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USAGE OF GEOSYNTHETICS IN THE DESIGN OF PAVEMENT

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ABSTRACT :

In last 30 years geo-synthetics are used commonly for reinforcement, drainage, separation, filteration and containment functions of pavement designs. Every year use and sales of geo-synthetic material increases by 10 to 20%. This paper deals with the research on the application of materials which are geo-synthetic in nature, such as geo-textiles, geo-composites, geo-membranes, geo-synthetics, geo-foam, geo-cell and geo-synthetic clay liner in the design of pavement by focusing on its literature, basic characteristics and basic information of geo-synthetics. Among all, this study focuses on reducing the thickness of base course using geo-grid material in the layer of base course without any change in the load carrying capacity and performance of pavement. Results by modified AASHTO design shows by using geo-grid pavement design 20 to 40% reduction in the base course is possible.

KEYWORDS : Geo-synthetics, geo-textiles, geo-composites, geo-membrane, geo-foam, geo-cells, geo-grids, geo-notes, geo-synthetics clay liners.

1. INTRODUCTION

In recent past year, load due to traffic on pavement have been increased and still continuous. As per 2014 data, there are 797 motor vehicles per 1000 population in USA. Due to rapid expansion of shopping on line, the freight traffic increases. Pavement deformation also called as pavement distress is also increasing due to repetition of vehicles which are heavily loaded. Utmost care should be taken for the pavement structural capacity because people are dependent on the pavement.

Geo-synthesis with the reinforcement can play important role as they not only improve the capacity of load bearing but also reduces the deformation. Almost 3.5 times more repetition of traffic can be carried by geo-grid reinforced aggregate surfaced pavement. For the sub grade CBR having strength of 1.5 to 5.0 than equivalent non reinforced pavement before 1.5 in. rut depth reached. Research shows that sections of geo-grid

reinforced pavement can carry three times the number of load as compared to unreinforced pavement, and upto 50% thickness of the base course can be reduced (Webster, 1993) Geo-grid reinforcement gives us a cost effective solution for the flexible pavement design.

The Soil Geo-synthetic Aggregate (SGA) have some benefits as follows :- stiffness and confinement of the base material increases, shear stress reduction on the sub grade, permanent lateral displacement is reduced in granular material, distribution of load is improved on sub-grade layer.

Until 1980, geo-synthetic reinforcement in the design of pavement was based on the empirical method. FHWA in 1985, published the manual on Geo-Textile Engineering. Acceptable guidelines for the design of geo-synthetic reinforced pavement properties identification governing the performance, pavement performance of geo-synthetic, quantification of reinforcement mechanism is unavailable. However, the aim of this study to understand the design guidelines of geo-synthetic reinforcement mechanism, design of geo-synthetic reinforcement and the usage of the geo-synthetic in the design of pavement by reviewing its literature.

2. METHODOLOGY :

Methodology of design is based on its literature review. Design steps for geo-grid pavement are :-

Step 1 – Collection of the soil sample.

Step 2 – Laboratory testing : Soil Atterberg limits (LL, PL,SL), particle – size distribution, specific gravity (G), moisture content determination of soil, soil particle size distribution, California Bearing Ratio (CBR).

Step 3 – Counting traffic load and pavement modeling.

The methodology for solving the problem is based on the geo-synthetic reinforcement in corporation into AASHTO (1993) design. The pavement is considered as a multi layer elastic system which have an overall Structural Number (SN), which can be determined from the following equation:-

$$\log W_{18} = Z_R \times S_o + 9.36 \times \log(SN+1) - O.2 + \log\left(\frac{\Delta PSI}{2.7}\right) + \frac{\log\left(\frac{\Delta PSI}{2.7}\right)}{0.4 + \frac{1094}{(SN+1)^{5.19}}} + 2.32 \log M_R - 8.07$$

The variables in the equation are :-

W_{18} = anticipated cumulative 18-kip ESALs over the design life of pavement.

Z_R = standard normal deviate for reliability level.

S_o = overall standard deviation.

ΔPSI = allowable loss in serviceability.

M_R = resilient modulus (stiffness) of the underlying grade, M_R = 2555*CBR 0.64

After determination of the overall value of SN, the layers can be designed individually from the following equation :

SN=(a*d)hma+(a*d*m)base+(a*d*m)

Where a = structural layer coefficient

d=thickness of each layer in inch

m=Modifier accounting for the pavement moisture characteristics.

These equations are used in the geo-synthetic pavement by its modification. Traffic Benefit Ratio (TBR) and Base Course Reduction (BCR) expresses the improvement of geo-synthetic reinforcement in flexible pavement.

TBR=Nr/Nu ,

W18(reinforced)=TBR*W18(unreinforced)

Where, Nr=Number of the load cycles on a reinforced section.

Nu=Number of the load cycles on a unreinforced section.

The range of TBR value for geo-grid is 1.5 to 70 and for geo-textiles the range is 1.5 to 10 i.e. depending on the type of the geo-grid, location on the road, and testing scenario.

BCR=Tr/Tu where,Tr=thickness of the base course reduction (in %) by the addition of geo-synthetic reinforcement.

Tu=flexible pavement thickness by using same material but without reinforcement.

A modifier has been applied to SN equation :

SN=(a*d)hma+BCR*(a*d*m)base

+(a*d*m) subbase.

Reduced base course thickness (d base, (R)) due to the reinforcement is :

$$d_{base,(R)} = \frac{SN_u - (axd)_{hma} - (axdxm)_{subbase}}{BCR(axm)_{base}}$$

SN_u=structural number corresponding to equivalent W18 for pavement (unreinforced).

Range of BCR is 20% to 40% and for stronger sub-grade material percentage can be reduced.

Step 4 – Selection of geo-grid and placement. Size of aperture is 25mm*21mm. Aperture which is round or square in shape is better to use.

3. LITERATURE REVIEW

Geo-synthetic materials are the polymeric products which are used in roads, embankments, reservoirs, dams, sediment control, land fill covers, airfields, rail roads, agriculture and aqua culture for separation, filtration, containment, reinforcement, drainage. Type of Geo-synthetics : Geo-grids, geo-textiles, geo-composits, geo-tubes, geo-net, geo-membrane, geo-foam, geo-synthetic clay liners. Here more emphasis is given on the usage of geo-synthetics in the design of pavement.

3.1 Geo-grids :

It is a regular open net work of tensile elements which are integrally connected and is used for the reinforcement base or sub-base material, embankment, earth retaining wall etc. High density, Polyethylene (HOPE), high tenacity polyster or polypropylene is used for the manufacturing of geo-grids.

Types of Geo-grids : On the basis of manufacturing process, there are three types of geo-grids – Woven Geogrid, Extruded Geogrid and Bonded geogrid.

On the basis of direction of the stretching is done during manufacturing process, there are two types of geo-grids – biaxial woven geogrid and uniaxial geogrid.

3.2 Geo-textiles :

It reduces the deformation in the sub-grade when it is used at the top of the sub-grade. The performance of the geo-textile is better than the geo-grid when it is used as a separator between sub-grade and base layer. Pore water pressure is developed in sub-grade soil under dynamic traffic loading and soils slurry is formed when the pore water pressure is greater than total stress of soil. This soil slurry and sub-grade fines tends to migrate in to base course which affects the structural and drainage capacity of the overall pavement. For achieving proper filtration mechanism, geo-textiles are incorporated which prevents the generation of pore water pressure and also it will not allow the fine particles in to base course from the soil sub-grade. The large amount of the sub-grade strengthening comes by providing geo-textile fiber in double layer and the effectiveness fiber can be increased by increasing its deformation. Under the condition of dynamic traffic loading, a frictional capability geo-textiles of good quality can provide the tensional resistance to the lateral movement of the aggregate. Base course thickness of the pavement can be reduced by 32% by using woven geo-jute, for non-woven – 20% bearing capacity improvement lies in the range of 7 to 123% in different layers and in different bed conditions.

3.3 Geo-composites :

There are the combination of two or more different types of geo-synthetics to obtain good qualities of each material. They provide the hybrid facilities such as – filtration, containment, reinforcement, separation and drainage.

3.4 Geo Tube :

These are big container of tubular shape having geo-textile fabric with cross section of oval shape in which approx. 12 ft. is filled with sediment and local sand in manner to hold unstable banks at place. Geo tube comprises of heavy minerals and contains inates of pyretic rock that un-earthened from road construction. Due to it acid runoff problems are prevented.

3.5 Geo-net :

It is a mesh structure that form by overlapping threads (dia 3-15mm) and angle between 60-90 degree. Major importance of geo-net are – (i) existing reinforced new constructive road surface (ii) rigid pavements having reinforced joints, prevent cracks if road extends and patch work and so on. Geo net used in reinforcing sub-grade of soft clay.

3.6 Geo-membrane :

These are thin, flexible materials of polymer used primarily for containment of vapour barrier or liquid or both. It was used by OK Lohoma dot for problem of undulation in I – 35 because of clay expansion under road surface. As the moisture content of clay increases, it causes swelling and non-homogenous contraction and

expansion. Harmful effect is caused by them on pavement. With use of geo-membrane, significant change in moisture is minimized in pavement sub-grade. Also facilities like light weight, strength, costs saving and portability provided by geo-membrane.

3.7 Geo-Foam :

Through some studies we analysed that geo-foam may be used in sub-grade or sub-base as a light weight material and will simplify the construction and design activities. On other hand John. S. Horvath stated that some problems are raised in road construction like catch fire during Euro road E6, vestby (Norway) construction. Block shifted under traffic cause premature failure of pavement in Netherlands. Also damage to geo-form is caused by differential icing at surface of pavement, insect infestation, water absorption and so forth.

3.8 Geo Synthetic Clay Liners :

These are having application likewise less cost, less skilled labour, rapid insulation, less hydraulic conductivity to water. GCL having excellent property of self healing and ability to withstand differential settlement if installed properly. It is not dependent on accessibility of local soil. Effect of thaw/freeze is repaired easily and smaller thickness results in more air space. Testing of field hydraulic conductivity is not needed. Hydrated GCR reduces stress over burden on compressible sub-stratum. It prevents the sinkhole formation un-certainity beneath the pavement.

4. CONCLUSION :

All laboratory, field and numerical study shows that drainage, separation, filtration, reinforcement and containment function of pavement used by geo-synthetic material. By placing of geo-synthetic in top 1/3 of base course, pavement performance is improved. Geo-grids help in reducing accumulation of permanent deformation in sub-grade layer with distribution of load over large area. Nearly half thickness reduce with the use of geo-grid reinforcement in clay sub-grade by effect of inter locking if placed in convex shape. 20 to 40% base course is reduced by using geo-grid in design of pavement with grade reduction in sub-grade material. Research work in future is needed to design geo-grid reinforcement pavement with mechanistic empirical design and needs effort for establishing guidelines for geo-grid placement in pavement.

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