Efficient and vast highway infrastructure needs construction of highways through various terrains, most often through soft compressible strata e.g. marshy land or through backwaters. Construction of highways on such strata by conventional methods results in huge filling of expensive granular fill sinking progressively till a working platform emerges to suitable formation level. Even then the fill give rise to unacceptable settlements leading to damages to the road surface resulting in poor riding quality, which require frequent maintenance. Use of methods such as stone columns, sand drain etc., are time consuming and uneconomical. Methods of stabilization of soil by addition of stabilizers are usually not adopted due to it's inherent uncertainty to control moisture and difficulty in designing them. Normal unbound aggregate sinks rapidly on application of load, since the sub-grade accepts the load distribution without being able to mobilize sub-grade reaction. This result in sinking and mixing of sub-grade, induce heavy surface deformation and rutting.

The stability of foundation under an embankment or superstructure soil mass is governed mostly by the availability of shearing resistance of the foundation soil. Therefore based on imposed contact pressure, the founding layer poses a problem of bearing capacity. Geogrid reinforcement thus may be placed at the interface to prevent a shear failure for both in embankment fill as well as in foundation soil, wherein reduction of settlement comes as next consideration. The aspect of permeability plays the most important role during loading (the period of construction).
The gain in shearing resistance during the process of consolidation adds to the process of stability. Geogrid reinforcement is used in the foundation substructure to enhance the resistance of the founding layer to avoid failure through excessive deformation or shear in founding layers. While basal reinforcement stabilises an embankment over soft ground by preventing lateral spreading of the contained fill, extrusion of founding layers of soil beneath and overall rotational and local shear failure. Stabilisation is achieved by generating resistive force in Geogrid reinforcement by shear stresses transmitted from foundation fill, through integrally jointed junction of the Geogrid, which places the reinforcement in tension.

The main reason for the cracking and large settlement in pavements, particularly over soft soil foundation, is high stress concentration below the wheel load as shown above. Differential settlement caused by pavement failure is illustrated above, where the action of wheel load is shown to create an oscillatory pulse of sway at the bottom of pavement inducing tensile forces and tension cracks. High transient cyclic stress develops below the wheel load, which forces the particles in bottom layers away from each other. This lateral sway allows pumping of fines from the compressible clayey sub-grade, and loose aggregates slowly sink into the void created by the migration of fines. The pavement thickness reduces slowly and deformation increases heterogeneously depending on sub-grade strength and loading conditions. Ruts and potholes appear on surface apart from cracks etc. The solution is to provide a tensile inclusion of an integrally jointed HDPE Biaxial Geogrid placed as reinforcement cum separator. Inclusion of Geogrid reinforcement distributes the load uniformly over a larger area resulting in development of low stress at sub grade level hence induces far less settlement. Also Geogrid act as a separator and prevent sinking of pavement by interlocking the particles within its aperture. With enhanced stiffness the Geogrid provides effective confinement to the pavement particle sway, which has direct influence to reduce vertical permanent strain.

Geogrid need Integral joint, Stiffness & Dimensional stability to functions as reinforcement

A Geogrid is a planar structure...
formed by a regular network of tensile elements with apertures of sufficient size to allow interlocking with surrounding soil, rock earth. They are also characterized by high dimensional stability, high strength and high tensile modulus at very low elongation (achieved by patented processes of orientation of polymer molecules). They are of two varieties, viz., uni-axially oriented and bi-axially oriented with enhanced strength in one or both the directions. They are primarily used for soil reinforcement. Biaxial Geogrids are used under pavement as stresses are biaxial in nature in Boussinesq type load distribution.

MoRth highways specification of Ministry of Road Transport & Highways, in India, (4th Edition), for Geosynthetics in Cl:701.2.2 defines Geogrid properties as:

“Geogrid shall be made from integrally jointed mono or bi-directionally orientated or stretched mesh made from polyethylene or polypropylene or Polyester or similar polymer, with high secant modulus, is square, rectangular, hexagonal or oval mesh form. Their junction strength shall be high with high creep resistance, and dimensional stability. Their open structure shall permit effective interlocking with soil, aggregates, rock etc., they shall be used as a tensile member or reinforcement”

Therefore just any grid “look-alike” products are not capable to function as “Geogrid”, (examples: Geonets, coated or uncoated Woven or Knitted textiles using fibrillated mesh/fabrics, fused Tape-form mesh elements etc). Use of these can lead to serious consequences since they don’t conform to soil Geogrid interaction requirements defined above as well as in BS 8006. These are disqualified for use as Geogrid, as they lack integral joint, and have poor junction strength, which lead to failure of interlocking of the soil, thereby fail to confine soil particles needed to transfer load from soil to Geogrids.

Ground Improvement using Integrally jointed Geogrids

The construction of highways over poor soil exerts high bearing pressure over the soil strata. Such constructions require improvement of foundation soil strata and bearing capacity. Improvement of soil strata using Geosynthetics is done by use of layers of Bi-oriented Geogrids. Use of polymer Geosynthetics for ground stabilization provides long term and durable solution. The oriented Geogrids are inert to chemical and biological agents. Their use allows both economy and rapid construction.

Usually the earth filling volume is directly dependent on strength of sub-grade. Enormous volume of earth fill is required if the usual marshy terrain needs to be developed as a working platform for a proposed expressway. The typical conventional increase in requirement of aggregate sub-layer due to changing CBR is shown below. It may be noted that for low CBR the requirement can be very high, depending upon available boundary condition of fill. The foundation soil is improved by using layers of Bi-oriented Geogrid to the required depth and compacting soil over it in layers. This result in additional confinement of the base soil while taking shear stresses developed in the soil, thereby increasing the bearing capacity. Use of Geogrid reduces requirement of sub-base thickness by 40-50% and is a proven and accepted practice in highway construction worldwide.
Geosynthetics

Geogrids are high strength planar polymer materials which impart strength to soil mass with its interlocking action with the soil particles. Installation of layers of Geogrids within the bearing soil mass or Geocell™ mattress improves soil load bearing capacity. The treatment can even be used to improve the bearing capacity of soft compressible soils such as marshy land or soft compressible clay (Black Cotton soils).

HDPE/PP integrally jointed Geogrids as ideal soil reinforcement

HDPE/PP Geogrids were developed since early 70's and have a long development history. Current technology is extremely advanced with decades of research and evaluation, building user confidence. They are used as long term soil reinforcement in innumerable structures for last 40 years and standardized all over the world, including ASTM, BS 8006-1995 & FHWA. HDPE/PP extruded punched sheet, integrally jointed Geogrids conforms to the true definition of Geogrids, providing ideal junction strength, dimensional stability, oval aperture for optimum interlocking, connection strength for Geogrid continuity and load transfer from soil to grid, long term design strength and service life of 120 yrs. The design of Reinforced soil walls for highways require to meet MoRTH specification in India, meeting provisions of BS 8006:1995 and FHWA with seismic load considerations. Integrally jointed Bi-axially oriented Geogrids when laid in the layers is proven to improve the performance of the of foundation soil through three mechanisms:

- Interlocking & Confinement of soil composite (imparts pseudo-cohesive load transfer)
- Wider load distribution through reinforced aggregate basal layer
- Tensioned Membrane Effect (which absorbs tensile stresses)

The phenomenon of interlocking of the soil particles into the apertures of the Geogrid also reduces degradation of the mechanical properties of the aggregate and prevents lateral displacement of the soil particles, thereby increasing the overall stiffness of the foundation layer. When a proposed embankment is to be built over soft soil (CBR<5), passes through marshy waterlogged terrain, swamps mudflats or overlying compressible substratum with poor ground condition, for construction of Access roads, highways or Hardstand for large loading area, following problems are encountered:

1. Marshy soft ground condition, accumulation of water-logging causes difficulty in initiation of construction of embankment and access road. Unavailability of initial sub-grade strength initiates rapid deterioration of embankment bed materials, large scale deformation and sinking of valuable fill materials transported from far away sources.

2. Embankment fails due to flexural deformation of base and tension crack on embankment formation, sinking and loss of bed materials.

3. To ensure adequate stiffness, conventional embankment needs higher embankment thickness to ensure adequate modulus for controlled overlying pavement deformation, which is counter productive since higher the overburden, the embankment becomes more unstable. The deformation increases with time.


Applications in India, performing over 12 years

PWD Maharashtra took the pioneering effort as early as 1995, for strengthening and widening state highways in various stretches using biaxial integrally jointed Geogrids and Nonwoven Geotextiles for ground improvement over soft soil and black cotton compressible stratum. 12 projects were implemented between 1995-2000, where (i) surface deformation, (ii) rutting (iii) Cracking of asphaltic overlay (iv) Loss of shear strength due to high water table and water logging were observed. Integrally joined Polypropylene Biaxial geogrids of strength 20x20 kN/m and 30x 30 kN/m, having 90% junction strength were used in these applications, some supported by 150 gsm Nonwoven PP geotextile for prevention of surface cracks in asphaltic overlay.

Results in these state highway stretches are extremely satisfactory, where no further distress were reported. Some of the case details are shown in enclosed showcase.

Conclusion

The property of interlocking is the key to eminent load transfer of soil directly to lateral strands, leading to soil confinement. Though other forms of knitted or woven mesh form provide frictional interaction between soil and reinforcement, lack of interlocking (due to poor junction strength) does not enable these materials to impart soil confinement. In the light of above it amply explains why knitted mesh without junction strength cannot provide lateral confinement of soil and therefore does not perform as biaxial soil reinforcement.

The future of application in pavement/fill strengthening in India is very promising. With rapid development of large scale modern highways, Railway freight corridors, High speed railway tracks, new airfield pavements, Basal reinforcement would be prominently used to huge economic advantage. Need of the hour is for the planners, project authorities and consultants to come forward to use this proven technology with confidence. Needless to mention that caution is required to understand characteristic properties and not mere claims from the manufacturers.
### Case Histories of Highway Strengthening, Widening and Overlay Reinforcement using Envirogeo® Integral Polypropylene Geogrid System Technology

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