Evaluation of a mechanically stabilized layer for the Trans-Canada Highway in Antigonish Nova Scotia

Mark H. Wayne, Ph.D., P.E., Paul Hewgill, C.E.T.
Tensar International, Alpharetta, Georgia, USA
Adam Marlin, P.Eng.
Nova Scotia Transportation & Infrastructure Renewal
Jay Kwon, Ph.D., P.E.
Department of Civil and Construction Engineering – Kennesaw State University, Marietta, Georgia, USA

ABSTRACT
In the fall of 2015 the owners involved with the construction of Highway 104 in Antigonish Nova Scotia were faced with a dilemma. Sections of the project consisted of a subgrade that was built up during the winter months using backfill that was potentially frozen. The Nova Scotia Transportation and Infrastructure Renewal Department (NSTIR) chose to utilize a design which incorporated a multi-axial geogrid to overcome the poor subgrade and optimize the pavement such that the structural number for the section would meet or exceed the requirements for the highway and height restrictions would not be exceeded. This paper examines the process of design and presents the successful use of repetitive plate load testing to confirm that the foundation stiffness requirements were achieved on this project.

RÉSUMÉ
À l'automne 2015, les propriétaires engagés dans la construction de l'autoroute 104 à Antigonish, Nouvelle-Écosse, ont été confrontés à un dilemme. Des sections du projet consistaient d'une infrastructure qui avait été construite pendant les mois d'hiver en utilisant un remblai potentiellement gelé. Le Ministère des Transports et Renouvellement de l'infrastructure de la Nouvelle-Écosse (NSTIR) a décidé d'utiliser une conception qui comprenait une géogrille multiaxiale pour surmonter la mauvaise infrastructure et optimiser la structure de chaussée d'une telle façon que le nombre structurel de la section satisferait ou dépasserait les exigences de l'autoroute et que les restrictions de hauteur ne seraient pas dépassées. Le présent document examine le processus de conception et dévoile l'utilisation réussie d'essais répétitifs de charge sur plaque pour confirmer que les exigences de rigidité de l'infrastructure ont été atteintes dans ce projet-là.

1 INTRODUCTION

Over the course of the past three decades there has been an increased number of cases where geogrids have been utilized to permit roadway construction over poor existing foundation conditions. During this time the selection of a mechanically stabilized layer (combination of aggregate and geogrid) and design of the overlying pavement have been empirical in nature with an inability to directly confirm the resilient modulus of the foundation layers prior to placement of the surface course. This in-situ resilient modulus can be predicted from falling weight deflectometer (FWD) or light weight deflectometer (LWD) equipment. In practice, elastic modulus values calculated from these tests is based on total deformations (elastic + plastic) and as such these results are often confused with resilient modulus values where resilient deflections (recoverable) are required (White and Vennapusa, 2017). In recent years automated repetitive plate load testing (APLT) equipment has been developed to alleviate this knowledge gap. In the fall of 2015 the owners involved with the construction of Highway 104 in Antigonish Nova Scotia were faced with a dilemma. Sections of the project consisted of a subgrade that was built up during the winter months using backfill that was potentially frozen. They were concerned about the affect this would have on the constructability and long-term performance of the pavement section. Sub-excavation as well as over-building the subbase layer for the new section were not reasonable for all areas due to cost or physical constraints. The Nova Scotia Transportation and Infrastructure Renewal Department (NSTIR) chose to utilize a design which incorporated a multi-axial geogrid in some areas, to overcome the poor subgrade, optimize the pavement such that the structural number for the section would meet or exceed the requirements for the highway to ensure that height restrictions would not be exceeded. This paper examines the process of design, presents the successful use of automated plate load testing to confirm that the foundation resilient modulus requirements were achieved on this project and describes the post construction testing utilized to demonstrate the finished pavement was in conformance to project specifications.

2 Design

The original project pavement design was performed in accordance with AASHTO ’93 guidelines. The highway, located within the areas containing the weak subgrade, was designed for 13,000,000 ESALs based on a reliability of 95%, standard deviation of 0.49, initial serviceability of 4.2, and terminal serviceability of 2.0. The structural section of the pavement consisted of 42mm wearing course, 200mm dense graded asphalt course on 100mm of aggregate base course. The foundation support for this structural section was required to be a minimum of 85 MPa (12,330 psi). The section of roadway where foundation conditions required the use of a mechanically stabilized layer (aggregate plus multi-axial geogrid) was evaluated utilizing SpectraPave4-PRO software. The software generates pavement design in accordance with AASHTO ’93 and AASHTO R50-09. ARA et al. (2013) provides details associated with their independent review of the software.

The foundation layer designed to meet the 85 MPa resilient modulus requirement consisted of a nominal 480 mm (19 in.) thick aggregate subbase layer placed over a multi-axial geogrid, underlain by a 200 mm (8 in.) thick aggregate base layer and subgrade. The multi-axial geogrid (Tensar TX7 geogrid) consists of a hexagonal structure and triangular apertures with a 40 mm rib pitch and a radial stiffness of 365 kN/m (25,000 lb/ft). The aggregate base layer, per project design and construction specifications, required a $D_{50} \leq 27$ mm with a maximum particle size of 75 mm (3 in.) and maximum fines content of 7% passing the No. 200 sieve. The base course material sampled from the test section consisted of a maximum particle size of 2.0 in. with about 2% passing the No. 200 sieve and is classified as well-graded gravel with sand (GW) according to the USCS classification and A-1-a according to the AASHTO classification.

3 Installation of the mechanically stabilized layer

Construction, shown in Figure 1, involved placement of the multi-axial geogrid with a 1 m overlap followed by the placement of aggregate in two lifts. The first lift was 350 mm (14 in) and the second lift was 130 mm (5 in). Compaction was achieved using two self-propelled single drum smooth vibratory rollers and two self-propelled

Figure 1. Placement of the aggregate on the geogrid

smooth dual drum vibratory rollers all working in tandem. Project segments including multi-axial geogrid consisted of five segments in the east bound lanes, four segments in the west bound lanes, various ramps, and roundabouts. The work consisted of approximately 5 km of two-lane highway. The Highway 104 twinning project in Antigonish included approximately 16 km of two lane highway and was completed in early November 2016.

4 Automated Plate Load Testing

Automated plate load testing was performed September 8-9, 2016. As reported by White and Vennapusa (2017), Automated plate load tests were performed at three separate locations as shown in Figure 2. At each location 100 cyclic loads (0.2 second load pulse was followed by a 0.8 second dwell time) were applied at six (6) different stress levels. These levels were 34, 69, 103, 138, 207, and 276 kPa (5,10,15,20,30 and 40psi). Loading was applied to a 300mm (12”) diameter plate. Deflection basin measurements were recorded at three positions extending

Figure 2. APLT locations on Hwy 104, Nova Scotia, CN (White and Vennapusa, 2016)

away from the center of the plate as depicted in Figure 3. Addition details regarding testing for this project are reported by White and Vennapusa (2016).

Figure 3. APLT test setup with deformation measurements obtained at 2r, 3r and 4r from the center axis. (White and Vennapusa, 2016)

4.1 Performance Verification

White and Vennapusa (2017) describe the theory and calculations utilized to compute the individual subgrade and base layer resilient modulus values. Results for this project are summarized in Table1. As indicated in the table all results exceeded the design required resilient modulus of 85 MPa (12,330 psi).

Table 1. Automated Plate Load Testing Summary

In-situ testing at 3 locations	
Design Mr for TX7 stabilized base	12,330 psi (85 MPa)
Mr for TX7 stabilized base from 1000-1100 cycles	19,579 – 32,577 psi (135-225 MPa)
Mr of the subgrade	8,807 – 22,252 psi (60-116 MPa)

In addition to the resilient modulus a 10,000 cycle APLT was conducted to determine permanent deformation characteristics that are utilized to predict long-term rutting. From this testing White and Vennapusa (2016) estimated that 13.3 million cycles would be required to achieve 7.25 mm (0.285 inch) of permanent deformation at the surface of the mechanically stabilized layer under a cyclic stress of 178 kPa (25.8 psi). WinJULEA, a multi-layer linear elastic analysis software, was utilized to compute the expected level of stress at the interface between the dense graded asphalt course and the top of the mechanically stabilized layer. Based on the field values for the base, 135 MPa, and subgrade, 60 MPa, and the modulus of asphalt layers utilized in design the stress at the interface due to a 40 kN tire load was computed as 59 kPa (8.6 psi). Since the cyclic field loading was conducted at a higher stress state the potential permanent deformation over the life of the pavement should be less than the values estimated in this testing program.

4.2 Roughness

NSTIR applies a smoothness specification to the final lift (surface course) of all newly constructed asphalt concrete pavement. This data is collected at the project level via NSTIR's, or its designated representative's, class 1 inertial profiler as detailed in NSTIR's Standard Specifications for Highway Construction and Maintenance – Appendix H. The primary highway network is evaluated annually by the Department's ARAN 9000 vehicle at a network level. This data is used to monitor the highway condition on an ongoing basis.

The data collected and reviewed for this project is International Roughness Index (IRI) data. The study segments for this project include two control segments and two segments where multi-axial geogrid was installed. The control segments were selected to provide as fair as possible control data to the areas of weak subgrade. The control areas are within the overall Highway 104 project limits, were constructed in fill areas using similar construction materials and methodology but did not feature the very weak subgrade as observed in areas where geogrid was installed.

The post-construction IRI was averaged for all segments and reviewed in comparison with the network roughness data collection. The post-construction data was collected in November 2016 and the network data was collected in October 2017 as part of regular network collection. The segment averages are presented in Table 2. All data collected is from east bound travel lanes only.

Table 2. HWY 104 Eastbound Travel Lane-IRI Data for Control and Geogrid Segments

Segment	***STATION***		***LENGTH***	***Post Construction***	***Network Collection***
Type	***START***	***STOP***	***(m)***	***IRI (mm/m)***	***IRI (mm/m)***
Control	9+190	9+440	250	0.54	0.57
Geogrid	10+920	11+165	245	0.64	0.71
Geogrid	11+497	12+320	823	0.53	0.60
Control	12+930	13+780	850	0.51	0.58
Overall	7+500	14+800	7300	0.60	0.63

All segments reviewed feature IRI averages that are less than 0.80 mm/m which qualifies for incentive payment for highway work of this type.

5 Conclusions and Recommendations

The use of pavement design software allowed decision makers to establish a value of resilient modulus that would be required for a pavement section to be placed on soils deemed problematic. Automated plate load testing was utilized to confirm:

- Subgrade resilient modulus
- Mechanically stabilized layer resilient modulus
- Conformance with the design resilient modulus
- Predicted permanent deformation of the pavement

NSTIR field testing demonstrated that the pavement was in conformance with project specifications and qualified for positive payment adjustment.

NSTIR will monitor IRI and rut data as part of regular network collection for future comparisons. It is recommended that, as more rut data becomes available, these pavement segments' rut performance should be reviewed and analyzed. In addition to the annual automated IRI and rut data collection, NSTIR conducts pavement condition surveys and distress evaluations. NSTIR uses the Highway Pavement Management Application (HPMA) as its pavement management software which stores this data and calculates a roughness index, distress index, and pavement quality index. In the future NSTIR will use these indices to review these highway segments' performance against other new highway construction projects and control segments.

6 References

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