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Chapter Twenty-Two
BRIDGE REHABILITATION

The State of Montana contains more than 4500 bridges on its public roads and streets. Approximately 2600 of these are on the State highway system. Occasionally, these bridges require repair or rehabilitation which exceeds the scope of normal maintenance. In these cases, the bridge work is programmed as a capital improvement project. For the purpose of this Chapter, rehabilitation refers to:

1. restoring to a former state and/or capacity,

2. improving serviceability (structural and/or functional),

3. strengthening, and/or

4. widening.

22.1 SCOPE OF WORK

The Scope of Work for a bridge rehabilitation project typically meets one of the descriptions in the following Sections. The **Montana Bridge Design Standards** should be referenced to assist in determining an appropriate Scope of Work. Traffic control is often the most expensive component of a bridge rehabilitation project, and the cost and difficulty of maintaining traffic must be considered when selecting an appropriate project Scope of Work.

If the estimated cost of a bridge rehabilitation project approaches or exceeds 50% of the cost of a new structure, an in-depth cost analysis must be completed. It should include life-cycle cost analysis, alternative methods and different levels of rehabilitation.

22.1.1 Safety

Safety work is performed with a roadway overlay or overlay and widening project, but it can be performed as a "stand-alone" bridge project to correct a specific safety problem. Safety work may include:

1. Bridge Rail. All bridge railing must comply with the MDT Bridge Rail Policy. See Section 22.6.

2. Anti-Skid Treatment for Decks. If the Skid Number of an existing bridge within the limits of a roadway project indicates a potential safety hazard, then this alone could warrant a bridge deck overlay, especially if there is a history of wet-weather accidents. See Section 22.3.3.

3. Widening. It may or may not be warranted to widen a bridge as part of a safety project within the limits of a roadway project. This will be based upon the roadway classification, traffic volumes, and the width of the existing bridge.

22.1.2 Minor Rehabilitation

Minor rehabilitation work will generally be the types of activities listed below and is often done with a roadway overlay or overlay and widening project. It is not, however, limited to these activities:

1. guard angles;
2. expansion joints;
3. deck seal (silane, HMWM, etc.);
4. spot painting of structural steel;
5. drains and drainage systems;
6. elevation adjustments;
7. repainting or overcoat painting; and/or
8. highway lighting upgrades.

It may or may not be warranted to widen a bridge as part of a minor rehabilitation project within the limits of a roadway project. This will be based upon the roadway classification, traffic volumes and the width of the existing bridge.

22.1.3 Major Rehabilitation

Usually, major rehabilitation work requires more plan development time than the corresponding roadway plans for an overlay or overlay and widening project, and it may be necessary to develop the project as a "stand-alone" bridge project. Major rehabilitation may include one or more of the following activities.

22.1.3.1 Bridge Deck

Bridge deck work, within the context of a major rehabilitation project, may include:

1. Deck Replacement. If the condition of an existing deck warrants replacement, the Bridge Area Engineer will perform a benefit-cost analysis to determine if widening the bridge is justified to meet the Department's bridge width criteria for new bridges. This will be based on the roadway classification, traffic volumes and the existing bridge width.

2. Deck Overlays. When deck conditions warrant, and sufficient lead time exists to obtain the deck survey and prepare plans, a deck overlay can be performed within the limits of a roadway overlay or overlay and widening project. If sufficient lead time does not exist to match the road project schedule, the deck overlay will be pursued as a "stand-alone" project. It may or may not be warranted to widen a bridge as part of a bridge deck overlay project within the limits of a roadway project. This will be based upon the roadway classification, traffic volumes, and the existing width of the bridge.

22.1.3.2 Structure Condition Ratings

All structural elements shall be returned to a condition rating of at least (7) as defined by the Montana Bridge Inspection Program. See Section 22.2 for a description of the Program.

22.1.3.3 Scour Countermeasures

If scour countermeasures are the only required work, no consideration will be given to widening the bridge.

22.1.3.4 Miscellaneous

Any safety or minor rehabilitation work listed in Sections 22.1.1 and 22.1.2 may also be performed as a part of a major rehabilitation project.

22.1.4 Seismic Retrofit

All bridges will be screened for seismic requirements in accordance with the Bridge Bureau's Seismic Screening Procedure. See Section 22.4.5 for MDT policies and practices for seismic retrofitting of existing bridges.

22.1.5 Trusses

Criteria for the rehabilitation of existing bridge trusses are in the **Montana Bridge Design Standards**. Secure the Bridge Engineer's approval before proceeding with design if the width, vertical clearance or load capacity in the standards cannot be obtained.

Structures with historical significance require special consideration when determining if they can be rehabilitated. See Section 13.8 for a list of the bridges in Montana that are included in or eligible for the National Register of Historic Places.

22.2 BRIDGE INSPECTION/BRIDGE MANAGEMENT

Many of the bridge rehabilitation projects programmed by MDT are identified through the Department's bridge inspection and bridge management activities. Section 22.2 provides a brief discussion on these.

22.2.1 National Bridge Inspection Standards (NBIS)

The National Bridge Inspection Standards (NBIS), a nationwide inspection and inventory program, is intended to detect structural problems. The Federal Highway Administration has regulations that each State transportation department must meet.

The following presents a brief discussion on the operational requirements of the NBIS:

1. Frequency of Inspections. Each bridge must be inspected at regular intervals.

2. Qualifications of Personnel. The Federal regulation lists the minimum qualifications for all bridge inspection personnel.

3. Inspection Procedures and Reports. Each State must have systematic methods for conducting field inspections and reporting its findings.

4. Records. Each State must have a systematic means of entering, storing and retrieving all bridge inspection data. The records must meet the Federal requirements.

5. Ratings. All bridges are rated according to their load-carrying capacity. This includes both the Operating and Inventory Ratings (see Section 22.2.2 for definitions). This information assists in the posting, the issuing of special overload permits, and the scheduling for rehabilitation or replacement.

22.2.2 Definitions

The following definitions apply to the NBIS and its implementation:

1. Inventory Rating. The load level that can be safely resisted by a structure for an indefinite period of time.

2. Operating Rating. The maximum permissible load level to which the structure may be subjected.

3. Sufficiency Rating. A numerical value from 0% to 100% that indicates a bridge's overall sufficiency to remain in service. The Rating is calculated from the Structure Inventory and Appraisal (SI&A) data.

4. Health Index The health index model is a single integral indicator of the structural health of the bridge. This indicator is expressed as a percentage value, which may vary from 0%, which corresponds to the worst possible condition, to 100% in the best condition.

22.2.3 MDT Bridge Inspection Program

22.2.3.1 Responsibility

The Bridge Management Section is responsible for collecting, maintaining and reporting bridge inspection information and for ensuring that the MDT Bridge Inspection Program complies with the requirements of the NBIS.

22.2.3.2 Description

The Bridge Management Section has published the following to describe and implement the MDT Bridge Inspection Program:

1. **MDT Bridge Inspection Manual**,

2. **MDT Fracture-Critical Inspection Manual**, and

3. **"Guidelines for Underwater Inspection."**

22.2.3.3 Classification of Substandard Bridges

To be considered for either *structurally deficient* or *functionally obsolete* classifications, the first digit of the Inventory Route Type (5A) must be coded "1," and the NBI Bridge Length Indicator must be coded "Y" to indicate a major structure (> 6.1 m face to face of supporting abutments).

To receive funding through the Highway Bridge Replacement and Rehabilitation Program (HBRRP) structures must be Structurally Deficient or Functionally Obsolete and have a Sufficiency Rating (SR) of 80% or below. Structures with an SR of 0 to 49.9 are eligible for replacement, and structures 50 to 80 are eligible for rehabilitation unless otherwise approved by FHWA.

The Sufficiency Rating formula is a method of evaluating highway bridge data by calculating four separate factors (structural adequacy, safety, serviceability, functional obsolescence and special reductions) to obtain a numeric value that is indicative of the bridge's sufficiency to remain in service. The result of this method is a percentage in which 100 is an entirely sufficient bridge and 0 is an entirely deficient bridge.

The following identifies the specific criteria for determining structural deficiency or functional obsolescence:

1. Structurally Deficient. A condition of "4" or less for:

   58) Deck or
   59) Superstructure or
   60) Substructure or
   62) Culvert

   Or, an appraisal of "2" or less for:

   67) Structural Evaluation
   71) Waterway Adequacy

2. Functionally Obsolete. An appraisal of "3" or less for:

   68) Deck Geometry or
   69) Under clearances or
   72) Approach Roadway Alignment

   Or, an appraisal of "3" for:

   67) Structural Evaluation
   71) Waterway Adequacy

Note: Any bridge classified as structurally deficient is excluded from the functionally obsolete category. Bridges shown as built or rehabilitated in the last 10 years are not eligible. However, once a bridge is on the eligibility list, it can stay on for 10 years even if the condition and appraisal ratings fluctuate.

22.2.4 MDT Bridge Management System (PONTIS)

The FHWA requires that all State DOTs develop management systems for bridges. This is to ensure that the planning, design, construction and maintenance will produce an optimum use of highway program resources.

The Bridge Management Unit has implemented a Management System called PONTIS. PONTIS is a network-level Bridge Management System that uses a probabilistic model and a bridge database to predict maintenance and improvement needs and to schedule projects within given budget and policy constraints. PONTIS is a tool for budget analysts and managers to develop annual and long-range maintenance and improvement programs and budgets.

The programming of bridge rehabilitation projects is in part based on recommendations from PONTIS. The program also reflects MDT District review and recommendations.

22.2.5 HBRRP

A major source of funding for bridge rehabilitation projects is the FHWA Highway

Bridge Replacement and Rehabilitation Program (HBRRP). The Program provides funds for eligible bridges located on any public road. Montana's share of HBRRP funds is basically determined by its number of structurally and/or functionally deficient bridges compared to the number nationwide.

In addition to replacement and rehabilitation, HBRRP funds may be used for preventive maintenance on highway bridges. Eligible activities include:

1. sealing or replacing leaking joints,

2. applying deck overlays that will significantly increase the deck service life, and

3. painting structural steel.

HBRRP funds available to non-State highway facilities (i.e., off-system) depends on the Federal provision that no less than 15% and no more than 35% of the funds must be used on public roads that are functionally classified as local roads (urban and rural) or rural minor collectors. The Montana Highway Commission has directed the Department to expend the maximum amount possible on off-system bridges.

22.3 CONDITION SURVEYS AND TESTS

To identify the appropriate scope of bridge rehabilitation work, the designer should select and perform the proper array of condition surveys, tests and analyses. This Section provides Department guidance for the designer.

22.3.1 Bridge Bureau Responsibility

22.3.1.1 General

The Bridge Bureau is responsible for:

- participating in field reviews;
- requesting specific tests to be performed by others (e.g., chloride-content analysis);
- evaluating data collected during the field survey and provided by others;
- determining the appropriate scope of rehabilitation or if replacement is appropriate; and
- providing contract documents.

22.3.1.2 Plan Preparation

In addition, at some time during the design and plan preparation phase, the designer should visit the site (or have the District obtain the information) to visually inspect and verify that the condition and configuration of the bridge match what has been assumed during design. In particular, close attention must be given to joints, guard angles and diaphragms. Determine if details match those shown in the plans and shop drawings. Check for evidence of repair work or revisions not indicated in the plans and shop drawings. It may be necessary to schedule the Snooper through the Bridge Management Section to get close enough to the underside of the bridge to observe and evaluate these components.

Within a year of the anticipated letting, another deck condition survey should be made. This is necessary because deck deterioration is constant and on-going. Because the original deck rehabilitation plan is developed from dated information, it is appropriate to check again to validate (or modify as needed) the proposed plans. This evaluation need not be more extensive than chain dragging the deck and verifying that the guard angles are still secure. Refer to Section 22.3.3.2.2 for a description of the chain drag test.

22.3.2 Selection of Surveys/Tests

The decision on the type and extent of bridge rehabilitation is based on information acquired from condition surveys and tests. The selection of these condition surveys and tests for a proposed project is based on a case-by-case assessment of the specific bridge site. The designer should consider the following factors:

1. age;
2. estimated remaining life (i.e., before bridge replacement is necessary);
3. size;
4. historic significance; and
5. potential investment in bridge rehabilitation.

The following information is normally available and may be requested by the designer if deemed pertinent:

1. original design plans and previous rehabilitation plans;
2. as-built plans;
3. shop drawings;
4. pile driving records;
5. previous surveys;

6. accident records;

7. flood and scour data, if applicable;

8. traffic data;

9. roadway functional classification;

10. bridge inspection reports;

11. structural ratings (sufficiency, operating, inventory); and

12. maintenance work performed to date.

Based on an assessment of the structural factors and the available information, the designer will select those condition surveys and tests which are appropriate for the bridge site conditions.

22.3.3 Bridge Decks

22.3.3.1 General

For the purpose of this Chapter, decks include the structural continuum directly supporting the riding surface, deck joints and their immediate supports, curbs, barriers, approach slabs and utility hardware. The bridge deck and its appurtenances provide the following functions:

1. support and distribution of wheel loads to the primary structural components;

2. protection of the structural components beneath the deck;

3. a smooth riding surface; and

4. safe passageway for vehicular and bicycle/pedestrian traffic (e.g., skid-resistant surface, bridge rails, guardrail-to-bridge-rail transitions).

Any deterioration in these functions warrants investigation and possible remedial action. A bridge deck has a finite service life, which is a function of both adverse and beneficial factors in the deck's environment. The most common cause of concrete bridge deck deterioration is the intrusion of chloride ions from roadway deicing agents into the concrete. The chloride causes formation of corrosive cells on the steel reinforcement, and the corrosion product (rust) induces stresses in the concrete resulting in cracking, delamination and spalling. Chloride ion (salt) penetration is a time-dependent phenomenon. There is no known way to prevent penetration, but it can be decelerated such that the service life of the deck is not less than that of the structure. Chloride penetration is, however, not the only cause of bridge deck deterioration. Other significant problems include:

1. Freeze-Thaw. Results from inadequate air content of the concrete. Freezing of the free water in the concrete causes random, alligator cracking of the concrete and then complete disintegration. There is no known remedy other than replacement.

2. Impact Loading. Results from vehicular kinetic energy released by vertical discontinuities in the riding surface, such as surface roughness, delamination and inadequately set or damaged deck joints. Remedial actions are surface grinding, overlay or replacement of deck concrete and rebuilding deck joints.

3. Abrasion. Normally results from metallic objects, such as chains or studs attached to tires. Remedial actions are surface grinding or overlay.

Certain factors are symptomatic indicators that a bridge deck may have a shorter than expected service life or that it is actually in the final phases of its service life. Some examples are:

1. extensive delamination,
2. exposed reinforcing steel, and
3. spalls.

These symptomatic indicators are generally examined at 2-year intervals by bridge inspectors under the auspices of the NBIS. During these inspections, a subjective numerical rating from 0 to 10 is given to the deck based on the nature and extent of these indicators. See Section 22.2.

The deck can be placed into one of the following categories:

1. Very good decks that need little attention. These are the (8) and (9) rated decks. The application of a sealer is considered to be an effective treatment of decks in this condition range.

2. Decks that are in reasonably good shape and need no substantial repair, but their lives can be extended with a nominal maintenance expenditure. These are the (7) rated decks. Decks in this condition range would most likely need some patching.

3. Decks that need considerable repair, but they are still quite sound and capable of serving adequately for several more years. These are candidates for repair and overlay with some type of non-permeable concrete. These are the (5) and (6) rated decks. The designer would most likely be looking at an overlay for bridge decks in this condition range, depending on the extent of chloride contamination. Very few bridge decks in Montana have ratings less than 5.

4. Decks that are no longer serviceable and will soon need replacement regardless of any remedial action. Significant expenditures of funds are not justified until replacement. However, minor maintenance expenditures could extend the remaining life several years. These are the (3) and (4) rated decks. Decks in these conditions then fall into the "replace deck" category.

Although bridge designers rely heavily on NBIS data to focus attention on decks that may need repair, it is not appropriate to rely solely on NBIS data to determine the Department's deck rehabilitation needs. The NBIS inspections are frequently performed during winter. Because of snow cover and inclement weather, it frequently is not possible for the inspector to perform a thorough visual assessment of the condition of the deck. When a bridge deck rehabilitation project is tentatively identified, the bridge designer should request deck surveys on all bridge decks within the limits of the proposed roadway project. There are at least three good reasons to do this:

1. Identify other marginal decks that may not show up based on NBIS screenings.

2. It provides background information for the assessment of deck deterioration rates and future program needs.

3. Visual inspection alone can not provide enough information to assess deck condition.

Ensuring the safety of the traveling public and meeting public demand for "bare" roads in winter requires the use of salts containing chloride (sodium chloride and magnesium chloride) in deicing compounds. Chloride ions from these sources diffuse through the deck, causing corrosion of the reinforcing steel over time. Expanding rust from the steel leads to deck delaminations and spalls.

When considering a bridge for rehabilitation, the Bridge Bureau requests a number of tests to gather information on the deck's condition. The gathered information allows the designer to determine whether deck rehabilitation or deck replacement would use MDT funds more effectively and, if the choice is rehabilitation, the information allows the determination of the appropriate level of treatment.

The Bridge Bureau requests the following information to perform a deck evaluation:

1. a plot locating existing delaminations, spalls and cracks;

2. measurement of the depth of cover on the top mat of reinforcing steel on a grid pattern;

3. sampling and laboratory analysis to determine the existing levels of chloride contamination;

4. measurement of electrical potential on a grid pattern to locate areas of active corrosion; and

5. deck concrete compressive strength assessed through destructive testing of deck core samples.

Section 22.3.3.2 provides more information on the individual forms of data gathered and their use in determining an appropriate deck treatment.

22.3.3.2 Condition Assessment Tests

22.3.3.2.1 Visual Inspection

Description: A visual inspection of the bridge deck should establish:

1. The approximate extent of cracking, delamination, spalling and joint opening.
2. Evidence of any corrosion.
3. Evidence of pattern cracking, efflorescence or dampness on the deck underside.
4. Rutting of the riding surface and/or ponding of water.
5. Operation of deck joints.
6. Functionality of deck drainage system.
7. Bridge rails and guardrail-to-bridge-rail transitions meeting current Department standards.
8. Deterioration and loss of integrity in wood decks.

Purpose: The visual inspection of the bridge deck will achieve the following:

1. By establishing the approximate extent of cracking, corrosion, delamination and spalling (and by having evidence of other deterioration), one can determine if a more extensive inspection is warranted.
2. The inspector will identify substandard roadside safety appurtenances.

When to Use: All potential deck rehabilitation projects.

Analysis of Data: Pattern cracking, efflorescence or dampness on the deck underside suggest that this portion of the deck is likely to be highly contaminated. In addition, the designer should consider:

1. traffic control,
2. timing of repair,
3. age of structure,
4. average annual daily traffic (AADT),
5. slab depth,
6. structure type,
7. depth of cover to reinforcement,
8. seismic factors, and
9. accident history (e.g., wet-weather accidents).

22.3.3.2.2 Delamination Testing or Sounding

Description: Establishes the presence of delamination, based on audible observation, by chain drag or hammer. Based on the observation that delaminated concrete responds with a "hollow sound" when struck by a metal object. See ASTM D4580 *Standard Practice for Measuring Delaminations in Concrete Bridge Decks by Sounding.*

Purpose: To determine the location and area of delamination.

When to Use: On all concrete deck rehabilitation projects, except where asphalt overlays prevent performance of the test.

Analysis of Data: Based on the extent of the bridge deck spalling, the following will apply:

1. 5% delamination of surface area is a rough guide for considering remedial action.

2. 10% delamination is a rough guide for considering bridge deck replacement.

Quantities are approximate for bid purposes only and should be rounded off to the nearest 5%.

22.3.3.2.3 Half-Cell Method

Description: Copper/copper sulphate half-cell method for the measurement of electrical potential as an indicator of corrosive chemical activity in the concrete. See ASTM C876 *Test Method for Half-Cell Potentials of Uncoated Reinforcing Steel in Concrete*.

Purpose: To determine the level of active corrosion in the bridge deck.

When to Use: On all concrete decks that are being evaluated. Even if a concrete deck has a wearing surface, half-cell readings can be made after areas of the deck are exposed.

Analysis of Data: A voltage potential difference of -0.35 volts or less indicates active corrosion as established by FHWA; more recent work suggests that -0.23 volts is the threshold of corrosion. Less negative readings indicate more active corrosion, while higher negative (smaller in absolute value) readings indicate lower corrosion.

22.3.3.2.4 Coring

Description: 50-mm or 100-mm diameter cylindrical cores are taken. In decks with large amounts of reinforcement, it is difficult to avoid cutting steel if 100-mm diameter cores are used.

Purpose: To establish strength, composition of concrete, crack depth, position of reinforcing steel.

When to Use: On all concrete deck rehabilitation projects when questions exist relating to the compressive strength or soundness of the concrete or if the visual condition of the reinforcement is desired. Also, when compression tests are requested.

Analysis of Data: Less than 50 mm of concrete cover is considered inadequate for corrosion protection. Less than 21 MPa compressive strength of concrete is considered inadequate. If compressive strengths are less than 21 MPa, the designer must obtain a determination from the Bridge Area Engineer whether to proceed with the deck rehabilitation or to proceed with a deck replacement. The choice of core locations can have a significant impact on the findings.

22.3.3.2.5 Chloride Analysis

Description: A chemical analysis of pulverized samples of the bridge deck concrete extracted from the deck or by in-place drilling. Concentrations of water-soluble chlorides are determined using the *Gravimetric Method — Silver Chloride Method* as described in *Scott's Standard Methods of Chemical Analysis*, 6th Edition, March 1962, D. Van Nostrand, publisher.

Purpose: To determine the chloride content profile from the deck surface to a depth of about 75 mm or more.

When to Use: Use on all bridge deck evaluations. Take chloride samples at three to five locations from the driving lane per span from each span 30 m or less in length. Increase the number of samples for longer spans.

Analysis of Data: The "threshold" or minimum level of water-soluble chloride contamination in concrete necessary to corrode reinforcing steel is 0.71 kg/m^3 (1.2 lbs/yd^3) or 0.03% chloride by weight. Chloride concentrations equal to or greater that this value above the top reinforcing mat require the removal of at least enough concrete so that the remaining concrete contamination is below the threshold.

Threshold or greater chloride concentrations at the level of the top reinforcing mat require either 1) hydro-demolition to remove enough concrete to ensure that the remaining concrete is below the threshold values or 2) deck replacement.

Threshold contamination or worse at or near the level of the bottom mat of reinforcing steel requires deck replacement.

22.3.3.2.6 Pachometer Readings

Description: The pachometer produces a magnetic field in the bridge deck. A disruption in the magnetic field, such as induced by a steel reinforcing bar, is displayed.

Purpose: To determine the size, depth and cover of steel reinforcing bars. These properties can be established to a depth of approximately 70 mm.

When to Use: Pachometer readings are used on virtually all concrete rehabilitation projects to verify reinforcement size and location.

Analysis of Data: Depth readings are taken at each grid point and the data is analyzed. If a deck will be mechanically milled or scarified, a removal depth can be selected that will avoid construction problems caused by milling machines snagging reinforcing steel.

22.3.3.2.7 Skid Test

Description: A test performed with a specially designed skid trailer to measure the available frictional resistance between a tire and the aggregate within the pavement surface.

Purpose: To determine if the Skid Number, which represents the frictional resistance, is sufficiently low to present a potential hazard when the pavement is wet.

When to Use: For a bridge rehabilitation project (e.g., Safety) where the structural evaluation of the bridge deck warrants no remedial action but there is a suspicion that the deck's surface may have inadequate skid resistance, especially if there is an adverse history of wet-weather accidents. This test may be used any time the skid resistance of a bridge deck warrants quantification. The decision to perform a Skid Test should be made in coordination with the MDT Safety Management Section.

Analysis of Data: To be performed by the MDT Safety Management Section.

22.3.3.3 Analysis of Multiple-Test Results

Delaminated areas usually indicate high half-cell and chloride content readings. Expect to obtain at least some degree of conflicting test results. Thus, sampling multiple locations within a traffic lane is important to determine the true state of the deck condition and the extent of active corrosion. Even if unsubstantiated by test results, the designer should assume that at least 1% of the deck area will require full-depth patching when estimating the project cost and determining the project scope.

Engineering judgment should be applied in analyzing test results.

22.3.4 Superstructure

For this Chapter, the superstructure includes all structural components located above the bearings, except decks. For bridges without bearings, such as rigid frames, fixed arches, etc., this includes every visible structural component, except decks. The following briefly describes those condition surveys and tests which may be performed on the superstructure elements to determine the appropriate level of rehabilitation.

22.3.4.1 Visual Inspection

Description: A visual inspection of the superstructure should include an investigation of the following:

1. Surface deterioration, cracking and spalling of concrete.

2. Major loss in concrete components.

3. Evidence of efflorescence.
4. Corrosion of reinforcing steel or prestressing tendons.
5. Loss in exposed reinforcing steel or prestressing tendons.
6. Corrosion of structural metal components.
7. Loss in metal components due to corrosion.
8. Cracking in metal components.
9. Excessive deformation in components.
10. Loosening and loss of rivets or bolts.
11. Deterioration and loss in wood components.
12. Damage due to collision by vehicles, vessels, ice or debris.
13. Leakage through deck joints.
14. Ponding of water on abutment seats.
15. State and functionality of bearings.
16. Distress in pedestals and bearing seats.

Purpose: To record all deterioration and signs of potential distress for comparison with earlier records and for initiating rehabilitation procedures if warranted.

When to Use: On all bridge rehabilitation projects.

Analysis of Data: As required.

22.3.4.2 Fracture-Critical Members

A fracture-critical member is a metal structural component, typically a superstructure tension or bending member, which would cause collapse of the structure or span if it fails. Fracture-critical structures in Montana have been identified and are noted in the inspection records on file in the Bridge Management Section. The designer must recognize typical fracture-critical details when conducting the Preliminary Field Review because it may affect the scope of bridge rehabilitation. Typical bridges in Montana containing fracture-critical members are listed below:

1. Steel trusses (pins, eye-bars, bottom chords and other tension members).
2. Two-girder steel bridges.
3. Transverse girders (supporting longitudinal beams and girders).
4. Pin-and-hanger connections (located on suspended spans or at transverse girders).

22.3.4.3 Tests for Cracking in Metals

The extent and size of cracks should be established to determine the appropriate remedial action if visual inspection reveals cracking in steel components. The following are the most common test methods used in locating cracks in steel components and measuring their extent and size:

1. Dye-Penetrant Testing. The surface of the steel is cleaned, then painted with a red dye. The dye is wiped off. If a crack is present, the dye penetrates the crack. A white developer is painted on the cleaned steel and any cracks are indicated where the red dye "bleeds" from the crack.
2. Magnetic-Particle Testing. The surface of the steel is cleaned and sprinkled with fine iron filings while a strong magnetic field is induced in the steel. Magnetism is not resisted by the void in the cracks; therefore, the particles form a footprint thereof.
3. Radiographic Testing. This is a highly reliable but cumbersome and expensive test because it requires a medium producing x-rays which penetrate the cracks and mark the film located at the other side. The film provides a permanent record of the x-ray test. Public and operator safety is an issue

when using an x-ray source on an existing bridge.

4. Ultrasonic Testing (UT). Testing devices that use high-frequency sound waves to detect cracks, discontinuities and flaws in materials. The accuracy of UT depends upon the expertise of the individual conducting the test and interpreting the results.

All tests must be conducted by, at a minimum, a Level II ANSI approved technician. For more information, see *Detection and Repair of Fatigue Damage in Welded Highway Bridges*, NCHRP Report 206, June 1979.

22.3.4.4 Fatigue Analysis

Description: Fatigue is defined as crack growth to a size at which fracture is no longer effectively resisted, leading to failure of the component. The crack growth is a function of:

1. crack size;
2. location of crack (i.e., structural detail);
3. energy-absorbing characteristics of metal;
4. temperature; and
5. frequency and level of stress range (transient stresses).

Purpose: To establish type and urgency of remedial action.

When to Use: Where cracks, found by visual inspection, are believed to be caused by fatigue or at fatigue-prone details.

Analysis of Data: Analysis should be performed by a structural engineer, experienced in fatigue-life assessment.

22.3.5 Substructures/Foundations

The substructures of the bridge transfer loads to rock or soil. Substructures include piers, bents and abutments, footings, driven piles and drilled shafts. Substructures including driven piles and drilled shafts are referred to as "deep foundations." Substructures including spread footings are referred to as "shallow foundations." The following briefly describes those condition surveys and tests which may be performed on these elements to determine the appropriate level of rehabilitation.

22.3.5.1 Visual Inspection

Description: A visual inspection of the substructure components should address the following:

1. Surface deterioration, cracking and spalling of concrete.
2. Major loss in concrete components.
3. Evidence of corrosion of reinforcing steel.
4. Loss in exposed reinforcing steel.
5. Deterioration or loss of integrity in wood components.
6. Leakage through joints and cracks.
7. Dysfunctional drainage facilities.
8. Collision damage.
9. Changes in geometry such as settlement, rotation of wing walls, tilt of retaining walls, etc.
10. Seismic vulnerabilities.
11. Accumulation of debris.
12. Erosion of protective covers.

13. Changes in embankment and water channel.

14. Evidence of significant scour.

Purpose: To record all deterioration and signs of potential distress for comparison with earlier records and for initiating rehabilitation procedures if warranted.

When to Use: On all potential bridge rehabilitation projects.

Analysis of Data: As required.

22.3.5.2 Other Test Methods

Other test methods described in Section 22.3.3 for bridge decks may be used to determine the level and extent of deterioration of concrete substructure components. The test methods described in Section 22.3.4.3 for cracking of metal components may be used for metal substructures.

22.4 BRIDGE REHABILITATION TECHNIQUES

As discussed in Section 22.3, the bridge condition surveys, tests, analyses and reports will indicate the extent of the problems and the objectives of rehabilitation. Section 22.4 presents specific bridge rehabilitation techniques that the designer may employ to address the identified deficiencies. This Section is segregated by structural element (i.e., bridge decks, steel superstructures, concrete superstructures, substructures/foundations and seismic retrofit). For each technique, Section 22.4 presents a brief description.

In addition, where applicable, several typical Department practices are presented which apply to bridge rehabilitation projects. The discussion in Section 22.4 is not intended to be all inclusive, but it provides the designer with a good starting point on the more common bridge rehabilitation techniques used by MDT. On individual projects and for individual applications, the designer is encouraged to review recent highway engineering literature for more information and to consult with the Bridge Area Engineer for assistance in determining an appropriate course of action. See Section 22.7.

22.4.1 Bridge Decks

22.4.1.1 Manual Reference

Chapter Fifteen of the **Montana Structures Manual** provides an in-depth discussion on the design of decks for new bridges. Many of the design and detailing principles provided in the Chapter also apply to deck rehabilitation. Therefore, the designer should review Chapter Fifteen to determine its potential application to the bridge rehabilitation project.

22.4.1.2 Typical Department Practices

The Department has adopted several typical practices for the rehabilitation of bridge decks. These are enumerated in the following:

1. Bridge Deck Overlays. The following summarizes typical Department practices:

   a. Patching. Patching the bridge deck should be considered a temporary measure to provide a reasonably acceptable riding surface until a more permanent solution can be applied.

   b. Latex-Modified Overlay. This is typically applied in conjunction with deck patching. Since the 1970s, the latex-modified overlay has been the most common bridge overlay technique used.

   c. Bituminous Overlay with Sheet Membrane. This method is considered a last resort treatment to extend the deck life until a replacement deck can be programmed. Because of MDT's desire to maintain visual surveillance of the concrete deck surface, the designer must obtain the approval of the Bridge Engineer before proceeding with this option. Breakdown of the membrane underneath the overlay and difficult construction tolerances preclude its further use.

   d. Low-Slump Concrete. This is also generically referred to as the "Iowa Deck." These were dense, low-slump concrete overlays, 50-mm to 60-mm thick, which were specified as an alternative to latex-modified overlays for over 25 years. Because this product has similar characteristics as the latex-modified overlay and is more expensive, it is no longer specified.

   e. Second Overlays. Department policy is not to allow a new overlay to be placed over an existing bridge deck overlay, because it is counterproductive and adds to the dead-weight of the structure.

2. Joints. The Department recognizes that the service life of bridge deck expansion joints is much shorter than that of the bridge, and leaking and faulty joints represent a hazard

for the deck and the main structural components. Therefore, the Department's standard procedure is to eliminate expansion joints as part of the bridge rehabilitation project where practical. Where applicable, the bridge deck rehabilitation should be consistent with the Department's criteria in Section 15.3 on the design of bridge deck expansion joints.

Compression seals (Type BS joints) are not allowed on bridge deck rehabilitation projects, and all such existing joints should be removed during rehabilitation.

3. Minimum Class A or Partial-Depth Patching Quantities. In general, the quantity summaries for bridge rehabilitation projects only include an estimate of the percent of bridge deck patching; the exact amount of patching needed is determined in the field during construction. However, the minimum amount of bridge deck patching shown in the quantities summary should be 5% of the bridge deck area.

22.4.1.3 Rehabilitation Techniques

The following pages present a brief description on those bridge deck rehabilitation techniques that may be considered on Department projects. The designer should review the technique and determine its applicability to the project. The techniques include:

- Technique BD-1 "Deck Repair"
- Technique BD-2 "High Molecular Weight Methacrylate (HMWM)"
- Technique BD-3 "Concrete Overlay"
- Technique BD-4 "Deck Drainage Improvements"
- Technique BD-5 "Joint Elimination"
- Technique BD-6 "Joint Replacement"
- Technique BD-7 "Silane Sealers"
- Technique BD-8 "Membrane with Asphalt Overlay"
- Technique BD-9 "Approach Slabs"
- Technique BD-10 "Introduce Composite Action"
- Technique BD-11 "Wood Deck Replacement"

Bridge Rehabilitation Technique
BRIDGE DECKS

Reference Number: BD-1
Title: Deck Repair

Description:

This rehabilitation technique is used under two distinctly different circumstances. One possible application is to repair isolated popouts or delaminations and restore the driving surface of the deck; another possible application is the repair of unsound areas after scarification or hydrodemolition of a deck that will receive an overlay.

If the intended application is to repair isolated popouts and restore the driving surface, consider the following guidance. The area to be patched is defined by sounding. Boundaries of the area are sawed at least 450 mm outside of the delaminated area to a depth of at least 13 mm. The concrete is then removed. Any exposed reinforcing steel is cleaned. A bonding agent is then applied to the existing concrete surface. Usually, a sand-cement grout or epoxy bonding agent is brushed onto the concrete surface.

Although conventional portland cement concrete is often used, other materials have been developed to permit early opening of the deck to traffic, such as accelerators, and fast-setting cements.It is essential that the manufacturers' specifications for mixing, placing and curing be rigidly followed.

Deck patching alone is usually only moderately successful and should be considered as a stopgap measure to extend the service life of the deck until overlay or replacement is justified.

The designer must prepare a special provision setting forth the work to be done on the specific project.

MDT uses two classifications of deck repair. Partial-depth patching is called Class A patching; full-depth patching is called Class B patching.

Bridge Rehabilitation Technique
BRIDGE DECKS

Reference Number: BD-2
Title: High Molecular Weight Methacrylate (HMWM) (Low Viscosity Sealants for Crack Repairs)

Description:

A low-viscosity organic liquid compound is flooded over the deck, and it fills the cracks by gravity and capillary action. Accordingly, the success of this operation depends on the crack size, selection of the appropriate compound, temperature, contamination on the crack walls and the skill of the operator.

Bridge Rehabilitation Technique
BRIDGE DECKS

Reference Number: BD-3
Title: Concrete Overlay

Description:

This rehabilitation technique is used for several purposes. Its most common application is for the re-establishment of a riding surface after scarification or hydrodemolition have removed chloride-contaminated concrete. The thickness and impermeability of the overlay reduce the rate of the chloride defusion with a resulting increase in deck life:

1. Deck Preparation. Surface milling or scarification usually removes the top 6 mm of the entire bridge deck surface. Hydrodemolition can be more precisely controlled to remove only the concrete that is unsound.

   Following the clean up from the surface removal operation, areas of unsound concrete are marked for further removal. Removal of the unsound concrete should be performed by either handchipping or hydrodemolition. Jack hammers should not be heavier than nominal 20.5-kg class, and chipping hammers than nominal 6.8-kg class. Hydrodemolition equipment should be calibrated to remove only unsound concrete.

   The removal areas should be thoroughly cleaned to assure the complete bonding of the new concrete to the old concrete.

2. Patching. Cavities left after the concrete removal operation should be patched prior to overlay by either normal portland cement concrete or latex-modified concrete. The cavity should be filled to the level of adjacent concrete.

A latex-modified overlay can be placed when the concrete that has been placed in the cavities has adequately cured. Latex-modified concrete has unique handling and finishing properties and, if the contractor is not familiar with these properties, the possibility exists that an unsatisfactory product will result.

After finishing, the surface is given a burlap drag finish. Transverse grooves will be sawn in the deck after the cure is complete.

The overlay should receive a wet cure for a minimum of 24 hours, followed by 72 hours of dry cure. In lieu of 72 hours of dry cure, the overlaid bridge deck may be opened any time if the compressive strength of the latex-modified concrete exceeds 27.5 MPa. Burlap for wet curing should be placed as soon as the overlay surface supports it without deformation. Approximately one hour after placing the first layer of burlap, a second layer, consisting of wet burlap or polyethylene film, should be placed and secured in position.

MDT has developed a “standard” Special Provision to address this work.

Bridge Rehabilitation Technique
BRIDGE DECKS

Reference Number: BD-4
Title: Deck Drainage Improvements

Description:

The most common drainage problems are:

1. deterioration around drainage facilities,
2. an inadequate number of facilities,
3. clogging of facility due to insufficient size and lack of maintenance, and
4. spilling water onto other structural components or the roadway below and/or causing erosion.

Details should ensure positive attachment of the facility to the existing structure and permit proper compaction of the new concrete in the deck.

See Section 15.3.8 for more information on bridge deck drainage.

Bridge Rehabilitation Technique
BRIDGE DECKS

Reference Number: BD-5
Title: Joint Elimination

Description:

On many bridges, the deck joint may be eliminated by simply making the concrete deck continuous. This can be achieved by removing sufficient concrete on both sides of the joint to permit adequate lap joints in the longitudinal steel, then form and place the concrete.

The structural implications of joint removal should be investigated:

1. A portion of the deck concrete is removed to permit placement of deck steel.

2. The effects of additional longitudinal movements must be investigated at the remaining joint locations.

3. For integral and semi-integral superstructures, consider the effects of cumulative movements on the substructures.

4. Consider the need for discontinuity in the barriers at the points where the joints are eliminated.

5. If two bearings are used, consider the effects of increased eccentricity of reaction forces on the substructures.

Making decks continuous by eliminating joints generally improves the seismic performance of a bridge. Adequate lap splices and proper development length are required along with sufficient reinforcement to transfer the loads from one span to another. The reinforcement should approximately match the reinforcement in as-built continuous slabs over simply supported beams.

Bridge Rehabilitation Technique
BRIDGE DECKS

Reference Number: BD-6
Title: Joint Replacement

Description:

Short of eliminating a joint, a simple replacement of an existing damaged or malfunctioning joint may be part of a bridge rehabilitation project. Joint replacement may be made where joint elimination is not possible due to structural or practical reasons.

Bridge Rehabilitation Technique
BRIDGE DECKS

Reference Number: BD-7
Title: Silane Sealers

Description:

One method of preventing the entry of chloride ions into the concrete is sealing its surface. In Montana, the useful life of this sealant is usually no more than three years. However, the minor costs associated with this technique give it a favorable cost-benefit ratio.

MDT maintains an approved list of sealers, which includes information identifying the manufacturer, sealer designation and additional requirements for specific sealers,

The designer must prepare a Special Provision setting forth the work to be done.

Bridge Rehabilitation Technique
BRIDGE DECKS

Reference Number: BD-8
Title: Membrane with Asphalt Overlay

Description:

MDT has traditionally discouraged placing asphalt overlays on bridge decks. This is primarily due to the reduced ability to properly inspect bridge decks covered with asphalt. Other problems associated with covered decks include added dead load, which reduces live load capacity, and trapping of moisture in the concrete, further aggravating corrosion of the slab reinforcing steel.

In recent years, the Bridge Bureau has designed and constructed a few deck rehabilitation projects using membrane systems in conjunction with asphalt overlays. These overlays were placed in selected areas on aging decks that were near the end of their useful lives and where replacement of the deck or entire bridge was being considered in the near future.

Where the existing deck surface is spalling or delaminated and traffic control issues demand a quick fix for ride improvement, this system will generally result in a reasonably smooth surface with little expense. Where the existing concrete deck is distorted or out of plane due to poor initial construction or due to settlement, this method has had limited success in providing ride improvement.

To use this overlay system, the Bridge Area Engineer must document the project-specific data justifying its use and obtain the approval of the Bridge Engineer.

Bridge Rehabilitation Technique
BRIDGE DECKS

Reference Number: BD-9
Title: Approach Slabs

Description:

Abutments for on-system bridges are typically designed to accommodate a future approach slab. As such, the addition of an approach slab should be considered during bridge rehabilitation if distress of the approach pavement due to settlement or lateral displacement is observed.

Bridge Rehabilitation Technique
BRIDGE DECKS

Reference Number: BD-10
Title: Introduce Composite Action

Description:

Introducing composite action between the deck and the supporting beams is a "natural" way to increase the strength of the superstructure. The **LRFD Bridge Design Specifications** encourage the use of composite action where current technology permits. Composite action can be achieved by welded studs.

Composite action considerably improves the strength of the upper flange in positive moment areas.

Bridge Rehabilitation Technique
BRIDGE DECKS

Reference Number: BD-11
Title: Wood Deck Replacement

Description:

On older bridges with wood decks (especially trusses), it may be impossible to rehabilitate the bridge with a new replacement concrete deck, because the increased dead load of the concrete deck will reduce the available live-load capacity. In such cases, deteriorated wood decks may be replaced in kind with a glue-laminated or nail-laminated wood deck.

22.4.2 Concrete Components Below the Deck

22.4.2.1 Manual Reference

Chapters Sixteen, Seventeen, Nineteen and Twenty of the **Montana Structures Manual** provide a detailed discussion on the design of concrete components below the decks of new bridges of reinforced concrete and prestressed concrete. Many of the design and detailing principles provided in these Chapters also apply to the rehabilitation of an existing concrete bridge. Therefore, the designer should review those Chapters to determine their potential application to the bridge rehabilitation project.

22.4.2.2 Rehabilitation Techniques

The following pages present a brief discussion on those concrete rehabilitation techniques which may appropriate for rehabilitating concrete portions of superstructures and substructures. These include:

- Technique CC-1 “Remove/Replace Deteriorated Concrete”
- Technique CC-2 “Shotcrete”
- Technique CC-3 “Epoxy Injection”
- Technique CC-4 “Post-Tensioning Tendons — Strengthening

Bridge Rehabilitation Technique
CONCRETE COMPONENTS

Reference Number: CC-1
Title: Remove/Replace Deteriorated Concrete

Description:

A clean, sound surface is required for any repair operation; therefore, all physically unsound concrete, including all delaminations, should be removed.

To prevent removing sound concrete, pneumatic hammers should be restricted to 14 kg for surface operation, and to 7 kg for chipping below steel. Saw-cut the edges of removal areas to a minimum of 13 mm. If the reinforcement bars are rusted, they must be exposed. Loose bars should be tied at each intersection point. Finally, the existing concrete surface and the exposed bars should be blast cleaned.

The remaining concrete should be capable of resisting its weight, any superimposed dead load, live load (if the bridge will be repaired under traffic), formwork, equipment and the plastic concrete. The formwork should resist the plastic concrete without slipping or bulging. Prior to placing concrete, the forms should be cleaned, oiled and wetted.

If the concrete surface is cleaned by high-pressure water blasting, it should be allowed to dry before any epoxy bonding agent or cement paste is applied. The new concrete should be applied before the bonding agent sets.

Bridge Rehabilitation Technique
CONCRETE COMPONENTS

Reference Number: CC-2
Title: Shotcrete

Description:

Instead of placing the new concrete in forms, it may be applied at high velocity by a pump through a hose and nozzle. For this application, the concrete should have a high cement content, low water-cement ratio, and the coarse aggregates replaced by fine aggregates.

Forming thin patches on vertical and overhead surfaces is often difficult as is placing and consolidating thick layers. This method may not be economical for small jobs because of the high mobilization costs.

For small areas, latex-modified concrete or mortar may be employed. Troweling or other finishing should be discouraged because they tend to disturb bonding. Scraping and cutting may be used to remove high points or material that has exceeded the limits of the repair after the concrete has become sufficiently stiff to withstand the pull of the cutting device.

Dimensions are difficult to control with this method, and the finish is often rough. It should not be used on exposed surfaces in urban areas.

The designer must prepare a Special Provision setting forth the work to be done.

For additional information, see the FHWA Workshop Notebook **Rehabilitation of Existing Bridges**, 1984.

Bridge Rehabilitation Technique
CONCRETE COMPONENTS

Reference Number: CC-3
Title: Epoxy Injection

Description:

Epoxy resin injection is commonly used to fill cracks in substructure units. Because the resin is injected under pressure, it is possible to fill nearly all of the cracks. Reinforcing bars are located with a Pachometer and holes are drilled to an appropriate depth into the cracks between reinforcing bars. The crack between the injection ports is sealed with a putty-like epoxy applied to the concrete surface by hand. Injection ports are placed at the holes, and a suitable epoxy system capable of bonding to wet surfaces is injected into the entry hole under pressure until it appears in the exit hole(s). A pumping system, in which the two components of the epoxy are mixed at the injection nozzle, is usually employed.

For selecting the epoxy resin and for the method of application, advice from the suppliers of the resin should be sought.

The designer must prepare a Special Provision setting forth the work to be done.

Bridge Rehabilitation Technique
CONCRETE COMPONENTS

Reference Number: CC-4
Title: Post-Tensioning Tendons — Strengthening

Definition: The addition of post-tensioned tendons to restore the strength of the prestressed concrete beam where original strands or tendons have been damaged. Strengthening by post-tensioning is also applied to non-prestressed concrete beams or hammerhead piers and not only as a result of collision.

Application: Collision of overheight vehicles or equipment with a bridge constructed with prestressed concrete beams may result in breaking off the concrete cover and subsequent damage to or severing of the beam tendons. Exposure to water and salt may also cause damage, particularly where the concrete cover is damaged or cracked. Because the steel tendons determine the load-carrying capacity of the beam, any damage impairs resistance and must be repaired. Transverse cracking of hammerhead piers is a candidate for external longitudinal post-tensioning along the sides of the hammerhead to close the cracks.

Procedure. At a minimum, the following steps apply:

1. Conduct a structural evaluation to determine the extent of the damage.

2. Evaluate the existing diaphragms to ensure their adequacy to support the end anchorage of the tendons.

3. Determine the placement of the temporary load to be applied to existing beams prior to removal and placement of concrete in prestressed concrete beams, if any.

The post-tensioning system should be designed and constructed in accordance with the manufacturer's recommendations. All wedge-type anchorages are susceptible to seating losses; therefore, for short lengths, rolled steel bars are preferred.

Special Note: The designer shall prepare a special provision setting forth the work to be accomplished for completion of this technique on a specific project. This special provision shall be included in the contract documents.

Reference: FHWA Workshop Notebook **Rehabilitation of Existing Bridges**, 1984.

22.4.3 Steel Superstructures

22.4.3.1 Manual Reference

Chapter Eighteen of the **Montana Structures Manual** provides a detailed discussion on the structural design of steel superstructures for new bridges. Many of the design and detailing practices provided in that Chapter also apply to the rehabilitation of an existing steel superstructure. Therefore, the designer should review Chapter Eighteen to determine its potential application to bridge rehabilitation projects.

22.4.3.2 Rehabilitation Techniques

The following pages present a brief discussion on those steel superstructure rehabilitation techniques which may be considered on Department projects. These include:

- Technique SS-1 "Grinding"
- Technique SS-2 "Peening"
- Technique SS-3 "Drilled Holes"
- Technique SS-4 "Bolted Splices"
- Technique SS-5 "Welding"
- Technique SS-6 "Addition of New Stringers — Strengthening"
- Technique SS-7 "Bearings"
- Technique SS-8 "Heat-Straightening"
- Technique SS-9 "Painting"
- Technique SS-10 "Pin and Hanger Rehabilitation"

Bridge Rehabilitation Technique
STEEL SUPERSTRUCTURES

Reference Number: SS-1
Title: Grinding

Description:

If the penetration of surface cracks is small, the cracked material can be removed by selective grinding without substantial loss in structural material. Grinding should preferably be performed parallel to the principal tensile stresses, and surface striations should carefully be removed because they may initiate future cracking.

Grinding can be used when beams are nicked while sawing off old decks.

Bridge Rehabilitation Technique
STEEL SUPERSTRUCTURES

Reference Number: SS-2
Title: Peening

Description:

Peening is an inelastic reshaping of the steel at the surface location of cracks, or of potential cracks, by using a mechanical hammer. This procedure not only smooths and shapes the transition between weld and parent metal, it also introduces compressive residual stresses that inhibit the cracking. Peening is most commonly used at the ends of cover plates to reduce fatigue potential.

A new computer-controlled peening process utilizing high-speed peening called ultrasonic peening has been introduced, which removes the dependency of the quality of mechanical-hammer peening on the operator's proficiency. This process promises weld enhancement for unavoidable poor fatigue resistance details such as terminations of longitudinal stiffeners.

Bridge Rehabilitation Technique
STEEL SUPERSTRUCTURES

Reference Number: SS-3
Title: Drilled Holes

Description:

At the sharp tip of a crack, the tensile stress exceeds the ultimate strength of the metal, causing rapid progression if the crack size attains a critical level. The purpose of drilled holes is to blunt the sharp crack tip. The location of the tip should therefore be established by one of the crack detection methods provided in Section 22.3.4.3. Missing the tip renders this process useless.

Bridge Rehabilitation Technique
STEEL SUPERSTRUCTURES

Reference Number: SS-4
Title: Bolted Splices

Description:

Where rivets or bolts in a connection are replaced, or where a new connection is made as part of the rehabilitation effort, the strength of the connection should not be less than 75% of the capacity or the average of the resistance of and the factored force effect in the adjoining components. Almost exclusively, the connections are made with high-strength bolts (ASTM A325). The connection must be designed by a structural engineer.

This method can also be used to span a cracked flange or web, provided that such connection is designed to replace the tension part of the element or component.

The preferred method of tightening bolts is by direct tension indicators; however, the designer must be aware that, if only a few bolts will be installed, an alternative method to control bolt tension such as calibrated torque wrenches or the “turn-of-nut” method, are acceptable. Regardless of the method used, all the bolts in the group are brought into a “snug-tight” condition and, then, the bolts are individually tightened to the specified tension.

For drilling holes, washers, tightening bolts and ensuring adequate pretensioning, the designer should refer to Section 556 of the **MDT Standard Specifications**.

Bridge Rehabilitation Technique
STEEL SUPERSTRUCTURES

Reference Number: SS-5
Title: Welding

Description:

It is common practice to use welding for shop fabrication of steel members and for welding pieces in preparation for rehabilitation work. Field welding is often difficult to perform properly in high-stressed areas, and individuals with the necessary skill and physical ability are required. The proper inspection of field welds is equally difficult. A shop weld is preferred to a field weld. All welding, whether in the shop or in the field, must be performed by a certified welder using welding processes and materials as approved on their certification card.

Field welding should only be allowed on secondary members, for temporary repairs, or in areas where analysis shows minimal fatigue stress potentials.

See Section 556 of the **MDT Standard Specifications** for additional specifications for welding of steel.

Bridge Rehabilitation Technique
STEEL SUPERSTRUCTURES

Reference Number: SS-6
Title: Addition of New Stringers — Strengthening

Description:

If the deck is removed, a new set of stringers added to the existing bridge is one alternative to strengthen the superstructure. To ensure proper distribution of live load, rigidity of the new stringers should be close to that of the existing ones.

The old stringers may also need rehabilitation, in which case, their removal may be considered as both a structurally and economically more proper alternative. The presence of lead paint may make replacement more economically feasible. Using modern deck designs and composite action, continuous stringers with a large spacing should be explored as an alternative.

Bridge Rehabilitation Technique
STEEL SUPERSTRUCTURES

Reference Number: SS-7
Title: Bearings

Description:

Often, the existing bearings may only need cleaning or repositioning. Extensive deterioration, or frozen bearings, may indicate that the design should be modified. A variety of elastomeric devices may be substituted for sliding and roller bearing assemblies. If the reason for deterioration is a leak in the deck joint, it should be sealed.

Rocker bearings and elastomeric bearings should not be mixed on the same pier/bent, due to differences in movement.

If the bearing is seriously dislocated, its anchor bolts badly bent or broken, or the concrete seat or pedestal is structurally cracked, the bridge may have a system-wide problem usually caused by temperature or settlement, and should be so investigated.

The bearing design may require alteration if warranted by seismic effects.

See Section 19.3 of the **Montana Structures Manual** for more information on bearings.

Bridge Rehabilitation Technique
STEEL SUPERSTRUCTURES

Reference Number: SS-8
Title: Heat Straightening

Description:

This technique is restricted to hot-rolled steels. Steels deriving their strength from cold drawing or rolling tend to weaken when heated. The basic idea of heat straightening is that the steel, when heated to an appropriate temperature (usually cherry color), loses some of its elasticity and deforms plastically. This process rids the steel of built-up stresses. While at an elevated temperature, the steel can also be hot worked and forced into a desirable shape or straightness without loss of ductility. Special care should be exercised not to overheat the steel; accordingly, this technique should be implemented by those having experience with this process. Note also that the heating temporarily reduces the resistance of the structure. Measures such as vehicular restriction, temporary support, temporary post-tensioning, etc., may be applied as appropriate.

Bridge Rehabilitation Technique
BRIDGE DECKS

Reference Number: SS-9
Title: Painting

Description:

Technically, bridge painting is maintenance work and not rehabilitation work but, frequently, during project development painting is discussed in conjunction with rehabilitation work on steel structures. In general, bridge painting is not economical but, in some circumstances, it may be warranted on a specific project. When considering bridge painting options, three scenarios present themselves. These are:

1. full removal of existing paint and repainting,
2. a complete recoat over the top of the existing paint (overcoat), and
3. touch-up painting.

The single driving factor in all discussions on painting bridges is that virtually all paint applied to bridges prior to 1977 contained lead. To remove existing paint, the current state of practice is abrasive blast removal, full enclosure, environmental and worker monitoring. The price for all this work approaches, and at times exceeds, the cost of replacing the existing steel bridge members with weathering steel.

The paint industry has developed products that can be successfully applied over existing paints and marginally prepared surfaces. An overcoat may be an economic alternative to full removal and repainting where a uniform appearance for the structural members is desired at the conclusion of the rehabilitation, but the problems associated with lead-based paints are not solved, merely deferred until a subsequent rehabilitation or structure replacement. Touch-up painting neither gives a uniform appearance nor solves the long-term lead problem. Touch-up painting may be appropriate in localized zones where corrosion could cause section loss.

Careful consideration must be given to the proper selection of paint for an overcoat. An improperly specified or improperly applied overcoat can cause failure of the original paint that was performing satisfactorily. Close attention must be given to the manufacturer's literature on any paint's service environment and recommended application environment. Proper surface preparation, application and field inspection are 80% of the challenge in applying paint.

See Section 612 of the **MDT Standard Specifications** for additional specifications on painting.

Bridge Rehabilitation Technique
STEEL SUPERSTRUCTURES

Reference Number: SS-10
Title: Pin and Hanger Rehabilitation

Description:

Pin and hanger details were originally used to facilitate the analysis of bridges by providing pins in otherwise continuous bridges. Their use today is not necessary due to modern computer-based structural analysis. These details are particularly susceptible to corrosion. Corrosion can result in the initiation of fatigue crackings in the hangers due to frozen pins and the unseating of the hangers on the pins due to misalignment from the corrosion product. The infamous collapse of one span of the Mianus River Bridge on I-95 in Connecticut was the result of corrosion of a pin and hanger detail.

Three solutions are possible for pin and hanger details:

1. Unlock frozen pins and hangers. The pin and hanger detail can be disassembled after providing alternative support to the suspended girder. Then, the various components of the detail can be cleaned of rust and dirt or replaced before re-assembly.

2. Provide a catch girder. As a safeguard against failure, especially for fracture-critical girders, an alternative permanent support system can be fabricated to "catch" the suspended girder ends if the pin and hanger detail fails. Such a structure must be temporarily provided to perform the unlocking of frozen details discussed above.

3. Eliminate the pin and hanger detail. If the girder sections allow, a bolted splice of the web and flanges can be fabricated to replace the pin and hanger. A structural analysis of the resulting continuous structure must verify that the resulting loads do not exceed the resistance of the existing girder section.

22.4.4 Substructures/Foundations

22.4.4.1 Manual Reference

Chapters Nineteen and Twenty of the **Montana Structures Manual** provide a detailed discussion on the structural design of substructures and foundations for new bridges. Many of the design and detailing principles provided in these chapters also apply to the rehabilitation of the substructures and/or foundations of an existing bridge. Therefore, the designer should review Chapters Nineteen and Twenty to determine their potential application to the bridge rehabilitation project.

22.4.4.2 Foundations for Bridge Widening

When a bridge will be widened, it is usually prudent to order cores to determine soil engineering properties for the design of additional substructure elements. The bridge designer should send a copy of the existing core logs (if they exist) to the Geotechnical Section. If the new core logs conflict with the old cores, then additional coring may be required.

If the MDT has cores for a bridge but they are not included in the contract documents, then the bridge designer should note in the construction plans that the cores are available for review in the Bridge Bureau.

22.4.4.3 Rehabilitation Techniques

The following pages present a brief discussion on those substructure and foundation rehabilitation techniques which may be considered on Department projects. These include:

- Technique SF-1 “Enlarge Footings”
- Technique SF-2 “Riprap”
- Technique SF-3 “Wing Wall Repair”
- Technique SF-4 “Drainage Improvements”
- Technique SF-5 “Grout Bag Underpinning”
- Technique SF-6 “Pile and Pier Section Loss Repair”

Bridge Rehabilitation Technique
SUBSTRUCTURES/FOUNDATIONS

Reference Number: SF-1
Title: Enlarge Footings

Description:

The most common reasons for enlarging the footings are:

- to widen the structure, or
- excessive settlement, or
- inadequate strength, or
- scour.

The method of rehabilitation is usually one of:

- enlargement of spread footing,
- enlargement of spread footing with piles, or
- enlargement of pile cap with additional piles.

Enlarging an existing spread footing:

1. The preferred alternative is to consult with MDT's Geotechnical Section for appropriate soils information.

2. Where a scour condition exists (spread footing in a stream), extend footings using piles. Designer should consult with MDT's Geotechnical Section for appropriate soils information. Design piles to carry all loads, and do not assume any contribution to the capacity by the footing itself acting as a spread footing.

Enlarging an existing pile-supported footing:

1. Extend the footing with additional piles similar in capacity to the original piles. Check the pile driving records of existing structure.

2. Overhead clearances from beams, decks and cantilever caps should be checked when locating new piles.

For forming, placement of steel, pouring and curing concrete, the same criteria apply as for new construction.

Bridge Rehabilitation Technique
SUBSTRUCTURES/FOUNDATIONS

Reference Number: SF-2
Title: Riprap

Description:

The stability of streambeds and banks is largely a function of water velocity, the size of the material in the streambeds and the size of material and presence or absence of vegetative cover on the banks. The energy of the moving water is a function of the water depth and water velocity. For a given water depth and velocity, if the material size exceeds critical dimensions, scour will not likely occur.

Artificially placed protective material is most usually natural stone that is specifically quarried to be angular for riprap applications, but it can be specially made concrete shapes. For steeper embankments, galvanized, gravel-filled, wire mesh envelopes called gabions can be an option.

The MDT Hydraulics Section will recommend the need for riprap and design its application.

Bridge Rehabilitation Technique
SUBSTRUCTURES/FOUNDATIONS

Reference Number: SF-3
Title: Wingwall Repair

Description:

In many old concrete abutments, the wingwalls tend to break-off and to separate from the main body due to earth-pressure and differential settlement. If the opening has been stable, the do-nothing option may be the best policy. If not stable, the wings should be removed and completely rebuilt. Footings for the new walls should be at the same level as that of the main body.

Bridge Rehabilitation Technique
SUBSTRUCTURES/FOUNDATIONS

Reference Number: SF-4
Title: Drainage Improvements

Description:

Water is a primary cause of instability of fills and embankments. As the water content of a fill behind a retaining structure increases, lateral pressure on the structure is amplified.

If the fill contains excessive amounts of silt or clay, it should be internally drained. This can be achieved either by perforated plastic pipes or by french drains. The latter is a deep trough, the bottom of which is filled with crushed stone or riverbed gravel of equal size. The gravel is covered with a plastic sheet to prevent intrusion of the fill above. Both systems should have exits to ditches permitting unimpaired gravity flow.

Water retention behind retaining structures, such as abutments and walls, is caused either by non-existing or undersized drainage pipes or by clogging thereof. New weep holes of adequate size can be drilled into the concrete if so required. Clogged holes should be thoroughly cleaned.

To prevent future clogging, the entry side of the holes should be provided with a filter and/or a lump of crushed stone or gravel, covered with perforated construction fabric.

Drainage improvement measures that should be considered for preventing erosion of the embankment surfaces at the corners of a structure caused by surface runoff include sodded flumes, erosion control mats, riprap drainage turnouts and curb inlets with piping.

Bridge Rehabilitation Technique
SUBSTRUCTURES/FOUNDATIONS

Reference Number: SF-5
Title: Grout Bag Underpinning

Description:

Scour may cause excessive settlement or tilting of spread footings. Grout-filled bags offer a reasonably simple and economical method of rehabilitation. The construction procedure is as follows:

1. Remove boulders that protrude under footing.
2. Install preformed grout bags and fill with pressurized concrete to mold to and completely fill cavity under the pier.
3. Place grout bags around the periphery of the pier to increase footing size and depth, thereby reducing further potential for undermining.
4. Install horizontal and vertical reinforcement through the grout bags.
5. Drill and grout dowels on 1.0-m centers into the existing seal or footing to anchor new work to old.
6. After jacking and blocking the superstructure, build new seats or pedestals and install the bearings.

Bridge Rehabilitation Technique
SUBSTRUCTURES/FOUNDATIONS

Reference Number: SF-6
Title: Pile and Pier Section Loss Repair

Description:

For steel piles, the following applies to section losses:

1. Small Loss. The restoration of the section of piles that experience a small loss of section associated with "normal" rusting is usually not warranted.

2. Medium Loss. When rusting has reduced the section of the pile such that it becomes a structural concern, the missing cross section is rebuilt by adding plates to the flanges and/or web as appropriate by either welding or bolting.

3. Extensive Loss. When the pile has deteriorated such that there is not enough sound remaining material for the section to be rebuilt, a new pile is installed; the damaged pile may or may not be removed.

For wood piles, section losses may be repaired by:

1. partial replacement,

2. epoxy injection, and/or

3. jacketing.

More information on wood piles can be found in "Timber Bridges – Design, Construction, Inspection and Maintenance" by M. A. Ritter, United States Department of Agriculture, Forest Service, EM 7700-8, June 1990, Chapter 14.

For concrete piles and piers, section loss may be repaired by removing all deteriorated material, constructing a formwork for a jacket, placing a reinforcing steel cage of appropriate size in the formwork and filling it with compacted concrete. The technique has extensive literature on its application.

22.4.5 Seismic Retrofit

22.4.5.1 Responsibility

MDT has developed a program to evaluate the existing bridges on the State highway system. Based on MDT warrants, the Seismic Unit reviews existing bridges for seismic vulnerability and designs the appropriate seismic retrofit on a priority basis.

22.4.5.2 Seismic Evaluation

Earthquakes cause what is best described as a shaking of the entire bridge structure. The ability to predict the forces developed by this motion is limited by the complexity of predicting the acceleration and displacements of the underlying earth material and the response of the structure. The motion can generally be described as independent rotation, in any direction, of each bridge abutment or pier, in or out of phase with each other, combined with sudden vertical displacements. Ground between piers can distort elastically and in some cases rupture or liquefy.

The bridge failures induced by the motions of the abutments and piers stem from two major inadequacies of many existing bridge designs — the lack of adequate connections between segments of a bridge and inadequately reinforced columns. Other deficiencies include inadequately reinforced footing and bent cap concrete and inadequate design force levels considering the likelihood of earthquakes at the location.

Fortunately, tying the segments of an existing bridge together is an effective means of preventing the most prevalent failure mode — spans falling off the bearings, abutments or piers. It is also the least expensive of the inadequacies to correct. Bridges with single-column bents are particularly vulnerable where segments are not connected.

Columns inadequately reinforced, because of too few and improperly detailed ties and spirals or short-lapped splices, generally do not sufficiently confine the concrete. This is particularly critical in single-column bents.

Determining the retrofit technique to use involves these considerations:

1. mode of failure anticipated,
2. influence on other parts of the bridge under seismic and normal loadings,
3. interference with traffic flow, and
4. cost of fabrication and installation.

Some retrofit procedures are designed to correct inadequacies of bridges related to earthquake resistance. The procedures may be categorized by the function the retrofit serves, including:

1. restraining uplift,
2. restraining longitudinal motion,
3. restraining hinges,
4. widening bearings,
5. strengthening columns, and
6. restraining transverse motion.

22.4.5.3 Application

Most of Montana's bridges are in Zone 1. The performance of a seismic evaluation on these existing bridges will be made on a case-by-case basis considering, for example:

1. the scope of the rehabilitation work (i.e., for more extensive rehabilitation work, a seismic evaluation may be appropriate); and
2. the importance of the structure (i.e., for major structures, a seismic evaluation may be appropriate even if the proposed scope of work is limited).

For the rehabilitation of existing bridges within the Montana Districts of Missoula and Butte, the designer is required to perform a seismic evaluation of the structure when major rehabilitation (i.e., deck replacement or superstructure widening) is anticipated.

22.4.5.4 Typical Department Practices

The following summarizes typical Department practices for the seismic retrofitting of existing bridges:

1. General. Bridges that are selected for seismic retrofitting shall be investigated for the same basic criteria that are required for all new bridges, including minimum support length and minimum bearing force demands. Bridge failures have occurred at relatively low levels of ground motion. It is clear, therefore, that MDT's systematic effort to identify seismically deficient bridges is warranted. Specific details for seismic retrofitting may be found in **Seismic Design and Retrofit Manual for Highway Bridges**, FHWA, 1995.

2. Minor. Minor seismic retrofit will usually be limited to seismic restrainers, dynamic isolation bearings and widening of beam seats. For the most part, it will be limited to work at or above the beam seats. The cost of minor retrofits should generally not exceed 25% of the cost of a new, seismically designed structure.

3. Major. Major seismic retrofit includes such items as strengthening columns, piers, bent caps, etc. It will generally include work below the level of the beam seats and may include work requiring cofferdams. The cost of major retrofits should generally not exceed 50% of the cost of a new, structure seismically designed structure.

4. Steel Rocker Bearings. For bridges within the Missoula and Butte Districts, the retrofitting measures shall include modification or elimination of existing steel rocker bearings. Major reconstruction projects in Zone 1 may also be good candidates for the elimination of existing steel rocker bearings, which will be decided on a case-by-case basis.

22.4.5.5 Seismic Retrofit Techniques

The following pages present a brief discussion on those seismic retrofit techniques which may be considered on Department projects. These include:

- Technique SR-1 "Techniques for Increasing Seismic Resistance of Columns"
- Technique SR-2 "Seat Width Extension"
- Technique SR-3 "Structural Continuity"
- Technique SR-4 "Restrainers and Ties"
- Technique SR-5 "Bearing Replacement"
- Technique SR-6 "Seismic Isolation Bearings"
- Technique SR-7 "Integral Abutments"

Bridge Rehabilitation Technique
SEISMIC RETROFIT

Reference Number: SR-1
Title: Techniques for Increasing Seismic Resistance of Columns

Description:

The following techniques may be used to increase the seismic resistance of columns:

1. Steel Jacket. A solid-steel shell may be placed around the column with a small space which is pressure grouted for a perfect fit.

2. Increase Flexural Reinforcement. If circumstances warrant, the flexural reinforcement may be increased. The vertical bars are located in a concrete jacket which is shear connected to the column by drilled and grouted dowels. This also increases the rigidity of the column, potentially rendering it counterproductive.

3. Infill Shear Wall. A concrete shear wall can be added between the individual columns of the bent. If the existing footing is not continuous, it should be made so. The wall should be connected to the columns by drilled and grouted dowels. This method substantially changes the seismic-response characteristics of the structure, requiring a complete re-analysis.

Bridge Rehabilitation Technique
SEISMIC RETROFIT

Reference Number: SR-2
Title: Seat Width Extension

Description:

Seat width extensions allow larger relative displacements to occur between the superstructure and substructure before support is lost and the span collapses. The extensions are likely to be exposed to large impact forces due to the dropping span; therefore, they should either be directly supported by the footing or be adequately anchored to the cap. Provisions in the **LRFD Bridge Design Specifications,** relative to the design of seat widths, should be followed as practical.

Bridge Rehabilitation Technique
SEISMIC RETROFIT

Reference Number: SR-3
Title: Structural Continuity

Description:

Superstructures have often been constructed without longitudinal continuity. Deck joints, beam ends, bearings, bearing seats and piers are potential sources of seismic problems. Structurally unconnected units of the superstructure tend to respond to seismic excitation differently, resulting in the dropping of the bearings or sliding off the substructure.

In older structures, shrinkage, creep and settlement have already occurred, and only the effects of temperature need be considered. The structural behavior of a bridge made continuous is fundamentally different from the non-continuous one, and it should be re-analyzed from every relevant perspective as if it were a new structure. Continuity for seismic purposes can often be attained by making the deck continuous.

Bridge Rehabilitation Technique
SEISMIC RETROFIT

Reference Number: SR-4
Title: Restrainers and Ties

Description:

In general, restrainers are add-on structural devices which do not participate in resisting other than seismic force effects. Mostly, these components are made of steel, they should be designed to remain elastic during seismic action, and special care should be exercised to protect them against corrosion.

There are three types of restrainers — longitudinal, transverse and vertical. The purpose of the two former ones is to prevent unseating the superstructure. The objective of the third one is to preclude secondary dynamic (impact) forces that may result from the vertical separation of the superstructure.

The restraint devices should be compatible with the geometry, strength and detailing of the existing structure. The designer may need to create new devices if those reported in the literature are not suitable.

Ties are restrainers that connect only components of the superstructure together. They are activated only by seismic excitation.

Bridge Rehabilitation Technique
SEISMIC RETROFIT

Reference Number: SR-5
Title: Bearing Replacement

Description:

Damaged or malfunctioning bearings can fail during an earthquake. In addition, steel rocker and roller bearings perform poorly for obvious reasons. One option is to replace these bearings with prefabricated steel-reinforced elastomeric bearings. To maintain the existing beam elevation, either a steel assembly is inserted between the beam and the elastomeric bearing, or the elastomeric bearing is seated on a new concrete pedestal. Construction of new concrete pedestals may create significant additional traffic control costs. Existing anchor bolts may assist in resisting shear between the pedestal and the pier. In both cases, the beam should be positively connected to the substructure by bolts, either directly or indirectly.

Bridge Rehabilitation Technique
SEISMIC RETROFIT

Reference Number: SR-6
Title: Seismic Isolation Bearings

Description:

There is a broad variety of patented seismic isolation bearings which are commercially available. They permit either rotation or translation or both. They have special characteristics by which the dynamic response of the bridge is altered, and some of the seismic energy is dissipated. The primary change in structural response is a substantial increase in the period of the structure's fundamental mode of vibration. The **LRFD Bridge Design Specifications** determine the equivalent lateral static design force as a function of this period. The devices are designed to perform elastically in response to normal service conditions and loads.

Accordingly, seismic isolation bearings normally contain an elastomeric element. The inelastic element is usually either a lead core or a viscous liquid damper whose resistance is a function of the velocity of load application. They are effective for seismic loads due to their high velocity. The liquid dampers are prone to leakage, thus requiring back-up safety devices.

When considering the use of seismic isolation bearings, see Section 19.3 for more information.

Bridge Rehabilitation Technique
SEISMIC RETROFIT

Reference Number: SR-7
Title: Integral Abutments

Description:

One plausible method to provide continuity between superstructures and substructures is the integral abutment. Minimum design requirements for integral abutments are provided in Section 19.1. Integral abutments are only feasible if pile supported and if the arrangement of piles permits the longitudinal temperature movement of the bridge. Cut off existing battered piling below grade.

22.5 BRIDGE WIDENING

22.5.1 Introduction

A bridge widening can present a multitude of problems during the planning and design stages, during construction and throughout its service life. Special attention is required in both the overall design and details of the widening to minimize construction and maintenance problems.

Section 22.5 presents Department guidelines for widening existing bridges. The following briefly summarizes the basic objectives in bridge widening:

1. Match the structural components of the existing structure, including splice locations.

2. Match the existing bearing types in terms of fixity.

3. Do not perpetuate fatigue-prone details.

22.5.2 Existing Structures with Substandard Capacity

An existing structure may have been originally designed for either live loads or seismic loads less than those currently used for new bridges. If such a structure becomes a candidate for widening, the MDT Bridge Management Unit should be consulted on the condition of the existing structure. A rating of the existing bridge must be made to quantify the capacity of the existing bridge. Based on this information, the designer will determine whether the existing structure should be strengthened to the same load-carrying capacity as the widening. For the evaluation, the following should be considered, if appropriate:

1. cost of strengthening existing structure;

2. physical condition, operating characteristics and remaining service life of the structure;

3. seismic resistance of structure;

4. other site-specific conditions;

5. only structure on route that restricts permit loading;

6. width of widening; and

7. traffic accommodation during construction.

22.5.3 Girder Type Selection

In selecting the type of girder for a structure widening, the widened portion of the structure should be a construction type and material type consistent with the existing structure. An exception to this is for an existing conventionally reinforced concrete girder structure. It is preferable to use prestressed concrete I-beams for the widened portion.

22.5.4 Existing Bridge-Deck Assessment

The rehabilitation or replacement of the existing bridge deck shall be considered after an assessment of the existing deck, as discussed in Section 22.3.3.

22.5.5 Epoxy-Coated Bars in Widenings

Epoxy-coated steel reinforcing bars shall be placed in a deck widening if the existing deck contains epoxy-coated bars, and "black" bars shall be used if the existing deck was constructed with "black" bars.

22.5.6 Bridge Deck Longitudinal Joints

Past performance indicates that longitudinal expansion joints in bridge decks between a bridge widening and the existing bridge have been a continuous source of bridge maintenance problems. Therefore, as a general policy, no longitudinal expansion joints should be employed.

Experience has shown that a positive attachment of the widened and original decks by lapping reinforcing steel provides a better riding deck, usually presents a better appearance and reduces maintenance problems. A positive attachment of the old and the new decks shall be made for the entire length of the structure.

In some cases, it may be desirable to use a type of anchorage system other than lapping reinforcing steel. If the bridge widening exceeds the Department's geometric design criteria for clear roadway width, lapped reinforcing steel may be more expensive than other options because of the need to provide adequate bond length.

The following recommendations should be considered when widening an existing beam/girder and deck-type structure:

1. Structures with large overhangs should be widened by removing the concrete from the overhang to a width sufficient to develop adequate bond length for lapping the original transverse deck reinforcing to that of the widening.

2. Structures with small overhangs, where removal of the overhang will not provide sufficient bond length, should be either doweled to the widening or have transverse reinforcing exposed and extended by mechanical lap splice.

3. Structures with no overhangs should be attached by doweling the existing structure to the widening. Double row patterns for the dowels are preferred over a single row. Benching into the existing exterior girder as a means of support has proven to be unsatisfactory and should be avoided.

22.5.7 Effects of Dead Load Deflection

It is recommended that, where the dead load deflection exceeds 6 mm, the widening should be allowed to deflect and a closure pour considered to complete the attachment to the existing structure. A closure pour serves two useful purposes: It defers final connection to the existing structure until after the deflection from the deck slab weight has occurred; and it provides the width needed to make a smooth transition between differences in final grades that result from design or construction imperfections.

For the effects of dead load deflection, two groups of superstructure types can be distinguished — precast concrete beam or steel beam construction, where the largest percentage of deflection occurs when the deck concrete is placed and, for cast-in-place construction (e.g., reinforced concrete slab bridges), where the deflection occurs after the falsework is released.

In the first group, dead load deflection after placing the deck is usually insignificant but, in cast-in-place structures, the dead load deflection continues for a lengthy time after the falsework is released. In conventionally reinforced concrete structures, approximately ⅔ to ¾ of the total deflection occurs over a four-year period after the falsework is released due to shrinkage and creep. A theoretical analysis of differential deflection that occurs between the new and existing structures after closure will usually demonstrate that it is difficult to design for this condition. Past performance indicates, however, that theoretical overstress in the connection reinforcing has not resulted in maintenance problems, and it is generally assumed that some of the additional load is distributed to the original structure with no difficulty or its effects are dissipated by inelastic relaxation. Good engineering practice dictates that the closure width should relate to the amount of dead load deflection that is expected to occur after the closure is placed. A minimum closure width of 500 mm is recommended.

At the present time, MDT is satisfied with the performance of its bridge decks that are widened without the use of deck closure pours. This satisfactory performance also applies to deck replacements that are poured in two phases while maintaining traffic and without the use of deck closure pours. Consequently, deck widening and phased deck replacement projects normally do not require deck closure pours unless the designer recommends otherwise. An example of when a closure pour may be warranted is for two-span steel beam/girder structures where uplift could occur.

22.5.8 Vehicular Vibration During Construction

All structures deflect when subjected to live loading, and many bridge widenings are constructed with traffic on the existing structure. Fresh concrete in the deck is subjected to deflections and vibrations caused by traffic. Studies such as NCHRP 86 *Effects of Traffic-Induced Vibrations on Bridge-Deck Repairs* have shown that:

1. good-quality reinforced concrete is not adversely affected by jarring and vibrations of low frequency and amplitude during the period of setting and early strength development;
2. traffic-induced vibrations do not cause relative movement between fresh concrete and embedded reinforcement; and
3. investigations of the condition of widened bridges have shown the performance of attached widenings, with and without the use of a closure pour, to be satisfactory.

22.5.9 Substructure

An existing structure will ordinarily not be subjected to settlement of its footings by the time the widening is completed. Pile capacities of existing structures should be investigated if additional loads will be imposed on them by the widening. It is possible for newly constructed footings under a widened portion of a structure to settle. The new substructure should be tied to the existing substructure to prevent differential foundation settlements. If the new substructure is not tied to the existing substructure, suitable provisions should be made to prevent possible damage where such movements are anticipated.

22.5.10 Design Criteria (Historical Background)

22.5.10.1 AASHTO Standards

It is not normally warranted to modify the existing structure solely because it was designed to AASHTO Specifications prior to the adoption of the **LRFD Bridge Design Specifications** and its latest interim changes.

When preparing plans to modify existing structures, it is often necessary to know the live load and stress criteria used in the original design. Since approximately 1927, with few exceptions, structures on the Montana highway system have been designed for loads and stresses specified by AASHTO.

The designer should be aware of the historical perspective of design criteria, such as live loads, allowable stresses, etc., when analyzing a rehabilitated structure. For accurate and complete information on specific structures, see the General Notes of as-built plans, old standard drawings and special provisions, and the appropriate editions of the AASHTO Specifications.

22.5.10.2 Materials

Figure 22.5A presents the historical properties of materials from the **Montana Standard Specifications for Road and Bridge Construction** since 1946.

22.5.10.3 Rolled Steel Beams

Throughout the years, modifications to rolled steel beam sections have occurred. Designers should refer to the construction-year AISC steel tables for rolled beam properties and other data.

Material	1946	1962	1970	1976	1987	1994
"A" Concrete (f'_c)	2.4 ksi	2.4 ksi	2.4 ksi	2.4 ksi	2.4 ksi	2.4 ksi
"AD" Concrete (f'_c)	3.0 ksi	3.0 ksi	3.0 ksi	3.0 ksi	3.0 ksi	3.0 ksi
"AS" Concrete (f'_c)	NA	NA	2.4 ksi	2.4 ksi	2.4 ksi	2.4 ksi
"BD" Concrete (f'_c)	NA	NA	NA	3.5 ksi	3.5 ksi	3.5 ksi
"DD" Concrete (f'_c)	NA	3.0 ksi	3.0 ksi	3.0 ksi	3.0 ksi	3.0 ksi
"S" Concrete (f'_c)	2.4 ksi	2.4 ksi	NA	NA	NA	NA
Prestressed Beams (f'_c)	NA	5.0 ksi	5.0 ksi	5.0 ksi	5.0 ksi	5.0 ksi
Reinforcement Steel (f'_c)	A15 Int Gr 40 ksi	A15 Int Gr 40 ksi	A-615-68 Gr 40 40 ksi	A-615 Gr 60 60 ksi	A-615 Gr 40 or Gr 60	A-615 Gr 40 or Gr 60
Structural Steel (f_y)	ASTM 47 33 ksi	ASTM A36 36 ksi	ASTM A36 36 ksi	ASTM A36 36 ksi	ASTM A36 36 ksi	ASTM A36 36 ksi

Notes:

1. *Consider increasing typical concrete strengths from the table by 50% for girders and beams to account for conservative batching practices and strength gains from aging. Do not assume strength gain for decks. (See Priestley, Seible & Calvi* ***Seismic Design and Retrofit of Bridges****, pg 546).*
2. 1 ksi = 6.894757 MPa.

MATERIAL PROPERTY VALUES FROM MONTANA STANDARD SPECIFICATIONS FOR ROAD AND BRIDGE CONSTRUCTION

Figure 22.5A

22.6 OTHER BRIDGE REHABILITATION PROJECT ISSUES

A rehabilitation project for an existing bridge requires the consideration of several issues other than the structural design rehabilitation. These include:

1. project development;
2. project reports;
3. plan preparation conventions;
4. geometric design issues;
5. roadside safety issues;
6. maintenance and protection of traffic through construction zones; and
7. other project elements (e.g., hydraulics, geotechnical, environmental procedures, permits, right-of-way).

These topics are discussed elsewhere in the **Montana Structures Manual**. Section 22.6 identifies these references for bridge rehabilitation projects and, where appropriate, provides additional information.

22.6.1 Project Development

Chapter Two presents detailed project development networks for major bridge rehabilitation projects and bridge deck rehabilitation projects. Reference these networks to identify the typical level of effort commensurate with the Project Scope of Work for a given engineering/procedural function (e.g., geotechnical, permits).

22.6.2 Project Reports

Section 4.1 presents an in-depth discussion on the format, content and distribution of Project Reports, including the:

1. Preliminary Field Review Report,
2. Scope of Work Report,
3. Design Parameters Report, and
4. Plan-in-Hand Report.

These apply to all bridge rehabilitation projects.

22.6.3 Plan Preparation

Chapter Five discusses the preparation of plans for Department projects (e.g., content of individual sheets, scales, symbols). As applicable, bridge rehabilitation projects should be prepared consistent with these plan preparation conventions.

22.6.4 Roadway Design

The **Montana Road Design Manual** discusses the Department's roadway design criteria, and Sections 13.5 and 13.6 of the **Montana Structures Manual** discuss geometric design criteria specifically for highway bridges. The following discussion applies to geometric design considerations for bridge rehabilitation projects.

22.6.4.1 Horizontal/Vertical Alignment

Many existing bridges have alignments which do not meet MDT's current criteria for horizontal and vertical alignment. Except in rare cases, for bridge rehabilitation projects, it is unlikely to be cost effective to realign the bridge to correct any alignment deficiencies.

22.6.4.2 Roadway Cross Section

Section 13.5.4 presents information and criteria for the roadway cross section across a bridge, including:

- profile grade line,
- cross slopes and crowns,
- width,
- sidewalks,

- bikeways, and
- medians.

The application of these criteria to a bridge rehabilitation project will depend upon the Scope of Work and the practicality of meeting these provisions.

Specifically for roadway widths across bridges, MDT has produced the **Montana Bridge Design Standards**, which is a separate document. Officially adopted standards are the highest order control document over design criteria. The bridge designer should reference this document to determine MDT policies and criteria for bridge widths on existing bridges to remain in place (or bridge rehabilitation projects). Many documents within MDT commonly referred to as "standards" are in fact guides. Among these guides is the **Montana Road Design Manual**. Within some broad parameters, virtually all information in the **Montana Road Design Manual** is considered guidance. If descrepencies exist between the **Montana Bridge Design Standards** and the **Road Design Manual**, the **Montana Bridge Design Standards** is the controlling document. When deviating from the **Standards**, formal design exception approval from the Bridge Engineer must be secured.

22.6.5 Appurtenances

22.6.5.1 General

Section 15.5 discusses the various appurtenances that may be present on bridges:

1. bridge rails,
2. pedestrian rails,
3. bicycle rails,
4. fences,
5. utility attachments,
6. sign attachments, and
7. lighting/traffic signals.

With the exception of bridge rails (Section 22.6.5.2), the policies and criteria in Section 15.5 apply to bridge rehabilitation projects. For example, the bridge designer will refer to Section 13.5.4 "Fences" to determine if protective fencing across the bridge is warranted.

22.6.5.2 Bridge Rails

The need to revise existing bridge rails will be based upon the Department's "Montana Bridge Rail Policy and Practice," dated August 1988. This Policy is located at the end of Section 22.6. If the existing bridge rail will be replaced, the criteria in Section 15.5.1 for new bridge rails will apply.

For guardrail-to-bridge-rail transitions, the Road Design Section, in coordination with the bridge designer, is responsible for determining if any modifications are warranted.

22.6.6 Maintenance and Protection of Traffic During Construction

Work zone traffic control is an important element of a bridge rehabilitation project. The proposed strategy for maintaining traffic during construction could include alternating one-way traffic with signals, lane restrictions, median crossovers, or diverting the traffic to a detour route. See the **Montana Road Design Manual** for detailed information on Department policies and procedures.

August 1988

Montana Bridge Rail
Policy and Practice

This policy and practice statement will provide additional clarification regarding the Montana Department of Transportation's bridge rail policy which the FHWA Division Office concurs in. Since the meeting of January 13, between MDT and the FHWA Division Office, Mr. Morgan has concurred in Mr. Loveall's additional guidelines to AASHTO's proposed guide specifications for bridge railings. The additional guidelines specifications state, in part, that railing designed and built subsequent to the institution of the 1964 Interim AASHTO Specifications railing provisions are not subject to replacement, provided its performance record is proven satisfactory. Existing Montana bridge rail that does not meet the 1964 specifications will be required to be upgraded to a crashworthy design.

Since the preface of the Guide Specifications clarifies that the Guide is for new bridges and for bridges being rehabilitated to the extent that railing replacement is obviously appropriate, therefore, on a case-by-case basis, bridge rails designed and constructed subsequent to the 1964 AASHTO's Specifications may be retained in service. Site-specific data and railing performance data will need to be reviewed to determine whether to replace or retrofit the existing bridge rail to a crashworthy configuration or leave the existing bridge rail in place.

If the bridge rail has been previously blocked out and only requires repairs, which are normally performed by MDT maintenance forces, then the rail can remain in place provided the rail will be repaired before the contract is let. The period between the field check stage and letting date should allow adequate time for the rail to be repaired.

Montana's Type No. 5 bridge rail with a 150-mm offset was designed prior to the 1964 interim specifications and, therefore, should be retrofitted. A blocked out thrie beam is currently being used. The Type No. 5 rail with a 75-mm offset to rail from curb was designed after the 1964 interim specifications. Therefore, this rail, contingent on a review of each site and performance data, can remain in place.

Montana's Type No. 3, Type No. 4, and concrete post bridge rails were designed prior to 1964. If these rails have not been blocked out, they should be replaced or retrofitted. The Type No. 3 rail, when within a Federal-aid project, is being replaced with a cast-in-place, concrete barrier. The T4 and concrete post bridge rails are retrofitted, with Division Office approval, by blocking out a thrie beam to the face of the curb.

An existing steel beam bridge rail, SBBR, that is blocked out to the curb can remain in place. Again, site-specific data regarding railing performance and condition of existing rail components will need to be evaluated to determine if the blocked out SBBR can be left in place. If the existing SBBR is not blocked out, then a cast-in-place concrete barrier rail will be constructed. The blocked out SBBR's first steel post will be modified to accept Montana's crashworthy approach rail. The blocked out SBBR will still be treated as a bridge rail to remain in place since this modification to the first bridge rail post is only for accepting a crashworthy approach rail.

An existing timber bridge rail that is blocked out to the curb satisfies the requirements of the 1964 provisions of AASHTO's Interim Bridge Railing Specifications. An existing timber bridge rail that is not blocked out to the curb does not satisfy these requirements. In accordance with previous correspondence from the FHWA Regional and Washington Offices, the precast concrete barrier, originally proposed by the MDT, is not an acceptable retrofit. A continuous, cast-in-place concrete barrier rail secured to the deck, proposed by the MDT, is an acceptable solution.

In accordance with accepted policy, bridge rails for new bridge construction or bridge replacement are being constructed to a crashworthy design. The FHWA Regional Office concurs with holding off of Montana's crash testing of the T5 rail with a 75-mm offset and the SBBR until the proposed guide specifications are adopted. The adopted specifications may not require crash testing of rails designed after the 1964 Interim Bridge Specifications.

The 1988 bid estimates for retrofitting bridge rails with a blocked-out thrie beam has averaged about $16 per lineal foot. Assuming traffic control to be 20% results in a total unit cost of $20 per lineal foot for blocking out with a thrie beam.

The 1988 bid estimates for placing a cast-in-place concrete barrier has averaged $85 per lineal foot. Assuming traffic control to be 20% results in a total unit cost of $102 per lineal foot for the concrete barrier.

For the remaining August through December 1988 lettings, the cost to upgrade bridge rail to a crashworthy configuration within Federal-aid projects is estimated to be $150,000.

Summary of Guardrail Retrofit Policy by FHWA:

1. Montana SBR-T3. Retrofit with cast-in-place concrete barriers.

2. Montana SBR-T4. Thrie-beam retrofit upon Division Office approval only. Dependent upon needed repairs, performance and other criteria.

3. Montana SBR-T5. Design prior to the AASHTO Interim 1964 (curb to rail spacing of 150-mm) — Use blocked-out thrie-beam retrofit.

   Design after the AASHTO Interim Specifications of 1964 (curb to rail spacing of 75 mm) — no retrofit needed. This system can remain as is.

4. Montana SBBR. If this rail system is blocked out to the face of the curb, no retrofit is needed. This will also depend upon the condition and the performance of the existing rail.

   If this rail system is not blocked out to the face of the curb, a cast-in-place concrete barrier rail retrofit is required. New approach rail corresponding to a crashworthy bridge rail is also required.

5. Timber Rails. If blocked out to the face of the curb, no retrofit is needed. This curb-rail system can be left in place, depending upon the condition and the performance.

   If the existing rail is not blocked out by a W-beam rail, then a cast-in-place concrete barrier rail retrofit is required. The approach rail also has to correspond to a crashworthy rail.

22.7 BRIDGE REHABILIATION LITERATURE (other than AASHTO documents)

22.7.1 FHWA Documents

1. Extending the Service Life of Existing Bridges by Increasing Their Load-Carrying Capacity, 1978.

2. Seismic Retrofitting Guidelines for Highway Bridges, 1983.

3. Inspection of Fracture-Critical Bridge Members; supplement to the Bridge Inspector's Training Manual, 1986.

4. Seismic Design and Retrofit Manual for Highway Bridges, 1987.

5. Seismic Design Retrofit Manual for Highway Bridges, 1989.

6. Economical and Fatigue-Resistant Steel Bridge Details, 1990.

7. Bridge Inspector's Training Manual, 1991.

8. Evaluating Scour at Bridges, 1991

22.7.2 TRB Documents

1. National Cooperative Highway Research Program (NCHRP) Report 141: *Bridge Deck Joints*, 1989.

2. NCHRP Report 206: *Detection and Repair of Fatigue Damage in Welded Highway Bridges*, 1979.

3. NCHRP Report 243: *Rehabilitation and Replacement of Bridges on Secondary Highways and Local Roads*, 1981.

4. NCHRP Report 248: *Elastomeric Bearings Design, Construction and Materials*, 1982.

5. NCHRP Report 271: *Guidelines for Evaluation and Repair of Damaged Steel Bridge Members*, 1984.

6. NCHRP Report 280: *Guidelines for Evaluation and Repair of Damaged Prestressed Concrete Members*, 1985.

7. NCHRP Report 293: *Methods of Strengthening Existing Highway Bridges*, 1987.

8. NCHRP Report 298: *Performance of Elastomeric Bearings*, 1987.

9. NCHRP Report 299: *Evaluation Procedures for Steel Bridges*, 1987.

10. NCHRP Report 301: *Load Capacity Evaluation of Existing Bridges*, 1987.

11. NCHRP Report 302: *Fatigue and Fracture Evaluation for Rating Riveted Bridges*, 1987.

12. NCHRP Report 333: *Guidelines for Evaluating Corrosion Effects in Existing Steel Bridges*, 1990.

13. NCHRP Report 336: *Distortion-Induced Fatigue Cracking in Steel Bridges*, 1990.

14. NCHRP Synthesis of Highway Practice 41: *Bridge Bearings*, 1977.

15. NCHRP Synthesis of Highway Practice 88: *Underwater Inspection and Repair of Bridge Substructures*, 1981.

16. NCHRP Synthesis of Highway Practice 136: *Protective Coatings for Bridge Steel*, 1987.

17. NCHRP Synthesis of Highway Practice 141: *Bridge Deck Joints*, 1989.

22.7.3 Other Documents

1. American Concrete Institute (ACI), *Guide to Joint Sealants for Concrete Structures*, 1977.

2. ACI, *Guide for Repair of Concrete Bridge Superstructures*, 1980.

3. Wasserman, Edward P., "Jointless Bridge Decks," *Engineering Journal*, American Institute of Steel Construction (AISC), Third Quarter, 1987.