Resurfacing Transit Track Slabs

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Abstract:

Several types of track built on at-grade track slabs at the Metropolitan Atlanta Rapid Transit Authority required vertical surface remediation. Challenges to the work included strict transit service interruption prohibitions, track fastener systems with limited capability for vertical adjustment, and adjacent urban structures with very low lateral movement tolerances. Various methods were used for lifting.

A pilot site was selected with a service track bridge abutment approach slab that had settled and rotated requiring a 9 ½ inch lift. Urethane foam was utilized and field tested for evaluation of the post construction conditions. Material evaluations were conducted before methods were approved for use on revenue tracks.

At-grade track slabs with bolted fastener plates exhibited differential settlement causing grade changes at abutments approaching unacceptable values and at station platforms causing passenger boarding tripping hazards. Another site exhibited settlement in a deep embankment causing differential settlement affecting slab track with two block ties that afford limited capability for vertical adjustment without modifications to second pour plinths.

Case study chronicles the initial design process, new materials acceptance testing, field monitoring, how obstacles were addressed during construction and lessons learned.
The Metropolitan Atlanta Rapid Transit Authority (MARTA) opened the first heavy rail transit (HRT) service to the public in 1979. Transit system expansions were constructed until 1998. Today the system consists of 48.1 miles of double track, 38 high capacity stations, four yards, 18 Substations, parking facilities, 4 bus maintenance garages, and other infrastructure. Rail revenue operation headways have been shortened and lengthened at different times to meet public demand and budgeting challenges but the longest interval between trains during off-peak periods is typically 20 minutes. Although single tracking is employed for short periods to allow access for maintenance and rehabilitation activities, MARTA strictly avoids inconveniencing the public patrons by suspending rail service except for a 4 hour non-revenue period each night.

For the past decade maintenance programs were planned and undertaken to repair infrastructure deterioration from wear and aging. Since track, train control, and traction power maintenance receive priority to assure safety and continuous service, access for infrastructure rehabilitation projects is very limited, typically the 4 hour non-revenue period and occasional 30 to 54 hour single tracking windows on weekends. Creative construction methods and materials are required to facilitate repairs under these limited access conditions.

**YA Track Abutment Approach Slab Pilot Project**

During routine bridge abutment inspections in 2003 significant vertical track profile settlement was detected at the YA track. This service track was constructed in 1985 to dispatch and recover out-of-service trains between the South Maintenance Yard and the South Line terminal station at Hartsfield-Jackson Atlanta International Airport. The approach to the bridge spanning 10-lanes of I-85 interstate highway and ramps is on a 500’ radius curve and built on a 2:1 embankment supported by a 25’ high MSE wall (overall fill height of approximately 45 feet). The only vehicle access to the site is over the track. The 40’ long x14’ wide x16” thick reinforced Portland cement concrete approach slab had rotated 9 inches at the end farthest from the bridge, pivoting on the abutment wall seat. This approach slab was a hybrid design with 20 feet of direct fixation track and 20 feet of ballasted track. The underdrains and ditches showed no apparent evidence of failure. In addition, a series of 9 panels in the MSE wall below the abutment and beside the interstate on-ramp exhibited a distinctive diagonal pattern of misalignment directly below the settled track.

Focus shifted to designing rehabilitation measures to restore the track after the wall and bridge structures were analyzed and found to be stable by the Georgia Department of Transportation and MARTA. Although this work was not on a revenue track requiring the most restricted access, engineers selected the site as a pilot for lifting with polyurethane grout. The choice was made to take advantage of the opportunity to verify the anticipated benefits of the material on a track not critical to revenue operations: short set time, construction without heavy equipment, and limited access requirements and impacts to rail operations.

Once the material was approved, an implementation plan was developed to perform the lift over a single weekend track outage while adjacent yard lead tracks were active. The running rails were unclipped and jacked in-place so that they would not hamper the lift. The third rail and train control equipment were de-energized and left attached to the concrete ties. The contractor excavated ballast from tie cribs to uncover the approach slab, drilled several dozen 2” holes, and drove injection tubing to three different depths (0, 3.5, 6 feet below bottom of slab) and began lifting. The polyurethane grout and steam are produced from two different component liquids combined in an injection gun. The steam provides the expansion in the foam that generates lifting forces and controls the set time.
During the second day of grouting the approach slab reached 7 ½” of lift and stopped rising. After a few hours, the decision was made to discontinue grouting, close construction, and return the track to service. The track was reassembled and ballast tamped at the restored profile grades.

Subsequent to construction activities, various theories were discussed concerning whether the excess grout had densified the embankment or had migrated into remote subsurface zones in the embankment. Pipe cameras were used to monitor underdrains and storm sewer pipes during grouting and it was clear they were not fouled. The only plausible space that might have received the grout seemed to be the void space in the MSE wall backfill holding reinforcing straps behind the adjacent MSE wall. A better understanding of the subsurface behavior of the polyurethane grout beneath the approach slab was sought before the material was authorized for use in repairs to revenue track. Concerns about the material included:

- Did achieved densities have adequate compressive strength for track foundation?
- Did movement and expansion of grout cause fractures the embankment that could expose it to internal drainage erosion and eventual resumption of loss of ground?
- Did foam in contact with the bottom surface of the slab achieve adequate density, related shear strength, and surface friction to resist track lateral forces without breaking or slipping?
- Did grout reach a lifting limit for the load and continue to densify or continue moving outside the slab foundation zone?

MARTA requested Golder Associates Inc. propose an investigative drilling program to detect the in-situ densities and resolve open questions. Three holes were located on the track centerline but between polyurethane injection points. The concrete approach slab was cored and the embankment was drilled using Geoprobe continuous sampler and CME continuous sampler within a hollow stem auger in an attempt to extract samples of embankment fill / polyurethane

Urethane was encountered in all three boreholes as thin layers, typically 0.5-inch thick, either as individual layers or grouped into a zone of multiple layers. The thickest individual layer and zone encountered were 0.75 and 8 inches, respectively. The total thickness of polyurethane encountered in the boreholes ranged from approximately 1.5 inches nearest the abutment to 12 inches furthest from the abutment with polyurethane encountered at a maximum depth of about 10 feet below the top of slab.

The limited thickness of the polyurethane did not result in samples suitable for compressive or shear strength testing; therefore, only unit weight could be measured. Unit weight of six samples, observed as solid pieces of polyurethane, measured in the laboratory ranged from 28.1 to 69.4 pounds per cubic foot (pcf), with an average of 49.6 pcf. These results were much greater that the supplier’s 5 pcf free-rise specification.

**At-Grade Track Slab Rehabilitation Project**

Although investigations at the YA track were not conclusive, polyurethane grout was approved for limited use during design of a remediation project to lift track with differential settlement of at-grade slabs. The project included a variety of different track founding structures and access conditions; however, the site with the most critical surface defects was Redding
Road. The ride quality and surveyed settlement measurements were approaching threshold limits to justify slow orders. The site has reinforced Portland cement concrete two-block ties cast into second pour plinths on at-grade slabs. These slabs bear on earthfill embankment varying from 15 to 40 feet; with the right track supported on an 8 to 12-foot high retained earthfill wall. Ties are seated in elastomeric boots that isolate them from the plinth concrete. This track type was chosen to reduce noise and vibration to protect sensitive adjoining properties during initial route design and construction. The tie system was designed to allow shimming beneath the precast blocks but differential settlement exceeded allowable reductions in tie seat depths. The two main alternative remediation methods that were studied were replacement with ballasted track and lifting the existing slabs.

Multiple stations included in the rehabilitation project were built with elastomeric-encased direct fixation steel fasteners bolted to at-grade slab second pour plinths. The track slabs are founded on retaining wall fill sections predominately bearing on spread footings except in the passenger platform which are supported on deep foundations. Some also had backfill that did not meet compaction specifications documented during original construction. In addition to settlement exceeding the practical limits of fastener shimming, substantial vertical mismatches between vehicle door thresholds and platform edge elevations were developing (passenger tripping hazard). Also, track slabs and runoff slabs throughout the stations had significant differential settlement causing accelerated deterioration due to water incursions into embankment fills from uncontrolled storm runoff.

**Doraville Station DF Track on At-Grade Slabs**

The Doraville Station work site, largest in the project, was scheduled for construction first in order to work out a construction protocol on a section of low speed track that could accommodate post-injection adjustments using shims. Doraville Station is elevated on retained earth fill behind approximately 20 feet high retaining walls. Differential settlement of the retained backfill with respect to the Station platform (founded on deep foundations) had necessitated lifting the track slab. The grouting method planned during design by consultants assumed lifting the 50-foot long at-grade slabs to the design grade with cementitious grout columns and void filling with polyurethane foam. The grouting subcontractor agreed to try the method and some consolidation of the underlying soils was achieved with the cementitious grout but lifting was only possible with the polyurethane grout. MARTA had concerns of thick layers of polyurethane supporting the loaded track slabs, particularly the durability of the polyurethane under repeated loading. Since no laboratory testing literature or applicable test standards were found for this material, MARTA agreed to approve the material for primary lifting if an acceptance test was developed and the material passed the criteria determined prior to testing.

Manufacturers’ specification for polyurethane provides a compressive strength for the free-rise (unit weight of 5 pcf) expanded material. However, the polyurethane would be confined by an 18-inch thick, heavily-reinforced track slab during injection and higher unit weights were theoretically possible. From a quality assurance standpoint, the design team developed a laboratory testing protocol to test the strength and compressibility of the polyurethane on formed samples of known unit weight and use the unit weight of the field-sampled polyurethane as the basis for accepting the material.

A testing protocol was developed by MARTA and Golder based on the compressive strength test standard cited by the polyurethane manufacturer, ASTM D1621. A cyclic loading
test regimen was developed to test the material for 300,000 load cycles – approximately one year of train operation.

As the field unit weights were initially unknown for the Track Slab Rehabilitation, MARTA selected the free-rise and 30 and 55 pcf unit weight sample based on data collected by Golder in 2008 of polyurethane materials injected under the YA Track near the South Yard.

The contractor formed one cubic foot samples within 6-inch diameter, approximately 5-foot long PVC (for free rise weight) and steel pipe forms for the 30 and 55 pcf materials which would take approximately 100 and 200 pump strokes of material to fill, respectively. The steel forms were capped on each end, with a grout nipple on one end to inject the polyurethane and a valve to release trapped air on the other. The valve was closed once material was observed coming through. The forms with the expanded polyurethane were transported to the Avondale Maintenance Facility, where MARTA personnel cut the steel forms into approximately 12 to 15 inch long sections. Golder took possession of these sections and had approximately 4-inch diameter cores removed from the formed samples. The cores were cut into approximately 4-inch long sections.

Once the cores of these materials were taken, it became apparent that the samples were not uniform throughout their length and that the planned 30 and 55 pcf materials were not achieved. The cores from the 30 pcf attempt weighed between 12.8 and 18.9 pcf and the 55 pcf attempt weighed between 25.0 and 57.5 pcf, with 10 of the 15 cores between 25 and 30 pcf. This variation in unit weights is attributed to the fact that the polyurethane expansion is generated by a chemical reaction which begins immediately, so that the first material to enter the form is expanding before the last material is injected. The 57.5 pcf core had the appearance of hardened, unexpanded polyurethane resin while the 30 pcf attempt yielded more uniform appearance and core unit weights.

Urethane cores from the free-rise and the 30 pcf attempts were tested in general accordance with the protocol developed for acceptance testing; however the cycle frequency had not yet been set (maximum frequency of the testing equipment was 5 Hz). Since free-rise polyurethane foam is known for its insulating properties, concern was raised on the potential for sample degradation due to retention of internally-generated heat during cyclic compression testing. Additionally, the manufacturer had no data on this type of testing on the free-rise material. Before production testing, a free-rise specimen was instrumented with a thermistor and tested at a 5 Hz frequency for 300,000 cycles (16.7 hour test). The data showed no increase in the internal temperature at the 5 Hz frequency; therefore, all core specimens were tested at the 5 Hz frequency. Test results indicated that polyurethane materials are durable with accumulated strain for both of the unit weight materials tested at the 15 psi load of 0.0 to 0.07 percent. However, the modulus of the polyurethane is much less than the modulus of the base material supporting the track slab in the field. A composite modulus of subgrade reaction of 400 pounds per cubic inch (pci) has been estimated for up to 3” thick layers of polyurethane with existing base material. Based on AREMA guidance that subgrade reaction should exceed 350 pci (refer AREMA Manual for Railway Engineering, 2009, Chapter 8, 27.5.2 Concrete Slab Track Subgrade), the use of polyurethane was accepted for fully supporting the track slabs on the rehabilitation project.

The contractor cored through the left track of the Doraville Station to retrieve field-injected materials. Cores were removed at 4 locations with 3 of the 4 cores yielding polyurethane materials between approximately ¾ and 2-1/4 inches thick. Polyurethane retrieved from the 4th core had penetrated into the base material to form a polyurethane-
cemented aggregate concrete. The unit weight of these field samples was approximately 10 pcf; between the free rise and 30 pcf attempt material. Because the unit weights of the laboratory test samples bracket the field unit weights, no further laboratory strength testing was conducted.

During construction, movement was detected immediately in retaining walls adjacent to the grouting work apparently due to the developed lateral pressures on the wall from high pressure cement low mobility grout (LMG) injections and a thin but large surface area of fugitive underground polyurethane grout escaping into voids on the inside surface of the wall. As a result of this deflection, MARTA requested that Golder evaluate the allowable deflection of the retaining wall from the point of the bearing pressure and sliding factor of safety.

A simplified calculation was used to estimate a point load that could cause various deflections from 0 to 1 inch for all wall heights of the standard wall design. The retaining wall stability for bearing and sliding was recalculated by adding this back-calculated point load with the goal of a:

- Sliding factor of safety greater than 1.3
- Toe bearing pressure less than 4 ksf or
- Resultant of the vertical forces within the middle third of the wall footing (trapezoidal bearing pressure distribution)

Based on the analysis, MARTA directed the contractor that no deflection of retaining walls less than 15 feet high will be allowed and for retaining walls greater than 15 feet, grouting must stop if the deflection equaled ¼-inch. To meet this requirement, the contractor modified the injection procedure by performing continuous wall monitoring from inside the trackway and injecting small amounts of grout between track slabs and walls to prefill voids before larger volume lifting injections were placed. Deflection monitoring was continuously conducted real-time during the grouting process. Since deflections were caused by the grouting process, additional movement was not expected to occur once the grouting stopped. Additional intermittent deflection monitoring is planned after the completion of all work.

**Redding Road Resiliently Supported Track on At-Grade Slabs**

Redding Road design and construction records research and field observations indicated potentially three modes of deterioration, lateral spreading at the left base, continued initial consolidation due to a design change from aerial to at-grade on new fill, and surficial loss of ground where utilities and structures within 10 feet of the track surface had been installed with inadequate compaction effort of the backfill.

The remediation design philosophy for this site was to correct the track surface with shallow track slab grouting and installation of monitoring measures to determine the geotechnical processes occurring in the future should significant settlement continue. Retaining wall monitoring at Redding Rd. was conducted from outside of the trackway with terrestrial scanning methods and embankment monitoring baseline data was collected from conventional survey points installed on the slopes and readings from inclinometers and extensometers installed by the contractor.

The contractor was authorized to remediate the track slab surface with polyurethane foam grouting only. Lifts of up to 2.5’ were achieved and each track was repaired in single weekend outages followed by work sessions to destress the running rails and repair runoff.
slabs. The strategy of directing the contractor to begin the project on sites with adjustable direct fixation track paid off as the work at this critical site went very smoothly.

Subsequent as-built track surface survey was conducted by loading the track with a tamper to assure that data reflected the track with ties completely seated in the second pour seats. Since the lifting was approved without compaction of the subgrade, additional track, wall, and slope monitoring is planned after several months to determine if localized movement requires treatment before site repairs are complete.

Conclusions

Grout injections described in this paper were used to address specific grade deficiencies in reinforced concrete transit track slabs. These deficiencies resulted from a variety of potential sources in both the design and construction phases. The grouting procedures were only meant to address the near-surface grade deficiencies, not deeper seated supporting materials.

The following conclusions are offered based on the experiences gained during this project:

- Remediation of track slab elevations with grouting is effective under limited access conditions. For this application on revenue track polyurethane foam passed strength and cyclic loading acceptance testing. Long term monitoring and eventual in-situ samples should be extracted and tested to confirm continued suitability.
- Consideration of adjacent retaining structures and utilities must be included in the design and contract specification development. A rigorous monitoring program is advisable.
- Performance-based specification is recommended as it can provide flexibility to make corrections during construction.
- A controlled injection procedure must be implemented in the field program.
- Extremely mobile polyurethane material can become fugitive, unlike cementitious grout, flowing long distances and filling any voids it encounters, as evidenced by lateral retaining wall deflections.
Resurfacing Transit Track Slabs

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At-Grade Slab Vertical Realignment with Grouts

Three Sites:
- **YA Track** - Aerial to ballasted track approach slab, combination DF and ballast, bearing on earthfill
- **Doraville Station** - Direct fixation on at-grade slabs bearing on retained earthfill
- **Redding Road** - Resiliently-supported track on at-grade slabs bearing on earthfill / retained earthfill

**YA Track - Slab Lifting Pilot Site**
- **YA Track - 500’ Radius Bridge Abutment**
  - Non-Revenue Service Track Selected
  - Fill thickness = 45’, No Access road
  - Some differential Settlement Observed in MSE Wall
  - 40’ concrete transition approach slab (20’ direct-fixation and 20’ ballasted track). MARTA Standard transitions slabs are 20’ long.
  - Slab had apparently rotated vertically about the abutment seat
  - Earthfill settlement at end of slab = 9-1/2”

**YA Track Alignment Deviations**

**YA Track Types**
- **Ballasted Track**
- **Direct Fixation Track**
Urethane Injection Pilot Project

- Urethane Injection Depths (think Great Stuff™)
  - Bottom of slab in subballast
  - 3 feet below top of slab (ft-bts)
  - 6.5 ft-bts
- Lift slab to grade
- Anticipated Lift Technique Advantages
  - Quick Set Time
  - Minimal Access Requirements and Impacts

YA Track Mobilization

- Grout Pump and Supply Vehicles On Interstate Ramp
- Grouting to Abutment Approach Slab Behind Trees

YA Track Profile - Injection and Sampling

- Injection Point (typ.)
- Recovered Urethane
- Urethane recovered
  - Typically ½-inch thick layers, max. ¾-inch layer
  - Zones of urethane between 0.2 and 0.75 feet thick

YA Track Injection Ports

- Direct fixation track injection tubes were driven into subballast and subgrade through holes cored in Portland cement concrete approach slab. Pointed inserts were seated in the bottom of tubes and sacrificed when tubes extracted.
- Ballasted track approach slab was excavated, cored, and PVC pipe placed before restoring ballast in tie cribs to allow operations. During subsequent track outage, injection ports were driven into subballast and subgrade.

YA Track Urethane Injection Operation

- Approach slab lifting was monitored with survey levels. Nearby drains and electrical ductbanks were monitored with remote push camera.

YA Track Urethane Sampling

- Cored through reinforced concrete slab
- Recover urethane-treated embankment fill
  - Distribution through embankment between injection points (where did it go?)
  - Samples for laboratory testing
Geoprobe mounted on hi-rail truck

Recovered Urethane-Treated Embankment Fill

Urethane-Treated Embankment Fill

Tests on Field Samples

- No samples suitable for strength / compressibility testing
- Only unit weight measured
  - Range - 28 to 70 pounds per cubic foot (pcf)
  - Average - 50 pcf

Track Slab Project - Station Sites

- At-grade slabs with direct fixation track lifted during limited outages to maintain continuous revenue operations
- Underground drains cleared and repaired
- Runoff slab replaced
- Station platform pavement replaced during bus bridge to restore standard vertical relationship between track and platform edge (ADA compliant vertical gap restored from vehicle threshold to boarding platform)
Track Slab Project- Station Sites

- Required track slab lifts up to 3 inches, exceeding allowable DF fastener shimming
- Crossovers and pocket track turnouts lifted

Each at-grade station slab was 50’ long with direct fixation track and transfer dowels

Design vs. Actual Treatment

**MARTA Concept**
- Cement compaction grout columns - lift and support slab
- Urethane grout - fill gap between slab and subgrade caused by compaction grout

**Contractor Proposal**
- Cement compaction grout columns - treat subgrade materials - little lift
- Urethane grout - lift and support whole slab

MARTA agreed to contractor proposal provided Urethane materials met minimum requirements of Authority-devised acceptance testing program

Initial Grout Sample Corings

- Coring through PCC slab, isolated urethane layers, low mobility cementitious grout (photo inverted to replicate field condition)
- Polyurethane “concrete” formed when injections permeated subballast material (RE in background worrying material testing will delay the project)
Urethane Acceptance Testing

- Form samples at known unit weight
  - Free-rise (5 pcf)
  - 30 and 55 pcf (based on YA Track data)
- Test samples for strength and compressibility
  - Cyclic compression, 300,000 cycles ≈ 1 year of train operation
- Use field-sampled urethane unit weight as the basis for acceptance

Sample Preparation

- Contractor used 6-foot long pipe for forms (1 cubic foot)
  - Initially Sch. 80 PVC then steel pipe
- Use steel pipes for 30 and 55 pcf materials
- Based on pump delivery rate = 100 and 200 pump strokes needed to make 30 and 55 pcf samples
- Forms/samples cut to 15 to 18-inch long sections for handling
- Samples cored from form sections

Sample Preparation

- Test specimens cut to 4 in length

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<th>Target Unit Weight (pcf)</th>
<th>Compressive Strength (psi)</th>
<th>Strain (%)</th>
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- Manufacturer-stated compressive strength (free-rise) - 78 psi

Measured Unit Weight

- Target Unit Weight
  - 30 pcf
    - Actual Unit Weight: 14.8 to 18.9 pcf
  - 55 pcf
    - Actual Unit Weight: 25.0 to 57.7 pcf

55 pcf Target 30 pcf Target

- Manufacturer-stated compressive strength (free-rise) - 78 psi

Cyclic Compressibility

- Determine cyclic rate (equipment maximum = 5 Hertz)
- Urethane known for insulating properties
  - Unknown - Heat gain during cyclic testing degrading samples
  - Urethane manufacturer - Not evaluated
Cyclic Compressibility

- Thermocouple-instrumented samples tested at 5 Hz for 18,000 cycles showed no heat gain
- Use 5 Hz test frequency at 15 psi maximum stress for all samples

Photo by Boudreau Engineering, Inc.

Cyclic Compressibility, cont.

- Accumulated strain between 0 and 0.07%
- Urethane dynamic modulus showed a soft behavior
- Estimated composite modulus (base course + urethane) greater than 350 psi (AREMA Manual of Railway Engineering)

Field-Sampled Urethane

- Three of 4 core samples encountered free urethane underlying the track slab
- Thickness varied from ¾ to 2-¼ inches
- Average unit weight of urethane varied between 9.4 and 10.7 pcf

Retaining Wall Deflection

- After initial injection event, measurements of existing retaining walls showed walls had moved
- A simplified analysis was used to estimate the maximum effective point load that could cause wall stem deflection
- Wall stability recalculated using standard design guidelines for bearing and sliding
Retaining Wall Deflection, cont.

- Allowable deflection for wall height
  - Less than 15 feet - zero
  - Greater than 15 feet – < ¼ inch
- Contractor modified deflection monitoring in field to meet these criteria
- Authority conducted additional wall monitoring with traditional surveying and terrestrial scanning techniques

Station Site LMG Grout Preparations

- Coring track slabs in center only. Slab roll to be controlled with urethane injections.
- Predrilling subballast and subgrade containing old cement grout before driving injection tubes

LMG Mobilization

Station Site LMG Grouting

- Low mobility Portland cement grout lifts monitored with survey levels
- Injecting low mobility Portland cement grout to 200 PSI (pressure gage on hose)

Station Site Urethane Grouting

Station Site Slab Lifting Final Tasks

- Rails cut to take out extra length caused by restoring vertical chord from sagging track.
- Rail destressed, some fastener shims inserted, and exothermic field welds used to reassemble track. Some shimming also required to vertically align contact rail.
Two block ties afford no vertical adjustment capability without removing blocks from concrete plinths. All urethane grouting was approved to remediate slab track surface to allow operations to resume immediately after single tracking work outages.

100% urethane foam injections approved for use at Redding Rd. Work completed during two outages.

Under slab grouting methods can be used in limited access transit trackway to effectively lift track slabs with minimal impacts to continuous operations.

Urethane foam is a powerful expanding grouting tool with fast set times. High mobility can damage structures or utilities so must be carefully inject and monitored.
Conclusions, cont.

- Urethane foam has
  - Low unit weight - compared to normal construction materials
  - Strong - compared to soil
  - Soft - compared to aggregate base

- Composite modulus of urethane / aggregate base could be an issue to concrete slabs

Conclusions, cont.

- Performance-based specifications
- Urethane used to lift slab from existing aggregate base, did not address underlying / deep-seated settlement issues

Questions?

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