Maintenance Experience on the Pennsylvania Turnpike

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INTRODUCTION

The original section of the Pennsylvania Turnpike, from Middlesex to Irwin, was opened to traffic during the latter part of 1940. The design features for this section consisted of the following: two 12-ft. reinforced concrete lanes 9 in. in depth on each side of a 10-ft. wide grass median, the median and shoulder lanes had a straight slope of 1¼ in. per foot and 1¾ in. per foot respectively, special subgrade was not utilized, shoulders were 10-ft. wide in both cut and fill sections. Slope on the fill shoulder was ½ in. per foot whereas the slope on the cut shoulder was ¾ in. per foot for the first 7 ft. and 1½ in. per foot for the remaining 3 ft. and the shoulders were not paved or stabilized.

Although the design was adequate and superior at that early date, many features certainly were inferior when compared with today's traffic needs and design requirements. These facts resulted in the awarding of numerous construction contracts by the Commission to continually improve the facility and to help keep it in a good state of maintenance.

MAINTENANCE PROJECTS

The projects were many and varied. The work encompassed by the contracts included bituminous resurfacing, installation of medial barrier guard rail, special slab replacement, undersealing, installation of tile underdrainage, median stabilization, bituminous treatment of shoulders and median, painting of steel bridges, interchange modernization expansion or replacement, service area improvements, maintenance building enlargements or replacements, major structural repairs, major roadway repairs, and some experimental work.

A brief outline of the cost and number of contracts awarded in these areas will provide some idea of the scope of the work involved. More detail on the bituminous resurfacing and bridge repair phases will be given in the following pages.

The contracts awarded and the amounts involved are as follows:

TYPE	CONTRACTS	COST ($)
Experimental	2	20,000
Major roadway repairs	5	272,500
Major structure repairs	5	390,500
Maintenance buildings	4	843,000
Service areas	7	2,007,800
Painting steel bridges	18	311,307
Bituminous treatment of shoulders and median	8	532,700
Median stabilization	5	931,300
Tile underdrain	4	507,700
Undersealing	11	2,464,400
Special pavement repairs	19	3,940,306
Median barrier guard rail	10	4,775,600
Bituminous resurfacing	14	9,811,000
Totals	112	26,808,111

The magnitude of the work performed was large and the dollar value was quite high. These costs do not include any inspection, supervision, testing, or other special expenses that are associated with construction projects. They include contractor payments only. All necessary annual maintenance work expenditures are likewise not reflected in these amounts. Many of these items will not be a factor on today's newly constructed highways since design standards call for their incorporation into the initial construction phases.

RESURFACING OF THE ORIGINAL 160 MILES

One of the larger work items involved the bituminous resurfacing of the original 160-mile section, and the additional problems in maintaining this surface which occurred later. This section of pavement began to show extreme signs of deterioration in the early 1950's. The Commission decided to undertake an extensive resurfacing program soon thereafter.

Resurfacing 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 two-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.

The Pennsylvania Department of Highways specification was supplemented to meet certain Commission requirements. The special supplemental specifications called for the following:

1. Class A-1 asphalt cement with a penetration range of 70-80 and a specific gravity at 77F with a minimum of 1.010 was required.
2. Slag sand and slag coarse aggregate must be used in the wearing course.
3. Either stone or slag coarse aggregate could be used in the binder course.
4. The binder and wearing courses shall meet the following stability and density requirements:
   (a) Stability—Marshall Method: Binder Course—800 minimum; Wearing Course—1500 minimum.
   (b) Flow Value—Marshall Method, 16 maximum.
   (c) Density of laboratory compacted mixture in percent of calculated voidless mixture of same materials, 94-96 percent.
   (d) Compacted field density in percent of laboratory compacted density, 95 percent minimum.

The work proceeded as required and a smooth riding surface was obtained. However, the resurfacing work was undertaken at a rather late stage in the deterioration of the original concrete pavement. This factor caused accelerated wear and tear on the resurfacing project which required repair work on some sections in the early 1960's.

Consideration was given to the type of repair to be utilized. The use of a plant mix overlay or a surface treatment were the two methods considered. The decision to utilize a surface seal was made after much discussion and deliberation by Commission personnel since some members of the staff felt that a surface treatment would not hold up under the traffic volumes involved on the Turnpike and they further felt that the surface might tend to become fatty.

After thoroughly talking over the problem with representatives of the asphalt institute, with members of asphalt suppliers, and with the Turnpike consulting engineer, and after reviewing various test patches utilizing different types of aggregate, the Commission decided to proceed with a surface treatment on the area from milepost 123 to milepost 140 —17 miles in length—using slag aggregate and an F-2 asphalt emulsion.

Slag aggregate was found to give the best results on the test patches simply because it did not polish or become slippery under traffic. This fact has been further borne out by checking the surface treatments placed during 1961 and since that time.

Placement of the surface seal was done in the usual manner. All areas at transverse and longitudinal joints, which showed signs of 1- to 2-in. wide reflection cracks, spalling, or raveling, were replaced prior to the application. This repair work was also done in some areas in the surface where excessive alligatoring was observed.

Traffic was diverted to one side of the median and 0.25 gallons of F-2 asphalt emulsion per square yard at a temperature of 150F to 160F was placed by two distributors each spreading a 12-ft. wide pattern. Two 12-ft. wide Flaherty spreaders placed 15 pounds of slag per square yard. Rolling was done by two 10-ton steel tandem rollers and two 10-ton pneumatic rollers. The atmospheric temperature for this particular 17-mile section ranged from a low of 46F to a high of 96F.

Traffic was permitted to use the roadway four hours after the completion of rolling operations.

Ten miles of the westbound roadway, from milepost 130 to milepost 140, 30 miles of the westbound roadway, from milepost 67 to milepost 97, and 25 miles of the eastbound roadway, from milepost 67 to milepost 92, was surface sealed during July, August and September of 1962, and 25 miles of the eastbound and westbound roadway was surface sealed during 1964. The same application rate and equipment was utilized as that mentioned earlier. Several minor changes were made, however, for experimental purposes.

After finish rolling for several hours with rubber tire rollers, traffic was permitted on the completed surface under two separate and distinct methods. In one case, traffic was permitted to use the surface upon completion of rolling one hour prior to darkness. In the other case, traffic was not permitted to use the surface until the following day.

The cost per two 12-ft. wide lanes per mile for the various sections ranged between $1,422 and $2,000. 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 cents to 12 cents per square yard. Based on the 12 cents per square yard figure, the cost per mile for a roadway comparative to ours would approximate $1,686. Considering the high volume of traffic on the Turnpike and the necessary controls that are required for adequate patron safety, it is felt that the costs were more then realistic. This is especially true, when comparing it to Pennsylvania Department of Highways costs, since most highway jobs are done on low volume rural roadways where traffic controls are not required.

The gradation for the Type-A slag aggregate used was as follows:

SCREEN	PERCENT PASSING
½ in.	100
⅜ in.	60-80
No. 4	25-45
No. 8	0-10

To date all of our surface treatment jobs have been holding up quite satisfactorily.

The A-1 asphalt cement used in the original resurfacing work is the same as that covered by AASHO Designation 55-85. The F-2 asphalt emulsion is now designated by Pennsylvania Department of Highway specifications as E-2 asphalt emulsion which is equal to the AASHO RS-2 Designation.

BRIDGE DECK MAINTENANCE

Bridge deck deterioration 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.

Several methods to correct deck spalling and failures have been utilized. The treatment used is dependent upon the condition of the deck at the time repairs are made. Where possible, Turnpike maintenance forces are used to make the necessary repairs. On major failures, however, the Turnpike Commission contracts for the required corrective measures.

Linseed oil treatments have been applied in several critical areas in an attempt to prevent and curtail deterioration resulting from freezing and thawing or the use of de-icing chemicals. The results to date indicate that some beneficial effects are obtained. Application areas will have to be observed for a few more years before final opinions can be reached on the success or failure of this method.

There is concern, however, as to the possible effect a linseed treatment might have on a future application of a seal coat over a treated area. Will the seal adhere properly or will the linseed oil act as a lubricant?

A surface treatment was placed last year consisting of an application of 0.25 gallons of an F-2 asphalt emulsion and 15 pounds of slag aggregate on a 5-mile section of our asphalt pavement. Several concrete bridges were located within this area so we decided to surface treat over the bridge decks to see whether or not this type treatment would curtail spalling of the deck. To date very little surface deterioration of either the seal coat or the deck has occurred. The traffic on this section is rather light so probably the test is not as extensive as it should be for an analysis of the success of the treatment. It is felt that this method will not be the answer to the problem. The F-2 asphalt emulsion mentioned above is equivalent to the AASHO RS-2 Designation.

Generally Turnpike 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 and/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.
6. Cure with wet burlap for at least a 72-hour period.

The nonshrinking premixed mortar used consists of 1 part iron aggregate, 2 parts cement and 3 parts sand aggregate delivered in 100-pound bags. The nonshrink metallic aggregate is also delivered in 100-pound 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 an excellent repair when they are properly placed and cured. Maintenance repair longevity, like new construction, is dependent upon good workmanship.

Allegheny River Bridge Deck

Considerable spalling and concrete damage occurred on the Allegheny River Bridge several years ago. The need for extreme corrective measures was determined after an extensive bridge inspection was made by Turnpike maintenance personnel. A contract was entered into with a paving company in the fall of 1962. The type of original deck construction prohibited the usual type of deck slab replacement repairs sometimes utilized to correct problems of this nature.

The bridge deck is composed of a steel grid bridge flooring 4¼ in. deep, filled with concrete and covered with a ¾-in. integral concrete wearing surface. Considerable amounts of the ¾-in. surfacing became loose from the underlying concrete or was in unsound condition. This spalling necessitated placement of many bituminous patches of various sizes and thicknesses. This fact along with additional deterioration required immediate attention on the part of the Commission. A contract was let and the work consisted in general of the following:

(a) Constructing a 10-ft. by 110-ft. long median cross over at the east end of the bridge for maintenance of traffic purposes. At the west end of the bridge a median cross over was in place and was utilized.

(b) Cleaning and repairing the concrete deck of the bridge.

(c) Altering the bridge dams and scuppers to permit placement of a 3-in. bituminous surface over the existing deck.

(d) Tack coating the concrete deck and then placing a scratch coat of JA-1 bituminous material, an ID-2 binder course and a JA-1 wearing course.

In preparatory for and incidental to the resurfacing of the bridge deck, the contractor removed and disposed of all bituminous patch material, and all loose and unsound concrete. Only the use of light pneumatic hammers and hand tools was permitted, and only methods which would not result in loosening the concrete encased in the steel grids was permitted. Final cleaning, which was accomplished by air blasting, was carried on immediately ahead of the tack coat operations.

The contractor removed the concrete, installed such sections of new metal form pans as necessary and refilled the voids for the depth of the 4¼-in. steel grid with Embeco premixed grout (mix No. 2) at all locations where the bond between the encased concrete and the steel beams of the bridge deck was broken and the concrete had become loose or missing.

Immediately following the final cleaning of the bridge deck, the contractor applied a tack coat of Class F-3, Type II asphaltic emulsion. The rate of application was determined by the engineer on the basis of furnishing an asphaltic residue on the surface from 0.04 to 0.07 of a gallon per square yard.

Following the tack coat operation, the surface of the bridge deck was brought to proper section by the placement of a scratch coat of bituminous surface course JA-1 material. The material was 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 was made by a pneumatic-tired roller and rolling continued until all areas were thoroughly compacted. The bituminous binder course ID-2 utilized an asphalt cement of the Class A-1 designation having a penetration range of 70 to 80 and a minimum specific gravity at 77F of 1.010. Slag coarse aggregate was used for the binder course. The Marshall method was used in determining the plant formula and the mixture met the following Marshall stability tests requirements:

A.	Stability	1500 minimum
B.	Flow value	8-16
C.	Percent voids—Total mix	4-6
D.	Percent aggregate voids filled	65-72

The bituminous surface course JA-1 utilized an asphaltic material of asphalt cement Class A-1, with a 70 to 85 penetration. The mineral aggregate was a mixture of slag sand and snuff sand meeting the requirements of the Pennsylvania Department of Highways specifications.

Delaware River Bridge Deck

The Delaware River bridge deck may be generally divided into three units consisting of about 2,977 ft. on the Pennsylvania approach spans extending from the westerly abutment to the end pier of the main spans, 1,364 ft. of deck on the three-span continuous main river crossing, and finally 2,231 ft. on the New Jersey approach spans between the easterly end of the main spans and the New Jersey abutment. The total deck area between curbs and extending from the Pennsylvania abutment to the New Jersey abutment is a little more than 500,000 square feet. Almost all of this deck was in excellent condition. Generally the pavement showed very little sign of normal wear under traffic. The condition of most of the transverse joints was very good. Expansion dams appeared to be in excellent condition, and generally there was little wear of the pavement adjacent to the dams. There were, however, deteriorated areas of very limited extent estimated to total approximately 500 square yards.

Two small holes through the bridge deck on the main spans, one located near the center and the other about six panels east of the end main-span pier on the Pennsylvania side were detected early in May. Both holes were in the curb lanes. Most of the other damaged deck was located in the curb lanes of the main spans between the end pier on the Pennsylvania side and centerline of the bridge. Some damage occurred in areas adjacent to expansion dams or transverse joints. There was some minor damage on both the Pennsylvania and New Jersey approach spans, being limited to some very small areas at transverse joints.

The exposure of the deck of the main span with its location high above the Delaware River is more severe than for any other location on the Pennsylvania Turnpike. In addition, drainage is sluggish in this particular area. The Pennsylvania and New Jersey approaches are on grades of 3 percent, which create very good drainage conditions. The necessary provision of a long vertical curve for full length of the main spans to provide safe sight distance for high-speed traffic results in a long length of deck with very flat grade conditions. The severe exposure and grade conditions probably account for the deck damage being largely confined to the main-span unit.

Bituminous material had been used almost entirely to patch spalled or deteriorated deck areas. It was noted that adjacent to one joint or dam, Embeco grout had been used for the patch material. Damaged areas adjacent to or in all other joints had been patched with bituminous materials. The condition of several patched areas was examined by removing the surface bituminous material and checking the condition of the deck immediately below. In every case it was found that there was disintegrated deck below the patch and that moisture was present. It is very evident that the porous bituminous patches permit penetration of moisture and brine resulting in chemical action which destroys the cement matrix. This combined with numerous cycles of freezing and thawing during winter months results in rapid deterioration and additional damage to the deck.

The Delaware River bridge was jointly contracted for and erected by the New Jersey Authority and the Pennsylvania Turnpike Commission. Several meetings were held by representatives of the two agencies to determine the extent of damage and the corrective measures to be taken. A contract was then awarded to make the necessary repairs.

The principal item consisted of deck slab replacement in the two areas of complete failure and in several other areas where complete failure appeared to be most imminent. Three other items were considered necessary. These three items covered repairs to spalled deck concrete with metallic aggregate concrete, repairs to 2400 square feet of expansion joints with a coal tar epoxy mortar and a small amount of parapet and walk replacement.

The possibilities of resurfacing the entire bridge deck this year are being considered. The exact method has not been determined, but it will probably consist of an epoxy seal with a 1½-in. layer of bituminous material utilizing a Neoprene treated asphalt and containing asbestos fibers. The exact method will be determined later.

ADDITIONAL TUNNELS AND TUNNEL BYPASSES

Another rather extensive improvement involved the two-lane tunnels constructed as a part of the original section of the roadway.

When the facility was opened in October of 1940, the tunnels were adequate to handle the normal volume of traffic using the Turnpike—approximately 26,000 vehicles per day. In the intervening years, traffic volumes increased five to eight percent annually, with 82,000 vehicles using the road daily in the fiscal year ending May 31, 1959.

This increase in traffic began to present some difficulties in the operational aspects. Extremely heavy concentrations of traffic over long holiday weekends and on many normal weekends during the tourist season were sufficient to cause congestion and tie-ups extending several miles and lasting several hours in the vicinity of the Allegheny and Laurel Hill Tunnels—the two most westward tunnels. The fact that the roadway narrows from a four lane highway to two lanes at and through the tunnel and the seven-mile long ascending three percent approach grade from the east caused a marked slow down of traffic as it approached the tunnel.

The Commission soon realized that some means of traffic relief was necessary at these two-lane tunnels and ordered an engineering study in August 1959. The wisdom of the Commission's actions in proceeding with the necessary engineering work at the Allegheny and Laurel Hill Tunnels is clearly borne out by the increase of traffic on the system since fiscal year 1959. Traffic on the Turnpike increased from the 82,000 vehicles per day on that date to 99,650 vehicles per day during the fiscal year ending May 31, 1964.

The engineering studies included two distinct methods to solve the problem. The first method provided for the construction of a four-lane bypass and the second method provided for the construction of a new parallel tunnel and the rehabilitation of the existing tunnel. After considering the merits of the respective methods, the Commission decided to proceed with the construction of a new parallel tunnel and the necessary repair work to the existing tunnel at Allegheny and to construct a bypass at Laurel Hill.

The Laurel Hill bypass was opened to traffic prior to Thanksgiving last year. The New Allegheny Tunnel was opened to traffic on the 15th of this month. Bids will be received next month for the rehabilitation of the existing tunnel at Allegheny Mountain. The Laurel Hill improvement cost the Commission $7,554,000 and the Allegheny Tunnel project was completed at a cost in excess of $11,000,000. The rehabilitation of the existing tunnel will cost approximately $4,000,000.

Plans are being developed to construct a bypass around Sideling Hill and Rays Hill Tunnels and to construct new parallel tunnels and rehabilitate the old tunnels at the remaining three locations: Tuscarora, Kittatinny, and Blue Mountains. Costs will be approximately $60,000,000 on the items previously mentioned and on routine maintenance operations for these projects.

The problems mentioned previously are some of the major ones experienced by the Commission. Some of them are unique to the Pennsylvania Turnpike while others will be encountered on most highways including the new interstate system.

INTERSTATE HIGHWAY MAINTENANCE

As a result of experience, it is safe to say that the following items are applicable to and will be a factor in the necessary increased costs required to maintain the new interstate system now under construction:

1. More and better equipment will be required.
2. More personnel will be needed on the permanent maintenance organization.
3. More repairs will be necessary as a result of deterioration caused by the use of chemicals for snow removal operations.
4. Snow removal and ice treatment costs will increase.
5. More grass cutting and roadside development will be required to maintain the wide grass median, flatter slopes and large interchange expanses.
6. Signing and sign maintenance costs, including electrification, will spiral upward.
7. Interchange lighting will be necessary.
8. Traffic maintenance signing costs will increase as a result of the safeguards required to work under high speed traffic conditions.
9. Bridge maintenance will increase since more bridges will be constructed to eliminate street and railroad grade crossings and to provide for traffic separation at complex interchanges.

Toll facilities furnish other services and have other advantages which cannot be presently found along the interstate system.

The advantages include maintenance buildings located at strategic locations along and within the Turnpike operating right-of-way and median crossovers located at reasonably close intervals for the use of maintenance equipment and police patrols.

The rules prohibiting these features on the interstate system are causing numerous problems to the state highway departments. Mr. L.

H. Krick, general supervisor of highway maintenance, New York State Department of Public Works, presented a paper on the subject of "Interstate Problems" at the AASHO annual meeting in Atlanta, Georgia and mentioned these two features. In this paper, Mr. Krick stated that

> "The rules pertaining to establishment of crossovers are unrealistic. Too much time is lost by maintenance forces traveling many miles to get to the other side of a median. Police and emergency vehicles are also handicapped. The requirement that maintenance facilities may not have direct access to the interstate is also troublesome. It reduces efficiency and increases costs."

The Pennsylvania Department of Highways is considering the need for more maintenance buildings near its interstate system. Present thinking calls for placing one about every 25 miles. Since land owners are becoming more and more aware of land values in interchange vicinities, acquisition costs for land for these buildings may prove to be rather expensive.

Toll roads furnish a 24-hour patrol to spot and help motorists who are unable to continue as a result of motor failures, running out of gas, flat tires and other reasons. As a result, motorists expect this service on all high speed highways. State highway departments or motor clubs will soon have to provide some services of this type on the interstate system. Whether it be by patrol or by the use of an alarm system as used on California freeways will be up to the individual states to decide.

Toll facilities notify their users of the roadway and weather conditions to be encountered on the system. This is another service which the interstate user may demand.

MAINTENANCE COSTS

Comparison of the Pennsylvania Turnpike maintenance expenditures with those of the Pennsylvania Department of Highways might help point out the magnitude of the maintenance costs that can be expected on the interstate system. Turnpike costs may not be entirely applicable since maintenance crews "wait" for snow as firemen in paid fire companies "wait" for fires. Turnpike maintenance men are on an around-the-clock operation regardless of needs and opportunities for other work.

The Pennsylvania Turnpike system is 470 miles in length. It spends approximately $5,500,000 per year for roadway and structure maintenance and traffic services. This averages out to about $11,700 per mile or $2,925 per lane-mile. It is a well known fact that some urban freeways now require annual maintenance expenditures of up to $25,000 per mile while other freeways require considerably less.

A representative of the Pennsylvania Department of Highways provided lane-mile costs for several typical counties. Costs for these counties are:

Allegheny	Urban	2,507 miles	$1,724 per lane-mile
Dauphin	Median	1,195 miles	762 per lane-mile
York	Rural	2,658 miles	618 per lane-mile

Pennsylvania Turnpike costs appear to vary from 2 to 5 times as great. This is not quite a realistic comparison, however, since all types of roads are included in the Pennsylvania Department of Highways costs. Taking this into consideration, the costs for dual-highway maintenance would probably fall between $1,300 and $3,400 per lane-mile.

These comparisons are not exact nor firm, they are included only to provide a means to draw conclusions as to the effect the interstate system will have on maintenance expenditures in various states.

The February 1965 issue of *Public Works* has an interesting article in it entitled, "Trends in Highway Maintenance Costs". This is an abstract of a report prepared by the Research Department of the National Highway Users Conference, Inc. A portion of the article on expenditure trends on page 122 states as follows:

> "Maintenance expenditures on state-administered highways were estimated to be $1.15 billion in 1963 while maintenance expenditures on county, city and town roads were estimated to be $1.85 billion—a total expenditure of $3 billion on all roads and streets. Total expenditures in 1950 were $1.42 billion, $500 million for state roads and approximately $900 million for local roads.
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> [A graph accompanying the article shows that expenditures on state-administered roads, local rural roads and local urban roads increased at approximately the same rates during most of the 1950's.] "Since the late 1950's, maintenance expenditures on state-administered roads increased at a significantly higher rate than previously and, according to the Bureau of Public Roads' forecasts, state expenditures will continue to increase through the 1960's at higher rates than local expenditures.
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> "Extending the trend lines through 1973, the first full year after the interstate system is expected to be completed, state maintenance expenditures are forecast to be four and one-half times greater than in 1950. By comparison, local expenditures would triple during the same period. Thus maintenance outlays have been increasing by about nine percent each year since 1950.

The corresponding figures for 1973 are:

Local Municipal	$1.25 billion
Local Rural	1.40 billion
State	2.20 billion
	$4.85 billion"

If these cost estimates prove correct, the various state highway departments have a tremendous job ahead in obtaining the increased funds required to properly maintain their respective systems including the interstate system.