Stress responses of geosynthetic-reinforcement pavement foundation

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ABSTRACT: This study investigates the stress distribution of geosynthetic-reinforced pavement foundation using a rolling wheel large-scale accelerated pavement test. Pressure cells embedded in different vertical locations under a wheel path are used to indicate the variations of vertical stress in both subgrade material and base course material. Large-scale test specimens enclosed in a 6ft (1.8m) L x 6ft (1.8m) W x 2ft (0.6m) D metal box is prepared both with and without a geosynthetic. The pressure cells display pressure variations over the course of testing in different locations which help evaluate the effects of using a geosynthetic between the base and subgrade layers of a pavement compared to control specimens built with no geosynthetic. Pressure measurements give a good indication of the pressure experienced at given locations for each traffic loading cycle. These measurements allow for an evaluation of the geosynthetic for the reduction of vertical pressure at the top of the subgrade.

Keywords: Geotextile, Geosynthetics, Pressure Cell, Base, Subgrade

1 INTRODUCTION

Geosynthetics used on soft subgrades provide both cost and performance benefits due to the reinforcing properties of the geosynthetic which are: Reducing stress intensity on subgrade, reducing the depth of excavation required of unsuitable subgrades, reducing the thickness of aggregate required to stabilize subgrades, reducing the disturbance of soft subgrade during construction, and providing a more uniform support for the base course layer by decreasing differential settlement and minimizing variations of subgrade strength. The reinforcing properties of geogrids and geotextiles are based on several mechanisms. Friction produced by geotextiles, and interlock produced by geogrids produce lateral restraint of base and subgrade materials [1].

A series of large-scale tests are planned on soils to investigate the effect of woven geotextiles on pavement foundation behavior. To run a large-scale test, a 6ft (1.8m) x 6ft (1.8m)x 2ft (0.6m) metal box (shown in Figure 1) was manufactured to fabricate pavement foundation specimens in. The box is passed under a wheel load attached to a hydraulic press to simulate the field traffic loadings. The wheel load applied was determined from a Finite Element Analysis (FEA) model in which a simulated 9000-pound (4082 kg) load applied to the surface of a 8” (20.32 cm) thick Asphalt Concrete (AC) Layer [2]. The analysis determined that approximately 2250-pounds (1020 kg) is transferred through the AC layer to the top of the aggregate base layer from the simulated wheel load. This load was used for the large-scale wheel loading in this study. Throughout the large-scale testing, continuous measurements of vertical pressure are recorded from various pressure cells embedded in the specimen in order to determine the effectiveness of the geotextile. These cells are embedded into both the subgrade and Unbound Aggregate Base (UAB) layers to evaluate how the use of geotextile changes pressure distribution throughout the pavement foundation.

Figure 1. Large Scale Testing Apparatus.

Before large-scale testing began, a preliminary test run was done to calibrate pressure cells and see how equipment reacted when a load was applied. To begin the test, a specimen was prepared in the large-scale box. The box contained UAB and subgrade that were compacted in layers of 12 inches (30.48 cm), separately. Two pressure cells were placed on each wall parallel to the wheel path. One wall contained a memory foam that was put in place to help dissipate confining pressure. The other wall contained no foam. The last pressure cell was placed 18 inches (45.72 cm) below the tire load. It was determined that there were no boundary effects from the walls for the pressure cells under the tire loading [2].

2 TESTING PREPARATION

Before running a large scale testing a substantial amount of preparation including pressure cell calibration was required in order to obtain accurate readings from all the testing apparatus installed in the specimen. The locations of the pressure cell are displayed in Figures. 2 and 3.

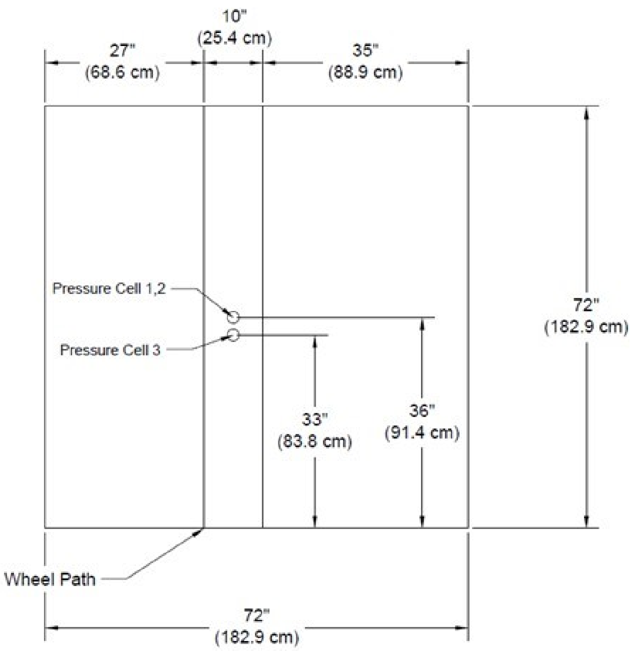

Figure 2. Plan View of the Pressure Cell Layout

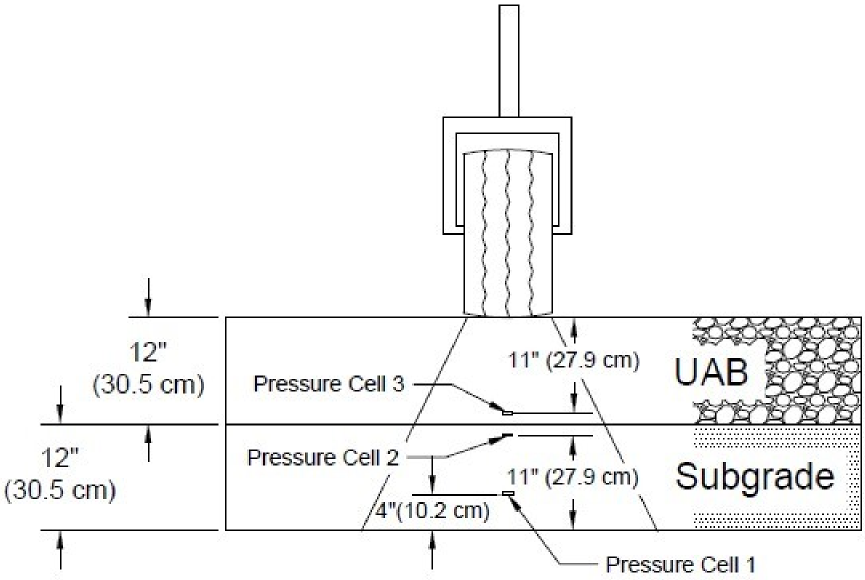

Figure 3. Elevation View of the Pressure Cell Layout

2.1 *Calibration of pressure cell*

Each of the four pressure cells were individually calibrated using 0.5-pound increments (0.23 kg). When attached to the data acquisition system, each pressure cell reads an initial value with zero load on top of the cell, only reading atmospheric pressure. Once a load is applied, the cell reads another value, all in pounds. The difference in this weight is the theoretical load that has been applied to the cell (weight on the cell). However, this weight on displayed does not represent the actual weight placed on the cell. In order to calibrate each pressure cell reading, a relationship has been made to correlate the weight reading from the data acquisition system to the actual weight on the cell. Numerous data points have been collected and the graphs below show different data points for all four cells. The graphs represent actual weight in the y-axis, versus weight read by the cell in the x-axis. From these data points, the best fit line was developed which ultimately provides a factor to determine and calculate actual weight from the weight reading on the pressure cells. Figure 4 shows the pressure cell readings versus actual weight and the best fit line in this study. The cells were calibrated up to 25 pounds (11.3 kg) of weight due to the small expected pressure values from the wheel load after being dispersed through the base course layer of the sample. Individual graphs were developed for each pressure cell but are not included in this report for conciseness. The graph shows a very linear relationship between pressure displayed versus actual load with an R-value of .99 or higher as shown in Table 1 indicating a high likelihood of the relationship giving correct pressure values during the conversion process.

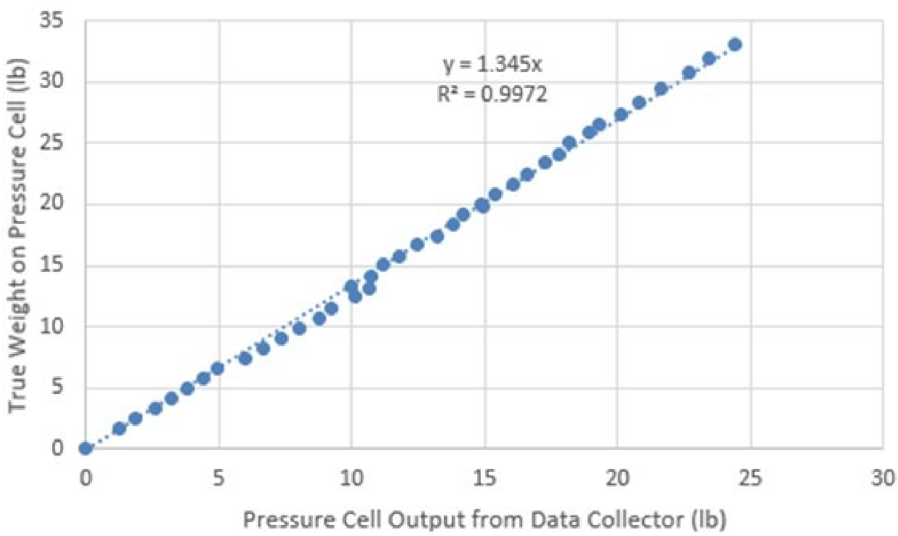

Figure 4. Plot for Actual Weight vs. Pressure Cell Reading
(Note: To Convert to Kg, Multiply lb weight by 0.454)

Table 1. Calibration & Coefficient of Determination factors.

Pressure Cell #	Calibration Factor	R^2 Value
1	1.025118	.999
2	1.026195	.996
3	1.196229	.988
4	.905724	.997

2.2 *Materials properties*

For subgrade soils, highly plastic silts (MH) were selected to simulate the poor subgrade condition. A thorough geotechnical characterization of the soils was carried out using Proctor compaction (modified method, ASTM D1557), and Atterberg Limits tests. Soil index properties for the subgrade soils and UAB are shown in Table 2.

Table 2. Subgrade Soils and UAB Index Properties.

	Soils Tested	
	Subgrade	**UAB**
Specific Gravity	2.76	2.70
USCS Classification	MH	GW
Percentage Fines (%)	53.14	5.0
Plastic Limit	41.7	-
Liquid Limit	63.4	-
Plasticity Index	22	-
*Max Dry Density (*kg/m^3 (pcf)*)*	1818.1 (113.5)	2138.5 (133.5)
Opt Water Content (%)	14.7	7.2

The geosyntetics used for this study is a woven geotextile manufactured by TenCate Geosynthetics. Most specifically, the Mirafi HP 270 geotextile was selected and is composed of high-tenacity polypropylene yarns which are woven into a network such that the yarns ran their relative position. The specifications for HP 270 woven geotextile are shown in Table 3.

Table 3. Mirafi HP 270 Geotextile Properties

Mechanical Properties	Test Method	Unit	Minimum Average Roll Value	
			MD	CD
Tensile Strength (at Ultimate)	ASTM 4595	lbs/ft (kN/m)	2640 (38.5)	2460 (35.9)
Tensile Strength (at 2% Strain)			504 (7.4)	600 (8.8)
Tensile Strength (at 5% Strain)			1272 (18.6)	1440 (21)
	ASTM D4751	Sieve No. (mm)	30 (0.60)	

2.3 *Large scale test*

The vibratory plate compactor was used to compact the soils, that has a 7 hp engine that delivers 4,496 pounds (2039 kg) of force at 5,400 blows per minute. After compaction of the subgrade is completed, several soil quality control tests are performed on the specimen to determine its condition and ensure control and geosynthetic test specimens were similar. Once the subgrade properties are deemed sufficient the second 12” (30.48 cm) layer of steel walls are attached to the test specimen. If a geosynthetic is required at the interface of the specimen, it is placed with the machine direction parallel to the wheel path as it would be in the field. The foam walls are then placed on top of the geosynthetic before loading a single bobcat bucket of UAB material from the holding pit into the test specimen. This UAB is then distributed over the geosynthetic with shovels in a consistent manner. The remaining pressure cells are then placed in the wheel path of the UAB layer at their specified heights. When the instrumentation is sufficiently placed and protected, two more bucket loads of UAB is placed in the container for a total UAB thickness of about 12” (30.48 cm). After the soil specimen is completed and ready for testing, large-scale tests were performed. Because of the slow 1 mph speed of the testing, it takes approximately 10 hours to run 5400 total passes. This 5400 number was deemed sufficient to see a leveled out constant pressure. After the total of 5400 passes has completed, the motor is disconnected and data is then exported from the acquisition system to a flash drive to be analyzed. For this study, two different testing specimens were built to compare the effects of using a geotextile at the base subgrade interface. Using a control section and a geotextile reinforced section allows for comparisons to be made between the two to determine the effects of using the geosynthetic.

2.4 *Test results*

Figure 5 shows that there is modest pressure reduction in the aggregate base layer and a significant reduction in the subgrade layer. The top of subgrade and bottom of UAB layer showed a 43.08%, and 10.60% pressure reduction respectively. The stiffening/ strengthening of the aggregate base through the use of geotextile reinforcement does little for the pressure reducing in the base layer but more importantly can greatly reduce pressure in the subgrade. Figure 5 shows that even soils compacted at their optimum moisture content can have significant pressure reductions in the subgrade layer with the use of a geotextile.

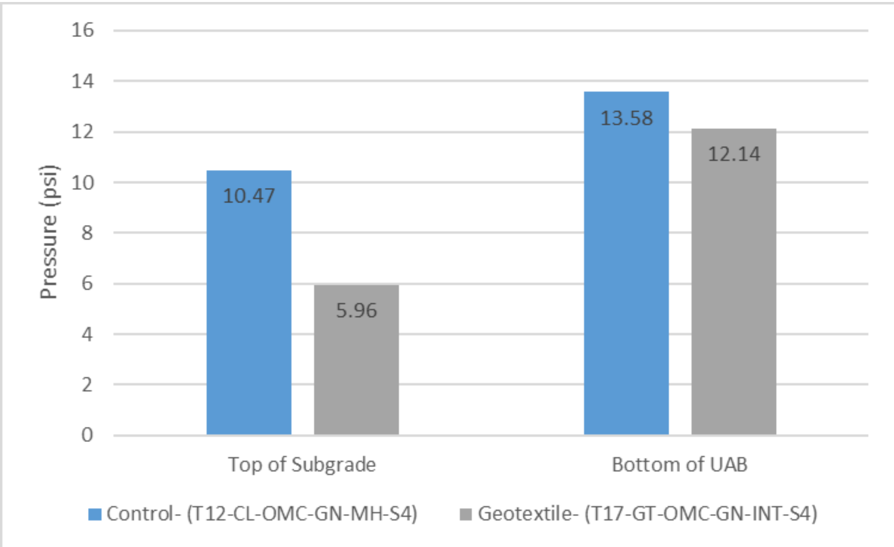

Figure 5. Pressure Results from Testing Series 4
(Note: To Convert to Kg, Multiply lb weight by 0.454)

3 CONCLUSION

The University of Georgia conducted a large-scale test and calibration of pressure cells as preliminary tests for this study. Calibrating all pressure cells individually provides accurate factors that can be used in the determination of actual pressure during full-scale testing. These factors will be applied in the data analysis portion of the experiment in order to provide accurate data ultimately showing the effects of using a geosynthetic between the subgrade-base course layers of pavement systems. This study investigated the effects of geotextile on pavement foundation and performance using newly-developed large-scale systems simulating full-scale moving-wheel condition. The large-scale tests studied the vertical pressure variations across the base and subgrade layers. Vertical pressure at the top of the subgrade soil in the large-scale test decreased approximately 43% with geotextile compared to the control case (without geotextile). It clearly shows that vertical pressure distribution due to geotextile utilization is effective for low bearing strength subgrades.

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