

**STRENGTH AND INTERFACE FRICTION
BEHAVIOUR OF EXTRUDED GEOGRIDS
– AN EXPERIMENTAL STUDY**

by

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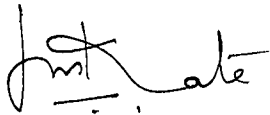
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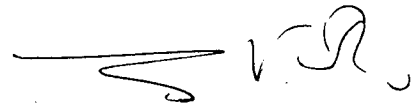
CERTIFICATE

This is to certify that the thesis entitled "STRENGTH AND INTERFACE FRICTION BEHAVIOUR OF EXTRUDED GEOGRIDS - AN EXPERIMENTAL STUDY" submitted by Mr. Anand Ramanath Katti to Indian Institute of Technology, Delhi, for the award of the degree of Doctor of Philosophy is a record of the bonafide research work carried out by him. Mr. Anand R. Katti has worked under our supervision for the submission of this thesis, which to our knowledge has reached the requisite standard.

This thesis, or any part thereof has not been submitted to any other University or Institution for the award of any degree or diploma.



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ABSTRACT

India is a country of diverse geology, climate and land forms. This diversity gives rise to a wide range of problems that include landslides, and other natural disasters, which necessitate stabilization of soft soils or the construction of retaining and many other diverse civil engineering structures. Geosynthetics offer the wide variety of materials required to tackle the numerous problems faced by the Indian civil engineers.

The geogrids that are being manufactured in India are the first generation low spectrum extruded civil engineering geogrids. In view of their successful use in the country and vast potential, a **thorough examination and evaluation of the geogrids** is called for in order that the choice of the design parameters may be rationalized for optimal utilization.

Towards a better understanding of the extruded geogrid-soil behaviour the **proposed research** included:

- a. a study of in-isolation tensile strength behaviour at widely varying deformation rates,
- b. a study of the in-soil tensile strength behaviour at different normal stresses,
- c. an evaluation of the in-isolation load-strain-time behaviour under sustained loading,
- d. an in-depth study of the geogrid-soil interaction behaviour through modified direct shear and pull-out procedures, and

- e. an assessment of vertical wrap around geogrid reinforced retaining wall through large scale laboratory models.

These have been achieved through an extensive laboratory programme carried out on two geogrids G1 with an aperture of 8x6 mm and thickness of 3.3 mm and G2 with an aperture of 27x27 mm and thickness of 5.3 mm; both being made of HDPE. Three granular fills S1 (uniform fine grained sand), S2 (medium to coarse grained sand) and S3 (fine gravel) ranging from fine grained sand to fine gravel are used for the studies.

Chapter 2 presents a detailed literature review. The test equipment developed/used is described along with the detailed experimental procedures and test programme in Chapter 3.

The **in-isolation tensile strength tests** are carried out on both the geogrids using a INSTRON 1195 universal testing machine. The quality control tests and wide width tensile strength tests at widely varying rate of deformation were carried out on both the geogrids. To conduct these wide strip tensile strength tests, special jig plates and clamps have been designed and fabricated. The **in-soil tensile strength tests** were carried out in a specially designed and fabricated steel tank having dimensions 60 x 60 x 40 cm. With a little modification the same was used to carry pull-out tests. To carry out the **creep tests**, a creep bay with provision to hold 12 specimens was designed and fabricated, to which a multi-point digital data logger was

coupled. The shear box used for **geogrid-soil interaction behaviour** was a strain controlled shear box having dimensions 30 x 30 x 15 cm and with a provision to apply normal stress up to 550 kPa. This shear box was modified appropriately to carry out modified shear box tests both Vidal and ASTM types.

The **model large scale laboratory retaining wall studies** were carried out in a rigid steel tank having overall dimensions 175 x 125 x 120 cm. Sand filled HDPE bag facing and wrap around tuck back method was adopted for all the tests. The lateral deformation of the face, normal deformation of the wallfill and lateral pressures on the face are measured at each load increment.

The various **test results** have been presented in the form of figures and tables in Chapter 4. A detailed analysis is carried out, to assess the **behaviour of the geogrids** thoroughly in relation to the three sands. The **following salient observations** are drawn.

In-Isolation Tensile Strength : For both geogrids the quality control tests give higher values than wide width tensile strength tests. The peak tensile strength increases steeply upto a deformation rate of around 50 mm/min, beyond which the increase is nominal. The ratio of lateral strain to longitudinal strain is found to be 0.5 in case of geogrid G1 in both machine and cross-machine directions and 0.56 for geogrid G2. This clearly reveals that the two grids used in the studies are comparatively weak and have low stiffness.

In-Soil Tensile Strength : The tensile strength is found to increase steadily with confining pressure, at all strain levels.

Load-Strain-Time Behaviour : The geogrids exhibit very high strains (around 11% for a surcharge load of 2kN/m at the end of 30 minutes). Thus these geogrids appear to be better suited for temporary structures.

Geogrid-Soil Interaction : In case of pull-out test, the pull-out load increases with embedment length and the coefficient of friction is found to decrease with the length of embedment. For lower embedment length the failure is due to slip while with increase in embedment length there was tension failure due to an anchoring effect of the rear end of the grid.

Conventional shear box test gives the maximum shear strength compared to the other combinations.

- i. Among the conventional shear box tests the granular fill S3 (fine gravel) with the largest grain size yields the maximum shear stress at all stress levels and hence the highest coefficient of friction. The least value is exhibited by the fill S1 (uniform fine grained sand) and the fill S2 (medium-coarse grained sand) falls in between the two, but is nearer to that of fill S3.
- ii. Modified direct shear box test (ASTM type) gives a higher estimate of the coefficient of friction compared to the Vidal type.

- iii. From both Vidal type and ASTM type of modified direct shear tests it is observed that granular fill S1 in conjunction with both geogrids gives the minimum values of shear stress/coefficient of friction compared to other combinations (with exceptions).
- iv. From both Vidal type and ASTM type of modified direct shear tests the combination of the granular fill S2 with geogrid G1 gives higher values of coefficient of friction than with geogrid G2.
- v. From the ASTM type of test it is observed that the combination of granular fill S3 and geogrid G1 gives a very low value while the combination of fill S3 and geogrid G2 provides the maximum shear strength.
- vi. In the modified direct shear box test (Vidal type) the combination of geogrid G1 with granular fill S2 gives an higher value compared to fill S2 with geogrid G2 or any other case.
- vii. The efficiency is nearly equal for all the cases at all the strain levels with an exception of granular fill S2 with geogrids G1 and G2. In these cases it can be seen that the efficiency suddenly increases at 6% and 8% strain while the efficiency at peak shear stress is much lower. So it is clear that comparing the efficiency at peak shear stress alone is hypothetical. The comparison, as such, is only meaningful at a given strain level. Similar trends have also been observed for ASTM type of tests.

viii. A general reduction in coefficient of friction of the geogrid-soil interaction with increase in normal stress has been noticed in the study. In some instances the values of friction are even more than that of the granular fill. This aspect substantiates earlier research.

Model Large Scale Laboratory Retaining Wall : Nine series of experiments were carried out on the model large scale laboratory wall setup. A critical study of measured data clearly indicates that as the deformations and the pressures are as expected in regard to their embedment length, the validity of the technique developed in this study is clearly established. The theoretical analysis for the laboratory large scale model retaining wall studies was carried out in a manner similar to the geotextile reinforced retaining wall wrap around type. The analysis reveals that only friction becomes critical. Through the analysis it has become possible to arrive at a definite recommendation regarding sand by facing type of geogrid reinforced retaining walls.

Chapter 5 presents the summary and the brief conclusions drawn from the experimental investigation. With the influence of the various parameters on the strength and interface friction thus delineated, depending on the site conditions, a rational choice of design parameters can be effectively made. The HDPE woven bags facing with wrap around geogrid reinforcement was shown to be a viable alternative in the Indian context especially for low height walls.

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