Pavement-Salvaging Experience on the Pennsylvania Turnpike

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This paper outlines the experiences of the Pennsylvania Turnpike Commission in salvaging concrete pavement with bituminous overlays and in salvaging bituminous pavement with either a bituminous overlay or a surface treatment. Design features, specification requirements, construction operations, and problem areas are outlined briefly. This is not a research paper and is not so intended. It is an informative paper only.

•THE PENNSYLVANIA TURNPIKE heads into its thirtieth year in 1970, bigger and better in every respect than the original toll road that opened to the public on October 1, 1940.

The Turnpike was authorized by the General Assembly of the Commonwealth of Pennsylvania on May 21, 1937. This first of the modern turnpikes had a modest beginning and an uncertain future. The 4-lane highway started in Irwin in Westmoreland County, crossed the Appalachian Mountains, and ended in the little town of Middlesex in Cumberland County, a distance of 160 miles.

Many doubters appeared on the scene when the turnpike concept was first mentioned. Few people had enough foresight to anticipate the welcome a superhighway would receive from the average motorist. The facility was referred to by many names—some complimentary and some uncomplimentary.

Two weeks after the road was opened to traffic, an average of 26,000 vehicles used the scenic highway daily. Today, more than 140,000 vehicles use the facility daily.

Since the opening of the original section, 4 extensions have been built to the original 160 miles to make its present length 470 miles. The Turnpike now extends from the Ohio-Pennsylvania line eastward to the New Jersey-Pennsylvania line and northward from the Philadelphia area to the city of Scranton.

The rapid growth of the Turnpike, from 160 miles in 1940 to 470 miles in 1957, is all the more remarkable because all construction work is paid for out of tolls collected from the users. Taxes are not utilized for Turnpike construction, maintenance, or operations.

DESIGN FEATURES

Design and construction on the original section of the Turnpike took place in the middle and late 1930's, and traffic began using the roadway in October 1940. When the Turnpike was opened to traffic it was considered to be one of the finest highways ever constructed. In fact, many features incorporated into this facility were so modern that they have been incorporated into the Interstate System, but on a much larger scale than was ever anticipated at that early date. Think about these modern ideas and the place they play in today's superhighway design: limited access, fenced-in facility; access at interchanges only; no at-grade crossings of highways and railroads; opposite traveling lanes of traffic divided by a 10-ft median, thought by many at that time to be excessive; service plazas, roadside rest areas, and roadside picnic tables; maximum grades of 3 percent; high speed limit of 65 mph; and patron service and roadway patrols 24 hours every day.

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The fact that all of these features—except the service plaza and patron service concepts—have been incorporated into the Interstate System points out the foresight of the designers of this pioneering road construction program.

As I indicated earlier, the original section of the Pennsylvania Turnpike was opened to traffic during the latter part of 1940. The design features for this section consisted of the following:

1. Two 12-ft reinforced concrete lanes 9 in. in depth on each side of a 10-ft grass median;
2. A straight slope $1\frac{1}{4}$ in. per 12-ft lane and $1\frac{3}{4}$ in. per 12-ft lane on the median and shoulder lanes respectively;
3. No special subgrade;
4. Shoulders 10-ft wide in both cut and fill sections, but not paved or stabilized, with slope on the fill shoulder $\frac{1}{2}$ in./ft, and slope on the cut shoulders $\frac{3}{4}$ in./ft for the first 7 ft and $1\frac{1}{2}$ in./ft for the remaining 3 ft; and
5. A right-of-way of 200 ft.

Although many of these design features were adequate at that early date, the large increase in passenger car and heavy truck traffic after World War II had a tremendous effect on the roadway surface. So great was the effect that in the early 1950's the original pavement began to show extreme signs of deterioration. The Commission decided to undertake an extensive salvage program soon thereafter. No attempt was made to increase the design strength of the pavement except the increase that resulted through the additional depth due to the overlay.

SEQUENCE OF ORIGINAL SALVAGE OPERATIONS

This salvage program consisted of the following progressive sequential operations to effect the necessary repairs over the original 160-mile section:

1. Concrete slabs removed where deterioration or adverse drainage conditions necessitated such action and subgrade and drains placed before replacing the concrete;
2. Hot asphalt underseal introduced to fill the voids beneath the slabs and to provide a more stable base for concrete pavement but not to change pavement elevation (Pennsylvania Class U-1 asphalt cement at a temperature of 400 F ±25 F introduced under pressure was used to effect the underseal);
3. Mud jacking used to provide a smoother riding surface in a few isolated areas where uneven pavement settlement was evident (in these areas a cement slurry pumped beneath the slab was used to raise the pavement to the proper elevation);
4. Six-inch perforated or porous pipe placed to drain the roadways where underdrain had not been placed previously or where existing underdrain was not functioning; and
5. Concrete pavement resurfacd with bituminous material and median and shoulders stabilized with an asphalt and aggregate mixture compacted in place.

Salvaging work was undertaken during the summer of 1954 and was completed during the summer of 1962. The work consisted of the resurfacing of the pavement including interchange ramps, approach lanes to service stations, bridges, and other Turnpike facilities with a 2-course bituminous hot mix designated as an ID-2 mix in the Pennsylvania Department of Highways Specification Form 408. The binder course was placed to a 2-in. compacted thickness, and the top course was placed to a 1-in. compacted thickness.

SPECIFICATION REQUIREMENTS

The Pennsylvania Department of Highways specification was supplemented to meet the following Commission requirements:

1. Class A-1 asphalt cement with a penetration range of 70-80 and a specific gravity at 77 F with a minimum of 1.010;
2. Slag sand and slag coarse aggregate in the wearing course;
3. Either stone or slag coarse aggregate in the binder course; and

4. Binder and wearing courses with the following stability and density requirements: stability (Marshall method) of binder course 800 minimum and of wearing course 1,500 minimum, flow value (Marshall method) 16 maximum, density of laboratory-compacted mixture in percentage of calculated voidless mixture of same materials 94-96, and compacted field density in percentage of laboratory compacted density 95 minimum.

The work proceeded as required, and a smooth riding surface was obtained.

SURFACE-TREATMENT EXPERIENCES

The resurfacing work just discussed was undertaken at a rather late stage in the deterioration of the original concrete pavement. This factor along with continual heavy traffic growth caused accelerated wear and tear on the salvaged pavement, which required repair work on some sections in the early 1960's.

Consideration was given to the type of repair to be utilized. Plant mix overlays and surface treatments were the 2 methods considered. The decision to utilize a surface treatment was made after much discussion and deliberation by Commission personnel, inasmuch as some members of the staff felt that a surface treatment would not hold up under the traffic volume encountered on the Turnpike and that the surface might tend to become fatty.

In May 1961 eleven experimental test patches were placed in the Allegheny Mountain area. Each patch was 1 by 9 ft and extended across the driving lane so that both wheels of a westbound vehicle would cross the patch. After several weeks of observation, Test 9, 0.25 gal of F-2 emulsion covered with fine slag aggregate, proved the most satisfactory. In order to substantiate this result, a 1,500-ft patch covering the entire 24-ft lane was placed at milepost 129, eastbound. Visual inspection of this patch indicated that good results could be expected from a surface treatment.

After thoroughly discussing the problem with representatives of The Asphalt Institute, with asphalt suppliers, and with its consulting engineer, and after reviewing various test patches utilizing different types of aggregate, the Commission decided to proceed with a surface treatment of slag aggregate and an F-2 asphalt emulsion on 17 miles from milepost 123 to milepost 140.

Slag aggregate was found to give the best results on the test patches simply because it did not polish or become slippery under traffic. The conclusion has been further verified by checking the surface treatments placed during 1961 and thereafter.

Placement of the surface seal was done in the usual manner with bituminous pressure distributors and stone spreaders. All areas at transverse and longitudinal joints that showed reflection cracks greater than ½ in. width, spalling, or raveling were replaced prior to application. Similar repair work was also done in some areas in the surface where excessive alligatoring was observed.

Slag was delivered to assigned locations prior to the start of the job. Here experience taught us a lesson. We found that we could utilize the haul trucks for additional rubber-tire kneading if we located the stockpiles near the starting point of the work.

Traffic was diverted to one side of the median, and 0.25 gal/sq yd of 150 to 160 deg F-2 asphalt emulsion was placed by 2 distributors each spreading a 12-ft wide pattern. Two 12-ft wide Flaherty spreaders placed 15 lb of slag per square yard. Rolling was done by three 10-ton steel tandem rollers—one tandem at each edge and one 3-wheel roller between them. Three passes were made, and the steel rollers continued. Back-rolling was done by two 10-ton pneumatic rollers.

Gradation tests were made for every 100 tons delivered, and a very close inspection resulted in obtaining the best possible material.

I think I should point out a few specific details concerning this operation at this time. Seventeen miles of the eastbound roadway from milepost 123 to milepost 140 was surfaced-treated on September 12, 13, 14, and 15, 1961. Six miles of the westbound roadway from milepost 123 to milepost 129 was surface-treated on September 18. The ranges and weather conditions on the respective dates were as follows:

Date	Temperature	Weather
September 12	74 to 94	Clear
September 13	72 to 96	Clear
September 14	68 to 90	Clear
September 15	53 to 70	Cloudy
September 18	46 to 74	Clear during the day, rain in the evening

Traffic was permitted to use the roadway 4 hours after the completion of the rolling operation. No detrimental effect was noted due to the early use by traffic on the sections treated on September 12, 13, and 14. The same cannot be said about the sections completed on September 15 and 18. The day after the portion placed on the fifteenth was opened to traffic, the roadway surface showed some signs of distress and excessive streaking. The Commission staff felt that this condition could be traced to the lower temperatures experienced on that day. A different type of problem was experienced on the 6-mile section placed on the eighteenth. A rain storm developed soon after this section was opened to traffic. The roadway surface—on a 3 percent upgrade with heavy truck traffic concentration—showed some signs of serious distress the following day. A considerable amount of slag chip-off and some asphalt carry-over was noted in the wheel tracks.

SURFACE-TREATMENT REPAIRS AT PROBLEM AREA

Repair work on this 6-mile section was carried out on September 22 and 23. Repairs were made on one 12-ft lane at a time under varying methods and strict controls during placing operations.

Asphalt was placed at a rate of 0.2 gal/sq yd on the entire section, and slag—dried and heated to a temperature of 300 deg—was then placed and rolled. Traffic was restricted for a 36-hour period after rolling operations were completed. The other 12-ft lane was repaired with unheated slag and traffic was restricted for an 18-hour period. The temperature range during repair work was from 71 to 92 F.

Some slight bleeding was noted, but this was corrected by a dust application. The surface seal—on both the repaired and the unrepaired sections—held up equally well.

REVISED SURFACE-TREATMENT PROCEDURES

Additional surface treatments have been placed at other locations since that first project in 1961. The same application rate and equipment were utilized as those mentioned earlier. Several minor changes were made, however, for experimental purposes.

After finish-rolling for several hours with rubber-tired rollers, traffic was permitted on the completed surface under 2 separate and distinct methods. In one case, traffic was permitted to use the surface on completion of rolling and 1 hour prior to darkness. In the other case, traffic was not permitted to use the surface until the following day. No appreciable difference was noticeable on the lanes regardless of the method of traffic control.

SURFACE-TREATMENT COSTS

The cost per two 12-ft wide lanes per mile for the various sections ranges between $1,400 and $2,100. The average per mile costs for calendar years 1962, 1963, 1964, 1965, 1967, and 1969 were $1,706, $1,422, $1,681, $1,605, $1,623, and $2,057 respectively. Variations in costs seem to be dependent on the length of the project and the traffic volumes encountered in the given area rather than on the material and labor cost index for the given year. These costs compare favorably with the costs used by the Pennsylvania Department of Highways for its surface seal projects. Department estimates are based on a range from 10 to 12 cents/sq yd. Based on the 12 cents/sq yd figure, the cost per mile for a roadway comparable to ours would approximate $1,686. Considering the high volume of traffic on the Turnpike and the necessary traffic controls that are required for adequate patron safety, I feel that our costs are more than realistic. This is especially true when compared with Pennsylvania Department of Highways costs because most highway surface seal jobs are done on low-volume rural roadways where extensive traffic controls are not required.

One of the unknown factors to us was the actual cost of the various operations involved in surface-treatment work. At least we had never broken these costs down in a refined manner. We decided to do just that on our latest job. On a sq-yd basis our costs were as follows:

Item	Cost
Traffic control	$0.01
Labor and equipment	0.035
Material	0.07
Total	$0.115

Traffic control—although a minor item normally—accounts for 8.7 percent of the total cost. This is higher than we thought it would be.

Aggregate gradation in surface-treatment operations were as follows:

Screen	Percent Passing
3/8 in.	100
1/4 in.	60-80
No. 4	25-45
No. 8	0-10

PRESENT PAVEMENT-SALVAGE PROCEDURES

In 1965 it was evident that 32 miles of the originally resurfaced roadway was in need of extensive repairs to preserve the riding quality and to prevent deterioration of the bituminous surfacing placed earlier. This section extended from Irwin to the Laurel Highlands of the Alleghenies. Extensive lengths on 3 percent grades and increasingly heavy volume of truck traffic were responsible for the deterioration.

The roadway was repaired by removing distressed areas and patching with a bituminous wearing course material. Most of the distressed areas were over the existing concrete pavement joints and resulted from pumping action of the pavement. Additional drainage and concrete pavement replacement was necessary to repair this condition. We also discovered that in many instances the 6-in. underdrain placed earlier to prevent such pumping action was no longer functioning and required replacement. The extent of these repairs further indicated the adverse effects of the increased traffic and truck loadings.

After considerable investigation by and discussion among all interested parties, we decided to improve the entire roadway, including shoulders and drainage, during resurfacing operations. The selection of the methods to be used was complicated by the necessity to maintain traffic during operations with minimum disturbance to the patrons. Complete repaving of the roadway and removing and replacing the existing 3-in. bituminous surface were 2 repair methods considered. Because it was not economically feasible to rebuild the entire roadway and because all agreed that the base was satisfactory, we decided to utilize the same resurfacing technique over the bituminous surface as was used previously over the concrete surface. Specifications were upgraded, however, to reflect our experience as well as to utilize the latest thinking regarding materials, equipment, and construction methods.

The first operation consisted of placing 6-in. perforated underdrain within the median to provide additional subgrade drainage. All unsatisfactory existing underdrain along the pavement edge was replaced. Numerous sections of this underdrain were found to be clogged with fine silt. Additional outlets were located to facilitate drainage and to prevent a recurrence of the drainage problem.

The median and shoulders were then reconstructed with aggregate to provide an adequate base for a bituminous paved shoulder capable of supporting traffic. After the pavement was repaired and cleaned of all patches and joint material, a leveling course was placed. The leveling course was either the standard bituminous wearing course or the binder course material used for bituminous surface course. The mix was dependent on the depth of application.

The roadway was then resurfaced in the usual bituminous paving sequence. After the shoulders and median were resurfaced with a bituminous course-binder material, they were sealed with 2 applications of asphalt cement aggregate.

Reconstruction of drainage structures to the revised roadway elevation and construction of additional drainage facilities were necessary as a result of this extensive repair work.

The Pennsylvania Department of Highways specifications were used as a general specification but were modified to meet Commission requirements. These modifications changed the previous Commission specifications by (a) requiring Class AC-2000 asphalt cement, which was similar to the Class A-1 previously used except that the designation reflects the viscousness of the asphalt; (b) increasing the stability of the binder course to 1,500 minimum; (c) decreasing the percentage voids allowable per total mix to 3-6 for binder course and 2-5 for wearing course; (d) increasing the percentage aggregate voids filled to 65-75 for binder course and 82-90 for wearing course; (e) providing for a more positive means of control to ensure a satisfactory mix (the compacted field density was changed from 95 percent of the laboratory compacted density to 95 percent of corresponding daily compacted specimen density); (f) requiring 4 hot bins for binder course material separation in lieu of the 3 previously specified to provide more consistency in the mix; (g) predrying slag aggregate and storing in covered supply areas so that the hot gases could escape and yet the aggregate would not be subject to an increase in moisture content; (h) regulating the temperature of the asphalt cement in the mix to yield a kinematic viscosity within the range of 280 and 150 centistokes; (i) requiring that paving machines be controlled electronically to maintain the desired slope and grade; and (j) operating tandem pavers within 150 ft of each other to prevent the formation of cold longitudinal joints.

With the exception of items e, f, g, and j, which were changed as a result of our experience, these changes were made to incorporate the latest asphalt technology into our overlay projects.

Although these repair methods may seem extensive, they enable the Turnpike Commission to provide a satisfactory roadway capable of handling the heavy traffic volumes and loadings common today on all major highways. Further, we feel that, in our situation where the comfort and protection of the user is considered of prime importance and where alternate Turnpike facilities are not available, the cost, although high, is fully justified especially when the extended roadway life is considered.

We have repaired 33 miles of the originally salvaged pavement to date, and we are currently salvaging 10 additional miles of concrete pavement with a bituminous overlay. The average cost per 12-ft lane-mile exclusive of the cost of bridge repair and traffic control for the last 43 miles repaired in this manner is $60,000.

BRIDGE DECK PAVEMENT SALVAGE

Salvage of bridge deck pavement is probably the most serious of all bridge maintenance problems, and the Pennsylvania Turnpike Commission has experienced its share of problems in this area. The causes for deck deterioration are many and varied and have been discussed in many articles on the subject. Regardless of the cause, repairs must be made immediately if complete deck failure is to be prevented.

We have utilized several methods to correct bridge deck spalling failures. The treatment is dependent on the condition of the deck at the time repairs are made. Where possible, we use our own forces to make the necessary repairs. On major failures, however, we contract for the required corrective measures.

We have placed linseed oil treatment in several critical areas in an attempt to prevent and curtail deterioration caused by freezing and thawing or the use of de-icing chemicals. The results to date indicate that some beneficial effects are obtained. Generally, our maintenance forces correct spalled conditions by using the following procedure:

1. Saw a vertical edge around the limits of the crack;
2. Use a light chipping hammer to clean out all deteriorated concrete until sound concrete is exposed;
3. Remove all dust and chips with air, water, or brooms;
4. Apply a premixed mortar paste to the entire surface including the vertical face;
5. Place a metallic aggregate concrete in the hole while the paste is still wet or tacky and finish concrete in the normal manner; add stone in those areas where the holes extend 1 or 2 in. in depth; and
6. Cure with wet burlap for at least a 72-hour period.

The nonshrinking premixed mortar we are now using consists of 1 part iron aggregate, 2 parts cement, and 3 parts sand aggregate delivered to us in 100-lb bags. The nonshrink metallic aggregate is also delivered in 100-lb bags. Stone is added to the mix in those areas where the holes extend 1 or 2 in. in depth. The premixed materials are furnished by the concrete service company and the mortar is designated as C-S-C premixed shrink-proofer mortar. Embeco and Perma Cement have also been used in lieu of the C-S-C mortar and aggregate.

These patches prove to be excellent repairs when they are properly placed and cured. Maintenance repair longevity, however, like new construction is dependent on good workmanship.

As indicated earlier our major repair work is performed under contract, and we have had many bridges repaired by contract. Preparatory for, and incidental to, the resurfacing of bridge decks, the contractor is required to remove and dispose of all bituminous patch material and all loose and unsound concrete. Final cleaning, which is accomplished by air-blasting, is carried on immediately ahead of the tack coat operations. Immediately following the final cleaning of the bridge deck the contractor is required to apply a tack coat of Class F-3, Type 2, asphaltic emulsion. The rate of application is determined by the engineer on the basis of furnishing an asphaltic residue on the surface from 0.04 to 0.07 gal/sq yd.

Following the tack-coat operation, the surface of the bridge deck is brought to proper section by the placement of a scratch coat of bituminous surface course JA-1 material. The material is placed by means of a finishing machine over the full width of deck in a manner to fill all irregularities and to bring the surface just slightly above the normal surface of the deck's concrete wearing surface. Compaction of the material is made by a pneumatic-tired roller, and rolling is continued until all areas are thoroughly compacted. The bituminous binder course ID-2 utilizes an asphalt cement having a penetration range of 70 to 80 and a minimum specific gravity at 77 F of 1.010. Slag coarse aggregate is used for the binder course. The Marshall method is used to determine the plant formula and the mixture must meet the following Marshall stability test requirements:

Requirement	Minimum
Stability	1,500
Flow value	8-16
Percentage voids, total mix	4-6
Percentage aggregate voids filled	65-72

The bituminous surface course utilizes an asphaltic material with a 70 to 85 penetration. The mineral aggregate is usually a mixture of slag sand and snuff sand meeting the specifications of the Pennsylvania Department of Highways.

Results to date from using the methods described have been satisfactory.