MATERIALS, RESEARCH AND STANDARDS

"Implementing research findings"

MINNESOTA DEPARTMENT OF HIGHWAYS

Report Prepared for

OFFICE OF BRIDGES AND STRUCTURES

MINNESOTA DEPARTMENT OF HIGHWAYS

1976 REPORT AND POLICY FOR PROTECTION OF CONCRETE BRIDGE DECKS

Prepared by

Bridge Deck Task Force

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INTRODUCTION

A task force composed of personnel from the Offices of Bridges and Structures, Materials, Research and Standards has reviewed and analyzed existing procedures for protection of bridge decks.

The objectives of the task force were:

1. To develop policy for installation of protective systems on new bridge decks.

2. To develop policy for establishing priorities and selecting methods for contract restoration and protection of in-service bridge decks.

3. To develop policy for systematic maintenance utilizing M.H.D. forces, for the preservation of in-service bridge decks which are not being considered for contract restoration.

The objectives were set to protect the bridge deck investiment in a cost-effective manner and within budget limitations.

PROBLEM

In recent years premature bridge deck deterioration has been recognized as a serious and widespread problem. This deterioration is caused by corrosion of the deck reinforcement. Chlorides, used as de-icing agents, accelerate the corrosion rate far beyond normal levels. As the reinforcing bars corrode, they expand and cause cracks in the bridge decks. Spalls (pot holes) then develop under traffic action when the cracks fill with water or ice.

The department has become active in a national program to study possible solutions to the deterioration problem. Although it may be several years before the present systems can be fully evaluated, some trends have become evident. The task force has analyzed these trends to develop the policy contained in this report.

Since recognizing the problem, approximately 230 bridges have been protected with "waterproof" systems of some type. Since there are 2,679 structures with concrete decks on the trunk highway systems, this is only a beginning. The remaining 2,450 bridges are without protection, and are in various stages of deterioration. If the problem can't be resolved, complete removal and replacement of these decks will be required, at an estimated cost of $400 million.

OVERVIEW

In accordance with the task force objectives, all new and in-service bridge decks are categorized by their importance and exposure to de-icing agents. The relative importance of each bridge is determined by the traffic volume it carries. The degree of protection required is based upon the traffic volume, bridge location, and application of de-icing agents.

New bridge decks will be constructed to standards which insure a reasonably long maintenance free life. The new bridges have been grouped into four categories with a deck protective system designed to be cost effective for the anticipated exposure to de-icing salts in each of these categories. Policy for contract restoration is based on the premise that contract work is more economically justified if;

1. Initiated on basically intact decks as a protective measure, or
2. Deferred on severly deteriorated decks until full deck removal and replacement is warrented.

Decks which have moderate to severe deterioration should have their service life extended with M.H.D. maintenance forces until full deck removal and replacement is warranted.

In the past contracts were let to restore only those decks in an advanced stage of deterioration. Accordingly, many of the approximately 230 bridges protected had been in this deteriorated condition. It would appear that we are now in a position to utilize a portion of the contract repair dollar on preventive deck maintenance. Such protection would provide an extended service life, and help to eliminate the problem before it reaches the critical stage.

Priorities for contract restoration are based on deck condition, relative importance, and level of de-icing agent application. Since the goal in setting these priorities is to provide the best overall cost benefit ratio, contract work will not be uniformly distributed, but will be allocated on the basis of need.

Interstate contract restoration should be programmed for completion within five years, and trunk highway restoration over a longer period of time. When programming, every effort should be made to utilize "package" contracts, which include a number of bridges in close proximity, to minimize cost and traffic disruption.

Restoration methods recommended in this report are based upon a cost-per-square-foot analysis, for each year of anticipated service life. The repair techniques detailed are those which are considered to be most cost effective.

Considering the large number of bridges in some state of deterioration, and the limited funds available for contract work, there exists the need for effective bridge deck maintenance by M.H.D. forces. Those bridges which receive a low priority for contract repair will necessarily be maintained with M.H.D. crews.

SUMMARY OF RECOMMENDATIONS

The following is a brief summary of recommendations compiled by the task force to achieve its objectives. For more detailed information, see the specific sections of the report outlined below:

POLICY FOR NEW BRIDGE DECKS

	Category	Protective System
I.	Trunk highways with greater than 10,000 ADT, and all interstate highways	Coated reinforcing bars and special concrete overlay.
II.	Trunk highways with 2,000 to 10,000 ADT.	One of these: a.) Coated reinforcing bars; b.) special concrete overlay; c.) *membrane and bituminous overlay; or d.) other promising protective systems.
III.	Trunk highways with less than 2,000 ADT.	Three-inch concrete cover.
IV.	All others.	Two-inch concrete cover.

*A membrane and bituminous overlay may be considered where the approach roadway is bituminous.

POLICY FOR RESTORATION BY CONTRACT

	Deck Condition	Procedure
I.	0-5% Unsound (Slight deterioration)	*Spot removal and concrete overlay
II.	5-20% Unsound (Moderate)	*Spot removal and concrete overlay
III.	20-40% Unsound (Severe)	*100% removal of surface down to reinforcing bars and minimal spot removal of fractured concrete below reforcing bars. Overlay with concrete.
IV.	More than 40% Unsound(Critical)	Program new deck.

*A membrane and bituminous overlay may be considered where the approach roadway is bituminous and/or when necessary for the shortest traffic delay.

POLICY FOR MAINTENANCE BY M.H.D. FORCES

Deck Condition	Procedure
I. 0% to 20% Unsound (Slight to Moderate)	*Place low slump or 2 inch maximum slump concrete patches and treat with oil or place thin bituminous mat.
II. Greater than 20% Unsound (Severe)	Maintain rideability with concrete, epoxy or bituminous patches and bituminous mats.

* Application of linseed oil is recommended for all bare concrete air-entrained decks with moderate or lesser deterioration. Air-entrained decks are those built since 1946.

POLICY FOR NEW BRIDGE DECKS

To provide extended service life for new concrete bridge decks, the following policy has been developed. Bridges are grouped into categories, with those structures carrying the heaviest traffic volumes and receiving the greatest amount of chemical application falling into the higher categories. As traffic and de-icer chemical application decreases, the bridges fall into progressively lower categories.

The categories are as follows:

1. High traffic volumes and heavy application of de-icers

   Any of the following bridges:
   a. All bridges carrying Interstate traffic,
   b. All Interstate highway bridges at an interchange,
   c. All bridges carrying trunk highway traffic within municipalities,
   d. All bridges on highways with projected ADT greater than 10,000.

   These structures shall be designed with coated reinforcing bars in the structural slab, topped with a special concrete overlay. The overlay will normally be low slump concrete or latex modified concrete, however, other concrete materials may be considered on an experimental basis. Reinforcing bar coating will be either an epoxy coating on the top layer of reinforcing bars, or a galvanized coating on all of the deck reinforcing bars.

The protective system recommended for decks in category 1. include a special concrete overlay and the resulting two course construction to resolve problems of:

a. Subsidence of concrete under reinforcing bars and the resulting voids,

b. Cracks over the reinforcing bars,

c. Obtaining the specified cover over the reinforcing bars.

This quality concrete overlay acts to resist cracking, abrasive wear, and penetration of chlorides since it is less pervious than regular concrete. Coated

reinforcing bars alone do not provide complete protection against spalls which may result from ice and water accumulating in voids and cracks in the concrete.

The concrete overlay and coated bar system is estimated to cost 20% more than other systems, but the anticipated service life makes this system cost-effective in high traffic areas. (See appendix for cost data.)

2. Moderate traffic and application of de-icers

Bridge decks not included in the above criteria which carry trunk highway traffic with projected ADT between 2,000 and 10,000 shall be designed with any one of the following:

a. Coated reinforcing bars or,
b. Special concrete overlay or,
c. Membrane and bituminous overlay or,
d. Other promising protective system.

The protective system selected will vary from bridge to bridge on an experimental basis. It appears to be more economically feasible to place experimental systems in this category rather than on those structures with the higher traffic volumes. Bituminous overlays will be considered only where the approach roadways are bituminous. Coated reinforcing bars will be either epoxy coated or galvanized as described above for category 1.

3. Low traffic volumes and chemical application

On those trunk highway bridges with projected ADT less than 2,000 which are not included in the above two categories, a conventional bridge deck shall be used with three inches of concrete cover over the top reinforcing bars. If deck is being replaced and Federal funding is desired coated reinforcing bars with a two inch cover shall be used in lieu of the three inch cover, in order to meet Federal requirements for funding.

4. Systems other than interstate and trunk highway

The bridge deck details for those bridges not included in the interstate or trunk highways systems shall be the same as those currently used for a conventional bridge deck, with two inches of concrete cover over the top reinforcing bars. Any bridge within a municipality, and not on the interstate or trunk highway systems, should be reviewed with district personnel concerning the amount of de-icer chemical application, and possible inclusion in a higher category.

The Bridge Engineer shall determine the appropriate action on any individual exceptions to this policy. Such exceptions may occur in areas where there exists a high use of chloride de-icer chemicals and where the bridge falls into one of the categories that provides little or no protection against such chemicals.

Table 2

1976 POLICY FOR CONTRACT BRIDGE DECK RESTORATION

All bridge decks except bridges with protective systems inplace

DECK CONDITION (Area estimated to be unsound concrete at time of performing the work) Condition codes from current bridge inspection data.	PROCEDURE (A.D.T.'s shown below are current traffic counts)		
	Greater than 10,000 ADT	2,000 to 10,000 ADT	Less than 2,000 ADT
I. 0 to 5% – Slight Condition code 9	Priority 3 Spot removal and concrete overlay 556,894 sq. ft. 14 bridges	Priority 4 Spot removal and concrete overlay or membrane and bituminous overlay 1,241,599 sq. ft. 91 bridges	Priority 10 Spot removal and concrete overlay or membrane and bituminous overlay 483,684 sq. ft. 52 bridges
II. 5% to 20% – Moderate Condition codes 7 and 8	Priority 6 Spot removal and concrete overlay 8,343,999 sq. ft. 497 bridges	Priority 7 Spot removal and concrete overlay 5,452,920 sq. ft. 641 bridges	Priority 11 Spot removal and concrete overlay or membrane and bituminous overlay 2,738,729 sq. ft. 565 bridges
III. 20% to 40%* – Severe Condition codes 5 & 6	Priority 8 100% removal to reinforcing bars and minimum spot removal below bars concrete overlay 2,229,429 sq. ft. 111 bridges	Priority 9 100% removal to reinforcing bars and minimum spot removal below bars concrete overlay 2,250,501 sq. ft. 214 bridges	Priority 12 100% removal to reinforcing bars and minimum spot removal below bars concrete overlay 1,081,791 sq. ft. 236 bridges
IV. Greater than 40%* – Critical Condition codes of 4 or lower	Priority 1 Program new deck 516,821 sq. ft. 13 bridges	Priority 2 Program new deck 30,346 sq. ft. 7 bridges	Priority 5 Program new deck 276,233 sq. ft. 10 bridges

*See page 9 of the report for exceptions to these percentages for concrete box girder, concrete slab and concrete deck girder bridges.

POLICY FOR RESTORATION BY CONTRACT

These guidelines apply to in-service bridges which must be protected from chlorides, and also must be maintained to provide adequate rideability. This can be most economically accomplished by setting priorities for contract restoration, based upon the best possible cost-benefit ratio.

This preventive maintenance would be done on those structures on which the deck surface is basically intact, with little or no signs of corrosion, delamination or spalls. The problems encountered with removal quantity overruns are minimized when working with decks which are basically intact. The possibility of making an effective permanent repair is also much greater in these situations. Thus, the cost-benefit ratio is very favorable for decks which are candidates for preventive contract maintenance under the above criteria.

For the purpose of establishing contract guidelines, in-service bridge decks are categorized into four groups based upon deck conditions, and into three groups dependent upon projected traffic levels. (See Table 2, page 9.)

Condition of a bridge deck can usually be determined by chain-dragging one wheel track or referring to the most recent annual bridge inspection report if the chain-dragging was done during the inspection. For contract purposes, however, a detailed Bridge Deck Condition Survey (Form 13290) should be prepared. Guidelines for preparation of this survey are contained in the appendix section of the report.

Anticipated removal quantities shown in the guidelines are to be based upon the area of repair that would exist at the time the work is to be performed. This will necessitate a detailed field examination, plus extrapolation of these quantities, in order to classify the bridge deck condition. Procedure for these determinations is contained in the "Condition Survey" section of the appendix.

Priorities

Bridge decks with the highest traffic loads and the most severe deterioration should receive the highest priority for contract restoration under these guidelines.

(See Table 2 for priorities and anticipated scope of problem).

Those bridge decks which are in good condition and located in high traffic areas should be protected prior to restoring severely deteriorated decks in areas of low traffic volumes, (less than 2,000 ADT).

Procedures

Three basic groups exist for repair procedures to be followed, based upon the deck condition and extent of anticipated removal quantities.

1. 0-20% unsound - Spot removal of fractured and unsound concrete, and overlay with a suitable concrete material.

2. 20-40% unsound - Complete removal of the top surface, down to the reinforcing bars, and minimum spot removal of fractured concrete below the reinforcing bars. Overlay with a suitable concrete.

3. Greater than 40% unsound - Complete deck removal and replacement with a deck in conformance with the New Bridge Deck Design Policy.

A membrane and bituminous overlay may be considered in lieu of a concrete overlay in areas where the approach roadway is also being overlaid with bituminous material in the same contract. Bituminous overlays and membrane may also be considered where traffic conditions dictate that the overlay must be placed with the least possible traffic delay.

Exceptions

Exceptions to the guidelines in Table 2 are needed for bridges in which the deck is a portion of the main structural support member. (Concrete box girder, concrete slab span, and concrete deck girder bridges).

Since decks on these structures cannot be removed without supporting the structure on falsework, the amount of unsound concrete should be changed to 20-60% in category 2, and full deck removal should not be considered in category 3 until more than 60% of the deck surface is unsound. Every effort should be made to repair these bridge decks before deterioration requires full removal of the deck. Within any category in table 2, these structures should receive priority over other bridges.

Another exception is those decks which have "waterproof" overlay systems in place. Removal of these systems should be deferred until there is surface break-up, including patches, in at least 40% of the deck area. The Office of Bridges and Structures should then make an evaluation and reach an agreement for action together with the district, based on the economy of replacing the overlay system or the entire bridge deck.

POLICY FOR MAINTENANCE WITH M.H.D. FORCES

Various systems for providing extended service life are given in the appendix of this report. Although this work is described as being completed by maintenance forces, there exists the possibility that bituminous mats and surface concrete treatments could be provided under a district maintenance contract, on a package basis.

Priorities

Bridge decks carrying the highest traffic volume and having the most severe deterioration should receive the highest priorities for maintenance work.

The second highest priority groups consists of those bridges with a moderate amount of unsound concrete, and where there exists the likelihood of greatly extending the service life with permanent concrete patching. A short term sealer such as linseed oil should also be used on these decks, in addition to the patching.

Lowest priority is given those structures with a moderate amount of deterioration, but where permanent patching will not significantly extend the service life.

Procedures

Procedures for repair can be grouped into three basic types, depending upon the deck condition and extent of anticipated unsound concrete removal. Complete deck condition surveys are not required for application of this maintenance guideline, however chain-dragging is highly recommended to insure that proper repairs are being made.

The basic patching procedures are as follows:

1. Slight to moderate deterioration, 0–20% unsound concrete. – Remove unsound material and patch using low slump concrete or 2 inch maximum slump concrete patches.

   Every effort should be made to patch with quality concrete and good construction practices in order to obtain the best results. To remove unsound concrete, saw cuts are recommended for the perimeters of all areas designated for slab patching in order to provide vertical edges to a minimum depth of one inch. Care should be taken during the saw cutting to prevent damage to the reinforcing bars. Saw cutting is recommended, but other methods may be used, if they can provide vertical edges.

   A low slump concrete mixture bonded to the deck with a cement grout is the preferred concrete patch. Until the equipment is available for handling low slump concrete, the two inch slump concrete may be used. Chloride and additives containing chloride should not be used at any time, because chloride causes increased corrosion of reinforcing bars.

   See page 47–50 for other changes to current patching procedures.

2. Severe deterioration, greater than 20% unsound concrete. – Patch with concrete, epoxy or bituminous materials as needed to maintain rideability. A deck condition survey including items 2 and 3 of the recommended survey procedures should be made on bridges in this category prior to resorting to temporary patching. The districts have complete flexibility to use their own judgement on the materials and methods used to patch these decks.

   After determining that 20% or more of the concrete is unsound, the most economical maintenance methods should be used to extend the deck life and provide rideability. The deck life should be extended until full deck removal is economically justified and funding is available.

In addition to the patching, various temporary "holding" systems are recommended in the "Protective Systems" section of the Appendix. However, the Office of Bridges and Structures should be contacted before any overlay is placed. These systems include bituminous mats, modified bituminous mats, and membrane and bituminous overlays. Bituminous mats without membranes should only be considered for use on air-entrained concrete bridge decks. (Those decks built after 1946.)

Linseed oil treatment as protection is also recommended for all bare concrete bridge decks with moderate or lesser deterioration. This includes all decks built since 1946. A general schedule for application is to apply the treatment annually for the first two years, and once every four years thereafter. The treatment is most effective when applied to a "thoroughly" dry deck during hot weather, most likely in July or August. Research shows the benefits of treating oil application as a relatively inexpensive treatment, which appears to have significant merit from a cost-benefit standpoint. However, care must be taken in controlling traffic for a period of four hours after application, due to severe loss of skid resistance during this period. See the "Protective Systems" section of the Appendix for complete details on oil application.

Exceptions

The Office of Bridges and Structures should be contacted for recommendations prior to M.H.D. maintenance forces carrying out any patching on structures with in-place "waterproof" overlays.

Equipment

The task force recommends that the necessary equipment required for low slump concrete patching be purchased for use in the Metropolitan area. One crew should also be equipped in each of the other two regions in the state.

Equipment needed includes the following:

1. Paddle type mortar mixer
2. Platform scale
3. Vibrating screed (Kelly or equal)
4. Membrane cure spraying machine (See page 50)
5. Internal vibrator
6. Concrete saw

Appendix A

CONDITION SURVEY

The determination of the extent and type of bridge deck repairs must be based on a deck condition survey. This survey should include various combinations of the following procedures, depending on the type of deck repairs anticipated:

1. Estimation of the area of visible open spall (include bituminous patches).
2. Determination of the area of delaminated concrete (Include Item 1 areas).
3. Estimation of area that has been patched with "permanent" type patches.
4. Estimation of concrete removal areas (to top of rebars and full depth).
5. Determination of the chloride content of the concrete, and optional determination of corrosion level using the half-cell method.
6. Evaluation of the quality of the concrete, as determined when drilling for chloride samples, if a judgement can be made on that basis.
7. Inclusion of a sketch with dimensions, condition, and profile of the approach panels, if any.
8. Evaluation of condition of such items as railings, curbs, joints, expansion devices, paint, bearings, approach panels and drains for possible inclusion in repairs.
9. Recommendations for traffic control.

The following table indicates which of the above survey steps are recommended for various operations.

Work to be Performed	Items included in Deck Survey
Program for contract reconstruction	Item 1 thru 9
M.H.D. crews to place permanent patches	Items 1,2,3 and 4
M.H.D. crews to place temporary patches	Items 2 and 3

It is important to note that for all deck restoration operations, sound judgement by individuals performing the deck survey is a major factor. Many problems and over-runs start with an inaccurate evaluation of the structure to be repaired. In all cases, the person in the best position to estimate the extent of deterioration should be the man performing the survey.

Each bridge that is a candidate for repair or reconstruction work should be surveyed for Items 2, 3, and 5. Using the results of this survey along with the 1976 Guidelines for Bridge Restoration, the type of work to be performed can be identified. In addition, the other survey information is needed to qualify for federal funding, to provide information for the Investigation 639 Study, and to aid in estimating removal quantities.

The following guidelines should be used in performing the Bridge deck survey:

The Bridge should be closed to traffic, as practicable, to enable the deck surveying to be done with the least traffic noise and interference. It is acknowledged that the survey on high traffic volume bridges will usually have to be done with only one lane of traffic closed at a time.

The areas of open spall, areas of delamination, areas where deep concrete removal is anticipated, and areas of bituminous overlay breakup should be recorded on a square foot per 50' increment of bridge length basis. Plotting of these areas on a plan sheet will not be required. However, photographs of each 50' increment of the bridge deck should be taken whenever possible (from a high angle), with paint marks on the deck to identify the area covered by the photograph.

SURVEY PROCEDURES

1. Determination of Chloride Content and Corrosion Level (half-cell).

District personnel should take samples for chloride content determinations, and the Physical Research Section should make evaluations in conformance with instructions defined in an attached memorandum titled Investigation Number 639, Bridge Deck Deterioration and Restoration, dated November 10, 1975.

Half-cell testing is performed so as to define the areas in which ongoing corrosion is present. These areas frequently coincide with areas of delamination, high chloride contents, and shallow rebar cover. When properly employed and evaluated, these tests assist in evaluation of the extent of corrosion cell development in the bridge deck. (Initial testing will be performed by Central Office Research personnel.)

2. Estimation of open spall area.

The open spall areas, including all bituminous patches, should be noted separately from delaminated areas to permit evaluating these areas separately.

3. Determination of delaminated concrete.

The entire bridge deck surface should be surveyed to locate delaminated areas. All hollow sounding areas should be "swept" with the chain broom so as to estimate the size of each delaminated area (in square feet).

The moisture content and temperature of the deck at the time of survey can have a significant affect on the results achieved. Waterfilled cracks dampen the effect of the chain broom, or other detection equipment. When the water in the cracks freezes, the effect is very similar to that of a solid mass, thus completely negating the performance of delamination detection equipment. Therefore, surveys should be performed on relatively dry decks and when the deck temperature is above freezing. (The air temperature may be above freezing, but

this does not indicate that all ice in the delaminations has melted.) The area of delaminated concrete should be measured separately from the area of open spall.

An automated delaminated detection device, "Delamtect," has been developed to help speed up deck surveys. The instrument has successfully completed several years of field testing on actual bridges.

Advantages of the "Delamtect" are:

1. Reduced survey and lane closure time.
2. Detects delaminations thru overlay, and over objectionable traffic noise.
3. Provides permanent record on strip chart, of delaminated areas.

A "Delamtect" is presently on order for M.H.D. and is expected later this year. Once delivered it will be available to the Districts thru Research and Standards.

4. Estimation of concrete removal areas.

The bottom of the deck should be visually observed, and approximate size and locations of all areas having map cracking with efflorescence recorded. All areas having "Stalactites" or concrete spalled from the bottom reinforcing bars shall also be recorded. Those areas of the slab underside having map cracking, and especially areas with stalactites or spalled concrete, should be noted as probable full depth removal areas. Diaphragms adjacent to leaking expansion devices must also be examined.

If extensive full depth removal is indicated by the visual survey of the bottom of slab, M.H.D. bridge crews should be called in to cut exploratory holes with jack hammers. Full depth removal is the most costly corrective procedure and therefore warrants a careful survey to verify the need for this repair.

5. Determination of areas patched with "permanent" type patches.

Experience has shown that permanent patches, although they may be sound at the time of the survey, will probably be loosened in the process of scarifying the deck.

6. Sketches, condition, and profile of approach panels.

Provide a sketch of each approach panel giving the dimensions and general condition of the panels. Also provide some profile shots across the panels and about 25 feet onto the bridge and onto the adjoining roadway. This information will enable us to determine if we can taper down on the existing panels, need to replace the panels, or if more extensive work is required to correct the grade adjacent to the bridge.

7. Estimation of concrete condition at sample holes.

A statement from the drill operator should be noted on survey sheets if the operator feels that such a judgement can be made, stating his feelings as to the hardness or the concrete at the different depths. These comments may provide some indication as to the soundness of the concrete below the surface.

8. Additional information.

Include data regarding condition of such items as railings, curbs, joints, expansion devices, paint, bearings, and drains for evaluation of possible repairs.

COMPUTATION OF REMOVAL QUANTITIES

Prediction of concrete removal quantities is difficult and the following problems and possible controls should be considered:

The time differential between the deck survey, when removal quantities are initially established, and when the actual restoration work begins can cause overruns due to ongoing concrete deterioration. To minimize this time differential, an additional deck condition survey should be made as near to the letting date as practical. If the deck goes through a winter season between the survey and start of removal, this should be compensated for by increasing plan quantities above the survey quantities.

There should be cooperative understanding between the deck survey team and the workers or inspectors who control the removal work. During performance of the work, overruns may be encountered unless there is a mutual understanding concerning the proposed removal work. Whenever possible, the survey team should include inspectors who will subsequently be involved with the removal operations.

For example, the continuation of concrete removal past the limits of apparent subsurface fractures, due to the finding of light corrosion on the exposed reinforcement steel or the noting of small deck cracks during removal operations, can lead to substantial overruns unless these areas were measured and agreed upon beforehand. By limiting concrete removal to only the delaminated areas or to grouped delaminated areas (as identified in the pre-design deck survey) the probability of contract overruns can be minimized.

Quantity overruns often arise when impact from jack hammers, and other removal operation forces, enlarge subsurface fractures. These overruns should be compensated for by increasing the plan removal quantities above the field survey quantities.

The total estimated area of bridge deck to be restored must be determined for each bridge in order to use the 1976 Guidelines for Bridge Deck Restoration. Measurement of the existing areas of deck deterioration and the addition of an appropriate increase to this amount will be performed by the district.

For districts which do not have a standard practice for increasing the measured quantity of spall and delamination the following guide is suggested:

For each 50' long increment of superstructure, calculate restoration areas as follows:

MEASURED AREA OF DELAMINATION, OPEN SPALL AND PATCHES	EST. REMOVAL QUANTITY (SAME SEASON AS SURVEY)	ESTIMATED REMOVAL QUANTITY (ONE WINTER AFTER SURVEY)
0% - 30%	Measured Area x 1.25	Measured area x 1.50
30% or more	Measured Area x 1.50	Measured area x 1.75

Where areas of removal are closely grouped, so as to suggest combining into fewer larger areas, the quantities must be adjusted so as to reflect the increase.

It is expected that the deck condition survey will help provide a "best estimate" of quantities involved and repair work required for each individual bridge. Its primary application will be to evaluate structures where contract work (major repairs) are expected. For maintenance operations, the deck survey will act as a guideline to field maintenance forces.

Appendix B.

PROTECTIVE SYSTEMS

The primary cause of bridge deck spalling is related to corrosion of the deck reinforcing steel. This corrosion rate is dependent upon the amount of chloride, water, and oxygen present at any given time. The purpose in placing a bridge deck protective system is to either reduce salt penetration into the deck (protective overlay systems) or to minimize the corrosive effect of the salt that reaches the rebars (coated reinforcing bar systems and cathodic protection systems). These protective systems are classified as:

A. Permanent "Long Term" Systems
B. Temporary "Short Term" Systems
c. Experimental Systems.

A. PERMANENT "LONG TERM" SYSTEMS

1. Coated Reinforcing Bars.

a). Epoxy Coated Rebars

This system is designed to isolate the deck reinforcement by coating it with a non-reactive epoxy. Initially, such systems boardered on being cost prohibitive. However, a recent review of manufacturer's price quotes reveals that costs for materials and application have declined to acceptable levels. In this system, only the upper mat and crank shaft bars require a protective coating. It is expected that this system will receive increased usage in the near future. (M.H.D. is presently monitoring one such system closely.)

b). Galvanized Rebars

The galvanized system differs from the epoxy system in that all deck and railing rebars require coating. The epoxy coating acts

to isolate the bars and eliminate all corrosion. The galvanized (zinc) coating is sacrificial in nature and does corrode, only at a much slower rate than standard bars. Therefore, the life expectancies for decks with epoxy coated bars are greater than those with galvanized bars.

2. Low Slump Concrete, 2" Overlay

This system is based on reducing the penetration of salt and water to the reinforcing bars by placing a 2" thick protective layer of denser, more impervious concrete over the structural slab.

This method is generally applicable to work as described for latex modified concrete and is specified as an alternate to latex modified concrete overlay.

Potential disadvantage of this system is that low slump concrete is not totally impervious, but is less permeable than regular concrete. The problem is thereby delayed but not resolved.

3. Latex Modified Overlays

a). Latex Modified Concrete - (1½" minimum thickness)

As the name implies, this material consists of portland cement concrete which is modified by the addition of liquid latex in the mixing stage. Research comparing latex modified concrete and mortar with standard portland cement has shown that corrosion of rebars is greatly retarded where bars are encased in, or sealed off by the modified concrete. Cost of this system has been shown to be reasonably competitive with the membrane/bituminous overlay system. An added advantage is gained on severely deteriorated decks, since only a single construction operation (placement of

patch and overlay both in one step) need be performed once the deteriorated concrete is removed eliminating the need for saw-cutting vertical edges. This material is also stable on steep grades and superelevated roadways.

b). Latex Modified Mortar – (3/4" minimum thickness)

This material is basically the same as latex modified concrete except in the applied thickness and possible reduced aggregate size. It is employed whenever maintaining the existing grade and expansion devices is of primary importance.

4. Waterproof Membranes with Bituminous Overlays

The waterproof membranes included in this group generally consist of preformed, fabric reinforced rubberized sheets. This water-proofing material is bonded to the deck concrete and covered with two lifts of bituminous material. The first lift is 1½" thick and the second 3/4" thick. In cases where decks have received considerable traffic wear and patching prior to membrane placement, a thin slurry seal leveling course (approximately 1/16" to 1/8" thick) is used in place of membrane adhesives. This slurry leveling course protects the membrane from punctures thru depression. In all cases where membrane and bituminous overlay systems are employed, care must be taken to insure that proper drainage of the membrane surface interface is provided. Deck protection systems of this type are used extensively in Europe and are undergoing intensive field evaluation in this country.

Advantages of these systems include short installation time, reasonable cost, and ability to open the roadway to traffic immediately upon placement of the wearing course.

Factors which must be considered in selecting these systems are:

1. The need to perform thorough restoration of deteriorated deck concrete and
2. The necessity of providing a smooth surface for installation of the membrane.

Use of this system must be avoided on grades in excess of 4%, at stopping points, and on bridges with maximum superelevation, since the system is not stable under these conditions.

The two membrane systems most widely used at this time are Heavy Duty Bituthene and Protecto Wrap. Both are preformed, fabric reinforced sheets.

Waterproof membranes are considered to have a shorter life expectancy than other systems in this group, due to the limited service life of the bituminous overlay.

B. TEMPORARY "SHORT-TERM" SYSTEMS

Linseed Oil Surface Treatment

The annual use of boiled linseed oil as a surface protective treatment is still regarded as an effective low cost maintenance operation. Application rates of a 50-50 mixture of boiled linseed oil and kerosene are:

1. First application - 1 gallon per 40 square yards.
2. Subsequent applications - 1 gallon to every 67 square yards.

Studies have confirmed that this process acts to seal the surface and reduce the chloride penetration.

2. 3/4" Thickness of M.H.D. 2361 Asphaltic Concrete

M.H.D. 2361 asphaltic concrete has been used as a thin (3/4") topping for bridges where a low cost but possibly short-term extension of deck service life is needed. Since this material is permeable, it must be realized that salt and water will reach the deck concrete. Bridges where this material has the best chance of extending the bridge service life appear to include:

a. Air entrained decks where the deck concrete is sound. (The material will break-up if applied over delaminated concrete.)

b. Bridges that have good drainage characteristics. (Where water will not pond on the deck.)

3. Modified Asphaltic Concrete Overlays

Asphaltic concrete material modified by additives such as asbestos and/or rubber are reputed to be more impervious than M.H.D. 2361 asphaltic concrete. They are therefore considered to have potential additional value in providing waterproofing protection for a bridge deck. A current memo from the FHWA suggests application of ½" of asbestos asphalt "membrane" topped by a 3/4" protective layer of asphaltic concrete.

4. Epoxies and Penetrating Sealers

Limited success has resulted from use of various penetrating sealers and epoxies. Epoxies are generally used to seal cracks in the deck surface. Applied directly over the crack in a liquid or semi-liquid form, they usually are rapid setting. Once cured, they provide protection for the steel from further chloride attack. Application rates are variable, depending upon the amount of cracking in any given area.

Penetrating sealers are applied in dilute form over the entire deck, usually by spraying. They act to seal microscopic channels, rather than visual cracks in the concrete. However, these sealers, at best protect only the upper 1/16 to 1/8" of the deck. Application rates are generally several hundred square feet per gallon.

Both epoxies and penetrant sealers provide some degree of short term protection and are presently undergoing both field and laboratory evaluation.

C. EXPERIMENTAL SYSTEMS

1. Cathodic protection

The cathodic systems protects the reinforcement by providing sacrifical anodes in a conductive layer on the deck surface. This conductive layer consists of a coke modified bituminous material about 2½ inches thick. A wearing course of M.H.D. 2361 is then placed to protect the cathodic system. A small D.C. current (0.8 to 1.1 volts, 40 watts) is applied to the anodes and radiates into the conductive layer. It is this current which enters the grounded rebar, and supresses the corroding current. When properly installed and regulated, this system stops all corrosion. (The first cathodic system installed by M.H.D. is presently being monitored.)

2. Polymer Concrete

Research is being conducted by various agencies towards developing a polymer modified concrete. This concrete would have far greater strength and impermeability than regular portland cement concrete. Large scale field tests have not yet been conducted, but are being planned.

3. Internally sealed concrete using wax beads

   Internally sealed concrete is made by mixing small, spherical particles of wax with the conventional components of concrete. After the concrete has cured, heat is applied and the wax melts and flows into the capillaries and bleed channels of the concrete. Upon removal of the heat source, the wax solidifies in the pores and capillaries, thus preventing the penetration of water and/or chlordies.

4. Penetrating rust inhibitors

   These are chemical solutions which could be applied to the deck at low cost, and would act to retard the corrosion rate. It is expected that they would provide only short term protection, however.

DEPARTMENT HIGHWAY - Physical Research Section
Ext. 3460 Room G29

Office Memorandum

TO :

DATE: 11-10-75

In reply refer to: 607

FROM : Robert G. Tracy
Research Project Engineer
Physical Research Section

SUBJECT: Investigation Number 639, Bridge Deck Deterioration And Restoration (Supercedes letter of May 16, 1973 to District Materials and Soils Engineers) Concrete Samples for Chloride Determination

Following is the procedure we would prefer for drilling and submitting samples obtained from decks which have been exposed to traffic. Samples should be obtained before reconstruction and once yearly for three years thereafter. New construction will not require the initial samples but these decks should be sampled once yearly for a three year period after the waterproof treatment has been installed.

Size of sample holes - 3/4 inch diameter - 1 inch deep increments to below steel.

Method of Sampling - Drill to 1 inch, recover and bag drill dust

- Drill 1 inch to 2 inches, recover and bag drill dust

- Drill 2 inches to 3 inches, recover and bag drill dust

Number of holes - One per area, three representative areas per deck

Packaging - Place dust from each 1 inch increment in an area in a 4 inch x 8 inch plastic sample bag, label as below:

Area 1 inch 1	Area 2 inch 1	Area 3 inch 1
Area 1 inch 2	Area 2 inch 2	Area 3 inch 2
Area 1 inch 3	Area 2 inch 3	Area 3 inch 3

Identification - Each group of samples should be numbered and referenced on a "Sample Identification Card" (see example on attached sheet). Samples and identification for each bridge should be shipped in a manila envelope.

Shipment - Ship to: Robert G. Tracy
Research Project Engineer
Central Office - Room G29
John Ireland Boulevard
St. Paul, MN 55155

c/o C. L. Thomsen
Room G31A

Charge Out Number - Investigation Number 639 99-779-074

Equipment required by fiedl crews includes:

a. One-rotary hammer capable of drilling 3/4 inch holes
b. Supply of 3.4 inch x 9 inch (minimum) carbide drill bits
c. Supply of 4 inch x 8 inch plastic sample bags
d. Supply of Number 3 rubber test tube stoppers
e. Calking gun and calk
f. Two feet of 1/4 inch rubber tubing
g. Wire brush for cleaning bits
h. Dust collector (see sketch)
i. Steel locator (optional)

When drilling through bituminous the residue up to the concrete surface should be wasted but a note as to depth should be entered on the identification card. Then placing the dust collector over the hole a sample from 0 inch to 1 inch is secured and bagged. The hole is then blown clean using the rubber tubing and the sample from 1 inch to 2 inch procured and bagged. The hole is again blown out and the sampling sequence continues. If large aggregate is penetrated the hole should be abandoned and a new one drilled. On bridges scheduled to be repaired the hole does not have to be patched. On concrete or epoxy decks not scheduled to be repaired a patch of cement-sand slurry should be placed. When holes are drilled through a bituminous mat and/or waterproof membrane a Number 3 rubber test tube stopper should be driven to the concrete-membrane-bituminous interface and the hole filled with calking compound (a silicone rubber would be ideal).

If there are any questions which arise on sampling procedures or rates please contact me.

Robert G. Tracy
Research Project Engineer

RGT/mw

FORM 2410 (6-70) 3 1

LAB. I.D. NUMBER

MINNESOTA DEPARTMENT OF HIGHWAYS

SAMPLE IDENTIFICATION CARD

DATE SAMPLED 7-6-73

FIELD I.D. 1, 2, 3

SPEC drill dust Year

S.P. Br. 960042

SUBMITTED BY J. Jones

PROJ. ENGR. J. Smith

TO BE USED FOR

MIX PROPORTIONS %

PIT NO.

SOURCE

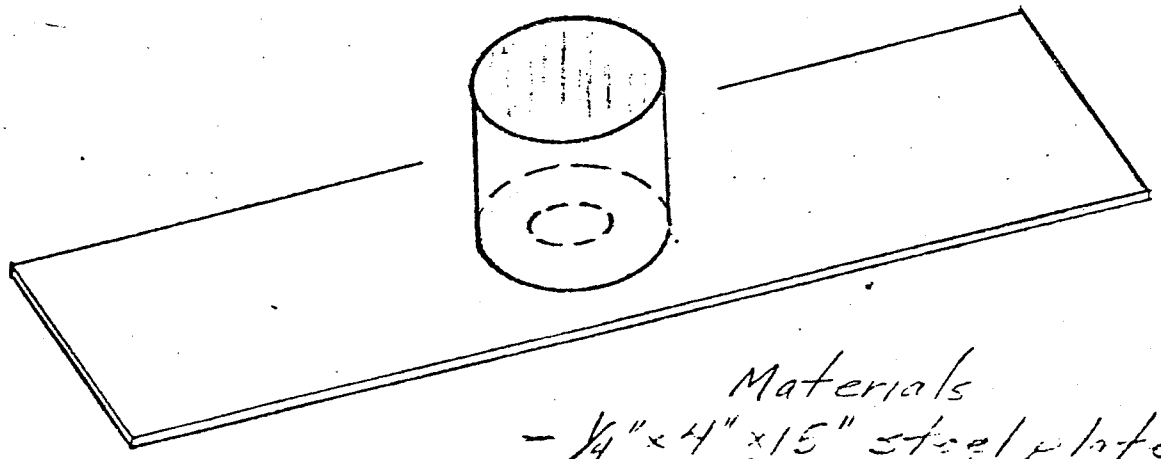
LOCATION				
E.B.L. - Sample #	(1)	(2)	(3)
SAMPLE TAKEN FROM Station	0+23	0+75	1+15

TESTS REQUIRED Chloride Content

REMARKS:

PLEASE FILL OUT COMPLETELY

Dust Collector



Materials

- ¼" x 4" x 15" steel plate with 25/32" drilled hole in center
- 2" Ø pipe - 1/4 inch weld or brass pipe to plate both inside and out

Appendix D

TESTING PROCEDURE–CORROSION DETECTION

The following procedures should be followed when testing reinforced concrete bridge decks or continuously reinforced concrete pavements, for active corrosion of the reinforcing steel:

1. Measure and mark a 5-foot grid on the surface to be tested. (If conditions warrant, the grid may be increased or decreased.)

2. Locate a reinforcing bar or other connection to the reinforcing steel. A positive connection to the top of reinforcing steel is desired; however, if this is not feasible, the bridge railing expansion joints, light standards, drainage scuppers or other exposed steel may provide a positive connection to the reinforcing steel provided:

   a. The connection must not be galvanized.

   b. The ground must be electrically connected to the reinforcing steel.

3. Uncoil an ample length of wire to reach all areas to be tested, attach negative (–) jack of voltmeter to the reinforcing steel and positive (+) jack to the copper copper-sulfate half cell.

4. Check voltmeter battery for satisfactory change.

5. Zero voltmeter on lowest scale.

6. Switch to WM–AM on the one (1) volt scale and make measurements of the electrical potential at each grid point. The half cell requires a wet sponge attached to the bottom of the half-cell to aid in making a good electrical contact with the concrete.

7. Record the readings on graph paper and plot the lines of equipotential.

Appendix E

EQUIPMENT LIST FOR CORROSION DETECTION EQUIPMENT

The basic components of the steel corrosion detection device are commercially available and are listed as follows:

1. Two wire reels, containing 125 feet of No. 18 single wire and 300 feet of No. 18 single wire, respectively. These are available from the Agra Engineering Company, 551 South Quaker Street, Tulsa, Oklahoma 74120. Price $30. each.

2. One 36-inch-long copper sulfate reference cell. These are available from the Harco Corporation, 4600 East 71st Street, Cleveland, Ohio 45216. Price $25. each.

3. A good quality volt-ohm meter capable of being battery operated and having a +2 percent end of scale accuracy at the voltage ranges in use. The input impedance shall be no less than 10 million ohms when operated at a full scale of 100 millivolts. The minimal overlapping scale ranges of the voltmeter shall be: 100 millivolts (mv), 300 mv, 1.2 volts and 3 volts. The volt-ohm meter we are using is a Simpson Model 313 VOM, available from Simpson Electric Company, Division of American Gage and Machine Company, 5200 West Kinzie Street, Chicago, Illinois 60644. Price $125.

Appendix F

SCHEDULE OF ACTIONS REQUIRED FOR PROCESSING BRIDGE DECK REPAIR & OVERLAY CONTRACTS

In order that all information required for the orderly and timely processing of bridge deck repair and overlay contracts will be available when and where needed, it is essential that a relatively rigid schedule of actions be maintained by all organizations charged with responsibility for these actions.

The following schedule has been prepared so that each unit involved in the processing will be aware of their particular area of responsibility for keeping the chain of actions on schedule. Particular emphasis should be placed on the initial item, that of obtaining reliable information for the submittal of the condition survey so that it will be in the Bridge Office not later than 18 weeks before the letting date. Also, please not that in order to "make a letting," all 10 steps in the schedule must have been completed not later than 8½ weeks prior to the letting so as to provide time for printing, FHWA approvals, advertising, etc. It should be evident that earlier processing of the initial steps would alleviate congestion in the final processing.

In the event that a bridge has been rescheduled for a letting several months later than the originally scheduled date, and the condition survey has been submitted for the earlier letting, an updated condition survey that would more nearly represent the current condition of the bridge deck should be submitted.

BRIDGE DECK REPAIR & OVERLAY SCHEDULE

Action	Responsibility	Weeks B/4 Letting
1. Deck Condition Survey in Bridge Office	District	18
2. Joint Field Review	District & Bridge	16
3. Bridge Office Recommendations to District	Bridge	14
4. District Reply to Bridge Office Recommendations	District	13
5. Pre-Design Conference	District & Bridge	12
6. Time and Traffic Recommendations	District	11
7. Location/Design Study Report in Road Design Office	District	11
8. Plans and Special Provisions to Bridge Construction Office	Bridge Design	10
9. Bridge Construction Office Review completed	Bridge Construction	9
10. Plans and Special Provisions complete	Bridge Design	8½

LETTING DATE: MONTH ________ DATE ________ YEAR ________

PRE-LETTING SCHEDULE AND PROGRESS RECORD FOR BRIDGE DECK PROJECTS

DIST. NO.	BRIDGE NO.	LOCATION	DES. GROUP	COND. SURVEY IN BR. OFFICE	JOINT FIELD REVIEW MADE	BRIDGE OFFICE RECOMM. TO DIST.	DIST. REPLY TO BR. OFFICE	PRE-DESIGN CONFER. HELD	TIME & TRAFFIC RECOMM. FR. DIST.	LOC./DES STUDY REPORT FR. DIST	PLANS-SPPR. IN BRIDGE CONST. O.	BR. CONST. OFFICE REVIEW COMPL.	PLANS-SPEC. PROV. COMPL.
		TARGET DATES →	X										

THIS FORM IS USED IN THE BRIDGE OFFICE WITH THE "TARGET" DATES FILLED IN, SO WE CAN DETERMINE WHERE WE STAND IN RESPECT TO THE SCHEDULE.

BRIDGE DECK CONDITION SURVEY

Bridge No. _____

Date _____

Year Built _____ T.H. No. _____ Dist. No. _____ Total Rdwy. Area (Sq. Ft.) _____

Bridge Location _____ Bridge Description _____

CHLORIDE CONTENTS

Core Locations									
Depth	0"-1"	1"-2"	2"-3"	0"-1"	1"-2"	2"-3"	0"-1"	1"-2"	2"-3"
Chloride P.P.M.									

SPALLING AND DELAMINATION

Define Portion of Deck Covered Below (South bound roadway, etc.) _____

Spalling and delamination by Segmental Areas, Starting at _____
End of the Portion of Deck Defined Above.

Segment No.	Segment Length	Segment Area (Sq. Ft.)	Open Spall (Sq. Ft.)	Open Spall %	Delamination (Sq. Ft.)	Delamination %
TOTALS (this sheet)						

Estimated removal quantities (sq. ft.) to top rebars _____ Below top rebars _____ Full depth _____

Item	Estimated Area and Type of Repair
Railing	
Curb/Sidewalk	
Other	
Item	**Location Within 100' of Bridge**
Approach drains	
Approach joints	

Attach photos, additional information and comments.

ADMIN 1000

STATE OF MINNESOTA

Office Memorandum

DEPARTMENT HIGHWAY - Bridge, Room 610
Ext.

TO : _____, Dist. Engineer
District._____

DATE:

FROM : K. V. Benthin
Bridge Engineer

SUBJECT: Proposed Bridge Deck Restoration
Bridge (s)

Two copies of the Bridge Office recommendations for work to be accomplished for each of the above referenced bridges, are attached.

Please review our recommendations and complete the right hand column, as indicated on the report form. If you concur with all recommendations made by the Bridge Office for a particular bridge, it will only be necessary to check off the last entry on the tabulated portion of the report for that bridge, and to sign the report.

Please return one completed copy of each report to this office as scon as possible, so that we may proceed with the final design. The second copy is for your files.

K. V. Benthin
Bridge Engineer

RECOMMENDATIONS FOR BRIDGE DECK RESTORATION

BR. NO. _____ T.H. NO. _____ OVER UNDER _____ SLAB AREA (SQ. FT.) _____

DESCRIPTION
(TYPE, SPAN LENGTHS, WIDTH) _____ DISTRICT NO. _____

Based on information contained in reports received by this office regarding the condition of the deck on the above referenced bridge, the following restoration procedures are recommended. This report, in addition to the column check-off format for Bridge office recommendation, also provides a column for District recommendations. If the District concurs in all Bridge office recommendations, merely check that statement at the end of the report.

Please return one completed copy to the Bridge office.

Item No.	Considerations	Recommendations By					
		Bridge Engineer			District Engineer		
		Yes	No	*	Yes	No	*
1	Is some type of deck protective system recommended?						
2	If the answer to Item 1 is yes, the recommended treatment is:						
	a) "Black" (membrane waterproof and asphaltic concrete) _____						
	b) "White" (latex mod. mortar or concrete, low slump conc.) _____						
	c) Other (See comments) _____						
3	The following types of surface preparation should be included:						
	a) Sweeping and cleaning _____						
	b) Sand-blasting and cleaning _____						
	c) Scarifying (¼" sound concrete) _____						
	d) Removal to top of rebars (sq. ft.) _____						
	e) Removal to below top rebars (sq. ft.) _____						
	f) Full depth removal (sq. ft.) _____						
	g) Other (See comments) _____						
4	If the recommended treatment is "Black," membrane waterproofing should include the following options:						
	Type 1 (Uniroyal 6125) _____						
	Type 2 (H.D. Bituthene) _____						
	Type 5 (Protecto Wrap M-400) _____						
	Type 6 (Uniseal 2000) _____						
	Type – _____						
	Type – _____						

*Key to notations by Bridge Engineer and District Engineer appearing on second sheet: B-1, B-2, etc. for Bridge Engr.; D-1, D-2, etc. for Dist. Engr.

Bridge No. _____

See explanation front page margin.

Item No.	Considerations		Recommendations By					
			Bridge Engineer			District Engineer		
			Yes	No	*	Yes	No	*
5	If treatment is "White," include the following options: a) Latex modified mortar _____ b) Latex modified concrete _____ c) Low slump concrete _____ d) Other (Specify) _____							
6	Expansion Devices	Taper paving to original devices						
		Raise original devices						
		Install new waterproof devices						
7	Will raising drains be required?	On bridge?						
		Off bridge?						
8	Will approach tapers be required? If so, indicate dimensions	Height						
		Length						

The District concurs in all Bridge Office recommendations _____

Explanation of Bridge notations, and additional comments.

Signed _____ Bridge Engineer

Date _____

Explanation of District notations, and additional comments.

Signed _____ District Engineer

Date _____

Appendix K.

STATE OF MINNESOTA
DEPARTMENT OF HIGHWAYS

LOCATION/DESIGN STUDY REPORT

FOR

RECOMMENDED:

_____ _____
District Engineer *Date*

_____ _____
Bridge Engineer *Date*

_____ _____
Road Design Engineer *Date*

APPROVED:

_____ _____
Director *Date*
Design and Right of Way Division

INTRODUCTION

This report has been prepared for the purpose of documenting the location and design of the proposed action.

A Project Development Report was prepared, and the advancement of this action was authorized. The proposed construction has been determined to be a non-major action. There will be no change in layout or function of connecting roads nor is additional right-of-way required, thus no public hearing will be held.

The only alternative to the proposed action that was considered was to do nothing. Based on the field survey and review of this bridge, the proposed construction is considered necessary to provide a safe and efficient transportation facility and a do-nothing alternative would not accomplish this objective.

PROJECT LOCATION AND DESCRIPTION

STATE PROJECT NO._____ T.H._____

MINN. PROJECT_____ BRIDGE NO._____ COUNTY_____

PROJECT LOCATION:

TYPE OF WORK:

Estimated date of commencing work or letting date_____

Anticipated Funding_____ (Federal or State)

Traffic Data

ADT (current year 19___)_____ HCADT_____
ADT (future year 19___)_____ HCADT_____ (If presently available)

EXISTING BRIDGE

BRIDGE NO._____ WIDTH (Curb-to-Curb)_____

ORIGINAL FUNDING_____ (Federal, State, Other)

Approach roadway width at bridge ends_____

Approach guardrail is ☐ is not ☐ inplace (check appropriate box)

Approach guardrail does ☐ does not ☐ conform to Standard Plan sheet
No's. 5-297.601 ☐ or 5-297.603 ☐ (check appropriate boxes)

Special or peculiar features:

PROPOSED CONSTRUCTION

Deck protective system: Estimated Cost of overlay system_____

The deck overlay protective system includes the following categories of work:

- ☐ Surface preparation (sandblasting and cleaning or scarifying)
- ☐ Protective overlay
- ☐ Modification of expansion devices and/or drains as required
- ☐ Overlay tapers at each end of bridge as required

The deck protective system will require the following category of deck surface preparation (reconstruction) in addition to the surface preparation indicated above:

- ☐ Removal to top of rebars
- ☐ Removal to below top of rebars
- ☐ Full depth removal

Estimated cost of removal_____

Effect of additional imposed load on the bridge:

Bridges that are to receive repairs and protective waterproofing overlay systems have been reviewed for live load capacity. The effect of the additional dead load weight of the overlays will reduce the live load inventory and operating ratings of the bridge to some extent, however, this reduction in live load capacity is not significant and will not require load posting restrictions.

Bridge Maintenance

The following type of maintenance work will be performed on this bridge: (State Funds)

Describe: (such as bridge railing repair, painting, etc.)

Estimated cost of maintenance work_____

Social, Economic and Environmental Effects

Due to the nature of the proposed action no significant adverse environmental effects are foreseen as a result of this proposal. This determination is based on the following considerations:

-- No additional right-of-way is required.
-- Traffic volumes will not increase as a result of this action.
-- The proposed action is unrelated to increased traffic noise levels.
-- The proposed action is consistent with the air quality State Implementation Plan as documented in the Memorandum of Understanding with the Minnesota Pollution Control Agency.
-- The specifications for the proposed action relating to the use of equipment and materials associated with this construction will be consistent with the air quality State Implementation Plan.
-- The specifications for bridge work over public waters will include provisions to minimize to the extent possible pollution of the public waters.
-- At location where bridge work involves work in public waters a permit will be obtained (when required) from the Department of Natural Resources.
-- Bridges will be kept open to traffic to the extent practical and all lane closures will be made in accordance with the MHD Temporary Lane Closure Standards.
-- The State Historic Preservation Officer has been consulted and a determination has been made that there are no historic sites on the National Register or eligible for nomination to the National Register that would be affected by the proposed highway improvement. This determination is documented in and by the State Historic Preservation Officer/Minnesota Department of Highways Memorandum of Understanding which is presently being executed.
-- There are no Section 4(f) involvements.

The benefits of the proposed action will: extend the service life of the bridge; obtain the lowest possible cost-per-year maintenance for the bridge; and provide for safe usage of the bridge. Approval and implementation of the action described in this report is recommended.

ENGINEERING MEMORANDUM
OFFICE OF MAINTENANCE
MAINTENANCE NO. 75-2
August 14, 1975

TO: Distribution List 57-C

FROM: William C. Merritt
Deputy Commissioner and Chief Engineer

SUBJECT: Guidelines for Maintenance Bridge Deck Patching with Concrete

Bridge deck patching by maintenance forces accounted for a large portion of the $1,900,000 bridge repair expenditure in fiscal year 1975. Patching with substandard concrete and undesirable construction techniques has been noted in several instances. Every effort should be made to patch with quality concrete and good construction practices in order to obtain the best results from this large maintenance expenditure.

A Bridge Maintenance Committee is currently developing standard bridge deck repair procedures. The following procedures should be used for concrete patching of bridge decks in the interim until the new standards are issued.

I. Unsound Concrete Removal

Saw cuts should be made on the perimeters of all areas designated for slab patching to provide vertical edges to a minimum depth of 1 inch. Care should be exercised to prevent damage to reinforcing bars during this saw cutting. *

Removal should be restricted to methods which will not damage the structure. The removal should continue to a minimum depth of the top of the reinforcing bars and until the exposed surface is sound concrete. The concrete surface should be cleaned of all remaining unsound or fractured concrete by sandblasting just prior to placing the new concrete. All exposed reinforcing bars should also be cleaned of all rust and concrete by thorough sandblasting.

II. Concrete Patching

A. Mix Proportions

Two mixes are given below for deck patching and you are urged to use the low slump mix whenever possible. If equipment is not available for handling the low slump concrete the 2 inch slump concrete may be used until this equipment is made available. Chloride and additives containing chloride should not be used at any time because chloride causes increased reinforcing bar corrosion.

Mix Portions for 1" Maximum Slump Mix (3U17A)

Item	Per Cubic Yard	Per Bag of Cement	Per Bag of Cement
Cement	799 Lbs.	94 Lbs.	1.0 Cubic Ft.
Water	270 Lbs.	32 Lbs.	3.8 Gallons
Sand (M.H.D. 3126)	1412 Lbs.	167 Lbs.	1.7 Cubic Ft.
Coarse Aggregate (M.H.D. C.A. 70 Class A)	1412 Lbs.	167 Lbs.	1.7 Cubic Ft.
Air Entraining Agent (Protex)		1.0 to 1.5 oz.	1.0 to 1.5 oz.
Water Reducing (PDA 25XL) Admixture		4.0 oz.	4.0 oz.

Mix Portions for 2" Maximum Slump Mix (3U27A)

Item	Per Cubic Yard	Per Bag of Cement	Per Bag of Cement
Cement	826 Lbs.	94 Lbs.	1.0 Cubic Feet
Water	282 Lbs.	32 Lbs.	3.8 Gallons
Sand (M.H.D. 3126)	1385 Lbs.	158 Lbs.	1.6 Cubic Feet
Coarse Aggregate (M.H.D. CA 70 Class A)	1385 Lbs.	158 Lbs.	1.6 Cubic Feet
Air Entraining Agent (Protex)		1.0 to 1.5 oz.	1.0 to 1.5 oz.
Water Reducing Admixture (PDA 25XL)		4.0 oz.	4.0 oz.

B. Mixing

The following mixing procedure should be used for job site mixing of the one inch slump concrete:

1. Dry mix fine aggregate and cement for one minute.

2. Add coarse aggregate and dry mix for one minute.

* 3. Add the air entraining agent with approximately 40% of the mix water.

4. Mix for approximately 15 seconds

* 5. Add the water reducing admixture with an additional 40% of the mix water.

6. Add additional water and adjust to a slump of $3/4 \pm 1/4$ inch.

7. Continue mixing until 3 minutes have elapsed since step 3.

* Concentrated air entraining agent and water reducer should not come in contact with one another.

C. Bonding

The prepared surface should be dry to permit some absorption of the grout into the inplace concrete. Immediately prior to placing the grout, the inplace concrete surface shall be thoroughly cleaned with air blast. The air system shall have a suitable oil trap in the air supply line between the storage tank and the nozzle.

The surface of the inplace concrete that will be in contact with new concrete should be coated with bonding grout immediately prior to placing the new concrete.

The grout shall consist of equal parts, by weight, of portland cement and sand, mixed with sufficient water to form a slurry. The consistency of this grout should be such that it can be applied with a stiff brush or broom to the inplace concrete in a thin, even coating that will not run or puddle in low spots. The grout should not be so stiff that it forms globules when broomed.

The rate of progress in applying the grout should be such that the grout does not become dry before it is covered with the new concrete.

D. Curing **

The patch should be covered with white plastic sheeting which is held tightly in place during the curing period.

One inch slump concrete patches may be opened to traffic within 6 hours when temperatures are 60 degrees or above. When temperatures are below 60 degrees the cure time should be extended to 12 hours and below 45 degrees the cure time should be extended to 24 hours.

Two inch slump concrete patches should be cured for a minimum of 48 hours at temperatures of 60 degrees and above and for 72 hours at temperatures below 60 degrees prior to opening to traffic.

No concrete patching should be done at temperatures below 40 degrees.

III. Patching "Waterproof" Overlays

The Office of Bridge and Structures and the Office of Research Coordination should be contacted prior to making any repairs or bituminous or concrete "waterproof" overlay systems for recommendations on the repair procedure. Most of the inpalce waterproof overlays are being evaluated under the M.H.D. Research Investigation 639 "Bridge Deck Deterioration and Restoration" study as required to obtain federal funding for the original construction. It is very important that all research evaluaiton be completed prior to partial or complete removal of any of these "waterproof" systems.

William C. Merritt

William C. Merritt
Deputy Commissioner and Chief Engineer

Changes in Memorandum

*The task force recommends saw cutting, but recognizes that other methods may be used, if they can produce vertical edges.

**In the "Curing" section of the Memorandum, the following exceptions should be noted.

Curing time for one inch slump concrete patches may be cut from 6 hours to 4 hours if a spray membrane is applied with the recommended mechanical sprayer, in lieu of covering the patch with white plastic sheeting.

The spraying machine shall have as essential elements: a recirculating bypass system which provides for continuous agitation of the reservoir material; separate hose and nozzle filters; and a multiple or adjustable nozzle system that will provide for variable spray patterns. The membrane curing compound shall be in conformance with M.H.D. 3754, Type 2 Resin Base. Minimum Curing time for two inch slump concrete patches may be reduced from 48 to 24 hours at temperatures 60 degrees and above, and from 72 to 36 hours at temperatures below 60 degrees, if High Early Strength Portland Cement (Type III) is used for the patching.

The remaining portions of this sections remain in force.

COST ANALYSIS

The estimated prices in table 4 have a two fold purpose. They can be used for a comparison of economic feasibility between alternate restoration systems, and they can also be used for roughly estimating the first-cost of the system chosen. Since the cost of materials and labor tends to fluctuate with the changing state of the economy and conditions of construction, these prices are not intended to be final. Final estimates should be made with respect to the individual merits of each job.

In order to use the table properly it is necessary to familarize oneself with the derivation of the unit prices shown therein. The cost is expressed as a price per sq. ft.[1] of travelled roadway area on the bridge. In some cases work, such as tapers, must be done on the approaches. This has been taken into account in the price. It is not necessary to add any other cost. By multiplying the price ($/sq. ft.) by the roadway area of the bridge in question the first-cost of the job can be determined.

To compare feasibility of alternate systems, the life of the system should be considered. The unit prices following the anticipated life of each respective system were determined by simply dividing the price per sq. ft. by the years of life.[2]

The "New Bridge Deck Policy" should be referred to whenever deck replacement is considered. For example, under the category of "Greater than 10,000 ADT", two alternates are shown, Epoxy Coated Rebars or Galvanized Rebars. In the Policy, either of two types of concrete wearing courses would be required in combination with epoxy coated or galvanized rebars. The lower priced overlay (low-slump concrete) was chosen for the table along with alternates for the rebars.

It should be understood that whenever "Program new deck" is stated the price includes the cost of removing the old slab, curb, rail, and rebars plus the cost of a new slab and barrier curb. The alternates should be used in accordance with the Policy.

Each ADT category for deck condition contains a Max. cost. This number was determined by multiplying the maximum unit price by the sq. ft. area shown for the respective number of bridges in the category. Example; 0% to 5% unsound and Less than 2,000 ADT:

483,684 sq. ft. @ $5.90/sq. ft. = $2,853,700.

[1]The square-foot-costs for the various deck condition categories shown in the quidelines are based on information available at the time this study was made. Obviously, continued inflation will adversely affect these prices, but hopefully new procedures and greater expertise by contractors will tend to offset inflationary increases.

[2]The square-foot-cost-per-year figures are based on the composites of "guesstimates" (made by members of the task force) of the life expectancy of each of the systems under consideration. These "guesstimates" may or may not have a relationship to reality, since the systems under consideration have not been time-proven.

For all bridge decks except those with protective systems inplace

DECK CONDITION (Area estimated to be unsound concrete at time of performing the work.)	PROCEDURE (ADT's shown below are current traffic counts)		
	Greater than 10,000 ADT	2,000 to 10,000 ADT	Less than 2,000 ADT
0% to 5% unsound	Priority 3 Spot removal and concrete overlay 14 bridges; 556,894 sq. ft. Cost - $5.90/sq.ft. Life - 8 to 12 yrs. = $0.74 to $0.49/sq.ft./yr. Max. Cost = $3,285,700	Priority 4 Spot removal and concrete overlay 91 bridges; 1,241,599 sq. ft. Cost - $5.90/sq.ft. Life - 10 to 20 yrs. = $0.59 to $0.30/sq.ft./yr. Max. Cost = $7,325,400	Priority 10 Spot removal and concrete overlay or membrane and bituminous overlay. 52 bridges; 483,684 sq. ft. Concrete Overlay Cost - $5.90/sq.ft. Life - 10 to 20 yrs. = $0.59 to $0.30/sq.ft./yr. or Membrane and Bituminous overlay Cost - $3.10/sq.ft. Life - 6 to 10 yrs. = $0.52 to $0.31/sq.ft./yr. Max. Cost = $2,853,700
5% to 20% unsound	Priority 6 Spot removal and concrete overlay 497 bridges; 8,343,999 sq. ft. Cost - $6.70/sq.ft. Life - 8 to 12 yrs. = $0.84 to $0.56/sq.ft./yr. Max. Cost = $55,904,800	Priority 7 Spot removal and concrete overlay 641 bridges; 5,452,920 sq. ft. Cost - $6.70/sq.ft. Life - 10 to 20 yrs. = $0.67 to $0.34/sq.ft./yr. Max. Cost = $36,534,600	Priority 11 Spot removal and concrete overlay or membrane and bituminous overlay 565 bridges; 2,738,729 sq. ft. Concrete overlay Cost - $6.70/sq.ft. Life - 10 to 20 yrs. = $0.67 to $0.34/sq.ft./yr. or Membrane and Bituminous overlay Cost - $4.40/sq.ft. Life - 6 to 10 yrs. = $0.73 to $0.44/sq.ft./yr. Max. Cost = $18,349,500

20% to 40% unsound	Priority 8 100% Type 1 removal, min. Type 2 and 3 removals (possible epoxy bonding). Concrete overlay 111 bridges; 2,229,429/sq.ft. Cost – $9.30/sq.ft. Life – 8 to 12 yrs. = $1.16 to $0.78/sq.ft./yr. Max. Cost = $20,733,700	Priority 9 100% Type 1 removal, min. Type 2 and 3 removals (possible epoxy bonding). Concrete overlay 214 bridges; 2,250,501 sq. ft. Cost – $9.30/sq.ft. Life – 10 to 20 yrs. = $0.93 to $0.47/sq.ft./yr. Max. Cost = $20,929,700	Priority 12 100% Type 1 removal, min. Type 2 and 3 removals (possible epoxy bonding). Concrete or bituminous and membrane overlay. 236 bridges; 1,081,791 sq. ft. Concrete overlay Cost – $9.30/sq.ft. Life – 10 to 20 yrs. = $0.93 to $0.47/sq.ft./yr. or Bituminous and membrane overlay Cost – $8.80/sq.ft. Life – 6 to 10 yrs. = $1.47 to $0.88/sq.ft./yr. Max. Cost = $10,060,700
Greater than 40% unsound (Greater than 60% deck part of main supporting structure)	Priority 1 Program new deck 13 bridges; 516,821 sq. ft. Epoxy Coated Rebars & Conc. O/L Cost – $17.10/sq.ft. Life – 20 to 30 yrs. = $0.86 to $0.57/sq.ft./yr. or Galvanized Rebars & Conc. O/L Cost – $16.00/sq. ft. Life – 18 to 28 yrs. = $0.89 to $0.57/sq.ft./yr. Max. Cost = $8,837,600	Priority 2 Program new deck 7 bridges; 30,346 sq. ft. Epoxy Coated Rebars Cost – $13.40/sq.ft. Life – 30 to 40 yrs. = $0.45 to $0.34/sq.ft./yr. or Galvanized Rebars Cost – $12.30/sq. ft. Life – 20 to 35 yrs. = $0.62 to $0.35/sq.ft./yr. or Concrete Overlay Cost – $15.20/sq. ft. Life – 15 to 40 yrs. = $1.01 to $0.38/sq.ft./yr. Max. Cost = $461,300	Priority 5 Program new deck 10 bridges; 276,233 sq. ft. 3 inches concrete cover Cost – $11.60/sq.ft. Life – 15 to 35 yrs. = $0.77 to $0.33/sq.ft./yr. or 2 inch concrete cover Cost – $11.50/sq. ft. Life – 10 to 25 yrs. = $1.15 to $0.46/sq.ft./yr. Max. Cost = $3,204,300