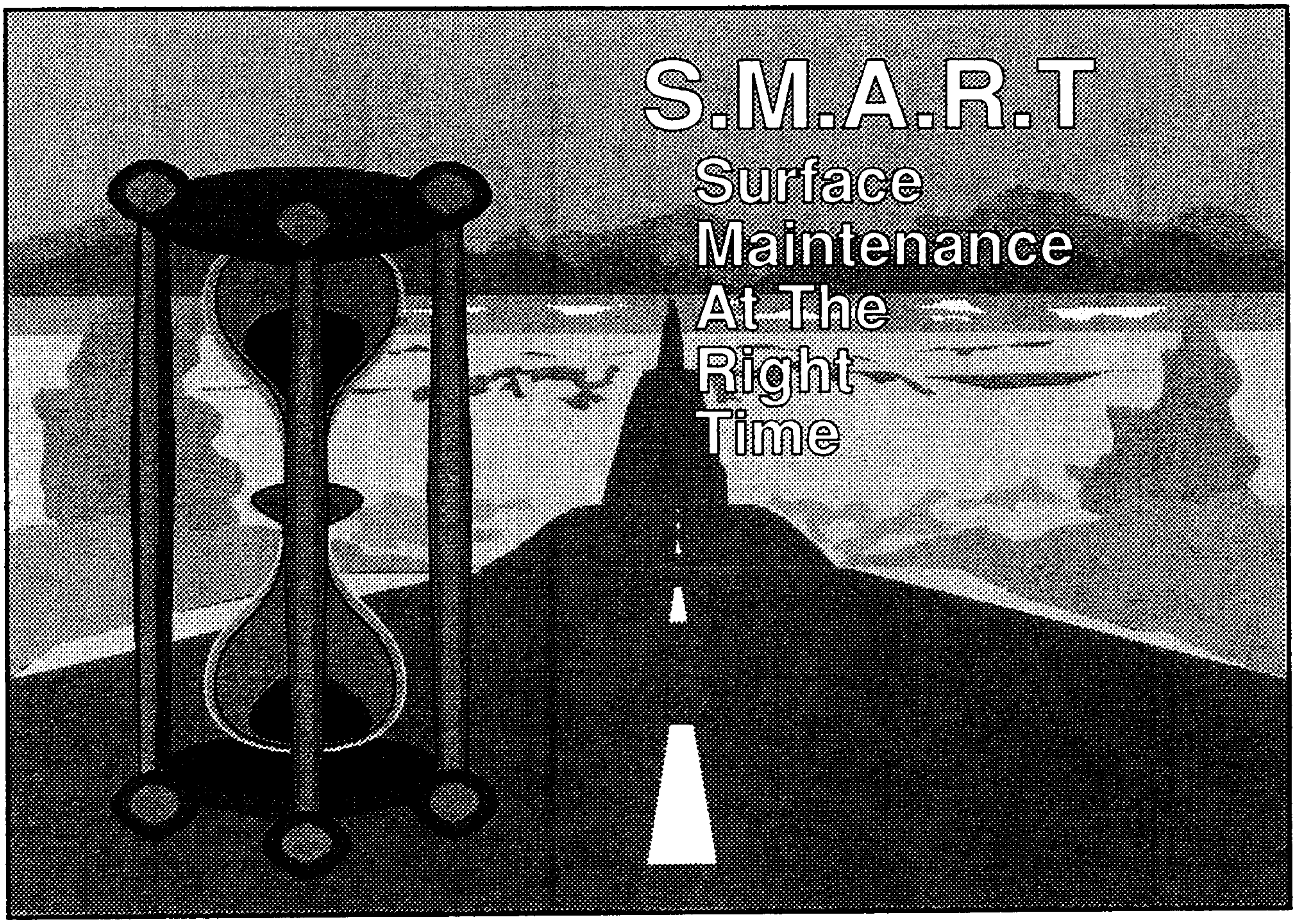
Performance Evaluation of Single Pass Thin Lift Bituminous Overlays



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16. Abstract

In the mid 1980's, the Illinois Department of Transportaion (IDOT) found itself challenged to maintain an aging highway network at an acceptable level of service on a limited financial base. This made programming rehabilitations for the rural highways difficult under the existing rehabilitation policies. In an effort to minimize the required maintenance effort on these highways as well as maximize the available rehabilitation dollars, IDOT initiated a new single pass, thin lift overlay rehabilitation strategy in 1986. The new rehabilitation strategy was titled Surface Maintenance at the Right Time (SMART).

As part of this study, a three-phased performance evaluation was conducted. The first phase of the evaluation focused on the Condition Rating Survey (CRS) values. When the SMART program was established in 1986, it was hoped that the CRS value of a selected project, at least five years after rehabilitation, would be no lower than it was prior to rehabilitation. The methods of analyzing the CRS values included in this study indicated that this standard is being surpassed by a vast majority of the projects. The second phase of the evaluation investigated the riding quality indexes of the SMART projects. Like the CRS values, the analysis of the riding quality indexes indicated the SMART projects are exceeding expectations. The final phase of the evaluation focused on the construction costs of the SMART projects. The construction costs were subject to yearly fluctuations; however, the fluctuations were not excessive.

Five years of close monitoring has shown the SMART program to be a viable rehabilitation alternative. This study concludes that the SMART program should be continued under the current guidelines.

17. Key Words
single pass overlays, thin lift overlays, second generation rehabilitations, rehabilitation peformance

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1992 REPORT
IHR-523
THE PERFORMANCE EVALUATION
OF
SINGLE PASS BITUMINOUS OVERLAYS

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ACKNOWLEDGEMENTS

This paper is based on the results of Project IHR-523, Performance Evaluation of Single Pass Thin Lift Bituminous Overlays. IHR-523 was sponsored by the Illinois Department of Transportation (Division of Highways) and the U. S. Department of Transportation (Federal Highway Administration).

The staff of the Planning and Systems Section in the Office of Planning and Programming is acknowledged for the thorough collection of project data and consistent support throughout the conduct of this project.

DISCLAIMER

TABLE OF CONTENTS

EXECUTIVE SUMMARY

The Illinois Department of Transportation (IDOT) is responsible for over 17,000 miles of state highways. In the mid 1980's IDOT found itself challenged to maintain the aging highway network at an acceptable level of service on a limited financial base. Many of the miles of highways had been in service for several years and were showing significant signs of wear. Programming rehabilitations for the rural highways, especially those with low levels of traffic, was difficult under the existing rehabilitation policies. In an effort to minimize the required maintenance effort on these highways as well as maximize the available rehabilitation dollars, IDOT initiated a new single pass, thin lift overlay rehabilitation strategy in 1986.

The new rehabilitation strategy was titled Surface Maintenance at the Right Time (SMART). Highway miles rehabilitated under the SMART program had to meet specific guidelines, such as low levels of traffic, minimal structural failures and an existing bituminous surface. In addition, cold milling the existing surface and using reflective crack control treatments were strongly encouraged. In 1990, a task force was created to review the performance of the SMART projects and to make a recommendation for the future of the SMART program. The task force concluded that the early SMART projects were performing better than was anticipated and recommended that the SMART program be continued with the guidelines revised to require cold milling, limit the truck traffic, and limit the degree of fatigue cracking in the existing surface.

As part of this study, a three-phased performance evaluation was conducted. The first phase of the evaluation focused on the Condition Rating Survey (CRS) values. When the SMART program was established in 1986, it was hoped that the CRS value of a selected project, at least five years after rehabilitation, would be no lower than it was prior to rehabilitation. The methods of analyzing the CRS values included in this study indicated that this standard is being surpassed by a vast majority of the SMART projects. The second phase of the performance evaluation investigated the riding quality indexes of the SMART projects. Like the CRS values, the analysis of the riding quality indexes indicated that the SMART projects are exceeding expectations. The final phase of the evaluation focused on the construction costs of the SMART projects. The construction costs were subject to yearly fluctuations; however, the fluctuations were not excessive.

Five years of close monitoring has shown the SMART program to be a viable rehabilitation alternative. This study concludes that the SMART program should be continued under the revised guidelines developed by the task force.

I. INTRODUCTION

In the mid-1980's the state of Illinois had many miles of resurfaced roads with low levels of traffic which were deteriorating faster than they could be rehabilitated. The primary distresses exhibited by these resurfaced roads were due to the age of the overlay and not due to structural deficiencies within the pavement. Due to limited funding, the Illinois Department of Transportation (IDOT) could not afford to apply a standard second generation overlay, and it was clear an alternative rehabilitation strategy was necessary.

Due to low levels of traffic and age-related distresses, this new rehabilitation strategy did not need to be as extensive as a total structural rehabilitation. After reviewing rehabilitation strategies in other states and interviewing both district and central office personnel, IDOT decided to try a "thin lift, single pass overlay" on a few pavement sections. Other states and a few districts within Illinois claimed to have had great success with this type of rehabilitation strategy. The first single pass, thin lift overlays under the new Surface Maintenance at the Right Time (SMART) program were placed in 1986.

The main objective of this study is to evaluate the performance of the single pass (1.25-inch to 1.5-inch thickness) overlays placed on previously resurfaced pavements that did not need significant and extensive structural repair. The benefits of a successful SMART program would include improved ride quality and reduced life cycle costs of pavement rehabilitation. Originally, this study was designed to review the performance of a few selected SMART projects. Since the early SMART projects were highly successful, the entire program was expanded significantly in subsequent years (Figure 1). Consequently, the scope of this study was expanded to evaluate the entire SMART program. For the past five years IDOT has been monitoring the Condition Rating Survey (CRS), ride quality, and construction costs for all SMART projects. A review of these values indicates that virtually all of the early SMART projects are performing above expectations, and anticipates that subsequent SMART projects will continue to exceed expectations.

II. SELECTION CRITERIA

In order for a single pass, thin lift overlay to be successful, it must be applied in a timely manner (1). Therefore, pavement selection is crucial to the project's success. If the pavement is allowed to deteriorate to a low level of service, a thin overlay will fail quickly as it cannot correct significant structural deficiencies. Conversely, if the pavement is overlaid before rehabilitation is necessary, the rehabilitation will have been unwarranted and not cost-effective (2).

Early Guidelines

The initial selection guidelines for the early SMART projects included the following:

1. The projects had to be at least one mile in length in rural areas, but could be less in urban areas.

2. The projects could not contain high accident locations.

3. The truck traffic could range up to 500 multiple units per day (M-U's per day) if the required patching was less than 5 percent of the pavement surface. If the patching quantities were between 5 and 10 percent, the truck traffic was limited to less than 250 M-U's per day. Pavements with patching quantities greater than 10 percent were not allowed in the SMART program.

4. The projects had to have at least one prior resurfacing.

5. The projects could not have extensive structural load-related distresses.

As long as a prospective SMART candidate met the above criteria, there were no limitations placed on roadway type.

Along with these selection guidelines, the districts were strongly encouraged to use reflective crack control treatments and to mill the existing overlay prior to resurfacing. Milling consists of using carbide steel bits to chip off the surface of a pavement and works best when used on an existing bituminous overlay. Milling is used to remove surface irregularities and provide a textured patterned surface, which is an excellent surface for a new overlay to bond with (3).

The districts were also encouraged to use the Condition Rating Survey (CRS) values for assistance in selecting candidates. CRS is a visual inspection of pavements which is performed by a trained panel of raters and is conducted on the 17,000-mile state system on a biennial basis (4). The assigned CRS value is a visual measurement of the pavement condition with values ranging from 1.0 for a failed pavement to 9.0 for a pavement in excellent condition. If a pavement is critically deficient - in need of immediate improvement, it is assigned a CRS of 4.5 or less. If the pavement is approaching a condition that will likely necessitate improvement over the short term, the pavement is assigned a CRS value of 4.6 to 6.0. A CRS value of 6.1 to 7.5 is assigned to pavements in acceptable to good condition and a high quality pavement is assigned a CRS of 7.6 to 9.0.

1991 Guideline Review

The original selection criteria and construction recommendations were followed closely. Although these recommendations were based on limited experience with thin overlays, they worked well. Due to the success and expansion of the SMART program, a task force consisting of personnel from several central office bureaus was created in 1990 to review the original project selection and construction recommendations, to evaluate project performance under the guidelines and to make recommendations for the future of the SMART program.

The task force met several times to discuss the direction of the SMART program and conducted three extensive field reviews of both the early, fiscal year (FY) 1987 and 1988, SMART projects and proposed FY 1992 SMART projects. FY 1987 runs from July 1, 1986 to June 30, 1987. Projects let in FY 1987 could be constructed at any time in that time frame; however, most FY 1987 SMART projects were constructed in the fall of 1986. At the end of their investigation, the task force made the following recommendations:

1. Milling should be required on all of the projects.

2. Strip reflective crack control should be required whenever the distress level for widening cracking consists of one or more of the following conditions: (1) crack width is greater than 0.5 inch, (2) the crack is severely spalled, (3) medium or severe random parallel cracking exists near the crack, or (4) major sealing or other major maintenance activity has been performed on the crack. It should also be required at the centerline when the centerline deterioration is frequently and severely spalled.

3. Bare concrete pavements should not be allowed in the SMART program.

4. A CRS rating between 4.0 and 6.0 for marked routes should be required. A CRS rating between 3.8 and 5.4 for unmarked routes should also be required.

5. The truck traffic must be 500 M-U's per day or less.

    - No more than 10 percent patching if 250 M-U's per day or less.

    - No more than 6 percent patching if 250 to 500 M-U's per day.

6. Pavements should have no more than 4 percent alligator cracking which requires patching.

The revised guidelines are very similar to the original guidelines because the SMART program was very successful under the original guidelines. To make project selection easier, the task force defined specific limits for CRS values. The only other addition to the original guidelines was to limit the degree and extent of alligator cracking allowed. Alligator or fatigue cracking is a key indicator of base and structural failures in an asphalt concrete overlay. Alligator cracking can be identified by a series of interconnecting cracks caused by the fatigue failure of the asphalt concrete surface (4).

During the review of the project guidelines, the task force investigated the potential application of using the SMART rehabilitation guidelines on bare concrete pavements. In the past, there had been noted problems with thin overlays of asphalt concrete bonding to bare concrete pavements. Typically, when a thin lift of asphalt concrete is placed over an existing overlay, the surface has been milled, and the rough surface allows the overlay to bond to the existing surface. In addition to the bonding problems, there is a danger of the overlays being too thin to survive structurally on a rigid platform. Due to these potential problems, the task force retained the original recommendation to refrain from allowing bare concrete pavements in the SMART program.

The new guidelines for SMART projects have been in effect since July 1991, and do not appear to have had a significant effect on the number of projects proposed for the SMART program.

III. PERFORMANCE MONITORING

The performance evaluation of the SMART projects includes a review of the CRS histories, the ride quality histories, and the contract completion costs. The CRS histories and the contract completion costs were collected by the Office of Planning and Programming. The ride quality measurements were made by the Central Bureau of Materials and Physical Research. Although these three indicators provide some measure of performance to date, the SMART program is only five years old. A long-term evaluation is not possible at this time.

CRS Histories

Even though a long-term evaluation is not possible, the historical CRS values provide some indication of future project performance. All of the CRS values discussed in this phase of the report have been weighted by the individual project length. Some SMART contracts incorporated several different sections which were in need of rehabilitation. In these instances, the CRS values were weighted by the segment of the total project mileage that they were applicable to.

In FY 1987, 215.61 miles of roadway were rehabilitated by SMART. By 1990, 197.42 (91.6 percent) of these miles were still rated in the good to excellent (6.1 to 9.0) CRS range, see Figure 2. Only 18.19 miles were rated in the fair range. Of these fair pavements, the average CRS value was still a respectable 5.7, indicating they were not priority candidates for rehabilitation. It is worth noting that projects constructed in FY 1987 could have been built in calendar year 1986 or 1987 since FY 1987 runs from July 1, 1986 to June 30, 1987.

Although Figure 2 shows that the FY 1987 SMART projects are performing well, it does not give an indication of future performance. It is possible to predict future performance if a deterioration rate of the CRS values can be established. The following is an evaluation of two methods for establishing CRS deterioration rates.

Method 1

The first method projects future CRS values using the CRS history over the past five years of the FY 1987 projects. Projects under construction, as well as projects being let for construction in the FY 1987 program, were automatically given a CRS rating of 9.0 during the 1986 CRS review. In 1990 the average CRS rating had dropped to 7.0 (Figure 3). This would indicate a decrease of 0.5 rating points per year. Assuming a straight line deterioration rate, the average SMART project which was constructed in FY 1987 would not reach a CRS value of 5.0 for eight years or a critical value of 4.5 for nine years. It should be noted that with this method, there is a potential for error if a 0.5 deterioration rate is applied to the average CRS values for projects constructed in subsequent years, because these projects were not constructed with the same materials or in the same manner as the FY 1987 projects.

Method 2

Perhaps a better method of predicting a deterioration rate is to compare the average 1990 CRS values of projects rehabilitated in different years. Figure 4 is a graph of the SMART project age versus the average 1990 CRS. The average deterioration between these values is 0.6 points per year. Using this deterioration rate and assuming a CRS of 9.0 at the time of construction, the average SMART project can be expected to last for more than eight years before reaching a critical CRS level of 4.5.

Caution must be exercised when using these prediction models because it is believed that, in general, the CRS values do not follow a straight line deterioration rate. Instead, it is believed that the CRS ratings decrease sharply early after rehabilitation and less drastically as the rehabilitation age increases. Thus, the use of deterioration rates of 0.5 or 0.6 rating points per year is conservative.

Using the CRS values as an indication, the projects rehabilitated by the SMART program are demonstrating a high potential survival rate. It was hoped that the CRS value of a selected project, at least five years after rehabilitation, would be no lower than it was prior to rehabilitation. Not only is this standard being achieved, but it is being surpassed by a vast majority of the projects.

Ride Quality Histories

Along with the CRS values, SMART project performance can be evaluated by riding quality indexes and degree of rutting. When this study originated, the ride quality of selected SMART projects was to be measured with the Department's Roadometer which was patterned after the Bureau of Public Road's (BPR) Roadometer. The BPR-type roadometer is a single-wheel trailer which is towed along the highway. Bumps and dips in the pavement surface cause vertical displacement of the wheel with respect to the frame. An accumulation of these displacements is recorded and used to represent road roughness. Testing is usually confined to the outer wheelpath of each lane and is continuous over the entire construction section (5).

The data is translated into a Roughness Index (RI) which represents the accumulated displacement. The RI is recorded in inches per mile and can be translated into adjective ratings. An RI of 33 inches per mile or less translates to an adjective rating of a very smooth pavement; whereas, an RI of 300 inches per mile or more indicates an unsatisfactorily rough pavement.

In 1987 through 1990, selected projects were tested with the roadometer and a summary of these averages is included in Figure 5. Although the rehabilitated sections were demonstrating a slight increase in roughness with each successive year, on the average, they still fell in the smooth to slightly rough range (Table 1). After four years, it was apparent the projects were not failing due to the ride quality as measured by the roadometer.

In 1990, IDOT switched to measuring ride quality with a road profiler, which was patterned after the South Dakota Road Profiler, to increase the reliability of the roughness measurements and to enable IDOT to directly measure the longitudinal profile. The road profiler is more accurate than the roadometer in measuring ride quality because it measures roadway profiles independent of the test vehicle's suspension characteristics, and it has the added benefit of automatically measuring rut depths (6). The road profiler measures ride quality and rut depths with three ultrasonic sensors mounted on the front bumper of a van. The sensors continuously measure the distance between the test vehicle and the pavement.

In 1991, an extensive testing program with the road profiler was conducted on 64 SMART projects. As with the data collected by the roadometer, the road profiler records roughness in inches per mile. There is no direct correlation between the two readings, however, since they employ different measurement methods. The ride quality measured by the road profiler is called the International Roughness Index (IRI). These values can be translated into adjective ratings; however, the adjective ratings can be deceiving as the IRI adjective rating scale was originally defined for developing countries with lower quality road networks. The adjective rating ranges for IRI's are included in Table 2.

A comparison of the average IRI values in Figure 6 shows that the average SMART project for each fiscal year is providing a smooth ride. The slight variation in IRI values with project age demonstrates that the average ride provided by a SMART project is not deteriorating at a detectable rate at this time. These results, along with the roadometer test results, indicate that the SMART projects should not receive a rough pavement rating for quite some time. As with the CRS values, all of the riding quality values are weighted by the total project length.

A comparison of the average rut depths for each fiscal year of construction is included in Figure 7. The trend of rutting by the SMART projects is minimal. As with all overlay rehabilitations, the rate at which rutting occurs is expected to decrease with time. This could be why there was no measurable increase in rutting between the jobs four and five years old.

Construction Cost Histories

The final phase of the performance evaluation is a review of the construction costs of the SMART projects. All of the costs included in this report were obtained in the following manner. The total project mileage was multiplied by the number of lanes in the project. In most cases the number of lanes was two, but some projects had as many as six lanes. The total project cost was then divided by this number to obtain a cost per lane-mile. Finally, the costs per lane-mile were averaged. This number was then multiplied by two to give a yearly average cost for a two-lane mile of highway. The average yearly costs are included in Figure 8.

The fluctuations in average yearly costs cannot be explained easily. At first, it was believed that the jumps in cost could be reflecting the increased use of reflective crack control treatments, milling, and leveling binder. Figure 9 tracks the use of each of these products over the last five years.

The percentages presented in Figure 9 were obtained through extensive investigations. In the case of the use of reflective crack control treatments, any project which listed reflective crack control in its contract quantities was included in the percentage in Figure 9. It would be impossible to determine exactly where and to what extent the reflective crack control treatment was used on individual projects because the treatments come in many different types and widths. It was assumed that if used, the reflective crack control treatments were applied in all of the warranted areas, such as highly distressed centerlines or widening cracks. The field reviews by the task force showed very promising signs of the ability of the reflective crack control treatments to slow down the rate of reflective cracking.

In the case of milling, the simple listing of milling in the contract quantities was not enough. It was necessary to define a level at which the use of milling significantly impacted the performance of the project. Nearly all of the SMART projects included milling the existing overlay for butt joints to assist construction. Many of the projects, however, did not mill any of the remaining surface, and many more projects milled only limited areas of the existing overlay. Since the purpose of examining the use of milling was to determine its effect on the project costs, it was essential to distinguish between the projects which used extensive milling and those that did not. It was decided that the milling quantities would only be included in the Figure 9 percentages if they included at least 50 percent of the total project surface. When evaluating the projects on an individual basis, there were very few projects that were on the borderline of this cut-off point. Eighty-nine percent of the projects which were milled contained at least 90 percent milling of the entire surface.

As with the milling quantities, the leveling binder quantities were only included in the analysis if they covered at least 50 percent of the project. Since both the leveling binder quantities and surface mix quantities are in tons, the percentage of the leveling binder should be a proportional percentage of the surface mix. The absolute thinnest lift thickness for leveling binder is 0.5 inch. The average surface thickness is 1.5 inches; therefore, if leveling binder was used on the entire job, the tonnage of the leveling binder would be approximately 33 percent of the surface tonnage. As stated earlier, to have a significant impact on the project cost, the leveling binder had to incorporate at least 50 percent of the job, thus the leveling binder tonnage should be at least 16.7 percent of the surface tonnage. As with the milling quantities, there were very few projects on the border of this cut-off point.

Although the percentage of projects using leveling binder and milling are estimates, they give a good indication of the construction options used on the typical SMART projects. The trends of increasing the use of milling and reflective crack control should improve the overall project performance. The decreased use of leveling binder is also promising as the SMART program, by definition, should only contain a single pass, thin lift overlay. The trends depicted in Figure 9 are indeed interesting, and encouraging, but they offer no definitive assistance in determining why the average yearly costs increased and decreased as shown in Figure 8.

There are other possible reasons why the costs appear to be slightly variable. First, the costs could reflect the amount of urban projects being rehabilitated. Urban projects require more drainage work, traffic signals, curb and gutter, and possibly even paved shoulders. Second, the project length can significantly impact the total project costs. Shorter projects mean more mobilization costs. Third, in the late 1980's more SMART projects were requiring extensive patching. On some projects, the patching costs were 40 to 50 percent of the total project costs. With the new restrictions on patching percentages, this problem should be minimized if not totally eliminated. Fourth, construction in the various geographical areas of the state creates cost differentials. Rural projects may require contractors to work in areas far from their plants, which in turn increases the project costs. Finally, the cost fluctuations could be reflecting the use of non-paving items, such as raised pavement markers and traffic tape instead of paint. Most likely the cost fluctuations are some combination of these reasons. Although the average yearly costs are not excessive, and are usually below the anticipated average costs of $80,000 per two lane mile, there is reason for concern and continued evaluation.

IV. CONCLUSIONS

Since 1987, 1164.91 miles have been rehabilitated under the SMART program. The SMART program is a successful way of rehabilitating low traffic volume roads which have an existing asphalt concrete surface. By limiting the degree of structural failures in a project and by specifying the use of milling and reflective crack control treatments, pavements which meet the established selection guidelines have been projected to last eight years or more. As previously stated, it was hoped that the CRS value of a selected project, at least five years after rehabilitation, would be no lower than it was prior to rehabilitation. Not only is this standard being achieved, but the SMART projects also appear to be resistant to early rutting problems and ride quality deterioration.

The SMART program is cost-effective, but the costs are sensitive to project size and location. Shorter projects mean more mobilization costs and urban projects mean more secondary costs, such as curb and gutter, marking tape, and traffic signals.

V. RECOMMENDATIONS

- Five years of performance monitoring has shown the SMART program to be a viable rehabilitation alternative. Use of the SMART program should be continued under the 1991 guidelines developed by the SMART task force.

- Only previously overlaid pavements should be considered for rehabilitation in the SMART program.

- The CRS, ride quality and construction cost histories should continue to be collected to monitor the long-term project performance.
- The SMART task force should remain in existence to continue monitoring the program.
- The use of reflective crack control treatments, milling, and leveling binder should be monitored to determine their effect on project performance.

2374i

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TABLE 1

Illinois Roadometer
Roughness Index (inches/mile)

Bituminous Pavement	Adjective Rating
60 or less	very smooth
61 - 75	smooth
76 - 105	slightly rough
106 - 145	rough
146 - 190	very rough
191 - 330	unsatisfactory

TABLE 2

Illinois Road Profiler
International Roughness Index (inches/mile)

Group	IRI Roughness Range (inches per mile)
Smooth	0-190
Medium	191-320
Rough	more than 320

MILES REHABILITATED
By SMART Since FY 1987

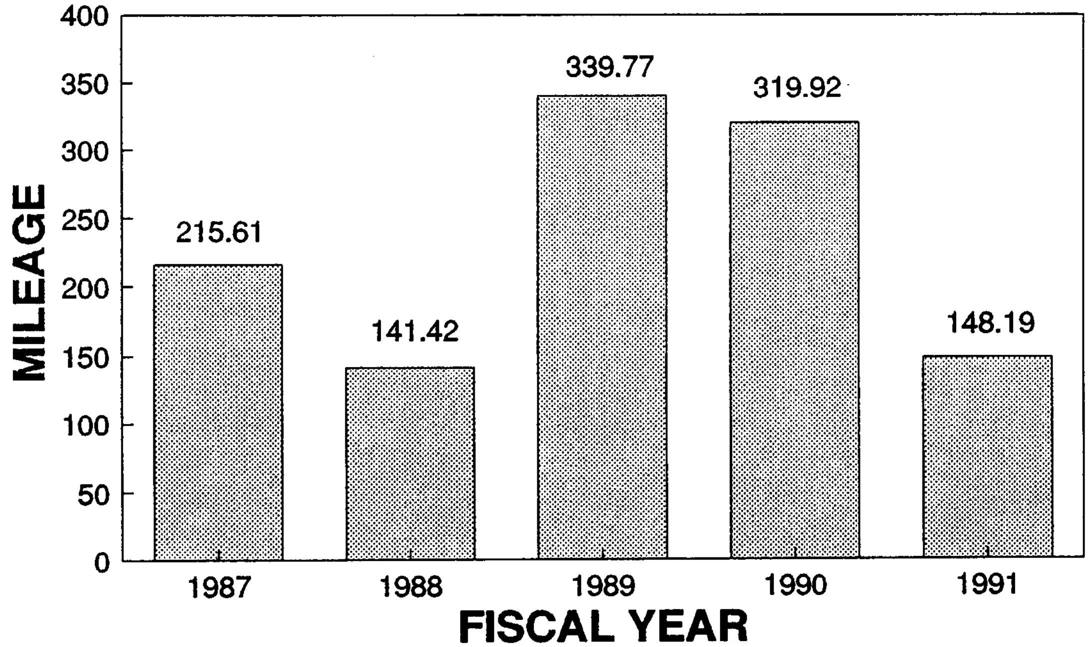

Figure 1: SMART Rehabilitation Mileage Chart.

FY 1987 SMART Projects
Average CRS Adjective Rating in 1990

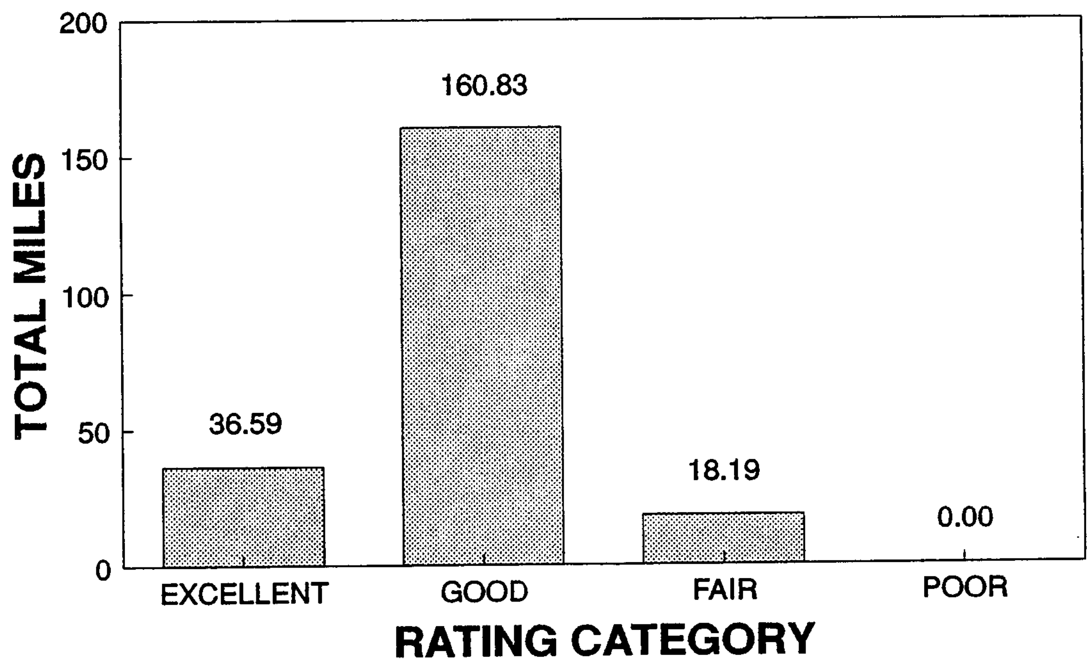

Figure 2: Average 1990 CRS Chart for FY 1987 SMART Projects

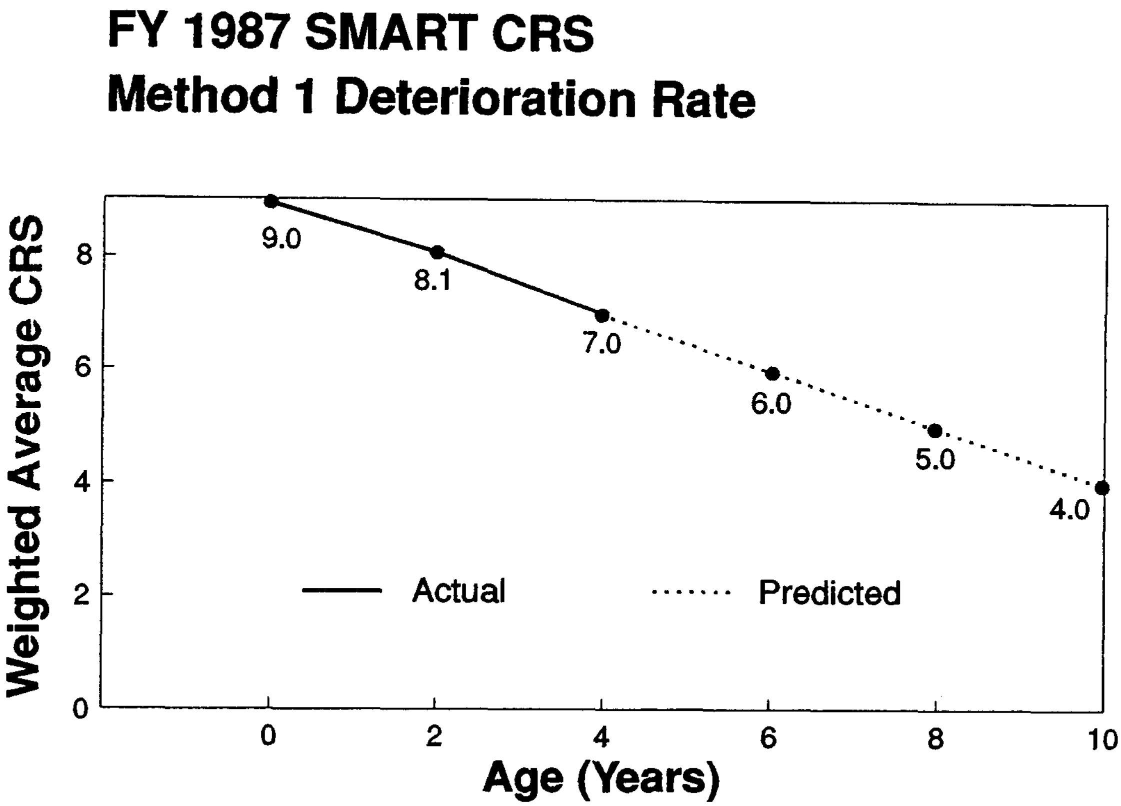

Figure 3: Method 1 Deterioration Rate.

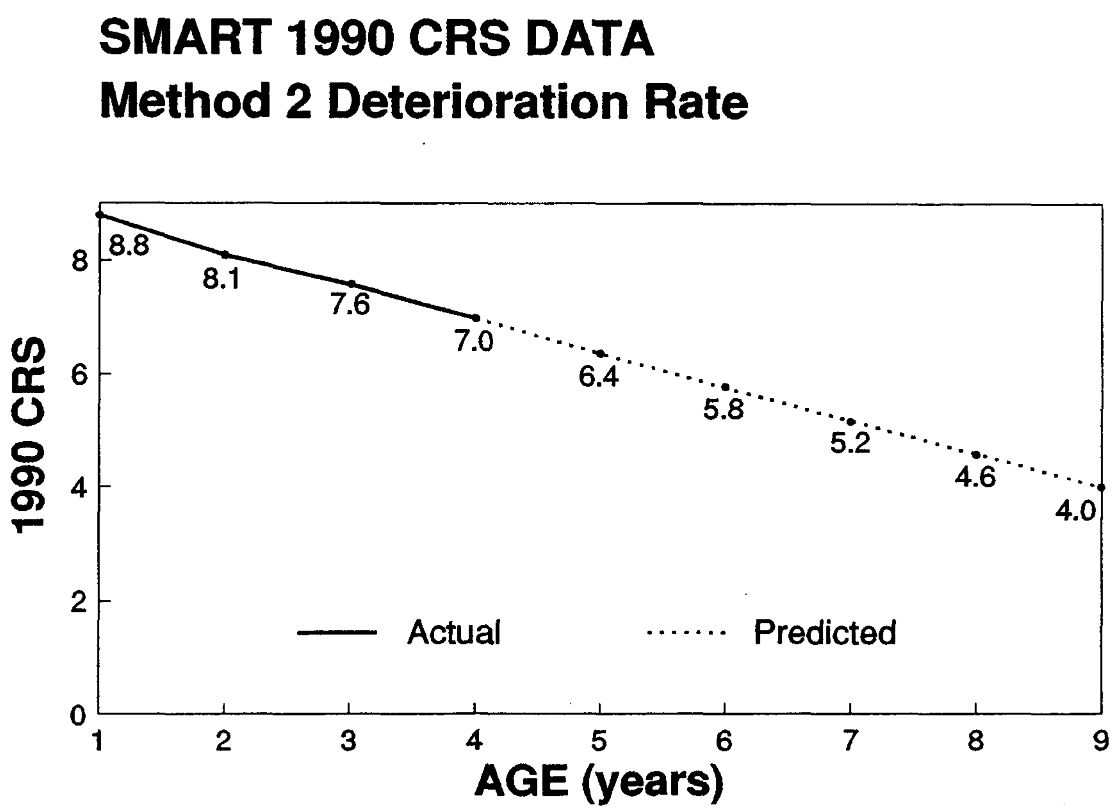

Figure 4: Method 2 Deterioration Rate.

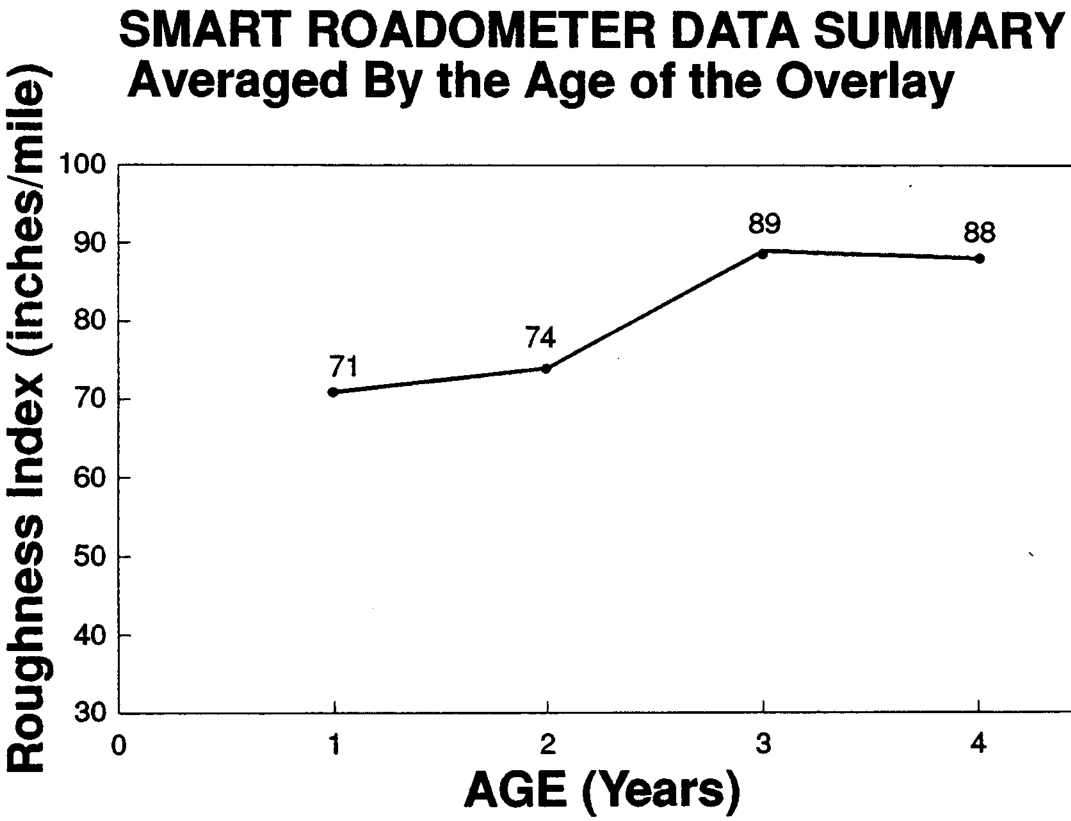

Figure 5: SMART Roadometer Ride Quality Chart.

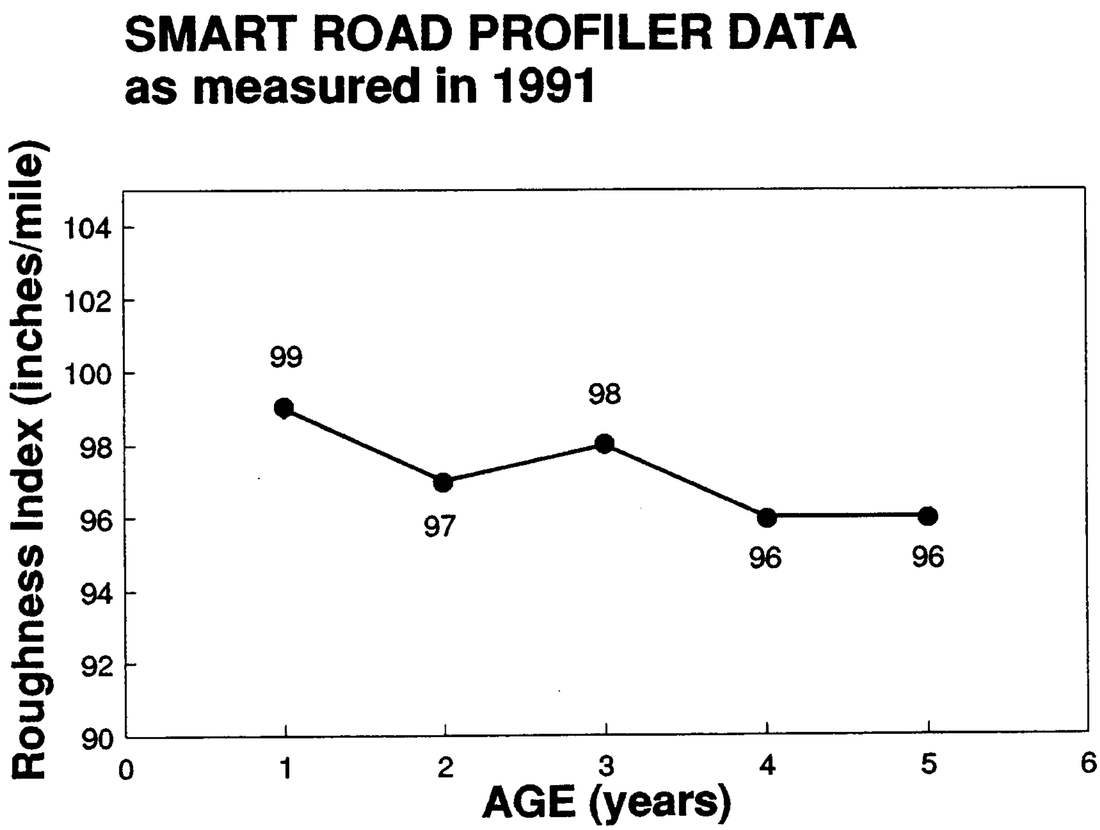

Figure 6: SMART Road Profiler Ride Quality Graph.

SMART Rut Depth History as measured in 1991

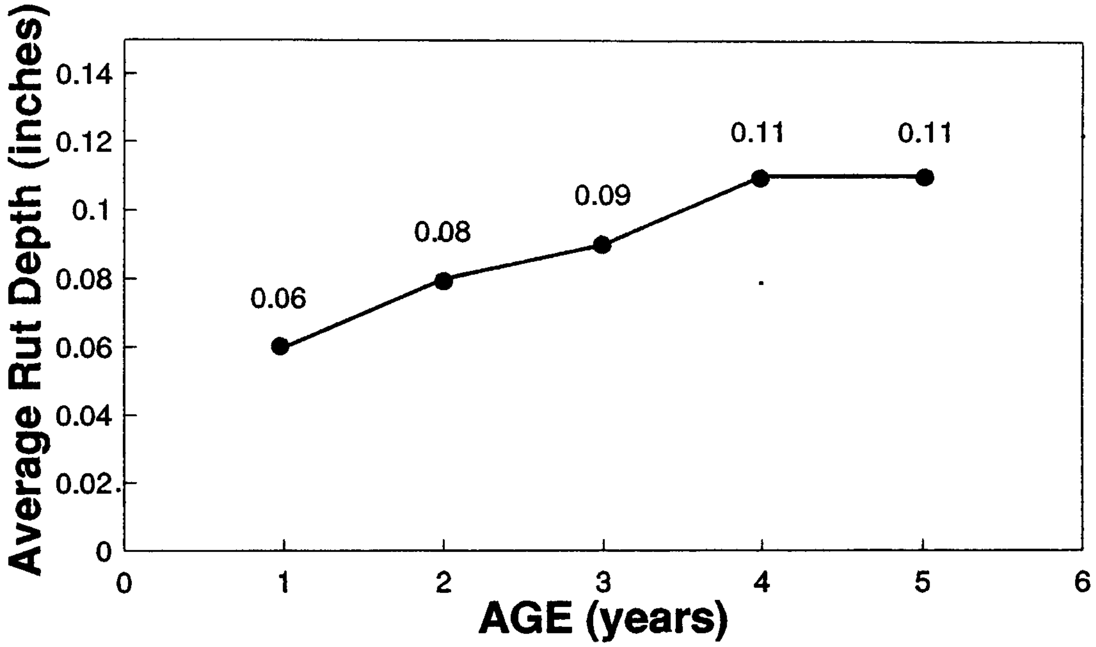

Figure 7: SMART Road Profiler Rut Depth Graph.

AVERAGE COST FOR SMART PROJECTS Cost per Two Lane Mile

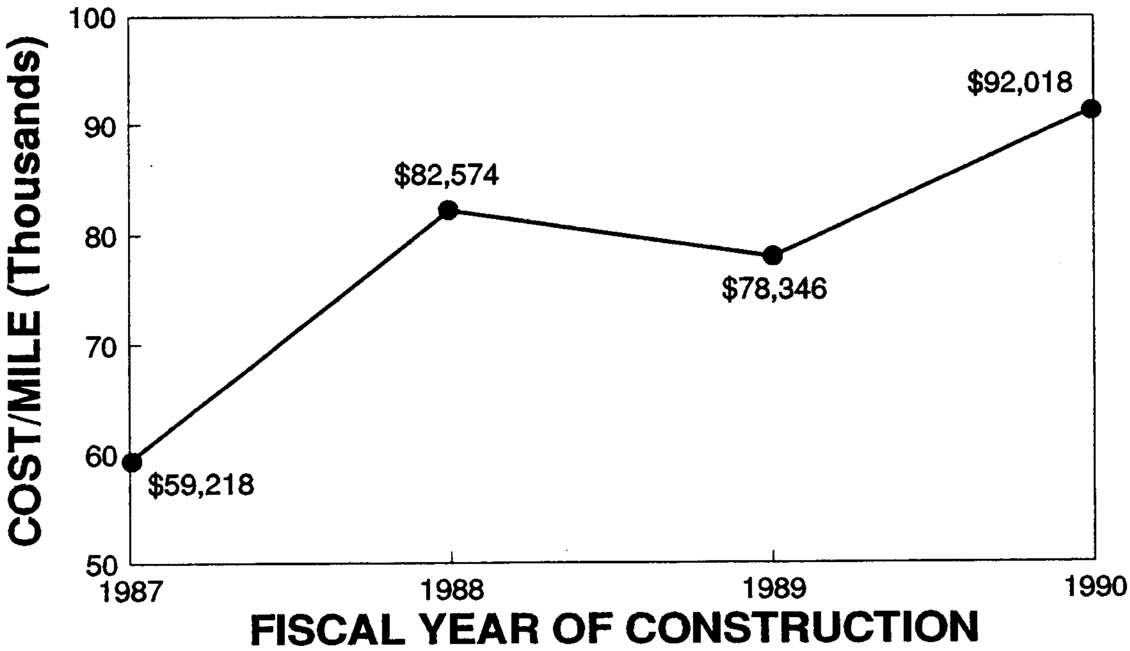

Figure 8: SMART Cost per Two Lane Mile Graph.

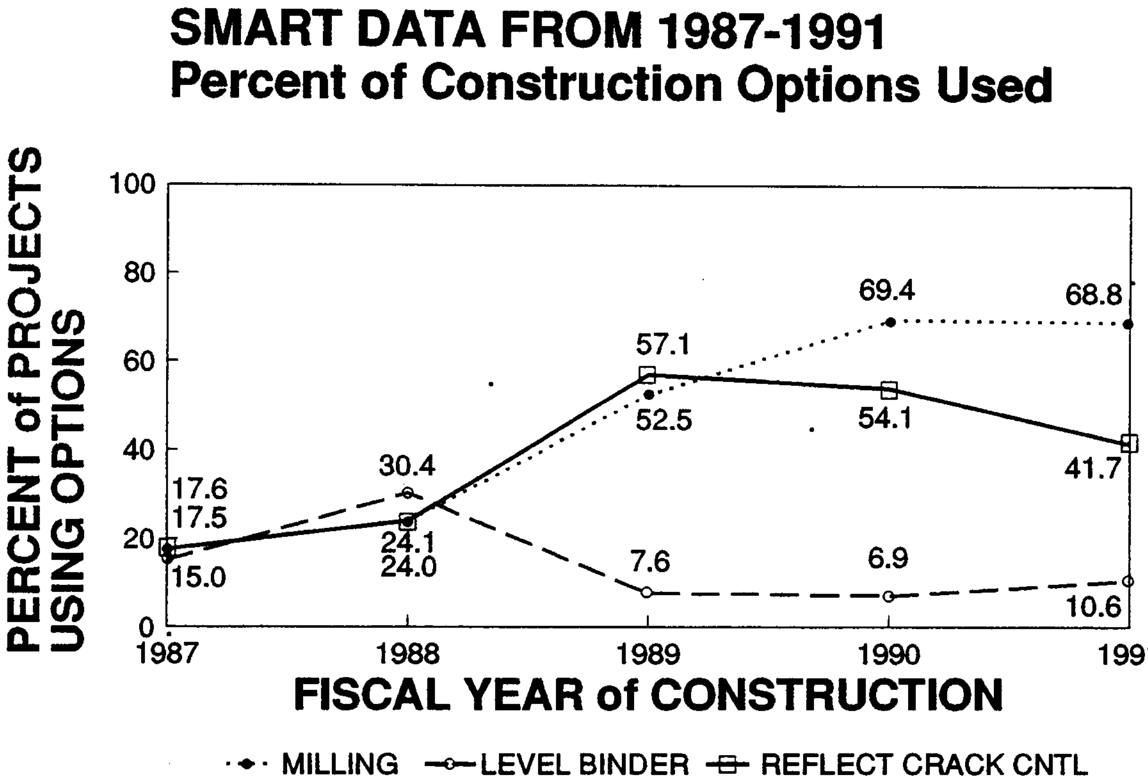

Figure 9: Construction Options Graph.