Seven-Year Performance Evaluation of Single Pass, Thin Lift Bituminous Concrete Overlays

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In the mid-1980s, the Illinois Department of Transportation (IDOT) faced the challenge of maintaining an aging highway network at an acceptable level of service with limited finances. Programming rehabilitation for rural highways was difficult under the existing rehabilitation policies. To minimize the required maintenance effort on these highways, and maximize the available rehabilitation dollars, IDOT initiated a single pass, thin lift bituminous concrete overlay policy. The new rehabilitation strategy, Surface Maintenance at the Right Time (SMART) was designed for rural highways with low levels of traffic, which otherwise probably would not be rehabilitated under the current rehabilitation policy. Pavements chosen for rehabilitation under SMART ideally would have age-related distresses, with few indications of structural failure. Project rehabilitation consists of pavement patching, milling, and reflective crack control treatments where necessary, followed by a 30- to 40-mm (1.25- to 1.50-in.) bituminous concrete overlay. The SMART program has been very successful. Performance is high: rehabilitations are expected to last 7 to 10 years. Through proper project selection and construction, this program is a cost-effective method for reducing the number of highway kilometers needing rehabilitation.

In 1986, the Illinois Department of Transportation (IDOT) initiated a single pass, thin lift bituminous concrete overlay rehabilitation strategy for rural highways with low volumes of traffic. It was anticipated that the new policy would minimize the required maintenance effort on these highways, as well as maximize the available rehabilitation dollars. The new policy was titled Surface Maintenance at the Right Time (SMART). Performance of projects rehabilitated under the SMART Program has been monitored for 7 years.

PROJECT SELECTION CRITERIA

For a single pass, thin bituminous overlay to perform well, it must be applied in a timely manner (*1*). Therefore, pavement selection is crucial to the project's success. If the pavement has deteriorated to a low level of service, a thin bituminous overlay will fail quickly because it cannot correct significant structural deficiencies. Conversely, it would not be cost-effective to overlay before rehabilitation is necessary (*2*). To ensure proper project selection for the SMART program, selection guidelines were developed that focus on pavement type, traffic levels, and pavement condition.

Pavement Type

The SMART program is limited to rehabilitating pavements with an existing bituminous concrete surface. IDOT experience has shown that thin bituminous concrete overlays on bare concrete pavements are likely to develop bonding problems. In addition, there is concern within IDOT that a thin bituminous concrete overlay would not survive structurally on a rigid platform.

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Traffic Levels

For a pavement section to qualify for the SMART program, multiple-unit truck traffic must be less than 500 units per day if required patching is less than 6 percent of a section's surface area. If required patching is between 6 and 10 percent of the section, multiple-unit truck traffic is limited to 250 units per day or less. Pavements requiring patching on more than 10 percent of their surface are not eligible for the SMART program.

Pavement Condition

Every 2 years IDOT performs a condition rating survey (CRS) of all highway kilometers maintained by the state. CRS involves the visual inspection of pavements by a trained panel of raters. Existing distresses, including severity and quantity, are noted for each pavement section. In addition, each pavement section is assigned a CRS value, which represents its current condition. Each panel member selects a CRS value for the pavement condition, and these values are then averaged to obtain the CRS value that is assigned to the pavement section. CRS values can range from 1.0 for a failed pavement to 9.0 for a new pavement surface (*3*). Table 1 gives a complete description of the ranges of CRS values. The project selection guidelines require that all projects selected for rehabilitation through the SMART program have a CRS value of 4.0 to 6.0 for marked routes and 3.8 to 5.4 for unmarked routes. Marked routes include any route with an Illinois or U.S. designation, such as IL 67 or US 30.

In addition to falling within the designated CRS range, all potential SMART projects should have less than 4 percent alligator cracking that requires patching. Alligator or fatigue cracking can be seen as a series of interconnecting cracks and is a positive indication of base and structural failures in bituminous concrete pavements (*3*).

CONSTRUCTION GUIDELINES

IDOT defines the SMART overlay thickness as 30 to 40 mm (1.25 to 1.50 in.) of bituminous concrete. The IDOT standard bituminous-concrete surface mix most commonly used contains between 5 and

TABLE 1 Ranges of CRS Values

Numerical Range	Adjective Rating	Description
1.0 - 4.5	Poor	Pavement is critically deficient, in need of immediate repair.
4.6 - 6.0	Fair	Pavement is approaching a condition that will necessitate repair over the short term.
6.1 - 7.5	Good	Pavement is in acceptable to good condition.
7.6 - 9.0	Excellent	Pavement is in excellent condition.

6 percent asphalt cement, has a void in the mineral aggregate (VMA) near 14, and has 3 to 5 percent air voids. It contains a coarse aggregate with a top size of 9.5 to 12.5 mm (3/8 to 1/2 in.). Overlays are placed in accordance with standard IDOT practices (*4*).

Most pavement sections selected for rehabilitation were overlaid several years ago and are failing because of the age of the overlay instead of structural inadequacies. Age-related pavement distresses are surface distresses, such as block cracking, weathering, and raveling. To eliminate these surface distresses and to remove any rutting problems, milling is usually recommended on SMART projects.

Strip-reflective crack control treatments that have been tested and approved for use in Illinois (*5*) are also recommended whenever the distress level of a widening or centerline crack is significant. If the widening crack's width is greater than 15 mm (0.5 in.) or it is moderately to severely spalled, a strip-reflective control treatment should be used. Strip-reflective crack control treatments should be used at the centerline whenever the centerline is spalled frequently and severely. Field checks of SMART projects indicate that both milling and strip-reflective crack control treatments improve the performance of a SMART overlay (*6*).

Because the SMART program is intended to be a single pass, thin lift bituminous concrete overlay for pavement sections that might not be rehabilitated under standard policies, the use of a leveling binder before overlaying is strongly discouraged. The percentage of projects for which a leveling binder was used over 50 percent or more of the project's surface area was calculated for each fiscal year. The percentage of projects for which reflective crack-control treatments and milling were used over at least 50 percent of the surface area was determined. From these statistics (Figure 1), it is clear that SMART construction guidelines usually are followed.

PERFORMANCE MONITORING

Long-Term Performance of Early Projects

The first SMART projects were constructed in late summer 1986, during fiscal year 1987. As Figure 2 shows, 346.98 km (215.61 mi) were rehabilitated during fiscal year 1987. CRS values for these projects were recorded in 1986, 1988, 1990, and 1992. CRS ratings indicated all of the projects were excellent in 1986. By 1990, 317.71 km (197.42 mi) of the 346.98 km (215.61 mi) rated in the good to excellent range, as shown in Figure 3. Figure 3 also shows that in 1992, 6 years after construction, 200.60 km (124.65 mi) of the 346.98 km (215.61 mi) still rated in the good to excellent range. It was hoped originally that five or more years after rehabilitation the CRS value of a selected project would be no lower than it had been before rehabilitation. CRS values compiled in Table 1 and Figure 3 indicate that 136.95 km (85.10 mi) had a low enough CRS value to qualify for rehabilitation a second time. Only 0.48 km (0.30 mi) was rated critically deficient and in need of immediate repairs. Although there is not enough data at this time to conduct a thorough long-term performance evaluation, these historical CRS values provide an indication of the average life of a SMART overlay.

Average CRS values evaluated in this paper were weighted by the individual project's pavement length. For fiscal year 1987 pro-

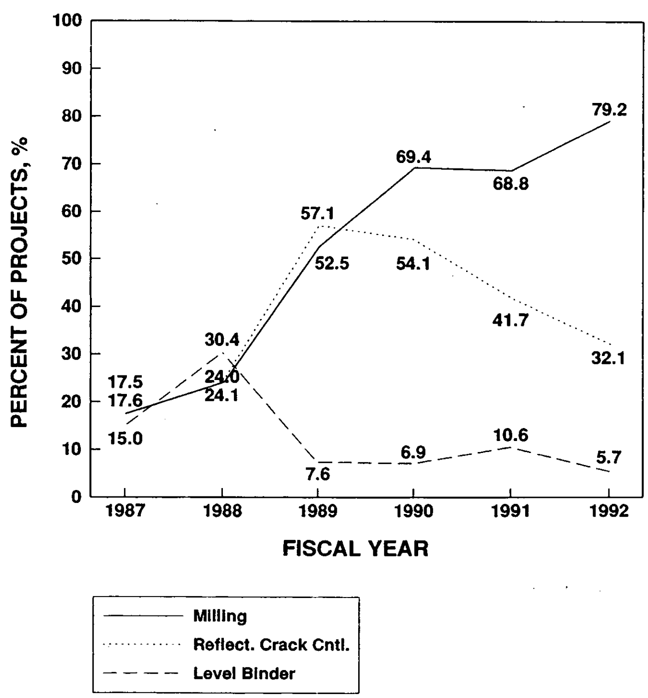

FIGURE 1 Percentage of projects using level binder, reflective crack control treatments, or milling.

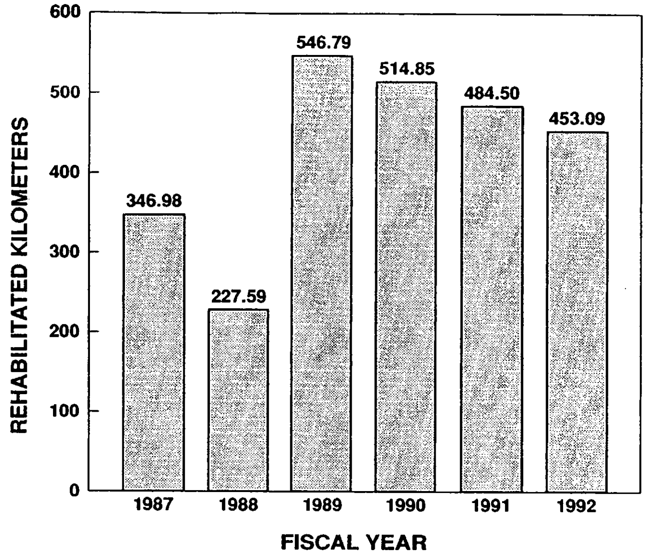

FIGURE 2 Kilometers rehabilitated under SMART program.

jects, weighted average CRS values from 1986, 1988, 1990, and 1992 are shown in Figure 4. The average decrease in CRS value per 2-year interval was 0.9. Projecting a decrease of 0.9 in CRS values for 2 years, Figure 4 shows that the average SMART project will not reach a critically deficient CRS of 4.5 or less for at least 10 years. However, after 7 years, the average SMART project will have a CRS value of 6.0, which is low enough to qualify for a second rehabilitation under the SMART program.

Average 1992 CRS Value Evaluation

Perhaps a better method of predicting the expected life of a SMART project is to compare the weighted average 1992 CRS values of projects constructed in different years. The average 1992 CRS value for each fiscal year of construction is shown in Figure 5. The average decrease in CRS values per year is 0.4. Projecting a decrease of 0.4 per year, the average SMART project will not reach a critical CRS value of 4.5 for over 10 years. The average SMART project will reach a CRS value of 6.0 or less in 7 years, qualifying it for a second SMART rehabilitation.

Hence, both methods for predicting the average life of a SMART project indicate that a SMART rehabilitation should last 7 to 10

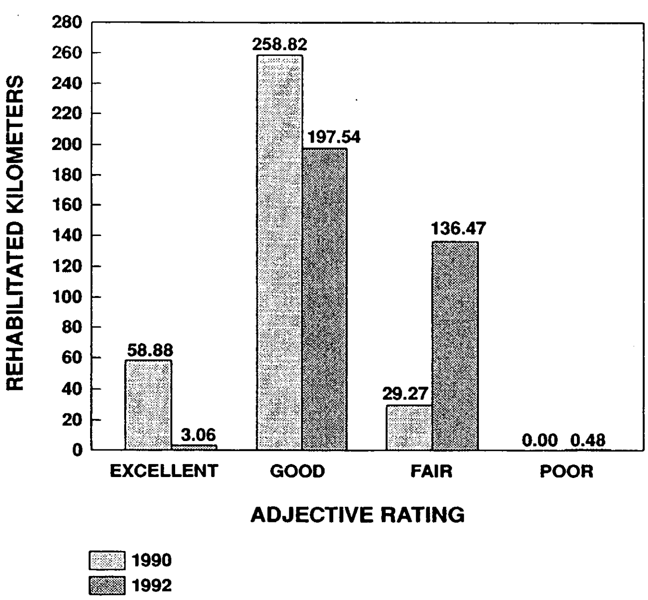

FIGURE 3 1990 and 1992 CRS adjective ratings for SMART projects constructed in fiscal year 1987.

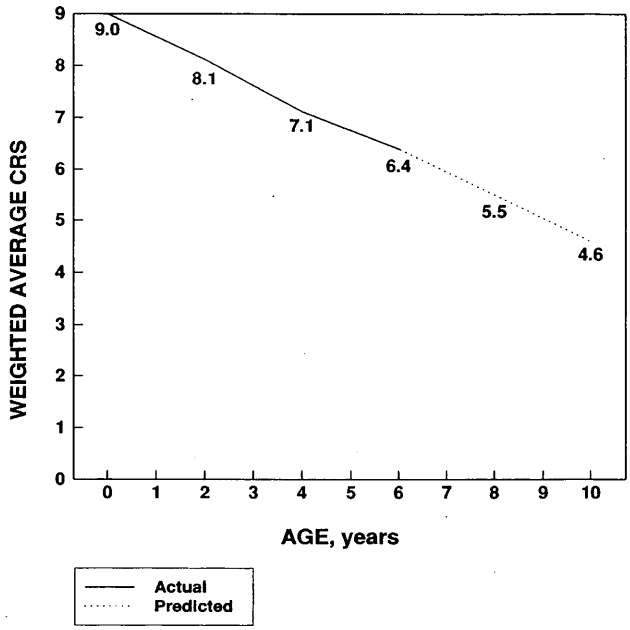

FIGURE 4 CRS values for SMART projects constructed in fiscal year 1987.

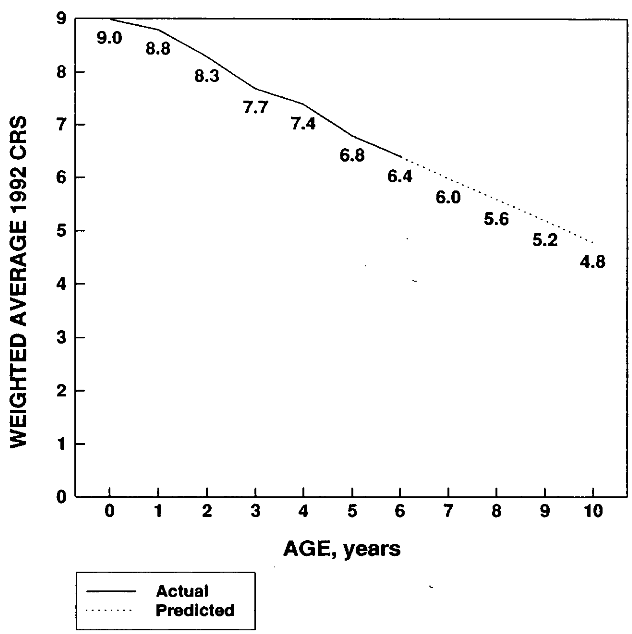

FIGURE 5 Weighted average 1992 CRS ratings for all SMART projects.

years. A project's life expectancy therefore exceeds IDOT's original expectation of 5 years. As more data become available, better estimates of long-term project performance will be made. It is clear at the present time, however, that the average SMART project is lasting longer than was anticipated.

Ride Quality

In addition to CRS values, ride quality, measured in International Roughness Indexes (IRI) and rut-depth measurements, can be used to evaluate the performance of the SMART projects.

In 1992, a report detailing the ride quality and rutting histories of selected SMART projects was published (*6*). Because IRI and rut-depths are now collected every other year, there were no new data to include at this time. No ride-quality data on these projects before rehabilitation are available either.

Figures 6 and 7, published in the 1992 report (*6*), are reproduced here. Figure 6 indicates that the IRI for SMART projects is not diminishing with age at this time. Figure 7 shows that increased rutting with age is minimal. As with the CRS values, the IRI and rut-depth measurement averages for projects were weighted by the length of road involved.

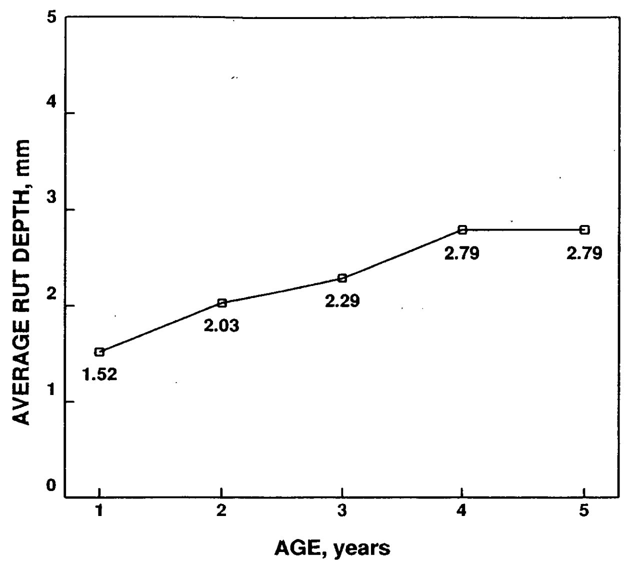

FIGURE 7 Average rut depths of selected SMART projects.

CONSTRUCTION COSTS

Bituminous-concrete overlay thicknesses on routes maintained by IDOT are determined by policy instead of structural design. Typically, a standard second-generation bituminous concrete overlay is 65 mm (2.5 in.) thick and the average cost per two-lane kilometer is approximately $110,000 ($175,000 per two-lane mile). It follows that a SMART overlay should cost significantly less than a standard overlay because the SMART overlay is thinner, requires minimal preparation work, and does not require any safety features, such as guardrails and shoulder improvements. At the start of the SMART program, it was expected that the average cost per two-lane kilometer would be $50,000 or less ($80,000 per two-lane mile).

The average cost per two-lane kilometer has been calculated for each SMART project for the past 6 years. Each project's total cost was divided by surface length to determine the average project cost per two-lane kilometer. If a project had four lanes, the total project was divided by two times the length of the project. The statewide project cost for each fiscal year was then calculated by averaging all of the project costs. Figure 8 shows the average project costs for the past 6 fiscal years. Project costs for fiscal year 1993 are not included, because many of the projects were not yet complete when this paper was written.

Some fluctuation in the yearly averages was expected, but not to the extent shown in Figure 8. Further evaluation revealed that some of the average project costs were as high as $185,000 per two-lane kilometer ($300,000 per two-lane mile). Most of the projects that

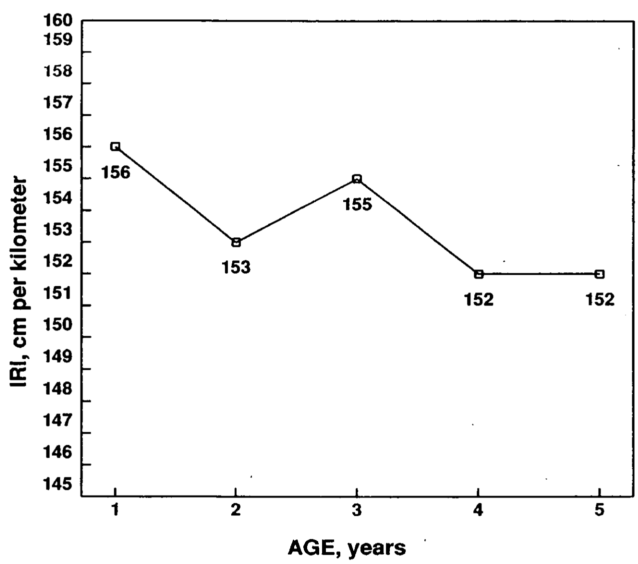

FIGURE 6 International roughness indexes of selected SMART projects.

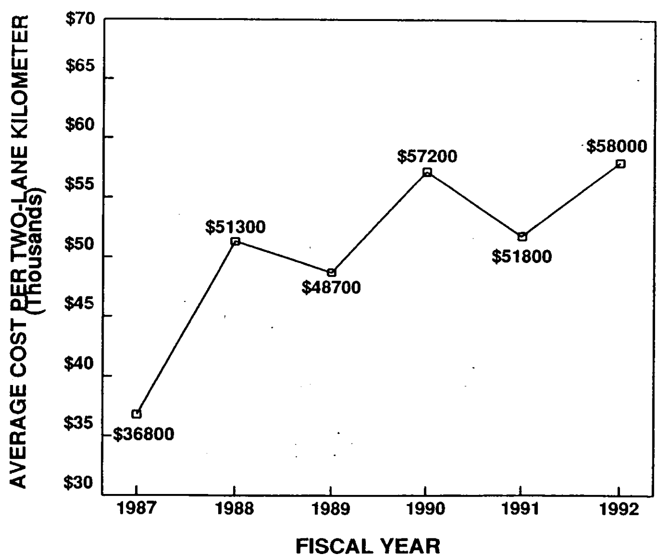

FIGURE 8 Average SMART project costs.

had high costs per two-lane kilometer were rehabilitations that included intersection work or patching of more than 10 percent of the surface area.

Originally, SMART was to include only rural highways that were structurally sound. In 1990 and 1992, however, several urban projects that required significant additional work were rehabilitated under the SMART program, and that is reflected in the high average project cost for both years. These types of projects should not be rehabilitated through the SMART program, but should be rehabilitated through standard rehabilitation policies. Figure 8 clearly illustrates why proper project selection is critical to a successful, cost-effective SMART program.

CONCLUSIONS

As Figure 2 indicates, more than 2,400 km (1,500 mi) of highway has been rehabilitated through the SMART program. Many of these kilometers probably would not have been rehabilitated under standard rehabilitation policies. Yet they have been rehabilitated under the SMART program at a minimal cost to IDOT, and the rehabilitations are lasting longer than was anticipated.

The highest average cost per two-lane kilometer is $58,000 ($93,000 per two-lane mile). For a standard second generation 65 mm (2.5 in.) thick overlay, the cost per two-lane kilometer is approximately $110,000 ($175,000 per two-lane mile). Through the SMART program, IDOT has realized a significant cost savings while not sacrificing the quality of the entire highway network.

Early success of the SMART program can be attributed to selection criteria and construction guidelines. Construction data collected to date indicate that construction guidelines are usually followed. Performance monitoring of the projects indicates that they are performing better than was expected: the average SMART project can be expected to last 7 to 10 years.

SMART is a cost-effective rehabilitation strategy for rural highways with low levels of traffic. It is not cost-effective for pavements that contain intersections, require extensive patching, or involve excessive secondary costs related to shoulder or drainage improvements, or thermoplastic paint striping.

RECOMMENDATIONS

On the basis of 7 years' experience with the SMART program, these recommendations are made:

- Only rural highways with multiple-unit truck traffic levels less than 500 should be considered for rehabilitation through the SMART program.
- Selection criteria should be followed when identifying projects for the SMART program.
- Construction guidelines should be followed to ensure a project's optimal performance.
- SMART should be continued because it is a viable rehabilitation alternative.

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