Thin Maintenance Surfaces for Municipalities

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ABSTRACT

In spite of increasing demands for service, many municipal street departments in Iowa have faced budget shortfalls due to revenue limitations. These budget shortfalls do not allow them to maintain an aging street system adequately without careful planning. Thin maintenance surface (TMS) techniques have been developed to extend pavement life by mitigating existing distresses. TMS techniques, such as seal coat, slurry seal, micro-surfacing, and fog seal, are cost effective preventive maintenance techniques that, when properly used, reduce pavement life-cycle costs. Currently, many municipal street officials cannot expend the effort to test or improve existing preventive maintenance techniques. By performing these evaluations, researchers hope to encourage improved selection of maintenance techniques in urban settings.

This research will show how TMS might be properly included in municipal street maintenance programs. The research evaluates the use of TMS in urban settings by constructing three sets of test sections in three Iowa cities. Condition surveys were performed before and after the application of the test sections and will be performed after the first winter to evaluate the performance of the each new surface. Construction was observed and crews used typical construction techniques so the results will be similar to those achievable using current techniques. This paper will report on the results of this effort based on information available at the time of writing.

Final results will be generalized to develop a practical guide of recommendations for TMS and preventive maintenance, which will be available for street officials.

Key words: micro-surfacing—preventive maintenance—seal coat—thin maintenance surfaces

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Proceedings of the 2005 Mid-Continent Transportation Research Symposium, Ames, Iowa, August 2005.

PROBLEM STATEMENT

Cities across the United States are continually facing budget cuts from decreased revenues. "In the National League of Cities' latest annual survey of city finance directors, more than three in five respondents (63%) said their cities were less able to meet financial needs during 2004 than in the previous year. Looking ahead, 61% say they expect their cities to be less able to meet their 2005 needs, relative to the current fiscal year" (Pagano 2004). As a result of decreased revenues, city officials are forced to cut budgets and streamline services provided. A major sector requiring large amounts of a city's budget is municipal public works departments. These departments are responsible for facilities such as streets, sewers, water works, electricity, cemeteries, and parks maintenance. Although a city cannot radically reduce public works funding for obvious reasons, the funding may not be adequate to meet current needs nor be increased to support growth.

To compound the problem of budget shortfalls, public works officials must also deal with aging public works systems, specifically streets. As these streets age, street officials must deal with rehabilitating and reconstructing these pavements to maintain safety and a comfortable ride. The maintenance, rehabilitation, and reconstruction activities of these streets are very costly, which reduces the amount of work the public works department can perform each season. This lack of resources and attention causes other streets and facilities to continue to degrade.

As public works officials evaluate the current condition of their street systems, cost effective methods and means of extending service lives will be necessary or the overall condition of the streets system will continue to deteriorate. By extending the life of a pavement beyond the designed service life, the streets department is able to spread out the workload and decrease the amount of rehabilitation and reconstruction necessary to maintain the system in good condition.

However, many street officials are not only responsible for maintenance of streets; they are also responsible for cemeteries, sewer systems, and city mowing. These additional responsibilities reduce time that could be used to investigate and test different techniques to determine how to maintain pavements effectively. Currently, many street officials have limited awareness of and experience with different maintenance techniques and their uses.

Public works directors and street superintendents are beginning to utilize preventive maintenance (PM) strategies to address their aging streets. As defined by the American Association of State and Highway Transportation Officials (AASHTO), PM is "the planned strategy of cost-effective treatments to an existing roadway system and its appurtenances that preserves the system, retards future deterioration, and maintains or improves the functional condition of the system (without substantially increasing structural capacity)." Many types of preventive maintenance techniques have been developed to maintain and extend the service life of streets. Each of these surfaces and techniques can effectively mitigate or prevent distresses such as cracking and raveling that shorten a pavement's service life. However, many of the techniques that work well with certain types of pavements and distresses are not effective on others.

Thin maintenance surfaces (TMS) are a set of cost effective preventive maintenance surfacing techniques that can be used to extend the life of a bituminous pavement. These surfaces do not increase the strength or structure of a road, but rather mitigate existing distresses and prevent future distresses that shorten a pavement's service life. TMS solutions include surfacing techniques, such as seal coats, slurry seals, micro-surfacing, fog seals, and smooth seals. By addressing the issues that cause early pavement deterioration with a TMS, a municipality is able to extend the life of a pavement, allowing other funds to be allocated to ones in need of rehabilitation or reconstruction.

Extensive research and numerous studies have been performed to improve and evaluate the effectiveness of these various TMS techniques. These studies have focused on developing new design techniques for each surface, determining which distresses are mitigated, determining ideal application times, defining best practices for construction, developing decision matrices for determining the surface that should be applied, and analyzing life-cycle costs of the maintenance techniques. Many of these studies are lengthy and do not provide street and road officials easy access to relevant material. Although these studies may provide useful information, street department superintendents are weary of placing trust in something that they cannot see for themselves or evaluate based on their colleagues' experiences. These studies also encourage municipalities to develop pavement management programs and overhaul existing programs to incorporate PM and TMS. However, if officials struggle to learn and test new techniques, the chances of adopting a new program are small. Furthermore, these types of programs are also not suitable for smaller cities that do not need an extensive program or simply cannot afford to overhaul an existing program.

RESEARCH OBJECTIVES

This research project is expected to provide street officials with appropriate solutions for pavement maintenance that officials can easily test and include in their current programs. Previous phases of TMS research projects have provided excellent information about using TMS in rural settings. A result of these previous phases was a decision matrix that officials can use to select treatments that have been developed. The results have limited application to urban settings that pose unique road maintenance challenges.

Under this research project, three test sections were constructed using TMS in urban settings. Test section sites and surfaces were selected to suit the needs of the cities, each site with different distresses and maintenance needs. The performance of the constructed test sections will be observed for one year.

These test sections will serve as great examples to street officials for many reasons. The test sections give officials the opportunity to observe and evaluate TMS in an urban setting. The generalizations will help these officials to make well thought-out decisions about their own maintenance procedures. Moreover, some TMS applications are still relatively unknown in Iowa, and these test sections will make officials aware of the various types of surfaces and materials that can be used. The test sections will be an example to municipalities of how to test different TMS applications and materials.

During construction of the test sections, hindrances were identified and lessons learned will be included in a technology transfer program that is being developed in conjunction with test section construction.

RESEARCH METHODOLOGY

City street engineers who expressed interest in this project were asked to serve on the technical advisory committee and recommend streets in their respective cities to become candidate test sections. The labor, equipment, and materials for test section construction was supplied by the sponsoring city. In each case, test section construction addressed a current maintenance need for each of the sponsoring cities. The researchers specified that the street needed to be located in an urban setting, the existing top surface needed to be bituminous, and the traffic count needed to be similar to what other urban streets were experiencing. Moreover, the city was asked to outline its current street maintenance program. This included brief descriptions of current maintenance practices and previous experiences with TMS. Researchers needed to become familiar with the needs of the city, as well as the level of funding available for the test sections.

Each city provided three to six streets of varying age, location, traffic loads, and pavement conditions. The researchers toured the designated roads and made final selections. Consideration was given to the pavement type, types of distresses present, density of the distresses, and the traffic volume. The researchers also wanted to test pavements with higher traffic volumes so streets with higher average daily traffic (ADT) were favored over others with lower ADT. The pavements needed to have a bituminous surface of either a hot mix asphalt pavement or a seal coat. A seal coat is an application of asphalt binder followed by a single layer of aggregate chips. If the test section had distresses that indicated structural failure of the pavement, the pavement was considered for a stopgap procedure, an attempt to extend pavement life for a few years before a more expensive rehabilitation or reconstruction project can take place. Because TMS techniques do not effectively mitigate or prevent structure-related distresses, researchers recommended that base stabilization be performed in the problem areas before application of the new surface. Three test sections were selected in West Des Moines, two in Cedar Rapids, and one in Council Bluffs, making a total of six.

Discussion between the city engineers and researchers helped in the process of selecting the test sections. Researchers interviewed the city engineers to collect further details on each test section to determine the goals for each effort. A number of TMS applications were suggested for each pavement that was a likely candidate. The advantages and disadvantages of each surface were discussed for each street. This discussion involved many topics, from construction limitations to material availability and funding concerns. City engineers questioned material availability and were not certain whether the materials for certain TMS applications could be acquired. These discussions required a number to ensure that all concerns would be identified and uncertainties could be mitigated.

After the final TMS selection for each test section, researchers finished investigating how the surface would be constructed, what materials were available, and which materials were the best to use. This investigation involved a review of past experiences, the literature, and case studies on TMS. Material suppliers and contractors were contacted.

A description of the construction process for each test section is described below.

Test Section Surveys

The survey type used to evaluate the condition of the different test sections was the pavement condition index (PCI), developed by the U.S. Army Corps of Engineers. The PCI is a numerical index, ranging from 0 for a failed pavement to 100 for a perfect pavement. PCI is calculated by visually measuring the type, severity, and density of pavement distresses. After the survey is completed, the ratings of the distresses are used as input for a series of formulas, and the output is the condition index for each sample section. The average PCI for all of the sample sections is the final PCI for the test section. This average addresses possible variability in the pavement condition due to location.

While performing PCI surveys on seal coat roads, the surveyor chose to ignore some distresses that were not caused by problems with the construction of the TMS themselves. An example of this is grooves left from a motor grader's ripper teeth before the application of the first seal coat. Although the grooves could be considered rutting, they were not caused by the seal coat construction process and therefore were not included in the survey.

Unfortunately, thieves broke into the graduate student's vehicle and stole a number of items, including the folder that contained many of the pre-construction surveys. Because the surveys were stolen after the application of the new surfaces, the PCI of the pavements before construction are unknown. However, the researchers performed surveys on similar streets with similar structure, history, and traffic for a general comparison. If the test section had no similar streets, no comparative analysis was made to quantify the added value of the surface. Only the performance of the surface was analyzed.

TEST SECTION DESCRIPTION AND CONSTRUCTION

College Road in Council Bluffs, Iowa

College Road is a collector street located near Iowa Western Community College in the northeast corner of Council Bluffs. College Road is a 2-inch (50.8-mm) full depth seal coat road, with pea rock as the aggregate for the surface course. The road has little to no shoulders and the ditches do not appear to be well drained. However the ditches are deep, approximately 10 feet, and standing water should not affect the sub-base. The test section is located on a curved section of the road where the speed limit is reduced to 25 mph because of the tightness of the curve. The traffic before construction was approximately 1,800 vehicles per day. The PCI of College Road before construction is estimated at 30–50 (poor). Some of the more severe distresses included alligator cracking, potholes, bleeding, and rutting. The alligator cracking and potholes were located in the outer wheel paths in the lane on the outside of the curve. Most of the rutting was also located in the outer wheel paths of both lanes. The structural deficiency was the largest contributor to the poor condition of the pavement. TMS applications are not usually recommended for pavements in poor condition. Researchers realized that a new seal coat would not yield any benefit to the pavement and made efforts to correct some of the structural distresses before construction, which would increase the PCI to a fair rating.

Because of the structural deficiencies, dynamic cone penetrometer (DCP) tests were conducted prior to construction to test the stability of the subbase. A DCP test (ASTM D 6951–03) is a procedure that measures the penetration of a steel rod with a cone tip into subbase, using a hammer of prescribed height and drop to drive the rod into the ground. The penetration rate may then be correlated to the California Bearing Ratio (CBR). The tests concluded that the base was sufficiently strong. Consequently, the researchers recommended only tearing up and stabilizing the areas where the rutting, potholes, and alligator cracking occurred. However, the city crews restabilized the entire test section. Reconstruction of the test section included mixing the seal coat in with the subbase, adding limestone aggregate and water, regrading the road, compacting, and applying a primer coat (MC150). When the road was regraded, the surface was inconsistent, with areas of tightly and loosely compacted subgrade. Due to a late start in the season (late September), crews were rushed through the reconstruction of the road and sufficient time was not given for the primer to cure before the seal coat was placed. After three days, the new seal coat was applied.

A three-eighths-inch pea rock aggregate was used with a CRS-2P (cationic, rapid setting, polymer-modified) emulsion. An emulsion is a mixture of asphalt binder, water, and a surfactant that allows the cold (150° F) application of an asphalt binder. Cationic refers to the charge of the emulsion (cationic is positive and anionic negative) and the setting time refers to how quickly the emulsion breaks (water separates from the asphalt binder). Council Bluffs typically uses a high-float (non–polymer-modified) emulsion; however, the original seal coat was experiencing areas of bleeding. A high-float emulsion is slow setting and very forgiving. High-float emulsions are typically used when dusty aggregate is common. Researchers recommended the polymer modifiers for the emulsion in order to correct the problems with bleeding, as well as to help resist any minor cracks from forming in the seal coat. These minor cracks were caused by the high shear stresses induced on the pavement due to the turning traffic and possible deflection of the stabilized base. Because the city of Council Bluffs does not own an electronically calibrated distributor or chip spreader, no design was made for the application of the seal coat. Application rates were similar to those the seal coat crew had successfully used in the past.

Prior to construction, the majority of the traffic was local to the Iowa Western Community College and consisted mostly of cars. After construction, earthmoving began on a new construction project adjacent to the test section. The earthwork required considerable use of tandem-axle dump trucks. There was also reconstruction on a section of College Road on the opposite end of the new construction. This reconstruction involved replacing the existing asphalt pavement with a concrete pavement. The construction equipment, dump trucks, and many of the concrete trucks used College Road as an access road to get to both job sites.

The CRS-2P emulsion is a rapid setting emulsion and requires application of chips within one to two minutes of the application of the emulsion. However, the seal coat crew was familiar with a high-float emulsion, which does not require the immediate application of chips. This unfamiliarity challenged the seal coat crew, as they were not used to having to cover the emulsion with aggregate quickly.

Aspen Drive in West Des Moines, Iowa

Aspen Drive is a residential street located in north-central West Des Moines. Before construction, Aspen Drive was a PCC pavement with an ACC overlay of unknown thickness. The street has concrete curbs, gutters, and storm sewers that provide excellent drainage. The major distresses prior to construction were low to medium severity reflective cracking and longitudinal and transverse cracking. Many of the reflective cracks had been sealed in 1991. The test section is located in a subdivision, and, based on previous experience, city officials estimated an ADT of approximately 500. The PCI of the test section was 49. One of the main concerns with the new surface citizen complaints about aesthetics.

Micro-surfacing was selected as the best surface for the West Des Moines test sections. Micro-surfacing is a slurry of aggregate, polymer-modified emulsion, mineral filler, and water that is mixed before placement on a pavement. The slurry application is only one-stone thick. Micro-surfacing was chosen because of it’s robustness against crack spalling, its waterproofing effect on the surface, and its appearance, which is similar to a new asphalt pavement. A limestone aggregate type III micro-surfacing mix was used (for gradation and other specifications, see “ISSA Recommended Performance Guidelines for Micro-Surfacing, A143 (revised), May 2003”). The contractor for all West Des Moines test sections was Sta-Bilt Construction, based out of Harlan, Iowa, and the emulsion provider was from Koch Materials. Researchers had experience in previous phases for this project and indicated that the Type III gradation band could produce an aggregate that is too course; therefore, they specified a modified gradation with more fines. The added fines helped the spreader apply a tighter surface with fewer drag marks, as the fines prevent the larger aggregate from getting stuck underneath the screed by creating friction between the pavement and the larger pieces of aggregate.

Fourth Street and Vine Street in West Des Moines, Iowa

Fourth Street is a collector street located on the east side of West Des Moines. Before construction, 4th Street was a PCC pavement with an ACC overlay of unknown thickness. Both 4th and Vine streets have concrete curbs, gutters, and storm sewers, which provide excellent drainage. The major distresses prior to construction were low severity reflective cracking and longitudinal and transverse cracking. Many of the cracks had been sealed in 1993. The test section is located in a residential/commercial area. An industrial company is on the north end of the test section, so a small amount of truck traffic delivers to that business. The estimated ADT is approximately 2,000 for 4th Street.

Vine Street is a collector street located on the east side of West Des Moines. Before construction, Vine Street was a PCC pavement with an ACC overlay of unknown thickness. The major distresses prior to construction were low severity reflective cracking and longitudinal and transverse cracking. There was also a moderate amount of low (1/4-inch to 1/2-inch) to medium (1/2-inch to 1-inch) severity rutting. Many of the cracks had been sealed, and the seals were in good condition. The test section is located in a residential/commercial area and has a low amount of truck traffic, which is only local to surrounding retail stores. The estimated ADT is approximately between 5,000–6,000.

Both limestone and quartzite aggregate were used for the type III micro-surfacing mix used on 4th Street and Vine Street.

When micro-surfacing is laid, many pieces of aggregate stand on edge, which increases tire noise. After the aggregate has been worked down to its side, the added tire noise diminishes. In order to help the aggregate lay down more quickly, a pneumatic tire roller was specified during construction. However, during actual construction, researchers and the city engineers concluded there was no noticeable added value, so the use of the roller was ceased.

Vermont Avenue in Cedar Rapids, Iowa

Vermont Avenue is a local residential street located on the south side of Cedar Rapids. Prior to construction, Vermont Avenue consisted of a seal coat over a full-depth asphalt pavement. The seal coat was laid many years ago (actual date unknown) and a pea rock aggregate was used as the cover aggregate. The major distress experienced by the pavement was low to medium alligator cracking. The street foreman in charge of maintenance on Vermont Avenue said that the alligator cracking reflected through the pavement after the first few years of the seal coat construction. He also said that since the initial alligator cracks formed, the alligator cracking has not propagated significantly, and at the time of test section construction, the cracks were dormant (the pavement did not pump under traffic). Other distresses included low severity longitudinal and transverse cracking and low severity raveling. A high percentage of the alligator cracks and longitudinal and transverse cracking had been sealed by the city in previous years, and the seals were in good condition. No efforts were made by the street maintenance crew to patch or reseal any cracks before the new surface was applied. The test section is located in a subdivision and experiences only local residential traffic, with the exception of a public transportation bus. One of the main concerns with a new surface was the aesthetics. The test section was located in a residential area and the city engineer was concerned with citizen complaints about dust problems and the appearance of a gravel road instead of an asphalt pavement.

For the construction of the test section, researchers recommended that a seal coat be placed over a majority of the pavement and a process called chipmat performed over the areas experiencing alligator cracking. A chipmat is a tack coat of hot asphalt binder or emulsion sprayed over the alligator cracking. A geo-technical fabric is then rolled over the tack coat. A layer of sand is spread over the fabric, and the fabric is seated into the tack coat with a pneumatic tire roller. The sand is then swept off of the fabric, and a standard seal coat is applied to the entire pavement. If an emulsion is used for the tack coat, the fabric should set for two to three days in order for the water to cure out of the emulsion. This is done to prevent the water from being trapped under the fabric and the seal coat, causing delamination between the fabric and tack coat. Using an emulsion is not common practice because of the problems that the water presents. Researchers realized that using an emulsion was not ideal; however, it was not feasible to use a hot asphalt tack coat because the city only had one distributor truck and it was normally filled with high-float emulsion. The procedure for changing from emulsion to hot asphalt is very time consuming. For Vermont Avenue, a pre-coated limestone chip and a high-float emulsion (HFE-90) were used.

Seventy-fourth Street in Cedar Rapids, Iowa

Seventy-fourth Street is a residential street located on the north side of Cedar Rapids. Seventy-fourth Street was an existing full-depth seal coat road with a limestone cover aggregate. It is not certain whether the limestone chip was pre-coated or not. The main distresses that the pavement experienced before construction was medium- to high-severity bleeding, low-severity alligator cracking, and potholes. A majority of the alligator cracking was on the east end of the project in a section approximately one block in length. Seal coats do not commonly have a large amount of longitudinal and transverse cracking because a seal coat is much more flexible and resilient than asphalt pavements. Before the new surface was applied, the street maintenance crew performed full-depth hot mix asphalt patches on any of the areas experiencing alligator cracking or potholes. These patches significantly improved the condition of the road. On the far east end of the project, where the alligator cracking was more severe, the crew stabilized the subgrade with magnesium chloride. The main concern with this test section was the aesthetics because it was located in a residential area, and the city engineer was concerned with citizen complaints about dust and the appearance of a gravel road instead of an asphalt pavement. The city engineer mentioned that 74th Street was going to be replaced with a concrete pavement in the next three to five years and only wanted the road to hold together until that construction took place.

The test section was divided into four sections to test the various types of aggregate locally available near Cedar Rapids. The following is a description of each segment:

- Segment I: Seal coat. 3/8-inch pre-coated limestone chips with high-float emulsion (HFE-90). Application rates unknown.
- Segment II: Seal coat. 3/8-inch washed limestone chips with high-float emulsion (HFE-90). Application rates unknown.
- Segment III: Seal coat. 3/8-inch pea rock with high-float emulsion (HFE-90). Application rates unknown.
- Segment IV: Double seal coat. 1/2-inch washed limestone base chip with a 3/8-inch pre-coated limestone cover chip with high-float emulsion (HFE-90). Application rates unknown.

Application rates were unknown because both the distributor’s and the chip spreader’s computers had malfunctioned and there was no accurate way to know the application rates. Time constraints did not allow a manual calibration of the equipment. Quality control during the construction of the various seal coats was not rigorous. The crews were rushed because construction did not start until very late in the season. The pneumatic tire roller did not arrive on the site until three hours after start of construction on the second day. For best results, it is desirable to set the chips in the emulsion quickly by using a pneumatic tire roller. Both the washed limestone chip and the pea rock aggregate were very dusty. Dusty aggregate sometimes does not bind well with the emulsion; however, the use of high-float emulsion mitigates such problems.

RESULTS

The following are the results of the test sections after one winter of performance. Because the test sections experienced a variety of traffic loadings, had different amounts of subbase support, and experienced different distresses, each test section stands as its own case study, and thus the sections cannot be compared to one another to measure performance.

College Road in Council Bluffs, Iowa

The post-construction survey revealed that there was little to no improvement of the condition of the road. The new PCI of the road was 48, which is a fair condition rating (previous estimated PCI was 30–50). This value does not include the portion of the test section adjacent to the new construction site, where earthwork was occurring and the truck traffic had caused a total failure in the pavement. This portion was left out because it did not reflect the condition of the rest of the pavement. The distresses in the new seal coat were similar to that of the original seal coat. Rutting, alligator cracking, bleeding, and potholes had formed in the same areas as the original distresses, even though the entire road was restabilized. As in the original seal coat, the majority of the distresses were located in the outer lane. The area adjacent to the entrance of the construction site had failed due to the heavy truck traffic. High-severity rutting, alligator cracking, bleeding, and raveling consumed most of the pavement near the entrance. Interestingly, the areas on the original seal coat where the seal coat was in excellent condition were the same areas that were in good condition on the new seal coat.

Aspen Drive in West Des Moines, Iowa

The post-construction survey revealed that there was considerable improvement in the condition of the road. The original PCI of the Aspen Drive section was 49, while the new PCI was 82, which is a very good rating and an increase of 33 points. The only distress present in the new micro-surfacing was reflected cracks. Many of the original reflected cracks in the overlay reflected through the new micro-surfacing treatment. This reflection is typical of micro-surfacing treatments. The micro-surfacing is performing well. In a few high spots, a snowplow sheared off the high edges of the limestone aggregate, but sufficient aggregate still remains to cover the original pavement.

Fourth Street and Vine Street in West Des Moines, Iowa

The post-construction survey revealed the PCI for 4th Street increased from an estimated 81 (very good) to 86 (excellent), while the PCI for Vine Street decreased slightly (81 to 80, very good). The estimated preconstruction PCI is taken from Maple Street, a pavement with a condition similar to 4th Street and Vine Street before the application of the micro-surfacing. Similar to Aspen Drive, the main distress for both 4th Street and Vine Street was reflected cracking. Vine Street had experienced some light-severity rutting before construction, and the micro-surfacing did not fill in the ruts (rut filling was not specified in the contract). The lack of rutting on Maple Street accounts for why Vine Street has a lower PCI than Maple Street. There was only one small spot where the snow plow completely removed the micro-surfacing mix. Both types of aggregate, quartzite and limestone, were used for both streets and are performing equally well. The sections of micro-surfacing with limestone aggregate seemed to have a tighter surface texture because there was a higher amount of fines in the limestone gradation.

Vermont Avenue in Cedar Rapids, Iowa

The post-construction survey revealed that the PCI for Vermont Avenue was 72, which is a fair rating. The seal coat is in very good condition, with no raveling or bleeding. The main distress was light-severity reflective cracking from the previous seal coat. The chipmat also performed very well. There was no reflective cracking in the areas where the chipmat was placed. For some of the areas that had alligator cracking, the researchers chose not to place fabric in order to provide a comparison. In these places, the alligator cracking reflected through to the new seal coat. There were a few concerns with the chipmat, including the inability of chipmat to prevent reflective cracking, its inability to bond well to the existing seal coat, and the potential for significant bleeding over the chipmat. Inspection after the first winter indicated no distress consistent with the previously mentioned concerns. The city engineer was very pleased with the chipmat and is considering using it again in the future.

Seventy-fourth Street in Cedar Rapids, Iowa

The post-construction survey revealed the overall PCI for 74th Street was 72, which is rated very good. As expected, results varied with each of the types of aggregates. The section of seal coat that performed the best was the section with the 3/8-inch pre-coated aggregate with a PCI of 81, a rating of very good. Other than slight raveling, the seal coat was performing well, with no visible distress. The seal coat lost many PCI points because of rutting and other distresses that existed before construction and could not be addressed by the seal coat. Interestingly, one of the sections of the pre-coated aggregate had been sitting for over a day and the other section had been sitting for many hours before a pneumatic tire seated the aggregate in the emulsion. This shows how well the emulsion and the pre-coated chips bonded to one another and gives evidence of the robustness of the pre-coated chip and high-float emulsion combination.

The 3/8inch washed limestone chip section did not perform well, with a PCI rating of 63, which is rated good. A large area of the seal coat was heavily raveled due to snow plow damage. The raveling problem might be attributed to poor bonding caused by the dusty aggregate used and the lack of the compaction by the pneumatic tire roller. It is possible that the raveling would not have been as severe had a roller been used because much of the raveling was outside the wheel paths. This is because the chips in the wheel path were seated in the emulsion by the passing traffic. The city engineer also mentioned that this section of the test section created large amounts of dust for several days after construction, which caused numerous citizen complaints. The city attempted to reduce the dust by washing the section with a water truck, but this effort was mostly unsuccessful.

The 3/8-inch pea rock section also did not perform well, with a PCI rating of 66, a rating of good. Similar to the washed limestone chip section, there was considerable medium- to high-severity raveling. Again, the raveling might be caused by dirty aggregate and a lack of compaction. This section also caused complaints of excessive dust generation.

The double seal coat section, 1/2-inch washed limestone chip base with a 3/8-inch pre-coated limestone chip, performed quite well, with a PCI rating of 95, which is excellent. This section experienced only slight bleeding and other distresses that were present before construction and could not be addressed by seal coating. There was one area with medium-severity alligator cracking and rutting; however, these distresses were not included in the survey because they were outside the sample boundaries. The lack of raveling can be attributed to the fact that this test section was rolled by the pneumatic tire roller immediately after application of both layers of chips. There were concerns that this section would have issues with bleeding. However, to date, there has been no bleeding on this section.

CONCLUSIONS

The following conclusions from this project were taken from the various test sections constructed. No statistical analysis was performed on the test section data to interpret the results because each test section stands as its own case study; the sections cannot be compared to one another to determine the most successful surface.

- Proper construction technique is one of the primary influences on the success of TMS. Failures on a TMS that occur early in the life can be traced back to poor construction or quality control.

- A conclusion could not be made regarding the effectiveness of polymer-modified emulsion. The test section used to investigate this topic had a number of construction issues that confounded the results.
- The use of micro-surfacing was successful. There were no apparent differences in the use of quartzite or limestone aggregate.
- The higher proportion of fines to the limestone aggregate gradation for the micro-surfacing helped in creating a smoother and tighter surface.
- The use of the pneumatic tire roller to aide in smoothing the micro-surfacing and reducing noise was not found to cause noticeable improvement**.**
- Cedar Rapids' current program, which uses a high-float emulsion (HFE-90) and a pre-coated limestone chip for a seal coat, is a very robust combination. This combination has out-performed the other aggregates, even though it was not rolled promptly with a pneumatic tire roller and quality control was not rigorous.
- The washed limestone chip and pea rock aggregate received numerous public complaints due to fugitive dust. This should be considered in areas where complaints regarding fugitive dust are likely to be an issue.
- The use of a pneumatic tire roller is essential to embed aggregate into the emulsion for successful seal coat construction.
- Emulsion can be used as a tack coat for a geotechnical fabric-reinforced seal coat if the tack coat and fabric are given ample time to cure before the first seal coat is applied. The chipmat using emulsion as a tack coat is a feasible and cost-effective solution for alligator cracking that does not deflect under load. This conclusion is based on the construction of one demonstration section.

ACKNOWLEDGMENTS

The authors gratefully acknowledge Jeff Krist (City Engineer, City of Council Bluffs, Iowa), Charlie Skokan (Street Superintendent, City of Council Bluffs, Iowa), Greg Parker (City Engineer, City of Cedar Rapids, Iowa), Denny Clift (Street Superintendent, City of Cedar Rapids, Iowa), Jeff Nash (City Engineer, City of West Des Moines, Iowa), Ron Wiese (Street Superintendent, City of West Des Moines, Iowa), and Sta-Bilt Construction for their contributions of the test sections, materials, and construction services.

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