Finding Buried Treasure Through Diamond Grinding Solutions

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Abstract

Many times in the past, an agency has overlaid a sound concrete pavement with asphalt concrete to improve the ride or noise characteristics. This may have been a cost-effective solution in the past, but with the recent increase in asphalt prices, this option is becoming too expensive. Current diamond grinding prices can be half the cost of an asphalt overlay and if the old concrete is still structurally functional, then diamond grinding becomes a cost-effective solution and allows for the recycling of the asphalt millings for future asphalt projects.

This paper presents a case study of a project completed in 2009. The project consisted of milling off the existing nova chip surface, repairing existing concrete pavement, and diamond grinding the surface. The selection process that the New Jersey DOT used to design and undertake the project, as well as the construction issues related to completing the work on a night-only construction schedule is described. Contractors were only allowed to work Monday night through Saturday night.

The diamond grinding contractor asked that the asphalt milling machines not cut into the concrete pavement. This required some Nova Chip removal by the diamond grinding equipment during the grinding of the existing concrete pavement.

The New Jersey DOT successfully completed a “buried treasure” project on a difficult urban construction scenario.

Introduction

Historically, concrete pavements have oftentimes exceeded their design life. This has allowed owners to defer concrete pavement preservation and to simply provide reactive maintenance repair activities as needed. Therefore, it could be inferred that concrete's long life works against it in terms of preservation strategies and activities.

Figure 1 indicates the traditional representation of when different strategies are applied to pavements. As indicated in Figure 1, the term preservation refers to treatments applied in the early stages of deterioration. These treatments could be applied for either functional or structural deficiencies.

In the last decade, the impact of approaching the peak oil point has become self evident, and could very well influence future pavement designs and preservation strategies. Figure 2 indicates the product pricing index for concrete and asphalt, along with the consumer price index. In addition, several inflation rate curves (e.g. 3.6%, 3.9%, and 5.5%) are also indicated. As evident in Figure 2, asphalt and concrete pricing inflate at different rates over time. Furthermore, the concrete inflation rate is below the consumer price index, while asphalt is significantly above the consumer price index. The asphalt PPI is better represented with an inflation rate of 5.5% while the concrete is best represented by an inflation rate of 3.6%.

It could be argued that the traditional notion of using a single discount rate for life cycle cost analysis (LCCA) is no longer appropriate and that proper LCCA can only be accomplished using actual commodity inflation rates to better account for future conditions. Assuming the CPI is the best predictor of future transportation buying power may very well become a thing of the past.

Similarly, it may become imperative to revisit historical preservation decisions in an effort to arrive at cost-effective future strategy selections. For example, during the 1970s and 1980s, it was common for agencies to use asphalt overlays to rehabilitate concrete pavement for both functional and structural deficiencies. With the rising costs of asphalt products, there is a need to revisit the previous strategies to "go back to the future". That is, if an asphalt overlay was placed on a concrete pavement due to functional reasons, it may very well be more cost effective to remove the overlay and initiate concrete preservation strategies. This technique of looking back at previous designs to identify future candidates has been termed "finding buried treasure" for this paper. The basis for such an approach should be self evident when comparing Figures 2 and 3. Figure 3 indicates the US National average diamond grinding costs over time for projects with 7,000 sq. yds. of grinding or more. Although there is variability from year to year, it is also evident that the costs have remained stable over the last decade and have not experienced the inflation rates indicated in Figure 2 for asphalt. As such, this strategy is more predictable for future costs and provides a significantly more cost-effective approach than asphalt overlays since few new materials are incorporated.

Finding buried treasure is the promotion of a systematic approach to identifying concrete pavements that were previously overlaid with asphalt concrete for functional reasons, but are still structurally sound. These projects should then be evaluated as candidates for removal of the AC and rehabilitation of the concrete surface.

The following is a case study conducted on a New Jersey DOT preservation project using this technique. The asphalt surface that was removed in this case example was Nova Chip, however, the technique is appropriate for any asphalt concrete surfacing that was applied for functional purposes.

New Jersey Case Study

Highway 21 in Newark, NJ, known locally as the McCarter Highway is an urban freeway. It has a 50 percent combination of elevated roadway using curbs and gutters for storm water drainage, and about 50 percent rural interstate design with paved shoulders and open ditch drainage into the Passaic River. The existing concrete pavement was constructed in three as-built projects: The first project in 1931, the second project in 1958, and the final project in 1971. The projects were constructed with 73-foot length panels and steel mesh. The pavement is 9 inches thick with 12 inches of aggregate sub base. Stainless steel dowels were used for load transfer.

The mesh was purposely placed in the top one-third of the pavement thickness to help control top down cracking from shrinkage of the concrete. The high location of the mesh subsequently led to many of the partial depth repairs on the project (overrun by twice the bid quantity). It also created concerns regarding milling into the concrete during the asphalt overlay removal since at some locations, the mesh was less than two inches in depth. This required all of the milling operations to be exact in order to leave as much of the old concrete as possible.

The contract was designed as nighttime only construction with the work hours extending from Monday through Saturday nights between the hours of 8 p.m. and 6 a.m.

The majority of the project is three lanes wide, with a ten-foot outside shoulder and one-foot inside shoulder. The project is 5.5 miles in length and extends from northbound milepost 5.01 to 10.57. In the southbound direction, the project extends from milepost 6.20 to 10.50 and is 4.3 miles long.

This section of Route 21 received two micro-surfacing treatments since it became a safety issue in the early 1990's with high wet weather accidents and less than desirable skid numbers. Because the 9 inch concrete pavement was structurally sound, only the concrete surface needed attention. The first micro surfacing was placed in 1993 to improve the skid numbers. A second micro surface treatment was placed in 2001 because of delamination of the 1993 micro surfacing. The total thickness removed in 2008 was about one inch with some localized areas of two inches maximum thickness.

Because the second micro surfacing was also suffering from delamination, Route 21 became a project again in 2008. It was determined that the old concrete was sound and in good condition, so the New Jersey DOT decided to try an experimental project on this roadway and employ the "finding buried treasure" concept. They decided to remove the asphalt overlay and diamond grind the underlying concrete pavement. In addition to the diamond grinding, the project included pre-cast panels for the full-depth repair areas as well. Partial-depth patches were accomplished using a flexible repair material called Techcrete. This product is a heated and flowable partial-depth repair material that stays flexible after placement.

Design and Bid Information

The project consisted of removing the existing asphalt overlay, and then diamond grinding the old concrete pavement underneath. Items included; asphalt milling, catch basin reconstruction, slab stabilization, pre-cast panels for full-depth repairs, and diamond grinding for the final ride and surface texture.

The underlying soils are silty sands and are susceptible to erosion beneath the transverse concrete joints. Due to the soil composition, the designers were concerned that voids existed and needed to be filled, so slab stabilization was included on the project. Polyurethane grout was chosen for the slab stabilization which was performed at each joint. Four hundred joints were stabilized in the northbound lane and 300 in the southbound lane.

Repairs

Slab Stabilization

Slab stabilization was accomplished using a polyurethane grout supplied by BASF Polyurethane Foam Enterprises, LLC. The actual grout was FE-800A-T-Isocyante and each transverse joint was stabilized. The process for each 12 foot lane, involved drilling four small holes (less than 3/4-inches in diameter) at each transverse joint (every 73-feet along the centerline) and then pumping polyurethane grout to fill voids under the concrete pavement (Figure 4). It took more material than was included in the bid quantities due to the soil in the area that was pumped out from under the transverse concrete pavement joints (Figure 5). Geo Tech Services, Inc. completed this part of the project in about four weeks. The bid called for 150,000 pounds of material equaling a total cost of $684,000. This item was overrun by approximately 80% indicating a lot of void area under each joint location. The worst voids were located on the oldest concrete pavement (1931). This was probably due to the sub base aggregate with the largest maximum stone size (i.e. greater than one inch top size) used in 1931. The newer pavement section built in 1971 had a much better gradation (top size ¾") for the sub base aggregate and does not pump as easily as the 1931 sub base material. The largest amount of grout material was used in the older pavement section due to the sub base and the fact these pavements received the greatest number of total wheel loads due to age of the 9 inch concrete pavement.

Catch Basin Repair

A major problem for this project was the need to lower drainage inlet structures after removal of the asphalt overlay. A great deal of this roadway included elevated sections with curbs, gutters, and catch basin inlets for storm water drainage. Many of the structures were old and in need of repair and this resulted in a quantity over run (Figure 6).

The other item that changed the nature of the project was the narrow inside shoulder at one foot or less. Typically, diamond grinding machines need a minimum side clearance of between 18 – 28-inches. In the areas of the narrow shoulder, the DOT decided to use an asphalt overlay. This resulted in approximately two miles of the northbound lanes and one mile of the southbound roadway being overlaid with asphalt.

Pre-Cast Panels for Full Depth Repairs

The Fort Miller Co. Inc. of Schuylerville, NY built the 4,900 square yards of precast panels. The cost was $472.89 per square yard for a total bid amount of $2,317,161. Standard precast panel sizes were constructed as follows: 12 feet by 9 feet, 12 feet by 10 feet, 12 feet by 14 feet. If a cut in the field was made too large by the contractor's forces, then the contractor had to remove enough extra pavement to allow placement of a second precast panel. This did not happen often, but did allow some flexibility in patch area sizes during nighttime construction schedules as extra precast panels were always available.

Using the standard sizes as guides, full-depth repairs were marked in the field, and then The Fort Miller Company made each pre-cast panel for every full-depth repair area. The field process involved the following steps:

- Measure and order the pre-cast panel.
- Remove the old pavement (Figure 7).
- Rough grade and back fill the area with black recycled granite sand (Figure 8).
- Check the depth using a simple template for depth off the edge of remaining pavement (Figure 9).
- Tamp with a 12-inch by 12-inch plate compactor.
- Final grading is done with a metal screed for accuracy and the grade was left ¼-inch high (Figure 10).
- Drill and grout dowel bars on transverse joints (four in each wheel path) and when needed longitudinal joints as well with #19 metric reinforcing bars (Figure 11) which was done with a HD-50 fast setting grout.
- Place pre-cast panels and grout into place with a bedding grout that set in two to three hours. (Figures 12-13).
- Finally, diamond grinding was accomplished for final riding surface and friction.

The subgrade backfill material was obtained locally from the waste in the production of gravel for roads. This material has the ability to achieve 75% of its compaction upon placement and is easily compacted to a suitable level with plate compactors for small or large patch areas.

The pre-cast panels have strips of foam that are about ¼-inch thick and four inches wide cast in the bottom of the panel to be embedded into the recycled granite sand sub-base material (Figure 14).

The panels are lowered by a crane and the eye hooks are removed after placement of the panel (Figure 15). To lock the panel in place, grout was pumped through the holes near the dowels and under the panel to level it to the slope of the roadway (Figure 16).

Partial-Depth Repairs

Partial-depth repairs had to be able to carry traffic in a very short amount of time, so the design called for the use of proprietary patching material poured into the partial-depth patch area. The product used by the contractor was a CRAFCO Inc. product called TechCrete. This product is a hot-pour repair solution that is different from conventional, rigid-repair methods. TechCrete remains flexible with a high tensile strength and has excellent adhesion to concrete surfaces. The final nature of this material is a rubber-like compound that bonds to the concrete surface to allow for movement but does not crack or de-bond. Normal cleaning and sandblasting operations have to take place ahead of the patching material (Figure 17). The material requires that the patch area be primed before placement of the TechCrete into the patch area (Figure 18). A friction layer of black granite sand was added to the top of the patch material. The diamond grinding equipment was able to cut through the tops of these patches without damaging the TechCrete. The challenge was with the diamond grinding equipment picking up rubber debris from the cutting action which congested the blades and pumps.

Diamond Grinding and Removal of Asphalt Overlay

The diamond grinding contractor, Northern Improvement Company (Figure 19) asked the asphalt contractor to leave a little of the asphalt on the concrete surface. If the asphalt milling machine went too deep, it would leave low pockets where the aggregate particles would break off. If these low areas exceeded ¾-inch, it would take at least two passes of the diamond grinding machine to cut to the bottom of the low spot. This left the project with an unfinished look and some thin layers of asphalt were left after the diamond grinding was completed (Figure 20). Figures 21 & 22 indicate a close-up side view of the concrete pavement using a quarter for scale, after some heavy removal of the asphalt overlay. Figure 23 indicates the final diamond ground surface after completion.

The diamond grinding contractor indicated that the material used for the partial-depth patches caused some problems with the grinding equipment. When the patches were small (less than two-feet by two-feet,) the

rubberized material removed by the diamond grinding machine was washed out of the blades and caused no problems. When the partial-depth patches were large (greater than two-feet by two-feet) the extra rubberized material got stuck between the blades, preventing cooling water from reaching the diamond blades correctly. This problem has subsequently been eliminated by the TechCrete product.

While there was not a specification for ride on this project, the final ride is excellent and provides the public with an improvement over the old asphalt surface. The diamond grinding contractor stated that a lot of the old concrete pavement material was removed at every other joint. This indicates a high degree of curl at the joints, which is to be expected with long panel lengths (73-feet). Cut measurements at most joints were at the one-inch level at every joint and as high as one and ¼-inch at every other joint. The concern by the engineers was the depth of steel mesh from the final surface elevation after diamond grinding. Currently, no problems have occurred.

The bid price for the removal of the hot mix asphalt overlay was $784,245 for 266,750 square-yards at a unit price of $2.94 per square yard. The bid price for the diamond grinding was $1,963,280 for 266,720 square-yards at a unit price of $7.63 per square yard.

Joint Resealing

The joints were resealed with a hot pour material after all repairs and diamond grinding were completed (Figure 24). Both transverse and longitudinal joints were re-sealed.

Removal of Diamond Grinding Slurry and Asphalt millings

The prime contractor, Crisdel Construction Inc. built a retention dike system near the project for collection of the diamond grinding slurry waste. By placing a layer of plastic on the grade and using the asphalt millings to make a dike around a retention pond, the diamond grinding contractor was able to unload the slurry quickly and safely. After the slurry dried via evaporation, the remaining aggregate chips minus 200 materials can be recycled into a gravel base. The asphalt millings can be either added to the gravel base or sold by the ton as recycled asphalt product into a future asphalt project.

Ride Information

The ride data indicated that the existing micro surfacing had an average IRI of 161 inches per mile as measured by the New Jersey DOT in December of 2007.

After completion of the removal of the asphalt layer, the ride increased due to the rough texture of the milled concrete surface. The average IRI was 223 inches per mile.

After diamond grinding was completed, the average ride was improved by over 30% from the initial IRI of 161 inches per mile. The final ride had an average IRI of 112 inches per mile as measured by the New Jersey DOT on February 11, 2009.

Summary and Potential for Other Projects

This project proved that an effective concrete preservation strategy was to remove a previously constructed asphalt overlay, repair the existing concrete, and then diamond grind the entire surface (e.g. finding buried treasure). The resulting ride was superior to the old micro surface treatments (at six years) and the concrete pavement still had the structural ability to carry today's heavy traffic load. While this project was a difficult project, it proved that an urban freeway with curb and gutter drainage can be rehabilitated with concrete repair techniques under a night-only construction schedule.

With advancements in ground penetrating radar, it is possible to determine if voids exist beneath old concrete pavements overlaid with asphalt concrete. If cores are obtained for concrete strength, it is also possible to use Dynamic Cone Penetrometers to characterize sub bases and subgrades. Falling weight deflector data can help pavement engineers determine the strength of composite pavement systems and the benefit from the old concrete pavement if values can be obtained before and after placement of the asphalt overlay. The use of high speed vans by DOT's for ride measurements can help engineers determine when to schedule preservation work.

If the price of asphalt cement remains at its present high values, then the value of the asphalt millings has to be considered in the overall cost of a concrete rehabilitation project with an existing asphalt overlay. If, through investigation, an agency can determine the soundness of the concrete, then CPR and diamond grinding can be cost effective tools to restore ride and improve the longevity of an old concrete pavement. The value of the old asphalt pavement can be used to offset the cost of removal and possibly some of the diamond grinding cost as well. This will be depended upon on the thickness of the asphalt layer and the value of recycled asphalt product (RAP) in the local market. Using the bid tabs on this project, it was determined that a one inch micro surfacing overlay generated approximately 0.05 tons of RAP per square-yard. A value of twenty dollars per ton for asphalt millings could

generate one dollar per square yard per inch of asphalt overlay. This value can be taken into account at the time of bids by the private industry the same as it has been done in the past for asphalt mill and overlay projects. Unfortunately, the asphalt millings on this project were used as a dike system to contain the diamond grinding slurry and as such got too contaminated to be of value to asphalt contractors. The material was used a recycled base material.

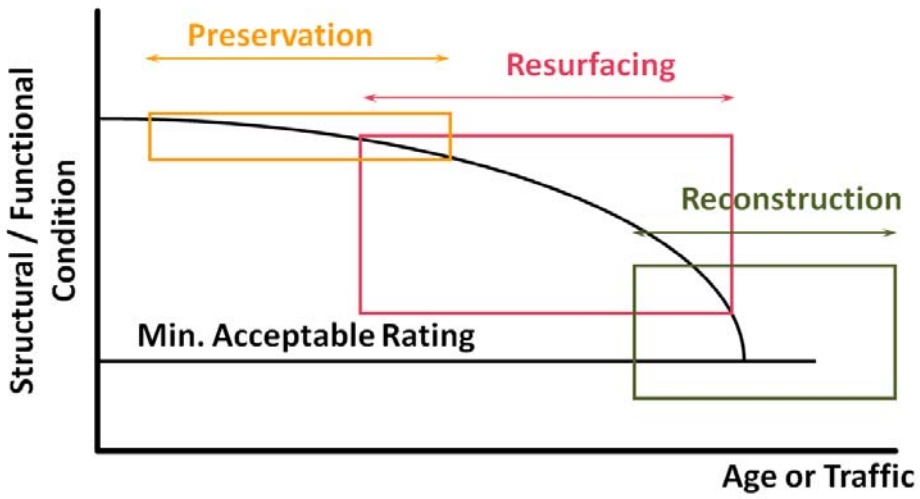

Figure 1 Timing of Typical Concrete Pavement Restoration Activities

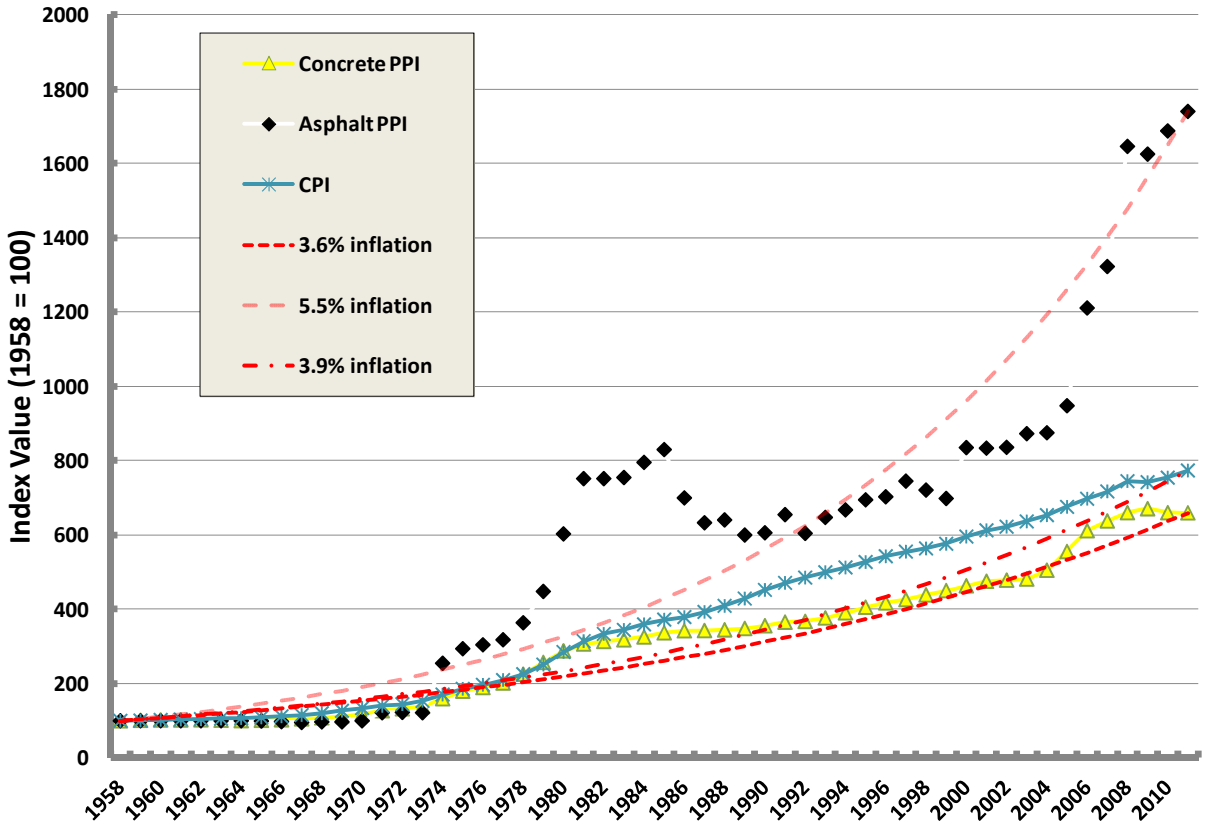

Figure 2 Commodity Price Increases Over Time

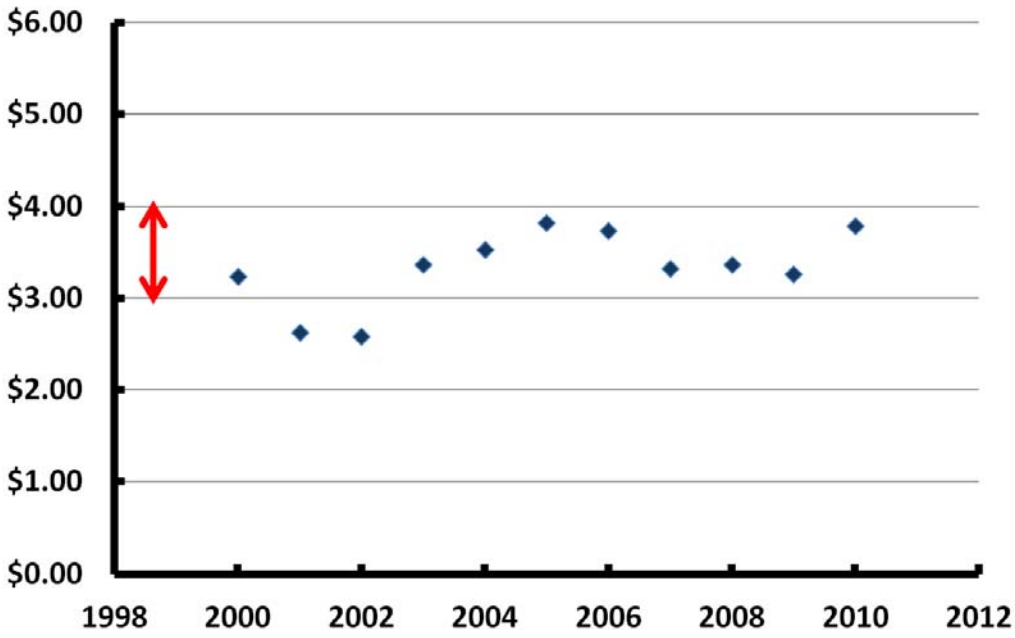

Figure 3 National Average CDG Costs for Projects Greater than 7,000 Sq Yds

Figure 4. Photo of Grout Placement on Both Sides of Joint

Figure 5 Grout Leaving Check Hole

Figure 6 Deteriorated Catch Basin After Removal of Pavement

Figure 7 Removal of Existing Pavement

Figure 8 Placement of Sand Backfill Material

Figure 9 Template for Checking Depth of Sand Backfill Material

Figure 10 Rail Screeds in Place for Final Subgrade Check Before Pre-cast Panel Placement

Figure 11 Grouting of Dowels into Existing Pavement

Figure 12 Full Depth Area Ready to Receive Pre-cast Panel

Figure 13 Staging Area on Roadway for Pre-cast Panels

Figure 14 Placement of Pre-cast Panel (notice black styrofoam on underside of pre-cast panel)

Figure 15 Final placement of Pre-cast Panel Using 4 Dowels per Wheel Path

Figure 16 Holes for Grouting Dowels and a Section of Damaged Concrete That was Filled with Grout

Figure 17 Partial Depth Repair Area After Removal of Existing Concrete and Sandblasting (Note the height of steel mesh)

Figure 18 Area primed for placement of patch material

Figure 19 Diamond Grinding Equipment Removing Asphalt

Figure 20 Showing Asphalt Left in the Wheel Path Low Areas

Figure 21 Surface After First Pass of Diamond Grinding Equipment

Figure 22 Final Surface After Diamond Grinding

Figure 23 Finished Diamond Ground Surface

Figure 24 Joint Resealing at Night