Expansion Pressure Testing of Polyurethane Foam for Concrete Stabilization and Lifting

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Introduction

The PolyLEVEL® product line manufactured and distributed by Foundation Supportworks, Inc. (FSI) includes several expanding foam products that are injected beneath concrete slabs to fill voids and/or lift settled sections. These products are made from two specifically formulated liquid components that when mixed, chemically react with each other, expand, and cure into rigid foam. PolyLEVEL expanding foam products are used successfully in many geotechnical/structural applications for concrete stabilization, including slab-on-grade floors, garage slabs, driveways, sidewalks, bridge approach slabs, warehouse and manufacturing facility floor slabs, parking lots, airport runways and taxiways, and road, highway and interstate sections. PolyLEVEL can essentially be considered wherever a relatively intact, rigid slab or pavement requires void filling or lifting. These applications typically involve slab thicknesses on the order of four to six inches, but are often even thicker for highways, interstates, commercial/industrial facilities and airport runways and taxiways.

Voids can form beneath rigid pavements and pavements can settle for a multitude of reasons. Even when fill and subgrade soils are initially adequately compacted, pavement support can deteriorate over time due to freeze-thaw cycles or due to the effects of water infiltration. Options for repair then typically involve void filling and lifting, or complete removal and replacement. Removal and replacement is generally only considered as a last resort due to factors such as cost, disruption, mess, loss of use, inconvenience to the public, and even aesthetics. Use of PolyLEVEL expanding foam products can alleviate many of those concerns.

The capacity of PolyLEVEL expanding foam to lift a slab is dependent on factors such as strength and reaction of the subgrade, confinement of the injected material, slab integrity, slab weight, and resistance (e.g., adhesion) from the soil. This study was completed to determine the potential expansion pressure of two PolyLEVEL expanding foam products under ideal laboratory conditions. By establishing expansion pressure versus density curves in the laboratory, the expansion pressure can be estimated for field applications when either samples of the foam are taken and density measurements are made, or typical in-place density values are assumed.

PolyLEVEL® PL250 and PL400

Polyurethane foams are created by the chemical reaction of diisocyanates (A-side) with polyols (R-side) to form a polymer chain (urethane linkage). The A-side is essentially the same for both PolyLEVEL PL250 and PL400. The R-side, which controls properties such as color, density, and reaction speed, differ for the two products. Respective unit weights for both the liquid A and R-sides of PL250 and PL400 are the same.

A free-rise application is one where the material is sprayed and allowed to expand without boundary constraints. PL250 is formulated to have a free-rise density of about 2.5 pounds per cubic foot (pcf) [1] with a corresponding compressive strength of 35 pounds per square inch (psi) [1]. However, in confined, sub-pavement applications, PL250 may locally achieve densities of 4 pcf with compressive strengths of about 70 psi. The PL250 R-side is also formulated to have a faster reaction time to spread less and provide a more immediate response for the installer. PL250 is therefore well suited for smaller slabs and sidewalks and lightly-loaded residential applications.

PL400 is formulated to have a free-rise density of 4 pcf with a compressive strength of 60 psi. In applications beneath slabs, PL400 may locally achieve densities of 7 pcf with compressive strengths on the order of 100 psi. In comparison to PL250, PL400 reacts about three times slower to allow for a greater spread from the injection point. At each injection location, the PL400 then applies pressures to a greater area of contact to mobilize heavier slab sections.

Test Program

Two proportioners from two manufacturers were utilized for the expansion pressure testing, a Graco Reactor E-20 and a Boss SFE-5/6,000. Proportioners provide two main functions; regulate temperature to affect viscosity and reaction time, and pump the material at high pressure to maintain a constant flow rate. Both the A-side and R-side components are pumped through separate hoses to provide a one to one ratio when combined in the mix chamber of the Graco GX-7A plural-component spray gun. Due to equipment availability at the time of

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Figure 1: Mold used for product samples and expansion testing

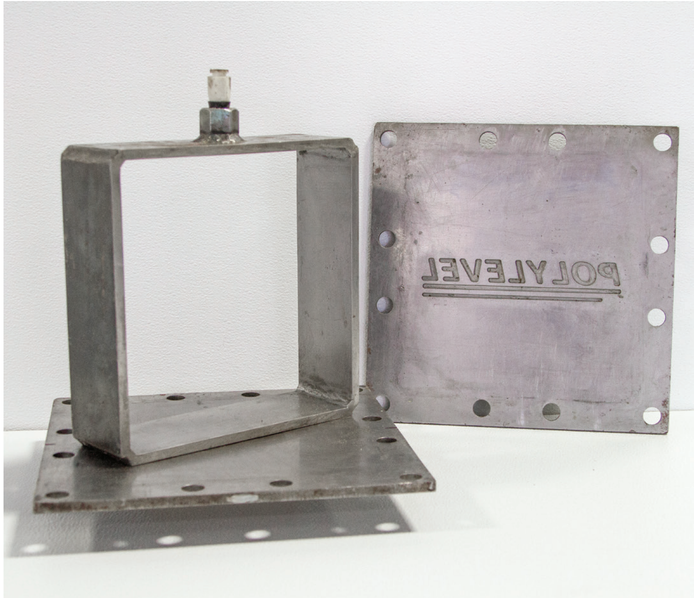
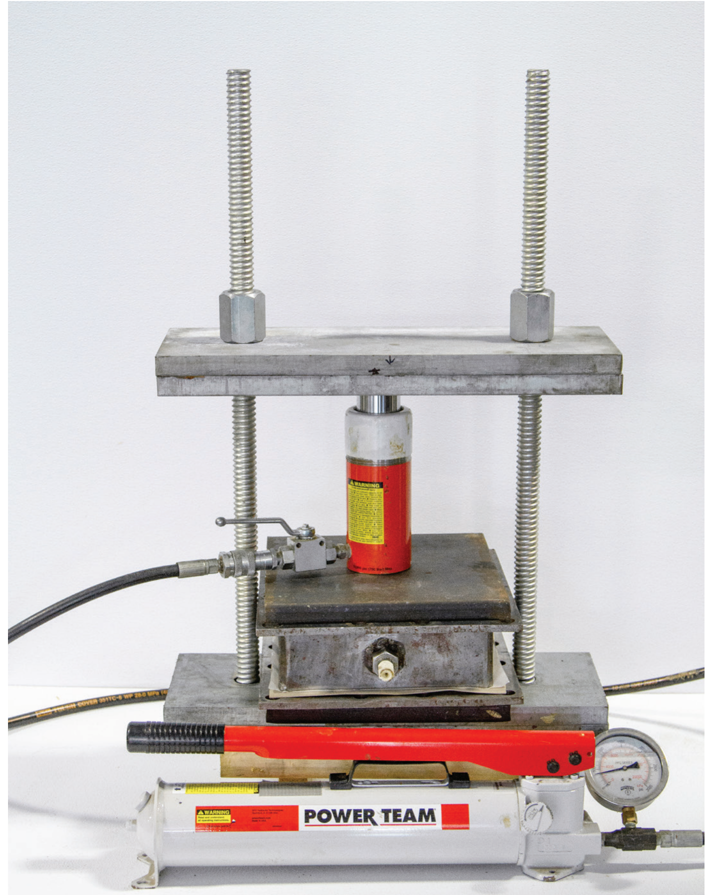


Figure 2: Test arrangement: mold, test frame, and hydraulic cylinder and pump



testing, the Graco Reactor E-20 was used for the PolyLEVEL PL250 testing and the Boss SFE-5/6000 was used for the PolyLEVEL PL400 testing several weeks later.

The expansion testing was completed using a steel mold originally fabricated for the purposes of material quality testing and to make product samples. See Figure 1. The square frame of the mold consisted of ⅜-inch thick welded plates with inside dimensions of 3 ¼ by 10 ¼ by 10 ¼ inches. A ⅝-inch diameter hole was drilled into one of the side plates and a ⅝-inch coil rod nut was welded around the drilled hole for insertion of the material injection port. Two 1-inch thick steel plates were added to the mold's original ¼-inch thick top and bottom plates to provide additional stiffness during the expansion testing.

The test frame consisted of two 1-inch thick steel plates top and bottom and 1 ¼-inch diameter coil rods. The mold was set within the frame and a calibrated 25-ton hydraulic cylinder was placed between the top of the mold and the top plates of the test frame. Figure 2 is a photo of the complete test arrangement including the mold, test frame, and hydraulic cylinder and pump.

The top and bottom plates in contact with the mold frame were covered with thin sheets of compressible foam to act as gaskets to limit product loss during the test. Wax paper was then used to cover the compressible foam sheets to aid in sample removal. The interior surfaces of the sidewalls of the mold were lubricated for the same reason. A seating load, or seating pressure, was applied to remove slack in the system and ensure that material would not escape the mold during the test. The initial seating pressure was determined by trial and error for the first several lower density tests. For subsequent higher density tests, the previously achieved expansion pressure from a lower density test was used for seating. The seating pressure was determined by simply reading the pressure gauge on the hydraulic hand pump. The seating pressure could not be set too high, otherwise the expansion of the foam would not register an increase to the reading on the pressure gauge. The expansion force generated by the PolyLEVEL products was determined by recording the maximum pressure observed on the dial gauge on the hand pump and then inputting this value into the calibration equation for the hydraulic cylinder. The expansion pressure of the foam was then calculated by dividing the expansion force by the horizontal contact area of the mold (10 ¼ inches by 10 ¼ inches). Samples were allowed to cure for roughly ten minutes before removal from the mold to be measured and weighed to determine density. The sample densities were varied between tests by injecting more or less material into the mold. The maximum tested densities were capped when the removed samples showed signs of charring. Mixing of the A and R-side components results in an exothermic reaction.

Results and Discussion

The test results indicate that under these ideal laboratory conditions PL250 has the potential to achieve expansion pressures exceeding 12,000 pounds per square foot (psf) and PL400 has the potential to achieve expansion pressures exceeding 5,000 psf. These expansion pressures correspond to in-place densities greater than 12 pcf. See Figure 3. PL250 also consistently achieved higher expansion pressures than PL400 for a given density. Stated another way, to achieve the same expansion pressure up to about 5,000 psf, PL400 must achieve a higher density, meaning that more PL400 versus PL250 would have to be placed.

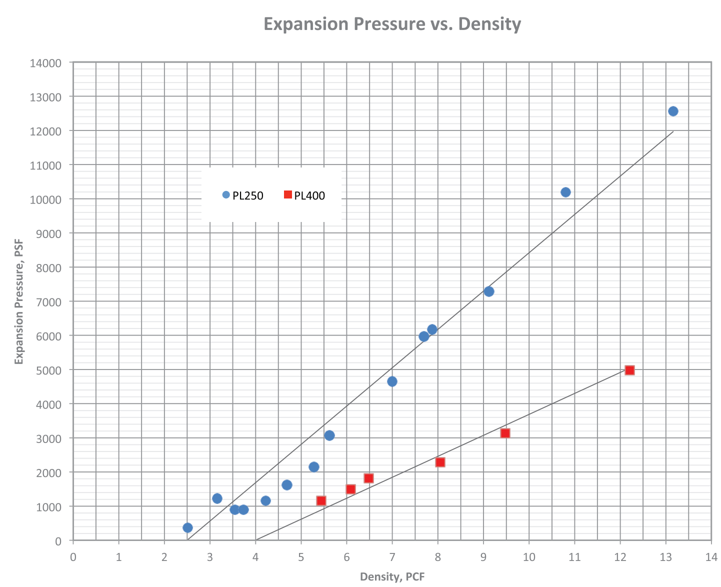
If PL250 can achieve higher pressures with less material, why would you consider PL400 over PL250? You have to consider the minimum anticipated free-rise densities and compressive strengths. In every application, the injected material will cure as a volume of varying densities. The material placed at the bottoms of deep voids, or the outer-fringe material that spreads laterally from the injection point, will generally cure to or near free-rise conditions. While you locally have higher density and higher strength material, free-rise conditions may exist beneath the slab. Using PL400 versus PL250 guarantees higher minimum densities and strengths. On the other hand, PL250 is specifically formulated to provide a more economical option to PL400, yet provide adequate support for lighter residential applications.

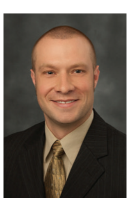
When the two products are utilized for appropriate projects for which they were intended; i.e., PL250 for lighter loads and PL400 for heavier loads, in-place densities for PL250 and PL400 may reach and even exceed 4 pcf and 7 pcf, respectively. At those densities, Figure 3 shows corresponding expansion pressures of about 1,700 psf for PL250 and 1,800 psf for PL400, much less than the measured maximum pressures, but more than what would be determined as necessary to stabilize and lift most slabs using proper installation procedures and techniques. High expansion pressures were anticipated for the laboratory tests since the tests were performed using a relatively low volume mold with well-defined, unyielding boundary constraints. The maximum densities and strengths observed in this test would rarely even be approached in the field.

The test results assist in answering general interest questions about lift potential of polyurethane foam, but likely will be of little use to an installer. Rather, with the right product selected for the project, experienced installers may adjust injection locations and spacing, as well as material temperature and flow, to achieve the desired effect. Other best practices may also be considered. A successful PolyLEVEL installation is therefore generally thought of to be more of an art than a science. Even so, this testing provides real numbers that support the logic about how polyurethane injection works to stabilize and lift concrete. This information will likely also be considered in the future as the basis for additional product testing and evaluation.

(1) See the current edition of the FSI Technical Manual for ASTM standards used for the determination of density and compressive strength.

Figure 3: Expansion pressure versus density curves for PL250 and PL400





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Jordan provides technical support to design professionals and the FSI contractor network. He communicates with engineers, architects and contractors on residential and commercial projects to determine appropriate solutions given site-specific conditions. Jordan also assists in product design, research and development, and verification testing.