CIVIL ENGINEERING STUDIES
Illinois Center for Transportation Series No. 21-005
UILU-ENG-2021-2005
ISSN: 0197-9191

Performance of Interstate Rubblization in Illinois

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Research Report No. FHWA-ICT-21-005

A report of the findings of

ICT PROJECT R27-193-2
Flexible Pavement Design
(Full-depth Asphalt and Rubblization)

https://doi.org/10.36501/0197-9191/21-005

Illinois Center for Transportation

July 2021

TECHNICAL REPORT DOCUMENTATION PAGE

1. Report No. FHWA-ICT-21-005	**2. Government Accession No.** N/A	**3. Recipient's Catalog No.** N/A
4. Title and Subtitle Performance of Interstate Rubblization in Illinois		**5. Report Date** July 2021 **6. Performing Organization Code** N/A
7. Authors David L. Lippert, Marshall R. Thompson, Charles J. Wienrank		**8. Performing Organization Report No.** ICT-21-005 UILU-2021-2005
9. Performing Organization Name and Address Illinois Center for Transportation Department of Civil and Environmental Engineering University of Illinois at Urbana-Champaign 205 North Mathews Avenue, MC-250 Urbana, IL 61801		**10. Work Unit No.** N/A **11. Contract or Grant No.** R27-193-2
12. Sponsoring Agency Name and Address Illinois Department of Transportation (SPR) Bureau of Research 126 East Ash Street Springfield, IL 62704		**13. Type of Report and Period Covered** Interim Report 7/16/18–7/15/21 **14. Sponsoring Agency Code**

15. Supplementary Notes

Conducted in cooperation with the U.S. Department of Transportation, Federal Highway Administration.
https://doi.org/10.36501/0197-9191/21-005

16. Abstract

In Illinois, hot-mix asphalt overlaid concrete pavements typically exhibit reflective cracking of joints and cracks from the pavement below, resulting in shortened life and maintenance issues. Over the years, various patching, fabric, and crack and seat techniques were attempted with few positive results. This led to more aggressive techniques to eliminate the slab action of the concrete pavement where the pavement would be broken or rubblized into pieces typically less than 12 inches. Since the first rubblizing project in 1990, policy, procedures, and specifications have evolved to the point that rubblization is the mainstream option in dealing with problematic concrete pavements. This report summarizes the performance of several interstate rubblizing projects in Illinois by analyzing available data in Illinois Department of Transportation's pavement management system. Condition rating survey data allowed the serviceability of these projects to be evaluated by surface mix types and asphalt performance grades. Traffic in the form of 18,000 lb equivalent single axle loads was determined for the projects to evaluate fatigue and rutting as well as compare section performance to the design procedure. The research team reviewed plans, design procedures, and specifications to determine best practices and identify where improvements might be made. Data showed that the use of stone matrix asphalt surface mixtures and mixes using PGXX-28 asphalt binders provides improved performance. Overall, rubblizing has shown good to excellent performance. To provide additional life with improved performance, recommendations include adopting softer asphalt grades, increasing the use of stone matrix asphalt, and improving procedures for protecting culverts.

17. Key Words Rehabilitation, Rubblization, Hot-mix Asphalt Overlay, Pavement Performance, Rutting, Serviceability Life, Illinois Condition Rating Survey	**18. Distribution Statement** No restrictions. This document is available through the National Technical Information Service, Springfield, VA 22161.		
19. Security Classif. (of this report) Unclassified	**20. Security Classif. (of this page)** Unclassified	**21. No. of Pages** 21	**22. Price** N/A

Form DOT F 1700.7 (8-72) **Reproduction of completed page authorized**

ACKNOWLEDGMENT, DISCLAIMER, MANUFACTURERS' NAMES

This publication is based on the results of **ICT-R27-193-2: Flexible Pavement Design (Full-depth Asphalt and Rubblization)**. ICT-R27-193-2 was conducted in cooperation with the Illinois Center for Transportation; the Illinois Department of Transportation; and the U.S. Department of Transportation, Federal Highway Administration.

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EXECUTIVE SUMMARY

This report summarizes a performance review of rubblized pavement on the Illinois interstate system. Illinois has utilized rubblization on all types of concrete roads, and it has been a viable option for low- to high-volume roads of all jurisdictions since first used in 1990. The subset of projects studied here were limited to the interstate system. The main source for data was Illinois Department of Transportation's asset management system, which has network-level summary information on surface condition, rutting, and traffic for each project.

Based upon an analysis of condition rating survey data, rubblizing is meeting or exceeding pavement surface life expectation of 15 years, as indicated in IDOT's pavement-selection process. The data showed that certain surface hot-mix asphalt (HMA) combinations can greatly improve performance. Stone-matrix asphalt (SMA) surfaces provided improved performance over IL-9.5 dense-graded surfaces. In addition, softer performance grade (PG) asphalt binders using PGXX-28 resulted in improved performance over PGXX-22 in both SMA and IL-9.5 mixes. This analysis supports recent PG asphalt binder selection recommendations that favor the use of PGXX-28 asphalt binder grades.

A comparison of the traffic served by the various projects with the design procedure (shown in the Illinois Department of Transportation [IDOT] Bureau of Design and Environment [BDE] Manual) showed that the design is conservative based upon HMA fatigue considerations. A review of rutting trends showed that SuperPave HMA mixes and asphalt PG binder selections result in acceptable rut depths. Trend lines predict an average rut depth of 0.25 in. at a cumulative traffic loading of 83 million equivalent single axle loads.

Current policies, procedures, and specifications are vague with respect to protection of underground structures such as pipe culverts and utilities. A review of the plans showed that several sets of plans included conservative restrictions that kept rubblizing 100 ft away from culverts. The review showed that rubblizing can proceed to within 8 ft of these structures. There may be a need to instrument culverts during rubblizing to confirm this analysis.

The inclusion of limiting strain criteria in the last design update has controlled the thickness of many recent projects and prevented excessively thick overlays. Still, the procedure is conservative and warrants more study into each of the parameters used to limit pavement thickness. In addition, the recent adoption of softer asphalt grades and increased usage of recycled materials in HMA mixes should be reviewed for impacts to modulus of the HMA and related fatigue response.

Replacing underdrains when the pavement is rubblized provides better drainage than relying upon existing drains. The use of larger 6 in. pipe drains should be monitored to determine if this size should be a standard replacement.

Overall, rubblizing has provided good to excellent performance. Adopting practices that have been shown to improve performance can enhance this cost-effective technique even more.

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CHAPTER 1: INTRODUCTION

HISTORY OF RUBBLIZATION IN ILLINOIS

Illinois' first rubblization section was constructed on Interstate 57 (I-57) as part of the Strategic Highway Research Program's Long-Term Pavement Performance experiments being built across the country in 1990 (FHWA, 2015). The rubblization was part of the Specific Pavement Study 6 (SPS-6) experiment and set alongside traditional rehabilitations of patch and overlay, patch only, and full concrete pavement restoration (CPR) such as patching and pavement grinding. The project was located 13.5 miles south of Champaign, Illinois, from US 45 to approximately 4 miles north of Pesotum, Illinois. Two experimental rubblization sections were constructed, one with a 6 in. hot-mix asphalt (HMA) overlay and the other with an 8 in. HMA overlay; each section was 500 ft in length.

The early success of this project led to six additional experimental projects by the end of the 1990s (Heckel, 2002). During this period, new rubblization equipment was developed, namely the multi-head breaker (MHB). SuperPave mixes were adopted by the Illinois Department of Transportation (IDOT) in the late-1990s as well. The next two decades saw the development of rubblization design and project evaluation procedures (Thompson, 1999). Close examination through deflection testing and performance monitoring led to refinements and updates in the mechanistic design algorithms shown in the IDOT Bureau of Design and Environment (BDE) Manual. A limiting strain criteria to truncate the design curves and prevent excessively thick pavement overlays was developed and incorporated into the design procedure (IDOT, 2017). The combination of these efforts increased the performance and cost-effectiveness of rubblization.

Early projects were built under traffic with "soft" barriers between the work lane and active traffic lane, similar to HMA overlay construction. Changing traffic conditions, namely increasing speed limits, higher volumes, and increased percentages of trucks, would later result in the use of median cross-overs and barrier walls to protect workers and travelers alike. The selection of stone-matrix asphalt (SMA) to address the demands of heavy traffic has become a common part of the rubblizing cross-section in recent years.

STUDY APPROACH

With one to three new projects being constructed annually over the past two decades, a review of projects to date was deemed appropriate to benchmark performance. To improve this rehabilitation option, it was hoped that best practices and trends in rubblization design/construction could be identified from the performance and cross-section details used. Early experimental projects concentrated on routine falling weight deflectometer data collection and detailed crack surveys. Summaries of these detailed studies (Heckel, 2002; Pava, 2011; IDOT, 2016) helped establish pavement-selection models and provided the basis for improving the current rubblizing design policy. However, after the completion of the experimental projects, detailed crack surveys became less routine because of the effort involved, and deflection testing was reduced to unique sections on a less frequent basis. For this study, the research team aimed to collect general performance trends that could be gathered with relative speed and ease that relate to network-level management and rehabilitation decision-making.

IDOT has a well-established process of collecting pavement management data on the interstate system annually and assigning condition ratings on pavements biennially, dating back to the mid-1970s, and annually, starting in 2018. The original network rating effort consisted of a trained survey team driving the highways and assigning a condition rating survey (CRS) value between 1.0 (impassible) and 9.0 (newly completed construction) to each pavement management section. Each management section is typically the same as the orginal pavement construction section, although subsequent rehabiliations may have resulted in smaller unique management sections over time. In the 1990s, IDOT adopted safer video and profile-collection techniques that resulted in a video and data record that could be revisited as well as have additional uses beyond pavement condition. The video record collected consists of various forward, reverse, and down pavement views. The automated sensor data results in the International Roughness Index (IRI—1/4 car simulation), rutting, and faulting values for the pavement surface, which can be summarized at intervals or averaged over the pavement management section. To obtain the pavement CRS value, a trained panel “drives” and reviews the various video views. The panel agrees upon type, frequency, and severity of the top five pavement distresses present in the pavement section. These pavement distresses are then translated into deduct values from a CRS of 9.0 along with deducts for the automated pavement data (IRI and rutting) that result in the final CRS value for the section (Ozer, 2018).

While rubblizing has been successfully used on a wide spectrum of highways, from two-lane rural roads to high-traffic interstates in Illinois, this study was limited to interstate projects. This was due to higher traffic volumes on these projects, which is key in evaluating the adequacy of the structural design and performance of this rehabilitation technique. The research team reviewed plans, when possible, for construction details that might be unique. The plans for projects with letting dates after 2005 are available on IDOT’s website. Details from past research summaries were used for projects with no online plans (Heckel, 2002; Pava, 2011; IDOT, 2016).

This report summarizes the data efforts undertaken to date and presents the findings and trends indicated by the data analyzed as of 2019. Data from the projects contained in this report represent a sampling of available data that could be generated and represent approximately two-thirds of the available data that should be representative of the overall data group. The reader should recognize that HMA mixes and cross-section details used by IDOT have changed over time. The researchers have made an effort to group like mixes together for improved analysis. The main groupings were by surface mix type, namely SMA or dense-graded IL-9.5 (9.5 mm nominal top size of the aggregate blend), as well as the performance grade (PG) of the asphalt cement binder used. Because of this segregation, there are cases that result in very few sections for study or those with limited service life to date.

The appendix provides a summary of the study sections by route, milepost, direction, contract, and basic cross-section data of the project in the study. Figure 1 provides a location map of the interstate rubblizing projects in Illinois.

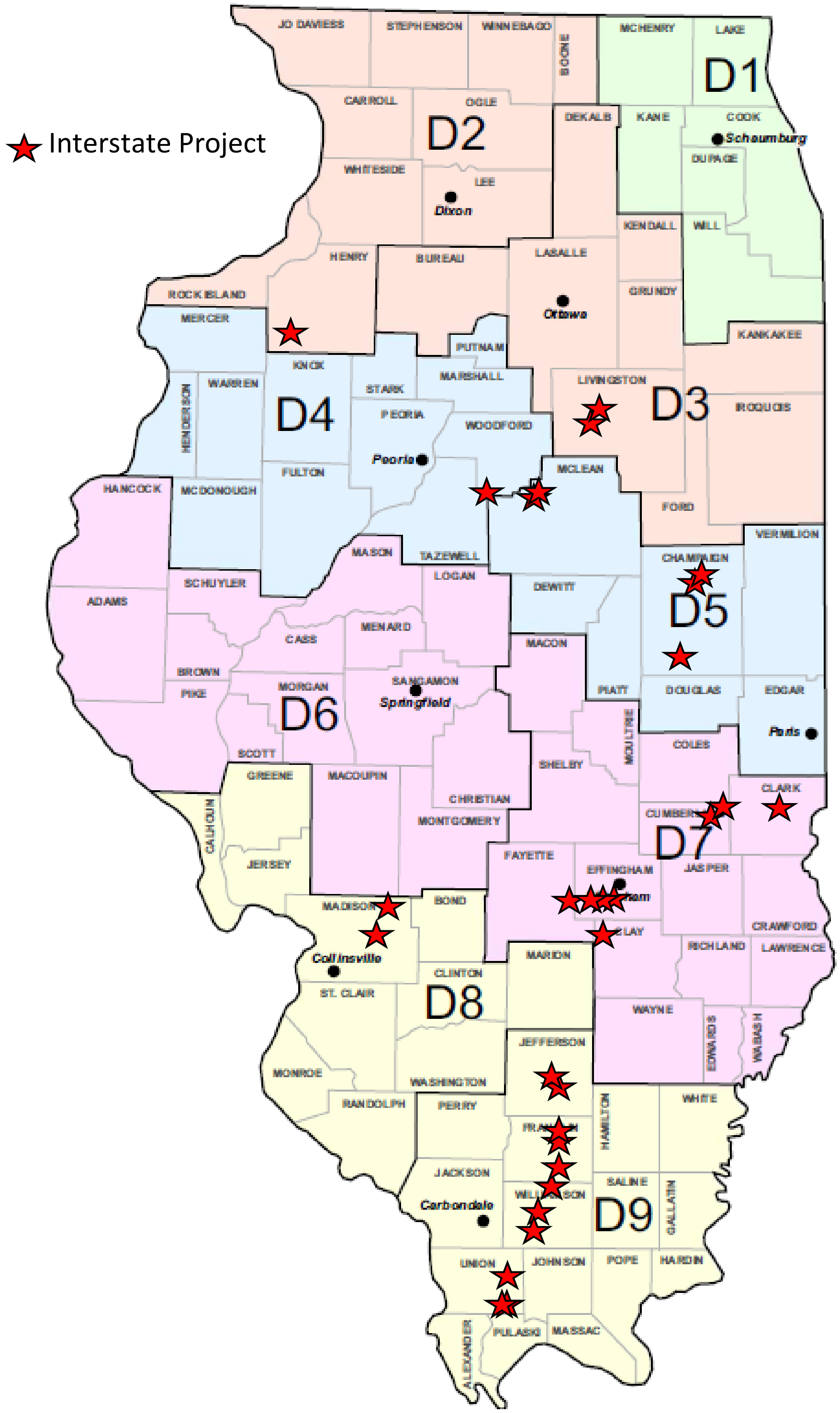

Figure 1. Map. Locations of interstate rubblization projects in Illinois.

CHAPTER 2: DATA DEVELOPMENT

IROADS—ILLINOIS ROADWAY ANALYSIS DATABASE SYSTEM

IDOT's Bureau of Research has been maintaining a listing of unique construction projects, including rubblizing projects. The main information collected and maintained by the Bureau includes location, contract numbers, letting dates, and related identification data so that project plans can be obtained. These are the keys to entering other more-detailed IDOT databases. Available data are on construction, materials, and, for this study, the performance data located in the Illinois Roadway Analysis Database System (IROADS) and Roadway Information System (IRIS). These databases contain details on location, jurisdiction, and condition, along with cross-section and performance information (IDOT, 2014). Of particular interest was the CRS, rutting, and IRI history of interstate rubblizing sections and the ability to access survey videos for reviewing pavement sections.

SECTION SUMMARIES

From the Bureau of Research's records, IROADS, IRIS, and project plans, a one-page project summary format was developed for the 35 unique sections constructed as part of 32 construction contracts (of which 31 utilized a HMA overlay and 1 used a continuously reinforced concrete overlay). Pavement management data in the form of CRS, IRI, and rut depth were retrieved and were made the core of the dataset along with specific surface mix information such as PG binder, friction aggregate classification, mixture type (IL-9.5 or SMA), and mixes/PG binder used throughout the lower lifts of the overlay. Included on these summaries were notes of interest from detailed review of the plans. Traffic counts and estimates of structural traffic were key points of interest. Structural traffic from time of original construction to first overlay, structural traffic on the overlay, and total structural traffic were estimated.

While the effort made a catalog of interstate rubblized sections, not all were used for analysis. For example, one section utilized a concrete pavement "overlay" rather than HMA, and there are very short multi-lane sections in congested interchange areas in which design lane traffic is not clear, so these were not used in analysis.

CHAPTER 3: DATA ANALYSIS

The data analyses included determining trends in rutting with structural traffic, CRS with age, and design traffic with actual traffic served. For the later analysis undertaken, the design curve is used to compare to the actual performance of sections to show sections in service along with those that have been overlaid (considered the "terminal" life of the original overlay). For CRS analysis, pavements were grouped by PG asphalt binder grade and surface mix type (IL-9.5 or SMA) to establish trends with age. Note that the "IL-9.5" trend line for AC-20/PG64-22 is a non-polymer mix that represents typical HMA mixes used until the full adoption of SuperPave mixes in the late-1990s. IL-9.5 mixes utilizing polymer-modified PG70-22 and PG76-22 asphalt binders are grouped together and represented by "Poly-22." Likewise, IL-9.5 mixes utilizing polymer-modified PG70-28 and PG76-28 asphalt binders are grouped and represented by "Poly-28" in the data. All polymer mixes in the data set use a SBS formulation.

CRS TRENDS

Figure 2 presents the CRS trends for IL-9.5 mixes, and Figure 3 presents the CRS trends for SMA mixes using the various PG defined above with age from original construction.

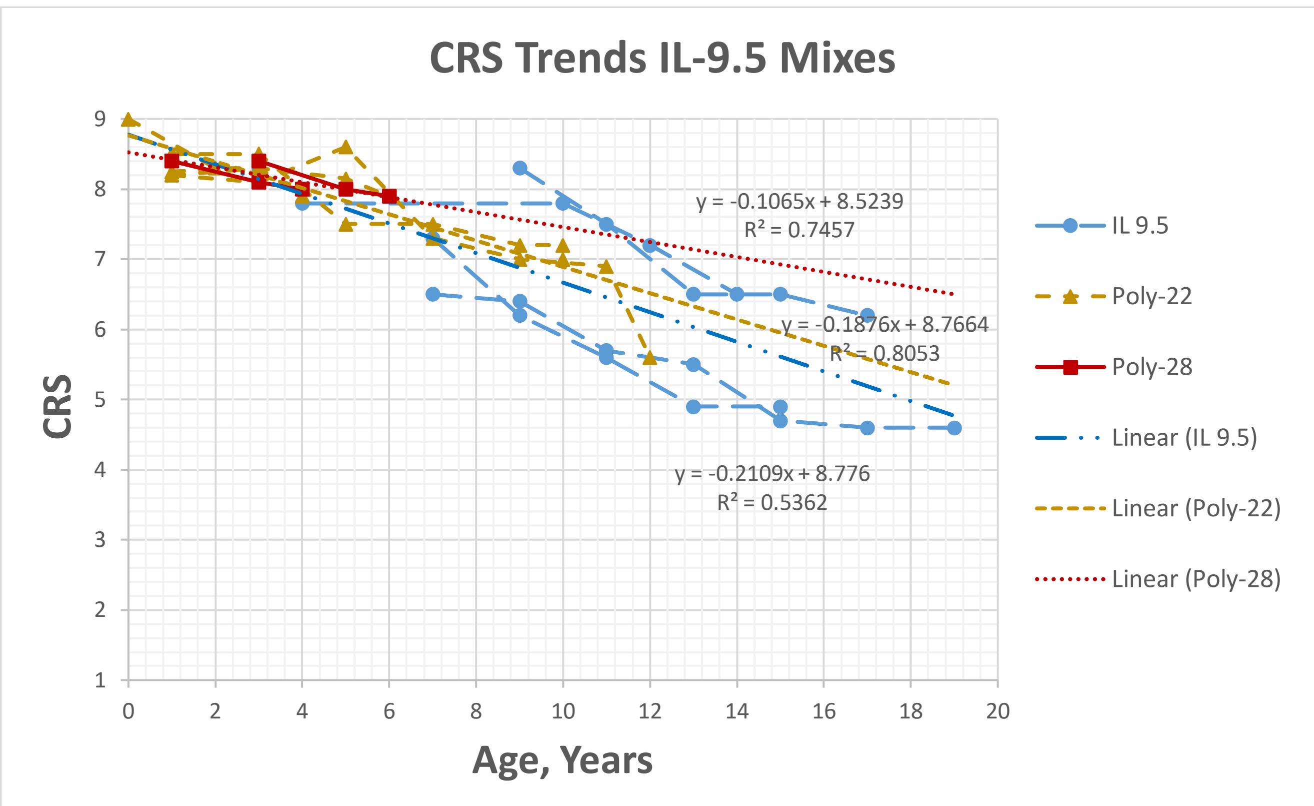

Figure 2. Graph. Data trends of IL-9.5 mixes.

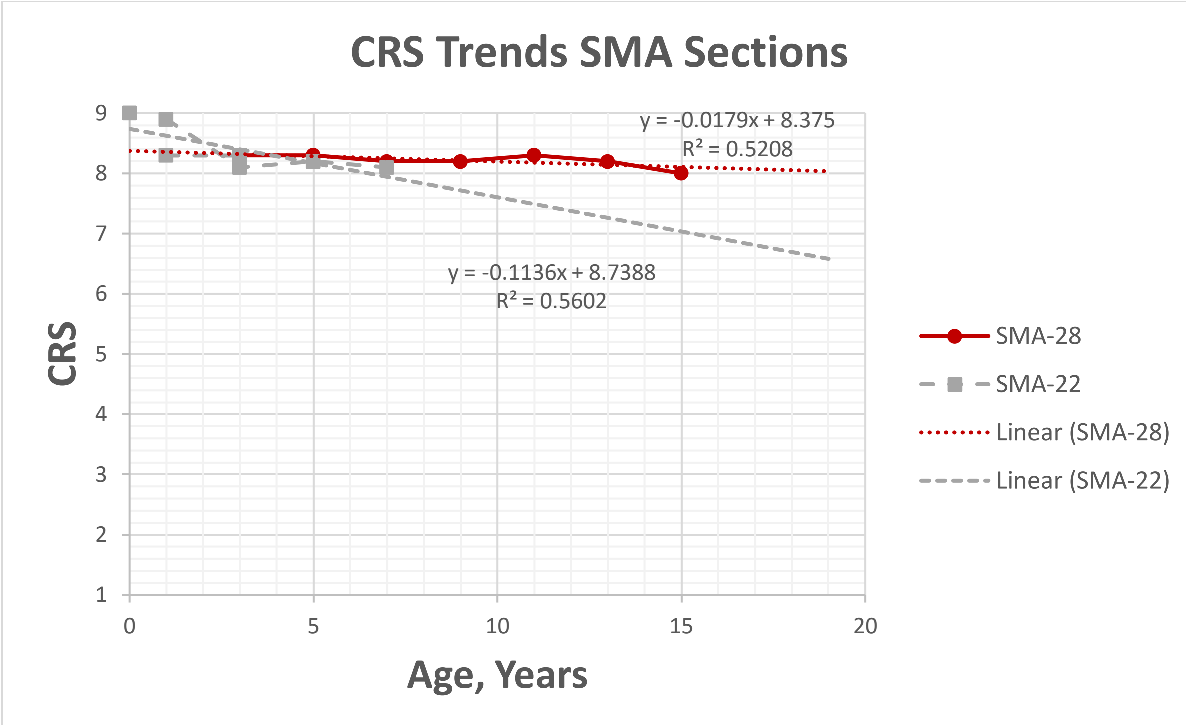

Figure 3. Graph. Data trends of SMA mixes.

Because the SMA-28 data trends are so flat over the early life of the pavement, the last three data points are likely a better predicter of future performance. For this reason, an additional trend line was determined using the last three data points, as presented in Figure 4.

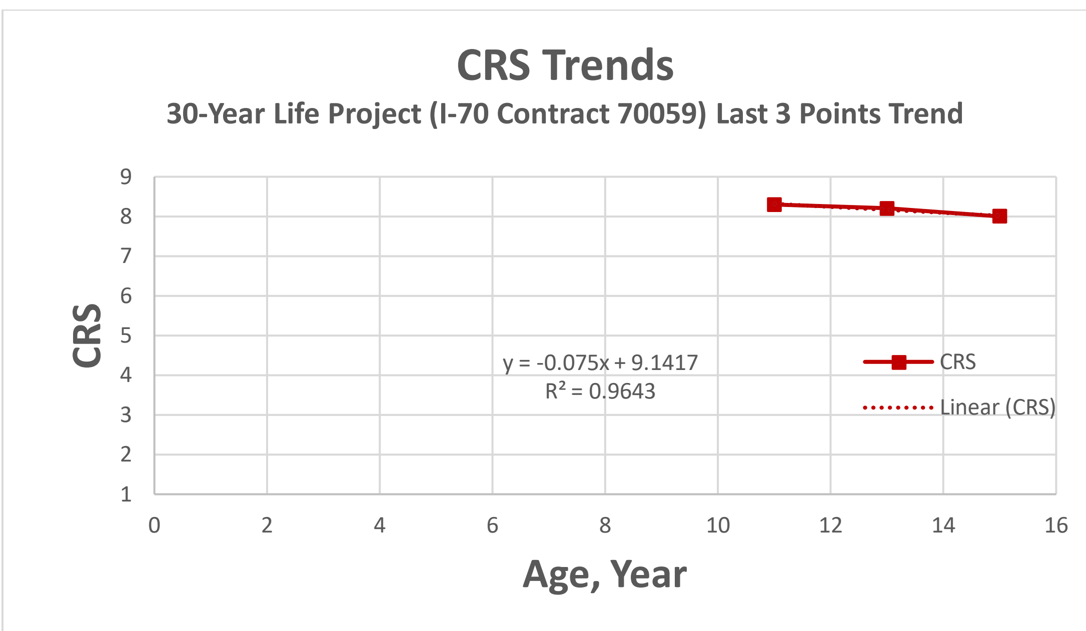

Figure 4. Graph. Last three data points trend of I-70 SMA with PG76-28—30-year life contract 70059.

Projected CRS Performance

Table 1 summarizes the slope and intercept data from the simple linear regression trend lines. This information was used to predict the number of years to a CRS service level of 5.5. A CRS value of 5.5 represents a state of acceptable condition on the interstate system. It should be recognized that this "prediction" is a rather simplistic approach. At best, this exercise provides a ranking between the various HMA mixes, not a true prediction of time to the end of service life. Seeing that this approach overpredicts the performance of the I-70 30-year-life project, an additional trend line using the last three data points was developed and presented. This projection is still likely excessive and is just an indication that this section has performed exceptionally well to date.

Table 1. Projected Years to CRS of 5.5 for Various HMA Surfaces

Surface Mix Group	Asphalt Binder Grade	Y-Intercept	Slope	R^2	Years to CRS of 5.5
IL-9.5	AC-20/PG64-22	8.78	−0.211	0.54	16
IL-9.5	Poly PGXX-22	8.77	−0.188	0.81	17
IL-9.5	Poly PGXX-28	8.52	−0.107	0.75	28
SMA	Poly PGXX-22	8.74	−0.114	0.56	28
SMA	Poly PGXX-28	8.38	−0.018	0.52	160
SMA (Last 3 data points)	Poly PGXX-28	9.14	−0.075	0.96	49

CRS Analysis

Within the IL-9.5 mixes, the Poly PGXX-28 mixes are showing improved performance trends over other IL-9.5 mixes. In general, the SMA mixes are shown to have superior performance over IL-9.5 mixes. One SMA section is showing outstanding performance, namely the 30-year design section on I-70 (Contract 70059). While the calculated life to a terminal CRS of 5.5 is not realistic, the data shows outstanding performance over the 15-year dataset retaining an unprecedented CRS value of 8.0. There were several additional features included in this section that are unique and worth exploring for future rubblizing projects. These areas are as follows. The first is longitudinal joint priming. This feature was intended to address longitudinal joint deterioration by filling air voids in this area. The second is SMA with a PGXX-28 grade. This softer asphalt grade helps provide protection from thermal cracking, helps prevent block cracking, and reduces the impact of aging on the surface. The third is overdesigned section. While not economical, the full-depth use of polymer in a much thicker than typical section likely benefits the section's performance. The biggest benefits to performance seem to be using a SMA surface mixture, using a PG76-28 asphalt grade, and priming the longitudinal joint (an improved longitudinal joint sealant has been adopted by IDOT), as block cracking and longitudinal joint deterioration are minimal on this project.

Current IDOT pavement-selection procedures analyze rehabilitation activities over a period of 45 years to compare concrete pavements to full-depth HMA pavements to determine the lowest life-cycle cost (IDOT 2013/2017). Considered in the selection process is rehabilitation of existing concrete pavement by rubblization. When rubblization is considered, the same maintenance models are used for rubblization and HMA pavement as for full-depth HMA. Within the activities of the maintenance models is a life of 15 years for the HMA surface, resulting in resurfacings at years 15 and 30. The data in this effort would indicate that the 15-year life used in the current selection process compares to older mix designs using AC-20 or PG64-22 mixes. As more advanced surface mixes using SMA or PGXX-28 asphalt grades are adopted, improved pavement performance is expected. This will precipitate the need to update the selection models to reflect the improved performance of these mixes.

To date, IDOT has not extensively used Poly PGXX-28 grades in SMA surfaces on rubblized projects. The outstanding performance to date using this combination would warrant additional construction of SMA and IL-9.5 mixes using Poly PGXX-28 in surface mixes. IDOT recently announced an effort to widely adopt both non-polymer and polymer PGXX-28 asphalt usage, which should make polymer PGXX-28 with SMA more the norm going forward (Trepanier, 2020).

RUTTING TRENDS

For rutting trends, all available rutting data was utilized without separating surface mix types or asphalt PG usage. Traffic counts of passenger vehicles as well as single-unit and multiple-unit trucks were converted to 18,000 lb equivalent single axle loads (ESALs) for flexible pavement, as outlined in Chapter 54 of IDOT's BDE Manual (IDOT 2013/2017). The result is presented in Figure 5 as rut depth versus ESAL. A logarithmic regression was developed through the dataset. Using the resulting trend line, a traffic value of 100 million ESAL would result in an average rut depth of 0.22 in. While this would be considered exceptional performance, such a projection far exceeds the dataset (currently 31.6 million ESAL). More data at higher traffic levels are needed to increase the reliability of such a projection.

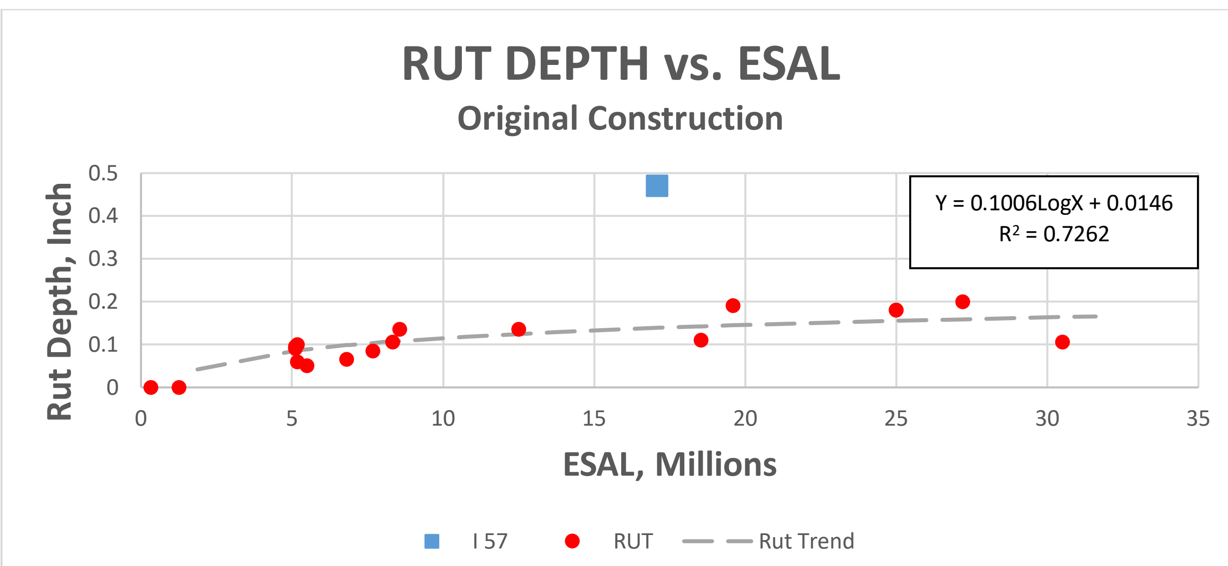

Figure 5. Graph. Rut depth trends of rubblized pavements.

The I-57 rubblizing project, constructed in 1997 as Contract 98387 in Union County, presented a rut depth of 0.47 in., which is considered excessive. Within two years of construction, this project was exhibiting excessive rutting to the point that a special investigation was warranted. Details and results were documented at the time and showed that the root cause of the rutting was the use of a level binder (currently termed as a binder by IDOT) layer added to the cross-section to provide the full pavement thickness shown on the plans (Heckel, 2002). Debonding and slippage at the level binder layer resulted in the excessive rutting seen. Due to findings of the investigation, this project was removed from the regression analysis in Figure 5.

DESIGN PERFORMANCE

The dataset contains performance information for three conditions of structural service: 1) original pavement construction still under traffic; 2) time and traffic to the time the original pavement was rehabilitated by an overlay; and 3) additional time and traffic on the overlaid pavement. The time at which the original pavement is rehabilitated can be viewed as a "failure" in the sense that the pavement surface could no longer provide the desirable level of service. Most of the "failures" were simply due to low CRS values. The main causes for CRS loss were block cracking, longitudinal joint deterioration, and edge of lane deterioration. Extraordinarily little fatigue cracking occurred on any of the sections studied. Most of the rehabilitation overlays were simple "mill and fill" operations to provide a new traffic surface with limited full-depth patching needed. Using a "failure" criterion of the "time of overlay" would be a conservative approach from a structural point of view because the main reason for the needed overlay was to address aging distresses in the surface. It should also be pointed out here that some of the early projects were included in larger CRS sections with standard treatments and probably were overlaid earlier than they needed to be.

In using the IDOT rubblization design procedure, the location of the project dictates the climate the pavement must serve throughout its life (IDOT, 2017). Illinois is a long state from north to south, so a pavement experiences different average temperature depending upon its location. The location as well as the PG asphalt selected correlates to a HMA mixture modulus that is typically between 500 and 700 ksi. Pavements in southern Illinois are warmer and, thus, have a lower modulus, requiring increased thickness. Pavements in northern Illinois remain stiffer and require less thickness for the same traffic and PG asphalt binder used.

Structural Design Analysis Original Construction

A simplistic approach was used to evaluate the adequacy of the structural design for rubblized pavement. A design graph was developed in Figure 6 that presents design ESAL vs pavement thickness for HMA modulus of 500 ksi (representing southern Illinois and/or softer PG binders) and 700 ksi (representing northern Illinois and/or stiffer PG binders). Plotted upon this figure are the original constructed pavement thickness vs. the ESAL count to date. The use of the upward pointing triangle is to indicate that the section is still in service and expected to move up the scale with time and additional loading. Pavement that has been overlaid (failed) are represented by an "X" to indicate the end life for that section. All X's are above the design curves, which indicate that the design procedure is more than adequate from a structural aspect.

Note that for the 30-year design warranty project constructed on I-70 under Contract 70059, an early design procedure for rubblized pavements was used, resulting in a 17.5 in. HMA thickness. This project also included several additional features, as noted above, to increase the durability of the pavement surface. From a structural viewpoint, the section was grossly overdesigned and precipitated a review of limiting strain criteria for incorporation into the design process that would result in a maximum pavement thickness regardless of the traffic loading. After this experience, the Bureau of Materials and Physical Research worked to provide limiting strain designs on a case-by-case basis. Limiting strain was incorporated into the design process in 2013 by an update to the BDE Manual (IDOT 2013/2017). To indicate this limitation, Figures 6 and 7 include a shaded box to indicate the maximum thicknesses where limited strain criteria is used to control the pavement thickness. Note that many of the rubblized pavement section designs are being controlled by the limiting strain criteria of the procedure.

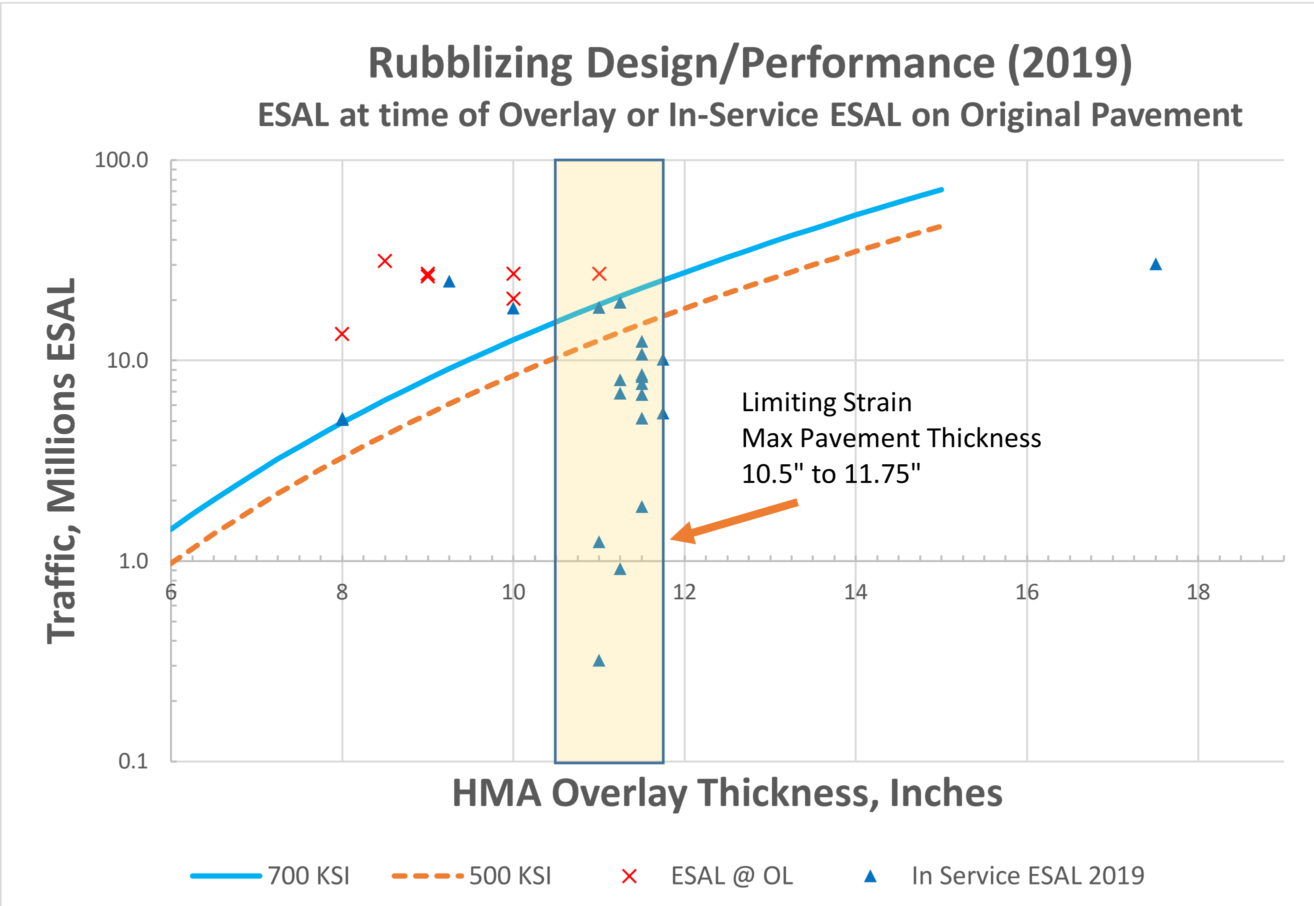

Figure 6. Graph. Terminal ESAL at overlay (failure) or ESAL to date of original rubblized pavement.

Structural Design Analysis—Overlay Rehabilitation

Of the original 31 rubblizing projects with HMA pavement, five projects (seven sections) have been rehabilitated to date. For those that were rehabilitated, Figure 7 extends the simple evaluation used above on the original pavement to those that have received an overlay. Overlays were mill and fill types of rehabilitation in the 2 to 3 in. range except for one project, which was a micro-surfacing. Patching because of structural failures was not present or minimal on these sections. The analysis is similar to above using the design chart to compare to the actual traffic served by the specific project.

The figure presents the original constructed pavement thickness vs. the ESAL to date, as in Figure 6. Sections that have been overlaid are represented by an "X" for the thickness and ESAL to indicate the end life for the original section. The circles represent ESAL traffic upon the new overlay, and the diamond represents the total ESAL traffic on both the original construction and new overlay.

The performance of the overlay sections is very encouraging. The critical fatigue location is the bottom of the HMA layer. Because only the surface has been replaced, the bottom of the original pavement has experienced the expected design traffic plus the overlay traffic, which in some cases is two to six times that of the original predicted design. To date, these sections have served with little to no fatigue distress.

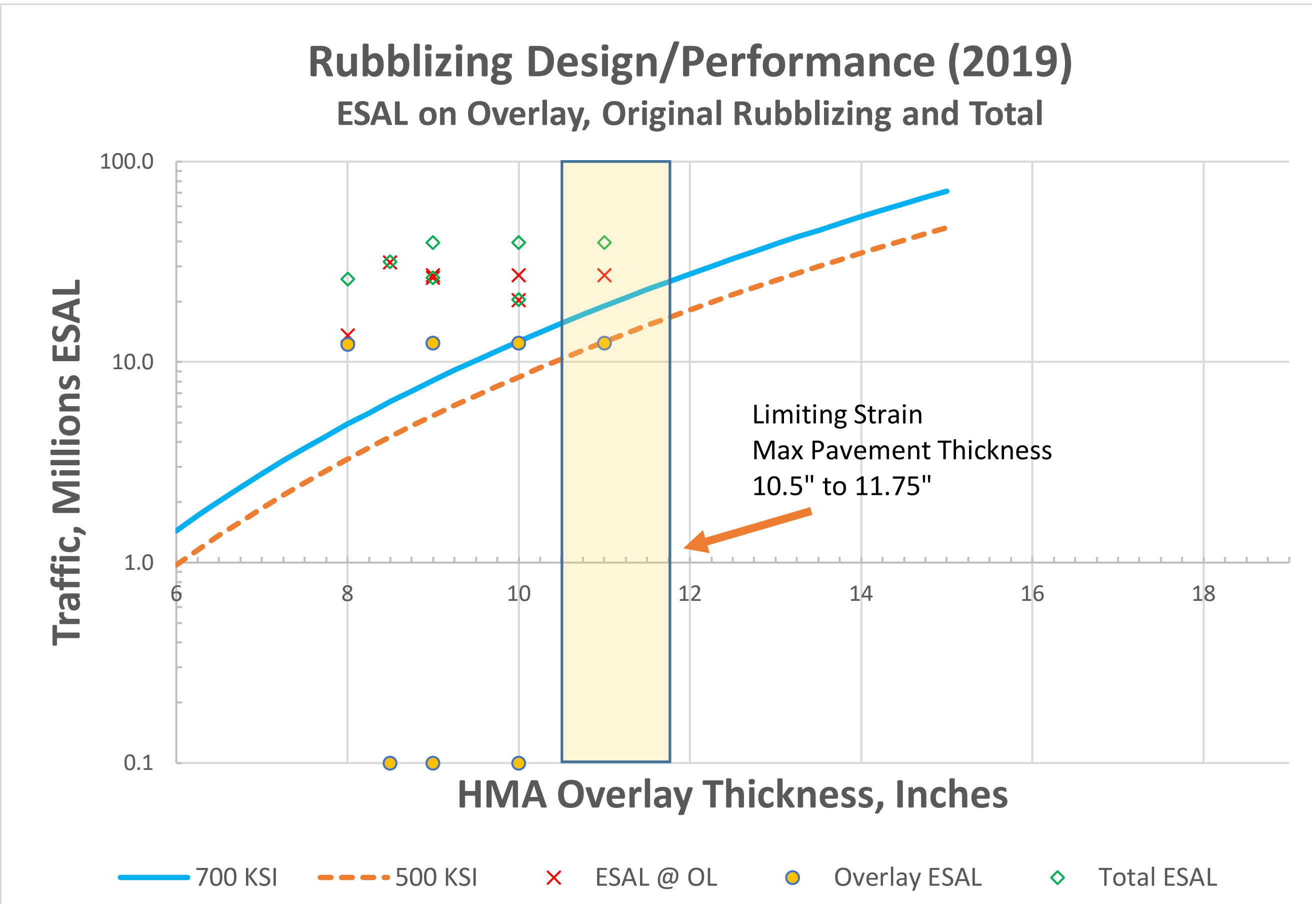

Figure 7. Graph. ESAL at time of overlay (failure), ESAL on overlay, and total ESAL to date.

Limiting Strain—Maximum Pavement Thickness

The limiting strain design check in the current design procedure was developed with the best available information and policy assumptions at the time (IDOT 2013/2017). These assumptions should be reviewed periodically to ensure the resulting limits provide long-term structurally sound pavements as intended and are not so overly conservative that financial resources are wasted. The CRS database has not identified any alligator cracking distress on any of the rubblized sections to date. Figure 7 shows that even after overlay without additional thickness, these pavement sections are serving many times the traffic for which the section was originally designed. This would indicate that sections are not being under-designed, so the question then is whether the maximum pavement thickness procedure is too conservative.

Table 2 shows each of the selected parameters used in the current procedure and compares them to the normal design procedure. For the limiting strain criteria, the most reasonable conservative values were selected to ensure that there would not be structural design problems in later years. For example, there is a long history of axle gross truck weight increasing through legislation. The current maximum legal limit of a 20,000 lb axle was selected to model the heaviest loads expected. Selecting the hottest month (July) provides the lowest HMA modulus and ensures that the selected limiting strain is the maximum the pavement will experience throughout the year. The poorest soil is selected for the entire state to model.

Table 2. Comparison of Inputs for Normal and Limiting Strain Criterion

Input	Normal Design	Limiting Strain
Temperature	Mean Springtime[A]	Mean Monthly for July[A]
Axle Load	18,000 lbs.	20,000 lbs.
Strain level	Determined by traffic Level from procedure	Selected as 70 με [B]
Subgrade ERI	Granular, Fair or Poor (2 ksi)[C]	Poor (2 ksi)

Notes:

A: Temperature at 4 in. depth in pavement.

B: 70 με selected as lowest strain needed to obtain unlimited fatigue life.

C: From soil analysis—approximately 90% of soils in Illinois are rated in the Poor category.

Of the limiting strain inputs that were selected, the strain level of 70 με is likely the input most subject to review and change. Some factors to consider for future reviews of the design procedure are which PG asphalt binders are to be used throughout the pavement section. The use of PGXX-28 grades in the lower lifts could result in some adjustments to the limiting strain thickness currently in use; however, additional review may be needed to determine if the limiting strain value selected should be increased for these softer grades.

CHAPTER 4: PLAN REVIEWS

As part of the study, plans available online were reviewed for general cross-section details and features that may have changed over time. This chapter highlights those items that are good practice and areas where improvements could be made to the current state of the practice.

UNDERDRAINS

Pavement edge underdrains are an important feature of high-volume pavement sections in Illinois. The need for this feature is due to poorly draining fine-grained soils common in Illinois, which result in water-filled pavement that can develop pumping distress on high-volume facilities after rains. As a result, underdrains are a standard feature on interstates and other high-volume highways for both concrete and HMA pavements.

Illinois has had a varied history with how existing underdrains have been addressed on rubblized projects. Because rubblizing is a rehabilitation technique, underdrains are typically present from a previous rehabilitation or from the original construction of the section. Past installations were either a longitudinal pipe or a mat style drain. Early rubblization projects would replace mat drains if present. Pipe underdrains were inspected for function and were typically left in place if deemed to be flowing. Unfortunately, some of the existing drains were not performing as well as needed for the increased drainage needs of a rubblized section and some problems resulted. The rubblizing process increases the void space in which water can enter and flow. If the underdrain system cannot remove the water quickly, then the water flows downgrade in the rubblized layer to vertical curve sag locations where water "bleeds" onto the pavement surface. Evidence of this is in the form of white calcium carbonate deposits on the shoulders once dry. Figure 8 shows such an area on Contract 78112 of southbound I-57 looking north at IL Route 154 near mile post 77.5 from 2010. While this did not seem to result in any structural problems, there is a potential for such areas to frost heave in the winter.

Another problem with underdrains on rubblizing projects is the effluent water is extremely high in dissolved calcium. As this water is exposed to air, a precipitate (calcium carbonate) forms and floats on the surface of any water ponding in the underdrain pipe after a rain. With the next rain, this calcium carbonate material or tufa is flushed out of the pipe as plate-like flakes. The process repeats with each rain. For newly rubblized sections, the result is clogging of the wire mesh rodent screens in the underdrain outlet. To ensure proper drainage, the outlets need to be maintained by removing/cleaning the screens and flushing the pipe to remove the built-up deposits. One state has taken the approach of eliminating the screen. The problem seems to clear up two to three years after construction.

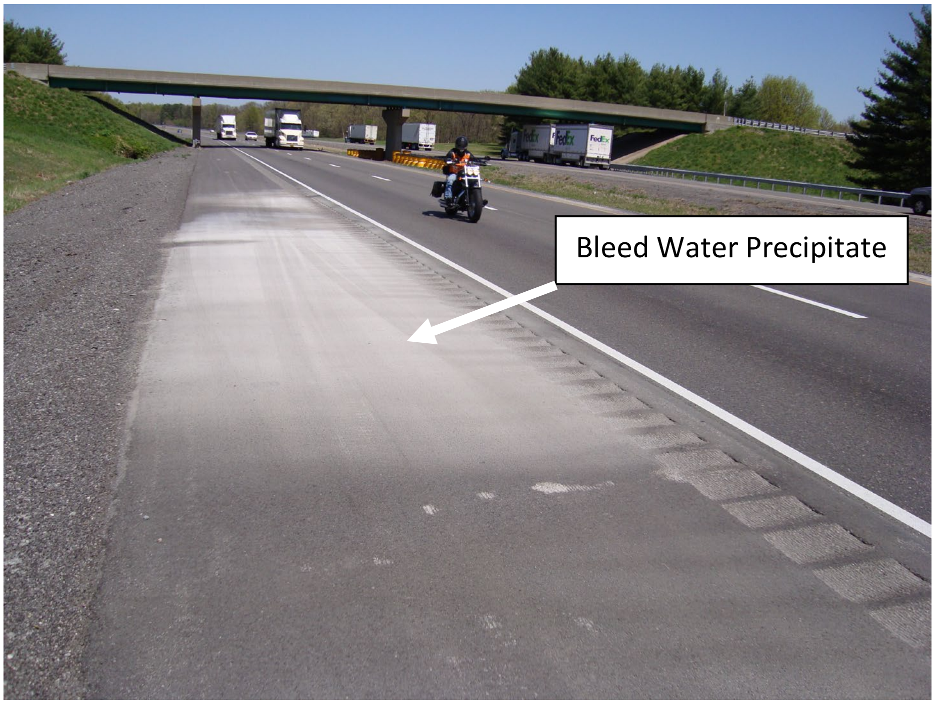

Figure 8. Photo. Bleed water precipitate—April 2010.

Because existing underdrains were not performing as well as needed on rubblized sections, more recent contracts have replaced the existing underdrains to ensure good drainage of the section. Several replacement underdrains utilized a 6 in. diameter pipe in lieu of the typical 4 in. pipe. The performance of these larger pipe drains should be reviewed to determine if this design results in less clogging and related maintenance overall. If found to be an improvement, this detail should be adopted as a standard on rubblized sections. To reduce maintenance of underdrain outlets with respect to the precipitate problem, alternatives to delayed installation or the elimination of the rodent screen should be investigated.

ALTERNATE BREAKING METHODS NEAR CULVERTS AND UTILITIES

Policies and specifications currently in use give general guidance and cautions on rubblizing over underground culverts and utilities. The specifications in use contain the following requirements (Heckel, 2002): "The Contractor shall prevent damage to underground utilities and drainage structures during rubblizing. Approved alternate breaking methods shall be used over underground utilities and drainage structures as specified on the plans or directed by the Engineer."

This wording in the design policy and procedures is vague. Over time, the result has been that designers have included very conservative limits on rubblizing in the vicinity of underground structures in the plans. Figure 9 shows an example of the limitations utilized in some recent plans for Contract 74416 on I-70. This detail leaves 100 ft of unbroken pavement over and near the culvert plus 50 ft of crack and seat on each end of the unbroken area for a total of 200 ft of non-rubblized pavement for each culvert.

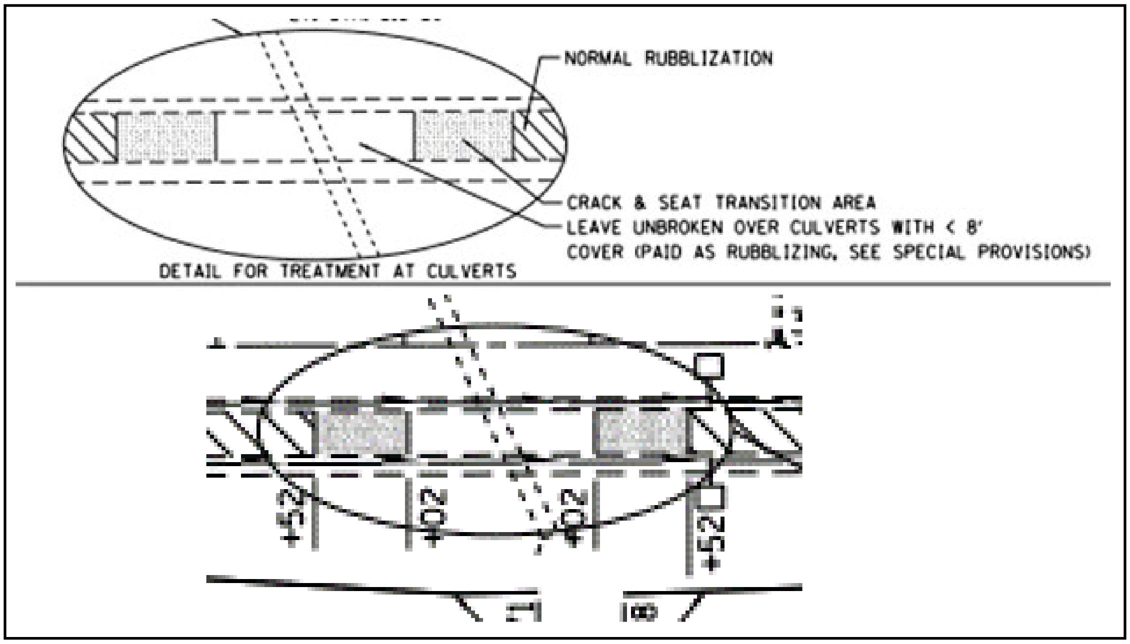

Figure 9. Drawing. Breaking details over and near culverts as shown in Contract 74416.

Source: IDOT eplans Contract 74416

Due to the frequency of culverts, 10% or more of the rehabilitation project may not be rubblized. To date, it is not evident that these areas have caused a performance problem. With time, these non-rubblized areas have the potential of reflective cracking, which may impact the performance of sections using this detail. Crack surveys would have to be performed to gather data to determine the impacts of this detail. It would be desirable to utilize rubblizing as extensively as possible to eliminate the possibility of reflective cracking altogether.

Analysis of Multi-Head Breaker Impacts on Culvert

There are no known issues at this time of rubblizing over culverts that have 8 ft or more cover, as adopted in the plan detail shown in Figure 9. Accepting this level of impact from the multi-head breaker on a culvert, one can determine the distance where rubblizing with the MHB should stop.

A simple approach was used that assumed the “shape” of the MHB hammer stress bulb in the subgrade is on a 45-degree angle from the point of impact. From this assumption, the minimum distance away from the culvert edge to the hammer that would not cause a problem is equal distance to the depth allowed, or in this case 8 ft. The limits of alternative breaking methods for culverts with less than 8 ft of cover would be the area directly over the culvert plus 8 ft each side of the structure. Figure 10 illustrates the concept.

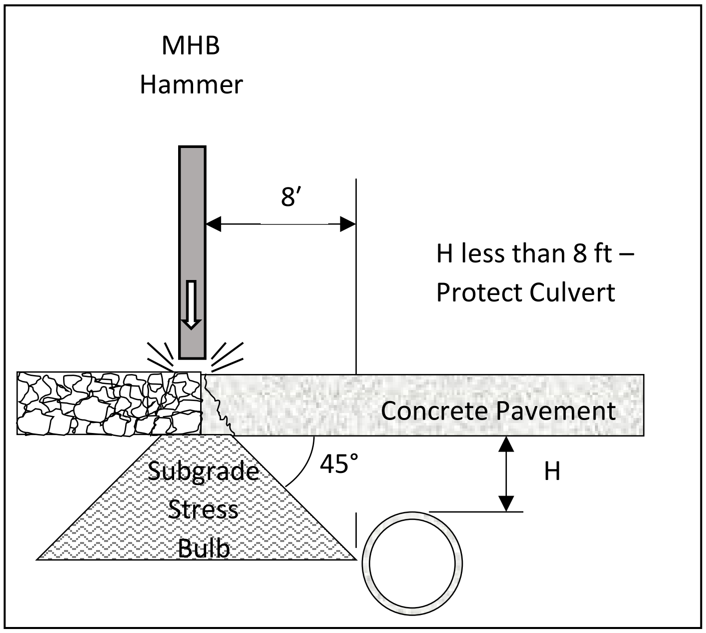

Figure 10. Drawing. Subgrade stress bulb under MHB hammer at pipe culvert.

Examples of an area to rubblize or protect include:

- A 36 in. RCC pipe with 9 ft of cover: Rubblize over pipe—no alternative breaking needed.
- A 36 in. RCC pipe with 4 ft of cover: 8.0 ft + 3.0 ft + 8.0 ft = 19 ft total length of alternative breaking method.
- An 8 ft wide double-barrel box culvert with 6 ft of cover: 8.0 ft + 8.0 ft + 8.0 ft = 24 ft total length of alternative breaking method.

An acceptable breaking method would be to change the MHB breaking pattern by alteration of speed or drop height. Another method would be to use a skid steer stinger to break the pavement into 18 in. or smaller blocks without displacing the concrete.

Clarified Specification Need

Specification language should be developed to provide clear guidance for the alternative breaking work to be performed and how it will be paid for. This will not only assist the contractor, but also make for consistent plan development by designers.

CHAPTER 5: FINDINGS

As a result of this study, several findings can be made as to the current state of the practice of rubblizing design, construction, and performance in Illinois, as follows:

- Overall, rubblization is providing good to excellent performance and exceeding design expectations.
- The design process is conservative. Fatigue cracking has not been observed in the original rehabilitation, which is providing service beyond the design traffic. Overlays that result in no additional structure (mill and fill) are not experiencing fatigue cracking.
- Rutting is not excessive and is similar to full-depth HMA. The exception is one project on I-57 (mile post 29.6–32.1 southbound) in which rutting was attributed to a level binder layer being added under the surface to make up for thin pavement.
- The selected HMA surface mix greatly impacts the CRS performance of the section, with SMA and softer PGXX-28 grade mixes providing increased life over PGxx-22 grades and IL-9.5 surfaces.
- The current conservative limiting strain criterion (10.5 in. to 11.75 in.) is controlling design thickness on many projects.
- Some plans have included exceptionally long non-rubblized areas to protect underground structures that are overly conservative.

CHAPTER 6: RECOMMENDATIONS

While rubblizing has demonstrated good to excellent performance to date, the data suggest that key policy and materials selection choices can greatly and consistently improve performance. The following factors are recommended to achieve this end:

- Select SMA with PGXX-22 or IL-9.5 with PGXX-28 for the surface mix to increase performance at limited additional cost. These combinations showed trends of an approximately 50% increase in life over IL-9.5 with PGXX-22.
- Limited data suggest that SMA with PGXX-28 could increase pavement life even more and may be the ultimate surface for HMA over rubblized pavement. Additional sections using this combination should be utilized to verify this trend, evaluate cost, and adopt as practical.
- Adopt an 8 ft buffer to rubblizing for structures with less than 8 ft of cover. The goal is to rubblize as much of the section as possible. Do not leave "islands" of intact pavement that may drive long-term performance issues of the section due to reflective cracking. To resolve any concerns, one may need to instrument and monitor culverts to define buffer distance needs and depth limits as well as how to break the pavement over culverts with modified MHB operations or a skid steer with a stinger.
- Current modulus and fatigue outcomes of recycled material specifications are not known for HMA mixes in use. Some modulus and fatigue work in this area would help define the impacts of these materials for both rubblized and full-depth HMA pavements.
- The limiting strain criterion of 70 microstrain warrants revisiting, especially in connection to expected usage of softer PG grades and recycled materials.

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APPENDIX

Route	Marked BMP	Marked EMP	Dir(s)	Key Rt BMP	Key Rt EMP	Contract	County	Letting Year	Base PCC	HMA Overlay	Rehab Year
I-39	~0	~4	NB	0.56	3.43	70A28	Mclean	2014	10.75″ HJ	8.0″	-
I-39	~2.5	0	SB	3.31	0.71	70634	Mclean	2013	10.75″ HJ	8.0″	-
I-39	~2.5	~4	NB/SB	3.43	4.75	70A28	Mclean	2014	10″ CRC	8.0″	-
I-55	19.62	30.81	NB/SB	0.91	12.81	76C93	Madison	2010	10″ JRCP	11.5″	-
I-55	31.05	33.9	NB/SB	12.18	14.95	76D99	Madison	2013	10″ JRCP	11.5″	-
I-55	194.71	200.92	NB/SB	7.01	13.22	66B64	Livingston	2018	9″ CRC	11.0″	-
I-55	200.92	204.62	NB/SB	13.21	16.84	66F23	Livingston	2017	9″ CRC	11.0″	-
I-57	20.76	25.84	NB	16.47,0.00	17.72,3.83	78289	Pulaski/Union	2012	10″ JRCP	11.5”	-
I-57	22.01	25.84	SB	0	3.83	78319	Union	2015	10″ JRCP	11.5″	-
I-57	29.6	32.1	SB	7.53	10.07	98387	Union	1997	10″ JRCP	9.0″	2019
I-57	43.27	52.82	NB/SB	0	9.55	78380	Williamson	2015	10″ JRCP	11.75″	-
I-57	54.07	62.1	NB			98948	Williamson	2006	10″ JRCP	8.5″	2019
I-57	54.07	71.93	NB/SB	0	9.93	78175	Franklin/Williamson	2010	10″ JRCP	10.0″	2019
I-57	71.93	80.68	NB	9.83	18.58	78046	Franklin	2009	10″ JRCP	9.25″	-
I-57	71.93	80.68	SB	18.58	9.83	78112	Franklin	2009	10″ JRCP	9.25″	-
I-57	80.68	87.58	NB/SB	0	6.9	78176	Jefferson	2010	10″ JRCP	10.0″	-
I-57	142.47	145.2	NB/SB	0/0	0.32/2.47	74417	Clay/Effingham	2011	8″ CRC	11.5″	-
I-57	143	149.3	NB	0.21	6.09	94389	Effingham	1996	8″ CRC	8.0″	2011
I-57	148.2	150.2	NB	5.47	7.43	94859	Effingham	2004	9.25″ CRC	11.25”	2017
I-57	238	243.01	NB	20.32	25.35	70716	Champaign	2013	7″ CRC	11.25″	-
I-57	238	243.3	SB	20.32	25.64	70923	Champaign	2011	7″ CRC	11.25″	-
I-70	~74	~82	EB/WB	0/21.47	3.12/26.3	74469	Effingham/Fayette	2014	10″ JRCP	11.5″	-
I-70	83.26	91.22	EB/WB	4.12	12.17	74664	Effingham	2017	10″ JRCP	11.5″	-
I-70	120.54	120.74	WB	14.53	17.83	90675	Clark/Cumberland	1997	8″ CRC	OL Sec	2013
I-70	120.74	120.93	WB	14.53	17.83	90675	Clark/Cumberland	1997	8″ CRC	9″ Sec	2013
I-70	120.93	121.13	WB	14.53	17.83	90675	Clark/Cumberland	1997	8″ CRC	11″ Sec	2013
I-70	121.13	123.75	WB	14.53	17.83	90675	Clark/Cumberland	1997	8″ CRC	10″ Sec	2013
I-70	120.7	127.9	EB/WB	14.64	21.83	74416	Cumberland	2012	8″ CRC	11.5″	-

Route	Marked BMP	Marked EMP	Dir(s)	Key Rt BMP	Key Rt EMP	Contract	County	Letting Year	Base PCC	HMA Overlay	Rehab Year
I-70	136.31	145.8	EB/WB	8.51	17.92	70059	Clark	2002	8″ CRC	17.5″	-
I-74	28.67	31.34	EB/WB	20.83	23.5	64065	Henry	1998	7″ CRC	11.0″	-
I-74	109.23	120.34	EB/WB	15.59Taz	1.76Mc	68A79	Taz/Wood/Mclean	2018	7″ CRC	11.25″	-
		Other Rubblizing Sections									
I-57*	52.6	53.2	NB/SB	9.32	10.01	98950	Williamson	2007	10″ JRCP	8.75″	-
I-57**	92	95.7	NB/SB	11.37	15.02	78172	Jefferson	2011	7″ CRC	12″ CRC	-
I-57/64*	~95	~96	NB/SB	15.23	15.96	78276	Jefferson	2014	7″ CRC	11.75″	-
I-57***	Pesotum SHRP LTPP SPS 6 Sections						Champaign	1990	10″ JRCP	6 & 8″	

* Short sections not included in analysis

** CRC overlay—not part of study

*** Historic short sections not included in analysis

CRC = Continuously Reinforced Concrete Pavement

HJ = Hinge-Jointed Concrete Pavement

JRCP = Jointed Reinforced Concrete Pavement (Typically 100’ Joint Spacing)

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