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Strength and Durability Characteristics of Stabilized Red Mud Cushioned Expansive Soil

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Abstract

Placement of cushion is one of the techniques to counteract the swell-shrink behaviour of expansive soil and increase its strength to make it suitable for construction. In this paper, the effects of fly ash (15%) and dolime fine (8%) stabilized red mud cushion on unconfined compressive strength (UCS), soaked California bearing ratio (CBR), percent swell, and durability of an expansive soil at 0,7 and 28 days of curing, have been discussed. The height of cushion: height of soil is varied as 0.25, 0.33, 0.5, 0.67 and 1. The maximum benefits of cushioning, measured in terms of increase in UCS and soaked CBR, reduction in percent swell, and durability of the cushioned expansive soil, are obtained when the height of the cushion is equal to the height of the soil and curing period is 28 days.

Key Words: Fly ash, dolime fine, red mud, cushion, soaked California bearing ratio, durability.

Introduction

Expansive soil is a term generally applied to any soil or rock material that has a potential for shrinking and swelling under changing moisture conditions [1]. Low strength and alternate swell-shrink behaviour are two critical problems associated with this type of soil. Damages occur to lightly loaded structures like, residential buildings, canal bed and linings, retaining walls, and pavements those are supported by it. The cost of damage done by expansive soil annually, to civil engineering structures in USA is $ 1000 million, £150 million in UK and worldwide many billion pounds [2].Placement of cushion is one of the techniques to counteract the swell-shrink behaviour and increase the strength of expansive soil. The expansive soil is removed fully, or partly up to certain depth and a cushion of non swelling material is placed between foundation and the expansive soil. Different types of cushions have been developed by researchers some of them are, sand [3], cohesive non-swelling soil [4], lime stabilized red soil [5], sand-lime [6] etc. Each cushion has one limitation or the other in terms of the efficiency in counteracting the swell-shrink behaviour with passage of time, availability of suitable cushion materials, economy etc. Stabilization using solid wastes [7]-[15] is a very popular and cost effective method normally adopted to make expansive soil suitable for construction. However, mixing of solid waste with expansive soil not only disturbs it but also mixing becomes difficult when the volume of soil is very large. The solid wastes however can be mixed among each other to make a new composite material to be laid as a cushion over expansive soil. In this manner the disposal problem of solid waste will be solved and the problematic expansive soil will be made fit for construction.

Red mud is one of the solid wastes produced from aluminum industry. It is estimated that the annual production of red mud in the world is 75 million tonnes [16].Fly ash is a solid waste produced from coal based power plants, dolime fine is another solid waste produced while crushing large dolomite chips and has high percentage of CaO. The strength of the red mud is very low and it is dispersive in nature. Sabat and Mohanta [17] had stabilized red mud using fly ash and dolime fine, based on UCS, soaked CBR and durability test, the optimum percentage of fly ash was found, as 15% and dolime fine as 8%. At the optimum percentage addition of fly ash and dolime fine, there was 713 % increase in UCS, 961% increase in soaked CBR as compared to virgin red mud, and the stabilized red mud was durable.

Solid wastes have been tried by researchers to use as cushion material by stabilizing them with binders .Some of the stabilized solid wastes used as cushion materials are, cement stabilized rice husk ash[18], cement stabilized fly ash[19], lime stabilized fly ash[20], ground granulated blast furnace slag with and without lime[21], marble dust stabilized fly ash[22].From the review of literature it is found that very limited research has been carried out to study the efficacy of fly ash and dolime fine stabilized red mud, as a cushion material.

The objective of the present investigation is to study the unconfined compressive strength (UCS), soaked California bearing ratio (CBR), percent swell, and durability of fly ash and dolime fine stabilized red mud cushioned expansive soil.

Materials and Methods

Materials

The materials used in the experimental programme are mainly, expansive soil, red mud, fly ash and dolime fine.

Expansive Soil

The expansive soil used in the experimental programme was collected from a place 120 km away from Bhubaneswar. The geotechnical properties of expansive soil are: i) Grain size analysis :a) Gravel size- 0% b) Sand size:- 10 % c) silt size- 22% d) Clay size:-68 % ii) Atterberg's Limit:

a) Liquid Limit -66% b) Plastic Limit- 32% c) Plasticity Index-34% iii) Specific Gravity:-2.67 iv) Compaction properties (standard Proctor) : a) Optimum moisture content (OMC)-22 %b) Maximum dry density (MDD)- 16.2 kN/m^3 v) UCS:- 102 kN/m^2 vi) soaked CBR:-1.82 %

Red mud

The red mud used in the experimental programme was collected from an aluminum industry located in Odisha, India. The geotechnical properties of the red mud are:

i) Grain size Analysis: a) Gravel size - 0% b) Sand size - 6% c) silt and clay size - 94% ii)Specific Gravity:-3.12 iii) Atterberg's Limit: a)Liquid Limit-29 % b) Plastic Limit-23% c)Plasticity Index- 6% iv) Compaction properties (Modified Proctor) - a) OMC -18.3% b) MDD -21.2 kN/m^3 v) UCS –137 kN/m^2 vi) Soaked CBR- 1.72 %.

Fly Ash

The fly ash used in the experimental programme was collected from a power plant located in Odisha, India. It is a class-F fly ash, the major chemical compositions of the fly ash are: CaO - 0.17%, Al_20_3 - 22.26%, SiO_2- 75.39%, and Fe_2O_3 - 0.51%.

Dolime Fine

Large dolomite chips were crushed to make dolime fine .The fines those passed 425 micron IS sieve were used in the experimental programme. The CaO content of the dolime fine is 52.31%.

Methods

Soaked CBR test and percent swell test were conducted on CBR mould. Expansive soil was compacted in CBR mould under standard Proctor compaction energy at its OMC and MDD, up to the depth of 0.8H, 0.75H, 0.67H, 0.6H, and 0.5H, where H=the height of the mould. The remaining height of the mould was filled with the cushion material, stabilized red mud (red mud-fly ash-dolime fine).In the stabilized red mud, the red mud: fly ash: dolime fine was 77:15:08.The stabilized red mud was compacted under modified Proctor compaction energy at its OMC and MDD. Thus the Hc/H_s ratio was found as 0.25, 0.33, 0.5, 0.67 and 1, where H_c= height of cushion and H_s= height of soil. The samples were cured at 0,7 and 28 days and then soaked under water for a period of 96 hours under a surcharge of 5 kg and the change in height of the samples was recorded. The value of the percent swell was calculated as the ratio of the change in height of the sample to the original height, of the expansive soil expressed as percentage. The UCS samples were prepared in a static compaction mould in a similar manner of CBR sample. Samples were cured at 0, 7 and 28 days. Different prepared samples were tested according to the relevant Indian Standard Codes.

Durability tests were conducted on expansive soil cushioned with red mud-fly ash-dolime fine mix at optimum height of the cushion, by subjecting it to 6 wet-dry cycles. For 5 hours, samples were submerged in water, then kept in oven for 42 hours at 70^0 C, this constituted one wet-dry cycle. Samples those found to have volumetric strain more than 10% were rejected.UCS tests were conducted on samples having volumetric strain less than 10%.Three samples were prepared for each tests and the average of the three test results was noted.

Analysis of Test Results

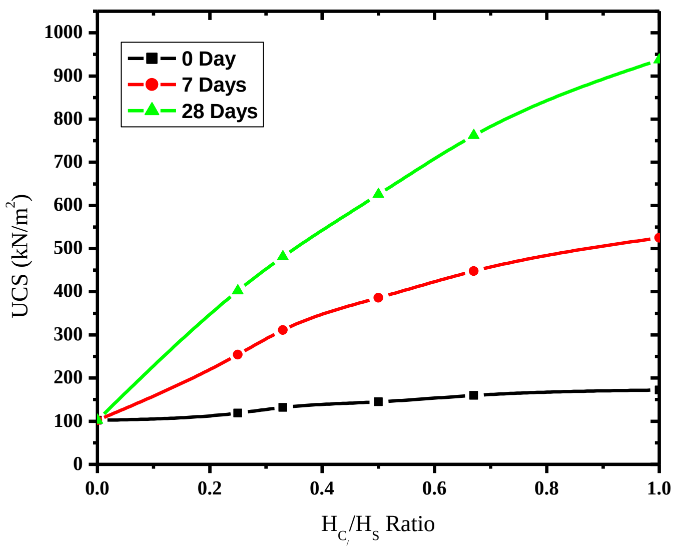

Figure 1: Variation of UCS with H_c/Hs ratio

Fig.1 shows the variation of UCS with H_c/Hs ratio. The UCS goes on increasing with increase in H_c/Hs ratio, it further increases with increase in curing period. The highest value of UCS is observed when the H_c/Hs ratio is 1 and the curing period is 28 days.

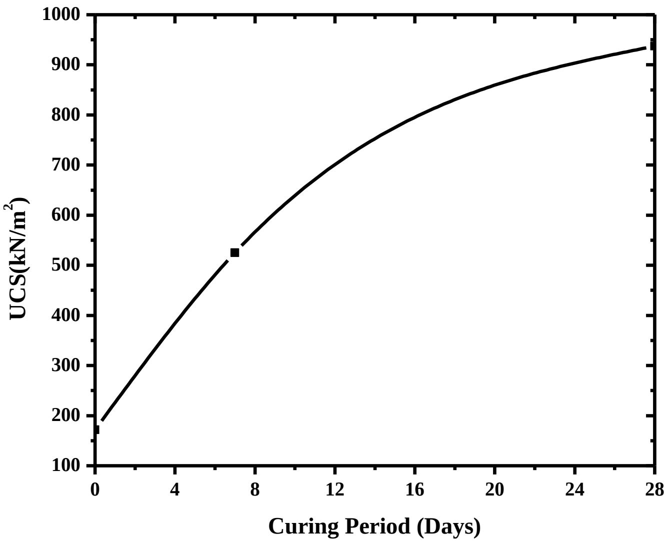

Figure 2: Variation of UCS (H_c/Hs ratio =1) with Curing Period (Days)

Fig.2 shows the variation of the UCS of the sample (H_c/Hs ratio =1) with curing period in days. The UCS increases to 525 kN/m^2 and 937 kN/m^2 from 172 kN/m^2 when the curing period increases to 7 and 28 days from 0-day respectively.

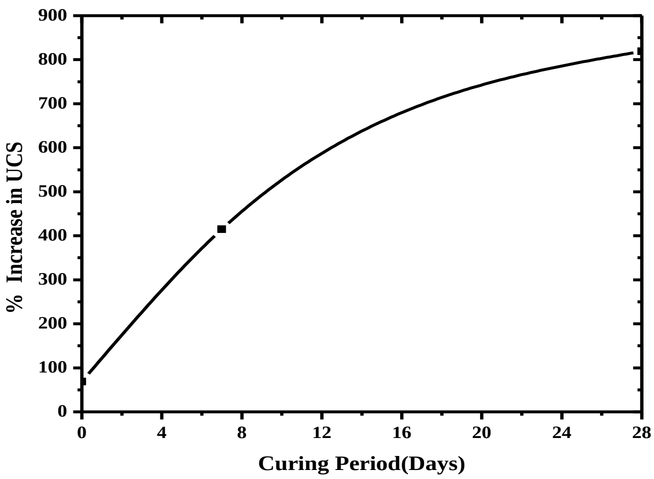

Figure 3: Variation of % increase in UCS (Hc/Hs ratio=1) with Curing Period (Days) as compared to virgin soil.

Fig.3 shows the variation of percentage increase in UCS of the sample having H_c/Hs ratio=1, with curing period as compared to virgin soil. It is observed that at 0, 7 and 28 days of curing period there is approximately 69 %, 415% and 819% increase in UCS respectively as compared to virgin soil

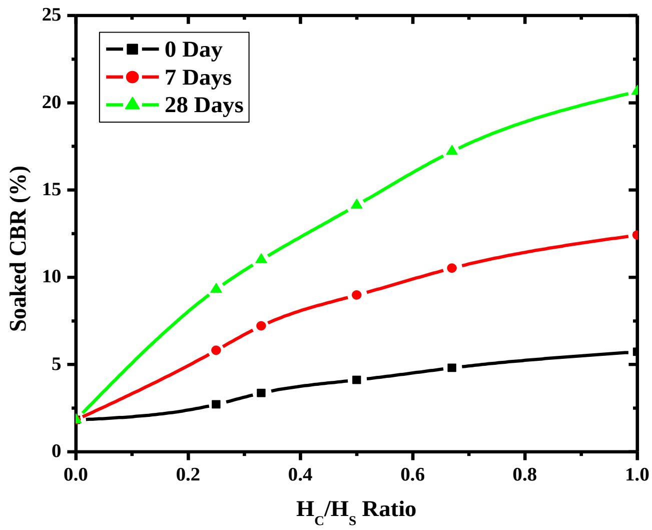

Figure 4: Variation of soaked CBR with H_c/Hs ratio

Fig.4 shows the variation of soaked CBR with Hc/Hs ratio. The soaked CBR goes on increasing with increase in H_c/Hs ratio, it further increases with increase in curing period. The highest value of soaked CBR is observed when the H_c/Hs ratio is 1 and the curing period is 28 days.

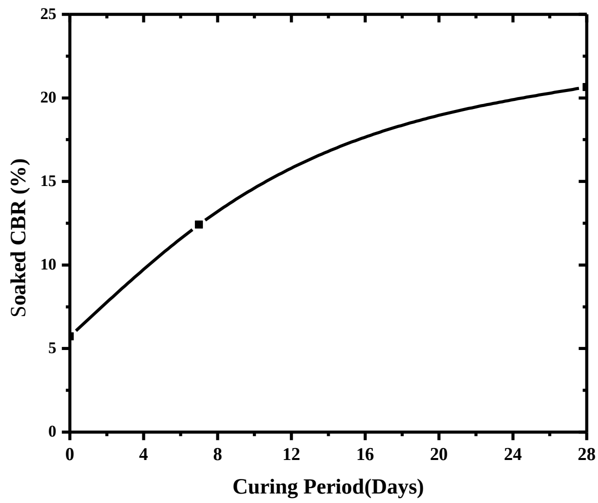

Figure 5: Variation of soaked CBR (H_c/Hs =1) with Curing Period(Days)

Fig.5 shows the variation of the soaked CBR of the sample having H_c/Hs ratio =1, with curing period in days. The soaked CBR increases to 12.42% and 20.65% from 5.73% when the curing period increases to 7 and 28 days from 0-day respectively.

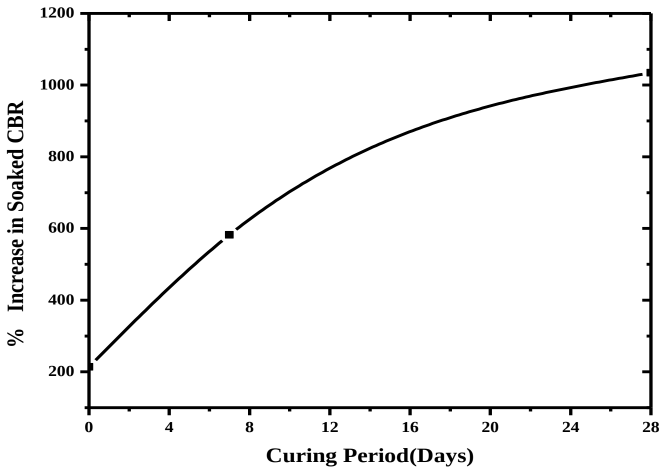

Figure 6: Variation of % increase in soaked CBR (Hc/Hs ratio=1) with Curing Period (Days) as compared to virgin soil

Fig.6 shows the variation of percentage increase in soaked CBR of the sample having H_c/Hs ratio=1, with curing period as compared to virgin soil. It is observed that at 0, 7 and 28 days of curing period there is approximately 214%, 582% and 1035% increase in soaked CBR respectively as compared to virgin soil.

The strength (UCS and soaked CBR) of stabilized red mud cushioned expansive soil increases due to replacement of expansive soil having low UCS and CBR values by red mud-fly ash-dolime fine mix having very high UCS and CBR values. As the Hc/Hs ratio increases the height of the stabilized red mud cushion increases and the depth of low strength expansive soil decreases. With increase in curing period, the strength of the stabilized red mud increases, hence strength of stabilized red mud cushioned expansive soil increases.

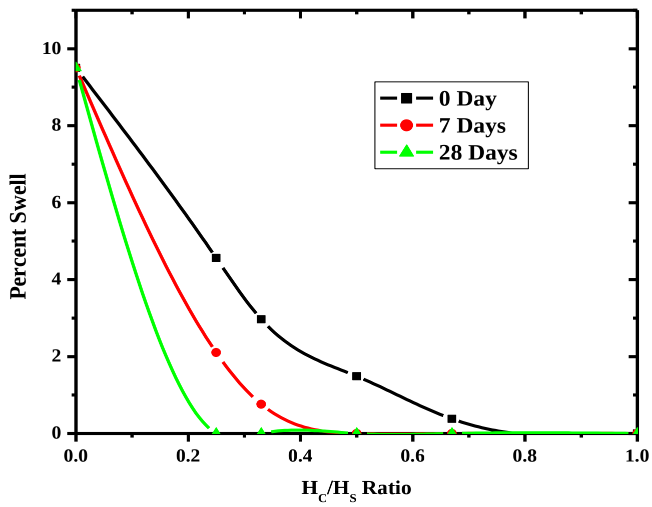

Figure 7: Variation of Percent Swell with H_c/Hs ratio

Fig.7 shows the variation of percent swell with H_c/Hs ratio. From the figure it is observed that percent swell goes on decreasing with increase in H_c/Hs ratio. It further decreases, with increase in curing period.

Fig.8 shows the variation of reduction in percent swell with H_c/Hs ratio. From the figure it is observed that with increase in H_c/Hs ratio the percentage reduction in percent swell goes on increasing, which further increases with increase in curing period. The reduction in percent swell is 100%, at the H_c/Hs ratio of 1, 0.5 and 0.33, for 0 day, 7 days and 28 days cured samples respectively

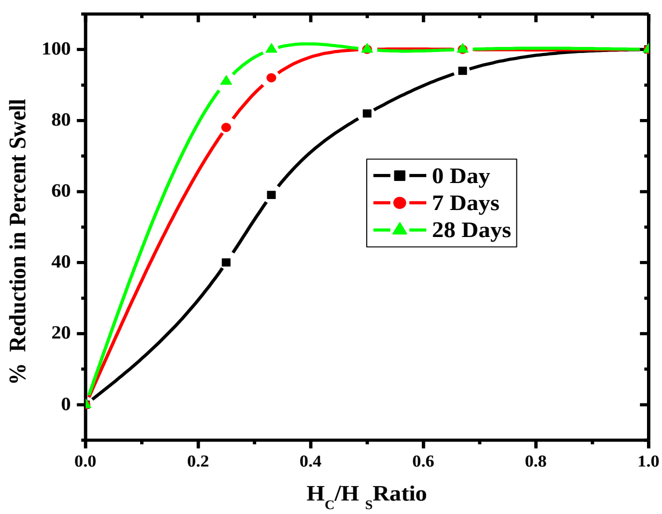

Figure 8: Variation of reduction in Percent Swell with H_c/Hs ratio

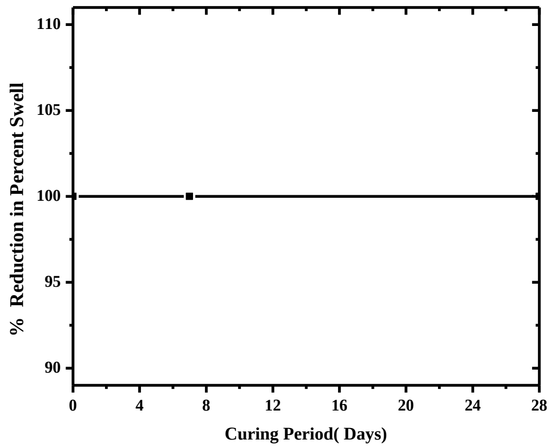

Figure 9: Variation of % reduction in Percent Swell with Curing Period (Days)

Fig.9 shows the variation of percentage reduction in percent swell (H_c/Hs =1) with curing period. From the figure it is observed that there is 100% reduction in percent swell irrespective of the curing period.

The swelling decreases due to replacement of expansive soil with non expansive red mud-fly ash-dolime fine mix cushion. With increase in H_c/Hs ratio the height of cushion increases and height of expansive soil decreases, hence swelling decreases. With curing, the strength of the stabilized red mud cushion increases, it becomes difficult for water to enter into the soil, resulting further decrease in swelling. Cushion also restrains the swelling by its own weight.

From the UCS, soaked CBR, and percent swell test it is found that the optimum ratio of H_c/Hs as 1, and the optimum curing period as 28 days.

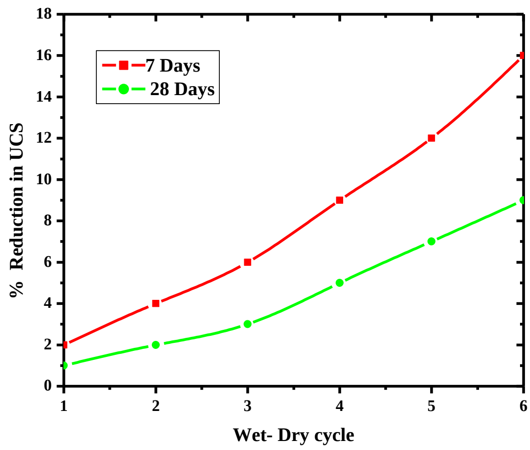

Figure 10: Variation of % reduction in UCS with Wet-Dry Cycle

The sample having 0 day curing was not able to survive any wet-dry cycle. However the sample cured at 7 and 28 days were able to survive.Fig.10 shows the variation of percentage reduction in UCS of the sample having H_c/Hs =1, with wet-dry cycle. The percentage reduction in UCS goes on increasing with increase in wet-dry cycles. The percentage reduction goes on decreasing with increase in curing period. The maximum percentage reduction in UCS occurred when the wet- dry cycle is 6 and curing period is 7 days. The percentages reductions in UCS after 6 wet-dry cycle at 7 and 28 days of curing are 16% and 9% respectively. Hence the stabilized red mud cushioned expansive soil can be treated as a durable material.

Conclusions

A series of laboratory tests were undertaken with a new cushion material developed with red mud, stabilized with 15% fly ash and 8% dolime fine, placed at varying heights over an expansive soil to study its effect on UCS, soaked CBR, percent swell and durability at 0,7 and 28 days of curing**.** The following conclusions are drawn from the study**.**

- With increase in H_c/Hs ratio the UCS and CBR goes on increasing and percent swell goes on decreasing.
- Increase in curing period further increases the UCS, soaked CBR and decreases the percent swell.
- The optimum ratio of H_c/Hs is found to be 1 and the optimum curing period as 28 days.
- At the optimum H_c/Hs ratio, there is approximately 69 %, 415 % and 819 % increase in UCS at 0, 7 and 28 days of curing respectively as compared to virgin soil.
- At the optimum H_c/Hs ratio, there is approximately 214 %, 582% and 1035 % increase in soaked CBR at 0, 7 and 28 days of curing respectively as compared to virgin soil.
- At the optimum H_c/Hs ratio even without curing, the soil is found to be a non swelling material.
- The cushioned expansive soil is found to be durable at the optimum H_c/Hs ratio at 7 and 28 days of curing.
- Fly ash and dolime fine stabilized red mud can be used as cushioning material to reduce swelling and increase the strength of expansive soil.

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