Soil Reinforcement and Geosynthetics

a) Use of Coir Fibers for Sustainable Development

In the context of *sustainable development* which is a balancing act between the fulfilment of human needs and the protection of the natural environment, the use of natural fibers such as coir in geotechnical applications is desirable. Reinforcing the soil with coir fibers/coir geotextiles is a cost effective solution to the ground/soil improvement problems. The effects of fiber parameters on the strength, stiffness and compressibility behaviour of soil were studied in detail. The effect of coir fibers on swell response of expansive black cotton soil was also studied in terms of percentage swell vs. time variation for various fiber contents. Results showed that inclusion of fibers increases strength, stiffness, reduces the compressibility and swell potential. The evaluation of hydraulic behavior of coir fiber reinforced soil is another area, in which studies were carried in detail. It is observed that addition of fibers reduces the seepage velocity of plain soil considerably and thus increase the piping resistance.

Numerical analysis of coir fiber reinforced soil was performed using the finite difference analysis. A soil specimen having the same size of the laboratory specimen is generated using cylindrical elements, with x- and z- axes located in the base of cylinder and y-axis pointing along the cylinder axis. Coir fibers were idealized as cable structural elements. Elastic-perfectly plastic Mohr-Coulomb model is used to simulate the elasto-plastic material behavior of sand specimen. The mechanisms by which random fibers reinforce sand are explained in terms of microstructure that prevents the formation of distinct localized strain bands and increases pull-out resistance.

b) Soil Nailing

Soil nailing is one of the extensively used techniques for stabilizing vertical cuts in India and work at Indian Institute of Science significantly contributed to this development. A few case studies and analytical results which have been published are described as follows.

In one of the case studies, a vertical cut supporting a masonry retaining wall in a hilly terrain (total height 13m) was stabilized using this technique. Calculations showed that the vertical cut was just marginally safe in the existing condition; hence, soil nailing was used for improvement of stability. The existing stability, soil nail design were examined by detailed finite element analysis and remedial measures were validated. In similar studies, results of finite element analyses of stabilization of vertical cuts of 5.0 m were examined. Numerical simulations provided an insight into the influence of nailing on global factor of safety and deformations of vertical cuts with reference to varying cohesive nature of in-situ soil and two different construction sequences.

In another study, Guidelines for the Soil Nail Walls given by Federal Highway Administration (FHWA), U.S. Department of Transportation were examined. Various analyses parameters such as development of axial forces in nails, maximum displacements, and important failure modes have been studied. A comparative study showed that the soil nail walls designed from conventional procedure are conservative. An attempt has also been made to study the performance of a soil nail wall of 8 m height under seismic conditions. Data from Bhuj and Uttarkashi earthquakes are used for the pseudo-static and the dynamic analyses. Results of numerical analyses indicate that the use of soil nail wall technique is desirable to impart stability to the retaining systems under seismic conditions.

Field pullout testing of soil nails is identified as the appropriate method for studying the nail-soil interaction and assessing the performance of soil nail walls. A methodology for the evaluation of field pullout tests is proposed for the determination of the design bond strength. The proposed methodology is illustrated with reference to the field pullout tests on soil nails conducted at a local site (Figure 21).

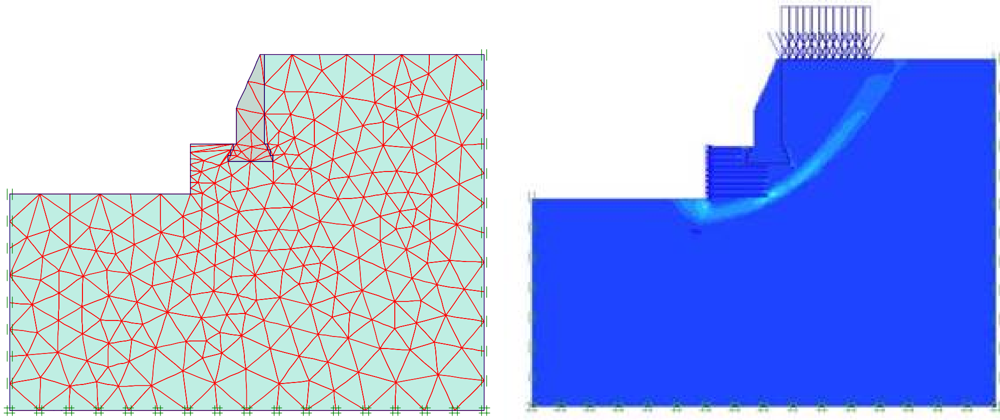

Figure 21: Shear strain contours in soil nailed wall from Finite Element simulations

c) Studies on Geocell Reinforced Foundation Beds

The 'Behaviour of Geocell Reinforced Foundation Beds' was studied in detail in which the efficacy of geocell reinforcement was brought out in different foundation beds such as sand beds, soft clay beds and sand overlying soft clay beds (Figure 22). Extensive instrumentation was done to obtain real behaviour of the reinforced foundation beds which include strain gauges to measure the accumulated strain in the geogrid material and earth pressure cells to measure the normal pressure transferred to the sub grade soil. Model load tests were also conducted to evaluate the potential benefits of providing geocell reinforced sand mattress over clay bed with a continuous circular void.

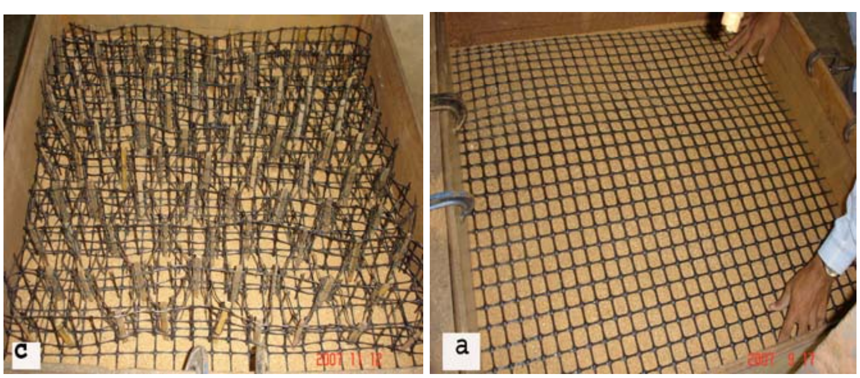

Figure 22: Geosynthetic reinforced foundation beds

d) Field Tests on Geosynthetic Reinforced Unpaved Roads

The relative advantages of different reinforcing materials placed at the interface of subgrade and base course in terms of increase in load carrying capacity and reduction in rut depth are studied through systematic field experiments (Figure 23). The experimental program consisted of field tests on a constructed unpaved road over a prepared soft soil subgrade. The type of reinforcement is varied for different tests. Tests are conducted with single or multiple layers of geosynthetics such as woven geotextile, biaxial geogrid and uniaxial geogrid, placed at the interface of the subgrade and aggregate base. In one test, tyre shreds are used as reinforcing layer. The test sections are subjected to moving vehicle load simulated by the passage of a scooter at the central section of the road. The rut depths are measured at specific grid points along three sections with increasing number of cycles and the results are analyzed to compare the relative efficiency of various reinforcement layers in reducing the formation of rut in unpaved roads (Figure 24).

Figure 23: Test on unpaved road section

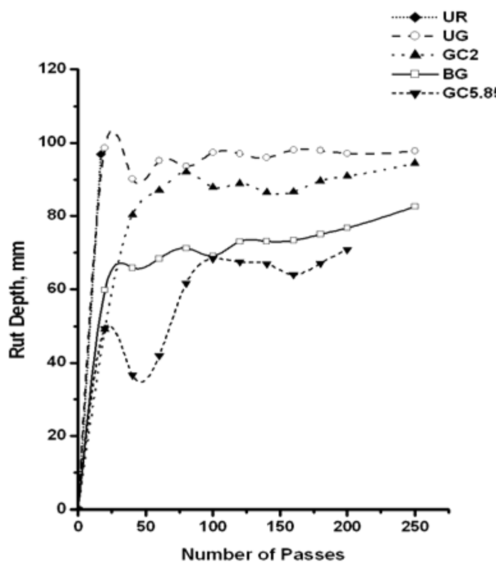

Figure 24: Role of reinforcement in reducing rut depth