Pavement Rehabilitation in an Urban Environment: Minnesota Repair Standards Rehabilitate Twin Cities Freeways

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INTRODUCTION

Over the last eight years, the Minnesota Department of Transportation has contracted in excess of 100 miles per year of concrete pavement rehabilitation projects in addition to repairs done by our maintenance forces. These projects used various repair strategies, including full depth repairs, partial depth repairs, surface texture planing, joint sealing and installation of sub-surface drainage.

Prior to the construction season of 1982, standard repair detail designs and construction practices varied from district to district. This produced problems in bidding and construction. During the winter of 1981-82, a meeting was held with construction personnel and designers who had concrete pavement rehabilitation projects during the previous construction season. Construction and design problems were discussed and remedies were recommended.

During the winter of 1982-83, the Concrete Rehabilitation Committee was formed. This committee was composed of district design and construction personnel with rehab experience and contractors who have worked on these projects. Repair techniques and problems were discussed, repair types were categorized, construction procedures, bid items and plans were standardized. This committee has met every year since to review these standards and to agree on common concerns.

PRIORITIES SET

Other MN/DOT personnel, including design, programming and Materials Engineers, decided that priorities were necessary to determine which projects for concrete pavement rehabilitation should be programmed. The programming of concrete pavement repairs should be based on some fixed guidelines and MN/DOT funding restraints. The basis for these guidelines would be condition rating data and field inspection. Concrete pavement repair will be prioritized using the following five conditions and funding restraints for that year. Priority 1 work should be completed first to insure extended pavement life.

Priority 1 - *Joint Sealing*
When previous joint sealing is over 12 years or 50% ofexisting joints need resealing. Used for all concrete pavements. Repair cost per mile is low.

Priority 2 - *Joint Sealing with Minor Crack and Spalled Joints*
When joints as in the condition listed in priority 1 and minor mid panel cracks and spalled joints. Used for all concrete pavements. Repair cost per mile is moderately low.

Priority 3 - *Joint Sealing, with Spalled Joints and Minor* Full *Depth Repairs.*
When the concrete pavement is in good condition but with less than 75% spalled joints and a few full depth repairs. Used for all concrete pavements less than 20 years old. Repair cost is moderate.

Priority 4 - *Joint Sealing, with Spalled Joints, Full Depth Repairs and Rough Ride*
When the concrete pavement is in good condition (with a non-"D" cracking aggregate) but less than 75% of panels with spalled joints and major mid panel crack and the pavement exhibits a rough ride. Used on all major concrete pavements and all concrete pavements less than 20 years old. Repair cost per mile is high

Priority 5 - *Joint Sealing, with Spalling, "D" Cracked Aggregate , and Faulting*
When the concrete pavement exhibits greater than 90% spalled joints or secondary mid panel cracks or mild "D" cracking aggregate, or major faulting or a combination of these conditions. It may be cost effective to consider other options to repair work. The pavement condition is beyond the critical stage. The repair cost per mile is extremely high.

The District Materials Engineer, in conjunction with construction personnel and/or Central Office Concrete personnel will evaluate the pavement rehabilitation candidate by use of on site inspection, chaining and concrete cores when necessary to determine the best possible solution to the adverse condition. Chain dragging the pavement determines the outside edges of spall, and areas of delamination. Without chaining, the spalled area would appear much smaller. The drilling of cores on all projects is recommended to insure uniform concrete consistency over the concrete depth. This practice will help the designer better determine the pavement condition for cost estimations. Also, information regarding the pavement design, construction and source of concrete aggregate should be considered.

REHABILITATION TYPES

MN/DOT Concrete pavement rehabilitation can be classified into three Repair Types:

Type A Repairs - Joint and Crack Maintenance
Type B Repairs - Partial Depth Repairs
Type C Repairs - Full Depth Repairs

TYPE A REPAIRS - JOINT AND CRACK MAINTENANCE

Joint repairs include the removal of the in place seal, resawing the joint to a new shape factor, water flushing to remove saw slurry, sandblasting and airblasting both faces of the joint clean, and a closed cell backer rod to achieve a

proper shape factor for the sealer. Finally, the joint is sealed with an approved sealer. Cold poured silicone sealant is specified in all transverse joints. This material is tooled into the joint to provide the correct shape factor and to improve bonding to the joint face. Hot pour elastic sealant is used in the longitudinal joints.

Crack repairs include the removal of old concrete in the joint area by sawing the joint with a small concrete saw or routing the joint. This process should produce a consistent shape factor for a silicone sealer. Prior to the placement of the silicone sealer, the crack should be sandblasted and airblasted clean to remove all loose particles. An approved bond breaker is necessary at the bottom of the crack to prevent adhesion before installing the silicone sealer.

TYPE B REPAIRS - PARTIAL DEPTH REPAIRS

Partial depth repairs include removing spalled concrete, placing concrete, and sawing and sealing the joints as necessary. Spalled concrete removal operations can be performed by either of the two approved methods, sawing the concrete and using a jackhammer for the removal operation or the milling operation. These types of repairs are used on surface spalled areas at joints, mid panels and at pavement edges.

The milling option is almost exclusively used by contractors in Minnesota. It is especially productive for full width partial depth repairs at joints. This type of repair leaves a good bondable repair surface over the entire area. In the milling operation, the joint is milled to a depth of 2" across the entire repair, leaving a dish-shaped area. If over 40 percent of the joint is spalled, it is cheaper to mill the entire joint.

The sawing method for removal of spalled concrete at joints will require a saw cut to a minimum depth of 2". The concrete is removed within the area by the use of an air hammer of a capacity not to exceed 30 pounds. To increase the bonding surface the saw cut edges are tapered at approximately 45 degrees. The sawing and chipping operation for partial depth repair may also apply to longitudinal joint rehabilitation. This method of repair is very seldom used in Minnesota.

In the removal operation at joints the minimum length shall be six feet and the minimum width shall be ten inches. The spalled concrete shall be removed to a minimum depth of 2" and a maximum depth of 1/2 pavement thickness or to the top of the dowel bars. Any exposed dowel bars shall be coated with MC-250 oil or an approved equal. If the outside edges of the dowel bars are exposed, a compressible spacer must be placed to ensure joint movement. Dowel bars that have significant cross sectional loss should be burned off to prevent joint lock-up. If there are more than three dowels removed in succession, a full depth repair is necessary to restore load transfer.

If, after the removal operation, the area under the dowel bar is deteriorated and is less than 6" wide, it is better to leave the debris in place since it will allow some movement in the joint. This determination is made depending on the magnitude of deterioration due to undercutting at the joint. When undercutting is serious, a full depth repair is performed. Each repair is different for each job and must be reviewed in the field. Partial depth repairs may be necessary for spalled or delaminated concrete located away from a joint as well as adjacent to a joint.

Spot surface repairs are usually located away from the joint and require the removal of spalled concrete to a minimum of 2" by either the sawing or the milling operation. The minimum dimension for this type of repair shall be 30 square feet. Another area where partial depth repairs may be necessary is at the pavement edge. The minimum removal area in this repair shall be 10" measured transversely and a minimum 2" depth.

When the edge deterioration is more severe, extending down to the grade, a repair special is necessary. This includes the procedures listed previously, plus installing No. 5 reinforcing tie steel, 10" long and 24" on center. These bars are installed into drill holes, using a non-shrink grout. No. 4 longitudinal steel is tied to the No. 5 bar for added strength.

After the removal operations, the surface is cleaned by sandblasting and airblasting the surface. A bonding grout consisting of equal parts of cement and sand is applied to the surface just prior to the concrete placement. The grout should have a creamy consistency and be brushed into the entire patch. If a whitened edge shows, bonding grout has set up and this will require regrouting. If whitening is extensive, the entire area may require sandblasting and regrouting.

Concrete mix MN/DOT grade 3U18 concrete is a high cement content concrete with a small gradation which is used for early set in small areas. This grade of concrete is mixed in a paddle mixer or concrete mobile and placed in the repair area. The concrete is vibrated and finished to the proper grade, slope and texture. The final finishing operation shall be toward the in place surface on all sides to prevent the patch from pulling away from the in place concrete. The joint is reestablished, as necessary, with an angle iron cutter bar to establish the original failure plane and later saw cut to the required dimensions. For partial depth repairs over a transverse crack, it is imperative that the original crack be reestablished in the exact location with the use of an insert at the time of concrete placement. Bonding grout is applied to the patched edges to seal the area. The bonding grout should be applied in a transverse direction so the reestablished area will be sealed.

The surface tolerance is checked, and the membrane cure is applied. Due to the high cement content of the MN/DOT grade 3U18 concrete and the minimum depth of the repairs, it is imperative that the repair have an adequate curing membrane applied as soon as possible, otherwise the repair will fail due to shrinkage.

The final step in the partial depth repair procedure is the restoration of joints. This is accomplished by using the Type A repair techniques of sawcutting the joint, water flushing,

sandblasting, and airblasting the joint clean. Finally, a closed cell backer rod is installed before the silicone sealer is applied and tooled into place. With adequate temperatures, construction practices and curing, these types of partial depth repairs may be opened to traffic in as little as four hours using our 3U18 bag mix and a water reducing accelerator.

TYPE C REPAIRS - FULL DEPTH REPAIRS

Full depth repairs are localized removal of the concrete to the full depth of the concrete. These removal areas may occur at locations with severe joint or crack deterioration, subsoil problems, and where panel replacement is necessary due to thermal expansion or at locations of major construction difficulty. If a full depth repair is proposed in a lane in excessively hot weather, a full lane relief cut may be sawn in the adjoining lanes to guard against pavement expansion or "blow-up" due to relief in the pavement.

The concrete is sawed full depth and removed to a three foot by three foot wide minimum, although full lane width is the norm. To maintain subgrade consistently, do not disturb the grade during the removal operations. After the debris is removed, holes are drilled in the adjacent slab face for No. 8 tie steel at 12" center. The tie steel is installed at a 20 degrees skew, normal to the joint to help prevent the new slab from separating from the adjacent slab. The tie steel is 18" long and should extend 9" into the in place pavement. The steel is placed in the holes, using a non shrink grout. The grout placement must be sufficient to bond the total surface of the steel into the holes. If an adequate job is not done grouting in the tie steel, a failure may develop at the tied joint.

At expansion joints full depth repair work will involve the removal of the old concrete and placing reinforcing steel where necessary. The pre-formed expansion joint is placed at the planned location and the free ends of the dowel bars are coated with MC-250, or approved equal. Sleeves are installed over one end of the dowel to allow movement equal to the joint width. The exposed surface of the in place concrete is sandblasted and airblasted, and grout is applied. The concrete mix is determined by the required time of opening to traffic. Surface tolerance are checked and curing membrane is applied.

A full depth repair at a contraction joint or mid panel crack is the major type of full depth repair used and will involve the removal of the old concrete and placing the new concrete similar to the work at expansion joints. In this type of repair one side will have the No. 8 rebar grouted in, while on the other side of the repair a straight dowel bar is installed. The dowel bar is an 18 inch by one inch diameter smooth bar and is installed on 12" centers parallel to the centerline joint. As in the expansion joint, it is imperative that the dowel bars are not misaligned by more than 1/8". Poor alignment will result in a non-working joint, resulting in a new spall.

Other areas where full-depth repairs are used are at mid-panels. These repairs are placed similarly to the previously described full depth repairs with the tie steel grouted into both sides of the in place pavement. If neither adjacent pavement joint is working, one may place a contraction joint at one side of the repair. Every repair is job specific. Panel size, load transfer mechanism, and subgrade conditions determine if reinforcing mesh is necessary.

Spot full depth repairs are used in areas of punch outs or where minor repairs are necessary. They are performed by sawing full depth and removing the concrete. Care must be taken not to create additional spalls or undercutting. Tie steel must be installed by grouting into the inplace slab in both the longitudinal and transverse directions. If the spot full depth repair is at an inplace joint, inspection of the dowels should include any misaligned dowels. These bars should be burned off and if three or more dowels are removed in succession, the dowels should be replaced.

When the centerline joint has deteriorated, it may cause a traffic hazard for motorcycles and compact cars. It is necessary to repair this area by a partial or full-depth method. If the full depth repair is necessary, a full depth saw cut is made, 12" minimum and parallel to the centerline joint, and the concrete is removed. No. 5 reinforcing tie steel, 10" long, 24" on center is grouted into the face of the in place pavement. To tie the pavements together a 10" No. 4 rebar spaced at 24" is used. For added strength two No. 4 longitudinal rebars are installed parallel to the centerline. The concrete is placed into the repair, and the joints are reconstructed. When repairs are necessary on nontied longitudinal joints the repair procedure is the same except a 1/4" joint filler is installed at the centerline location and no tie steel is necessary.

IMPLEMENTATION

Since 1985 the Minnesota DOT has had an aggressive program to utilize concrete pavement repair techniques on major metro freeways. Most of the freeway system in the Minneapolis/St. Paul area was constructed somewhere between the early 1960's and 1970. With ever increasing volumes of traffic and especially heavy truck traffic around the growing community and suburbs, pavement repair was inevitable. These freeways also suffered tremendous damage from studded tires, which were allowed on Minnesota highways from 1965 through the 1972 Winter, when legislation was finally passed to remove the hazardous studs from wreaking havoc on Minnesota highways.

Highway I-35W form 66th St. to I-94 in Mpls

Project No. SP 2782-229

Letting Date: May 24, 1985

Original Construction 1967

Initial Design 10 Inch With 40 Ft. Mesh Dowelled Joints

Traffic 150,000 ADT

Final Contract Amount	$4,990,000
Concrete Related Items	$2,406,000
Lane Miles	31
Normal Work Week	6 - 12 hour days
Working Days	45
Starting Date	July 8, 1985
Completion Date	Oct. 5, 1985

Interstate 35W was the first route chosen between its downtown connection with Interstate 94 and the Crosstown Highway, County Road 62. This section of the freeway system carried the heaviest volumes of traffic, some places in excess of 170,000 vehicles per day. This section consisted of mostly a 3-lane freeway in both directions, widening out to 4-lanes at Diamond Lake Road North, into the downtown Minneapolis area, and is common section with 35W and Interstate 94.

This project was the first concrete rehab and diamond grinding done in the Minneapolis - St. Paul area on a heavily travelled interstate. The plans were designed to allow the contractor to work between the morning and evening rush hours on two lanes of the three lane facility in each direction. He was required to maintain two lanes traffic clear before 9:00 AM and after 3:00 PM. The option of working at night was determined to be a safety and quality problem for state and contractor personnel. The effective time of patching was reduced to about one hour during daylight hours under this schedule. If you consider a minimum cure time of 3 hours and two hours to set up traffic control and remove concrete for patches, you are left with about one hour of effective patching time in the middle of the day. Production costs were high and progress was very slow under these constraints.

A meeting was scheduled between state and contractor personnel while work on the project came to a halt. Discussion centered around the rate of production and the remaining days in season. It was determined that the public could be better served by a shorter but more restrictive time schedule. It was decided to provide two lanes for the inbound traffic during the morning rush hour and two lanes for the outbound traffic during the evening rush hour. This allowed the contractor to more than double his production and finish the project within the prescribed working days.

Highway	I-35E from Maryland Ave. to I-694
Project No	SP 6280-255
Letting Date	June 6, 1986
Original Construction	1961
Initial Design	10 inch Concrete with 40 Ft MeshDowelled Joints
Traffic	**120,000 ADT**
Final Contract Amount	$4,204,933
Concrete Related Items	$2,515,915
Lane Miles	25
Normal Work Week	7 - 16 hour days
Working Days	30
Starting Date	July 11, 1986
Completion Date	August 24, 1986

This was the first project to have success using the power of advance publication in all forms of media, radio, papers, and even pamphlets handed out at the ramps months before construction commenced. After the experience of I-35W during 1985, the MN/DOT decided to do an aggressive campaign to warn the public of traffic problems on this stretch of I-35E. Some commuters found a quicker way to work by taking the route under rehabilitation but most heeded the advance warning and found alternate routes.

This six-lane freeway was restricted to one-lane in each direction while rehabilitation started on the outside lanes first as traffic was moved to the inside lane. The outside two lanes, plus the wide shoulder, were available for contractors and equipment at the start of the project. This provided the contractor plenty of roadway in which to build production and shorten the time for the entire project. In fact, the time schedule was dictated by the production schedule of the diamond grinding equipment.After completion of the work on the outside two lanes, traffic was moved to the outside lane and the contractor finished grinding and patching the two inside lanes.

Highway	I-35W from County Road C to County Road D
Project No.	SP 6284-111
Letting Date	May 22, 1987
Contractor	Forby Contracting Inc., Hinckley, Mn
Original Construction	1964
Initial Design	10 inch Concrete with 40 Ft. Mesh Dowelled Joints
Traffic	90,000 ADT
Contract Amount	$2,741,686
Concrete Related Items	$3,660,082
Lane Miles	31

Normal Work Week 6 - 16 hour days

Working Days 35

Starting Date July 7, 1987

Completion Date August 21, 1987

This project presented the designers and the contractors with a different challenge with 26 ramps in its 6 mile length. The contract dictated a set number of working days for each ramp, and the total of 45 was 12 days more than the allotted working days for the entire project. In order to provide access to the travelling public, the contract would not let two successive ramps be closed at any one time. This further complicated the process of scheduling by the contractor in order to complete the project on time.

The majority of the work on the ramps was accomplished during the evening hours, as well as the diamond grinding. It was necessary to work around the clock in order to meet the tough time schedule. Also this project incorporated all forms of media, including radio, newspapers, and pamphlets sent to all commuters along the project route. This project had an incentive/disincentive clause of $5,000 per day for each roadway direction, which allowed the contractor to finish one half of the job early, and receive a bonus if he was able to complete the other half by the completion date.

Highway I-694 from I-35W to TH 49

Project No. SP 6205-29

Original Construction 1962

Initial Design 10 inch Concrete with 40 Ft. Mesh dowelled Joints

Letting Date: April 22, 1988

Contractor Forby Contracting, Hinckley, Mn

Traffic 75,000 ADT

Contract Bid Amount $1,939,89

Concrete Related Items $1,595,606

Lane Miles 23

Normal Work Week 6 - 12 hour days

Working Days 42

Starting Date June 6, 1988

Completion Date July 28, 1988

In 1988 the MN/DOT decided to apply the diamond grinding concept to an Interstate highway that was rehabilitated in 1979 as one of the initial concrete pavement restoration projects. The techniques learned since their inception in the late 1970's were vastly improved. Most of the patches constructed in 1970 were still functional, but the pavement suffered from the distress caused by studded tire wear and poor performance of the joint sealers.

This interstate is a four lane facility that was rehabilitated one lane at a time starting with the outside lane. By starting there, the contractor can mobilize a large work force at the beginning of the project and also tackle the truck lane and the adjoining ramp areas where the most distress is located. When traffic is moved back to the truck lane, they regain full access to exit and entrance ramps.

This contract required the contractor to finish one half of the project before the 4th of July weekend. There was a penalty of $10,000 per day plus $500 per hour if the roadway was not opened to traffic for the holiday week-end. No incentive was given for early opening of the project, but the contractor was finished with the first half on Thursday June 30, 1988.

SUMMARY

The Minnesota Department of Transportation has used these repair methods extensively with good success. We have also contracted for repair projects where the repair work was performed and texture planing of the entire surface was required. At this time we have many repairs that have performed 10 years with no sign of distress.

Not all repairs that were first constructed in our first few contracts performed, but with good preconstruction investigation, construction practices and the annual meeting between State and contractor personnel to discuss failures, the major problems have been cured. Our major advancement in the concrete repairs has been the use of the milling operation for concrete removal. This type of removal gives a good surface for concrete bond and has proven highly successful in Minnesota. We believe that we can expect 15 years additional pavement life by proper concrete rehabilitation.