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84th Annual NESMEA Conference

Urethane Foam in Highway Construction and Maintenance

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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 VS. HYDROPHOBIC URETHANE GROUT

- 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 FOAM

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.

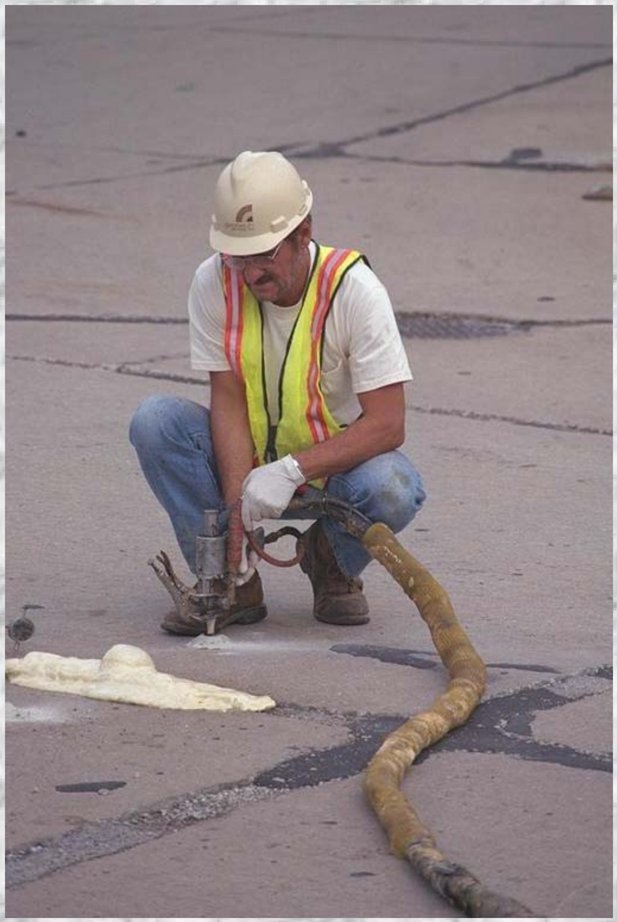
THE HDP PROCESS INVOLVES:

- 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

THE HDP PROCESS

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.

Slab Stabilization for Concrete Pavements

- 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.

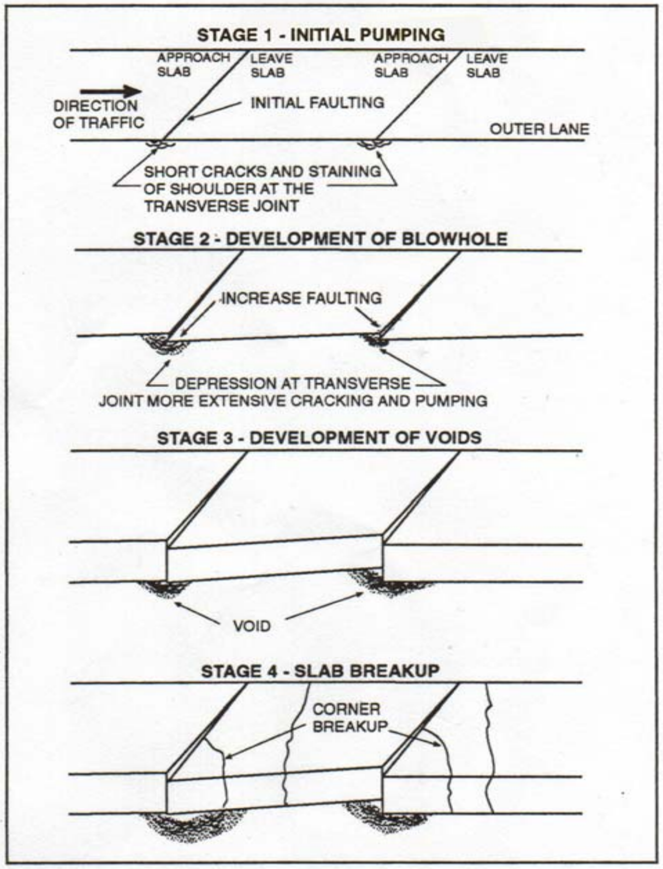


Figure 1 *Typical stages of loss of support and void development leading to concrete pavement deterioration.*

HDP PROPERTIES

- 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

PROPERTY	TEST	RESULTS
Density (pcf)	ASTM D-1622	5.00 – 8.00
Compressive Strength (psi) Parallel (psi) Perpendicular (psi)	ASTM D-1621	 107-139 114-157
Tensile Core (psi)	ASTM D-1623, Type C	70 – 124
Shear Strength (psi) Parallel (psi) Perpendicular (psi)	ASTM C-273	 99-127 99-127
Closed Cell Content %	ASTM D-2858	85 – 97
K-Factor (BTU in/hr ft2)	ASTM C-518	0.130 – 0.140
Percent Volume Change Humid Age-28 Days(158 F, 95% Humidity) Freeze-5 Days (-20 F, Dry)	ASTM D-2126	 +5.0 to +11.0 -0.1 to –0.9

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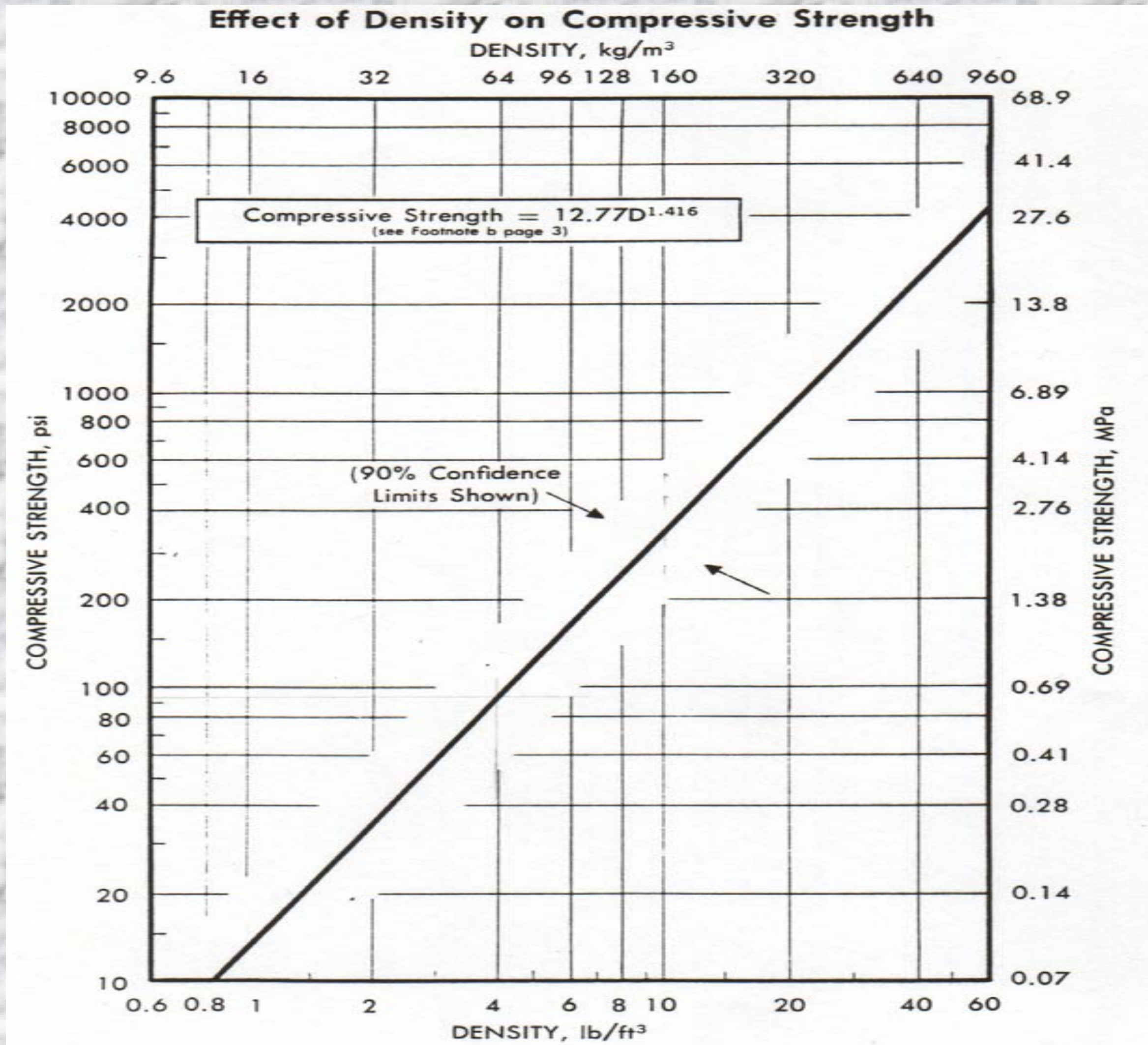
ASTM TEST DESCRIPTION

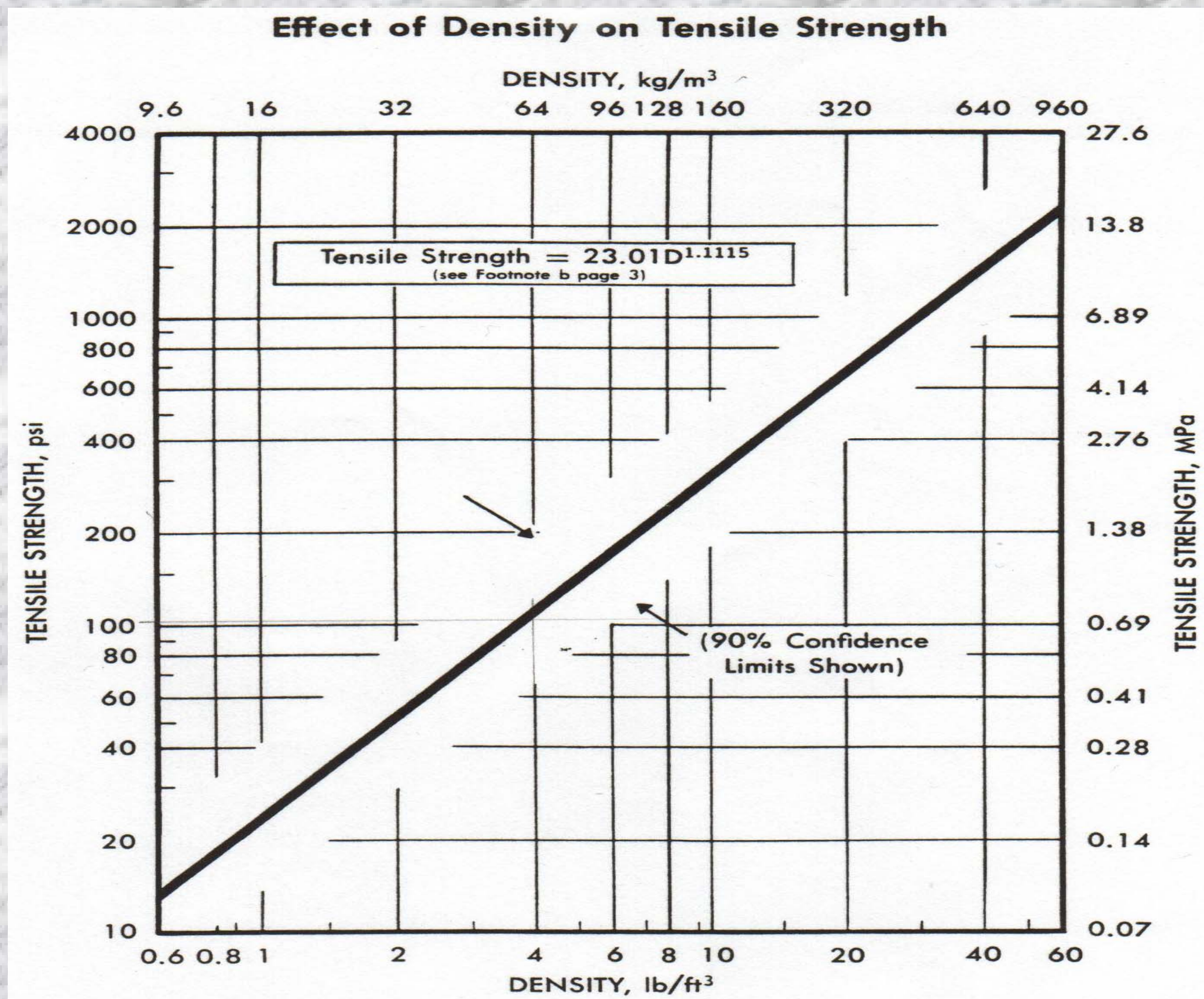
TEST TYPE	TITLE
Compressive Strength	ASTM D1621 - Test method for compressive properties of rigid cellular plastics.
Flexural Strength	ASTM D790 - Test method for flexural properties of unreinforced and reinforced plastics.
Shear Strength	ASTM C273 - Test method for shear properties in flatwise plane of flat sandwich construction of sandwich cores.
Density	ASTM D1622 - Test method for apparent density of rigid cellular plastics.
Dimensional Stability	ASTM D2126 - Test method for response of rigid cellular plastics to thermal and humid aging.
Coefficient of Expansion	ASTM D696 - Test method for coefficient of linear thermal expansion of plastics.
Solvent Resistance	ASTM D543 - Test method for resistance of plastics to chemical reagents.
Fungus Resistance	ASTM G21 - Recommended Practice for determining resistance of plastics to bacteria
Water Absorption	ASTM D2842 - Test method for water absorption of rigid cellular plastics.

HDP Compressive Strength:
Compressive strength increases with density.



HDP Tensile Strength:

The tensile strength of rigid urethane increases with density.



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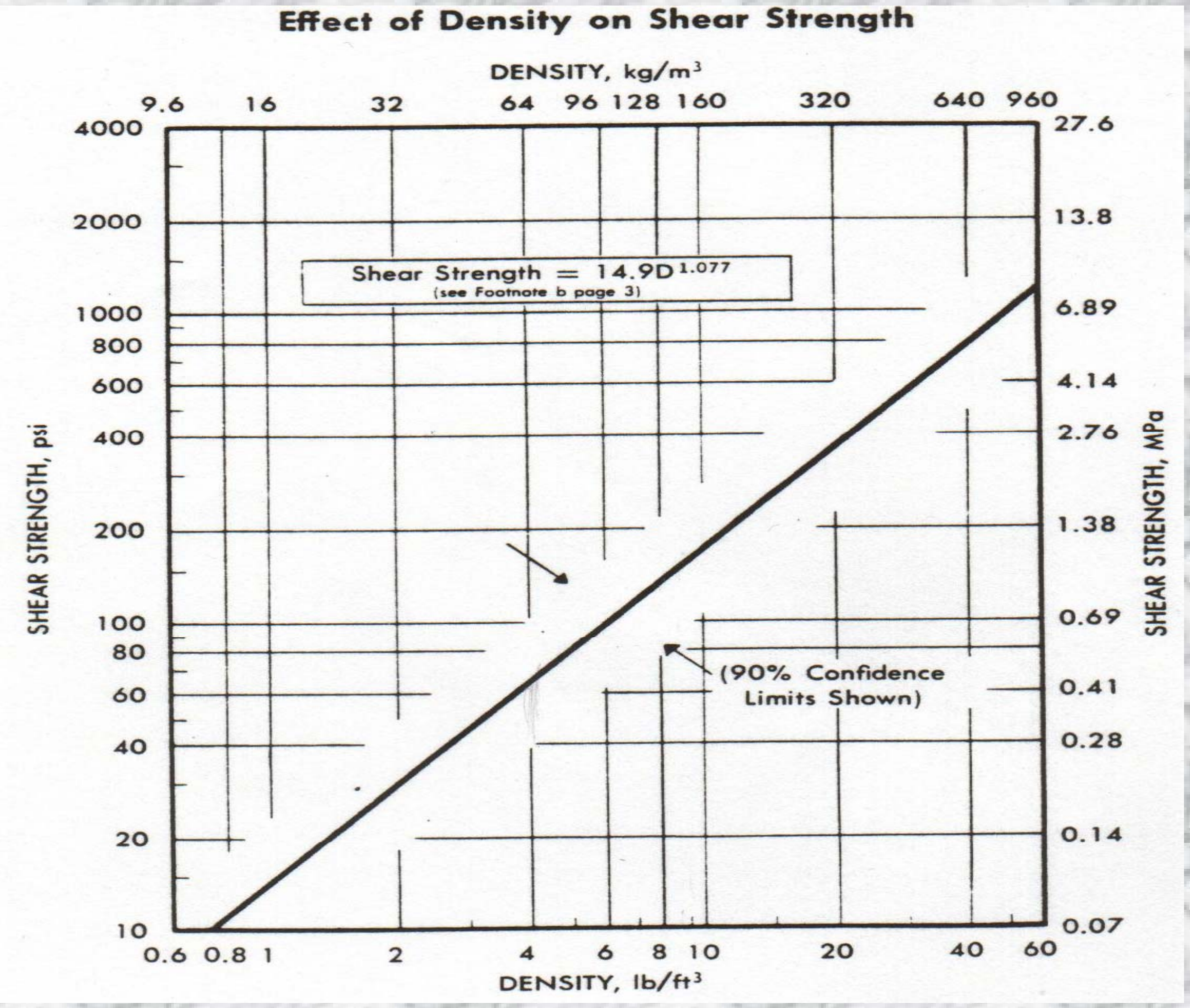
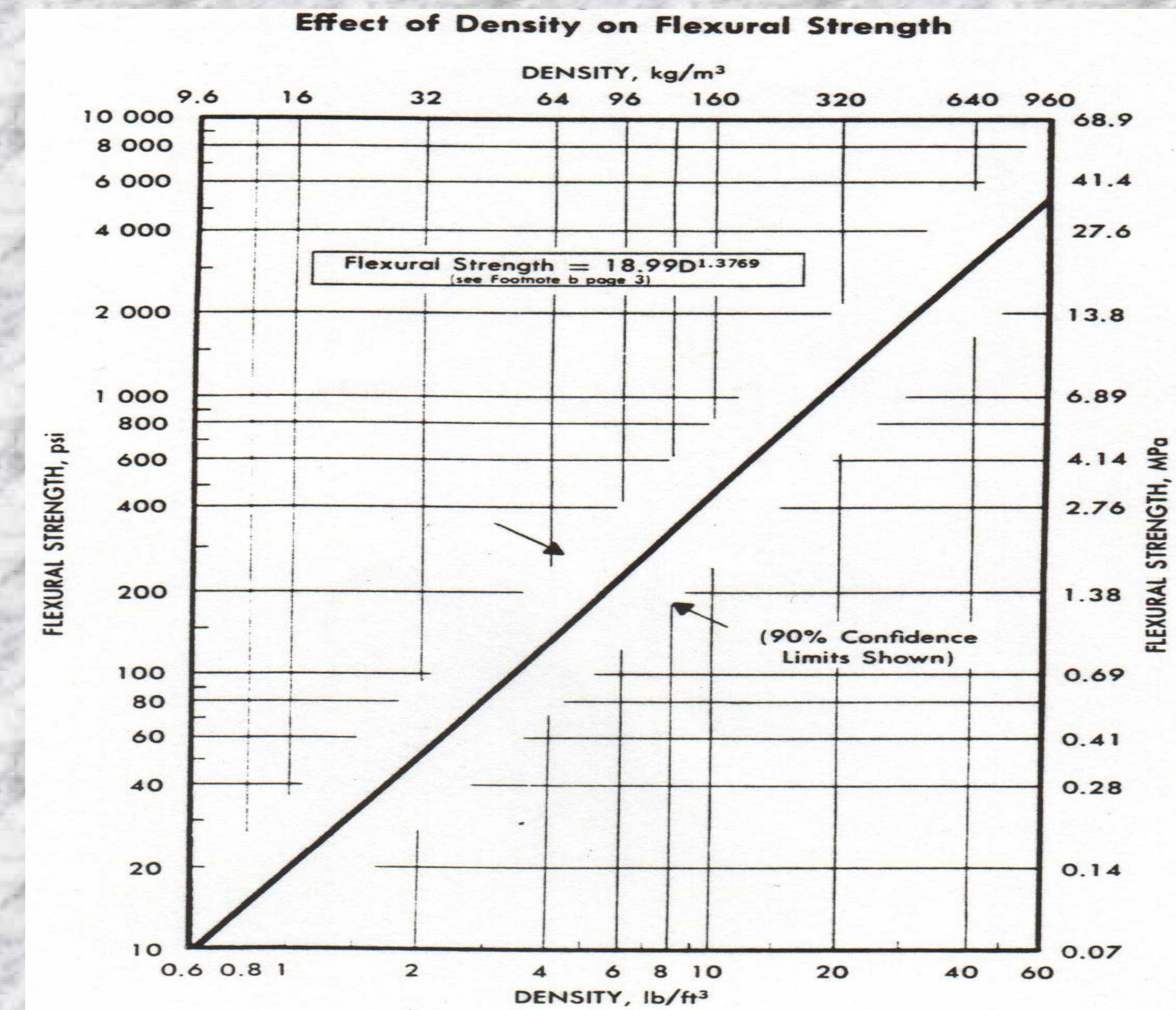
HDP Shear Strength and Shear Modulus: Shear strength and shear modulus both increase with density.



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.

SOLVENT RESISTANCE

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 RESISTANCE

Solvent Pickup of Rigid Urethane Foams

Characteristics of Foam Tested:
Density – 2 lb/ft^3 [32 kg/m^3]

Closed cell content – 90% of foam volume

Test Conditions:
Specimen size – cylindrical pellets, 1 in3 [16.4 cm3] volume
Immersion – one week at 75°F [24°C]

	Weight Gain, lb solvent per ft^3 of foam [kg/m^3]
	Polyether Foams^n
Hydrocarbons	
Diisobutylene	2.6 – 4.0 [42 – 64]
Hexane	2.2 – 3.2 [35 – 51]
JP-4 Fuel	2.6 – 3.8 [42 – 61]
JP-5 Fuel	2.4 – 5.4 [38 – 86]
Xylene	3.2 – 4.8 [51 – 77]
Halogenated Solvents	
o-Dichlorobenzene	4.2 – 5.6 [67 – 90]
Trichloroethylene	13 [208]
Oxygenated Solvents	
Cellosolve acetate	7.2 – 12 [115-192]
Ethanol	6.4 – 13 [103 – 208] (S)
Glacial acetic acid	11 – 24 [176 – 384]
Glycol dimethyl ether	4.4 – 11 [70 – 176]
Methyl ethyl ketone	15 – 32 [24 – 513] (S)

Common Reasons for Concrete Failure

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.

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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.

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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.

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General Methods for Concrete Repair

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.

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I-78 NEW JERSEY

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NJDOT CASE STUDY ROUTE I-287

THE RESULTS ARE IN:

"HDP grout is superior to standard cement grouts" *

** Independent field test report conclusion by French & Parrello Associates, P.A.*

NJDOT CASE STUDY ROUTE I-287

Situation Overview

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.

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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.

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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.

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Program Evaluation

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 Gucunski, a geotechnical consultant from Rutgers University in New Brunswick, New Jersey.

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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.

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Program Results

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.

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SUMMARY OF FWD TEST RESULTS USING HDP GROUT

	JOINT DEFLECTION	LOAD TRANSFER	JOINT INTERCEPT
GROUTED JOINTS	0.11 mm	85%	0.00mm
NON-GROUTED JOINTS	0.22mm	98%	0.08mm

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FWD TEST RESULTS FOR N.S.O.G. GROUTING

Design

Advanced Infrastructure Design, Inc.
1212 Raymond Blvd., Suite 120
Newark, NJ 07102
Voice: (973) 643-1945
Fax: (973) 643-6627

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

Grouted Joints Station	Before Grout			After Grout		
	Load (lb)	D0 (mils)	IC (mils)	Load (lb)	D0 (mils)	IC (mils)
MP 65.0+109'	6357 9772 12259	14.64 18.54 21.08	7.7	6302 9291 12087	2.33 3.56 4.67	-0.2
MP 65.0+265'	6389 9621 12321	14.08 18.22 21.08	6.6	6259 9317 12013	5.12 7.29 9.07	0.8
MP 65.0+343'	6320 9634 12213	18.19 22.87 25.89	10.0	6263 9268 12050	3.58 5.25 6.73	0.2
MP 65.0+421'	6206 9630 12261	19.9 26.1 29.04	10.7	6223 9219 12132	4.02 5.92 7.64	0.2
MP 64.9+054'	6357 9723 12382	18.36 25.28 28.47	8.0	6236 9230 12013	5.56 8.08 10.38	0.4

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

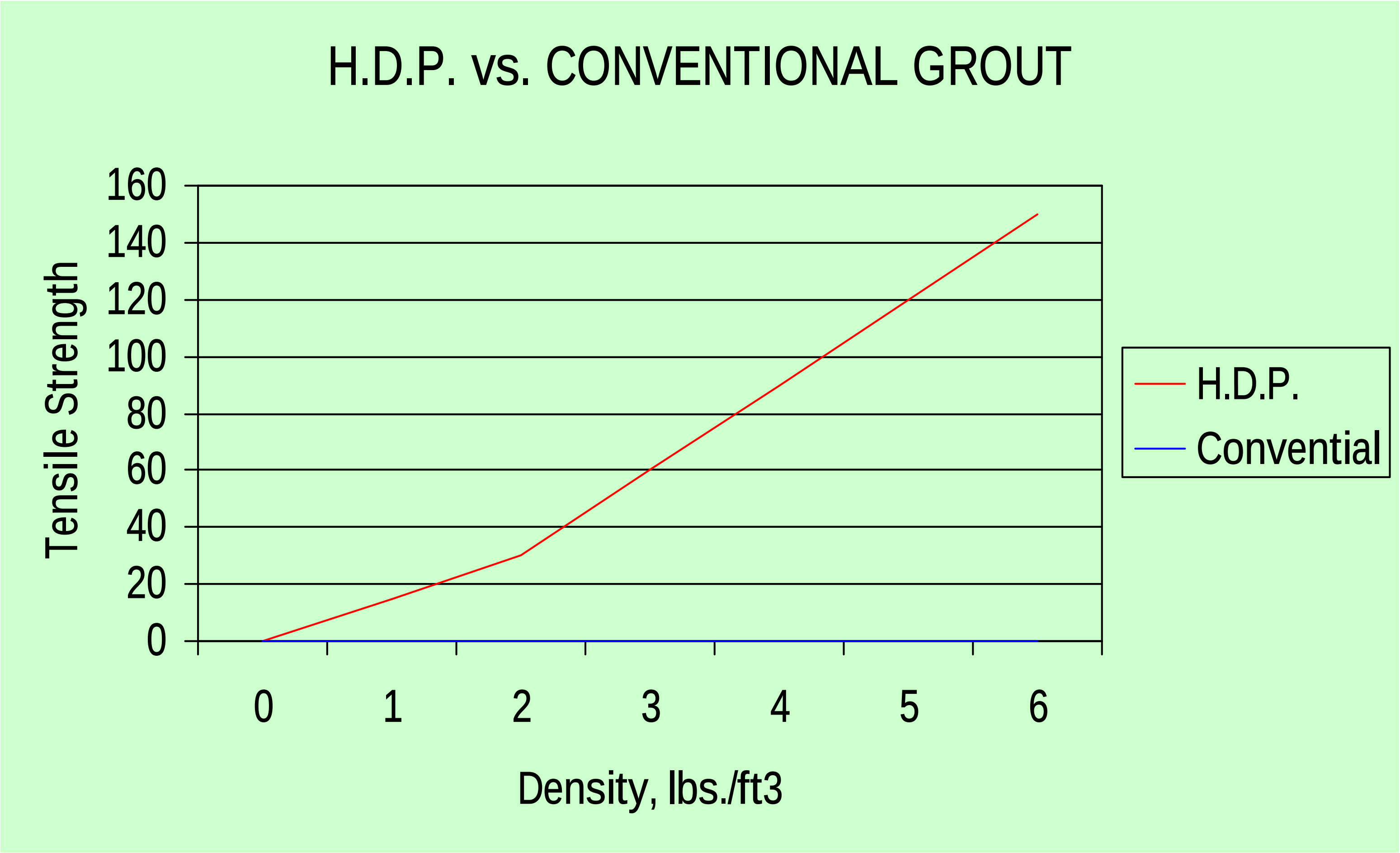
Grouted Joints Station	Before Grout			After Grout		
	Load (lb)	D0 (mils)	IC (mils)	Load (lb)	D0 (mils)	IC (mils)
MP 64.9+210'				6239 9180 12032	3.51 5.14 6.73	0.0
MP 64.9+366'				6214 9157 11910	5.79 8.19 10.1	1.1
MP 64.9+523'				6193 9119 11938	5.51 7.87 9.82	0.9
MP 64.8+153'				6280 9774 12010	6.63 9.09 10.78	2.1
MP 64.8+309'				6266 9256 12085	3.98 5.58 7.01	0.7

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.

TENSILE STRENGTH COMPARISON



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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!