Effect of Utilization of Geogrids on Reducing the Required Thickness of Unpaved Roads

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Abstract—The inadequacy of many existing roads due to rapid growth in traffic volume provides a motivation for exploring alternatives to existing methods of constructing and rehabilitating roads. The use of geosynthetics to stabilize and reinforce paved and unpaved roadways offers one such alternative. Many studies were conducted to evaluate the improvements associated with geogrid reinforcement of pavements. It is widely believed that geogrid reinforcement of roadways can extend the pavement’s service life and/or reduce the pavement’s structural thickness. This paper examines a method to compare traditional pavement structure designs, absent of geosynthetics, to pavement structure designs incorporating geosynthetics. At first, a specific unpaved road structure design is presented with recommended corresponding traditional road structure components. The road structure is then re-examined incorporating newly developed, reengineered geogrid. Finally, related costs with this particular design are outlined, analyzed and compared. In this case, cost savings achieved by using geogrid are substantial.

Keywords-Geogrid; Pavement; Reinforcement; Subgrade; Cost

I. INTRODUCTION

In the past 25 years, there has been a steady increase in the use of geosynthetics to improve road foundations. Geosynthetics are any of several durable polymeric materials designed for use in soils: for example, to separate layers of soil and aggregate, provide reinforcement or added strength, or facilitate drainage and filtration. Two common geosynthetic materials are geotextiles, or polymer-based fabrics; and geogrids, polymers formed into open, grid-like configurations.

A geogrid is defined as a geosynthetic material consisting of connected parallel sets of tensile ribs with apertures of sufficient size to allow strike-through of surrounding soil, stone, or other geotechnical material [1].

Geogrids perform two primary functions of geosynthetics within a pavement system: separation and reinforcement. Due to the large aperture size of most commercial geogrid products, they are typically not used for achieving separation of dissimilar materials. The ability of a geogrid to separate two materials is a function of the gradations of the two materials which is generally outside of the specifications for typical pavement materials. However, geogrids can theoretically provide some measures of separation, albeit limited. For this reason, separation is the secondary function of geogrids which could be used in pavements. The primary function of them is reinforcement, in which the geogrid mechanically improves the engineering properties of the pavement system.

Three primary applications of a geogrid in a pavement system are to (a) serve as a construction aid over soft subgrades, (b) improve or extend the pavement’s projected service life, and (c) reduce the structural cross section for a given service life. Geogrids have been successfully used to provide a construction platform over soft subgrades [2]. In this application, geogrid improves the ability of compaction in overlying aggregates, while reducing the amount of material which is required to be removed and replaced. Various research programs have also reported results regarding extended service lives for pavement sections with geogrids compared to similar sections without geogrids [3, 4].

In other researches, an attempt is made to investigate changes in strength characteristics of different granular base materials reinforced with geogrid by Duncan and Attoh-Okine [5]. Haas et al. [6] performed laboratory experiments and demonstrated the importance of variables such as geogrid placement position, base course thickness and subgrade strength. In
addition, Zornberg et al. [7] showed that geogrid reinforcement provides benefits by stabilizing pavement over weak subgrades and expansive clays with high plasticity.

A study attempted to identify mechanical and physical properties of geogrids which are critical to their effectiveness in the stabilization of pavement subgrade. The results demonstrate that aperture size, tensile strength at small strains, junction strength and flexural rigidity recognized as the most important attributes of geogrids in pavement subgrade stabilization [8].

II. PROJECT DESCRIPTION

For the purpose of comparison between pavement design with traditional materials and use of geogrid as reinforcement, it was decided to reconstruct one of the rural roads in the county of hoveyzeh in khuzestan province. Existing road is an unpaved two-lane road with width of 5 meters and a length of 10 km, which is located in the western part of the hoveyzeh. Due to passing traffic growth in recent years, it was decided that the existing road should be converted to a two-lane road with width of 8 meters.

Two options are proposed for road pavement design. Firstly, traditional pavement structure design without use of reinforcement and secondly, pavement structure design by applying geogrid as reinforcement on the surface of subgrade layer.

For designing the pavement structure, SpectraPave4™ design software for unpaved applications has been used. This software was developed by Tensar International Corporation, Inc. (TIC) for the analysis and design of roadways for temporary stone-surfaced haul and access roads. The design analysis method which has been used in the software is Giroud-Han method [9]. The method determines the minimum aggregate thickness required to support wheel loads on the surface and prevent bearing failure and/or excessive deformation of the subgrade. It can be used to design conventional, unreinforced and geosynthetic reinforced pavements.

III. MATERIALS AND PAVEMENT DESIGN

A. Traffic Loading Analysis

An Equivalent Single Axle Load (ESAL) is 18 kips, and this value is used by default in the program. It is assumed in the Giroud-Han analysis [9] that the contact pressure on the pavement is equal to the tire pressure. For this project, the tire pressure for a standard highway truck 80 psi (approximately 550 kPa) has been selected, and this is used by default in the program. Axle passes equals the number of vehicle passes multiplied by the number of axels per vehicle. For this road, the number of axel passes equals to 5500 ESALs was computed.

Rut depth describes the maximum surface deformation for an unpaved road or access platform required to main serviceability. For permanent unsurfaced pavements, 1.5 inches (40 mm) is normally appropriate.

B. Soil and Material Conditions

The required thickness of granular material calculated using the software is very sensitive to the magnitude of the subgrade strength. Caution should be exercised to ensure that the used value in the analysis is representative of the conditions likely to be experienced in situ during the life of the pavement. According to test results in the Technical & Soil Mechanics Laboratory, the type of subgrade soil is clayey with high plasticity (CH) and estimated CBR value in the state of saturation equals with 3%.

Another required parameter for pavement design structure is Aggregate Fill CBR. This parameter used to describe the strength of the unbound aggregate following placement and compaction on top of the proposed subgrade. In accordance with carried out tests, the estimated value of this parameter equals with 30%.

The reinforcing benefit provided by a geosynthetic is a function of its material properties as following: aperture size and stability, rib shape, rib thickness and its junction efficiency. In this project, two types of geogrids with names of TX140 and TX160 from products of Tensar International Corporation have been used.

IV. DESIGN ANALYSIS

After inputting the required data to the software, pavement design calculates by the software. Table1 summarizes the results of the calculations. As can be seen from this table, the required aggregate fill thickness for the unreinforced design is 480 mm whereas, for the reinforced designs, this thickness for TX140 and TX160 geogrids is 180 and 150 mm, respectively. The amount of aggregate fill thickness saving for TX140 geogrid is 300 mm which equals with 63% of the traditional or unreinforced one. In addition, this represents a saving of 330 mm or 69% for TX160 geogrid.
TABLE I. DESIGN ANALYSIS OF UNREINFORCED AND REINFORCED PAVEMENT STRUCTURES

<table>
<thead>
<tr>
<th>Geosynthetic</th>
<th>Aggregate Fill Thickness (mm)</th>
<th>Aggregate Fill Thickness Savings</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Calculated</td>
<td>Required</td>
</tr>
<tr>
<td>Unreinforced</td>
<td>472.4</td>
<td>480</td>
</tr>
<tr>
<td>Tensar® TX140</td>
<td>172.7</td>
<td>180</td>
</tr>
<tr>
<td>Tensar® TX160</td>
<td>100</td>
<td>150</td>
</tr>
</tbody>
</table>

Figure 1 shows a graphic representation of the relation between the field subgrade CBR and required aggregate fill thickness for both unreinforced and reinforced design options.

Figure 1. Relation between design subgrade CBR and aggregate fill thickness for design options

V. COST ANALYSIS

The Cost Analysis feature in the software is available for use with the Unpaved Application design. The required data for inputting in the software are as follows:

Length and width of the road are 10 km and 8 meters, respectively. Total in-place aggregate cost equals $18.4/m³, undercut and removal cost $2.20/m³, cost of placed and compacted aggregate to build up to finished level $2.8/m³, delivery cost to site for TX140 geogrid $2.4/m² and for TX160 geogrid $4.8/m² and finally, installation cost of geogrid equals $0.3/m². Table 2 summarizes the cost analysis for design options of this project.

TABLE II. COST ANALYSIS OF UNREINFORCED AND REINFORCED PAVEMENT STRUCTURE OPTIONS

<table>
<thead>
<tr>
<th>Item</th>
<th>Unreinforced</th>
<th>TX140</th>
<th>TX160</th>
</tr>
</thead>
<tbody>
<tr>
<td>Aggregate costs ($)</td>
<td>706,560</td>
<td>264,960</td>
<td>220,800</td>
</tr>
<tr>
<td>Geosynthetic costs ($)</td>
<td>0</td>
<td>232,200</td>
<td>438,600</td>
</tr>
<tr>
<td>Undercut costs ($)</td>
<td>84,480</td>
<td>31,680</td>
<td>26,400</td>
</tr>
<tr>
<td>Additional fill costs ($)</td>
<td>0</td>
<td>0</td>
<td>0</td>
</tr>
<tr>
<td>Total project costs ($)</td>
<td>791,040</td>
<td>528,840</td>
<td>685,800</td>
</tr>
<tr>
<td>Overall project savings ($)</td>
<td>0</td>
<td>262,200</td>
<td>105,240</td>
</tr>
<tr>
<td>Percent savings (%)</td>
<td>0</td>
<td>33</td>
<td>13</td>
</tr>
</tbody>
</table>

As can be seen from Table 2, total project costs without the use of reinforcement equals with $791,040 while, for the reinforced designs this item for TX140 and TX160 geogrids is $528,840 and $685,800, respectively. As shown in table 4, the
reinforced options indicated overall project savings of $252,200 for TX140 geogrid which equals 33% savings, and $105,240 which equals 13% savings for TX160 geogrid.

VI. CONCLUSION

In unpaved roads where the subgrade is unable to adequately support traffic loads, geosynthetic reinforcement can be placed at the aggregate and subgrade interface to improve pavement performance by decreasing the load distributed on the subgrade. As a result, an equivalent reinforced road section thickness yields an increased allowable traffic load as compared to the unreinforced road section.

In this project, the use of geosynthetic reinforcement option not only decreased the required pavement thickness, but it had a considerable effect on savings of total project costs.

REFERENCES