SUMMARY
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Expansive soils are those clay minerals which experience significant volume change upon wetting and drying. The seasonal movement of such materials causes subsidence of ground surface in the summer and heave during the rainy season poses the most challenging tasks for the geotechnical engineers.

Among the several alternatives for absorbing the swelling potential of expansive soil, replacement with non-expansive soil is one of the popular economic methods. The existing practice of soil replacement includes the use of locally available soil generally consisting of red earth (murrum) besides, laterite soils and laterite concretionary materials.

Katti et al. (1979) have reported from their study that the cohesive non-swelling (CNS) soil for stabilizing the canal lining in the black cotton soil regions. However, the CNS soil has got certain limitations and does not give solutions always in every place (Subba Rao, 1994; 2000; Kulkarni and Sawaleshwarkar, 1988). Further, it is very difficult to get the material having the CNS specifications and not economical to transport such materials from far distance.

Therefore, experiments were conducted to identify the most suitable and locally available red earth for replacing and amending the expansive black cotton soil. To study the physical and engineering properties of different red earths and the corresponding geotechnical behavior upon mixing with expansive black cotton soil, the laboratory experiments were carried out during 2002-2005 by applying the standard procedures with the following objectives:
To identify the ideal soil to replace and to amend the expansive property of the swelling clay

To study the physical properties of different non swell soils to be used as an amendment to the swelling black cotton soil.

To study the engineering behavior and their interactive soil mechanics of different soils with the expansive black cotton soil.

**Identification of ideal soil for replacing the expansive black cotton soil**

Soil/earth materials from different places of southern part of Karnataka are screened. The samples considered for the study are as follows:

**Red earth-1 (R₁):** Regional Research Station and College of Agriculture, Navile, Shimoga.

**Red earth-2 (R₂):** Chikkaballapura taluk of Bangalore rural district.

**Gravel soil (GS):** Undulating hilly region occurring in between Shimoga-Sowlanga of the Karnataka State.

**Expansive black soil:** Nyamathi, Honnali taluk, Davanagere district.

**Laterite soil materials:** The different laterite materials includes

- Laterite soil (LS), Fresh Laterite Brick (FLB), Single Season Exposed Laterite Brick (SELB), Two Seasons Exposed Laterite Brick (TELB), Three Seasons Exposed Laterite Brick (Th-ELB) and Laterite Brick Exposed for Many Seasons (LBM). All the samples were obtained from Sagar taluk of Shimoga District.
Mineralogical studies were carried out through X-ray diffraction method to identify the prominent minerals. Accordingly, all the red earth and laterite soil including concretionary brick materials are rich in minerals with varied degrees and amount of kaolinite and quartz as prominent minerals. Expansive black cotton soil is predominant in montmorillonite mineral.

**Physical properties**

**Particle size analysis**

According to HRB (AASHTO 1978) classification, the EBS belongs to A-7-5(0) soil class containing silt & clay and the remaining samples can be grouped under A-1-a(0) class with excellent rating for engineering constructions.

**Atterberg's limits**

EBS found to be having highest LL (68.34%) and the PI (33.90). As per Gibbs and Holtz (1956) classification, the EBS falling in the higher (<32) swelling category and the remaining samples coming in the low (<20) swelling category. Also the EBS categorized under higher (30-60) SI and the remaining samples falls under low expansive (0-20) with an exception of LS which comes under medium (20-30) category.

**ENGINEERING BEHAVIOUR**

**Differential free swell**

To identify the swelling potential of different soils individually and in combination with EBS experiment were carried out at the
beginning. The results indicate that the EBS is having the highest swelling of 60 per cent. According to IS code 2720 XL (1977) classification, EBS comes under very high expansive soil. The remaining soil materials are coming under non-swell class.

Swell behavior of EBS mixed with LBM in the 1:1 proportion given the effective control of free swelling and further reduction of LBM proportion given the reduced effect. Also, all the Sagar laterite brick combination with EBS showed the reduced swelling and the remaining non-swell materials fails to give effective control.

**Swelling pressure**

The maximum swell pressure of 2.33 kg/cm$^2$ was recorded for the EBS. The samples GS-1, RS-1, RS-2, LS and FLB showed recorded the very low fractional swell after a prolonged soaking. The samples, SELB, TELB, Th-ELB and LBM had not showed swelling. Among the combination samples EBS with GS exhibited the maximum swell pressure (1.59 kg/cm$^2$). The maximum control of swell was observed for the EBS + LBM (0.24 kg/cm$^2$) at the 96 hours of soaking. Among the different proportions of LBM with EBS, the proportion reduced from 1:1 resulted in increase of swell pressure and the swell was highest at the 1:0.10 proportions.

**Shear strength**

The results showed the very low shear strength (1.19 kg/cm$^2$) for the EBS and the highest shear strength (3.41 kg/cm$^2$) for the LBM. The friction angle (Φ) was also followed the similar trend. The EBS showing the highest cohesion (0.70 kg/cm$^2$) and the GS and LBM exhibited the nil cohesion. The remaining samples were having the
negligible cohesion. Regarding the combination samples, EBS + LBM had given the maximum shear strength (1.92 kg/cm²) with higher friction angle (22°) and showing the lowest cohesion (0.30 kg/cm²).

**California bearing ratio**

LBM exhibited the higher CBR per cent both under unsaturated and saturated conditions and also with an exception to EBS all the remaining samples were having very good CBR. In the laterite brick grade, more the period exposed to rain wash gives more and more CBR. The EBS was having the very low CBR and its bearing capacity was improved remarkable with the combination of LBM. Also the reduced proportion of LBM from 1:1 showed the declined CBR.

**Permeability**

The EBS was the very poor permeable soil and the remaining samples were having the good permeability. In the combination samples, EBS with LBM showed the better permeability followed with the GS combination. In general LBM, GS, FLB, SELB and TELB combinations with EBS showed the higher improved permeability. The reduction in proportion with EBS also showed the reduced and poor permeability.

**Soil compaction**

LBM sample exhibited the higher wet (2.166 g/cc) and dry (1.930 g/cc) densities. EBS was having the very low wet and dry densities. LBM was having the very low optimum moisture content (OMC) (12.25%) and the EBS can be compressed to high density at the higher OMC (21.74%). In the combination samples, EBS with LBM
showing the higher wet and dry densities. Also the reduced proportion of LBM with EBS indicated the declined wet and dry densities.

EBS was having the very low void ratio and porosity. The remaining samples were having higher void ratio and porosity. EBS combination with LBM had very much improved void ratio and porosity. The reduced proportion of LBM with EBS had given the reduced void ratio and porosity.

**Conclusion**

The studies conducted for amending the expansive black cotton Soil through replacement with different non expansive soil material is summarized as:

1) Mixing of expansive black cotton soil with laterite material has controlled the swelling. Therefore, replacement of expansive soil with non expansive Sagar laterite concretionary brick material can be more advantageous.

2) The Sagar laterite material kept in the open field for rain wash for many seasons can give the better results for controlling the expansive property of black cotton soil.

3) Sagar laterite concretionary materials are having very good geotechnical engineering properties over the other non swell red earth materials.
**Future line of work**

Sagar laterite concretionary bricks exhibited the sound engineering behavior as an amendment for expansive soil replacement. During the study, the engineering properties were well examined and propose the following further future line of work.

1. It proposes the detailed mineralogical study of the Sagar laterite brick subjected to varied weathering.

2. The chemistry aspect of laterite brick including the interactive chemical behaviour of laterite brick on the expansive black cotton soil.

3. Field evaluation of the laterite concretionary bricks which are exposed to rain wash for different periods needs to be tested in the actual field situations as a soil replacement material particularly for road and civil constructions.

4. Field evaluation of the exposed laterite concretionary materials as an alternative to CNS soil material.

5. Performance evaluation on lining of canals in the black cotton soil regions, laterite concretionary material to be included as one of the combination with CNS soil. On a layer of laterite materials, placing of CNS soil of different thickness are to be worked out.
PUBLICATIONS

