US Highway 65 Emergency Pavement Subgrade Improvement

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ABSTRACT: In May 2011, only days before a very busy traveling holiday, the Missouri Department of Transportation observed rutting and cracking in a stretch of flexible highway pavement. The section of pavement was being prepared to be put in service on the Friday before Memorial Day Weekend. As the base layer of asphalt was being placed the roadway began to rut and crack due to a subbase failure, most likely attributable to poorly compacted and/or saturated soils.

To rapidly improve the load-bearing support capability of the underlying soils, a patterned injection (with depth) of an expanding polymer grout was selected as the treatment option. This mitigation technique proved effective and efficient, as work was expeditiously performed and the roadway was adequately stabilized prior to the holiday weekend.

This paper demonstrates the improvements achieved using insitu measurements from a falling weight deflectometer (FWD). These improvements can be readily seen using before-treatment and after-treatment measures suggesting valuable enhancements to the mechanistic engineering properties of the pavement system.

Key Words: Subgrade Improvement, Resilient Modulus, Permanent Deformation, FWD, Pavement Performance, Insitu Soil Stabilization, Polymer Stabilization.

1 THE PROBLEM

A highway in the farmland of north central Missouri was originally constructed along the natural rolling hill topography laced with small streams. A relatively small vertical hump was removed in 2011 to improve the sight distance along a portion of this 24-foot wide asphalt-surfaced highway with aggregate shoulders. During reconstruction, approximately 540 feet of the alignment was identified as problematic.

The reconstruction of the pavement, which followed the grade-lowering efforts, consisted of placement of 10 to 12 inches of reclaimed asphalt concrete followed by placement of a 3.75-inch asphalt concrete wearing surface. The work was scheduled to be completed within a 3-week timeframe so reopening could occur prior to a very busy holiday weekend in late May.

Following the earthwork operations necessary to lower the existing elevation, grades and lines up to 5 feet, the reclaimed asphalt concrete base was placed and graded directly on the exposed subgrade soils and compaction commenced. Field personnel witnessed excessive vertical movement (pumping) directly below the compactor along a portion of the horizontal alignment, indicating the foundation support was insufficient. The length of these observed excessive deformations was approximately 540 feet in length.

To investigate, coring equipment was mobilized. Ruts formed below the coring vehicle, indicating a very soft and weak condition – presumably in the subgrade soils. Site personnel concluded that placement of the 3.75-inch wearing course would be wasteful without some form of mitigation. With only days before the required highway reopening, the mitigation technique needed to be quick.

2 THE INVESTIGATION

To improve the foundation support characteristics, a ground improvement technique consisting of deep injection of a polyurethane grout was chosen. When mixed, the specially formulated 2-component polymer produces expansive forces that can readily densify or consolidate weak, soft or even saturated soils.

The insitu soil stabilization by injecting polyurethane (ISSBIP) process requires knowledge of where the weak or soft zones of soil are located, and injections are "surgically" placed in strata where stabilization is needed. The profile of underlying soils can readily be logged using a dynamic cone penetrometer (DCP). For this project, a Pagani Model DPM 30-20 was used and data was logged continuously to a depth of 11 feet at numerous locations. Figure 1 illustrates the 'typical' profile with depth, suggesting very soft soils at a depth of 30 to 60 inches (2.5 to 5 feet).

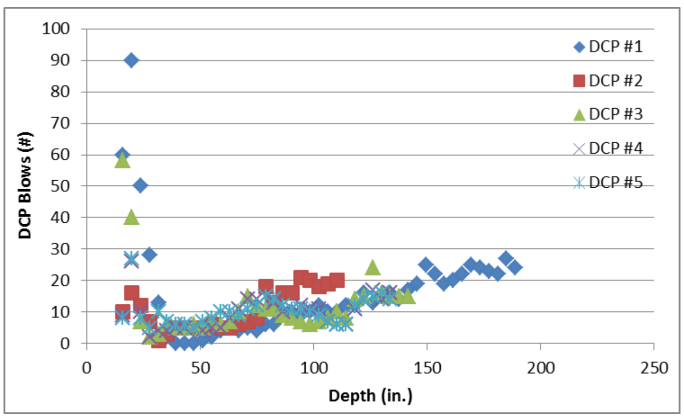

Figure 1 – Typical DCP Profile

In order to assess improvement gained by injection grouting, a Dynatest model 8000 falling weight deflectometer (FWD) was mobilized to record deflection profiles before and after the injection. The FWD tests were conducted at the surface of the reclaimed asphalt base layer prior to the installation of the 3.75-inch asphalt wearing course. Data from the before-treatment data collection effort is presented in Figure 2.

In summary, the benchmark data resulted in backcalculated subgrade modulus values ranging from 3,815psi to 15,000psi with an average value of 8,870psi. These values can be compared with similarly derived results following the mitigation efforts to determine the effect of treatment.

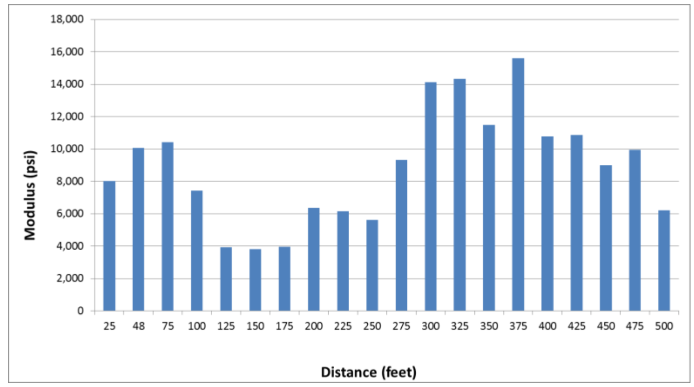

Figure 2 – Backcalculated Subgrade Modulus Before Mitigation (benchmark data)

3 THE FIX

Small holes (1/2-inch diameter) were drilled through the newly placed and under-compacted reclaimed asphalt base layer to allow installation of injection ports with access to the underlying soils (Figure 3). A grid spacing of 3-feet by 3-feet was established for areas where the largest FWD deflections (lowest modulus) were recorded. The spacings were increased to a 4-foot grid in areas where moderate to high FWD deflections were recorded.

Figure 3 – Injection ports installed in drilled holes

Injections were shot at 3 feet below grade for the 3-foot grid and at 4 feet below grade for the 4-foot grid. Injections at each location continued until a slight bump was indicated at the surface using a laser system.

4 LAB DATA

In an ongoing laboratory study, several tests have been conducted on geomaterials in the laboratory. The geomaterials consist of a graded aggregate base (GAB), a sand and a #57 stone. Specimens are prepared in 6-inch diameter molds to specific densities with the primary objective of evaluating stiffness improvement using the 2-component polyurethane polymers.

Resilient modulus testing (AASHTO T307) and repeated-load permanent deformation testing (NCHRP 598) were conducted on numerous test specimens in both untreated (control) and treated (injected) conditions. The results are summarized in Figures 4 through 6.

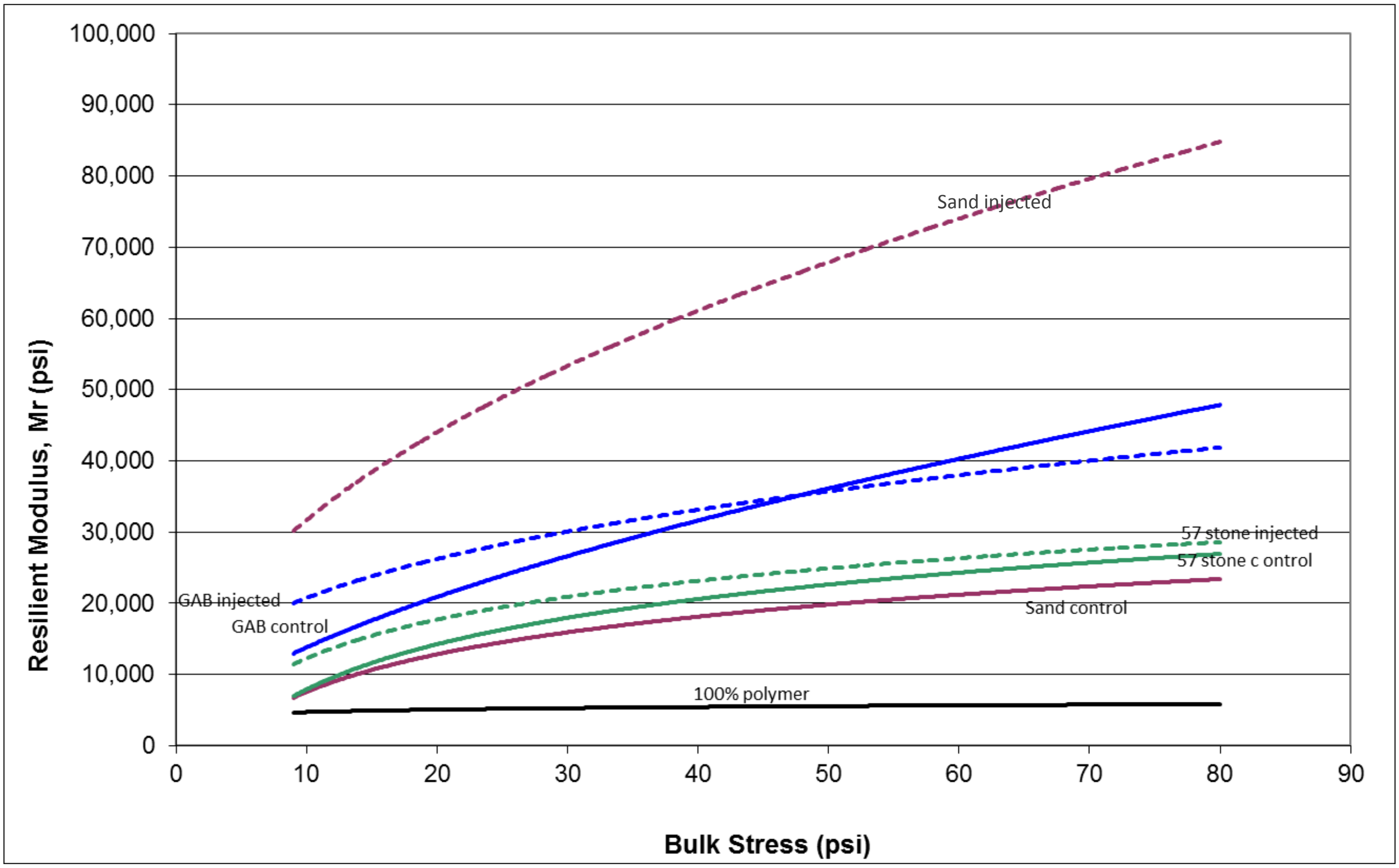

Figure 4 – Resilient modulus computed by the Universal Model (Based on AASHTO T307 Results)

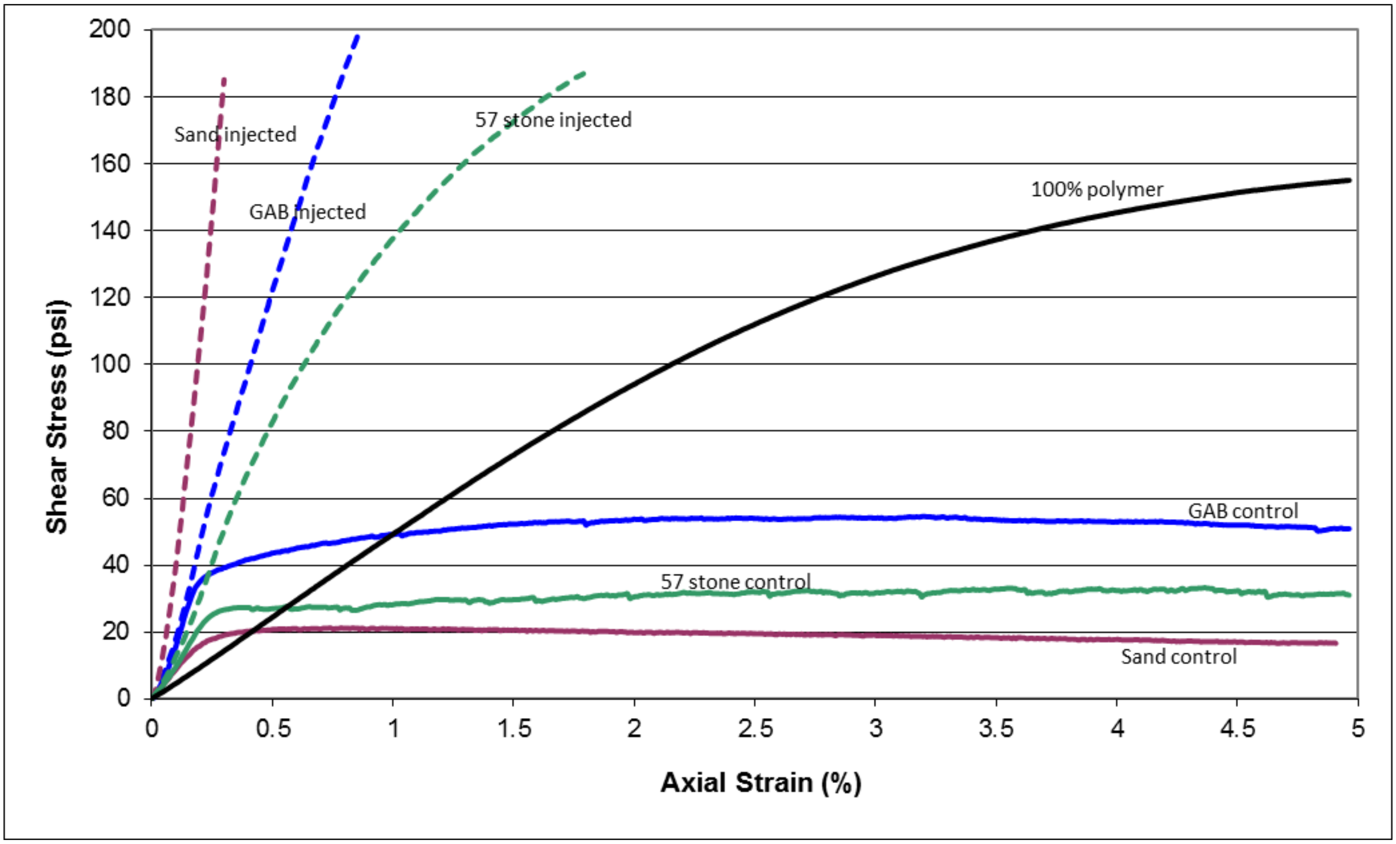

Figure 5 – Quick Shear (Based on AASHTO T307 Results)

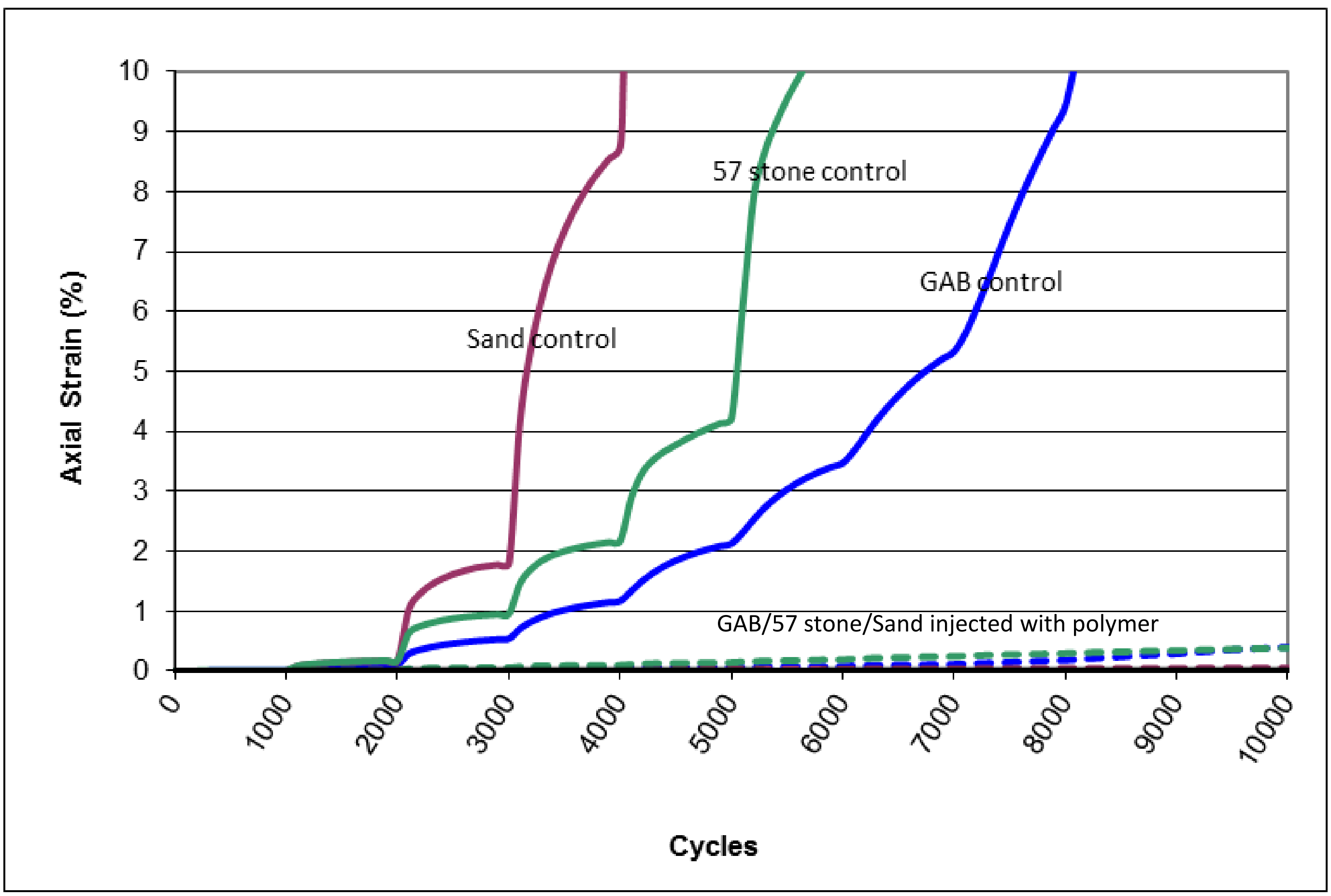

Figure 6 – Repeated Load Permanent Deformation (Based on NCHRP598 Results)

The laboratory data provided confidence and certainty that the polymer enhanced the strength and deformation resistance of common geomaterials (Figures 5 and 6) and could perhaps improve the resilient modulus properties of materials similar to sand (Figure 4). The polymer alone is not terribly stiff (resilient modulus of approximately 5,000psi, Figure 4) but is fairly strong (over 140psi, Figure 5). Perhaps the greatest influence of the polymer is the ability to resist permanent deformation (as seen in Figure 6) across each of the geomaterials studied.

5 ASSESSMENT

As previously mentioned, FWD testing was performed at the same locations both prior to and following the injections. FWD data was collected within hours of completion of all injections (*After Deep Injection*), again following the completion of the 3.75-inch hot-mix asphalt wearing course (*After Geogrid and 3.75"HMA*), and finally, 5 years after reopening (*After 5 Years*). Figures 7 and 8 depict the improvement measured. Overall, the subgrade modulus improved, on average, from the benchmark average of 8,870psi to nearly 13,000psi immediately following the injection. This represents an approximate 40 percent stiffness improvement, and provided a firm foundation to achieve reasonable compaction of the reclaimed asphalt base layer and subsequent 3.75-inch wearing course layer (installed in 2 lifts).

Following construction of the 3.75-inch HMA, the FWD testing was repeated, this time resulting in an average value of 14,750psi, or roughly 70% improvement compared with the benchmark tests.

Lastly, an updated phase of FWD testing was recently completed. This latest round of testing resulted in an average backcalculated subgrade modulus of nearly 23,000psi, or a nearly 160% improvement from benchmark tests. It is noted that no individual location consisted of a value below 20,000psi, whereas numerous benchmark test locations had values less than 10,000psi with several below 4,000psi.

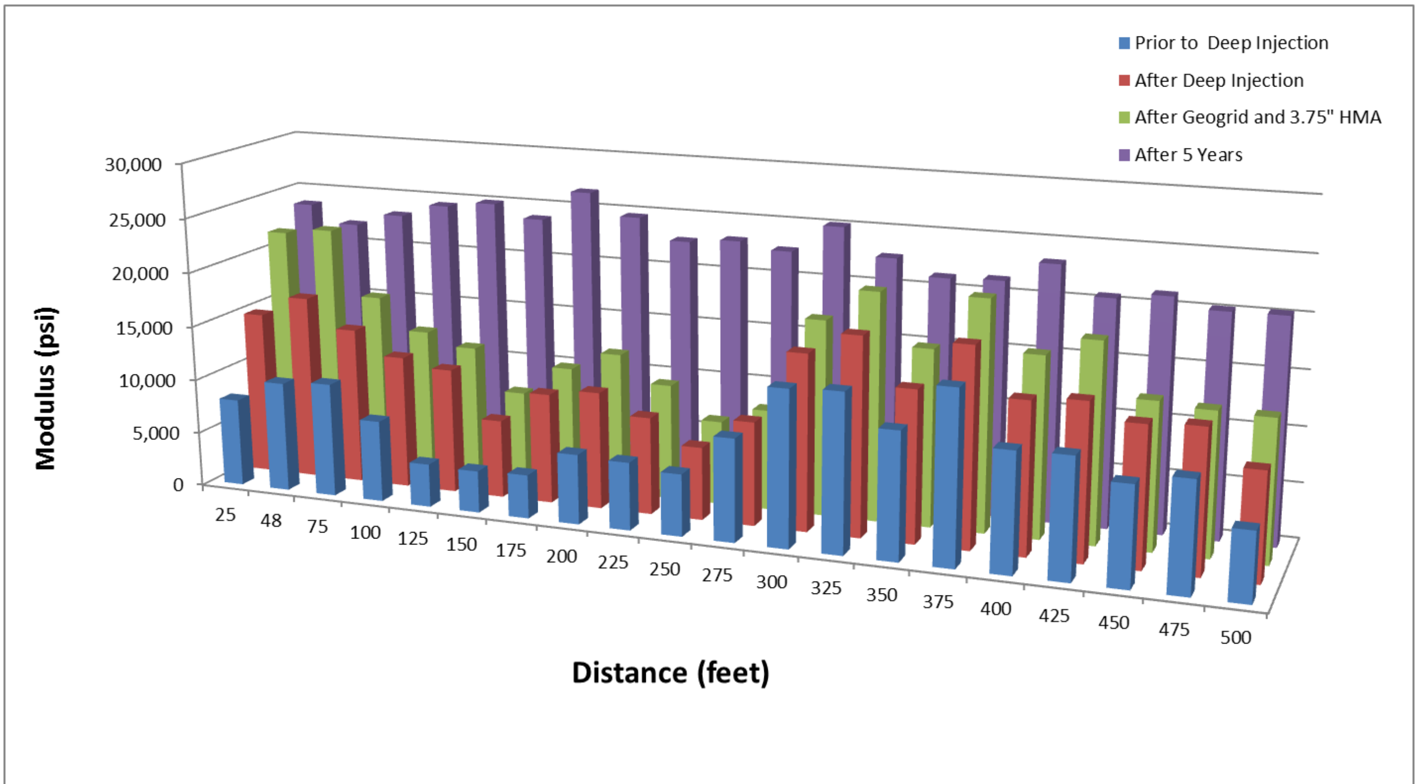

Figure 7 – Backcalculated subgrade modulus before treatment and after treatment

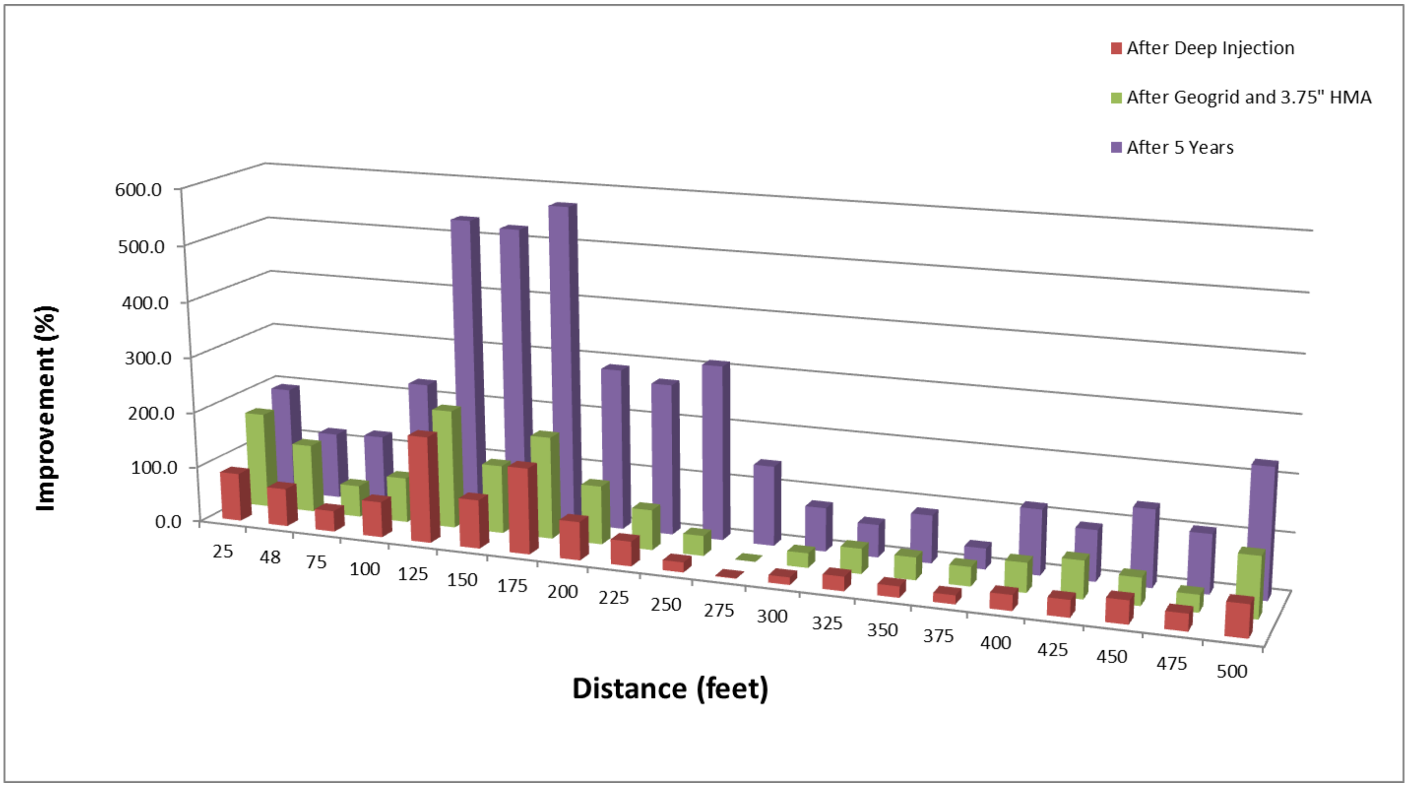

Figure 8 – Improvement compared with Pre-treatment data

The improvement gained is two-fold, both stabilization and densification play a major role; however, densification is believed to take on a more pronounced role in the particular case.

The injections at 'surgically' placed locations and depth generally create a polymer mass displacing a zone of soft soil or open pore space. The polymer then expands causing immediate compression of soil and its surrounding void space which contains air and water. The graphics shown in Figures 7 and 8 illustrate this immediate gain; however, the long-term gain illustrated in the 5-year data shows that pore pressure dissipation is slow rather than quick, and greater gains can be realized long after the initial benefit is achieved.

6 CONCLUSIONS

The rapid improvement realized on this project was a product of densification of a soft zone of subgrade soils beneath a newly constructed base layer of reclaimed asphalt pavement. The mitigation was performed over the course of a couple of days, enabling the highway agency to complete construction and open the roadway up for a busy travel weekend.