



Use of geosynthetics to reinforce low volume roads

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ABSTRACT :

The use of geosynthetics is widespread in the field of civil engineering. One particular application that has seen a great deal of use has been as a separating layer between the aggregate base layer and subgrade of low volume roadways. Since geosynthetics may be very stiff, they may provide an additional benefit of reinforcement to the roadway. For this study, only the reinforcement functions of geosynthetics were investigated. Long term separation and increased bearing capacity during construction were not considered. The research described herein was originated to investigate the reinforcement function of geosynthetics for typical Minnesota low-volume roadways. To this end, a series of numerical experiments were conducted using the finite difference program FLAC (1993). The tests consisted of a static, circular, 9 kip loading over a variety of typical surfaced and unsurfaced road cross sections that were reinforced with geotextiles and geogrids. The results are shown in terms of percent normalized deflection reduction and percent normalized accumulated standard axle load to a serviceability level of 2.5 (ASAL2.5) increase. Additionally, the effect of a geosynthetic reinforcement layer on the horizontal stress distribution is illustrated. The results of the study indicate that the addition of a geosynthetic does provide reinforcement to the roadway as long as the geosynthetic is stiffer than the subgrade material. However, for most of the cases studied, the benefit in terms of deflection reduction, was very small. Only for the poorest quality subgrades was the reinforcement benefit substantial.

INTRODUCTION :

The use of geosynthetics in geotechnical construction projects has gained tremendous popularity over the past 30 years. Ranging from the reinforcement and separation functions in roadway construction, to the filtration functions in earthen dams, geosynthetic applications are as varied as the types of geosynthetics available on today's market. Of special interest to civil engineers is the use of geosynthetics to reinforce roadways. Sometimes it is necessary to construct a road on very poor quality soil, and the intended use of the road does not merit the expense of constructing a high quality road. Examples of

such roads are service or access logging roads, and low volume rural roads. The use of geosynthetics in large-scale civil construction projects has not only saved both time and money, but also made the resulting structures safer. Typical applications for geosynthetics in civil engineering projects include reinforcement, separation, and filtration and drainage. Geosynthetics may be divided into two distinct categories: geotextiles and geogrids. Geotextiles are typically made from petroleum products such as polypropylene, polyester, and polyethylene; however, they may also be made from fiberglass. Geotextiles may be further divided by the



manner in which they were manufactured. For instance, woven geotextiles are made by weaving individual filaments together to create an interlocking structure. Conversely, nonwoven geotextiles are manufactured by bonding together randomly oriented short fibers or filaments to form a planar structure. For nonwoven geotextiles, the bonding process may be chemical, thermal, or mechanical. Chemical bonds utilized some sort of glue to hold the fibers together. Thermal bonding is achieved by melting the fibers together, and needle punching creates mechanical bonds. Due to the many different materials geotextiles may be created from, and the different creation processes, the range of material properties of geotextiles is very large. It is well known that geosynthetic basal reinforcement has been used in paved and unpaved roads to limit the occurrence of rutting, fatigue, and environmental-related cracking, as well as to permit reduction in base course thickness. Nevertheless, the lack of a representative, cost-efficient test that can be used to evaluate the behavior of largescale pavement trial sections has prevented detailed analyses of variables that may affect the performance of basally-reinforced flexible pavements or unpaved roads. The most important parameters that should be examined in such cases are the base thickness, subgrade and base soil properties, geosynthetic materials properties and functions, depth of geosynthetic placement, stress state, corresponding traffic loading and the corresponding environmental conditions. Accordingly, the main objective of this study is to highlight the importance of using the heavy vehicle simulator to characterize the full-scale, geosynthetic reinforced pavement response. This report includes a description of the methodology and historical use of the HVS all over the world

with a focus on the results from Swedish case studies that have been implemented using the HVS owned by the Swedish National Road and Transport Research Institute (VTI). In addition this report highlights the cost- benefit analysis from using the HVS as a testing approach as well as the use of geosynthetics as an effective and economical approach to enhance the performance of low traffic volume roads. Usually, the pavements are designed to support an expected amount of traffic over the desired design life, but unfortunately most of the pavements suffer from mechanical failure before they reach the desired design life due to unexpected loadings, environmental interaction, drainage problems, etc. Consequently, in order to reach the lifetime of paved and unpaved roads, pavement engineers have incorporated thicker layers of base material into flexible pavements. However, this strategy has led to excessive cost in some situations (Cox et. al. 2010). Accordingly, alternatives such as geosynthetic reinforcement of the base course have been used in flexible pavements as well as unpaved roads (Steward et al. 1977). Field studies have indicated that geosynthetic reinforcement of pavement base course layers can lead to reduced differential settlement, reduced base course thickness, extend the service life, and improved stress distribution (Hufenus et al. 2006), but most of these studies based on short term laboratory tests and initial costs assessments. Therefore, long term roads performance evaluation based on life cycle cost analysis is highly recommended.

2 Purpose of the Study

The objective of this study is to highlight the benefits of using the HVS to verify the subgrade soil reinforcement under long term traffic conditions. Correspondingly, provides a better



understanding of the importance of using large scale tests (e. g. the heavy vehicle simulator test) to simulate traffic associated deterioration of a road over its design life (usually 20 years) in as little as three months. Furthermore, this study deals with general aspects related to road's problems associated with low volume traffic in order to provide a better understanding of the problems that addresses the needs of testing new roads design approaches using full scale tests. In addition, this report presents a systematic step-by-step method for design and repair of roads suffering spring thaw weakening using geosynthetics. Consequently, the report will discuss whether and under what conditions geosynthetics (geogrids and geotextiles) increase the structural capacity of pavements and under what conditions geosynthetics increase the service life of pavements. At the same time this report will give a historical overview about the use of accelerated pavement testing all over the world and open the access over new accelerating testing programs using the heavy vehicle simulator to verify the validity of new road design approaches like the use of reinforced materials in roads constructions to extend the service life of the road. In principle, long term roads performance assessment will help in answering the most important pavement mysteries and questions, like: The road looks good today, but how will it perform tomorrow? What should we do in order to guaranty that the road everyday will perform as well as the first day of service? What should we do in order to get a better road surface and reduce road maintenance with simplified construction and lower costs? What test can give dependable results that reflect the full-scale performance of roads and could be the bases for pavements design guide? What materials should we use to

construct environmentally acceptable roads that can service over the whole design life?

3 The Accelerated Loading Testing

According to Byron and Choubane (2003), the accelerated loading testing is a controlled application of a realistic wheel loading to a pavement system simulating long-term loading conditions. This technique allows the monitoring of a pavement performance and response to accumulated load damage within a shorter time period (Byron and Choubane, 2003). The need for faster and more practical evaluation methods under simulated in-service conditions prompted several transportation agencies, including the Swedish National Road and Transport Research Institute (VTI), to consider accelerated pavement testing (APT). One of the large scaled accelerated pavement tests is the Heavy Vehicle Simulator, HVS, which can be simulate traffic associated deterioration of a road over its design life (usually 20 years) in as little as three months. The HVS is used to study how different types of road constructions manage heavy traffic while exposing the full-scale roads to accelerated traffic. Prior to the HVS, researchers had to wait many years to see if new laboratory test methods or field tests would indeed provide reliable results for pavements under actual truckloads and traffic. Regarding the HVS test, the mechanism of working is based on the rolling of a truck tire over a patch of asphalt or any type of road construction material. It goes back and forth to simulate years of traffic in just weeks or months while verifying whether a pavement structure will last or fall apart. Consequently, the following paragraph is intent to present a description of the HVS testing program all over the world with a focus on the main usage and findings of the Swedish HVS testing program.

3.1 The uses of the HVS test all over the world The following paragraphs address in details many of the experiments that have been carried out all over the world to evaluate the new road construction materials and design approaches using the heavy vehicle simulator. The literature review presented in this subject covers just few research studies carried out using the heavy vehicle simulator. Nevertheless, there are more studies in this area but unfortunately; it is not possible to address all of them here. Correspondingly, a research study has been carried out in Florida to evaluate the longterm performance of superpave asphalt mix design and modified superpave asphalt mix design using the HVS. The main objectives of this study were to evaluate the operational performance of the Heavy Vehicle Simulator, and its possible use in evaluating the rutting performance of pavement materials and/or designs under typical Florida traffic and climate conditions. As a result, the rutting performances of a typical superpave mixture used in Florida were sufficiently evaluated using the HVS as reported by Tia et al. (2002). Kohler et al. (2004) described the evolution of precast concrete pavements in various countries and, in particular, in the United States. The design, construction, and installation of a particular system of precast slabs called Super-Slab™, was explained, and an overview of the results of accelerated load testing with a heavy vehicle simulator (HVS) performed in California were presented by Kohler et al. (2004). According to Kohler et al. (2004), the HVS results indicate that the evaluated system of precast slabs can be safely opened to traffic in ungrouted condition, so that the panels can be installed in consecutive nights rather than completing the entire installation at one time. In addition, Kohler et al. (2004) pointed out that the

life of this system of precast slabs, is estimated to be between 142 and 242 million equivalent single-axle loads, equivalent to 25 to 37 years of service and the failure mechanism did not differ from the failure mechanism of cast-in-place jointed concrete pavements. Moreover, the Heavy Vehicle Simulator (HVS) was used to test pavements on two roads in South Africa that were recycled in place and treated with foamed bitumen and emulsified bitumen. The HVS testing was performed on road P243/1 near Vereeniging, Gauteng Province, and on the N7 road outside Cape Town in the Western Cape in order to characterize the foamed and emulsified bitumen treated materials. The other purposes of the test were to identify distress mechanism and to investigate how the distress progressed with increasing load repetitions. In principle, the APT testing has provided the tool for early assessment of a relatively new pavement technology such as foamed bitumen treatment and deep in situ recycling as described by Theyse et al. (2004). The California Department of Transportation requires that all new flexible pavements should include a 75-mm layer of asphalt-treated permeable base (ATPB) between the asphalt concrete and aggregate base layers to block off the entering of water to the pavement structure, either through cracks in the asphalt concrete or through highpermeability asphalt concrete. This layer will transport the cracks out of the pavement before it reaches the unbound materials. The validity of using the ATPB layer was examined using heavy vehicle simulator (HVS) to evaluate the performance of drained and undrained flexible pavements under wet conditions. Results of the accelerated pavement testing indicate that ATPB strips under combined conditions of wet base and heavy loading and the drained and undrained sections have similar

pavement lives; however, the primary mode of failure for the drained section was surface rutting and for the undrained sections was fatigue cracking (Bejarano et. al., 2004) According to Tia and Kumara (2005), in Florida, full slab replacement is a common method for repair of badly deteriorated concrete pavement slabs. However, there were certain requirements on the compressive strength as well as uncertainties on the optimum concrete mixtures to be used; therefore the Florida Department of Transportation requested research in this area using the HVS. For this purpose, five test concrete slabs were tested by the HVS and the results of this experiment helped the researchers to decide which slab could perform better than the other. Tia and Kumara (2005) found that the performance of the test slabs was independent of the cement content of the concrete used. Therefore, the HVS gave the researchers a complete idea about the factors that influence the concrete slabs performance. In addition, the tests parameters resulted from the HVS test were used to develop a Finite Element computer program (FEACONS) to model the response of the test slabs and to predict the stresses in the concrete slabs caused by the applied loads and the temperature differentials in the concrete slabs (Tia and Kumara, 2005). Plessis (2008) highlighted the benefits achieved from using the heavy vehicle simulator in roads testing. Plessis (2008) reported that the HVS had been used in verifying the validation of a new large stone mix design method; use of modified binders in mixes; in situ recycling of materials; upgrading of gravel roads as well as block paving and rehabilitation procedures for concrete roads. Moreover, Plessis (2008) added that the use of HVS had allowed a better (optimal) use of funds and natural resources.

4 Low Traffic Volume Roads

4.1 General information Pratico and Giunta (2011) defined the low-volume roads as facilities outside built-up areas with a traffic volume of less than 400 annual average daily traffic (AADT). In spite of the fact that these roads are of lower use because of their location, low-volume roads play an important social and economic role and sometimes represent a large part of the regional and national road network (Russell and Kornala, 2003 and Pratico and Giunta, 2011). In Sweden, the design of low traffic volume roads is governed by “Dimensionering av lågtrafikerade vägar- DK1, 2009” for roads up to 500 000 standard axle. Nevertheless, for traffic volume more than 500 000 standard axel, design method DK2 is used as referred to in TRVK Väg.

4.2 Feature of unpaved low traffic volume roads It is well known that the unpaved roads are roads built without an asphalt or concrete wearing surface, so they derive all structural support from their aggregate base layers. In principle, the unpaved roads are used for many purposes including industrial and private roads, temporary roads, detours and rural roads. Because unpaved roads have no asphalt or concrete wearing surface to help support traffic loads, they require a greater depth of aggregate base than the paved roads. This is applicable in designing roads for the same traffic. However, it is important here to mention that because of the increasing cost associated with asphalt repaving, interest has been rising in turning back damaged asphalt roadways into maintainable aggregate driving surfaces (Shearer and Scheetz, 2011)

4.3 Feature of paved low traffic volume roads According to Wayne et al., (2011), the flexible pavement structure for a low traffic volume road (LVR) consists of a relatively thin asphalt-

concrete wearing course and an aggregate base course constructed on subgrade layer. An asphalt wearing course provides a good riding surface and moisture protection for the base course. Service life of a thin asphalt pavement depends on material quality and thickness of granular layers (Wayne et. al., 2011).

4.4 Design principle for low traffic volume roads In spite of the fact that there are similar basic principles for pavement design, each country has adopted individual methods and structures that suits their requirements according to their experience. In general, unpaved-road construction using gravel requires that the material meet certain basic engineering demands. These demands include the following categories: Adequate cohesion to resist erosion,• A particle size distribution that assists a tight engagement of the individual• material particles, and Adequate strength to support the applied traffic loads without significant• deformations. 30 VTI notat 9A-2013 Insufficiency in any of these demands may result in poor riding quality which in turn leads to subsequent high agency maintenance costs. Consequently, road agencies have increasingly been faced with the demand of relying upon marginal materials in the construction of low-volume roads. However, the use of these materials necessitates that stabilization be used to alter the material's engineering parameters to ensure that erosion, rutting, dust, and bearing capacity problems are minimized (Paige-Green and Netterberg, 1987).

Conclusions and Recommendations It can be concluded from the collected studies that the accelerated pavement testing can produce early and beneficial results that lead to improving pavement technology and provide better

understanding of the application and effectiveness of new materials used to enhance the pavement systems performance. It is clear that using of geosynthetic materials in roads construction will result in reducing the thickness of the road pave layer and hence reduces the cost of construction. In addition, using of geogrids will decrease the intensity of stress on the subgrade and providing raw materials and energy, and reduce the carbon emission. When carrying out HVS test to validate the use of geogrids in roads construction, the impact of the subgrade strength and base course layer thickness will be crucial factors during the results analysis. Additionally, geosynthetics location and properties should also be considered during the analysis. In general, more research regarding the beneficial use of geosynthetics in roads construction should be conducted taken into account the HVS testing result according to the aforementioned issues. Such a study will result in recommendations regarding the performance of different types of geosynthetic materials under different loading conditions which in turn will result in economic economic analyses of the different options.

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