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In-Situ Behavior of Geosynthetically Stabilized Flexible Pavements

[1]B.Veerendranath & [2]D.Ashok

1.M.Tech,Bomma Institute of Technology and Science,Allipuram, Khammam, Telengana, INDIA - 507318
2.ASSISTANT PROFESSOR,Bomma Institute of Technology and Science,Allipuram, Khammam, Telengana, INDIA – 507318

ABSTRACT:-

The purpose of a geotextile separator beneath a granular base, or subbase in a flexible pavement system is to prevent the road aggregate and the underlying subgrade from intermixing. It has been hypothesized that in the absence of a geotextile, intermixing between base course aggregate and soft subgrade occurs. Nine heavily instrumented flexible pavement test sections were built in Bedford County Virginia to investigate the benefits of geosynthetic stabilization in flexible pavements. Three groups of different base course thicknesses (100, 150 and 200mm) test sections were constructed with either geotextile or geogrid stabilization or no stabilization.the selection of design parameters for geo synthetics has been complicated by the difficulty in associating their relevant properties to the improved pavement performance. Nonetheless, significant research has been conducted with the objectives of: (i) determining the governing mechanisms and relevant properties of geo synthetics that contribute to the enhanced performance of pavement systems, (ii) developing appropriate analytical, laboratory and field methods capable of quantifying the above properties for geo synthetics, and (iii) enabling the prediction of pavement performance depending on the various types of geo synthetics used.

INTRODUCTION:-

Geosynthetic materials have been used to stabilize soils in road construction and have proved in several cases to be successful (van Zanten, 1986). The addition of materials possessing properties that would enhance the behavior of the soil itself was no doubt done long before our first historical records. It seems reasonable to assume that the first attempts were made to stabilize swamps and marshy soils using tree trunks, small bushes and the like. Such stabilization attempts were undoubtedly continued with the development of a more systematic approach in which timbers of nearly uniform size and length were lashed together to make a mattressed surface. Such split-log “corduroy” roads over peat bogs date back to 3000 BC (Dewar, 1962). This art progressed to the point where the surface ridges were filled in smooth. Some of these systems were surfaced with a stabilized soil mixture or even paved with stone blocks. However, the deterioration of the timber and its lashings over time was an obvious problem. The concept of stabilizing poor soils has continued until the present day. The first recorded use of fabrics in roads was attempted by the South Carolina Highways Department in 1926 (Becham, 1935). A heavy cotton fabric was placed on a primed earth base, hot asphalt was applied to the fabric, and a thin layer of sand was placed on the asphalt. The Department built eight separate field experiments. Until the fabric deteriorated, the results showed that the roads were in good condition and that the fabric reduced cracking, raveling and localized road failures. That project was certainly the forerunner on the incorporation of geosynthetic materials in flexible pavements. In recent years polymer geotextiles and geogrids have been proposed and used to improve the performance of paved roadways and to reduce base course thickness. Performance improvements have been demonstrated for design conditions where relatively large rut depths are acceptable (unsurfaced roads) and where relatively weak pavement sections have been used. Incorporation of geosynthetic materials in the design of paved and unpaved road systems has been shown to improve the performance and service life of pavement. The major functions of geosynthetic materials are separation, reinforcement, filtration, drainage and liquid barrier (Koerner, 1994). In providing reinforcement, the geosynthetic material structurally strengthens the pavement section by changing the response of the pavement to loading. In providing separation it prevents contamination of an aggregate layer by the underlying subgrade and hence maintains a clean interface. In providing filtration and drainage, it aids in improving subsurface drainage and allows the rapid dissipation of excess subgrade pore pressures caused by traffic loading (Barksdale et al., 1989). However, the geosynthetic must minimize the possibility of erosion of the drainage layer and resist clogging of the filter over the design life of the pavement. The most commonly used types of geosynthetics are geogrids, geotextiles, geocomposites, geonets, and geomembranes. Geotextiles and geogrids are mostly used in roads for separation and reinforcement in flexible pavement systems. For many years, the principal use of geotextiles has been as a separator during the construction of roadworks and in the area of stabilization (Ruddock, 1978). Usually geotextiles are placed directly on the soft soil formation followed by layers of increasingly well compacted aggregate to build up a stabilized layer. Generally, the benefits of a separator in the reduction of the loss of granular material into the subgrade and the prevention of contamination of sub-base are greatest over soft subgrades, e.g. California Bearing Ratio (CBR) < 3% (Lawson, 1992). Over very weak soils, using a separator may be a particularly viable technique for fill placement, particularly in bad weather.

An optional subbase layer, which generally involves lower quality crushed aggregate, can be placed under the base course in order to reduce costs or to minimize capillary action under the pavement. The constructed layers are placed directly onto a prepared subgrade, which is generally graded and compacted natural insitu soil. Common uses of soil-geosynthetic reinforcement include the construction of roads, retaining walls, As the pavement flexes under the load, stresses are redistributed over a greater area than that of the tire-footprint. Figure 2 illustrates the stress redistribution under the wheel load.

Design of flexible pavement pays particular attention to two critical locations within the pavement structure the use of aggregates with excessive fines and inadequate inspection may lead to rapid pavement deterioration. Finally, pavement distress is also a function of maintenance or, more correctly, lack of maintenance Geosynthetics used for separation minimize intrusion of subgrade soil into the aggregate base or sub-base. The potential for the mixing of soil layers occurs when the base course is compacted over the subgrade during construction and also during operation of traffic. Additionally, a geosynthetic can perform a filtration function by restricting the movement of soil particles while allowing water to move from the subgrade soil to the coarser adjacent base. In addition, the in-plane drainage function of a geosynthetic can provide lateral movement of water within the plane of the geosynthetic. The geosynthetic reinforcement can decrease the shear stresses transferred to the subgrade and provide vertical confinement outside the loaded area. The tension developed in the geosynthetic contributes to support the wheel load and reduces the vertical stress on the subgrade. However, significant rutting depths are necessary to realize this effect. Higher deformations are required to mobilize the tension of the membrane for decreasing stiffness of the geosynthetic..

The revisions of the new 2002 **AASHTO 'Guide for Design of Pavement Structures'** are based on mechanical-empirical procedures. There are several advantages of mechanical-empirical procedures over the traditional empirical procedures which mainly enable

Bhutta et al. (1998) analyzed the M-E design procedure for geosynthetically stabilized flexible pavements considering a secondary road pavement section build as a part of realignment of Route 616 and 757 in Bedford County, Virginia to evaluate the performance of geosynthetically stabilized flexible pavements. The measured pressure at the base course-subgrade interface for the geotextile-stabilized sections was lower than the geogrid-stabilized and control sections, within a specific base course thickness group. This finding agreed with other measurements, such as rut depth, ground penetration radar survey, and falling weight deflectmeter survey.

Previous research considered several approaches in model formulation and assumptions (Hewany et al. 1998, Aliet et al. 1998, Roberts 1989, **Ioannides and Khazanorich 1998**, Mamlouk et al. 2000, Tielking and Roberts 1989, Das and Pandey 1999, Hudson et al. 1998, Sven et al. 1992, Bright and Mays 1996). The dynamic vehiclepavement-foundation interaction effect is significant for the analysis of dynamic response of pavements subjected to moving loads (Siddharthan et al. 1998, Wu and Shen 1996, Zafir et al. 1994, Lin and Gazis 1994).

2.1 GEOSYNTHETICS

Geosynthetics is the collective term applied to thin and flexible sheets of synthetic polymer material incorporated in or about soil to enhance its engineering performance. Applications of geosynthetics fall mainly within the discipline of civil engineering and are closely associated with geotechnical, transportation, and environmental engineering. The American Society for Testing and Materials (ASTM) has defined geosynthetics in D 4439 as follows: “A planar product manufactured from polymeric material used with soil, rock, earth, or other geotechnical engineering related material as an integral part of a man-made project, structure, or system.” Common types of geosynthetics are geogrids, geotextiles, geocomposites, geonets, and geomembranes and our review would concentrate on geotextiles and geogrids.

2.1 1 GEOTEXTILES

2.1.1.1 Early Use of Geotextiles

Geotextiles, as known and used today were first used in connection with erosion control applications and were intended to be an alternative to granular soil filters. Thus the original, and still sometimes used, term for geotextiles is filter fabrics. Barrett (1966) in his classic paper, tells of work originating in the late

1950's using geotextiles behind precast concrete seawalls, under precast concrete erosion control blocks, beneath large stone riprap, and in other erosion control situations. He used different styles of woven monofilament fabrics, all characterized by a relatively high percentage of open area (varying from 6% to 30%). He discussed the need both for adequate permeability and soil retention, along with adequate fabric strength and proper elongation. Barrett set the stage for geotextile use in filtration situations. In the late 1960's, Rhone-Poulenc Textiles in France began working with non-woven fabrics for different applications. Emphasis was on reinforcement for unpaved roads, beneath railroad ballast, within embankments and earth, and the like. The primary function in many of these applications was that of reinforcement and separation. Credit for early work in the use of geotextiles should also be given to the Dutch and the English (van Zanten,1985).

2.1.1.2 Geotextiles Manufacturing

The polymers used in the manufacture of geotextile fibers are made from polypropylene (83%), polyester (14%), polyethylene (2%) and polyamide, nylon (1%). The basic polymers are made into fibers (or yarns, which may consist of one or more fibers) by melting them and forcing them through a spinneret, similar in principle to a bathroom showerhead. The resulting fiber filaments are then hardened or solidified by one of three methods: wet, dry or melt. The melt process accounts for most geotextile fibers; these include polyolefins, polyester, and nylon. Hardening is by cooling and simultaneously stretching the fibers. Stretching reduces the fiber diameter and causes the molecules to arrange themselves in a more orderly fashion. In so doing, the fibers gain strength, the elongation at failure decreases, and modulus increases. A wide range of stress-strain patterns can be achieved. These monofilaments can also be twisted together to form a multifilament yarn. Geotextiles may be used for separation, reinforcement, filtration and drainage:

1- Separation of dissimilar materials; such as between subgrade and stone base in paved and unpaved roads and airfields, subgrade and ballast in railroads, foundation and embankment soils for roadway fills, and beneath curb areas.
2- Reinforcement of weak soils and other materials; such as over soft soils for unpaved, airfield and railroads, for lateral containment of railroad ballast, to enhance the bearing capacity of shallow foundations, to reinforce embankments, to reinforce jointed flexible pavements, and to bridge over cracked or jointed rock.
3- Filtration (cross-plane flow); such as beneath base course for paved and unpaved roads and air fields, around crushed stone surrounding underdrains and perforated underdrain pipe, and as a filter beneath stone riprap.

4- Drainage; to dissipate seepage water from exposed soil or rock surfaces, as a drainage interceptor for horizontal flow, and as a drain behind a retaining wall.

FIELD CALIBRATION

Field calibrations were performed on the instrumented test sections. A dual-wheeled, singleaxle truck with known load configurations was driven over the test sections at known speeds. This permitted the recorded data from the embedded instrumentation to be calibrated to known conditions of loading. Three calibration runs were made: April 1995, August 1995 and April 1996. In a typical calibration run, single-axle loads of 22, 53, 80 and 102kN ; tire pressures of 420, 490, 550, 630 and 700kPa ; and speeds of 40, 56 and 64km/h (25, 35 and 40 mph) were used. Much of the data collected in the calibration runs was used and reported for purposes out of scope of this investigation and can be found in Al-Qadi et al. (1996). However, in examining the development of a transition layer hypothesis, the pressure responses in the base course and subgrade under a standard load of 40kN (a standard half axle), a tire pressure of 550 kPa at a speed of 56km/h were used in the FWD analysis. These parameters correspond closely to the conditions of loading under an FWD.

CONCLUSION:-

As part of a field study on the performance of an instrumented geosynthetically stabilized flexible pavement, the development of a contaminated layer “transition layer” between base course layer and subgrade was hypothesized. The objective of the research was to investigate the occurrence of a base contamination in sections without geotextiles and quantify its progress over time. To achieve that, in situ stresses were measured as well as pavement responses to pulse loading, falling weight deflectometer (FWD). Comparing measured stresses to calculated stresses using elastic and viscoelastic methods were inclusive. The study used an iterative method to backcalculate the extent of contamination of the base layer over time. It was concluded that for under design sections with 100mm (4in) base course, 70% of the base course was contaminated in the first 2.5 years for the control section and 65% for the section stabilized with geogrid. Although this number may be considered high, it is in good agreement with rut measurements for the control which already failed. The contamination is expected to be very low (at this stage) in the other sections and this procedure (back-calculation) is insensitive to changes at this time. The short duration of the project prevents clear distinctions from being made in the thicker base sections (4 through 9). It may be concluded that in the 100mm base course sections, the geotextiles provide adequate protection against subgrade intrusion, while the geogrid provides a partial one. laboratory and numerical studies have demonstrated the benefits of using geosynthetics to improve the performance of pavements. That is, while methods have been developed for designing geosynthetic-reinforced flexible pavements, quantification of the reinforcement mechanisms, identification of properties governing the pavement performance and, ultimately, acceptable design guidelines are yet unavailable. Incorporating speed of axle loads into the derived M-E approach can encourage better utilization of other changing parameters into the design of flexible pavement structures and provide a better utilization of materials in roadway construction.

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