Overview

1) Concrete mix designations
2) Reinforcing bar development and splice lengths
3) Modification to HL-93 double truck live load
4) Use of Strength IV load combination
5) Wood structures section
6) Design and evaluation for bridge repair projects
7) Integral abutments
8) Standard plan notes
9) Revised plan sheets
10) Other changes
• Historically MnDOT Specs for concrete mixes were prescriptive

• Industry has been moving to performance specifications

• Contractor mix designs began with 2016 MnDOT Specs
### Design Concrete Mix Summary

<table>
<thead>
<tr>
<th>Location/Element</th>
<th>MnDOT Concrete Mix Designation</th>
<th>Design Compressive Strength (ksi)</th>
<th>Maximum Aggregate Size (in)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Cofferdam seals</td>
<td>1X62</td>
<td>5.0</td>
<td>1</td>
</tr>
<tr>
<td>Cast-in-place concrete piles and spread footing pads</td>
<td>1P62</td>
<td>3.0</td>
<td>2</td>
</tr>
<tr>
<td>Drilled shafts</td>
<td>1X62, 3X62</td>
<td>5.0</td>
<td>1</td>
</tr>
<tr>
<td>Footings and pile caps</td>
<td>1G52</td>
<td>4.0</td>
<td>1 ½ *</td>
</tr>
<tr>
<td>Abutment stems, wingwalls, cast-in-place wall stems,</td>
<td>3B52</td>
<td>4.0</td>
<td>1 ½ *</td>
</tr>
<tr>
<td>pier columns, and pier caps</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Integral abutment diaphragms and pier continuity</td>
<td>Same mix as used in deck</td>
<td>4.0</td>
<td>1</td>
</tr>
<tr>
<td>diaphragms</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Pretensioned superstructures</td>
<td>1W82 or 3W82</td>
<td>5.0 – 9.0 at final</td>
<td>1</td>
</tr>
<tr>
<td></td>
<td></td>
<td>4.5 – 7.5 at initial</td>
<td></td>
</tr>
<tr>
<td>Cast-in-place and precast box girders</td>
<td>3JM</td>
<td>6.0 or higher</td>
<td>1</td>
</tr>
<tr>
<td>Monolithic decks and slabs</td>
<td>3YHPC-M, 3YLCHPC-M or 3Y42-M</td>
<td>4.0</td>
<td>1</td>
</tr>
<tr>
<td>Decks and slabs that will receive a 2 inch</td>
<td>3YHPC-S, 3YLCHPC-S or 3Y42-S</td>
<td>4.0</td>
<td>1</td>
</tr>
<tr>
<td>concrete wearing course</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Barriers, parapets, medians, and sidewalks</td>
<td>3S52</td>
<td>4.0</td>
<td>1</td>
</tr>
<tr>
<td>Concrete wearing course</td>
<td>3U17A</td>
<td>4.0</td>
<td>5/8</td>
</tr>
<tr>
<td>MSE wall panels, PMBW blocks, and noisewall panels</td>
<td>3Y82</td>
<td>4.0</td>
<td>1</td>
</tr>
<tr>
<td>Precast box culverts, arches, and 3-sided structures</td>
<td>3W82</td>
<td>5.0 or higher</td>
<td>1*</td>
</tr>
</tbody>
</table>

In August 2015:
- Changes to BDM 5.1.1
- Memo to Designers (2015-01)
# Concrete Mix Designations – BDM 5.1.1

## Design Concrete Mix Summary

<table>
<thead>
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<th>Design Compressive Strength (ksi)</th>
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<tr>
<td>Cofferdam seals</td>
<td>1X62</td>
<td>5.0</td>
<td>1</td>
</tr>
<tr>
<td>Cast-in-place concrete piles and spread footing leveling pads</td>
<td>1P62</td>
<td>3.0</td>
<td>2</td>
</tr>
<tr>
<td>Drilled shafts and rock sockets</td>
<td>1X62, 3X62</td>
<td>5.0</td>
<td>1</td>
</tr>
<tr>
<td>Drill sonic pile caps</td>
<td>1G52</td>
<td>4.0</td>
<td>1 ½ *</td>
</tr>
<tr>
<td>Abutment stems, wingwalls, cast-in-place wall stems, pier columns, pier struts, and pier caps</td>
<td>3B52</td>
<td>4.0</td>
<td>1 ½ *</td>
</tr>
<tr>
<td>Integral abutment diaphragms and pier continuity diaphragms</td>
<td>Same mix as used in deck</td>
<td>4.0</td>
<td>1</td>
</tr>
<tr>
<td>Pretensioned superstructures</td>
<td>1W82 or 3W82</td>
<td>5.0 – 9.0 at final 4.5 – 7.5 at initial</td>
<td>1</td>
</tr>
<tr>
<td>Cast-in-place and precast box girders</td>
<td>3JM</td>
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</tr>
<tr>
<td>Monolithic decks and slabs</td>
<td>3YHPC-M, 3YLCHPC-M or 3Y42-M</td>
<td>4.0</td>
<td>1</td>
</tr>
<tr>
<td>Decks and slabs that will receive a 2 inch concrete wearing course</td>
<td>3YHPC-S, 3YLCHPC-S or 3Y42-S</td>
<td>4.0</td>
<td>1</td>
</tr>
<tr>
<td>Barriers, parapets, medians, and sidewalks, moment slabs, and approach panels</td>
<td>3S52</td>
<td>4.0</td>
<td>1</td>
</tr>
<tr>
<td>Concrete wearing course</td>
<td>3U17A</td>
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<tr>
<td>MSE wall panels, PMBW blocks, and noisewall panels</td>
<td>3Y82</td>
<td>4.0</td>
<td>1</td>
</tr>
<tr>
<td>Cast-in-place wall stems</td>
<td>3G52</td>
<td>4.5</td>
<td>1 ½ *</td>
</tr>
<tr>
<td>Precast box culverts, arches, and 3-sided structures</td>
<td>3W82</td>
<td>5.0 or higher</td>
<td>1*</td>
</tr>
</tbody>
</table>

Some changes are needed!
Concrete Mix Designations – BDM 5.1.1

Other things to note:

- Use the compressive strengths given in the BDM table for design and not the values found in MnDOT Spec 2461.

- For concrete box girders, high performance mix (HPC) will be used, but the pay item will be:

  2401.607 STRUCTURAL CONCRETE (STRUCTURAL BOX) CU YD
Major revisions occurred in 2015 interims of AASHTO LRFD Bridge Design Specs:

- New provisions more complex
- Class C splice length dropped, Class A and Class B retained

- Overall effect:
  - Development lengths increased
  - Splice length changes less drastic, with some increases and some decreases
New development length equation in AASHTO LRFD Article 5.11.2.1.1 (2015 interim version):

$$\ell_d = \ell_{db} \left( \lambda_{ri} \times \lambda_{cf} \times \lambda_{lw} \times \lambda_{rc} \times \lambda_{er} \right)$$

$$\ell_{db} = 2.4d_b \frac{f_y}{\sqrt{f'_c}}$$
\[ \lambda_{lw} \] lightweight concrete factor

- Changed from an equation to 1.3

However...

... it did not stay this way for long!
New development length equation (2016 interim version):

\[ \ell_d = \ell_{db} \times \frac{\lambda_{rl} \times \lambda_{cf} \times \lambda_{rc} \times \lambda_{er}}{\lambda} \]

\[ \ell_{db} = 2.4d_b \frac{f_y}{\sqrt{f_c'}} \]
Rebar Development and Splice Lengths
BDM 5.2.2

\( \lambda \) concrete density modification factor found in AASHTO LRFD Article 5.4.2.8
\[ \lambda = 1.0 \text{ for normal weight concrete} \]

\( \lambda_{rl} \) reinforcement location factor

- Changed from 1.4 to 1.3

\( \lambda_{cf} \) coating factor

- For bars with epoxy coating
- No change
Rebar Development and Splice Lengths

BDM 5.2.2

$\lambda_{er}$ excess reinforcement factor
- No change

$\lambda_{rc}$ reinforcement confinement factor
- New factor, adds complexity to the calculation
- Dependent on bar diameter, bar spacing, concrete cover, and transverse reinforcement index $k_{tr}$

\[
0.4 \leq \lambda_{rc} = \frac{d_b}{c_b + k_{tr}} \leq 1.0
\]
• Transverse Reinforcement Index

\[ k_{tr} = \frac{40A_{tr}}{(sn)} \]

- \( n \) = number of bars developed along plane of splitting

- \( s \) = max center-to-center spacing of transverse reinforcement within development length
• For simplicity in developing BDM tables, transverse reinforcement index $k_{tr}$ was set equal to zero.

$$0.4 \leq \lambda_{re} = \frac{d_b}{c_b + k_{tr}} \leq 1.0$$
### Tension Lap Splices for Epoxy Coated Bars with >12” Concrete Cast Below

- $f_r = 60$ ksi
- $f_c' = 4$ ksi

<table>
<thead>
<tr>
<th>Conc. Cover</th>
<th>Bar Size</th>
<th>4”</th>
<th>5”</th>
<th>5 1/2”</th>
<th>6”</th>
<th>6 1/2”</th>
<th>7”</th>
<th>7 1/2”</th>
<th>≥ 8”</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td>Class A</td>
<td>Class B</td>
<td>Class A</td>
<td>Class B</td>
<td>Class A</td>
<td>Class B</td>
<td>Class A</td>
<td>Class B</td>
</tr>
<tr>
<td>2”</td>
<td>3”-1”</td>
<td>4”-0”</td>
<td>3”-1”</td>
<td>4”-0”</td>
<td>3”-1”</td>
<td>4”-0”</td>
<td>3”-1”</td>
<td>4”-0”</td>
<td>3”-1”</td>
</tr>
<tr>
<td>3/4”</td>
<td>5”-2”</td>
<td>6”-9”</td>
<td>5”-1”</td>
<td>6”-7”</td>
<td>5”-1”</td>
<td>6”-7”</td>
<td>5”-1”</td>
<td>6”-7”</td>
<td>5”-1”</td>
</tr>
<tr>
<td></td>
<td>8”-3”</td>
<td>10”-9”</td>
<td>8”-2”</td>
<td>10”-9”</td>
<td>8”-2”</td>
<td>10”-9”</td>
<td>8”-2”</td>
<td>10”-9”</td>
<td>8”-2”</td>
</tr>
<tr>
<td></td>
<td>N/A</td>
<td>N/A</td>
<td>N/A</td>
<td>N/A</td>
<td>N/A</td>
<td>N/A</td>
<td>N/A</td>
<td>N/A</td>
<td>N/A</td>
</tr>
</tbody>
</table>

Note: The highlighted areas indicate the recommended lap splice lengths for different concrete cover depths and bar sizes.
DECKS:

Top Transverse Deck Bars
See LRFD Bridge Design Manual Table 9.2.1.1 or Table 9.2.1.2 for bar size and spacing. A Class A splice is provided where all top transverse bar splices occur between beams, with 50% of the bars spliced at a given location. A Class B splice is provided where 100% of the bars are spliced at a given location between beams or where 50% of the bars are spliced at a given location over beams. Avoid splicing 100% of bars over beams.

<table>
<thead>
<tr>
<th>Concrete Cover to Bar Being Considered</th>
<th>Bar Spacing</th>
<th>Bar Size</th>
<th>All Splices Between Beams and 50% are at Same Location (preferred)</th>
<th>100% of Splices at Same Location Between Beams or 50% of Splices Over Beams at Same Location</th>
</tr>
</thead>
<tbody>
<tr>
<td>3”</td>
<td>&gt; 5”</td>
<td>#4</td>
<td>1'-6”</td>
<td>1'-11”</td>
</tr>
<tr>
<td></td>
<td></td>
<td>#5</td>
<td>1'-10”</td>
<td>2'-5”</td>
</tr>
<tr>
<td></td>
<td></td>
<td>#6</td>
<td>2'-2”</td>
<td>2'-10”</td>
</tr>
<tr>
<td>5”</td>
<td>&gt; 5”</td>
<td>#4</td>
<td>1'-6”</td>
<td>1'-11”</td>
</tr>
<tr>
<td></td>
<td></td>
<td>#5</td>
<td>1'-10”</td>
<td>2'-5”</td>
</tr>
<tr>
<td></td>
<td></td>
<td>#6</td>
<td>2'-9”</td>
<td>3'-7”</td>
</tr>
</tbody>
</table>
• In 1996, Mn/DOT Bridge Design Manual had:

  136 pages

• In 2017, MnDOT LRFD Bridge Design Manual has:

  1154 pages
Modification to HL-93 Double Truck Live Load
BDM 3.4.1

• AASHTO LRFD Art. 3.6.1.3.1
  • For negative moment between points of contraflexure under a uniform load on all spans, and reaction at interior piers only, [apply] 90% of the effect of 2 design trucks spaced a minimum of 50’ between the lead axle of one truck to the rear axle of the other truck, combined with 90% of the effect of the design lane load.
• Originally, MnDOT modified the double truck LL to ensure adequate LF ratings for bridges designed by LRFD.

• Since all new bridges are now rated using the LRFR method, an internal study was completed to ensure that AASHTO HL-93 envelopes the MnDOT standard permit trucks.
• MnDOT LRFD Bridge Design Manual Art. 3.4.1

  • For continuous beam spans, to determine negative moments and reactions at interior piers only:
    • For bridges with longest span ≤ 60 ft, apply 125% (HL-93 double truck with dynamic load allowance plus lane load)
    • For bridges with longest span > 60 ft, apply 110% (HL-93 double truck with dynamic load allowance plus lane load)
    • Do not apply LRFD Art. C3.6.1.3.1 double tandem load

  • For simple spans, to determine reactions at interior piers only:
    • Follow AASHTO LRFD Art. 3.6.1.3.1
Modification to HL-93 Double Truck Live Load
BDM 3.4.1

• For Bridge Repair Projects
  • May analyze using AASHTO LRFD Art. 3.6.1.3.1, but must check for HL-93 and MnDOT standard permit trucks
Strength IV Load Combination – BDM 3.1

Found in AASHTO LRFD Article 3.4.1:

• **Strength IV**: Load combination relating to very high dead load to live load force effect ratios.

  1.5DC

  (was not calibrated)

• Calibration study was done by Modjeski & Masters

• Some past MnDOT projects used a modified Strength IV:

  1.4DC + 1.4LL
Strength IV: Load combination emphasizing dead load force effects in bridge superstructures.

- For MnDOT projects, use a modified Strength IV load combination, given in AASHTO LRFD Article C3.4.1:

  \[ 1.4DC + 1.5DW + 1.45LL \]

- Strength IV only applies to superstructures. It does not apply to investigation of construction stages, substructures, retaining walls, or bearings.
Wood Structures Section – BDM Section 8

• BDM Section 8 entirely updated in May of 2016
  • Includes design examples for:
    • Longitudinal spike laminated deck
    • Timber pile cap
    • Glulam beam superstructure
    • Transverse deck on glulam beams
      • Spike laminated deck
      • Glulam deck
Wood Structures Section – BDM Section 8

• Also includes load rating examples for the superstructure elements:
  • Longitudinal spike laminated deck
  • Glulam beam superstructure
  • Transverse deck on glulam beams
    • Spike laminated deck
  • Glulam deck
• Existing bridges requiring repair raise some questions:
  • Bridge original design was done per *AASHTO Standard Specifications for Highway Bridges*. Should Std Specs or LRFD Specs be used for repairs?
• Bridge original rating was done using Load Factor Rating.

Should LFR or LRFR be used for evaluating existing and repaired condition?
• For MnDOT bridges, use LRFD for design and LRFR for evaluation of existing bridges that need repair.

• Std Specs were last updated in 2002 & contain deficiencies.

• LRFD Specs have been used nationally for 10 years and multiple changes based on latest research have helped make it more mature.
• Does the entire bridge need to be evaluated?
  • For the superstructure, rerating is always required.

• Substructure is typically only rated when significant additional loads will be applied due to the repair or inspections have noted deterioration or damage to the substructure.

**Always** use LRFR!
Design & Evaluation for Bridge Repair Projects
BDM 4.6.2

• Minimum LRFR requirements:
  
  • For superstructures, minimum LRFR inventory rating factor = 0.9

  • For substructures of bridge rehabilitation projects, minimum LRFR inventory rating factor = 1.0
• Minimum LRFR requirements (cont’d):

• For substructures of major bridge preservation projects where bridge currently has permit restrictions, minimum LRFR inventory rating must be $\geq$ superstructure inventory rating.

• For substructures of major bridge preservation projects where bridge does not have current permit restrictions, minimum LRFR inventory rating must be $\geq 1.0$, but need not exceed the superstructure inventory rating.
Design & Evaluation for Bridge Repair Projects  
BDM 4.6.2

• If minimum LRFR requirements cannot be met?
  • Discuss options with Final Design Unit Leader
AASHTO Bridge Design Specifications

• In 1935, AASHTO Standard Specifications for Highway Bridges, 2nd Edition had:
  
  234 pages total
  
  69 pages on design

• In 1996, AASHTO Standard Specifications for Highway Bridges had:
  
  843 pages total
  
  425 on design
• Fast forward to 2016
  • AASHTO LRFD Bridge Design Specifications has:
    
    2150 pages
  
  • AASHTO LRFD Bridge Construction Specifications has:
    
    717 pages
• Stem height
  • Set abutment stem height as short as practical.
  • Preferred abutment stem height on the low side of the bridge is 5 feet, with 3 feet below grade and 2 feet exposure.
• Permissible construction joints - Contractor Option A

NOTES:
① UPPER PORTION OF WINGWALL MAY BE CONCRETE MIX 3852 OR SAME AS DECK CONCRETE, BUT WILL BE PAID FOR AS 3852 CONCRETE.
② DIAPHRAGM TO BE SAME MIX AS DECK CONCRETE AND PAID FOR AS DECK CONCRETE.
③ ABUTMENT STEM AND LOWER PORTION OF WINGWALL TO BE CONCRETE MIX 3852 AND PAID FOR AS 3852 CONCRETE.
④ PERMISSIBLE CONSTRUCTION JOINT WITH KEYWAY, IF UPPER PORTION OF WINGWALL IS PLACED WITH DIAPHRAGM AND DECK.
⑤ PERMISSIBLE CONSTRUCTION JOINT WITH KEYWAY, IF UPPER PORTION OF WINGWALL IS PLACED WITH ABUTMENT.
⑥ 2"-0" X 2'-0" FILLET Extends to Top of Stem.
⑦ MEMBRANE WATERPROOFING SYSTEM IF CONSTRUCTION JOINT IS USED.
⑧ CONSTRUCTION JOINT WITH KEYWAYS BETWEEN BEAMS.
• Permissible construction joints – Contractor Option B

NOTES:

1. UPPER PORTION OF WINGWALL MAY BE CONCRETE MIX 3852 OR SAME AS DECK CONCRETE, BUT WILL BE PAID FOR AS 3852 CONCRETE.
2. DIAPHRAGM TO BE SAME MIX AS DECK CONCRETE AND PAID FOR AS DECK CONCRETE.
3. ABUTMENT STEM AND LOWER PORTION OF WINGWALL TO BE CONCRETE MIX 3852 AND PAID FOR AS 3852 CONCRETE.
4. PERMISSIBLE CONSTRUCTION JOINT WITH KEYWAY, IF UPPER PORTION OF WINGWALL IS PLACED WITH DIAPHRAGM AND DECK.
5. PERMISSIBLE CONSTRUCTION JOINT WITH KEYWAY, IF UPPER PORTION OF WINGWALL IS PLACED WITH ABUTMENT.
6. 2"-0" x 2"-0" FILLET EXTENDS TO TOP OF STEM.
7. MEMBRANE WATERPROOFING SYSTEM IF CONSTRUCTION JOINT IS USED.
8. CONSTRUCTION JOINT WITH KEYWAYS BETWEEN BEAMS.
Integral Abutments BDM 11.6.2

Contractor Option A

Contractor Option B

5/17/2017 Bridge Office | mndot.gov/bridge
• Draft Standard Plan Notes sent out in January 2016

• Numerous changes

plan notes 5-1-2017.docx
Clarifying changes were made to the guidance on revised sheets. New guidance is as follows:

1) Make the necessary revisions

2) Add a revision block that includes the revision number within a triangle border, the revision date, a description of the revision, and the initials of the engineer who approved the revision.
Revised Plan Sheets – BDM 2.4.3
# Revised Plan Sheets – BDM 2.4.3

<table>
<thead>
<tr>
<th>REV. NO.</th>
<th>DATE</th>
<th>REVISION DESCRIPTION</th>
<th>APPROVED</th>
</tr>
</thead>
<tbody>
<tr>
<td>2</td>
<td>4/16/14</td>
<td>REVISED BEAM END EXTENSION AT ABUTMENTS.</td>
<td>J.P.E.</td>
</tr>
<tr>
<td>1</td>
<td>3/10/14</td>
<td>REVISED CIRCLE NOTE 1, ADDED ABUTMENT LABELS.</td>
<td>J.P.E.</td>
</tr>
</tbody>
</table>
• New guidance (continued):

3) “Cloud” the actual revisions to the sheet and include the revision number within a triangle border next to the “clouded” change. When sheets have been revised multiple times, remove previous revision “clouds”, only “clouding” the current revisions. However, leave previous triangles with their revision numbers in place.
Revised Plan Sheets – BDM 2.4.3
• New guidance (continued):

4) Change the sheet number by placing a “-R” and the revision number after the original sheet number. For example, revision 1 to sheet 7 will be designated “SHEET NO. 7-R1”, revision 2 will be designated “SHEET NO. 7-R2”, etc.
Revised Plan Sheets – BDM 2.4.3
New guidance (continued):

5) For situations where an additional plan sheet must be inserted as part of the revision, repeat the preceding sheet number with an “A” after it. For example, as part of revision 1 where a sheet needs to be added between sheet 5 and 6, designate the revised sheet as “SHEET NO. 5A-R1”.
Other BDM Changes

Published:

- Single Slope Barrier (Memo to Designers)
- Deck Overhang Design (Memo to Designers)
Other BDM Changes

Future:

- Section 2 – geometrics, pay items, modifying standards, etc.
- Prestressed beam charts (Type S barrier)
- Section 14 – Bridge Joints and Bearings
- Section 13 – Bridge Railings
- Adhesive anchors
- Section 9 - Decks
- Remove Section 15 on Load Rating (when New Bridge Load Rating Manual is complete)
Thank you!

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