obtained at 2.5mm and 5mm penetration are given in Table 2.

Geotextiles

Two woven and two non-woven geotextiles were taken for the research study. In this study they are named as WG1, WG2, NWG1 and NGW2 (Fig. 2). Laboratory tests were conducted to evaluate the important properties of geotextiles for reinforcement applications are described in Table 3.

Table 1. Geotechnical Properties of Black Cotton soil

Property	Value
Soil Type	CH
Liquid Limit (%)	81.2
Plastic Limit (%)	38.4
Shrinkage limit (%)	12.8
Maximum Dry Density (gm/cc)	1.5
Optimum moisture content (%)	21
Free Swell (%)	76
Specific Gravity	2.46
Unconfined Compression Test (kg/cm2)	1.41
Cohesion (kg/cm2)	0.46
Angle of internal friction (°)	6

Table 2. California Bearing Ratio Values Black Cotton soil

Specimen Description	*Unsoaked*		*Soaked*	
	2.5 mm	5.0 mm	2.5 mm	5.0 mm
At M.D.D	4.42	4.39	2.88	2.46
95% Dry Side	16.51	15.39	1.272	1.58

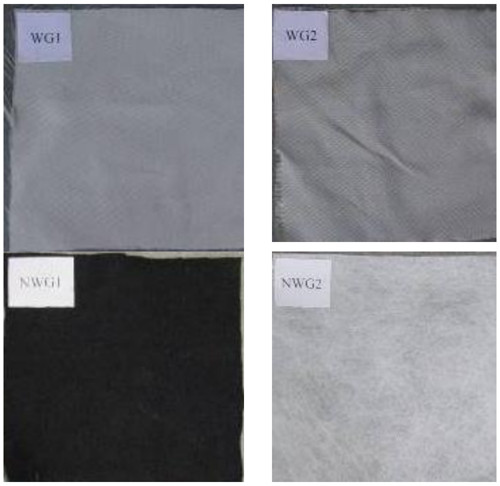

Fig. 2. Different Geotextiles used for research

Table 3. Properties of Different Geotextiles

Type of Test	Breaking Load (kg) for Geotextile			
	Woven		Nonwoven	
	WG-1	WG-2	NWG-1	NWG-2
Thickness (mm)	0.64	0.28	2.54	0.67
Grab Test	251.64	127.22	85.28	69.9

Narrow Strip Tensile Test	205.50	120.23	47.52	44.73
Trapezoidal Tear Test	113.24	29.358	34.95	78.29
Puncture Test	39.14	8.39	16.77	11.18
CBR Push Through Test	184.53	132.81	75.49	86.67

Cushion Material

Quarry dust

Engineering properties of quarry dust were found using standard methods prescribed in IS 2720, and are summarized in Table 4.

Table 4. Index Properties of Quarry Dust

Property	Value
D_{10} (mm)	0.09
D_{30} (mm)	0.41
D_{60} (mm)	1.05
C_u	11.67
C_c	1.77
Maximum Dry Density(g/cc)	1.57
Specific Gravity	2.071

Flyash

The geotechnical properties of Flyash have been determines by conducting laboratory test on the flyash. The results obtained are given in Table 5. The chemical analysis of the flyash is given in Table 6.

Table 5. Geotechnical Properties of Flyash

Property	Value
Liquid Limit	43.25%
Plastic Limit	Non-plastic
Maximum Dry Density (g/cc)	1.23
Optimum moisture Content	36.57%
Specific Gravity	2.071

Table 6. Chemical Properties of Flyash

LOI	8.4%
SiO_2	37.012%
CaO	1.121%
MgO	0.7731%

Filler Material

Metakaolin

The basic physical properties i.e. colour and specific gravity of Metakaolin is shown in table 7. Different percentages of Metakaolin are added to the BC soil to stabilize it thereby controlling the swell and if possible increasing the strength of the sub-grade.

Table 7. Properties of Metakaolin

Property	Value
Colour	Yellowish White
Specific Gravity	2.76

EXPERIMENTAL SET-UP

A major part of the experimental work was conducted with the help of CBR test apparatus. The basic properties of black cotton soil were determined by using Atterberg's limit apparatus, Compaction test apparatus, triaxial cell, swelling pressure measurement instrument etc. The tensile strength characteristics of geotextiles used for the study were attained using Narrow width tensile test, Grab test and Trapezoidal test. On these geotextiles Cone drop test and CBR push through tests were also conducted. The basic properties of the cushion materials were determined by using Atterberg's limit apparatus, compaction test apparatus etc. California Bearing Ratio apparatus was used to the study contribution of reinforcing action of geotextiles and cushioning effect of various materials since this test is universally adopted as a standard test in design of sub-grades. However, the standard CBR mould was modified to suit the requirement as described below.

A standard laboratory CBR test set-up consist of a mould of 150mm diameter and 175mm height with base plate and a collar, a compaction rammer for preparing specimen in the mould, a loading frame to penetrate the sample with cylindrical plunger of 50mm diameter, dial gauge for measuring penetration, a proving ring for measuring penetration resistance etc shown in Fig. 3. For conducting CBR test at standard proctor compaction energy, the clayey soil specimen with optimum moisture contents was compacted in 3-layers, each layer with 56 blows of 2.6 kg rammer dropped from a height of 31.0 cms. A surcharge weight of 5 kg (corresponding surcharge pressure equal to = 0.32 T/m^2), which is considered to be equivalent of 13 cms thickness of pavement, was placed on the specimen.

Fig. 3. Standard CBR Mould set-up

Improvement of CBR value by introducing of geotextile element is not fully mobilized in standard CBR mould. Reasons for that were given as follows:

- According to Terzaghi's observations on mechanism of bearing capacity of soil and failure surface under the footing extends laterally at least upto distance equal to 2 x diameter of footing from edge of the footing (in our case diameter of plunger = 50 mm). The diameter of standard CBR mould is only 150mm it does not provide enough side space for development of full failure surface.

- It is found that when the failure surface below the plunger is intercepted by the composite reinforcing elements, then only the element contributed to the improvement completely. (Patel N. M. 1981). This may be one of the reasons of inadequate improvements.

- It also felt that in the test conducted the reinforcing element was not anchored by the side soil and it was undergoing rigid body motion.

For the above-mentioned reasons the test was conducted with geotextiles and cushion material on a larger size mould. This large modified mould is of 260mm diameter with base plate, a collar and two surcharge plates of total weight 15.1 kg (corresponding surcharge pressure equal to 0.304 t/m^2). The CBR mould was filled, by compacting the soil with Standard proctor compaction energy Fig. 4.

Preliminary investigations have been carried out on specimens prepared in CBR moulds to assess the potential of fly ash and quarry dust cushions to control/absorbs swelling of expansive soil. The benefit of using reinforcing material in the form of woven and non-woven geotextiles at the interface of expansive soil and cushion materials has also been evaluated.
Expansive soil was compacted in CBR mould up to different heights (0.5H, 0.6H, 0.7H, and 0.8H) at 95% dry side of M.D.D with the remaining volume being filled with the cushion material. Fly ash was compacted at 34% water content and a dry unit weight of 1.17 g/cc whereas quarry dust was compacted in dry condition at its dry unit weight 1.57 g/cc corresponding to I.S light compaction condition. The specimens were soaked in water for a period of 96 hours and swell is recorded periodically and values of percent swell have been calculated.

Fig. 4. Modified CBR Mould

Laboratory investigations have been carried out to study the swell control of expansive soil by placing the fabric at the interface of expansive soil and the cushion material. The effects of simple placement and fabric held in position in controlling swell have been assessed. Pre-fabricated circular rings made from 6 mm diameter mild steel bars with three legs as shown in Fig. 5 have been used to hold the fabric in position. The reinforcing fabrics has been tightly folded around the fabricated rings and tied to its circumference using a 1mm binding thread at 05 c.m. c/c distances approximately. The rings have been fabricated to have differential lengths of legs to suit placement over expansive soil of varying thickness in the CBR moulds. Woven as well as non-woven geotextiles have been used in the laboratory investigations.

Fig. 5. Circular ring holding the geotextile in position

The fabricated ring with tied reinforcing fabric has been placed over the compacted expansive soil in the lower half of the mould and then its legs are gently pressed into the compacted expansive soil until the fabric is seated over the expansive soil. Above the fabric, the cushion material has been compacted in a manner similar to the case of preparation of specimen-unreinforced case. The swell values have been recorded by monitoring the dial gauges readings placed at top of the specimen, for a soaking period of 96 hours.

Based on the observed values of swell, the values of percent swell and hence percentage reductions in percent swell of expansive soil with cushion materials using woven and non-woven geotextiles fabrics have been determined.

COMPARISONS BETWEEN DIFFERENT CUSHION MATERIALS

The comparison of Quarry dust and flyash cushion is divided in following different groups.

- With Quarry dust and Flyash without geotextiles
- With geotextiles WG1 (unlocked)
- With geotextile WG1 (locked)
- Quarry dust and Flyash with Different Geotextiles (Unlocked)
- Quarry dust and Flyash with Different Geotextiles (Locked)

Quarry dust and Flyash without geotextile

The effect of percentage reduction in swell with quarry dust and fly ash is shown in table 8. From the results the comparison between Quarry dust and flyash cushion is shown in Fig. 6.

Table 8. Comparison between quarry dust and flyash

Cushion: BC	% Swell		% Reduction in swell	
	Q.D	F.A	Q.D	F.A
0.5/0.5	1.898	1.619	70.184	74.569
0.4/0.6	2.827	0.688	55.588	89.193
0.3/0.7	3.510	0.582	44.848	91.169
0.2/0.8	4.174	0.395	34.421	93.793

Analysis and discussion The values of percent swell have been calculated as the ratio of swell observed at the specimens to the thickness of expansive soil. The percent swell values of expansive soil with cushion materials have been presented in Fig. 6. Referring to it, it may be seen that the swell decreases with increase in cushion thickness. While for the flyash the swell decreases with increase in cushion thickness upto 20% removal of BC soil and replacement of flyash, after that further decreasing in the flyash thickness cause a drastic increase in the swell. For quarry dust the least percentage swell observed is 1.848% at 1 quarry dust to black soil ratio. It means that there is 70.184% reduction in swell has been observed. In the case of flyash least percentage swell is observed is 0.395% at 0.2/0.8 flyash to BC soil. It means there is 93.793% reduction in swell.

Quarry dust absorbs swelling of expansive soil rather than suppressing and so it cannot be advantageously used as a cushion to suppress swelling of expansive soils. The better cushioning effect of flyash can be attributed due to pozzolanic reaction forms stable compounds. It may be observed that the flyash cushions control swelling of expansive soil in a better manner in comparison to quarry dust.

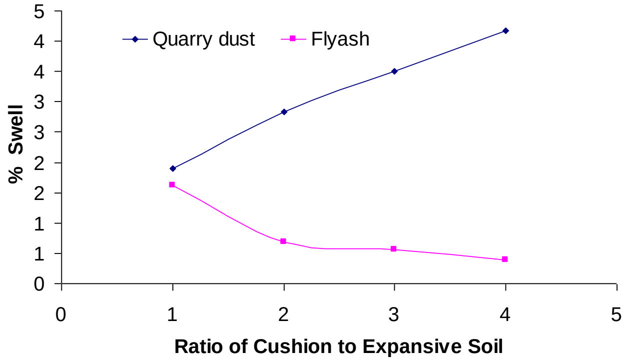

Fig. 6. Comparison between Quarry dust and Flyash

Quarry dust and Flyash with WG1 (Unlocked)

The effect of percentage reduction in swell with quarry dust and fly ash with WG1 (unlocked) is shown in table 9. From the results the comparison between quarry dust and flyash cushion is shown in Fig. 7.

Table 9. Comparison between quarry dust and flyash with WG1 (Unlocked)

Cushion: BC	% Swell		% Reduction in swell	
	Q.D	F.A	Q.D	F.A
0.5/0.5	1.613	2.892	74.648	54.549
0.4/0.6	2.402	1.285	62.247	79.817
0.3/0.7	2.601	3.098	59.129	51.312
0.2/0.8	3.184	0.471	49.970	92.593

Analysis and discussion. When the geotextile placed between expansive soil and cushion material it works as a separator. From the table 9 it can be seen that the maximum percentage reduction in swelling with WG1 (unlocked) observed is 92.59% at 0.2/0.8 flyash to BC soil and 74.64 % at 0.5/0.5 quarry dust to BC soil.

The object of placing the geotextile between dissimilar materials is that the integrity and functioning of both materials can remain intact or be improved. This object was achieved when quarry dust was used as cushion, but in case of flyash the thin thing is different.

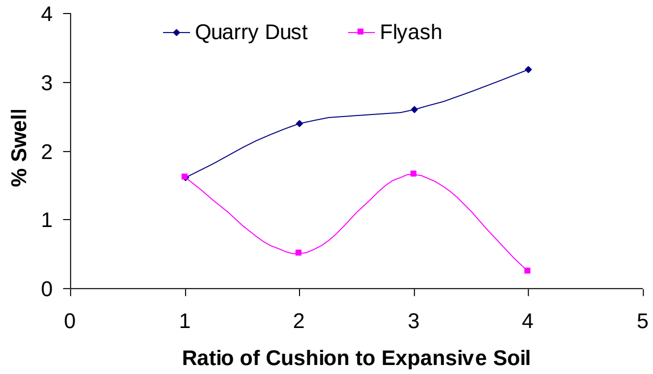

Fig. 7. Comparison between Quarry dust and flyash with WG1 (unlocked)

Quarry dust and Flyash with WG1 (Locked)

The effect of percentage reduction in swell with quarry dust and fly ash with WG1 (locked) is shown in table 10. From the results the comparison between quarry dust and flyash cushion is shown in Fig. 8.

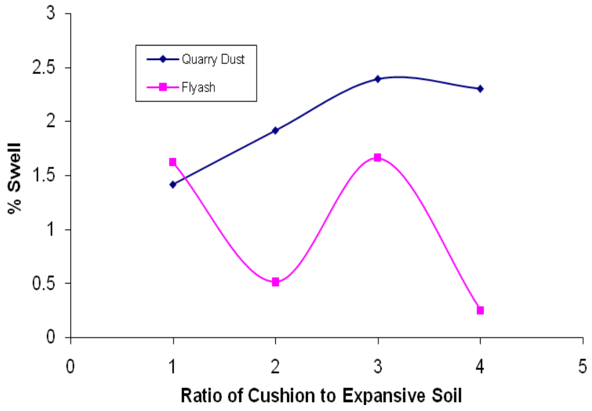

Fig. 8. Comparison between Quarry dust and flyash with WG1(Locked)

Table 10. Comparison between quarry dust and flyash with WG1 (Locked)

Cushion: BC	% Swell		% Reduction in swell	
	Q.D	F.A	Q.D	F.A
0.5/0.5	1.419	1.619	77.704	74.561
0.4/0.6	1.916	0.515	69.882	91.897
0.3/0.7	2.391	1.661	62.432	73.899
0.2/0.8	2.301	0.253	63.846	96.016

Analysis and discussion. The maximum % reduction swell has been observed with WG1 (locked) is 91.89% at 0.2/0.8 ratio and 96.06% at 0.5/0.5 ratio with flyash and quarry dust respectively. Simple placement of geotextile does not control swelling except acting as separators. It can be observed from the results presented that the reinforcing geotextiles held in position could suppress swelling of expansive soil due to their restraining ability. The reinforced flyash cushion has shown better swell control than rock flour cushions. Fig. 8 shows that the percent swell values of expansive soil have decreased significantly with usage of reinforcing textile in locked condition in association with cushion materials.

Quarry dust and Flyash with Different Geotextiles (Unlocked)

The effect of percentage reduction in swell with quarry dust and fly ash with different geotextiles (unlocked) is shown in table 11 and Fig. 9.

Table 11. Evaluation of quarry dust and flyash with Geotextiles (Unlocked)

Geotextiles	% Swell		% Reduction in swell	
	Q.D	F.A	Q.D	F.A
WG1	2.863	3.098	55.010	51.312
WG2	1.916	1.629	69.885	74.402
NWG1	1.642	3.251	74.198	48.920
NWG2	3.492	1.056	45.134	83.402

*QD = Quarry Dust
*FA = Flyash

Quarry dust and Flyash with Different Geotextiles (Locked)

The effect of percentage reduction in swell with quarry dust and fly ash with different geotextiles (Locked) is shown in Table 12 and Fig. 10.

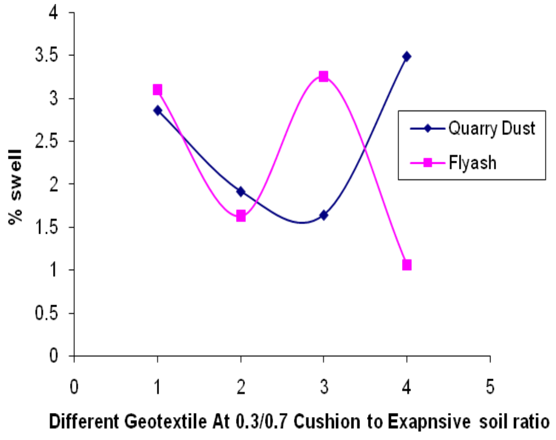

Fig. 9 Comparison between Different geotextiles (unlocked)

Table 12. Comparison between quarry dust and flyash with Geotextiles (Locked)

Geotextiles	% Swell		% Reduction in swell	
	Q.D	F.A	Q.D	F.A
WG1	2.391	1.661	62.432	73.899
WG2	1.179	0.944	81.471	85.154
NWG1	1.520	2.150	76.114	66.210
NWG2	2.221	0.808	65.101	87.296

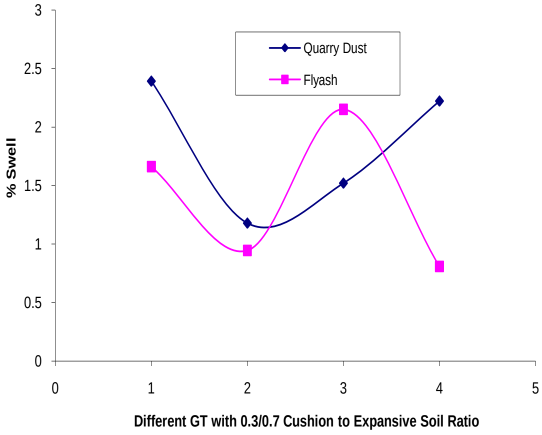

Fig. 10. Comparison between Different geotextiles in Locked condition

Analysis and Discussion. From the above figures and results it can be seen that the flyash cushion are effective over the quarry dust cushion in suppressing the swelling of expansive soils due the pozzolanic reaction with expansive soil. From the flyash cushion 80% of swelling reduction can be achieved by 20% removal and replacement. Further holding the geotextiles in position can reduce the swelling. Quarry dust cushion absorbs the swelling of expansive soils rather then suppressing. So the quarry dust cushion cannot be used as advantageously as flyash cushion.

Effect of Geotextiles with Locked and Unlocked Condition

The effect various geotextiles used with cushions in locked and unlocked condition is shown in Table 13 and in Fig. 11 and Fig. 12 the comparison between various locking conditions is shown.

Analysis and Discussion. The swell characteristics have been generated from the tests using cushions with woven geotextile WG1 is given in table 13. The rate of reduction in the percentage swell of expansive soil with quarry dust using WG1 without geotextile, unlocked and locked condition has been presented in Fig. 11 and similar for flyash has been presented in Fig. 12. Fig. 11 and Fig. 12 impress that the percent swell values of expansive soil have decreases significantly with usage of reinforcing textile in locked condition in association with cushion material.

Table 13. % Reduction in Swell with Varying Cushion to Expansive Soil Ratio in Locked and Unlocked Condition

Cushion: BC	% Reduction in Swell		
	Without GT	WG1(U)	WG1(L)
Quarry Dust			
0.5/0.5	70.18	74.65	77.71
0.4/0.6	55.59	62.25	69.88
0.3/0.7	44.85	54.92	62.43
0.2/0.8	34.42	49.97	63.85
Flyash			
0.5/0.5	74.57	54.55	74.56
0.4/0.6	89.19	80.88	91.89
0.3/0.7	91.17	51.31	73.90
0.2/0.8	93.79	92.59	96.02

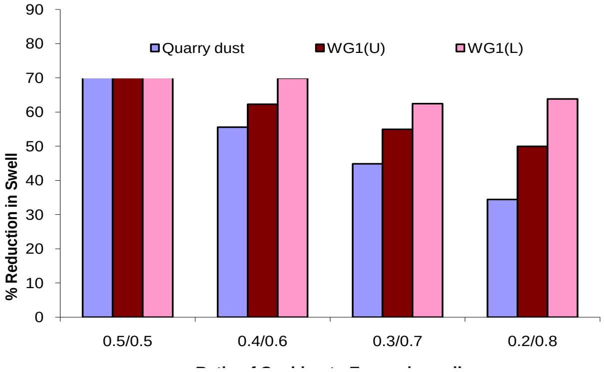

Fig. 11. Effect of (%) Reduction in swell with (WG1) different reinforcing condition

EFFECT OF METAKAOLIN ON SWELLING

Control of Expansive Soil

The swell pressure tests have been performed with various percentages of metakaolin added to expansive soil (Table 14). The results of UCS and CBR tests are shown in Table 15 and Table 16 respectively. The swell characteristic data generated from the tests shown in Table 17.

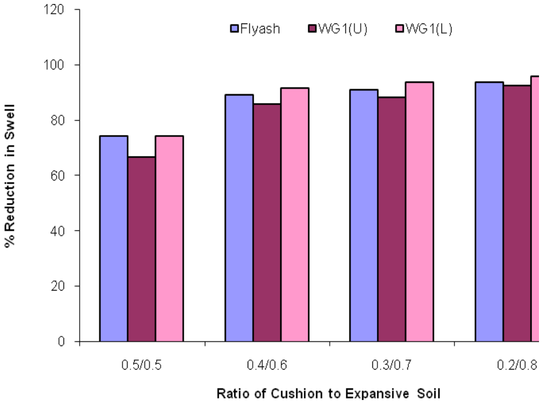

Fig. 12. Effect of (%) Reduction in swell with (WG1) different reinforcing condition

Table 14. Swell Pressure with Different % Metakaolin

% Metakaolin	*Swell Pressure in kg/cm^2*	
	At M.D.D	At 95% Dry Side
1%	0.185	0.123
2.5%	0.300	0.180
5%	0.370	0.261
7.5%	0.380	0.281
10%	0.628	0.350

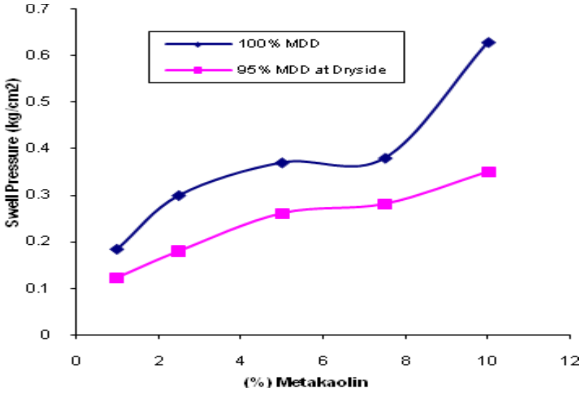

Fig. 13. Effect of Metakaolin on Swell Pressure

Table 15. UCS of Stabilized BCS with Different % of Metakaolin

% Metakaolin	UCS Value (kg/cm^2)	
	1 Day	2 Day
0%	*1.41*	-
1%	2.23	4.93
5%	2.52	3.61
10%	2.94	1.63

Table 16. CBR value of Black cotton soil with 1% MK

Specimen Description	*CBR Value*	*Swell (mm)*
Soaked	10.73	4.521
Unsoaked	14.80	

Table 17. Swell Characteristics of Metakaolin Stabilized Expansive Soil

% M.K	Ht of Specimen (mm)		Swell (mm)	% Swell	% Reduction in swell
	1 Day	2 Day			
0	76	80.1	4.1	5.40	
1	74.5	78.5	4	5.37	0.48
2.5	76	79	3	3.94	26.83
5	76	78.5	2.5	3.29	39.03
7.5	76	78	2	2.63	51.22
10	76.5	80	3.5	4.58	15.20

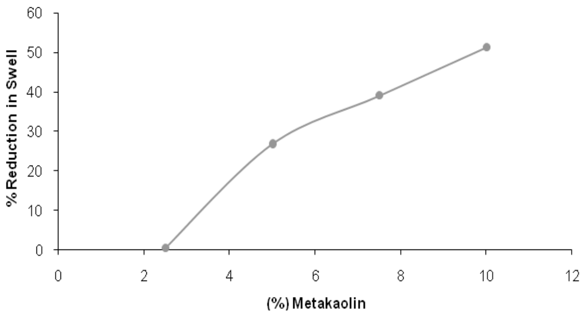

Fig. 14. Effect of Metakaolin in Percentage Reduction in Swell

<u>Analysis and Discussion</u> It can be seen from the results presented in the table 14 that when 1% of metakaolin added in the expansive soil the swell pressure was minimum, after that increasing the percentage of metakaolin there is also increase in the swell pressure. Table 15 shows the unconfined compressive strength of metakaolin stabilized expansive soil. It can be seen that with increasing the percentage of metakaolin the 1st day strength of expansive soil also increases while this is dissimilar with 4 days strength. Table 16 shows the CBR value of stabilized metakaolin, it can be seen that the CBR values increases compared to pure black cotton soil. The swell characteristics data generated for stabilized expansive soil was shown in table 17. From the results it can be seen that as the percentage metakaolin increases the percentage reduction in swelling also increases up to 7.5% of metakaolin. After that the percentage reduction in swelling reduces.

FOLLOWING ARE THE SUMMARY OF FINDINGS:

Effect of Cushions on Swelling

- The quarry dust absorbs the swelling of expansive soil, 70.184% of reduction in swell was observed by using it as a cushion of half the thickness of the sub-grade.

- Better cushioning due to use of flyash can be attributed to pozzolanic activity forming stable compounds. It may be observed that the flyash cushions control swelling of expansive soil in a better manner in comparison to quarry dust. Also when used with geotextiles in unlocked condition flyash does not come into contact with the soil thereby observing lesser improvement.

- Fly ash cushion reduces the swell by 91.90% when used at a thickness of 0.2H.

Effect of WG1 (unlocked) with Cushion on Swelling

- While using quarry dust as cushion material the geotextiles used as separators were advantageous but not as good as in case of flyash

The maximum percentage reduction in swelling with WG1 (unlocked) is 92.59% and 74.64 % with flyash and quarry dust cushion has been observed.

Effect of WG1 (locked) with Cushion on Swelling

- The most important two functions of geotextiles namely separating and reinforcement have been most effectively used in the locked condition.

- The maximum percentage reduction in swell has been observed with WG1 (locked) is 91.89% at 20% replacement of flyash and 96.06% at 50% replacement of quarry dust.

Effect of Different Geotextiles with Cushions on Swelling

- With quarry the woven geotextile WG1 is the most effective. It can be seen from the results that with 0.3/0.7-quarry dust to BC soil ratio 81.472% reduction in the swell have been noted.

- While in the case of flyash 85.154 % reduction in the swell has been noted with WG1.

- The non-woven geotextile NWG2 is the more effective in controlling the swelling. When 0.3/0.7 flyash to BC soil ratio has taken with NWG2 87.296% reduction in swelling has been observed.
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- From the swell pressure test and UCS after 4-days it can be seen that the 1% of metakaolin is more effective in controlling the swelling of expansive soil improving the strength of the soil.

- CBR value also increases by adding 1% of metakaolin, in the expansive soil.

- The maximum percentage reduction in the swell can be obtained with 7.5% of metakaolin, which is 51.22%, further increasing the percentage of metakaolin increases the percentage swell.

RECOMMENDATION

- Further work needs to be carried out on other types of cushion materials for better results

- Further it is required to see need of use of cheaply available waste materials for further reduction in the cost of overall improvement.
- It is recommended that work be carried out on the effect of atmosphere and U.V rays wherever it is likely that the geotextiles may come into contact with sunlight.

- It is required the model tests be carried to investigate the percentage of error due to locking on field and lab.

- Study needs to be carried to further reduce the swelling and swelling pressure by use of filler material like Metakaolin, as per the basic study carried out in the percent work.

LIMITATIONS

- The locked geotextiles should be used with utmost care only after performing sufficient number of field test to note the percentage of locking each and every geotextiles give for specific site conditions.

- Proper compaction and water content is advised since variation in it lead to large differences in swell consideration.

- Proper gradation of cushion material its compaction and water content control shall be ensured to get the required results.

- In case if any change in the compacted density and/or placement water control change will be observed in the overall result.

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