Using Precast Super-Slab® for Rapid Repair of Concrete Pavements

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Abstract

The need for rapidly repairing and replacing concrete pavement has reached near crisis proportions on portions of our most heavily traveled highways. Increasingly heavy traffic flows demand shorter and shorter repair work windows putting more and more pressure on DOT's to repair such highways invisibly. The practice of using "short term" repairs materials, just because they can be installed rapidly, compounds the problem because repairs made from such materials will themselves need to be repaired in just a few years – in addition to all of the "new" repairs that will need to be made. The use of precast slabs as a material for making rapid repairs has long been entertained because of the durable qualities inherent in concrete slabs manufactured under controlled conditions. The impediment to their use has been the lack of a good way to rapidly and efficiently install them as fully bedded and interlocked precast pavement. This paper will present an overview of the Super-Slab® System that was developed specifically to accomplish that. Specific references will be made to projects that have been successfully completed using the System.

Introduction

The Scope of the Problem

Full depth repair needs range from "patching" type repairs, referred to as "intermittent repairs" in this work, to full scale continuous replacement on curved alignment encompassing varying widths and superelevations. Full depth continuous replacement is frequently necessary under many bridges where overlaying exisiting pavement is unacceptable. Many intersections and ramps, to which there are no alternate routes, can not be closed long enough to permit durable cast-in-place replacement.

Intense traffic flow in some areas limit work closures to 8 or even 5 hours. Such intensity demands that repairs and replacement be made of high quality materials that will not need to be replaced again for a very long time.

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Background of Super-Slab® Development

The Super-Slab® System was conceived by the Fort Miller Co., Inc., located in Schuylerville, NY, in late 1999 and early 2000 when it was asked by the New York State Thruway Authority if precast slabs could be used to replace pavement at the Tappan Zee Bridge Toll Plaza without disturbing toll-paying traffic. Drawing upon its previous experiences in developing and supplying precast retaining walls, median barrier and bridge superstructure elements for fast-track construction projects, Fort Miller proposed a simple slab-on-grade precast "equilivant" to cast-in-place un-reiforced concrete pavement.

The basics of the System were presented on April 1, 2000 to representatives from the NY State Thruway Authority, the NY State Department of Transportation and FHWA and subsequently demonstrated on April 25 of the same year, when four 3.66 m X 5.49 m X 254 mm slabs were installed at Fort Miller's facility. The primary focus of the demonstration was to show that it was possible to grade a precise subgrade surface with laser-controlled concrete finishing equipment and that bedding grout could be pumped from the top of the previously placed slabs to fill any voids underneath them.

The demonstration was a success and it prompted the NYSTA to specify the System for off-peak-hour replacement of approximately 160,000 SF of pavement on the Plaza project launching full scale implementation of the Super-Slab® System.

The Important Features of the Super-Slab® System

General

The patented Super-Slab® System is an assemblage of precast slabs, methods for installing them and materials for interlocking them together to create an integrated pavement structure. The System is specifically comprised of the following:

1. Constant thickness precast slabs that are fabricated to length, width and thickness as required to a tolerance of $\pm$ 3 mm.
2. Techniques for precision grading to a similar tolerance.
3. Interlocking dowels, tie bars and matching slots cast into the bottom of adjacent slabs.
4. A method of installing non-shrink structural grout into the slots
5. A method of positively filling voids under the slabs by means of a bedding grout distribution system cast into the bottom of each slab

Each one of these features will be expanded upon in the sections that follow.

High Performance Precast Slabs

Precast slabs are cast from high performance concrete manufactured in the controlled environment of a precast facility. The concrete is of high quality because batching, casting and curing are all done under controlled conditions.

Slab Size

While precast slabs can be cast to any thickness, length and width as required, a number of factors are considered when establishing slab dimensions. Freight costs are minimized when full legal loads are shipped (48,000 lb. load in New York State) so it is more cost-effective to size slabs so two can be shipped in a single load. For example, a truck can legally haul two 3.66 m X 4.57 m X 254 mm slabs that weigh less than 48,000 together, but only one 3.66 m X 5.49 m X 254 mm slab that weighs over 27,000 lbs.

Another factor to consider is that repetition of sizes help keep fabrication costs to a minimum.

Slabs of Varying Cross Slope (Warped Slabs)

In the general case it is necessary to provide precast slabs that fit every segment of the highway. While single plane slabs are appropriate for many locations it is often necessary to provide warped-plane slabs, such as that shown in Figure 1, to accommodate varying three-dimensional geometry. The Super-Slab® System includes the technology for manufacturing slabs to the exact three-dimensional geometry of the position on the highway they will occupy.

Figure 1

To fit in the roadway and match adjacent slabs each warped Super-Slab meets the following definition:

1. All warped slabs are of constant thickness
2. Slabs are fabricated such that three corners establish a single plane. The forth corner is located either above or below that plane by a calculated amount (delta)

3. All sides of a warped plane are straight in both the vertical and horizontal planes.
4. All cross sections of the slab taken at right angles to the long side are straight line cross sections

From a detailed slab layout drawing, such at that shown in Figure 2, the "x", "y", "z" values of every corner of every slab is computed. Each mark-numbered slab is fabricated to its required dimensions in a form that is capable of being adjusted to that geometry.

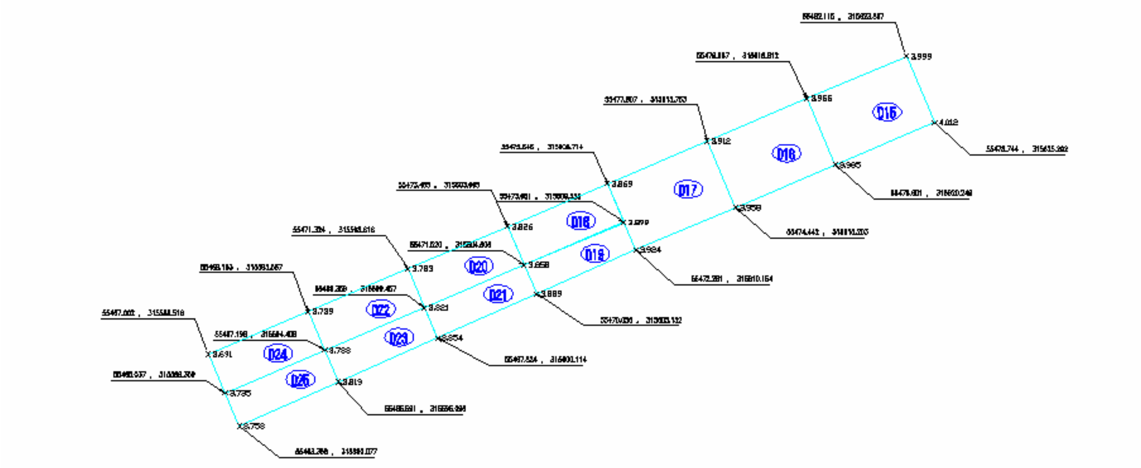

Figure 2

Slabs manufactured in accordance with the foregoing will fit on their respective locations on the highway as long as the subgrade upon which they are place is graded to the same "x", "y", "z" values. Figure 3 shows the finished ramp depicted in the engineering drawing shown in Figure 2. The far end of the ramp is sloped down to the right. The near end is sloped to the left. Though hardly perceptible by the naked eye a gradual super elevation transition occurred from one end of the ramp to the other. Some 3.66 m X 5.49 m slabs were fabricated to a "delta" of nearly 50 mm.

Figure 3

Slabs for Curved Geometry and Other Alignments

In addition to super elevation transitions it is sometimes necessary to provide slabs for curved alignments. Slabs for curves are fabricated as slabs with chorded sides, the dimensions of which are determined from the detailed "x", "y", "z" slab layout drawing. It is important to recognize that such slabs may also be warped as well, depending upon the radius and grade of the profile line

Other configurations and alignments may also be required as, for example highway intersections. The Super-Slab® System can accommodate any three-dimensional geometry as long as three-dimensional coordinates are calculated for each corner of each slab.

Load Transfer Dowels and Tie Bars and Matching Inverted Dove Tail Slots

Standard load transfer dowels are cast in the end of each slab at locations that match the location of dovetail-shaped slots cast in the bottom of each adjacent slab as seen in Figure 4. Similarly, standard tie bars (or the female half of a standard tie bar) are cast in one side of each slab matching the location of slots cast in the adjacent slab. Figure 4 is a close up view of how dowels and slots align during the placement process.

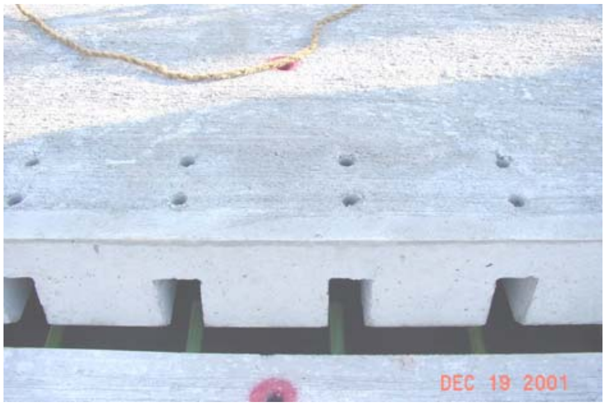

Figure 4

Two grout ports cast in the top of each slot make it accessible for grouting after the slab has been placed. Grout is pumped into one port until it exudes from the other, completing the structural load-transfer-connection from slab to slab. The core shown in Figure 5, taken from a dovetail slot - dowel bar connection, shows how grout completely encompasses the dowel for effective structural load transfer. Fully grouted slabs are essentially the equivalent of cast-in-place pavement slabs and perform the same way.

Dowel slots cast on the bottom of the slabs provide two benefits. First, they keep dowel grout on the bottom, protecting it from de-icing chemicals and degradation from freeze thaw activity. Secondly, they keep dowel grout out of sight maintaining a uniform-looking, high performance pavement surface.

The dovetail shape of the slots, clearly visible in Figure 5, provides another important benefit. It enhances the structural capacity of the connection by providing mechanical resistance to dowel grout pop-out in addition to resistance provided by the bond between the grout and the slab.

Figure 5

The Bedding Grout Distribution System

The bedding grout distribution system, visible on the bottom of the slab in Figure 6, is comprised of a series of half-round channels cast in the bottom of the slab that extend from nearly one end of the slab to the other that positively distribute bedding grout to all of the slab contact area. They are accessed from the top of the slab through grout ports cast in at each end of each channel that are identified red dots as seen in Figure 4.

Figure 6

Also visible in Figure 6 are black foam gaskets glued to the bottom edges (and in between half-round channels) of each slab to create discreet sealed grout chambers. The gaskets contain and channelize bedding grout as it is pumped into one port until it exudes from the corresponding port at the other end of the channel, having filled any voids along the way. The bedding grout distribution system provides a simple way to systematically fill any voids in the contact area if and wherever they may exist.

Reinforcing Options for Precast Slabs

Super-Slab® was developed as a replacement for, and an equivalent to, un-reinforced concrete pavement utilizing similar aspect ratios, joint details, load transfer devices and tie bars. On this basis alone reinforcing is not needed but other factors need to be considered.

Precast slabs are reinforced for handling and shipment to the job site and to resist temperature and shrinkage stresses they will be subjected to during curing and storage at the precast facility.

The following has been adopted as minimum reinforcing requirement for Super-Slab®:

1. Reinforce all Super-Slabs in accordance with ACI's requirements for temperature and shrinkage.
2. Reinforce all slabs as required for handling and shipping.

While both of these requirements may be satisfied by placing a single mat in the middle or in the bottom third of the slab, there is sometimes justification for two mats of steel as will be discussed in a later section.

Once slabs are placed on grade and fully grouted as a pavement structure, the above-designated steel, while not really necessary, provides capacity for bridging future voids and for holding slabs together should any cracks develop at some future date.

Post Tensioning Super-Slabs

Although is has not been done on any of the Super-Slab® projects so far, slabs may be post tensioned to enhance long term durability. Super-Slabs may be placed in the conventional manner and post tensioned as time permits. Careful consideration must be given to the practicality of fitting in this extra step if only 8 or 5 hour work windows are allowed.

Types of Mild Steel Reinforcing

Most Super-Slab® projects to date have utilized either galvanized or epoxy coated steel to enhance pavement life expectancy. Standard epoxy coated bars have typically been used where many different sizes and shapes of slabs were required. On projects where slab sizes were repetitive galvanized welded bar mat has been used efficiently. The choice of the type of steel is left up to the owner of the project.

Precision Grading

General

The speed of installing the Super-Slab® System is achieved by creating a subgrade surface that is sufficiently accurate to eliminate vertical adjustment of slabs that are placed upon it. This simple, yet powerful concept demands a surface accuracy that is more exacting than that commonly known and provided in the pavement industry.

"Fine grade" is defined by New York State DOT as a "fine grade surface that is at true grade and surface at any location, ± 6 mm". "Fine grade" required for Super-Slab® is defined as "a precisely graded subgrade surface that is theoretically accurate to a tolerance of ± 3 mm on single as well as on warped plane surfaces.

Clearly the difference between the two tolerances is profound. The latter is challenging since equipment and methods required to achieve it are non-existent in the pavement industry.

The Importance and Advantages of Precision Grading

The benefits of providing a precision grade for the Super-Slab® System are as follows:

1. It eliminates vertical adjustment to slabs after they have been set
2. It provides "complete and uniform" (within the tolerances indicated) support to rigid precast slabs allowing optional (safe) opening of slabs to traffic before they are fully grouted.
3. It uniformly and positively engages grout dam gaskets on the bottom of the slabs (discussed earlier)
4. It minimizes the amount of bedding grout required and the time required to install it.

It clear from the foregoing, that a precision grade, though difficult to achieve, provides important advantages that are vital to rapid placement of precast slabs.

Bedding Material for Precision Grading

A fine bedding material with a maximum aggregate size of 12 mm has been used for precision grading on most Super-Slab® projects to date because it is commonly available, easy to compact and easy to grade by machine or by hand. The latter is particularly important because it facilitates touch up grading and hand work around edges of the pavement bed. Gradation of this material, known in the Northeast as "stone dust" or screenings, is shown in Table 1.

Table 1 GRADATION

SIEVE SIZE DESIGNATION	PERCENT PASSING BY WEIGHT
½" MAX	100
NO. 4	80-100
NO. 10	55-75
NO. 40	10-40
NO. 200	0-20

A similar material with fewer fines, known as "washed stone dust", is also commonly available since it is frequently used in asphalt mixes. It is more difficult to compact, however and is not normally used for the Super-Slab® process.

It is worth mentioning that dense graded base (DGB) material was used as the primary bedding material on the Lincoln Tunnel Project in Kearny, NJ. Fully compacted DGB was initially graded 2 mm low. During a second and final grading pass made at grade, stone dust was used to fill in holes and the remaining 2 mm. While this concept minimizes the use of stone dust it requires the use of a large scale precision grader, described in a later section, since it is very difficult and impractical to grade compacted DGB with hand-operated grading equipment.

Specifying the Thickness of Bedding Material to Use

The proper thickness of bedding material is that thickness that is practical to install to facilitate compaction and precision grading of the subgrade surface. A 25 mm thickness has been used on most projects where excavator type equipment has been used to remove the existing pavement and to "rough grade" the subgrade.

On projects where the lift out method of removal was used a "design thickness" of 6 mm was specified to be used to "true and level" the existing subgrade. This saved a lot of work (and time) and maintained the integrity of the existing subgrade structure.

Compaction and Precision Grading

To achieve a fully compacted subgrade surface, bedding material is typically placed in two passes. In the first pass bedding material is placed and graded high to allow for compaction. Compaction is accomplished with standard rollers and plate compactors and monitored by conducting standard density tests on the subgrade. During the second and last pass the grader is set at grade to shave off the previously-placed and fully compacted bedding material left from the first pass.

Precision Grading Equipment

General

Conventional road graders and subgrade trimming equipment are too large to operate efficiently in the small areas that are typical of overnight precast slab installations and are incapable of achieving the required level of accuracy referenced above. Such accuracy requires specialized equipment such as that "discovered" and developed as follows.

Large Scale Precision Grading

Precision grading for large scale Super-Slab® projects has so far been accomplished with a modified laser-controlled concrete finisher manufactured by the Somero Corporation of Jaffrey, NH. This machine, called a Supergrader, Figure 7, is capable of grading both single and warped planes at an approximate rate of 1500 to 2000 SF per hour. It is designed to grade while positioned in or out of the hole and compact enough to fit in most traffic-confined work areas.

Figure 7

The Supergrader is capable of grading single plane as well as warped plane surfaces. For single plane grading the Supergrader utilizes a dual slope laser transmitter control system. Warped surface grading is accomplished with a different control system that uses total station surveying equipment, working in conjunction with computerized equipment controls built into the machine, to create pre-loaded computerized surfaces. Operation of the Supergrader requires specialized training that is conducted by the Somero Corporation.

Small Scale Precision Grading

The Fort Miller Co. has developed a hand operated grader (H.O.G.) that is more efficient for grading small areas such as those created by replacement of one single or a few continuous slabs typical of patching work. The H.O.G. is capable of grading fully compacted bedding material to the required accuracy at the approximate rate of 400 to 600 SF per hour.

A prototype of the H.O.G. is seen in Figure 8. It operates on pre-set rails placed on either side of the pavement area. The rails provide a grade reference that is independent from the existing roadway surface. It is capable of grading single or warped surfaces as determined by the grade of the rails. Proper and efficient operation of the H.O.G. requires specialized training that is conducted by the Fort Miller Co., Inc.

Figure 8

Other Grading Methods and Devices

"Traditional screeds" such as that shown in Figure 9 have proven to be slow, inaccurate and incapable of accurately grading or trimming fully compacted bedding material. Use of these may result in un-compacted and in-accurate subgrade surfaces that compromise long term pavement performance. It may also result in non-uniform surfaces that pose a safety hazard if slabs placed upon them are opened to traffic before they are grouted. For these reasons, use of these or other poorly-controlled grading devices is not recommended.

Figure 9

Checking for Accuracy and Touchup Work

The perimeter of the contact area needs to be graded by hand since the grading devices described above are incapable of grading to the very edge of the hole. All graded areas should be checked for accuracy with straight edges and edge depth gages during and after the grading operation. Routine and disciplined checking is the best way to insure surface accuracy and maximize the speed of the setting operation.

Super-Slab® Installation

Placing Slabs in the Correct Location

When setting one or two slabs in a single hole they are simply positioned such that all joints are equal in width. Setting slabs on a continuous replacement project, however requires careful field layout so that each slab is set in its correct plan location, as shown on the detailed slab layout drawing (discussed earlier), insuring a proper 3-dimensional fit and the completed assembly does not “creep”, too large or too small. Careful layout is important where new slabs are placed next to each other to insure that tie bar slots in one slab match up with tie bars in the adjacent.

Slab Layout for Placement

Accurate slab placement requires field layout of the slabs as shown on the detailed slab layout drawing. The leading end and leading edge of each slab are set to theoretical slab lines that are laid out by a qualified surveyor.

Setting Slabs

Just prior to slab placement bond breaker is sprayed or otherwise applied to the dowels and to the vertical edge of the previously set slab to prevent dowel grout from bonding to both sides of the transverse joint, minimizing potential breakup of the grout during subsequent expansion and contraction of the slabs.

Standard threaded lift anchors are cast in each slab for lifting purposes. For fastest setting results the length of each leg of the lift cables should be adjusted so all four corners of the slab hit the subgrade at once.

Tie off ropes should always be used for safe and controlled slab placement. As the slab nears its final location, slab position is best maintained with steel rods (used as positioning handles) inserted into corner grout ports. Steel bars, wedges or any other devices that create large point loads apt to spall or chip slab edges should not be used in the joints for alignment purposes.

Checking Slabs for Surface Match

As soon as each slab is set the vertical match to adjacent slabs is checked. In the unusual event the match is not within the specified tolerance the slab should be lifted and the subgrade corrected as required to make it match. A slab can not be picked up again after the next slab is set.

Grouting Load Transfer Dowels and Tie Bars

General

Since dowel grout completes the structural connection between individual slabs the importance of a quality dowel grout installation can not be over emphasized. Grout materials must be carefully chosen and installed as discussed in the following Sections.

Dowel Grout Materials

To be suitable for "overnight" Super-Slab® installations dowel grout must remain fluid long enough for it to be pumped and it must reach design strength soon enough to open slabs up to traffic. The following minimum criteria must be met:

1. Dowel grout must be pumpable for a minimum of 15 to 20 minutes
2. It must reach a compressive strength of 17.24 MPa (2500 PSI) before slabs are opened to traffic (in two hours for most projects)
3. It must meet DOT's non-shrink (and other) requirements
4. It must be freeze thaw durable

DOT approved mortars that are specified for backfilling dowel bar retrofit slots are not suitable materials because they can not be pumped - even though they meet all other requirements listed above. Two grout companies have developed formulations that meet all of the above listed requirements and are NY State DOT approved. They should be used in strict accordance with the manufacturer's recommendations.

Bedding Grout

General

Bedding grout is pumped into the bedding grout distribution channels to flow into and completely fill small voids that may exist between the slab and the subgrade. After it has fully cured it performs as a fully compacted subgrade material.

The bedding grout that has been used on all of the Super-Slab® projects to date is a formulation of cement, water and plasticizing admixture similar to that used for grouting post tensioning cables on bridges. The following criteria have been established:

a. The grout mixture must have a flow rate of 25 to 30 seconds as measured by ASTM C939 to insure adequate flow
b. The mixture should reach a minimum strength of 2 MPa (300 PSI) to insure it stays in place and performs as a subgrade material

Since bedding grout is not a prepackaged material its formulation is established on a project-by-project basis.

Criteria for Opening Slabs to Traffic

General

While it is recommended, whenever possible, to fully grout slabs before they are opened to traffic, the "slab-on-precision-grade concept" presents the option of opening slabs to traffic before they are fully grouted, since the grade provides "nearly complete" and uniform support to ungrouted slabs. If early opening is anticipated, reinforcing steel referred to earlier, is placed in two mats to provide both negative and positive moment capacity to the slabs before they are fully grouted.

Demonstration of the Concept

The full depth rehabilitation project on I-90 in Albany, NY in 2004 illustrates the concept. Nearly 500 slabs were installed intermittently during each 8 hour night window. Newly- installed ungrouted slabs were opened to traffic at 6:00 AM each following morning following their installation as shown in Figure 10. Dowel gout was installed at the beginning of the next shift and bedding grout was installed 24 hours later. This procedure of delaying the grouting operation for one day allowed the contractor to use his entire closure time for placing slabs.

Figure 10

Proper use of the Concept

A better solution is to specify that the contractor install dowel grout in as many slabs as possible the same night they are installed, leaving "as few as necessary" to be grouted the next night, further stipulating that he re-grade any un-grouted slabs that have moved out of position during the first 24 hours. If the contractor manages his grouting operation efficiently almost all of the slabs he installs each night can be dowel grouted and the risk of un-grouted slab displacement under traffic is minimized.

If un-grouted slabs are opened to traffic high density plastic shims are placed in transverse joints to maintain joint width under traffic.

Smoothness

Precast slabs vary slightly in thickness because they are cast in different forms and because of differences in finishing techniques even in the same form. Similarly, the subgrade surface is not perfect as recognized by specified allowable tolerances. It must be recognized, therefore, that the top surface of the pavement will not be "table-top" smooth. Experience has shown, however that if the previously referred to tolerances in the slabs and the subgrade are met, slabs will match within the specified $\pm$ 3 mm.

This surface variance is acceptable on some highways that service slow moving vehicles, as it was on the Tappan Zee Bridge Plaza shown in Figure 11. If a smoother pavement is required grinding is a well known and economical way of achieving it. This seems to be a small price to pay considering long life pavement slabs are installed so rapidly.

Figure 11

Completed Projects to Date

Table 2 is a compilation of projects completed as of Dec. 31, 2004. These projects total approximately 4.3 lane miles of precast pavement. About 85% of this total services over 100,000 vehicles per day and some slabs has been in service for nearly 4 years.

While most of the installations were “demonstration type” projects the bulk of the slabs were placed on the Tappan Zee Bridge Toll Plaza, including the adjacent 9A Ramp in Tarrytown and the I-90 Project in Albany, NY.

Table 2 Super-Slab™ Projects to Date
(Dec. 31, 2004)

JOB	TYPE JOB	TYPE SLAB	AREA (SF)	DATE COMPL.
TZ Plaza	Continuous	Plane	158,000	July, 2002
Dulles Airport	Intermittent	Warped	3,500	Nov. 2002
9A Ramp (Tarrytown, NY)	Continuous	Warped	15, 750	August, 2003
Lincoln Tunnel (New Jersey)	Continuous	Single Plane	8,100	July, 2003
Belt Parkway, (Jamaica, NY)	Continuous	Warped	16,030	August 2003
Korean Parkway Staten Island, NY	Intermittent	Single Plane	8,850	Dec. 2003
Port Jefferson NY	Intermittent Cross Walks	Single Plane	2,650	?
I-90 Albany, NY	Intermittent	Single Plane	56,400±	2005
Toronto, ON	Intermittent	Single Plane	1,220	2004
Total			270,400	

Continuous Replacement

The most notable of the continuous replacement projects was the Tappan Zee Bridge Toll Plaza project. The Plaza portion of the project was in a gradual super elevation transition normally requiring warped slabs. The contractor was able to replace the entire Plaza with single plane slabs by re-configuring the transition into a series of single planes. Work was scheduled during the day between the hours of 10:00 AM, at the end of the morning rush hour, and 6:00 PM. Grouting was done with a second crew in the eight hour shift following. The entire Plaza was opened to traffic as required at 6:00 AM each day in time for the morning rush hour. On average, the contractor removed and replaced 20 to 24 slabs (280 sm) each shift.

The adjoining 9A ramp, shown in Figure 12, was configured at a 75 m radius at a 2.79 % grade with a 5.2 % cross slope. All slabs were warped and trapezoidal in shape. During a 5 day closure the contractor installed the entire ramp averaging 12 warped slabs per shift. The intersection of the ramp and Rt. 9A in Tarrytown was completed under traffic conditions in two 8 hour night windows.

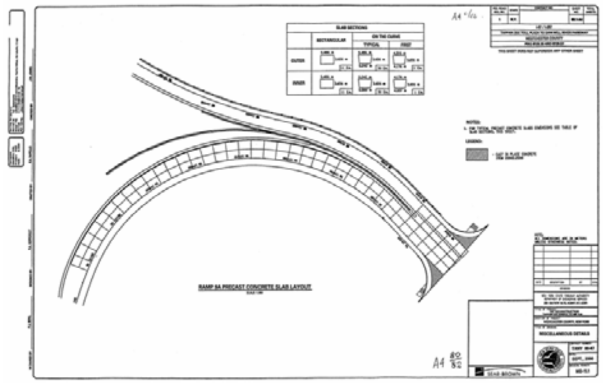

Figure 12

The replacement of 158,000 SF of concrete pavement in the Plaza project demonstrated that large areas can be replaced over a period of time during off-peak hours without affecting the flow of 135,000 vehicles per day. The actual rate of pavement replacement, once the traffic pattern was taken, was about 1500 SF per hour. If replacement were allowed to continue at that rate for a longer period of time, such as during a weekend closure, much greater production rates could have been achieved.

Intermittent Repair

The I-90 Project in Albany, NY was the largest of the intermittent repair projects. It was especially significant that the contractor initiated the use of precast slabs on the Project in lieu of the specified rapid set concrete repair material. The contractor submitted a value engineering proposal to use Super-Slab® to make the repairs - in half the time required for the specified material.

Repair areas on the project varied in size and location. In many areas a single slab was required in one lane while in other areas multiple slabs were required in a single or in multiple lanes. This was accomplished by establishing a menu of standard slab sizes at the start of the project from which an appropriate combination of sizes was picked for each repair location. Saw cuts were made at the exact locations to accommodate each combination. Using this system it was unnecessary to make custom sized slabs for each location.

Another time-saving technique was to leave the existing subgrade alone, after the old pavement was lifted out, and use a thin layer of bedding material to provide the precision subgrade. To accommodate the thickness of the bedding material the new slabs were fabricated slightly thinner (6 mm) than the original pavement. This was justified because the new precast concrete was stronger than the old.

After an initial learning curve the contractor installed 15 (3.66 m X 3.05 m) slabs during each eight hour night shift (on average). This was accomplished during one of the wettest summer seasons on record in the Albany, NY area.

Performance Data

Falling Weight Deflectometer Testing

Two sets of Falling Weight Deflectometer Testing have been conducted on the above listed projects. The first set of tests was performed on the first portion of the Tappan Zee Plaza Project in December of 2001. The average load transfer efficiency of 29 locations was 76.3 %. A second set of tests was performed on the Lincoln Tunnel Project where the average load transfer efficiency on 11 locations was 94.1 %.

While the former was lower than hoped it was on the very first Super-Slab® installation performed on some of the very first slabs the contractor placed. The better results at the Lincoln Tunnel Project demonstrated a significant improvement.

Visual Observations

It has been difficult to collect data on the number of cracked slabs on these projects because of the very heavy traffic. As of this time there are less than 20 known cracks on all of the 1869 slabs placed to date on 3 jobs or around 1 %. Most of these cracks occurred on the Tappan Zee Project in an area used extensively by heavy construction equipment and are not viewed as typical of the System since only two cracks appeared on all of the other projects and one of those were caused by contractor error. In any case, all cracks that developed are kept tightly closed together by the steel reinforcing, as discussed earlier

Costs

It is really too early to tell what the cost of Super-Slab® will turn out to be since most of the projects completed so far were demonstration type projects where contractors hardly had time to develop any degree of efficiency. Even the two larger projects were not necessarily indicative since the first one was certainly bid high, to cover the costs of such unknown technology and the second large project was value engineered.

At this writing the cost appears to be at about the same level as the cost for repairs made with rapid set concretes. It is hoped that as more projects are completed and better equipment and techniques are developed the cost will come down.

Conclusions

Successful installation of over 270,000 SF of Super-Slab® in the abbreviated work windows described above demonstrate that precast concrete slabs can be used as a viable repair material. Even large areas can be installed in a series of such windows in a manner that does not impact daily heavy traffic flow.

While all contractors demonstrated skepticism at the beginning they all became "believers" as they understood the concept and developed techniques for efficient installation. Training of contractor and inspection personnel aids the acceptance and implementation process.

The Super-Slab® System showed that it is versatile and be used on many different types of projects such as large scale continuous replacement, overnight repair of airport taxiways and large scale intermittent repairs (patching) on interstate highways.

Super-Slab® pavement repairs and replacement can be made in rainy and colder weather that is typically prohibitive to cast in place installations.

More Implementation Work to be Done

While the successes of the above referenced projects represent real progress in the implementation of precast slabs as a viable repair material more work needs to be done by agencies and owners in discovering how to justify the extra costs by fairly evaluating life cycle and user costs. Precast slabs will always cost more than cast in place pavements but in situations where it is not feasible to do the latter precast may prove to be more cost effective alternative when all costs are considered.

Agencies will also need to discover how to specify and incorporate all viable precast pavement systems in the public bidding process, even proprietary ones, recognizing the value they bring in meeting the need for rapid concrete pavement repair.

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