Application Note

Compression Testing of GS3 Sensors Embedded in Asphalt

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The purpose of this report is to give the results of compression testing performed on two GS3 sensors compacted into two asphalt samples; in one sample the sensor was embedded vertically, and in the other sample the sensor was embedded horizontally. This testing was performed to evaluate the potential placement of GS3 sensors in an asphalt layer during construction. This report presents a summary of the procedures and results associated with this testing.

Procedures:

First, the volume and weight of each sensor were measured. Then the samples were compacted using a modified Proctor hammer as displayed in Figure 1. In Sample 1 the sensor was oriented with the prongs vertical as shown in Figure 2, while in Sample 2 the sensor was oriented with the prongs horizontal as shown in Figure 3.

Figure 1. Asphalt sample compaction using a modified Proctor hammer.

In each sample, the sensor was centered vertically and horizontally within the compaction mold. Both samples were compacted in six lifts with a total of 115 blows. Because the lifts were not necessarily equal in thickness, as required to accommodate the sensor placement, each lift was not equal in number of blows; instead, an equal number of total blows was applied to both samples. After the sensors were placed in each sample, asphalt was compacted around them until they were completely covered; a minimum of 1 in. of loose asphalt was placed over each sensor prior to compaction. The asphalt was pre-heated to a temperature of 275 °F consistent with typical asphalt production temperatures.

Figure 2. Sensor 1 centered in Sample 1.

Figure 3. Sensor 2 centered in Sample 2.

After compaction, each sample was labeled and weighed, and the height was measured in four locations to obtain an average height of the sample. The samples were then allowed to cool to room temperature.

Several days later, unconfined compression testing was performed on the asphalt samples using a Baldwin compression machine with a floating head. The samples were heated to 140 °F before testing to simulate hot weather conditions typical of Utah pavements. Testing at a temperature of 140 °F is also consistent with the Marshall stability testing protocol. A strain rate of 2 in./min. was used, and load and displacement measurements were recorded throughout testing. The tests were video recorded in order to help determine when the sensors broke. During testing, however, the sensors did not break before the asphalt samples themselves began to fail. Therefore, the sensors, still intact, were removed from the failed asphalt samples and tested separately in the original configurations. Figures 4 and 5 depict the test setups for the vertical and horizontal configurations, respectively. For testing in the vertical position, Sensor 1 was positioned on a grooved metal plate that held the sensor in the desired orientation. A strain rate of 0.1 in./min. was used for this testing, and the tests were again video recorded.

Results:
Table 1 shows the weight and height of each sample, with the embedded sensor, as well as the density of the asphalt compacted around the sensor. The density of the samples is lower than typical values in the field, ensuring that the sensor would be required to carry a greater portion of the load during testing than if the asphalt had been more densely compacted.

Figure 5. Sensor 2 in compression machine.

Figure 4. Sensor 1 in compression machine.

The load-displacement plots for asphalt samples 1 and 2 are shown in Figures 6 and 7, respectively. Sample 1, in which the sensor was vertically oriented, sustained a load of about 2900 lb, which is more than three times higher than the load of 850 lb sustained by Sample 2, in which the sensor was horizontally oriented.

When tested individually, the sensors performed very differently than the asphalt samples. For Sensor 1, which was oriented vertically, three peaks were observed as shown in Figure 8. The first peak occurred at about 750 lb when the internal structure of the sensor failed under load. The second peak occurred at about 950 lb when the ends of the prongs within the sensor body penetrated the epoxy potting and outer casing, slightly protruding into the groove beneath the sensor body. The third peak occurred at about 1600 lb when the prongs began to bend, as illustrated in Figure 9. The first peak, which would be expected to cause failure of the electronics, is approximately one fourth of the peak load measured for the same sensor configuration when the sensor was embedded in asphalt. The difference is attributable to the concentration of the full load on the prongs when the sensor was tested by itself.

For Sensor 2, which was oriented horizontally, a continuous increase in load was observed during testing as shown in Figure 10. However, a pronounced change in slope occurred at a load of approximately 3000 lb, which probably resulted from the crushing of the internal components and would therefore be expected to cause failure of the electronics. The sensor began to separate from its outer casing at a load of about 6500 lb and was nearly completely separated by the end of the test as shown in Figure 11. The load at which failure of the electronics would be expected is more than three times greater than the load measured for the same sensor configuration when the sensor was embedded in asphalt. In this case, the difference is attributable to the fact that the strength of the sensor body exceeds that of the apparent strength of the asphalt.

Table 1. Height, Weight, and Density

Sample	Height (in.)	Weight (lb)	Density (lb/ft^3)
1	4.681	8.601	112.9
2	4.637	8.266	109.2

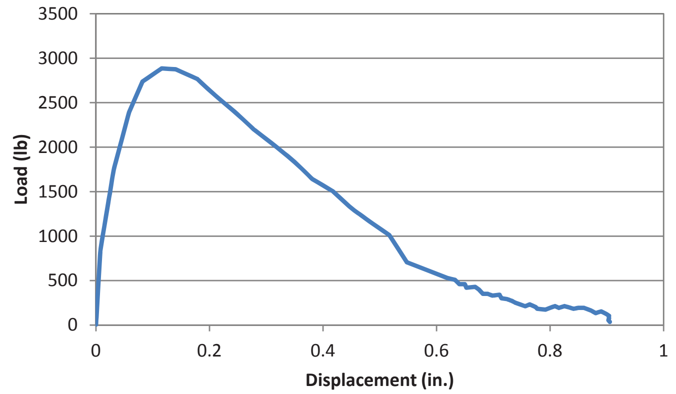

Figure 6. Load - displacement plot for Sample 1 (vertical orientation).

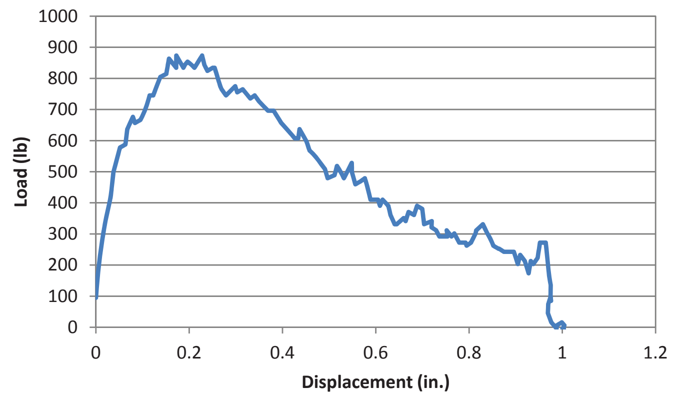

Figure 7. Load - displacement plot for Sample 2 (horizontal orientation).

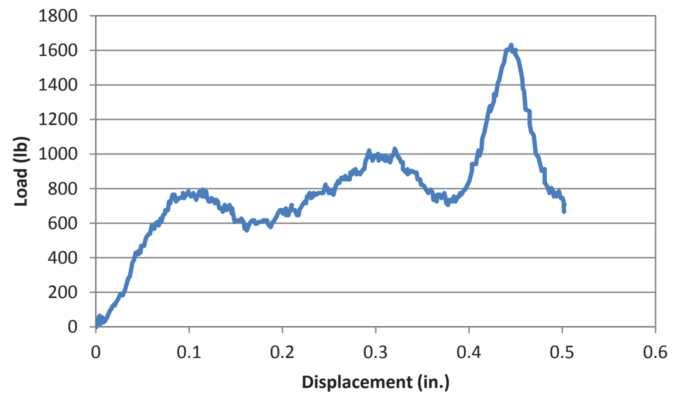

Figure 8. Load - displacement plot for Sensor 1 (vertical orientation).

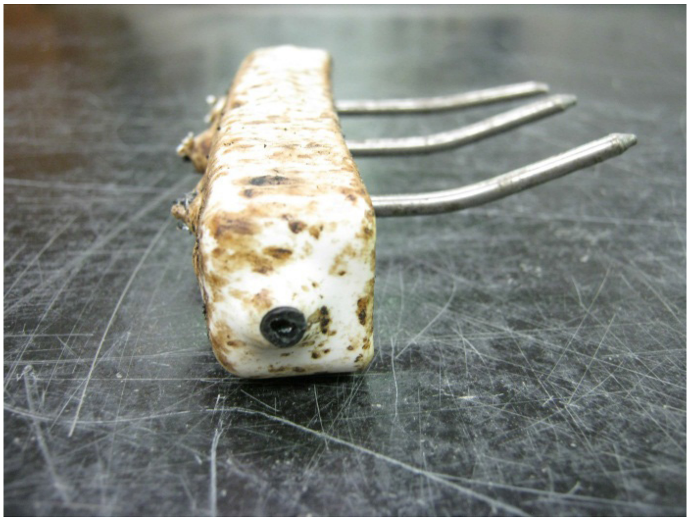

Figure 9. Sensor 1 after compression testing (vertical orientation).

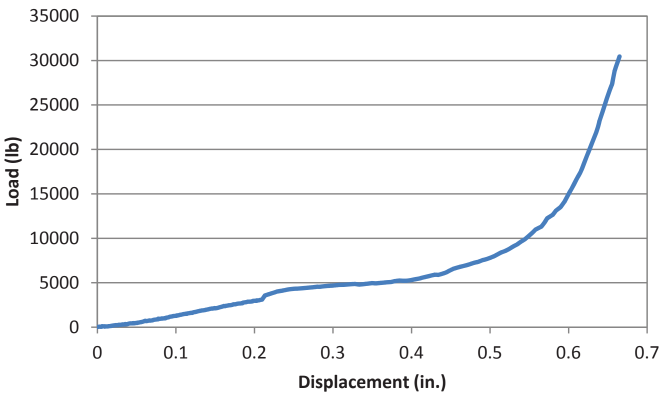

Figure 10. Load - displacement plot for Sensor 2 (horizontal orientation).

Figure 11. Sensor 2 after compression testing (horizontal orientation).

Conclusion:

The asphalt sample tested with the sensor oriented vertically sustained a peak load of 2900 lb, while the asphalt sample tested with the sensor oriented horizontally sustained a peak load of 850 lb. When tested separately, the sensor oriented vertically would be expected to experience electronics failure at a load of 750 lb, while the sensor oriented horizontally would be expected to experience electronics failure at a load of 3000 lb. Based on these data, the sensor may have the highest probability of survival when placed in the horizontal configuration with the body of the sensor oriented parallel to the direction of compactor travel so that the prongs are not likely to be loaded by themselves. During at least the initial compaction, the operator should also make an effort to approximately center the roller wheel over the sensor to ensure uniform compaction on both sides of the sensor.