84th Annual NESMEA Conference

Urethane Foam in Highway Construction and Maintenance

Steven Tartabini
About Geotech Services, Inc.

Geotech Services, Inc. is a full service geotechnical contractor specializing in undersealing, stabilizing and leveling pavements using High Density Polyurethane (HDP). The HDP method has many advantages over conventional methods and supports the company’s dedication to offering new solutions to old problems.
About Geotech Services, Inc.

With more than two decades of superior service throughout Northeast Ohio and beyond, Geotech is an industry leader in supplying its customers with the most advanced applications in geotechnical engineering:

- Pavement Rehabilitation
- Concrete Restoration
- Soil Stabilization
- Erosion Control
- Foundation Underpinning
- Epoxy/Urethane Injection
- Drilling and Grouting
Hydrophilic open cell polyurethane grouts are used to stop leaks through cracks and joints in underground structures. Hydrophilic polyurethane grouts readily mix with water and seek out water when trying to seal a crack in concrete.

Hydrophobic closed cell polyurethane grouts are typically used to fill voids and stabilize soils due to their low viscosity, high expansion rate, and ability to set up under wet conditions without diluting.
High Density Polyurethane (HDP) is a method for repairing or preventing faulting in concrete highways. It involves injecting a curable, flowable material under the concrete slab surface so that, after curing, it fills any voids present under the slabs and blocks the introduction of fines under the slabs.

THE HDP PROCESS INVOLVES:

- Providing a flowable, foamable, curable composition which cures to a flexible and resilient foam
- Injecting the above composition under a slab to completely fill any void located between slabs and/or sub-base
- Allowing the composition to foam and cure
Features and Benefits of High Density Polyurethane

- Tolerates moisture during cure
- Set times of 15 minutes or less
- Closed cell structure
- Tensile and compressive strength
- Seals cracks and joints from underneath
- Adds minimal weight to sub-base
- Requires minimal equipment and labor
Features and Benefits of High Density Polyurethane

- Smaller (5/8” diameter) holes are required.
- Lighter drilling equipment and less damage.
- Resistant to deterioration from most chemicals and to washout from broken utilities.
- Environmentally safe.
- More precise, controllable lift.
- Resistant to freeze / thaw cycles.
Concrete pavement restoration is an effective solution for extending the life of concrete pavement. One problem that causes distress and serviceability in concrete pavements is loss of support due to voids underneath the pavement slabs, usually near cracks or joints.

Figure 1 Typical stages of loss of support and void development leading to concrete pavement deterioration.
Principal requirements for slab stabilization materials are strength and the ability to flow into or expand to fill small voids. A good stabilization material should have adequate strength to support a slab and remain insoluble, incompressible, and non-erodible after installation and hardening. Polyurethane is a common material for stabilization projects.

The polyurethane is made from two liquid chemicals that combine under heat to form a strong, lightweight, foam-like substance. When injected under the pavement, the chemical reaction between the two materials causes the polyurethane to expand and fill the voids. For slab stabilization purposes the polyurethane density is about 4 kg/m³ (4 lb/ft³) and the compressive strength ranges from about 0.4 to 1.0 MPa (60 to 145 psi).

The main advantages of polyurethane grout are tensile strength and fast cure time. Traffic can typically be allowed onto the stabilized pavement 15 to 30 minutes after the repair. Good tensile strength also allows the polyurethane grout to withstand traffic vibration once it is under the pavement.
## H.D.P. PROPERTIES

<table>
<thead>
<tr>
<th>PROPERTY</th>
<th>TEST</th>
<th>RESULTS</th>
</tr>
</thead>
<tbody>
<tr>
<td>Density (pcf)</td>
<td>ASTM D-1622</td>
<td>5.00 – 8.00</td>
</tr>
<tr>
<td>Compressive Strength (psi)</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Parallel (psi)</td>
<td>ASTM D-1621</td>
<td>107-139</td>
</tr>
<tr>
<td>Perpendicular (psi)</td>
<td></td>
<td>114-157</td>
</tr>
<tr>
<td>Tensile Core (psi)</td>
<td>ASTM D-1623, Type C</td>
<td>70 – 124</td>
</tr>
<tr>
<td>Shear Strength (psi)</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Parallel (psi)</td>
<td>ASTM C-273</td>
<td>99-127</td>
</tr>
<tr>
<td>Perpendicular (psi)</td>
<td></td>
<td>99-127</td>
</tr>
<tr>
<td>Closed Cell Content %</td>
<td>ASTM D-2858</td>
<td>85 – 97</td>
</tr>
<tr>
<td>K-Factor (BTU in/hr ft2)</td>
<td>ASTM C-518</td>
<td>0.130 – 0.140</td>
</tr>
<tr>
<td>Percent Volume Change</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Humid Age-28 Days(158 F, 95% Humidity)</td>
<td>ASTM D-2126</td>
<td>+5.0 to +11.0</td>
</tr>
<tr>
<td>Freeze-5 Days (-20 F, Dry)</td>
<td></td>
<td>-0.1 to –0.9</td>
</tr>
<tr>
<td>TEST TYPE</td>
<td>TITLE</td>
<td></td>
</tr>
<tr>
<td>---------------------------</td>
<td>----------------------------------------------------------------------</td>
<td></td>
</tr>
<tr>
<td>Compressive Strength</td>
<td>ASTM D 1621 - Test method for compressive properties of rigid cellular plastics.</td>
<td></td>
</tr>
<tr>
<td>Flexural Strength</td>
<td>ASTM D 790 - Test method for flexural properties of unreinforced and reinforced plastics.</td>
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<tr>
<td>Shear Strength</td>
<td>ASTM C 273 - Test method for shear properties in flatwise plane of flat sandwich construction of sandwich cores.</td>
<td></td>
</tr>
<tr>
<td>Density</td>
<td>ASTM D 1622 - Test method for apparent density of rigid cellular plastics.</td>
<td></td>
</tr>
<tr>
<td>Dimensional Stability</td>
<td>ASTM D 2126 - Test method for response of rigid cellular plastics to thermal and humid aging.</td>
<td></td>
</tr>
<tr>
<td>Coefficient of Expansion</td>
<td>ASTM D 696 - Test method for coefficient of linear thermal expansion of plastics.</td>
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<tr>
<td>Solvent Resistance</td>
<td>ASTM D 543 - Test method for resistance of plastics to chemical reagents.</td>
<td></td>
</tr>
<tr>
<td>Fungus Resistance</td>
<td>ASTM G 21 - Recommended Practice for determining resistance of plastics to bacteria</td>
<td></td>
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<tr>
<td>Water Absorption</td>
<td>ASTM D 2842 - Test method for water absorption of rigid cellular plastics.</td>
<td></td>
</tr>
</tbody>
</table>
HDP Compressive Strength:
Compressive strength increases with density.

Effect of Density on Compressive Strength

Compressive Strength = 12.77D^{1.416}
(see footnote on page 2)

(90% Confidence Limits Shown)
HDP Tensile Strength:
The tensile strength of rigid urethane increases with density.

![Graph showing the effect of density on tensile strength.](image)
HDP Shear Strength and Shear Modulus: Shear strength and shear modulus both increase with density.
HDP Textural Strength and Flexural Modulus:

Flexural strength and flexural modulus both increase with density.
Additional Properties of Rigid Polyurethane Foams

Dimensional Stability

Foam density also has a definite effect on dimensional stability. Rigid urethane foams are essentially closed cell materials containing an inert gas as a blowing agent.

If the foam structure is not very strong, as in the case of many low density foams – particularly at densities below 2 lb/ft³ – the foam may swell so much on exposure to elevated temperatures (because of gas expansion and increased pressure caused by inward diffusion of air and moisture) that some of the foam cells will rupture.

At low temperatures, low density foams will very often exhibit shrinkage.
Additional Properties of Rigid Polyurethane Foams

ODOR

Rigid urethane foam slab stock or foamed-in-place rigid urethane foam is relatively free from odor after the foam has been cured.

During the foaming reaction the odors of toluene diisocyanate and amine catalysts are present. On curing at room temperature or at elevated temperatures the odor is reduced to a low level very quickly. Selection of catalysts that either react with the isocyanate or have very low volatility will also help reduce odor.
In general, urethane foams are quite resistant to solvent and pick up very small amounts on immersion. The table below shows the weight gain of several types of polyether rigid urethane foams as pounds of solvent per cubic foot of foam [kilograms of solvent per cubic metre of foam] after immersion.
**Solvent Pickup of Rigid Urethane Foams**

**Characteristics of Foam Tested:**
- Density – 2 lb/ft³ [32 kg/m³]

**Test Conditions:**
- Specimen size – cylindrical pellets, 1 in³ [16.4 cm³] volume
- Immersion – one week at 75ºF [24ºC]

<table>
<thead>
<tr>
<th>Solvent Type</th>
<th>Weight Gain, lb solvent per ft³ of foam [kg/m³]</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Hydrocarbons</strong></td>
<td></td>
</tr>
<tr>
<td>Diisobutylene</td>
<td>2.6 – 4.0 [42 – 64]</td>
</tr>
<tr>
<td>Hexane</td>
<td>2.2 – 3.2 [35 – 51]</td>
</tr>
<tr>
<td>JP-4 Fuel</td>
<td>2.6 – 3.8 [42 – 61]</td>
</tr>
<tr>
<td>JP-5 Fuel</td>
<td>2.4 – 5.4 [38 – 86]</td>
</tr>
<tr>
<td>Xylene</td>
<td>3.2 – 4.8 [51 – 77]</td>
</tr>
<tr>
<td><strong>Halogenated Solvents</strong></td>
<td></td>
</tr>
<tr>
<td>o-Dichlorobenzene</td>
<td>4.2 – 5.6 [67 – 90]</td>
</tr>
<tr>
<td>Trichloroethylene</td>
<td>13 [208]</td>
</tr>
<tr>
<td><strong>Oxygenated Solvents</strong></td>
<td></td>
</tr>
<tr>
<td>Cellosolve acetate</td>
<td>7.2 – 12 [115-192]</td>
</tr>
<tr>
<td>Ethanol</td>
<td>6.4 – 13 [103 – 208] (S)</td>
</tr>
<tr>
<td>Glacial acetic acid</td>
<td>11 – 24 [176 – 384]</td>
</tr>
<tr>
<td>Glycol dimethyl ether</td>
<td>4.4 – 11 [70 – 176]</td>
</tr>
<tr>
<td>Methyl ethyl ketone</td>
<td>15 – 32 [24 – 513] (S)</td>
</tr>
</tbody>
</table>
Modern highways are often constructed of end-to-end slabs of unreinforced concrete which are laid over an asphaltic or concrete sub-base. At the end of each slab is a transverse joint which allows the concrete to expand and contract with seasonal and daily temperature changes.
Common Reasons for Concrete Failure

The concrete slabs also curl due to temperature differences between the top and bottom of the slab, as can occur at the beginning or end of the day. When concrete slabs are in a concave configuration (i.e., the ends of the slabs are curled up), a void is created between the bottom of the slab and the sub-base.
Common Reasons for Concrete Failure

The diminished sub-base support at the joints causes a pumping action when traffic passes over the distorted slabs, which can lead to loose incompressible fines underneath the ends, a rough ride for vehicular traffic and eventual cracking at the slab ends.
I-78 NEW JERSEY
Many attempts to solve the faulting problems in highways have proved ineffective. Conventional sealants are often pumped under the slab, but the materials are too viscous to fill the void, too hard, or are not flexible enough to follow the movements of the concrete.
I-75, KENTUCKY
THE RESULTS ARE IN:

“HDP grout is superior to standard cement grouts” *

*Independent field test report conclusion by French & Parrello Associates, P.A.
Portions of New Jersey Route 287 linking Interstate Route 80 to the New York Thruway, were completed in the mid 1990s. The highway was constructed with jointed, reinforced concrete pavement (JRCP) underlain by non-stabilized open graded aggregate (NSOG).

A visual survey during the year 2000 indicated the presence of longitudinal and transverse cracking along the alignment. An engineering evaluation by French & Parrello Associates, PA., consulting engineers in Holmdel, New Jersey, determined that the roadway cracking resulted from poor pavement support at the joints related to the use of the NSOG drainage layer beneath the pavement. French & Parrello recommended the situation would be corrected by undersealing the joints.
NJDOT CASE STUDY
ROUTE I-287

Field Program

A field program was designed to test the effectiveness of High Density Polyurethane (HDP) grout for undersealing and slab-jacking. The HDP test grouting was performed in April 2001 along a four-mile stretch of the southbound lane of Route 287. These results were compared to a test-grouting program performed in July 2000, using a cement grout.

The HDP grout, applied at low pressure for both the undersealing of joints and slab jacking, consisted of a proprietary grout whose in-place density is approximately 4 pcf. The in-place compressive and tensile strengths are approximately 80 psi (11,500 psf) and 90 psi (13,000 psf), respectively. The initial set-up time for the grout is 15 to 20 seconds, with 90 percent of the compressive strength being attained within 15 minutes.
Field Program

The cement grouting program was limited to the undersealing of pavement joints. The grout consisted of a fluid mixture of cement, fly ash and water and was applied at a higher injection pressure than the HDP grout. The set-up time for the cement grout was approximately two hours with a curing time of six to 12 hours required for any substantial strength gains.

The High Density Polyurethane (HDP) grouting program was performed by Geotech Services, Inc. of Cleveland, Ohio.
Falling Weight Deflectometer (FWD) testing, performed during both the HDP and cement grouting programs, was used to evaluate improvement in pavement support after undersealing. Load levels of 6,000, 9,000 and 12,000 pounds were applied for each test. In addition, eight pavement cores were obtained at joints undersealed with HDP grout. FWD testing was performed by Advanced Infrastructure Design of Middlesex, New Jersey.

Seismic Pavement Analyzer (SPA) testing, in which elastic waves are generated and recorded within the pavement, was also used to evaluate the performance of the HDP grouting technique. These tests were conducted by Professor Nun ad Guncunski, a geotechnical consultant from Rutgers University in New Brunswick, New Jersey.
Program Results

The results of the test grouting programs indicate that the HDP grout will penetrate and fill the voids within the NSOG and bind the aggregate together to form a solid mass. Alternately, the cement grout will not substantially penetrate the NSOG drainage layer and the grout quantities will be limited to the amount of grout required to fill voids immediately beneath the pavement.

The FWD test results indicate improved pavement support utilizing both grout types. However, the HDP grout will provide for greater support both immediately after grouting as well as over the long-term service life of the pavement.
The long-term durability of the cement grout is questionable as it does not penetrate the NSOG. The SPA test results confirmed the improvement in pavement support achieved with the HDP grout.

HDP grout is also suitable for slab-jacking as the injection of the grout and lifting of the slab may be adequately controlled. The control of the injection of cement grout is less certain.
### SUMMARY OF FWD TEST RESULTS USING HDP GROUT

<table>
<thead>
<tr>
<th></th>
<th>Joint Deflection</th>
<th>Load Transfer</th>
<th>Joint Intercept</th>
</tr>
</thead>
<tbody>
<tr>
<td>Grouted Joints</td>
<td>0.11 mm</td>
<td>85%</td>
<td>0.00 mm</td>
</tr>
<tr>
<td>Non-Grunoted Joints</td>
<td>0.22 mm</td>
<td>98%</td>
<td>0.08 mm</td>
</tr>
</tbody>
</table>
FWD TEST RESULTS FOR
N.S.O.G. GROUTING

Table 1: Comparison of Intercept values of joints before and after the grouting program

<table>
<thead>
<tr>
<th>Grouted Joints Station</th>
<th>Before Grout Load (lb) D0 (lbs) IC (mils)</th>
<th>After Grout Load (lb) D0 (lbs) IC (mils)</th>
</tr>
</thead>
<tbody>
<tr>
<td>MP 65.0+109'</td>
<td>6357 14.64 7.7</td>
<td>6302 2.33  -0.2</td>
</tr>
<tr>
<td>9772 18.54 6.9</td>
<td>9291 3.56  -0.2</td>
<td></td>
</tr>
<tr>
<td>12259 21.08</td>
<td>12087 4.67</td>
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</tr>
<tr>
<td>MP 65.0+265'</td>
<td>6389 14.08 6.6</td>
<td>6259 5.12  0.8</td>
</tr>
<tr>
<td>9021 18.22 6.6</td>
<td>9917 7.29  0.8</td>
<td></td>
</tr>
<tr>
<td>12321 21.08</td>
<td>12013 9.07</td>
<td></td>
</tr>
<tr>
<td>MP 65.0+343'</td>
<td>6329 18.19 10.0</td>
<td>6263 3.58  0.2</td>
</tr>
<tr>
<td>9634 22.87 10.0</td>
<td>9268 5.25  0.2</td>
<td></td>
</tr>
<tr>
<td>12213 25.89</td>
<td>12050 6.73</td>
<td></td>
</tr>
<tr>
<td>MP 65.0+421'</td>
<td>9630 19.9  10.7</td>
<td>9219 4.92  0.7</td>
</tr>
<tr>
<td>12261 29.04 10.7</td>
<td>12132 7.64</td>
<td></td>
</tr>
<tr>
<td>MP 64.9+054'</td>
<td>6357 18.36 8.0</td>
<td>6236 5.56  0.4</td>
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<tr>
<td>9723 25.28 8.0</td>
<td>9236 8.08  0.4</td>
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<tr>
<td>12382 28.47</td>
<td>12013 10.38</td>
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</table>

Table 2: Results of FWD testing for the five joints after grout

<table>
<thead>
<tr>
<th>Grouted Joints Station</th>
<th>Before Grout Load (lb) D0 (lbs) IC (mils)</th>
<th>After Grout Load (lb) D0 (lbs) IC (mils)</th>
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</thead>
<tbody>
<tr>
<td>MP 64.9+210'</td>
<td>6239 3.51  0.0</td>
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<tr>
<td>9180 5.14  0.0</td>
<td></td>
<td></td>
</tr>
<tr>
<td>12092 6.23</td>
<td></td>
<td></td>
</tr>
<tr>
<td>MP 64.9+366'</td>
<td>6214 5.79  1.1</td>
<td></td>
</tr>
<tr>
<td>9157 8.19  1.1</td>
<td></td>
<td></td>
</tr>
<tr>
<td>11910 10.1</td>
<td></td>
<td></td>
</tr>
<tr>
<td>MP 64.9+523'</td>
<td>6193 5.51  0.9</td>
<td></td>
</tr>
<tr>
<td>9119 7.87  0.9</td>
<td></td>
<td></td>
</tr>
<tr>
<td>11938 9.82</td>
<td></td>
<td></td>
</tr>
<tr>
<td>MP 64.8+153'</td>
<td>6280 6.63  2.1</td>
<td></td>
</tr>
<tr>
<td>9774 9.09  2.1</td>
<td></td>
<td></td>
</tr>
<tr>
<td>12010 10.78</td>
<td></td>
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</tr>
<tr>
<td>MP 64.8+309'</td>
<td>6266 3.98  0.7</td>
<td></td>
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<tr>
<td>9256 5.58  0.7</td>
<td></td>
<td></td>
</tr>
<tr>
<td>12053 7.01</td>
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STABILIZED SECTION OF N.S.O.G. PAVEMENT

Photo No. 1:
Photo of pavement core with grouted 4" NSOG layer, taken 6" from grout hole.

Photo No. 2:
Photo of pavement core with grouted 4" NSOG layer, taken 1" from grout hole.
Summary and Conclusions

In its final report dated June 21, 2001, French & Parrello Associates, PA. concluded:

"It is our opinion that the HDP grout is superior to the standard cement grouts for both undersealing and slab-jacking. We recommend that HDP grout be considered for use on the remaining sections of the [Route] 287 project as well as other concrete repair projects..."
Applications For The H.D.P. Method

- State D.O.T.’s
- Airports
- Cities & Municipalities
- Industrial & Manufacturing
- Commercial Construction
- Engineers & Architects
- Military Bases
- Residential
IN CLOSING

- References are available.
- Geotech Services, Inc. is providing new solutions to old problems through new technology.
- The way of the future is here!