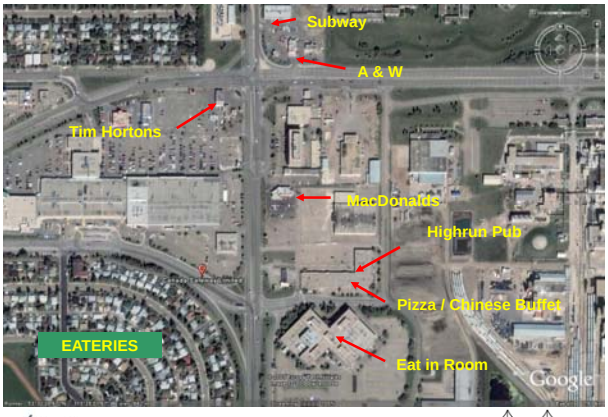
Welcome

Class A Bridge Inspection Course
Twin Atria, Edmonton, AB
October 3 - 7, 2016

General Information

- First Aid
- Fire Extinguisher
- Room Access
  - Opens at 7:30 am everyday
  - Locked at 5:00 pm everyday
  - Open at lunch
  - Washrooms
- Smoking
  - No smoking in building or field trip vehicles
  - Smoking allowed outside at ashtray locations



General Information Cont'd

- Field Trip on Thursday and Friday
  - Hard Hat, Traffic Vest, Hip Waders, Boots
  - Clip board, flashlight, hammer, tape measure
  - Transportation provided from Twin Atria
- Course Evaluation sheet must be filled in at end of course
- Questions allowed at anytime, or before lunch and at end of day

Self Introduction

- Name
- Organization
- Bridge Experience – Type and Years
- Present or Proposed Involvement with Bridges and Bridge Inspections

Quizzes

- Exams are Tuesday, Wednesday and Thursday mornings.
- Pass mark is 70%
- Marks posted daily
- If you have objections to posting marks contact lead instructor privately

Courtesies

- No cell phone or text messaging activities.
- No talking during exams – leave room and talk in hall once exam is completed.
- No cheating or peeking at other peoples exams.

Course Objective

- Learn Class A and B differences
- Detailed Concrete inspection
- Detailed Steel inspection – steel girders and trusses
- Learn inspection techniques
- Learn advanced terminology
- Learn details of inspecting major bridges

INSPECTION POLICIES AND, PROCEDURES

CLASS A CERTIFICATION REQUIREMNTS

Inspector's Role and Responsibilities

- Identify safety related deficiencies.
- Take appropriate action.
- Perform a thorough inspection.
- Accurately determine the condition of the bridge components.
- Rate the bridge elements in accordance with established criteria (BIM Manual).
- Identify deficiencies and recommend appropriate and timely maintenance.

Inspector's Role and Responsibilities

- Properly document required items on the appropriate inspection form.
- Provide additional documentation to back up ratings and maintenance recommendations.
- Verify, update or collect necessary inventory information.

Cl. A Inspector Skills

- Able to recognize safety related deficiencies.
- Be decisive in taking appropriate action.
- Accurately determine the condition of bridge components.
- Thorough and complete understanding of the rating system.
- Know the appropriate ratings for the full range of conditions encountered.
- Able to recognize maintenance requirements and make appropriate maintenance recommendations.
- Good written communication skills to produce a high quality inspection report.

Class of Inspectors

Inspectors are classified as Class A or Class B and are certified to carry out inspections of bridge structures on public roads as follows:

Class A

- Qualified to perform a Level 1 inspection on all major bridges, standard bridges and culverts (all structure types).
- Class B certification is a pre-requisite for Class A

Class B

- Qualified to perform a Level 1 inspection on standard bridges and culverts only.

Class A Certification Requirements

- Civil Engineering Degree
- or Civil Engineering Technical Diploma
- or equivalent combination of education and experience that is acceptable to Alberta Transportation.

Certification process is **4** Stages:

Stage 1:

- Current Class B Certification and completed minimum of 75 inspections.
- Successful completion of Alberta Transportation Class A BIM Training Course (5 day course – 70% average score required).

Class A Certification Requirements

Stage 2 – Mentorship Program:

•Successful completion of mentorship program.

•Mentor is Class A with minimum 6 years of certification, and approved by AT.

•Complete min. 45 training sites under guidance of mentor.

•Begin program by inspecting 10 different structure types together with mentor (these 10 can count toward total if complete inspections are done).

•Mentor reviews and recommends training sites.

•Minimum 60% of the 45 sites must have a maximum structural condition rating of 45% and Superstructure must be accessible.

•Variety of structure types

Class A Certification Requirements

Stage 2 – Mentorship Program – continued:

•Letter of Recommendation from mentor.

•Provide pdf copies of training inspections with mentor comments and other communication and feedback during mentoring program.

•Summary spreadsheet.

Stage 3:

•Certification exam (min. 75% score required)

Stage 4:

•Test inspections at 3 sites – completed in 1 day and using blank forms.

•Sites previously benchmarked by AT representative and reviewed for acceptability by AT

Class A Certification Requirements

Stage 4 - continued:

•Stage 3 and 4 can be done in reverse order

•If failure of any stage of process then:

➢one chance to redo that stage.

➢Two failures of any stage requires process to be re-started at Stage 1.

•Certification after all 4 stages have been successfully completed and with approval from Director of Bridge Engineering.

•Certification is valid until next certification renewal date – normally 3 years

Class A Re-Certification Process

- Active involvement in BIM and acceptable performance
- In order to be re-certified, inspectors must meet one of the following criteria:

1) Performed minimum average rate of 2 BIM inspections per month during previous 3 year period (50% must be major bridges) - or –
2) Performed a min average rate of 1 BIM inspection per month during previous 3 year period (50% must be major bridges) and have been active in management, design, or construction of bridges - or
3) Acted as reviewer for min average rate of 2.5 inspections per month during previous 3 years – or
4) Acted as AT reviewer for min average rate of 5 inspections per month during previous 3 years and have been active in management, design, or construction of bridges .

Class A Re-Certification Process

- Inspector status is reviewed by AT every 3 years
- Decision on re-certification is made by AT with assistance from Regional bridge staff as required
- Inspectors meeting requirements will be re-certified and notified by AT
- Inspectors not meeting requirements will be asked if they intend to maintain certification. If so, a 3 member AT panel will review inspector's status and make recommendation to Director of Bridge Eng.
- Panel may develop a plan for inspector – typically writing re-certification exam and 5 test sites.
- Following is the link to the Certification and Re-Certification Process for bridge inspectors:

http://www.transportation.alberta.ca/4827.htm

Levels of Inspection

- Most bridge structures can be visually inspected by a qualified inspector on a routine basis. (Level 1)
- Some structures or their components will require a specialized inspection (Level 1.5 or 2) to:
  - accurately determine their condition
  - gather additional information
  - access components that are not fully accessible during routine Level 1 inspections

Levels of Inspection

Level 1 Inspection

- A general inspection
- Primarily visual
- Requires completion of the Level 1 BIM inspection report
- Use of basic tools and equipment

Level 1.5 Inspection

- Level 1 inspection but within arms reach of all bridge elements using manlift or snooper

Levels of Inspection

Level 2 Inspection

- In-depth inspection.
- Completion of the appropriate Level 2 inspection report.
- Use of specialized knowledge, equipment or procedures

- All levels of inspections must be performed by a certified inspector.
- Level 1 inspections must be done at the minimum frequency specified by policy.
- Level 1.5 and Level 2 inspections are performed on a prescribed cycle or an as required basis.

Inspection Frequency

A Level 1 inspection must be performed on all bridge structures on a cycle not exceeding:

•All structures located on roadways designated as Level 1 or Level 2 in accordance with the Provincial Highway Service Classification – every 21 months.

•All structures located on roadways designated as Level 3 or Level 4 in accordance with the Provincial Highway Service Classification – every 39 months.

•Major bridges on local roads - 39 months.

•Standard bridges and culverts on local roads - 57 months.

•All new structures – as part of final construction completion.

•After significant maintenance or rehabilitation.

•Frequencies are intended to provide the benefit of inspecting during different seasonal conditions.

Inspection Frequency

- In special circumstances (e.g. park roads with summer access only) Department may modify frequency.
- A shorter cycle may be appropriate depending on:
  - age of the structure.
  - traffic characteristics.
  - known deficiencies.
  - inaccessibility of a component or element.
- If a shorter cycle is necessary make recommendation in "Special Comments For Next Inspection" box.
- Reviewer will flag and notify AT if in agreement
- AT will change inspection cycle if in final agreement
- A date beyond the next standard cycle date will not be accepted by the system.
- Refer to BIM Advisory Bulletin #2 – January 8, 2015 for more information:

http://www.transportation.alberta.ca/Content/docType30/Production/BIM_Advisory_Bulletin_1-2012.pdf

Training of Inspectors

- Technical Standards Branch manages the delivery of the BIM Class A Bridge Inspection Course
- Regions responsible for field training of Department Staff
- Non Department staff are responsible to arrange for field training/mentoring after completing 5 day BIM Class A Bridge Inspection Course by engaging appropriate mentor (Stage 2 Mentorship program described earlier)

Responsibility for Inspection
Technical Standards Branch

- Develop and manage the BIM System.
- Develop and monitor standards, policies and procedures.
- Perform audit inspections with assistance from Regions as required
- Provide technical support to Regions.
- Maintain and oversee updating of inventory databases.

Responsibility for Inspection
Regions

- Manage inspection programs for Provincial Roads and major bridges on Local Roads through BIM inspection consultant.
- Carry out ad hoc inspections.
- Arrange for specialized inspections by others.
- Review and accept Inventory updates
- Review and accept inspection reports
- Initiate appropriate action where deficiencies are identified.
- Provide technical support to Local Road Authorities as resources permit.

Responsibility for Inspection
Local Road Authorities

- Manage BIM inspection program for Standard bridges and Culverts on local roads.
- Control and manage all bridge structures in their jurisdictions.
- Monitor all bridge structures as required.
- Report hazardous or structural element concerns (rated 2 or less) to Bridge Manager.
- Perform maintenance.

Responsibility for Inspection
All Inspectors

Inspectors must follow established guidelines that define reporting procedures to ensure that:

- Proper action is initiated when safety related concerns are identified.
- Information is reported in a systematic and organized manner.
- Proper expertise is applied to inspection and maintenance.
- Follow-up is done for maintenance recommendations.

Responsibility for Inspection
All Inspectors

- Use the appropriate BIM report for inspections.
- Carry blank forms for possible structure changes
- Assign ratings according to BIM system
- Provide ratings that are consistent with explanations and supporting documentation
- Gather sufficient information and data to initiate structure change when encountered
- Verify or revise inventory data on the inspection form
- Provide missing inventory data.

Responsibility for Inspection
All Inspectors

- Condition ratings of 4 or less the inspector must
  - provide an explanation of condition.
- Condition ratings of 3 or less the inspector must
  - make appropriate recommendation for maintenance or monitoring .
  - supplement with photos - also sketches, measurements if needed.
  - consider decreasing the next inspection date.
- Hazardous conditions or structural load carrying elements rated 2 or less must be reported immediately to the Bridge Manager (and LRA if on local road).
- Rating of 1 on an element critical to the safe operation of the bridge, take immediate steps to close or restrict traffic on the structure and appropriate notification.
- Report any deficient signage to the appropriate road authority as soon as possible.

Responsibility for Inspection
All Inspectors

- Send completed inspection forms with all supporting documentation to Department's BIM consultant for review and entry of inventory updates and inspection data into BIS
- Inspection reports will be returned to the inspector if requirements are not met
- Inspector must revise report and resubmit to the BIM consultant
- Inspector should contact the BIM consultant or the Bridge Manager if there are concerns or questions about the review process

Questions??

Bridge Failures in Alberta

Introduction

- Bridges are inspected for three primary reasons
  - safety of bridge system
  - maintenance of bridges
  - management of bridge system
- Inventory or management of the system can be just as important as safety and maintenance

Need to Know

- Which bridges are:
  - substandard and not adequate to carry full legal loads
  - susceptible to flooding
  - high priority for replacement

Causes of Failure

- 70% of failures are caused by factors related to water flow
  - scouring of piers
  - undermining of the support elements
- Structural failure
  - element failure due to excess load or material deterioration
- Lack of knowledge or good judgment
  - Operation
  - Construction
  - design

Contributing Factors

- Structural engineering is a science
  - applied truckloads are known
  - material behavior is known and can be accurately predicted
  - everything can be accurately calculated and predicted
- River engineering is more of an art
  - the effects of a flood cannot simply be calculated
  - the effects of Mother Nature are not easily predicted
  - the velocity and angle of flow, the duration of flooding, etc.

Bear Creek on 84 Ave in Grande Prairie

- SPCSP HE 5.5 x9m
- Installed in 1973
- Total collapse of structure in 1988
- No inspection after installation

Bear Creek on 84 Ave in Grande Prairie

Structure on 84 Avenue in Grande Prairie

Bear Creek on 84 Ave in Grande Prairie

Total collapse of culvert. Only headwall intact

Bear Creek on 84 Ave in Grande Prairie

Inside of collapsed culvert

Bear Creek on 84 Ave in Grande Prairie

Outlet of culvert

Bear Creek on 84 Ave in Grande Prairie

Backfill characteristics

Bear Creek on 84 Ave in Grande Prairie

Water and sewer line in embankment

Beaver Ranch Creek on Hwy 58 East of Vermilion

- SPCSP HE 4.8 x 7.3
- Installed in fall of 1987
- Extensive deformation in 1988
- Total collapse in 1989 while fill being removed for repair of culvert

Beaver Ranch Creek on Hwy 58 East of Vermilion

Outlet showing intact end treatment

Beaver Ranch Creek on Hwy 58 East of Vermilion

Inlet with culvert still connected to headwall

Beaver Ranch Creek on Hwy 58 East of Vermilion

Overview of culvert inlet

Weed Creek on Highway 39 Near Thorsby

- Arch culvert
- Constructed in 1960
- Washed out July 3rd, 1990.

Weed Creek on Hwy 39 Near Thorsby

Concrete arch culvert in 1989

Weed Creek on Hwy 39 Near Thorsby

Water on U/S end up to shoulder of road

Weed Creek on Hwy 39 Near Thorsby

Hole in side slope on d/s side

Weed Creek on Hwy 39 Near Thorsby

Water now coming out of d/s fill

Weed Creek on Hwy 39 Near Thorsby

Road gone

Weed Creek on Hwy 39 Near Thorsby

Upstream inlet

Weed Creek on Hwy 39 Near Thorsby

d/s outlet

Weed Creek on Hwy 39 Near Thorsby

Centre section of culvert

Weed Creek on Hwy 39 Near Thorsby

Erecting 8.5 m SPCSP

Weed Creek on Hwy 39 Near Thorsby

u/s inlet of new culvert

BF 77496 – Hwy. 40 over Lineham Creek in Kananaskis

- 4.3M diameter Structural Plate Ellipse (SPE) culvert installed in 1983.
- 53M invert length.
- 9.1M road to streambed height.
- Washed out during 2013 flood event.

BF 77496 – Looking D/S at scale of washout (30m wide vs. 4.3M pipe).

BF 77496 – Drift blockage across inlet and heaved barrel.

BF 77496 – Inlet blockage and barrel heave

BF 77496 – Outlet and barrel floor folded and heaved nearly to roof

BF 77496 – Replaced in 2015 with new 8-14-8 M SLW girder bridge

Red Willow River on Local Road near Rio Grande

- 150' through truss built in 1927
- Bridge posted for 17 tons
- Bridge collapsed 1977
- Failure of rotten abutment corbel

Red Willow River on Local Road near Rio Grande

Collapsed bridge

Red Willow River on Local Road near Rio Grande

Abutment end of bridge showing timber deck etc.

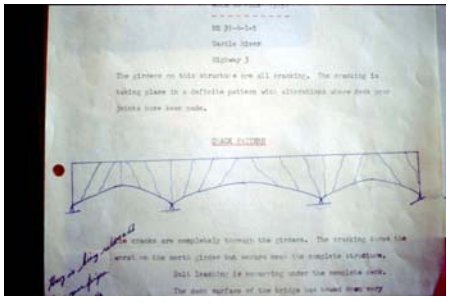
Red Willow River on Local Road near Rio Grande

Abutment end of truss dropped and buckled the bottom chord

Castle River Bridge on Local Road West of Pincher Creek

- built in 1951 designed by consultant in Toronto
- Concrete T girder poor condition in 1961
- replaced in 1981

Castle River Bridge on Local Road West of Pincher Creek



Recorded crack pattern in 1964

Castle River Bridge on Local Road West of Pincher Creek

Bridge condition in 1979 (28 years old)

Castle River Bridge on Local Road West of Pincher Creek

Shear crack in girder and efflorescence from cracks

Castle River Bridge on Local Road West of Pincher Creek

Shear crack at girder end

Castle River Bridge on Local Road West of Pincher Creek

Removing bridge in August 1980

Castle River Bridge on Local Road West of Pincher Creek

Bridge down

Castle River Bridge on Local Road West of Pincher Creek

Bridge remains

Simonette River Bridge on Forestry Trunk Road (South of Debolt)

- Timber and Bailey built in 1960 deck to s/b 3m
- 1982, 2 through trusses 60.96m 9m deck to s/b
- Washed out in 1987 (Tornado Flood)
- Rebuilt in 1988

Simonette River Bridge on Forestry Trunk Road (South of Debolt)

Forestry bridge built in 1960, 380 ft. long bridge

Simonette River Bridge on Forestry Trunk Road (South of Debolt)

Forestry Double Bailey, chord reinforced 2 @ 100 ft.

Simonette River Bridge on Forestry Trunk Road (South of Debolt)

Bridge built in 1982, 122m bridge

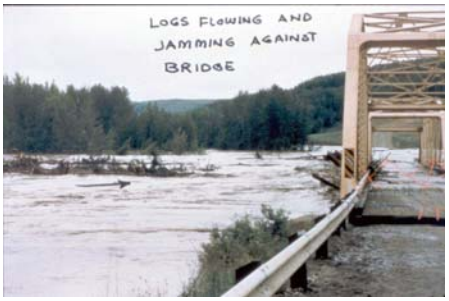
Simonette River Bridge on Forestry Trunk Road (South of Debolt)

Forestry road with river in flood, 1987

Simonette River Bridge on Forestry Trunk Road (South of Debolt)

Truss partly under water

Simonette River Bridge on Forestry Trunk Road (South of Debolt)



Drift jamming under bridge

Simonette River Bridge on Forestry Trunk Road (South of Debolt)

Bridge floating and starting to shift

Simonette River Bridge on Forestry Trunk Road (South of Debolt)

Bridge starting to move laterally

Simonette River Bridge on Forestry Trunk Road (South of Debolt)

Bridge floating downstream

Simonette River Bridge on Forestry Trunk Road (South of Debolt)

One span tipped in middle channel and other one around near shore

Simonette River Bridge on Forestry Trunk Road (South of Debolt)

Bridge gone

Simonette River Bridge on Forestry Trunk Road (South of Debolt)

New bridge

Beaverhill Creek on Local Road North of Lamont

- 3-28' Precast Concrete
- Constructed in 1959
- North pier cap failure in August 1980

Beaverhill Creek on Local Road North of Lamont

Local road with gravel truck pup remaining on bridge

Beaverhill Creek on Local Road North of Lamont

Pup tandem axle in hole left by dropped girder

Beaverhill Creek on Local Road North of Lamont

Sheared timber cap. One girder hung up on pile.

Beaverhill Creek on Local Road North of Lamont

Failed pier cap

Beaverhill Creek on Local Road North of Lamont

Failed pier cap with girder dropped to pile top level

Beaverhill Creek on Local Road North of Lamont

Bottom of cap with piles punching (North pier)

Little Smoky Bridge on SH 744

- Constructed in 1954
- 150 span failed in 1980 by cat and blade on high boy

Little Smoky Bridge on SH 744

Severed batter post U7 - L8

Little Smoky Bridge on SH 744

Broken hanger U7 - L7 and first diagonal U7 - L6

Little Smoky Bridge on SH 744

Members L6 - U5 and U5 - L5 buckled

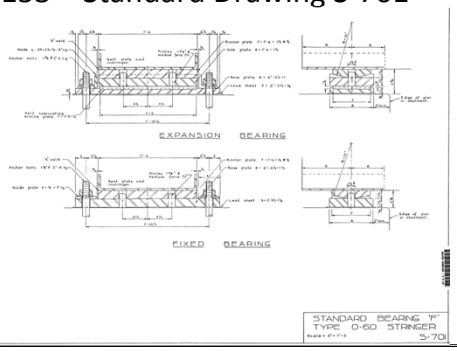
Little Smoky Bridge on SH 744

Inside of truss, sagged 2’-0 leaning 10”

BF 1153 – Hwy. 22 over Oldman River near Lundbreck

- 3 span Type PO girders on concrete substructure -built 1959.
- Span lengths of 20.7 – 29 – 29 M.
- Typ. Sliding Plate Bearing with Self-Lubricating Bronze Plates.
- Expansion Bearings at P1 and P3. Deck height is 18.5M.
- Routine Level 1 BIM inspection of December 2015 noted frozen bearings at the west end of P1 under Span 1 - G1 and G2.
- Significant portion of concrete pier cap under G1, G2 bearings had failed due to induced stresses into pier from frozen bearings resulting in G1 un-supported and near collapse.
- Lane above immediately closed and truck traffic detoured.
- Subsequent BIM Advisory bulletin #3 issued January 20, 2016.

BF 1153 – Standard Drawing S-701



BF 1153 – Failed concrete at west end of P1 from frozen bearings under G1, G2.

BF 1153 – Failed pier concrete and un-supported bearing under Sp. 1-G1.

BF 1153 – 30mm drop in rail and curb over Sp.1-G1.

Questions??

Steel - Properties

History of Steel

Cast Iron

- Cast iron preceded wrought iron.
- It is brittle, has high carbon content with low tensile strength.
- It has excellent casting properties.
- It was mainly used to carry axial compression loads.

Wrough Iron

- It replaced cast iron, because of good tensile strength properties.

History of Steel

Steel

- Steel gradually replaced wrought iron until about 1890.
- Steel in commercial quantities is just over 100 years
- The chemistry of steel was not controlled until about 1960
- Strength and elongation were guaranteed but not the chemistry
- This was satisfactory for riveted structures but not for welded details

History of Steel

Steel

- Welding was first introduced in bridges in about 1936.
- During the World War, US produced a large number of welded cargo vessels.
- Many of these ships broke apart due to brittle fracture of steel adjacent to the welds.
- Welding contributes to brittle fracture because of introduction of severe cooling rates in the steel adjacent to the weld HAZ (Heat Affected Zone).

History of Steel

Failure of Steel Structures

- The St. Maurice Bridge at Quebec failed in January 1951. It was four years old.
- Byte Bend Bridge in Sacramento, California, failed in 1970 during construction.
- The Freemont Bridge in Portland, Oregon, had a failure in truss joint in 1971.
- In St. Paul, Minnesota, a girder in the Lafayette Street Bridge failed in 1975.

Iron

- Iron in the pure form is a soft, shiny metal like aluminum.
- However, it is never found in this state.
- Iron oxidizes extremely easily.
- In nature it is always found as an oxide.

What is Steel?

Alloy

- Metal prepared by adding other metals or non-metals to secure desirable properties.

Steel

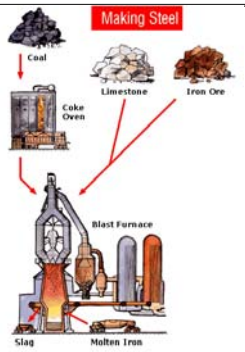
- It is an alloy of iron, carbon and other trace elements.

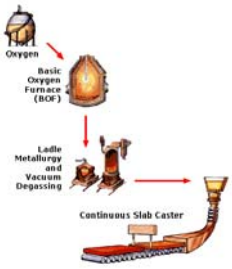
Steel Making Process

- Iron ore, coke and limestone are major raw materials.
- Coke is obtained by distilling coal.
- Raw material is charged into Blast furnace which has a temperature of 1600° C.
- Iron melts at the bottom.
- Solidified iron is called “Pig Iron”

Steel Making Process

- Molten metal from Blast furnace is taken into Basic Oxygen furnace
- Chemical analysis of the molten material is done
- Steel semis, billets are heated to 1200°C for rolling and finished products.





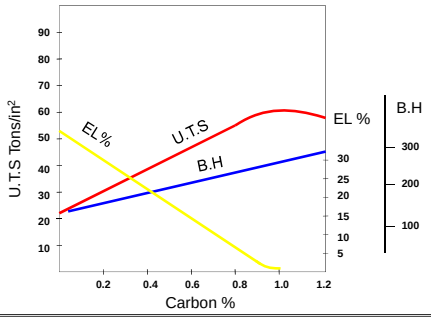
Effects of Carbon

- Increased carbon in steel:
  - Increases strength
  - Increases hardness
  - Increases hardenability
  - Reduces ductility
  - Reduces toughness
  - Reduces machinability

Effects of Carbon

% Carbon	Yield Strength (ksi)	% Elongation	Comments
4.0			Grey cast iron
2.5			White cast
1.1 to 1.7	90 – 100	0	Very high carbon steel
0.9 to 1.1	110 – 118	0	High carbon steel
0.7 to 0.9	94 – 118	8 – 14	Spring steel
0.55 to 0.7	75 – 94	14 – 19	Higher carbon steel
0.3 to 0.55	65 – 75	19 – 24	Medium carbon steel, weldable with care
0.15 to 0.3	48 – 65	24 – 28	Mild steel for bridges
0.05 to 0.15	40 - 48	28 - 34	Very mild steel, pure iron

Effects of Carbon



Effects of Other Alloying Elements

1. Sulphur:
   - Higher sulphur causes porosity and hot cracking in welding
   - Can cause brittleness in hot metal
   - Increases hardenability
   - It is not desirable and is kept as low as possible
   - Its ill effects are reduced by adding other alloying elements such as manganese.

Effects of Other Alloying Elements

2. Phosphorus
   - Like sulphur it is not desirable and is kept as low as possible
   - It increases strength and hardenability.
   - It reduces ductility and weldability.

3. Manganese
   - It is added to counteract the ill effects of sulphur
   - Increases strength, hardenability and notch toughness
   - It reduces weldability

Effects of Other Alloying Elements

4. Silicon:
   - It is used as de-oxidizer in steel making and produces fine grained steel.
   - 0.15 to 0.50 range is desirable and is known as “killed steel”.
   - It increases strength and hardenability.

Effects of Other Alloying Elements

5. Aluminum
6. Chromium
7. Copper
8. Columbium
9. Molybdenum
10. Nickel
11. Tungsten
12. Vanadium

Basic Metallurgy

Grains

- The crystals of metals are referred to as grains.
- The smallest grain of a metal contains a large number of atoms.

Space-lattice

- All grains are composed of atoms bound together in a definite pattern or structure. This atomic structure is called space-lattice.

Basic Metallurgy

Structure of a Metal

The characteristics of the structure of a metal are due to:

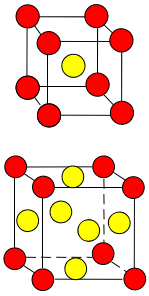
- The atoms making up the metal.
- The manner in which the atoms are arranged.

Space-lattice Types

There are 14 possible space lattice types.

- The body centered cubic has 9 atoms.
- The face centered cubic has 14 atoms.

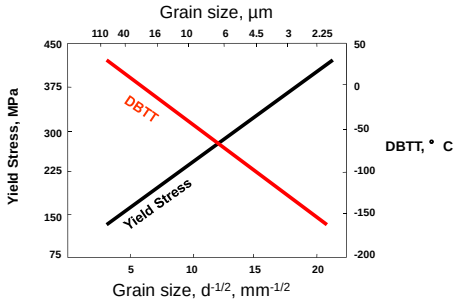
Space-Lattice Types



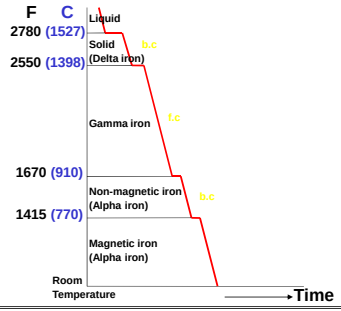
Body Centred

Face Centred

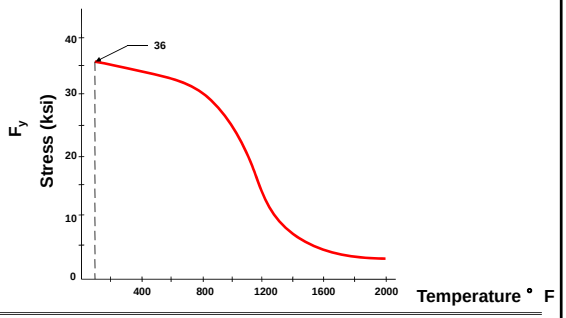
Grain Size



Cooling Molten Iron



Temp. Effect on Yield Stress



Definitions

Annealing:

Heating and holding at a suitable temperature and then cooling at a suitable rate. For such purposes as reducing hardness, improving machinability, facilitating cold working, producing a desired microstructure, or obtaining desired mechanical, physical, or other properties.

Hardenability:

Steel property which describes the depth to which the steel may be hardened during quenching.

Definitions

Hardness:

A measure of a material's resistance to localized plastic deformation.

Heat Treatment:

The way to produce particular microstructures and properties in steel by heating and cooling.

Killed Steel:

Steel deoxidized with a strong deoxidizing agent, such as silicon or aluminum, to reduce the oxygen content to such a level that no reaction occurs between carbon and oxygen during solidification.

Definitions

Normalizing:

In this process, the steel is heated to about 100 F above the transformation range, held there only briefly and then cooled in still air. This process refines the grain.

Quenching:

In heat treatment, the step of cooling metals rapidly in order to obtain desired properties.

Definitions

Stress Relieving:

Heating to a suitable temperature, holding long enough to reduce residual stresses and then cooling slowly to minimize the development of new residual stresses.

Tempering:

It is the process at which hardened steel is reheated at some point below the transformation range and cooled in air or water.

Definitions

Toughness:

An indication of steel's capacity to carry load and absorb energy, particularly in the presence of a notch or a crack.

Transformation Temperature:

The temperature at which a metal, when cooled, changes from one type of structure to another.

Physical Properties

- Strength
  - Compression
  - Tension
  - Fatigue
- Ductility
- Weldability
- Fire Resistant
- Corrosion Resistant
- Notch toughness
- Machinability
- Formability

Tensile Stress – Strain Curves

Elastic Range

Stress is proportional to strain. In this range there is no permanent deformation.

Plastic Range

In this strain increases without the appreciable increase of stress.

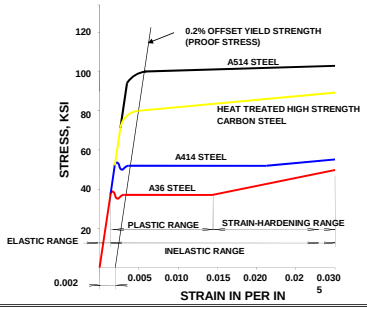
Strain Hardening Range

In this strain increase is accompanied with increase in stress.

Proof Stress

Stress required to cause a specified small , permanent extension.

Tensile Stress – Strain Curves



Charpy Test

Charpy Test

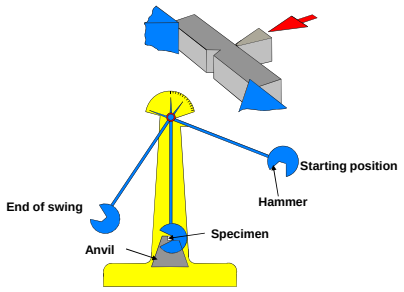
Charpy test is used to determine metal toughness (i.e. impact strength).

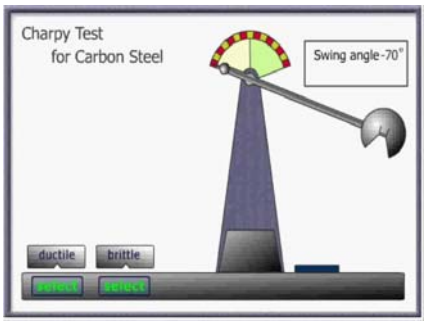
Impact Energy

It is the work done to fracture the specimen as measured by the Charpy test.

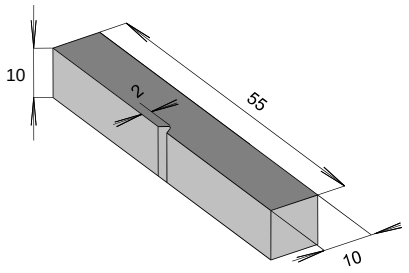
Impact energy = Elastic strain energy + Plastic work during yielding + Work done to create fracture.

Charpy Test





Charpy Test Specimen



Charpy Test

Charpy Test

Charpy Test

Factors Affecting Fracture Behavior

- Impact load
- Sub zero temperature range
- Notch

Common Steel Shapes

- Wires
- Cables
- Steel Plates
- Steel Bars
- Rolled Beams
- Built-up Shapes

Types of Steels

Steel Designation	Yield Strength (ksi)	Comments
OH Steel	26	Used until about 1905
EIC Steel	30	Used until about 1935
A7	33	Used until about 1960
A36	36	1960 to Present. (First steel with guaranteed chemistry)
G40.8 (A35)	40	Normalized and used by Alberta up-to 1968
G40.12 (A572)	44	Normalized and used by Alberta up-to 1968
A441	50	Normalized and used by Alberta up-to 1968

Current CSA G40.21 Steels

	Nominal yield strength, MPa							
Type	260	300	350	380	400	480	550	700
	Grade							
W	260W	300W	350W	380W*	400W	480W	550W	-
WT	260WT	300WT	350WT	380W T**	400WT	480WT	550WT	-
R	-	-	350R	-	-	-	-	-
A	-	-	350A	-	400A	480A	550A	-
AT	-	-	*350AT*	-	400AT	480AT	550AT	-
Q	-	-	-	-	-	-	-	700Q
QT	-	-	-	-	-	-	-	700QT

CSA Charpy Impact Requirements

Standard Charpy impact test temperature for specified category

Category	Standard test temperature °C
1	0
2	-20
3	*-30*
4	-45
5	To be specified by purchaser

CSA Charpy Impact Requirements

Standard Charpy impact energy for specified grade

Grade	Absorbed Energy (Joules)
260WT	20
300WT	20
350WT	27
400WT	27
480WT	27
350AT	*27*
400AT	27
480AT	27
700QT	34

What are the three most important properties for plate steel?

- Strength?
- Cost?
- Corrosion Resistant?
- Notch toughness?
- Machinability?
- Formability?
- Weldability?

Strength

✓***Yes*** **- for structural applications strength is a very important property, a bridge member must support a given load without yielding.**

Cost

✗***No*** **- Cost is always an issue with design and materials selection. In this case cost will need to be considered but is the fourth choice as there are other properties that are more critical.**

Corrosion Resistant

✗ ***No*** **- It is very important but is simply dealt with by painting. Also, the components can generally be checked visually for signs of corrosion and repairs made when appropriate.**

Notch Toughness

✓ ***Yes*** **- toughness is one of the top three properties to consider because we must guarantee structural components against sudden catastrophic failure.**

Machinability

✗ ***No*** **- This is not a very important property in this case because the steels are rolled to plate, flame cut and dressed to final size, then welded together.**

Formability

✗ ***No*** **- It is important that the steel can be rolled to produce plates, however little subsequent forming is required meaning that extremely good formability is not required.**

Weldability

✓*Yes* - **this is an extremely important property as ships, oil rigs, and bridge girders are constructed from a number of steel plates that are welded together to form the final product.**

Questions??

Concrete Physical & Mechanical Properties

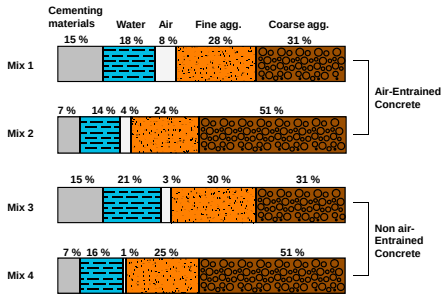
Introduction

- Composition.
- Physical Properties.
- Mechanical Properties.
- Defects & Deterioration.

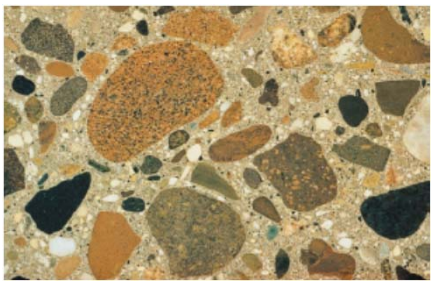
Composition

- Portland Cement.
- Aggregate.
- Mixing Water.
- Entrapped Air.
- Admixtures.
- Supplementary Cementing Materials.

Proportions of Materials in Concrete



Cross-section of Concrete



Portland Cement

- It was invented in 18th century and called Portland cement.
- Chemical compound which reacts with water to form a stone like mass (hydration).

Portland Cement

- 73% Limestone
- 23% Clay
- 2% Iron
- 3% Sand

Cement Manufacture

Cement Manufacture

Types of Cement

- Type "GU" – General use.
- Type "HE" – High early strength.
- Type "MS" – Moderate sulfate resistance.
- Type "HS" – High sulfate resistance.
- Type "MH" – Moderate heat of hydration.
- Type "LH" – Low heat of hydration.

Water

Water

- Impurities cause:
  - ➢abnormal set
  - ➢decreased strength
  - ➢volume change
  - ➢efflorescence
  - ➢corrosion of reinforcement

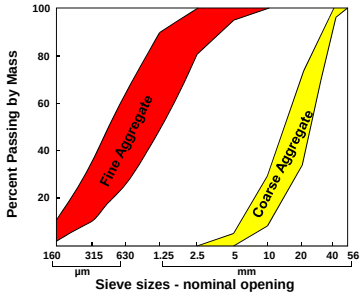
Aggregate

Aggregate

Characteristics of Aggregate

- Clean & sound.
- Abrasion resistance
- Freeze & thaw resistance
- Wetting & drying properties
- Chemical stability
- Alkali aggregate reactivity
- Shape and surface texture
- Aggregate grading

Grading Limits



Fineness Modulus

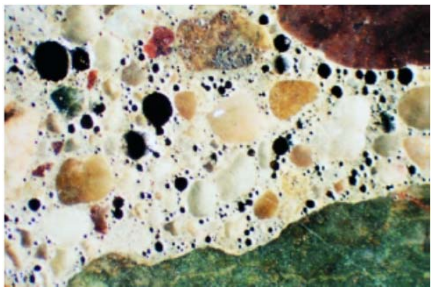
Sieve Size	Percentage Retained by Mass
10 mm	0
5 mm	2
2.5 mm	15
1.25 mm	35
630 µm	55
315 µm	79
160 µm	97
Total	283

Fineness Modulus = 283/100 = 2.83

Air-Entrained Concrete

- Freeze-thaw resistance
- Improves workability
- Finishes sooner
- Reduces water
- Reduces segregation and bleeding
- Improves sulfate resistance
- Entrained air 5% to 8%

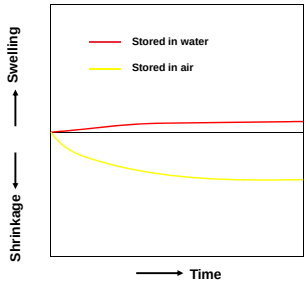
Air-Entrained Concrete



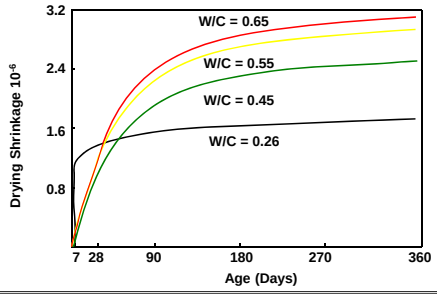
Physical Properties

- Thermal expansion:
  - Concrete 9.9 x 10^{-6}/° C
  - Steel 12.0 x 10^{-6}/° C
- Volume change due to moisture:
  - Swelling
  - Shrinkage

Swelling/Shrinkage



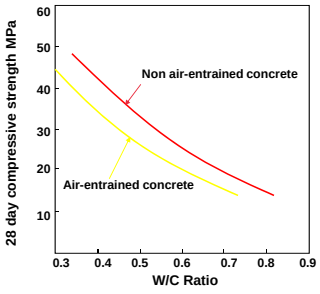
W/C Ratio & Shrinkage of Paste



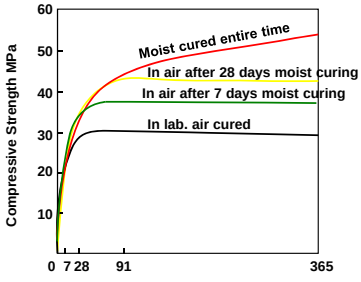
Mechanical Properties

- Strength
  - Compressive (28 day – f' c)
  - Tensile (10% of f' c)
  - Shear (12% to 13% of f' c)
  - Flexural (14% of f' c)
- Abrasion resistance
- Creep
- Fire resistance
- Durability
- Permeability

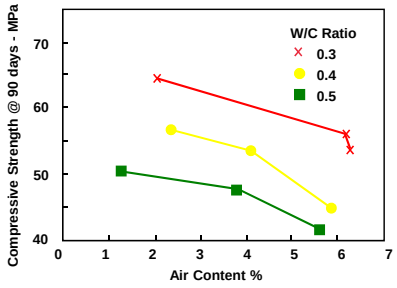
W/C Ratio vs. Strength



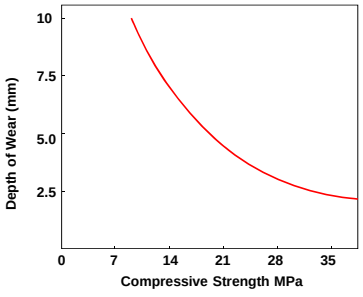
Effect of Curing on Strength



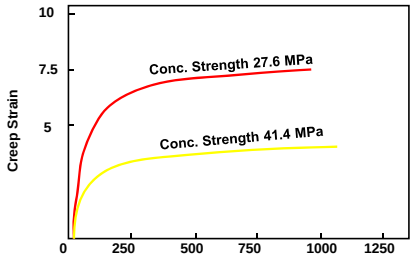
Compressive Strength & Air Content



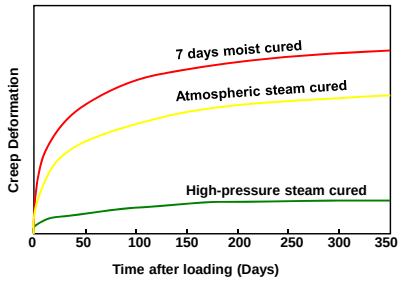
Wear vs. Strength



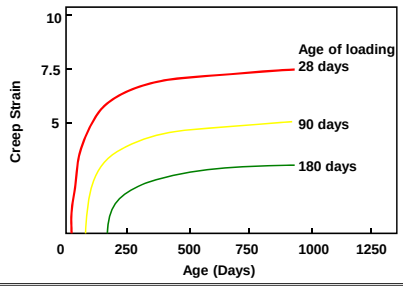
Concrete Strength & Creep



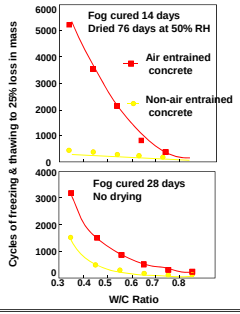
Curing Method & Creep



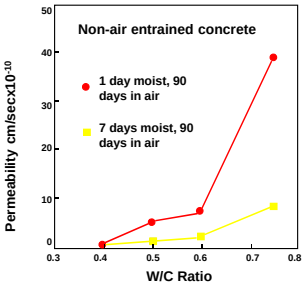
Age of Loading & Creep



Freeze/Thaw Resistance, Air & W/C Ratio



Permeability, W/C Ratio & Curing



Deterioration Stains

Staining, Efflorescence & Corrosion

Deck Ponding

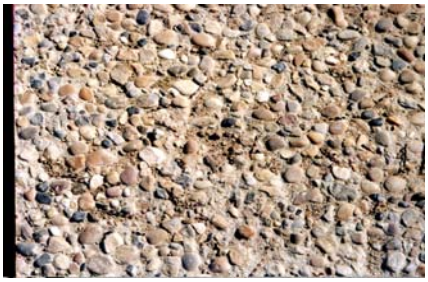
Surface Durability

Freeze-Thaw Damage

Light Scaling

Medium Scaling

Heavy Scaling

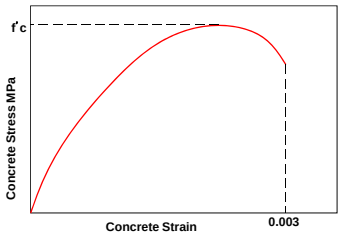


Sound Concrete Deck

Sound Concrete Deck

Surface Abrasion

Concrete Stress-Strain Relationship



Strain = $\Delta L/L$

$\Delta L = 0.003 \times 300 = 0.9$ mm

High-Performance Concrete

- High strength.
- High modulus of elasticity.
- High abrasion resistance.
- Low permeability and diffusion.
- Resistance to chemical attack.
- High resistance to frost.
- Ease of placement

Self-Compacting Concrete

- Able to flow and consolidate on its own.
- Must be cohesive to fill spaces without segregation.
- Useful wherever placing is difficult..
- SCC reduces the need for vibration.
- It is based on increasing the amount of fine material without changing the water content.

Shrinkage Cracks

Map Cracking

Flexural Cracks

Construction Joint

Corrosion Spalls & Pop-outs

Corrosion Spall

Corrosion Spall

Alkali Aggregate Reaction

High Load Chip

High Load Damage

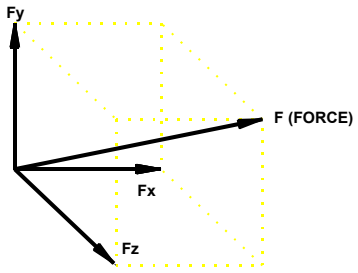
Questions??

Structural Considerations for Bridges

Introduction

- Bridge members must be able to carry loads applied to them.
- Forces resisted by bridge members:
  - Axial forces
  - Bending forces
  - Shear forces
  - Torsional forces
- This presentation considers:
  - How bridge members are stressed by loads
  - How bridge materials resist stress
  - How bridges accommodate thermal movements

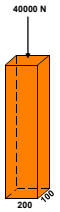
Force



Stress

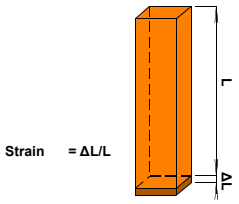
- What is a stress?
  - Loads cause stresses
  - Stresses are the internal forces
- How to calculate stress?

Stress = Force/Area
= 40000/200x100
= 2MPa



Strain

- It is described as the amount of deformation.
- It denotes the ratio of material's deformed dimension to its original dimension.



Deformation & Modules of Elasticity

- Elastic Deformation - It is reversible distortion of a material.
- Plastic Deformation – It is the irreversible distortion of a material.
- Modulus of Elasticity (E) = Stress/Strain

Response to Loading

- Forces resisted by bridge members:
  - Axial forces
  - Bending forces
  - Shear forces
  - Torsional forces

Response to Loading

Rigid Body

- **A rigid body does not deform under load.**

Equilibrium

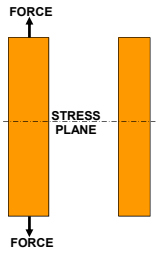
- **When a particle is at rest or moves with constant velocity.**

$\sum V = 0$

$\sum H = 0$

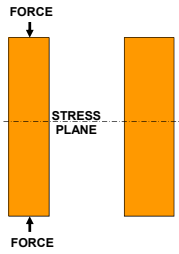
$\sum M = 0$

Types of Applied Stresses



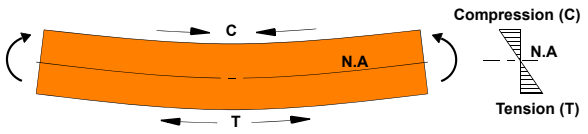
Tensile Stress

Types of Applied Stresses



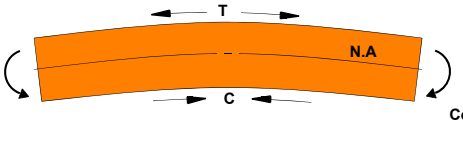
Compressive Stress

Types of Applied Stresses



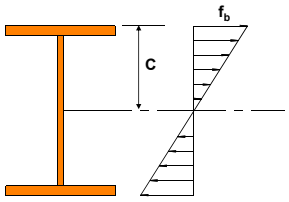
Positive Moment

Types of Applied Stresses



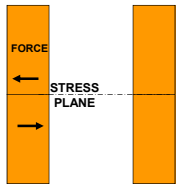
Negative Moment

Bending Stress



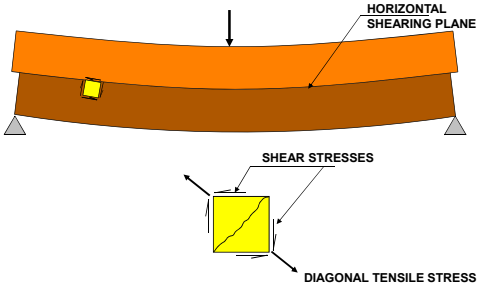
Bending Stress
$f_b = Mc/I$

Types of Applied Stresses

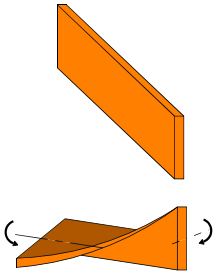


Shear Stress

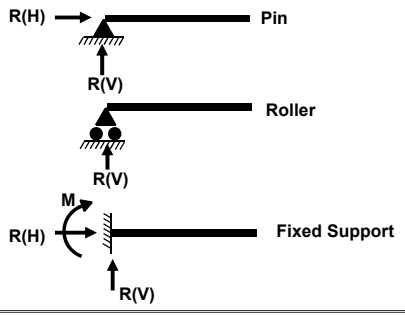
Beams – Horizontal Shear Stress



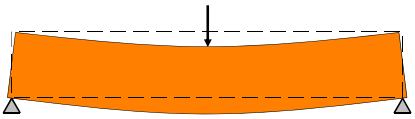
Torsional Forces



Types of Supports

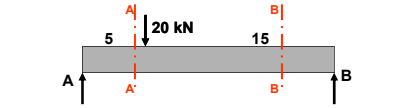


Span Classification



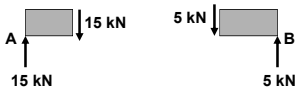
Simple Span

Shear



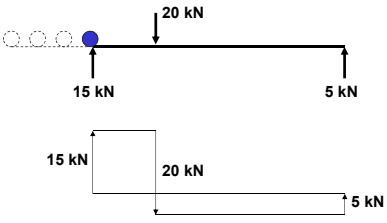
$R_A = 20x15/20 = 15$ kN

$R_B = 20x5/20 = 5$ kN

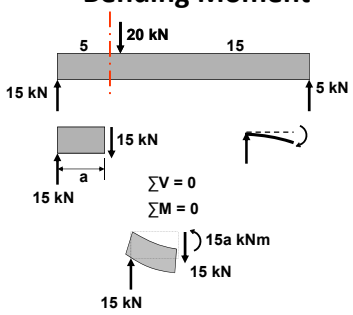


$\sum V = 0$

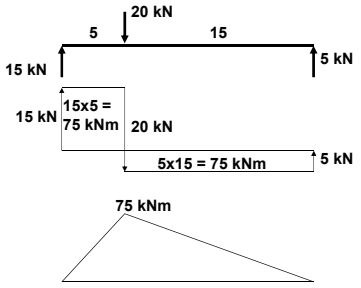
Shear Diagram



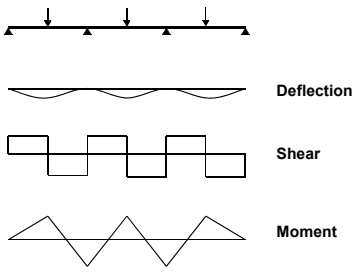
Bending Moment



Bending Moment Design

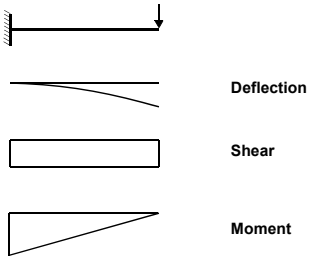


Span Classification



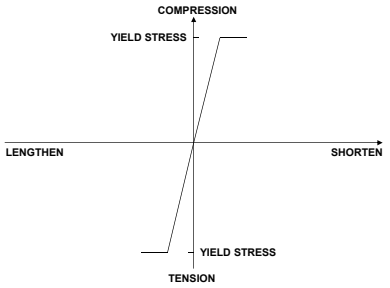
Continuous Span

Span Classification

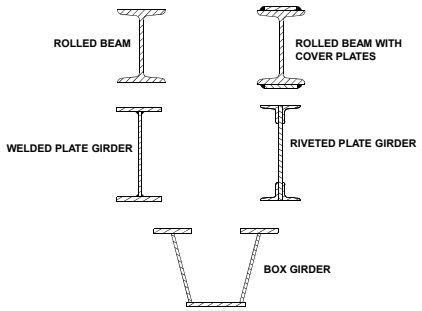


Cantilever

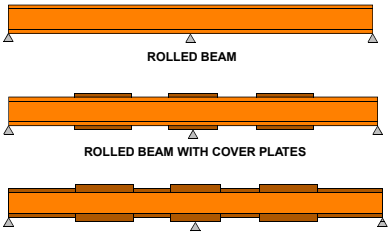
Stress in Steel



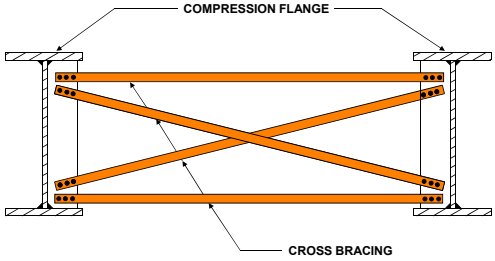
Steel Bridge Members



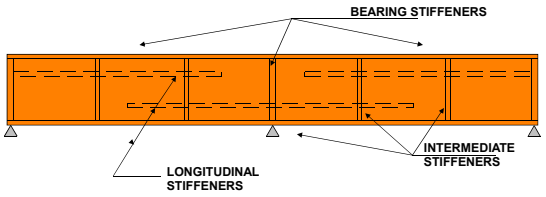
Steel Beams – Bending Stress



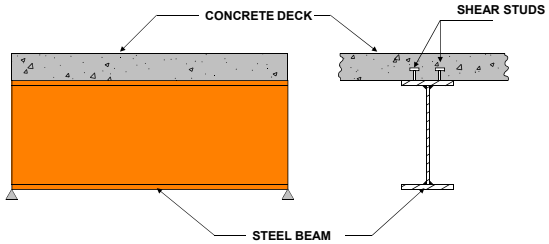
Steel Beams – Compression Stress



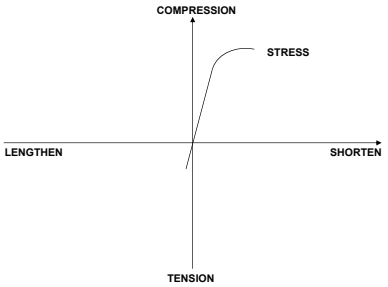
Steel Beams – Shear Stress



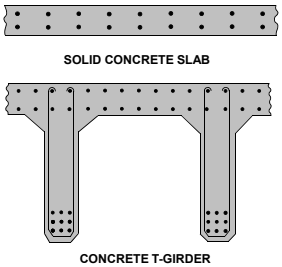
Composite Beam



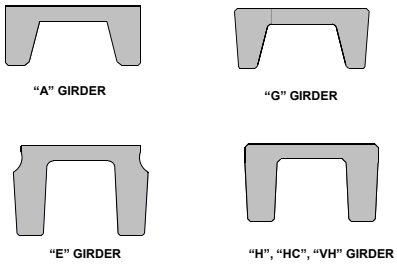
Stress in Concrete



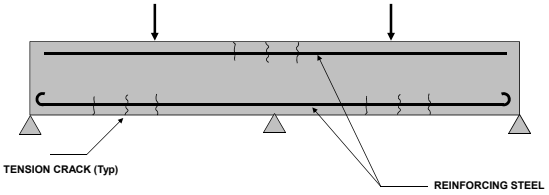
Concrete Bridge Members



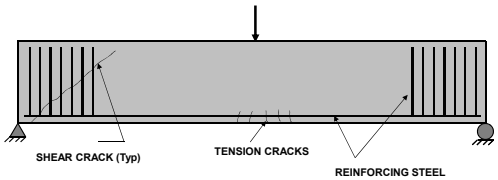
Concrete Bridge Members



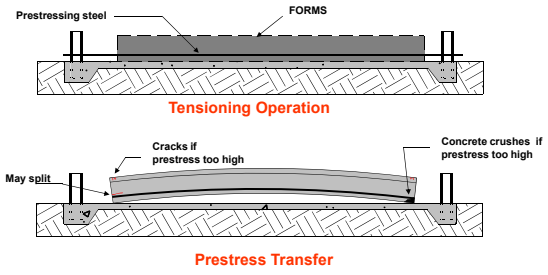
Concrete Beams – Bending Stress



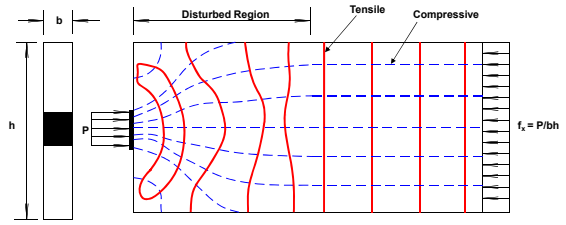
Concrete Beams – Shear Stress



Prestressed Concrete



Anchorage Stress



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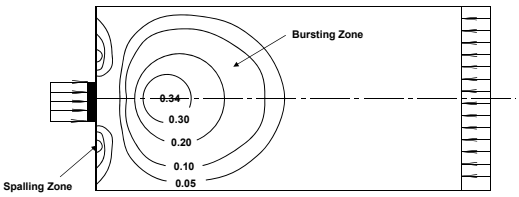
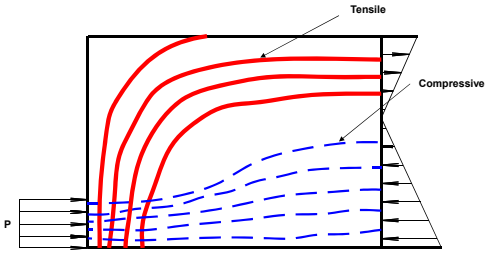
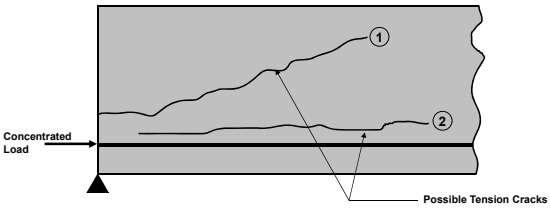


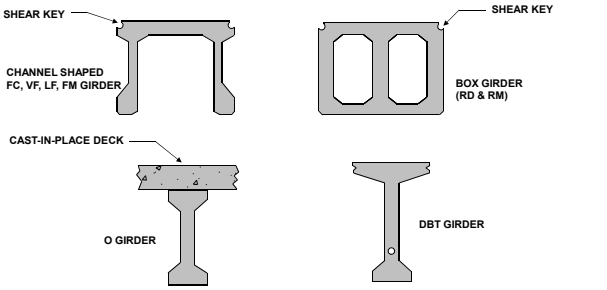
Anchorage Stress



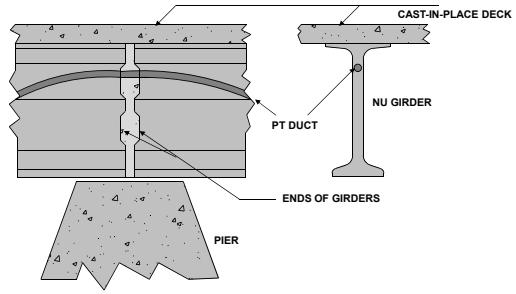
Anchorage Stress



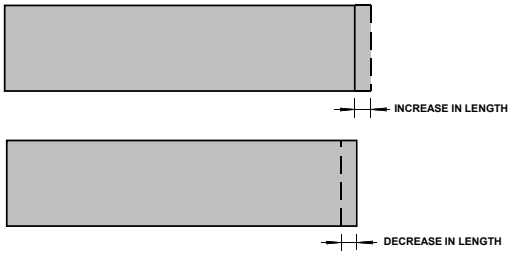
Prestressed Concrete Bridge Members



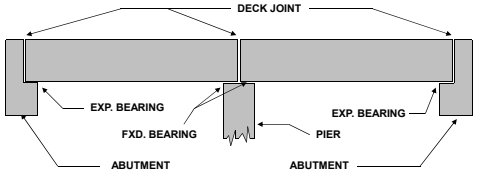
Prestressed Concrete Bridge Members



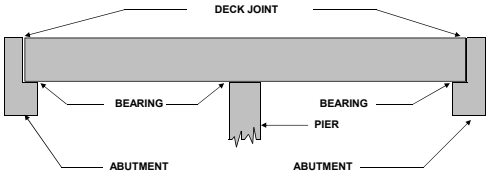
Thermal Stress



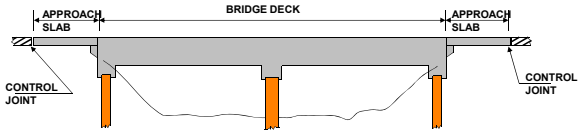
Thermal Stress



Thermal Stress



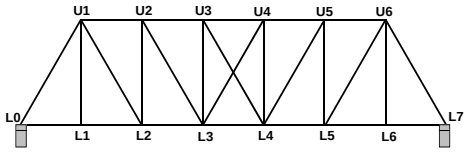
Stress in Concrete



END

Structural Considerations for Trusses

Introduction

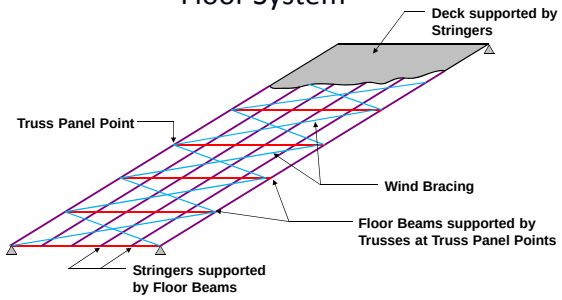


Pratt Truss

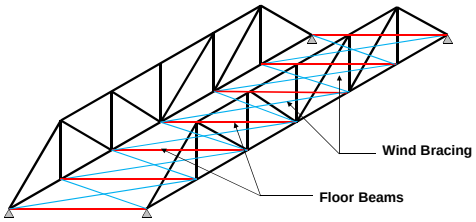
Truss Types

- Three types of trusses in Alberta:
  - Pony trusses
  - Through trusses
  - Deck trusses
- Traffic loads are transferred to the trusses by a floor system.

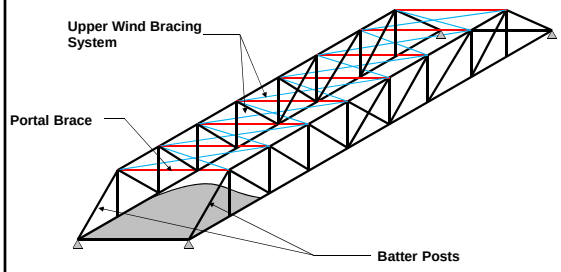
Floor System



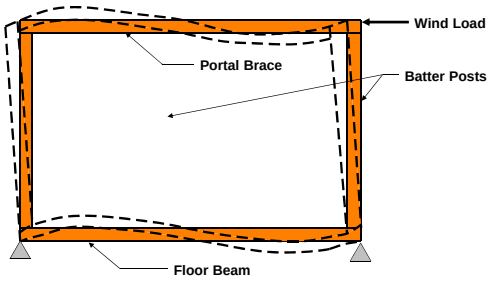
Pony Truss



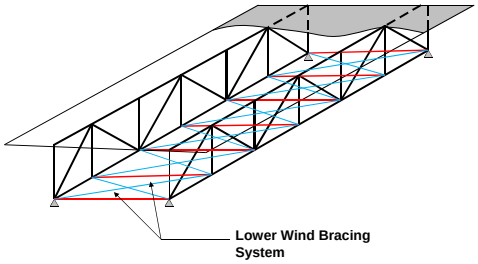
Through Truss



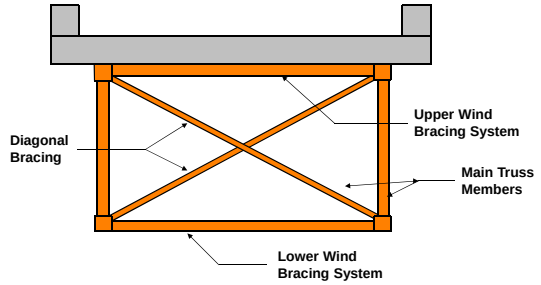
Portal Brace & Batter Posts



Deck Truss



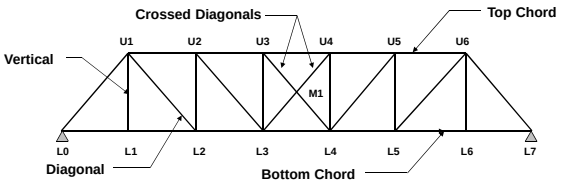
Deck Truss – Wind Bracing



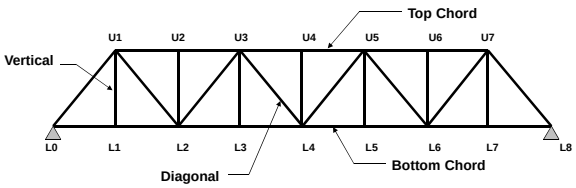
Truss Configurations

- The way truss members carry loads depends on the configuration of the truss.
- Most trusses are either Pratt or Warren trusses.

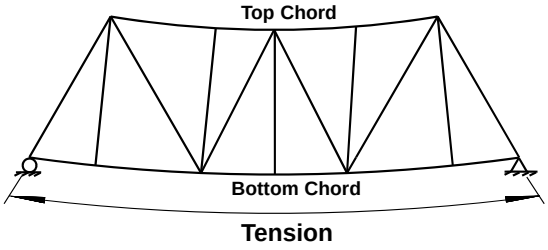
Pratt Truss



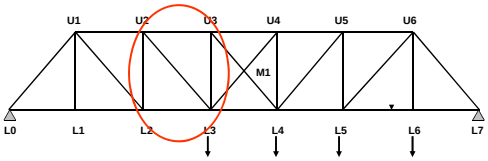
Warren Truss



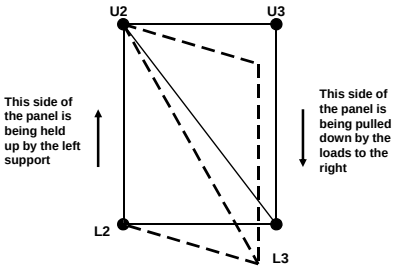
Truss Curvature



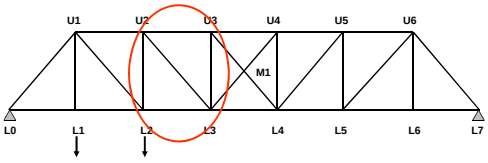
Loads in Diagonals



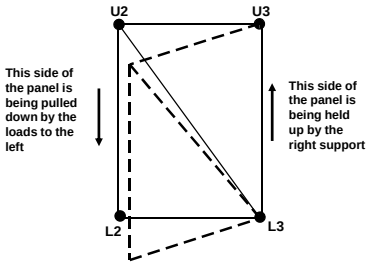
Loads in Diagonals



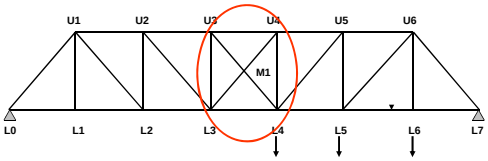
Loads in Diagonals



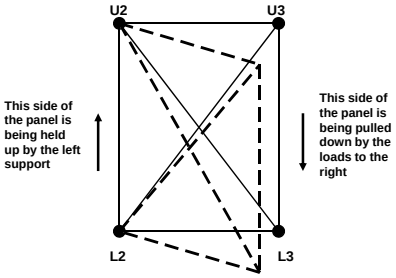
Loads in Diagonals



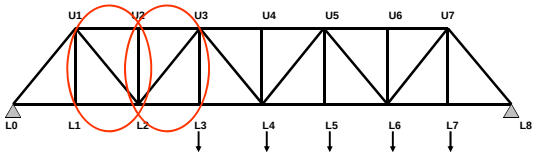
Loads in Diagonals



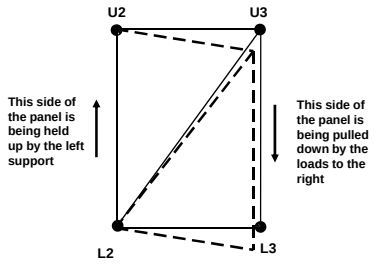
Loads in Diagonals



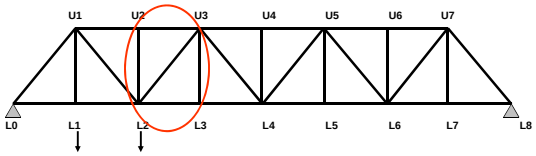
Loads in Diagonals



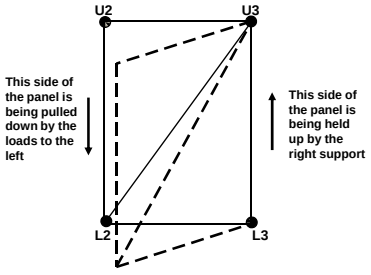
Loads in Diagonals



Loads in Diagonals



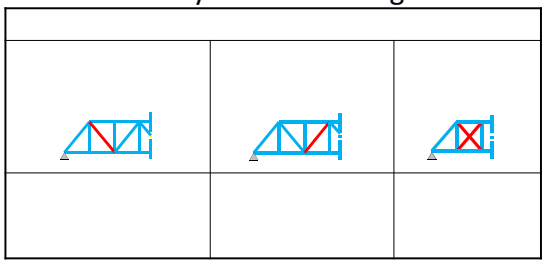
Loads in Diagonals



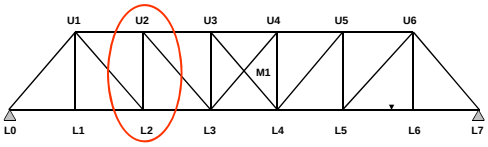
Summary – Loads in Diagonals

- Diagonals that slope away from the nearest support as they approach the bottom chord are primarily tension members.
- Some diagonals near the center of the truss may go into compression.
- Diagonals that slope towards the nearest support as they approach the bottom chord are primarily compression members.
- Crossed diagonals are tension members.

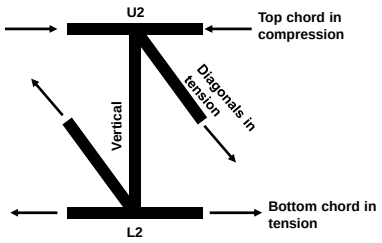
Summary – Loads in Diagonals



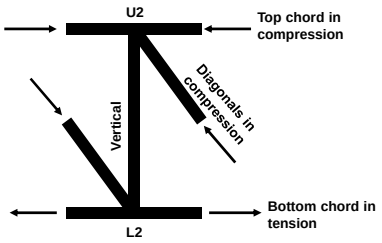
Loads in Verticals



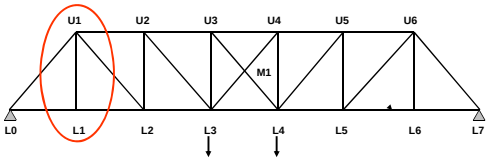
Loads in Verticals



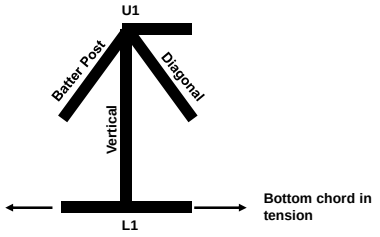
Loads in Verticals



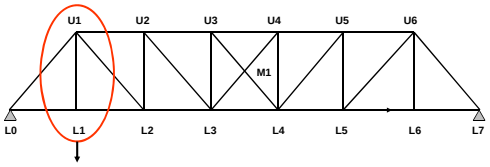
Loads in Verticals



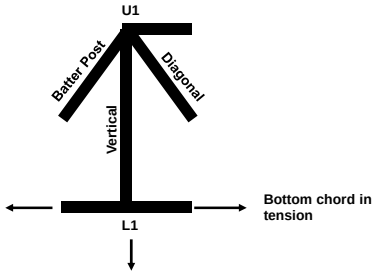
Loads in Verticals



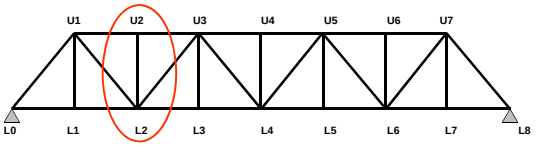
Loads in Verticals



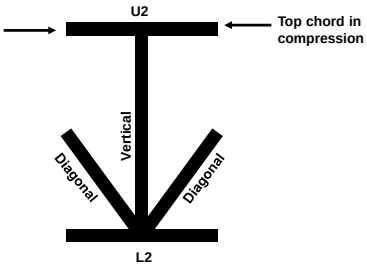
Loads in Verticals



Loads in Verticals



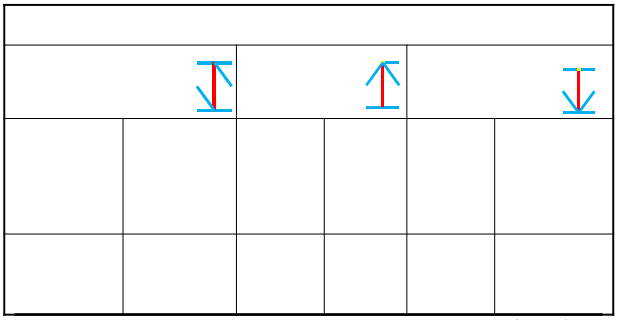
Loads in Verticals



Summary – Loads in Verticals

- Verticals connected to diagonals at both ends will be in compression if the diagonals are in tension and in tension if the diagonals are in compression.
- Verticals connected to diagonals at the top chord only will be in tension for pony and through trusses and will be unloaded for deck trusses.
- Verticals connected to diagonals at the bottom chord only will be in compression for deck trusses and will be unloaded for pony and through trusses.

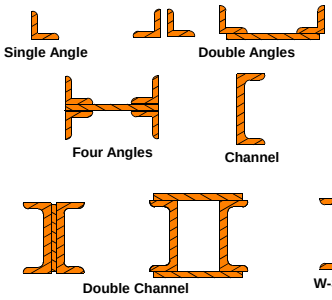
Summary – Loads in Verticals



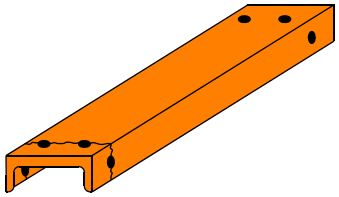
Summary – Loads in TC, BC & BP

- Top chords are in compression.
- Bottom chords are in tension.
- Batter posts are in compression.

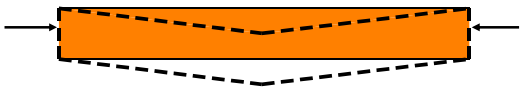
Steel Sections



Tension Member



Compression Member

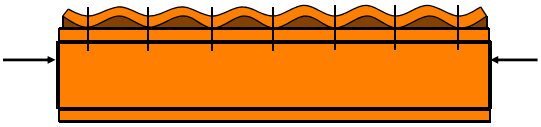


Misalignment of Member

Compression Member

Bent Member

Compression Member

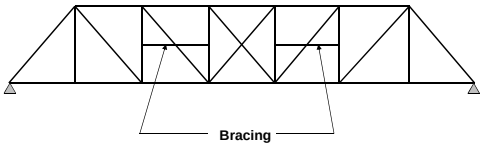


Rippling of Plate

Compression Member

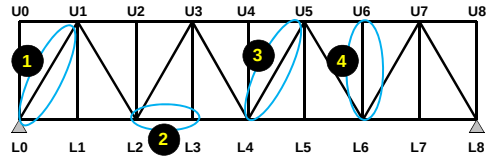
Rippling of Plate

Compression Member

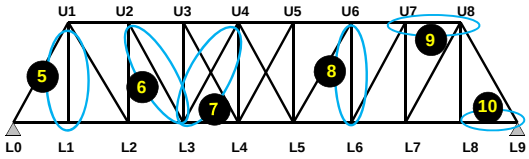


Bracing

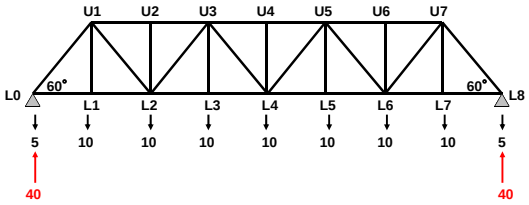
Class Exercise



Class Exercise



Truss Loads



Questions??

Major Bridge Inspection Forms

Inspection Form Types

- Each form has a unique form identification or Form ID
- 9 different inspection report forms for bridges with a single span type
- 1 report for sign bridges
- Custom forms generated to suit number & type of spans

Standard Bridge Inspection Forms

Forms used by Class B Inspectors:

Form ID	Span Description	Span Types
TT	Timber Bridges	TT, UT, XT
PCS	Standard Precast Bridges	HH, HC, VH, PG, GR, PE, PPS,VS, SM,SMC, SC, SCC
CUL1	Single Culvert	RP, SP, FP, MP, WP, TP, CP, BP, AP, XP, RPA, RPO, RPP, RPE, MPL
CULM	Multiple Culverts	Same as CUL1 in any combination
CULE	Culvert extended with a different material or size	RPX, APX, CPX, MPX

Major Bridge Inspection Forms

Additional forms used by Class A Inspectors:

Form ID	Span Description	Span Types
TH	Through Truss Bridges	TH
PT	Pony Truss Bridges	PT
DT	Deck Truss Bridges	DT
SG	Steel Girder Bridges	RB, RG, WG, FR
PSR	Regular Prestressed Girder Bridges	RD, FC, VF, PM, VM, PB, DBT, PQ, PO, LF, FM, RM, PJ
CON	All Cast-in-Place Concrete	CA, CB, CF, CV, CX, CC
	Concrete Tee Girders Bridges	CT
	Concrete Flat Slab Bridges	CS
SS	Other Trusses and Arches	SS
SIGN	Sign Structures	Z

Common Major Bridge Form Sections

- Bridge Site Inventory
- Bridge Inspection Details
  - Name, Date, Arr/Dep times
- Posting Information
  - Vertical clearance
  - Posted loading
  - Utilities
- Approach Road

Common Major Bridge Form Sections

- Channel
- Grade Separation
- Structural Condition Rating
- Sufficiency Rating
- Special Comments for Next Inspection
- ERY
- Next Inspection Date and Inspection Cycle

Unique Major Bridge Form Sections

- Superstructure
- Substructure
- Maintenance Recommendations

Superstructure Section

- Common Elements
  - Special Features
  - Deck Rideability
  - Bridge Rail
  - Sidewalk
  - Span Alignment Problems
  - General Rating

Wearing Surface

Wearing Surface
(Material Type :)
(Thickness (mm) :)

SG, DT, CON, and SS forms

Wearing Surface/Deck Top
(Material Type :)
(Thickness (mm) :)
(Planks Width (mm) :)

PT, and TH forms

Wearing Surface	
(Material Type :)	
(Thickness (mm) :)	
Lateral Connection Problem (Y/N)	

PSR forms

Deck Top

Deck Top

SG, DT, PSR and CON forms only

- PT, TH and SS have no Deck Top Element

Deck Joints

Deck Joints	
Temperature (deg.C)	
(Expansion Type :)	
(Fixed Type :)	
Gap Size (mm)	Gap Location

SG, DT, PSR and SS forms

Deck Joints	
Temperature (deg.C)	
(Expansion Type :)	
(Fixed Type :)	
Gap Size (mm)	Gap Location

PT, TH and CON forms

Deck Drainage

Deck Drainage	
Drains Clogged (Y/N)	

SG, DT, PSR, CON and SS forms only

- PT, TH form - No Drainage Element

Curbs / Medians / Wheel Guards

Curb/Median	
Scaling (Percent Area)	

SG, DT, PSR, CON and SS forms

Curbs/Wheel Guards
(Type :)
(Height (mm) :)
(Width (mm) :)

PT and TH forms

Truss Members
Pony and Through Trusses
(PT & TH)

Wide Load Damage (Y/N)				
High Load Damage (Y/N)				TH only
Top Chord				
Batter Posts				
Sway Bracings				TH only
Diagonals				
Verticals				
Portals				TH only
Connections				
Floor Beams				
Bottom Chord				
(No. of Stringers :)				
Stringer Detail Ratings				
	N (count)	1 (count)	2 (count)	3 (count)
Last				
Now				
Stringers				
(Type :)				
(Width (mm) :)				
(Depth (mm) :)				
(Spacing (mm) :)				

Deck Truss,
Other Trusses & Arches(SS)

Top Chord		
Diagonals		
Verticals		
Connections		
Floor Beams		
Bottom Chord		
Stringers		

Girders / Beams

Girders			PSR only
Cracking (Y/N)			
Spalling (Percent Area)			

Girder/Beam			SG only
Cover Plate			
Flange			
Web			
Stiffeners			
Splice			
Weld			

Girders			CON and SS

Diaphragm / Cross Frames

Diaphragms/Cross Frame			SG, DT, PSR, CON, SS none on PT, TH

Paint

Paint Condition			SG, DT, PT, TH, SS others none
(Colour Description :)			
(Colour Code :)			

Bearings

Bearings		
Temperature (deg. C)		
(Expansion Type :)		
(Fixed Type :)		
Coating Adequate (Y/N)		
Functioning (Y/N)		

Not on PT and TH

Deck Underside

Deck Underside		
Stains (Percent Area)		

SG, PSR, and CON forms

Deck Underside		
Stains (Percent Area)		
(Snow Slots Filled :)		

DT and SS forms

Sub Deck/ Deck Underside		
(Material Type :)		
(Plank Thickness (mm) :)		
(Plank Width (mm) :)		
Defects (Percent Area)		

PT and TH forms

Substructure - Abutments

Abutments				
(Extended Backwall Piles (Y/N) :)				
(Extended Backwall Piles Spacing (m) :)				
(Total Number of Caps :)				
Bearing Seats/Caps/Corbels Detail Ratings				
	N (count)	1 (count)	2 (count)	3 (count)
Last				
Now				
Bearing Seats/Caps/Corbels				
(Type :)				
(Depth (mm) :)				
(Width (mm) :)				
Backwalls/Breastwalls				
Greatest Height (m)				
Wingwalls				
(Total Number of Bearing Piles :)				
Piles Detail Ratings				
	N (count)	1 (count)	2 (count)	3 (count)
Last				
Now				
Piles				
Paint/Coating				
Abutment Stability)				
Scour/Erosion				

PT, TH and SS only

PT, TH and SS only

PT and TH only

Substructure - Piers

Piers/Bents				
(Type :)				
(Total Number of Caps :)				
Bearing Seats/Caps/Corbels Detail Ratings				
	N (count)	1 (count)	2 (count)	3 (count)
Last				
Now				
Bearing Seats/Caps/Corbels				
(Type :)				
(Total Number of Piles :)				
Piles Detail Ratings				
	N (count)	1 (count)	2 (count)	3 (count)
Last				
Now				
Pier Shaft/Piles				
Greatest Height (m)				
Bracing/Struts/Sheathing				
Nose Plate				
Paint/Coating				
(Colour Description :)				
(Colour Code :)				
Pier Stability				
Scour				
Debris (Y/N)				

PT, TH, and SS only

PT, TH and SS only

PT, TH and SS only

Not on CON

Maintenance Recommendations

Inspector Recommendations	
REPAIR/REPLACE BRIDGE RAIL	
GALVANIZE/PAINT BRIDGE RAIL	← Not on PT and TH
RETROFIT BRIDGE RAIL	← Not on PSR
REPAIR/SEAL CURBS	
PATCH DECK	
SEAL DECK	
OVERLAY DECK	
REPAIR/REPLACE DECK JOINTS	
RESET/PAINT BEARINGS	
REPAINT SUPERSTRUCTURE	
STRAIGHTEN/REPLACE MEMBERS	
WASHING	
SHOTCRETE REPAIRS	
REPAIR ABUTMENT SCOUR/EROSION	
PLACE ADDITIONAL RIP RAP	
REMOVE DRIFT ACCUMULATION	
OTHER ACTION	
OTHER ACTION	
OTHER ACTION	
OTHER ACTION	

Form Review

- Inventory items
  - Shaded fields on form (TIMS)
  - Verify/revise data on form
- Element Ratings
  - fill all blank fields
  - use N or X if necessary
- LHS Data or Explanation of Condition
  - Verify & check off if visible
  - Carry over if not visible

Reasons for Inspection

- Safety
- Maintenance
- Management

Rating Considerations

- Condition
- Functionality

Maintenance Priority

Rating	Maintenance Priority
5	No maintenance required
4	Low priority Recommendation is not required If made - not likely before next inspection
3	Medium priority Before next inspection (6 mo. to 3 years)
2	High priority Monitor until work is done (within 6 months)
1	Immediate action

Road Classifications

Current Department standards are:

Highway Type	Road Classification
Local Roads (Gravel	RLU 207G-60 RLU 208G-60 RLU 208G-90 RLU 209G-90 RLU 210G-90
Local Roads (Paved)	RLU 208-100 RLU 208-110
Provincial Hwys. (Gravel)	RCU-208G-090 RCU-209G-090

Road Classification (Continued)

Highway Type	Road Classification
Provincial Highways (Paved)	RCU 208-110 RCU 209-110 RCU 210-110 RAU 209-110 RAU 210-110 RAU 211.8-110 RAU 213.4-110 RAU 213.4-120
Provincial Highways (divided)	RAD 412.4-120 RAD 616.6-130 RFD 412.4-130 RFD 616.6-130

Refer to Table 4.2 in Manual

Major Bridges - Concrete

	Life Expectancy		
Type	Low	Ave	High
Prestressed Girder**	45	55*	70*
Precast Girder**	30	35	50
Cast-in-Place**	40	50	60

* Use Maximum of 50 years for timber sub-structure

** Add 5 years if overlaid with concrete

** Add 5 years if strengthened or laterally stressed

Major Bridges - Steel

	Life Expectancy		
Type	Low	Ave	High
Rigid Frame	60	70	80
Welded Girder	60	70	80
Deck Truss	60	70	80
Rolled Beams	50	60*	80*
Riveted Plate Girder	40	50	70*
Through Truss	40	50	70*
Pony Truss	40	50	70*
Bailey and Other Types	30	40	50

* Use maximum of 50 years for timber substructure

Estimated Remaining Life Major Bridges

Considerations:

- Traffic characteristics
  - volume, amount of truck traffic, log haul
- Salt usage
  - road surfacing, traffic, climatic conditions
- Deck drainage, leakage
- Decay favorable conditions
- Design or rated load capacity

Questions??

Inspection of Steel Girder Bridges

Course Outline

- Bridge superstructure systems
- Defects in steel members
- Failure mechanics
- Fatigue
- Constrained Induced fracture (CIF)
- Inspection
- Inspection of Pin & Hanger

Bridge Superstructure Systems

1. Rolled beams
   - Manufactured from one piece of steel
   - Webs are stocky, therefore no intermediate stiffeners.
   - Used as simple spans with span length from 9 to 15 m
2. Rolled beams with cover plates
   - Cover plates were added to increase the capacity
   - Cover plates were welded or riveted to the flanges
   - Welded cover plates created fatigue prone detail

Bridge Superstructure Systems

Rolled Beam

Bridge Superstructure Systems

Rolled Beam with Cover Plates

Bridge Superstructure Systems

3. Built-up Girders
   - Similar in appearance as rolled beams
   - Custom fabricated, not produced in rolling mills
   - Fabricated from thin plates, hence require stiffeners
   - Older built-up girders were riveted, the new are welded plates
   - Continuous girders can have spans over 150 m

Bridge Superstructure Systems

Built-up Girders

Bridge Superstructure Systems

4. Girders with Pin and Hanger
   - Analysis is simplified for a hinged structure
   - It moves drainage away from piers
   - Only one pin is required for rotation
   - For translation and rotation, two pins and hanger are provided

5. Steel Arches
   - Three types of arches: deck, through and tied
   - Arch spans range from 300 to 500 m

Bridge Superstructure Systems

Girder with Pin & Hanger

Bridge Superstructure Systems

Steel Arch

Bridge Superstructure Systems

6. Suspension Bridges

7. Trusses
   - Through Truss
   - Pony Truss
   - Deck Truss

Bridge Superstructure Systems

Suspension Bridge

Bridge Superstructure Systems

Through Truss

Bridge Superstructure Systems

Pony Truss

Bridge Superstructure Systems

Deck Truss

Primary and Secondary Members

Primary Members for Bridge Systems 1 to 4

- Fabricated girders / Rolled beams
- Diaphragms for curved girders
- Pin and hanger

Secondary Members for Bridge Systems 1 to 4

- Diaphragms

Primary and Secondary Members

Primary Members for Bridge System 7
- Trusses (chords, web members)
- Floor beams
- Stringers

Secondary Members for Bridge System 7
- Bracing

Steel Damage and Deterioration

- Corrosion
  - Environmental corrosion
  - Stray current corrosion
  - Stress corrosion
- Cracking
  - Fatigue
  - Impact
  - Excessive loading

Steel Damage and Deterioration

- Deformation
  - Excessive loading
  - Heat damage
  - Impact

Steel Damage and Deterioration

Corrosion

Steel Damage and Deterioration

Corrosion

Steel Damage and Deterioration

Fatigue Crack

Steel Damage and Deterioration

Impact Damage

Steel Damage and Deterioration

Impact Damage

Steel Damage and Deterioration

Fire Damage

Steel Damage and Deterioration

Fire Damage

Steel Damage and Deterioration

Overload Damage

Fatigue & Fracture in Steel Members

Fatigue

- Tendency of a member to fail at a stress level below its yield stress when subjected to repeated loading

Fracture Critical Member (FCM)

- Member is in tension
- Member is non-redundant, its failure causes partial or total collapse of a structure

Failure Mechanics

Describing the process by which a member fails when subjected to fatigue.

Types of Fractures in Steel Members

Fatigue Failure Process

Fatigue failure process consists of three stages:

1. Crack initiation
2. Crack propagation
3. Fracture

Fatigue Crack Categories

- Details and defects
- Out-of-plane distortion

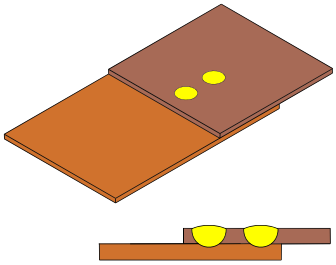
Factors Affecting Fatigue Crack Initiation – (Details & Defects)

1. Plug welds
2. Tack welds
3. Material flaws
   - External flaws (Surface scabs)
   - Internal flaws (Non-metallic inclusions, Rolled in plate defects)
4. Weld flaws
   - Non-visible flaws (IP welds, Porosity, Slag inclusions)
   - Visible flaws (Undercut, Overlap)

Factors Affecting Fatigue Crack Initiation – (Details & Defects)

5. Fabrication Flaws
   - Cutting of plates, Holes, Coping
6. Transportation & Erection Flaws
   - Nicks
   - Notches
   - Indentation
7. In-Service Flaws
   - Collision damage
   - Improper heat straightening
   - Torched or notched holes

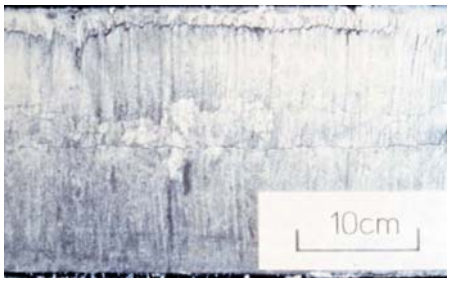
Plug Weld



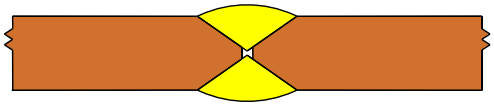
Tack Weld

Material External Flaw

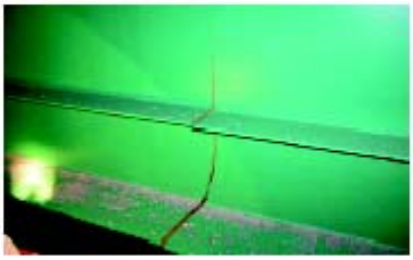
Material Internal Flaw



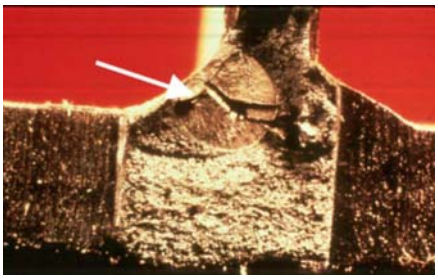
Incomplete Penetration Weld



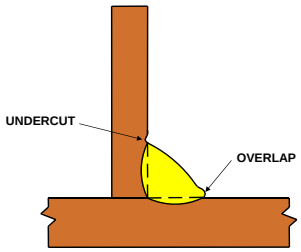
Incomplete Penetration Weld



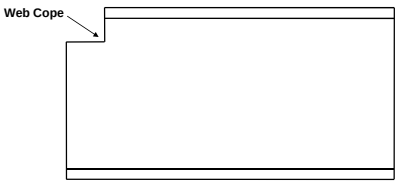
Weld Crack Due to Slag Inclusion



Fillet Weld Draws

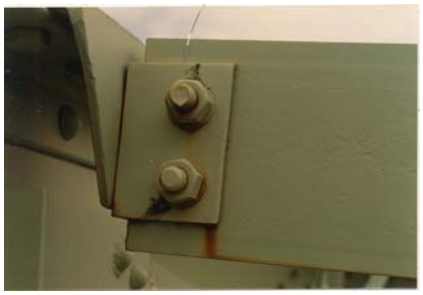


Improper Web Coping



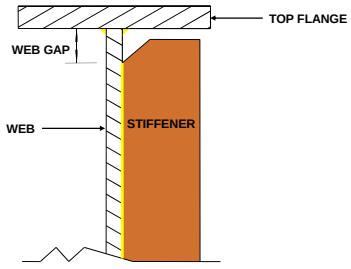
Correct Web Coping

Torched Hole

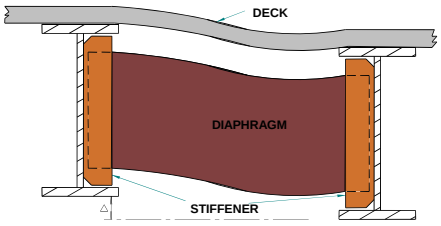


Torched Damage

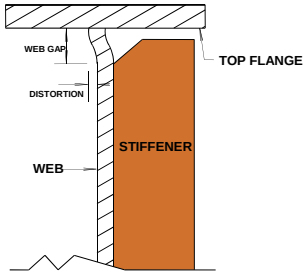
Factors Affecting Fatigue Crack Initiation – (Out-of-plane Distortion)



Girder Differential Deflection



Girder Web Gap Distortion

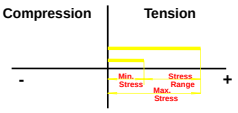


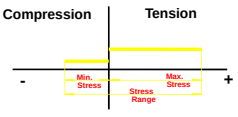
Girder Web Gap Distortion

Factors Affecting Fatigue Crack Propagation

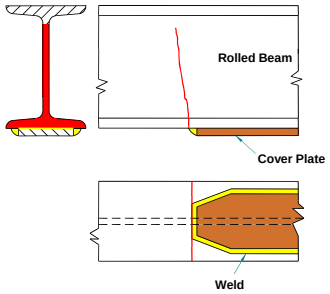
- Stress range
- Number of cycles
- Types of details
  - Flange cover plates
  - Transverse stiffeners
  - Bolted joints
  - Longitudinal stiffeners

Stress Range





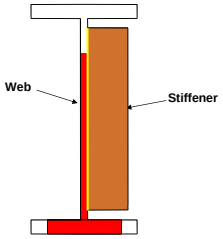
Flange Crack Growth Process



Through Crack at a Cover Plate

Crack Propagation Into the Web

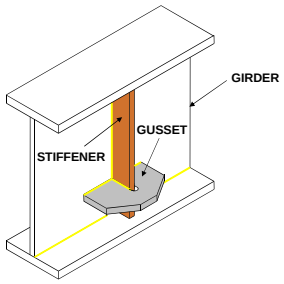
Crack Growth at Transverse Stiffener Welded to Web



Constrained Induced Fracture (CIF)

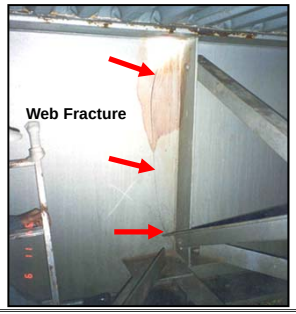
- Fracture is not due to fatigue or number of cycles
- Occurs suddenly with no prior signs
- Fractures are at intersecting welds or at small gaps between intersecting welds
- Girder fracture at Hoan bridge Milwaukee was due to CIF

Constrained Induced Fracture (CIF)



Constrained Induced Fracture (CIF)

Constrained Induced Fracture (CIF)



Constrained Induced Fracture (CIF)

Inspection Procedures & Locations

Procedures

- Visual
  - Hands-on inspection
- Physical
  - Removal of dirt, paint etc
- Identification
  - Fatigue crack may be identified by the development of rust stains
- Advanced Inspection Techniques

Inspection Procedures & Locations

Locations

- Bearing areas
- Shear zones
- Flexure zones
- Fatigue prone details
- Out-of-plane distortion
- Constrained induced fracture detail
- Secondary members
- Areas that trap water and debris
- Areas exposed to traffic

Corroded Shear Zone & Diaphragm

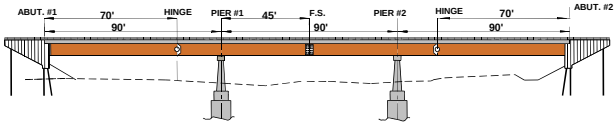
What to do if a Crack is Detected?

- Determine significance of crack on load carrying capacity
- Evaluate cause of cracking
- Show sketches with details of size and location
- Drill hole at the tip to arrest the growth
- Check with dye penetrant
- Take good photographs showing all the details

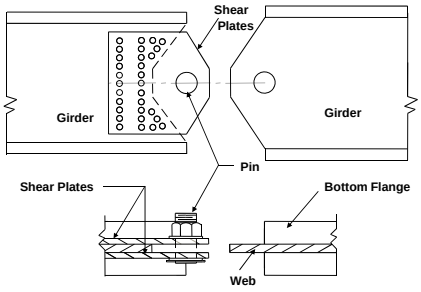
Note: Cracks perpendicular to primary stresses are very serious
Cracks parallel to primary stresses are less serious

Inspection of Pin & Hanger

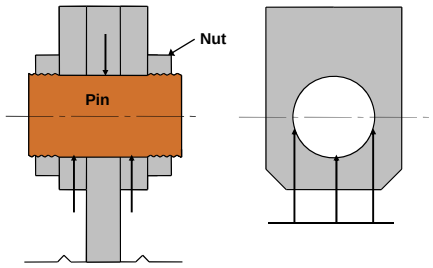
Pin Location



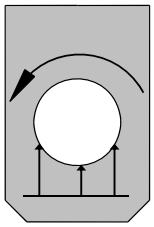
Pin Detail



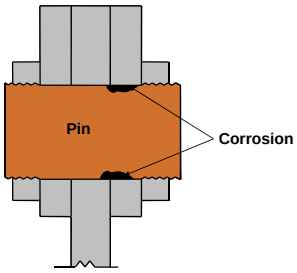
Design Stresses in Pin



Actual Stresses in Pin

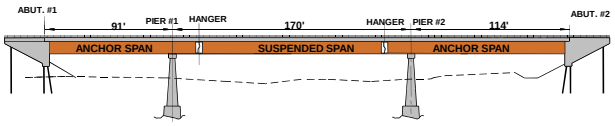


High Stress in Pin Due to Corrosion

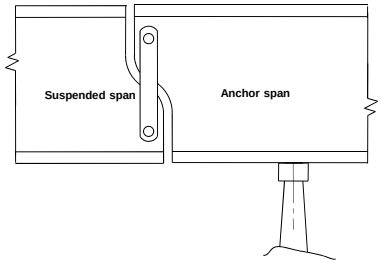


High Stress in Pin Due to Corrosion

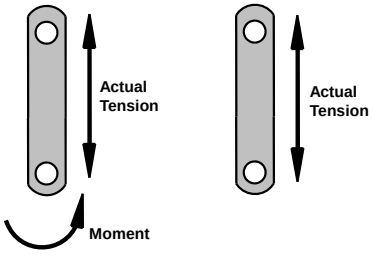
Hanger Location



Hanger Details



Stresses in Hanger



Deterioration of Pin & Hanger

Pin

- Frozen
- Corroded
- Cracks in welded shear plates

Hanger

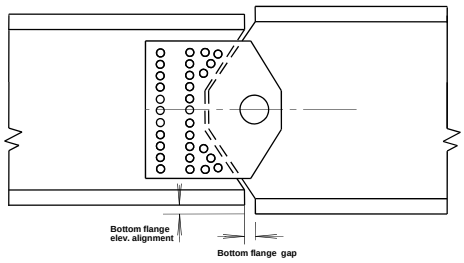
- Twisted or bent
- Ceased
- Cracks in edges

Inspection of Pins

Procedure

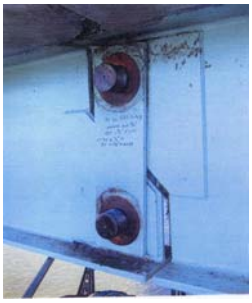
- Determine if pins are functioning
- Visual inspection not very effective
- Ultrasonic inspection is required
- Remove nuts if possible

Pin Measurements



Preparation for Inspection

Removal of Nuts



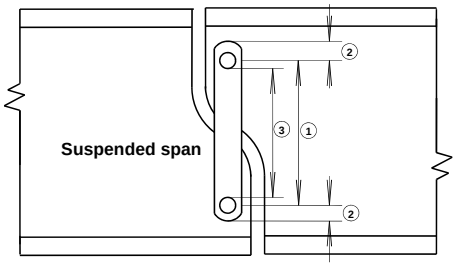
U/T Inspection

Inspection of Hangers

Procedure

- Report any corrosion
- Hanger plate is as critical as pin.
- Examine edges
- Check hangers for bowing, out of plane bending

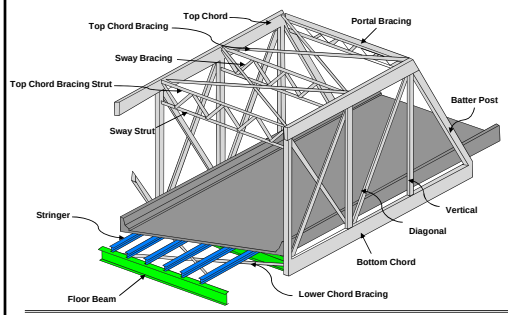
Measurements in Pin & Hanger



END

Inspection of Trusses

Truss Members & Elements



Level II Truss Inspection

Trusses for Alberta Highways

- Bridge system has about 340 sites with 460 truss spans
- Majority of these trusses were fabricated between 1920 & 1930
- Most of the spans are on secondary highways and local roads
- Level II Truss inspection started in the early 1970's
- Second round of U/T inspection in 1983 revealed numerous cracked members

Level II Truss Inspection

Frequency of Inspection

- Provincial highways 4 – 5 years
- Local roads 6 years
- Special monitoring – varies depending on truss condition, age, and traffic volumes.

Level II Truss Inspection

Preparation for Inspection

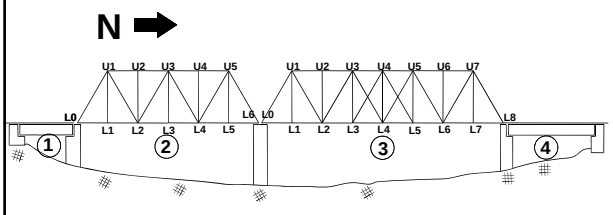
- Check previous reports
- Obtain inspection forms
- Hire ND inspection company
- Equipment for U/T
  - Ultrasonic testing machine with 60° and 70° probes
  - Coupling fluid
  - Spare batteries and charging unit
  - Extra probe and leads

Level II Truss Inspection

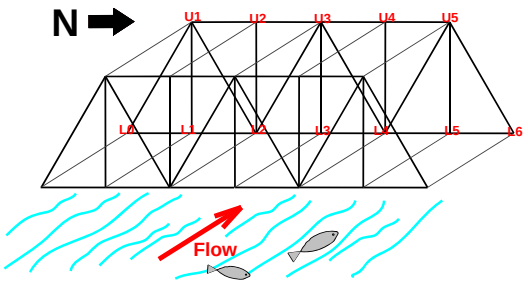
Preparation for Inspection

- Submit traffic safety and fall protection plans and obtain approval
- Access equipment:
  - Lift truck
  - Snooper truck
- Inspection tools
- Personal safety attire

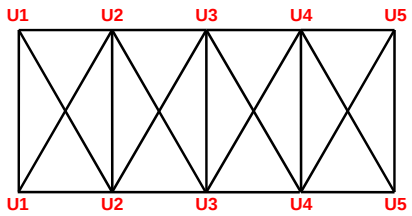
Truss Inspection



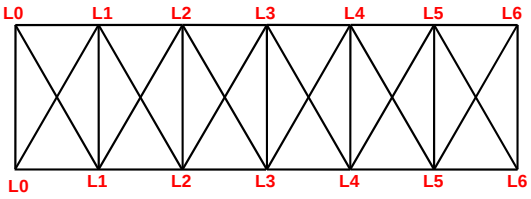
Truss Member Notation



Top Chord Bracing



Lower Chord Bracing



Level II Truss Inspection

Visual Inspection

- Check all members and connections for:
  - Cracks
  - Missing or loose bolts
  - Welds
  - Scabs, delamination, gouges and elongated holes
  - Note any strain indication
  - Note any collision damage
  - High water damage on bottom chord and bottom laterals

Level II Truss Inspection

Visual Inspection

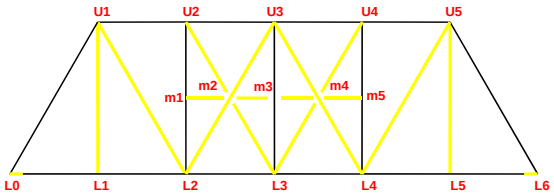
- Check all members and connections for:
  - Sags and buckling characteristics
  - Measure and report distortion
  - Floor beam copes
  - Report on extent of corrosion, pitting and section loss
  - Measure and report any top chord sweep for pony trusses
- Member/s requiring replacement shall be identified

Level II Truss Inspection

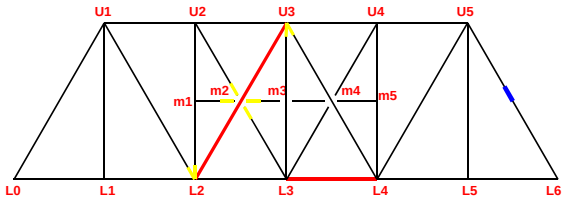
Visual Inspection

- Check posted and actual vertical clearance for through trusses
- Report condition of deck elements
- Check bearings
- Check railing

Level II Truss Inspection



Level II Truss Inspection



Level II Truss Inspection

Ultrasonic Inspection

- Report any rough holes
- Mark any member which has a crack
- Report all the findings on the U/T forms
- Try to determine the cause of cracking

Level II Truss Inspection

Photographs

- Take overall photograph of the entire bridge
- Take photographs to show condition of:
  - Deck, curbs, wheel guards
  - Bridgerail, bearings
  - Overall condition of paint
  - Typical underside
  - General condition of substructure
  - Specific problems

Level II Truss Inspection

Level II Truss Inspection

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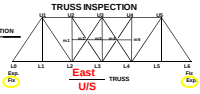
Level II Truss Inspection

Level II Truss Inspection

TRUSS INSPECTION

Edmonton
City of Champions

DIRECTION



East
U/S

TRUSS

MEMBER A END / B END	ULTRASONIC INS. A END	ULTRASONIC INS. B END	OTHER ITEMS	MEMBER A END / B END
TOP CHORD				
L0 - U1				✓
U1 - U2				✓
U2 - U3				✓
U3 - U4				✓
U4 - U5				✓
U5 - L6			Welded, UT done – no crack	✓
VERTICALS				
U1 - L1	✓	✓		✓
U2 - L2	✓	✓	Inward dent–20 x 200mm at L2	✓
U3 - L3	✓	✓		✓
U4 - L4	✓	✓		✓
U5 - L5	✓	✓		✓

BRIDGE NAME: Whitemud Ck SPAN NO. 2 OF 4 DATE: Yy-mm-dd FILE: xxxxx
TRUSS IDENT: A 75-3 6 PANEL TRUSS 90' FT./M. SPAN, INSPECTOR: J. Doe PAGE: 1

TRUSS INSPECTION
East
---------- TRUSS
U/S

MEMBER A END	MEMBER B END	ULTRASONIC INS. A END: No Crack	A END: Crack under Rivet Head	A END: Crack beyond Rivet Head	ULTRASONIC INS. B END: No Crack	B END: Crack under Rivet Head	B END: Crack beyond Rivet Head	OTHER ITEMS	MEMBER: Acceptable Member	MEMBER: Reject Member
DIAGONALS										
U1 - L2		✓			✓				✓	
U2 - m2		✓			✓				✓	
m2 - L3		✓			✓				✓	
U3 - L2		✓					✓	75mm dent and 12mm crack at L2		✗
U3 - L4		✓			✓				✓	
U4 - m4		✓			✓				✓	
m4 - L3		✓			✓				✓	
U5 - L4		✓			✓			bullet hole near middle at inside flange	✓	
m1 - m2		✓			✓				✓	
m2 - m3		✓			✓				✓	
m3 - m4		✓			✓				✓	
m4 - m5		✓			✓				✓	

BRIDGE NAME: Whitemud Ck SPAN NO. 2 OF 4 DATE: Yy-mm-dd FILE: xxxxx
TRUSS IDENT: A 75-3 6 PANEL TRUSS 90 FT./M. SPAN, INSPECTOR: J. Doe PAGE: 2

TRUSS INSPECTION
East
---------- TRUSS
U/S

MEMBER A END	MEMBER B END	ULTRASONIC INS. A END: No Crack	A END: Crack under Rivet Head	A END: Crack beyond Rivet Head	ULTRASONIC INS. B END: No Crack	B END: Crack under Rivet Head	B END: Crack beyond Rivet Head	OTHER ITEMS	MEMBER: Acceptable Member	MEMBER: Reject Member
BOTTOM CHORD										
L0 - L1		✓							✓	
L1 - L2									✓	
L2 - L3									✓	
L3 - L4		✓				✓		75 x 200mm dent near L4	✓	
L4 - L5									✓	
L5 - L6							✓		✓	
TOP CHORD BRACING (Note Truss Direction)										
U2E - U2W									✓	
U3E - U3W									✓	
U4E - U4W									✓	
U1W - U2E									✓	
U1E - U2W									✓	
U2E - U3W									✓	
U2W - U3E									✓	

BRIDGE NAME: Whitemud Ck SPAN NO. 2 OF 4 DATE: Yy-mm-dd FILE: xxxxx
TRUSS IDENT: A 75-3 6 PANEL TRUSS 90 FT./M. SPAN, INSPECTOR: J. Doe PAGE: 3

TRUSS INSPECTION
East
---------- TRUSS
U/S

MEMBER A END	MEMBER B END	ULTRASONIC INS. A END: No Crack	A END: Crack under Rivet Head	A END: Crack beyond Rivet Head	ULTRASONIC INS. B END: No Crack	B END: Crack under Rivet Head	B END: Crack beyond Rivet Head	OTHER ITEMS	MEMBER: Acceptable Member	MEMBER: Reject Member
TOP CHORD BRACING (Cont'd) (Note Truss Direction)										
U3E - U4W								20mm notch at C/L. Overall bow of 15mm.	✓	
U3W - U4E									✓	
U4E - U5W									✓	
U4W - U5E									✓	
PORTALS										
U1E - U1W									✓	
U5E - U5W									✓	

BRIDGE NAME: Whitemud Ck SPAN NO. 2 OF 4 DATE: Yy-mm-dd FILE: xxxxx
TRUSS IDENT: A 75-3 6 PANEL TRUSS 90 FT./M. SPAN, INSPECTOR: J. Doe PAGE: 4

TRUSS INSPECTION
East
---------- TRUSS
U/S

MEMBER A END	MEMBER B END	ULTRASONIC INS. A END: No Crack	A END: Crack under Rivet Head	A END: Crack beyond Rivet Head	ULTRASONIC INS. B END: No Crack	B END: Crack under Rivet Head	B END: Crack beyond Rivet Head	OTHER ITEMS	MEMBER: Acceptable Member	MEMBER: Reject Member
LOWER CHORD BRACING (Note Truss Direction)										
L0E - L1W									✓	
L0W - L1E									✓	
L1E - L2W								3mm section loss at horiz. gusset	✓	
L1W - L2E									✓	
L2E - L3W									✓	
L2W - L3E									✓	
L3E - L4W									✓	
L3W - L4E									✓	
L4E - L5W									✓	
L4W - L5E									✓	
L5E - L6W									✓	
L5W - L6E									✓	

BRIDGE NAME: Whitemud Ck SPAN NO. 2 OF 4 DATE: Yy-mm-dd FILE: xxxxx
TRUSS IDENT: A 75-3 6 PANEL TRUSS 90 FT./M. SPAN, INSPECTOR: J. Doe PAGE: 5

TRUSS INSPECTION

East TRUSS

U/S

MEMBER		ULTRASONIC INS.						OTHER ITEMS	MEMBER	
		A END			B END					
A BND	B BND	No Cracks	Crack under Bolt Head	Crack beyond Bolt Head	No Cracks	Crack under Bolt Head	Crack beyond Bolt Head		Accepts to Master	Reject to Master
FLOOR BEAMS										
L0 - L0								overall bow of 30mm	✓	
L1 - L1									✓	
L2 - L2									✓	
L3 - L3									✓	
L4 - L4									✓	
L5 - L5									✓	
L6 - L6									✓	

NOTE ANY STRINGERS, GUSSET PLATES, TOP CHORD BRACING STRUTS, HANDRAIL PANELS ETC. USE THIS SYSTEM OF NOTATION IF POSSIBLE AND MARK ON THE LINE DIAGRAM. BE SURE TO NOTE IF SPLICE PLATE IS INSIDE, OUTSIDE, UPPER OR LOWER ETC.

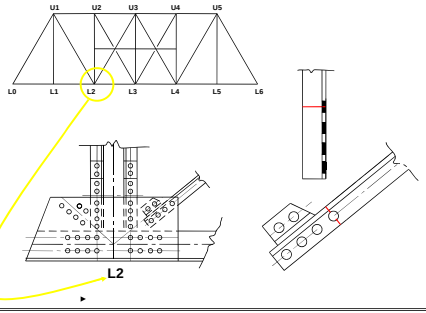
BRIDGE NAME: Whitemud Ck SPAN NO. 2 OF 4 DATE: Yy-mm-dd FILE: xxxxx

TRUSS IDENT: A 75-3 6 PANEL TRUSS 90' FT./M. SPAN, INSPECTOR: J. Doe PAGE: 6

Where to Find Cracks in Trusses?

- Damaged members.
- Tension members
- Rough holes
- Welds.
- Members with stress reversal

Truss Member Fatigue Crack



Questions??

Deck Joints and Bearings

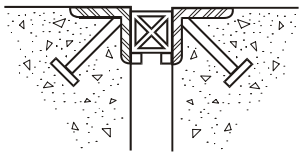
Deck Joints

- Purpose is to:
  - bridge the gap between spans
  - protect the ends of the girders
  - allow for expansion, contraction and rotational movement
  - prevent water and salt from leakage
- Most important features are:
  - watertightness
  - proper anchorage
- Can be fixed or expansion
  - fixed are for rotational movement only
  - expansion accommodate translation in addition to rotation

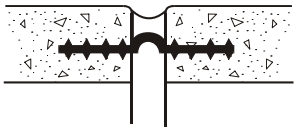
Deck Joints

- The main types of joints used on Alberta bridges are:
  1. Buffer angles
  2. Waterstops
  3. Sliding Plates
  4. Open Finger Plates
  5. Compression Seals
  6. Closed Finger Plates with Troughs
  7. Gland Joints
     - Open
     - Coverplated
  8. Thermoplastic Polymer Modified Asphalt
  9. Deck Joint Sealants
  10. Other Patented Devices/Processes
     - Fel Span
     - Interspan
     - Jeene

Deck Joints

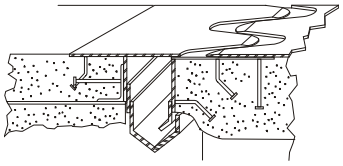


Compression Seal

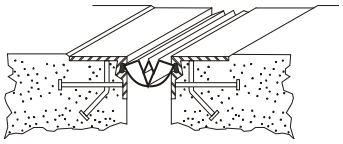


Waterstop

Deck Joints



Closed Finger Plates



Gland

Waterstop Joint

Buffer Angles for Fixed or Minor Expansion

Sliding Plate for Small Expansion Movements

Finger Plate Joint

Gland Cross-section

Close-up View of Gland Joint

"Honel" Gland Joint with Bolted Compression Connection

Cover Plated Joint

"Wabocrete" Joint

Two Component Elastomeric Material

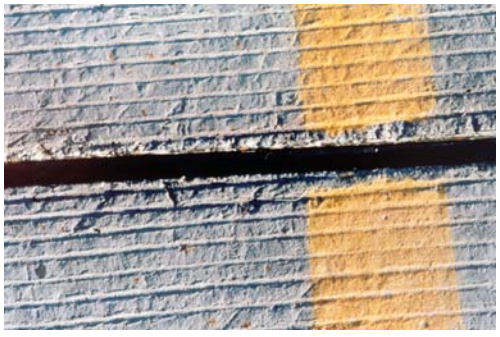
Placing Wabocrete

Completed Installation

"Koch" Joint with Elastomeric Material

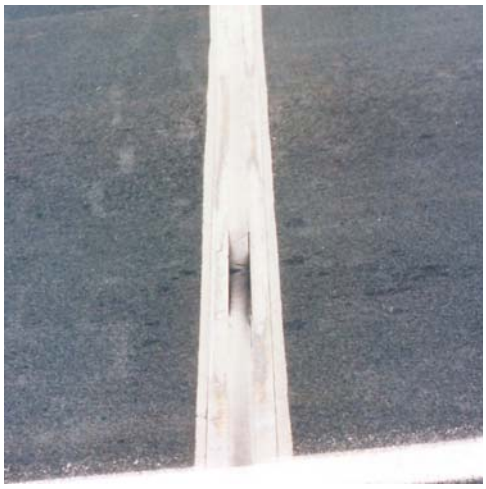
Complete Koch Joint

"Jeene" Joint Polymer Hot Pour



RCS Dow Corning Epoxy Joint

"Interspan" Joint



Transflex Joint

Problems and Inspection Considerations

Check for:

- watertightness of sealed joints
  - loose or torn seals
  - leakage or stains
- freedom of movement
- horizontal alignment
  - evenness of gap
  - fingers in alignment
- vertical alignment
  - joint aligned with deck
  - both sides of joint in alignment
- corrosion
- deteriorating concrete around anchorages, incomplete grout
- loose or missing bolts, coverplates or curb plates
- gouged, torn, cracked or broken
  - extrusions
  - angles
  - plates
  - fingers
  - welds

Finger Plate Joint with Broken Welds and Gap Under Fingers

Unmatched Finger Plate Joint, Snow Plow Guards & Plug Welded Fingers

Testing for Watertightness

Problems and Inspection Considerations

- Observe traffic passing over joints
  - listen for unusual noises and watch for movement of the joint
- Check drainage system
  - plugging of joint opening, troughs and downpipes with debris
  - corrosion
  - cracks, breaks or tears in any component
  - integrity of attachments and connections
    - loose or missing bolts
    - cracked or broken welds
    - loose or open connections
  - Check for:
    - signs of ponding on the deck
    - staining or deterioration on the deck, curbs, girders and substructure
    - erosion below downpipe

Hole in Gland Joint

Coverplate Missing Bolts

Wabo-crete Joint with De-bonded Material and Exposed Bars

Inspection Form and Rating

- Record temperature
- Verify joint type
  - fixed
  - expansion
- Measure and record average gap width in millimeters for each joint

Deck Joint Inspection and Rating

- Rate according to existing condition and functionality
- Includes condition and functionality of drainage system
- Leakage of sealed joints is reflected in both the deck joint rating and the deck drainage rating
- Defects in open joints with plumbing features are also reflected in both the deck joint rating and the deck drainage rating
- Leakage problems with open joints without plumbing are rated under deck drainage only
- Curb cover plates are rated with the deck joint and not the curb rating

Deck Joint Inspection and Rating

- Joints that are not fully free to move
  - rate 4 or less
- Watertight joints which allow leakage of water onto girders, bearings or substructure
  - rate 4 or less
- Open (non-watertight) joints should not be down rated because of leakage
- Joint defects causing problems with structure rate 3 or less
- Joints which are a hazard to traffic
  - rate 2

Bearings

- Bearings must transfer loads from the superstructure to substructure.
- The bearings accommodate movement caused by temperature changes, deflection, earth pressures, etc.
- Bridge bearings are generally classified as fixed or expansion type.
- Fixed bearings allow rotation but no vertical or horizontal movement.
- Expansion bearings allow both rotation and longitudinal movement of the superstructure. Expansion bearings sometimes also permit transverse movement.

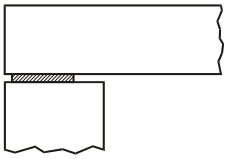
Bearings

- There are usually three distinct components in a bearing:
  - Sole plate
    - steel plate welded, bolted, riveted or cast to bottom of girders
  - Masonry plate
    - similar to sole plate except located on top of substructure element and usually anchored by bolts into concrete
  - Bearing
    - assembly between sole plate and masonry plate that permits movement of the bridge

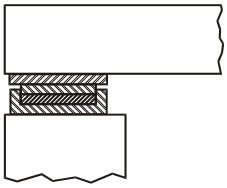
Bearings

- The main types of bearings used on Alberta bridges are:
  1. Elastomeric pads
     Usually neoprene (reinforced or plain) and sometimes incorporating stainless steel and teflon for expansion
  2. Rockers
     Massive steel "pie-shaped" bearings designed for large movements
  3. Pot
     Consists of an elastomeric pad confined by a heavy steel ring and loaded vertically by a cover component. Pot bearings can allow movement in one or more directions, can be fixed and can be designed to resist uplift.
  4. Spherical bearings
     Made of spherical machined steel plates that nest together to allow rotation and may have allowance for horizontal translation
  5. Rollers
     Cylindrical steel bearings either in the form of a single roller or in a group (nest). Rollers allow rotation and horizontal movement in one direction.
  6. Others
     - steel sliding plates (sometimes with a bronze insert)
     - disc bearings (round, confined polyurethane pad)

Bearings

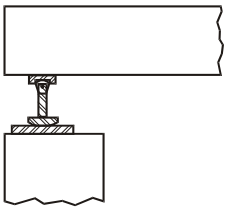


ELASTOMERIC PAD

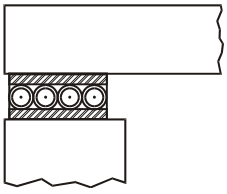


POT BEARING

Bearings

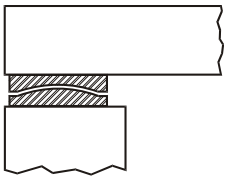


ROCKER BEARING

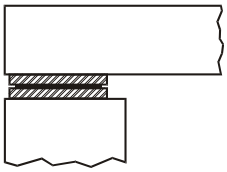


ROLLER BEARING

Bearings



SPHERICAL BEARING



BEARING WITH SLIDING SURFACE

Elastomeric Bearing Showing Pintel, Anchor Bolts, Sole and Masonry Plates

Elastomeric Expansion Bearing with Teflon & Stainless Steel

Pot Bearing

Sliding Plate Under Truss

Rocker Bearing Under Girder

Expansion Rocker Bearings

Roller Bearing Under Concrete Girder

Three Roller System Under Concrete Girder

Rocker/Roller Bearing Under Truss

Sliding Plate with Self-Lubricating Bronze Plate (Type PO Girders)

Bearings

Problems and Inspection Considerations

- Dirt or debris
  - may inhibit movement
  - promotes corrosion
- Corrosion
  - "frozen" bearing (2016 bulletin regarding "Type O" bearings)
  - deterioration of bearing
  - especially under leaking joints
- Loose or missing connections, cracked or broken welds
- Loss of bearing contact or uneven contact
  - rollers moved off masonry or sole plates
  - neoprene pads creeping out of position
  - can overstress steel or concrete members

Bearings

Problems and Inspection Considerations

- Wear
- Rocker alignment
  - overextension
  - should be approximately vertical at 0^0 Celsius
- Failure of elastomer
  - splitting, cracks, squeezing out, bulging
  - separation of the elastomer at reinforcing plates

Bearings

Problems and Inspection Considerations

- Anchor bolts
  - corrosion (strike with hammer)
  - bent
  - surrounding concrete cracked
  - nuts not properly secured (jam nut), nuts missing
  - binding on shoe plate or bearing device
- Indications of a non-functioning bearing
  - cracks in the bearing area of the substructure or superstructure
  - uneven gaps at expansion joints
    - bump at joint
    - variable gap in same joint
    - jammed joint
    - joint gap too wide
  - misalignment of superstructure at joint
  - unusual noise or movement under traffic

Bearings

Inspection Form and Rating

- Record temperature
- Record or verify bearing types and locations:
  - expansion
  - fixed
- Record or verify if coating is intact and functioning to protect the bearing from corrosion
- Record or verify whether the bearing is functioning as designed
  - proper bearing
  - proper movement

Bearings

Inspection Form and Rating

- If bearings are functioning properly and are in excellent condition but have inadequate coating
  - rate 7 or 8
- Bearings require resetting
  - rate 4 or less
- Bearings movement inhibited by dirt, debris or corrosion
  - rate 4 or less
- Concrete elements with wide cracks or visual signs of damage (not accessible for sounding) at bearing locations
  - Rate 3 or less (from 2016 Bulletin)
- Cracked hanger bearings
  - rate 2

Displaced Neoprene Pad

Extended Rocker Bearing

Failed Rocker/Roller Bearing

Displaced Roller Nest

Failed Sliding Plate with Self-Lubricating Bronze Plate Bearing

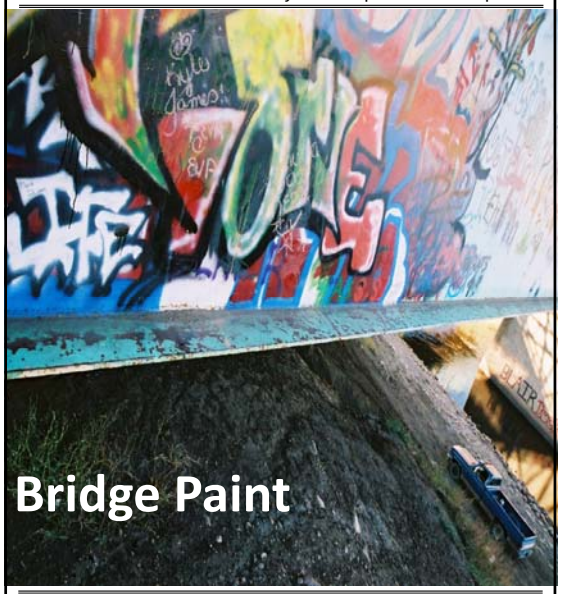
Failed Sliding Plate with Self-Lubricating Bronze Plate Bearing

BIM Advisory Bulletin #3

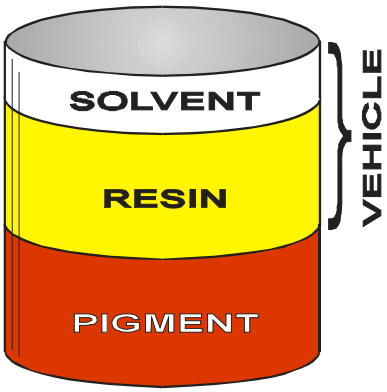
- Performance issues related to steel sliding plate bearings with self-lubricating bronze plates.
- Primarily found under Type “PO” girders between 1955 and 1965, and detailed on Standard Drawing S-701.
- Inspectors should be completely familiar with the details of this recent bulletin. Refer to the following link:

http://www.transportation.alberta.ca/4827.htm

Questions??



PAINT



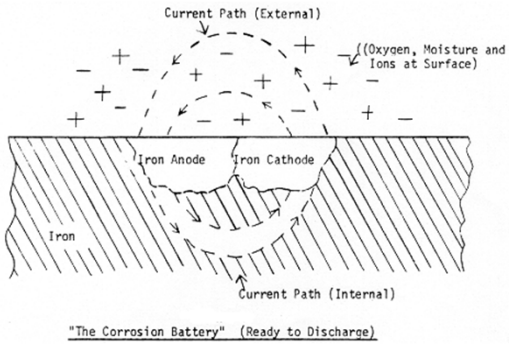
Types of Paint

Paints are generally solutions of solids such as pigments and other chemicals in a liquid carrier or vehicle used for transporting the solids to a surface needing protection. At the surface they may react chemically to polymerize. Some common types are:

1. latex coatings - emulsion in water (acrylics and vinyls)
2. lacquers - solutions in which the solid resins do not change or react as the solvent evaporates they become hard (chlorinated rubber, asphaltic coatings)
3. air oxidizing coatings - oil based coatings that react with oxygen to harden (alkyds, epoxy esters, linseed oil)
4. chemically reactive coatings - two component polymers sometimes without solvent (epoxy, urethanes)

Corrosion

1. Caused by thermodynamic instability of steel.
2. Is an electrochemical process.
3. The rate of corrosion is based on electric current generated by potential (voltage) differences with the steel.
4. Ohms Law: (current) $I = \frac{E \text{ (voltage)}}{R \text{ (resistance)}}$



"The Corrosion Battery" (Ready to Discharge)

Chemical Reaction (1st Stage)

Anode (where visible corrosion occurs)

(iron) Fe $\longrightarrow$ Fe^{++} (ions) + $2e^-$ (electrons)

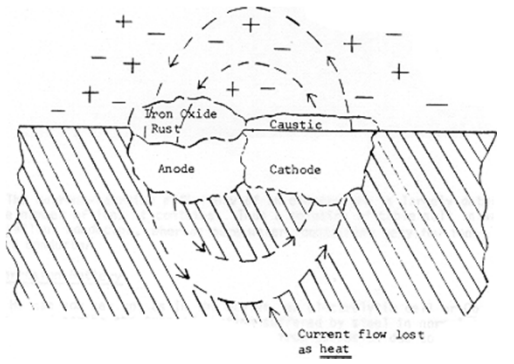
Cathode (adjacent protected area)

a) $2H^+ + 2e^- \longrightarrow H_2$ (hydrogen gas)

b) $4H^+ + O_2$ (air) + $4e^- \longrightarrow 2H_2O$ (water)

c) $O_2 + 2H_2O + 4e^- \longrightarrow 4OH^-$ (alkali)

The alkali buildup attacks some paints.



Chemical Reactions (2nd and 3rd Stages)

Fe^{++} (@ anode) + $2OH^-$ (@ cathode) $\longrightarrow$ $Fe_2(OH)_2$ (rust)

$2Fe(OH)_2 + O_2 \longrightarrow Fe_2O_3$ (iron ore hematite) + H_20

Requirements For Corrosion

1. thermodynamically unstable metal (iron)
2. electrolytic conduction of ions (water)
3. electrical conductor of electrons (metal)
4. electron acceptor (hydrogen ions or dissolved oxygen)

Corrosion Current At Breaks in Paint Coating

$$\text{electrical current } I = \frac{(PA - A_p) - (PC + C_p)}{RD\ t + RL + RC\ t}$$

PA = electrical potential @ anode

PC = electrical potential @ cathode

A_p = electrical potential @ anode from buildup of corrosion by products

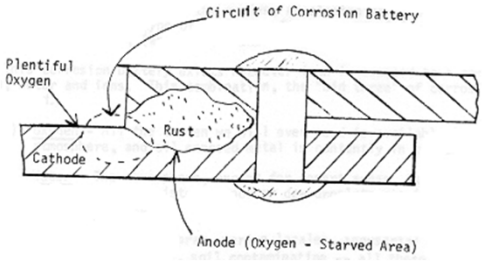
C_p = electrical potential @ cathode from buildup of corrosion by products

RD = electrical resistance at the discontinuity (electrolyte)

RL = electrical resistance of the moisture outside the discontinuity

RC = electrical resistance of the coating

t = coating thickness



Pack Rust or Crevice Corrosion

Pack Rust

Perforated Bottom Chord

Distorted and Perforated Plate Due to Pack Rust

How Paint Works To Prevent Corrosion

1. Eliminates the electrolyte (separates it from the steel)
2. Increases the electrical resistance of the corrosion circuit
3. Reduces the concentration of electron acceptors (H^+ and O_2)

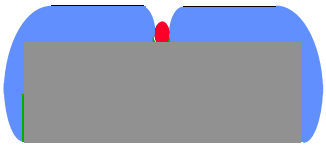
Paint System Design

1. Primer Layer:
   - a) inhibitive
   - b) barrier (increase RC t)
   - purpose - increase A_p, C_p and R
2. Intermediate Layer:
   - a) increase R
   - b) reduces pinholes and permeability
3. Topcoat:
   - a) ultraviolet resistance
   - b) colour
   - c) toughness

Wet Paint on Steel – Trapped Air

- Paint thins on drying in relation to solids content
- 60% solids – 5mils wet – 3 mils dry

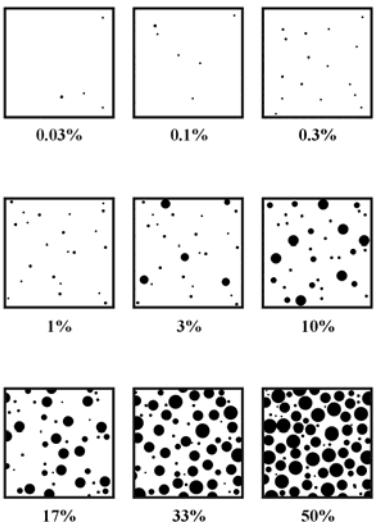
Results in a Pinhole



Physical Properties of Existing Paint Needed For Encapsulation

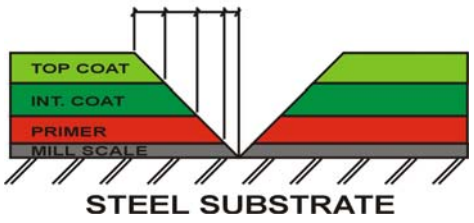
1. rust condition ≥ 7 (ASTM D610)
2. thickness ≥ 3, ≤ 12 mils
3. flexibility - chisel test
4. adhesion between layers and to substrate
5. Chalking
6. Substrate (Tooke Test)

ASTM D 610

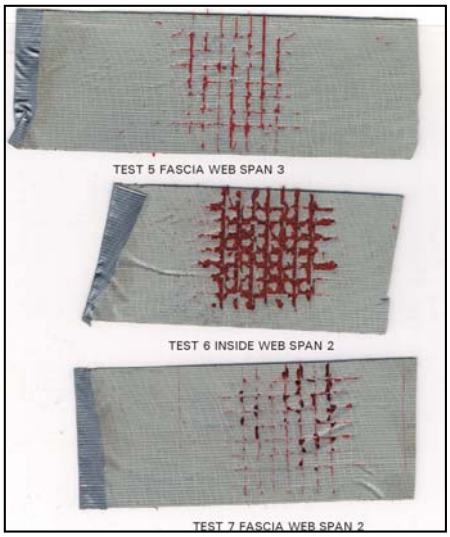


Blisters and Scaling

TOOKE TEST



CLASSIFICATION	SURFACE OF CROSS-CUT AREA FROM WHICH FLAKING HAS OCCURRED.
5B	NONE
4B	(1% TO 5%)
3B	(6% TO 15%)
2B	(16% TO 35%)
1B	(36% TO 65%)
0B	GREATER THAN 65%



Cause of Painting Cost Escalation

Various environmental and safety regulations concerning the removal and disposal of lead based paints.

LATE 1980's	NO CONTAINMENT	$ 15 TO $ 20 / M^2
EARLY 1990's	ENCLOSURE	$ 50 TO $ 60 / M^2
MID 1990's	80% RECOVERY	$ 80 TO $ 100 / M^2
1999	90% RECOVERY	$ 120 TO $ 140 / M^2
2002	90% RECOVERY	$ 180 TO $ 200/M^2
2004	90% RECOVERY	$ 225/M^2
2006	90% RECOVERY	$ 300 TO $ 350/M^2

Alberta Transportation Class A Bridge Inspection Course

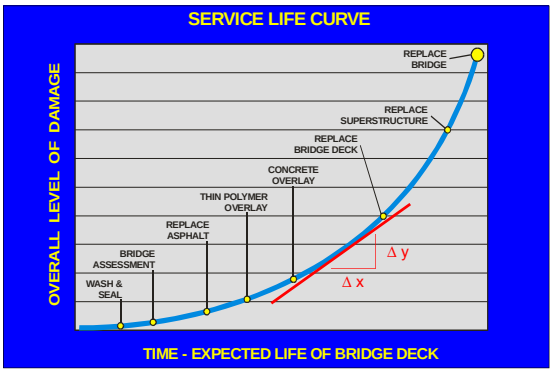
Level II Inspection of Concrete Bridge Elements

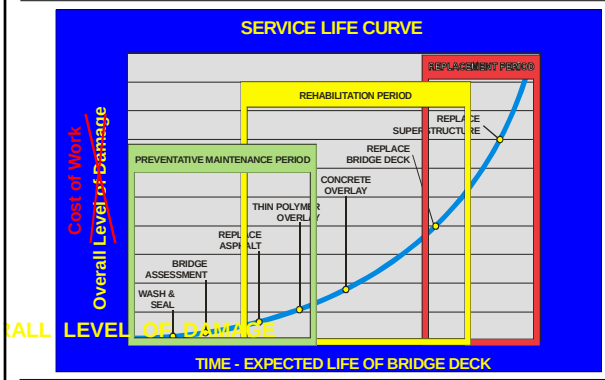
Overview

- Function of Level II Inspections for Concrete Bridge Elements
- Level II Concrete Inspection/Test Methods
  - Equipment
  - What does test data indicate
  - How is the data used

Level II inspections prevent surprises

This Didn't Happen Overnight



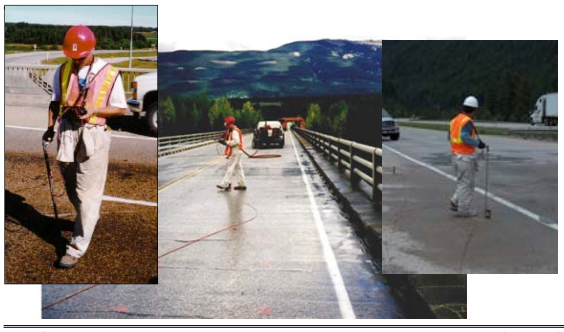


Alberta Transportation Level II Inspections of Concrete Elements

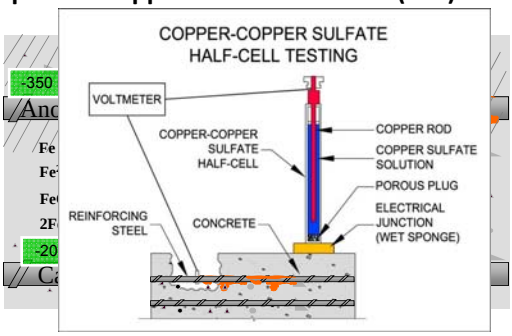
Level II BIM Manual

- Chapter 2 - Concrete Deck Inspection
- Chapter 3 - Copper Sulfate Electrode Testing
- Chapter 4 - Chloride Testing

Chapter 3 - Copper Sulfate Electrode (CSE)



Chapter 3 - Copper Sulfate Electrode (CSE) Testing



Chapter 3 - Copper Sulfate Electrode (CSE) Testing

ASTM C876 Interpretation of Results

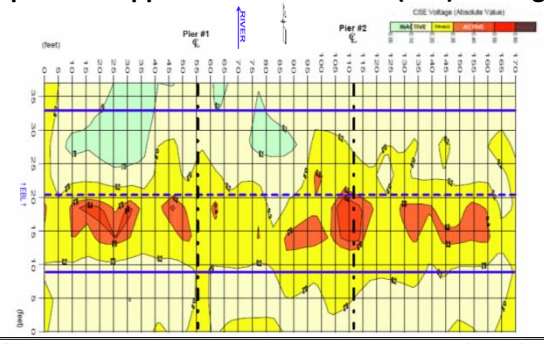
INACTIVE AREA (0 to – 0.2V):
95% Probability that active corrosion is not occurring

TRANSITION AREA (-0.2V to – 0.35V):
Potential for active corrosion indeterminate

ACTIVE AREA (-0.35V to – 0.8V):
95% Probability that active corrosion is occurring

Half-Cell Potential (Absolute Value)	Percent of Test Area	
0.000 to 0.099 V	0.0	1.4
0.100 to 0.199 V	1.4	
0.200 to 0.299 V	20.8	33.6
0.300 to 0.349 V	12.7	
0.350 to 0.399 V	14.7	65.0
0.400 to 0.499 V	30.3	
0.500 to 0.599 V	19.5	
0.600 to 0.699 V	0.5	
0.700 to 0.799 V	0.0	

Chapter 3 - Copper Sulfate Electrode (CSE) Testing



Chapter 3 - Copper Sulfate Electrode (CSE) Testing

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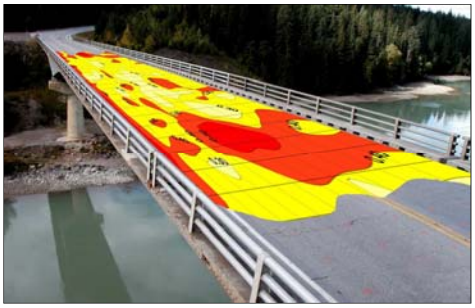
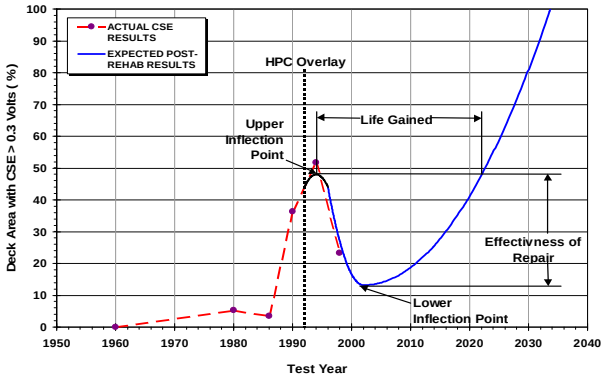
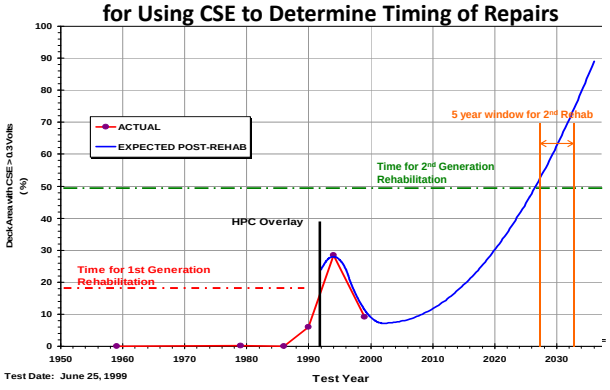


CSE Prediction Model



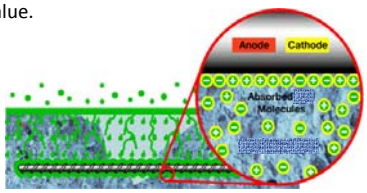
Alberta Transportation Guidelines for Using CSE to Determine Timing of Repairs



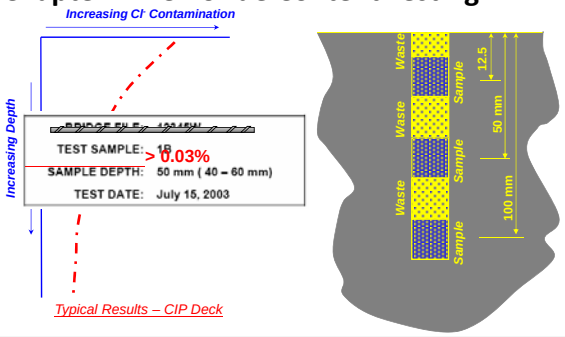
Chapter 4 – Chloride Content Testing

Chapter 4 – Chloride Content Testing

0.03 % Chloride per unit weight of concrete is known as the corrosion threshold value.



Chapter 4 – Chloride Content Testing



Chapter 4 – Chloride Content Testing

Rapid Chloride Test Method

Advantages
- Speed of testing
- Economical
- Tests completed on site

Disadvantages
- Testing completed on site
- Not to be taken on decks with waterproofing membranes in good condition

Chapter 4 – Chloride Content Testing

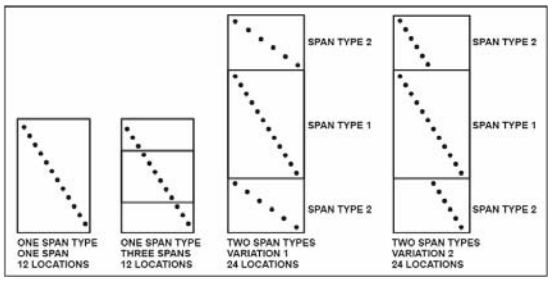
RCT-500

Calibration Liquids

Electrode Solution

Chapter 4 – Chloride Content Testing

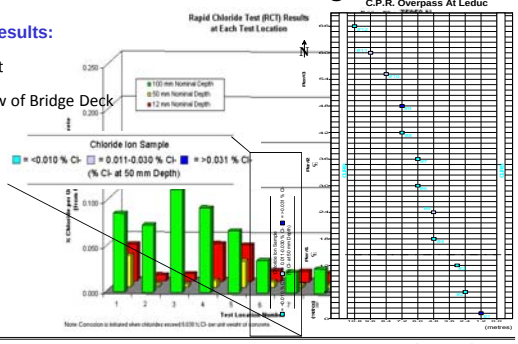
Selection of Test Locations:



Chapter 4 – Chloride Content Testing

Typical Results:

- Bar Chart
- Plan View of Bridge Deck



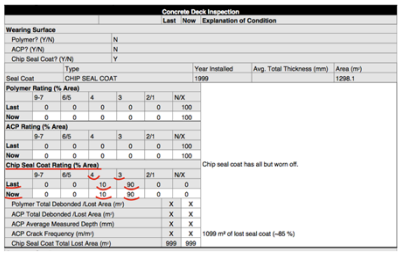
Chapter 2 – Concrete Deck Inspection

- **Quantitative** – Rating Methodology Different than Level I
- **Programmed** – Cyclic Basis to Monitor Condition
- **Specialized tools** – For Portions of the Inspection

Chapter 2 – Concrete Deck Inspection

Rating Methodology:

Rating	
9	Very Good
8	
7	Good
6	
5	Adequate
4	
3	Poor
2	
1	Immediate Action



Chapter 2 – Concrete Deck Inspection

Level II Concrete Deck Inspection Form Sections:

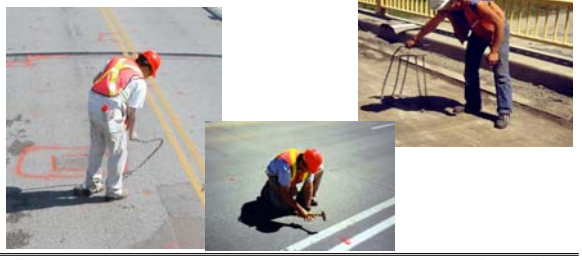
- Wearing Surface
- Concrete Overlay
- Concrete Deck
- Edge Elements (curbs/barriers/ medians/sidewalks)
- Deck Joints

Chapter 2 – Concrete Deck - Wearing Surface

								Last	Now	Explanation of Condition
Wearing Surface										
Polymer? (Y/N)									Y	
ACP? (Y/N)									N	
Chip Seal Coat? (Y/N)									Y	
			Type					Year Installed	Avg. Total Thickness (mm)	Area (m²)
Seal Coat			CONVENTIONAL CHIP SEAL COAT					2004		1892.2
Polymer Rating (% Area)										
	9-7	6/5	4	3	2/1	N/X				Covered by seal coat.
Last										
Now									100	
ACP Rating (% Area)										
	9-7	6/5	4	3	2/1	N/X				
Last										
Now									100	
Chip Seal Coat Rating (% Area)										
	9-7	6/5	4	3	2/1	N/X				There are areas of lost chip and epoxy.
Last										
Now			95	5						
Polymer Total Debonded /Lost Area (m²)									222	
ACP Total Debonded /Lost Area (m²)									X	
ACP Average Measured Depth (mm)									X	
ACP Crack Frequency (m/m²)									X	
Chip Seal Coat Total Lost Area (m²)									146	

Chapter 2 – Concrete Deck Inspection

Deck Delamination Survey
– ASTM D4580



Chapter 2 – Concrete Deck Inspection

Measured Damage:

Chapter 2 – Concrete Deck Inspection - Concrete Overlay

Concrete Overlay

Overlay? (Y/N): Y

(Span Type : CT)

(Span Numbers : **1, 2, 3, 4**)

(Overlay type : **CONCRETE (HIGH DENSITY)**)
(Area(m²) : **1298.1**)
(Year Installed : **1978**)
(Thickness(mm) : **50**)
(Average Cylinder Strength(Mpa) :)

Overlay Rating (% Area)

	9-7	6/5	4	3	2/1	N/X
Last	0	70	10	0	0	20
Now	0	65	15	0	0	20

Partially covered by chip seal coat.

There is widespread cracking along the overlay. Several core patches are deteriorated.

	Last	Now	Explanation of Condition
Total Crack Length - Medium/Wide (m)	371	453	
Total Scaled Area - Light (m²)	0	0	
Total Scaled Area -Moderate/Heavy/Severe (m²)	0	0	
Debonded Area (m²)	84	30	
Spalled Area (m²)	1	1.5	
Patched Area (m²)	0	0	
Average Measured Cover Depth (mm)	100	102	
Standard Deviation of Measured Cover Depth (mm)	14	15	

Chapter 2 – Concrete Deck Inspection - Concrete Deck

Deck

(Span Type : CT)

(Span Numbers : **1, 2, 3, 4**)
(Deck Type : **CONCRETE (CLASS C)**)
(Area(m²) : **1298.1**)
(Year Constructed : **1957**)
(Year Widened :)
(Thickness(mm) : **150**)
(Average Cylinder Strength(MPa) :)

	Type	Size	Design Cover (mm)	Spacing (mm)
Long. Reinforcing	REINFORCING STEEL	10	25	750
Trans. Reinforcing	REINFORCING STEEL	15	25	190

Deck Top Rating (% Area)

	9-7	6/5	4	3	2/1	N/X
Last	0	0	0	0	0	100
Now	0	0	0	0	0	100

	Last	Now
Total Crack Length - Medium/Wide (m)	N	N
Total Scaled Area - Light (m²)	N	N
Total Scaled Area - Moderate/Heavy/Severe (m²)	N	N
Delaminated Area (m²)	N	N
Spalled Area (m²)	N	N
Patched Area (m²)	N	N
Average Measured Cover Depth (mm)	N	N
Standard Deviation of Measured Cover Depth (mm)	N	N

Deck Underside Rating (% Area)

Could not inspect span 3 due to water levels.

	9-7	6/5	4	3	2/1	N/X
Last	0	74	1	0	0	25
Now	0	74	1	0	0	25

Staining between G1/G2 on the south span.
There is flexual and shear cracking along the CT girders.
There are narrow to medium wide transverse cracks in the deck underside. Isolated spalled patch between G2/G3 S4 (north span).

	Last	Now
Total Stained Area - Moderate (m²)	0	1
Total Stained Area - Heavy/Severe (m²)	0	0
Total Crack Length - Medium/Wide (m)	140	175
% of Medium/Wide Cracks Stained	80	85

Chapter 2 – Concrete Deck Inspection - Edge Elements

Edge Elements

Curbs? (Y/N): Y
Parapets? (Y/N): N

	Last	Now	Explanation of Condition
Medians? (Y/N)	N		
Sidewalks? (Y/N)	N		

Curbs...

(Type : **CONCRETE**)
(Total Length(m) : **170.8**)
(Height(mm) : . .)
(Width(mm) : . .)
(Average Cylinder Strength(MPa) : . .)

Reinforcement Type	Size	Design Cover (mm)	Spacing (mm)
	10	50	600

Curb Rating (% Length)

	9-7	6/5	4	3	2/1	N/X
Last	0	100	0	0		
Now	0	100	0	0	0	0

Transverse cracking.

	Last	Now	Explanation of Condition
Total Crack Length - Medium/Wide (m)	38	56	
Total Scaled Length - Light (m)	4	5	
Total Scaled Length - Moderate/Heavy/Severe (m)	0	0	
Delaminated Length (m)	0	0	
Spalled Length (m)	0.1	0.1	Isolated areas of exposed rebar due to insufficient concrete cover along the west curb.
Patched Length (m)	7	9	
Average Measured Cover Depth (mm)	64	73	
Standard Deviation of Measured Cover Depth (mm)	21	14	

Chapter 2 – Concrete Deck Inspection - Deck Joints

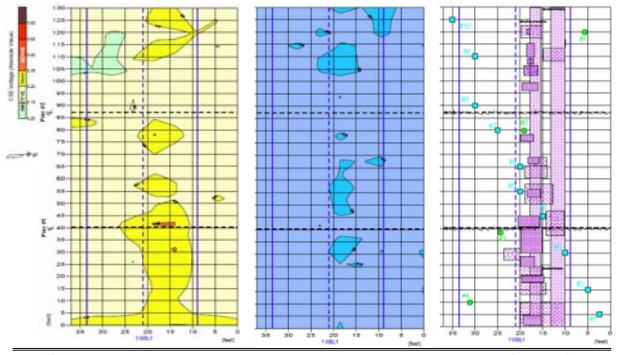
Deck Joints

(Type : **GLAND (WABO-MAUER, TRANSFLEX, ETC)**)
(Number of Joints : **2**)
(Expansion / Fixed? : **EXPANSION**)
(Location : **A1, A2**)

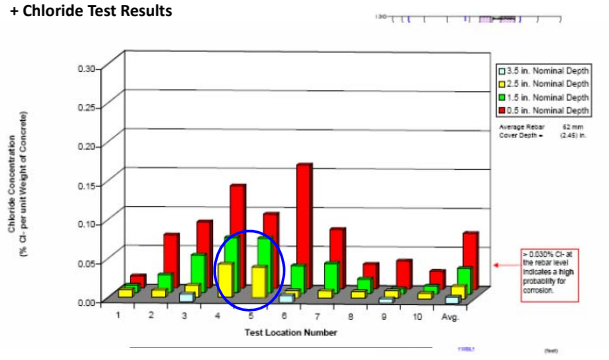
% Inspected	100	100	Inspected joints after a hard snow/rain, no leakage was observed.
% Joints Leaks	0	0	
% Joint Length Leaks	0	0	There are horizontal cracks in the abutments. There are vertical cracks along the piers.
Superstructure Damage Rating	6	6	
Substructure Damage Rating	6	5	
Level 1 Joint Rating	7	7	

Concrete Cover Measurement

CSE Results **+ Cover Depth Results** **+ Deck Inspection Results**



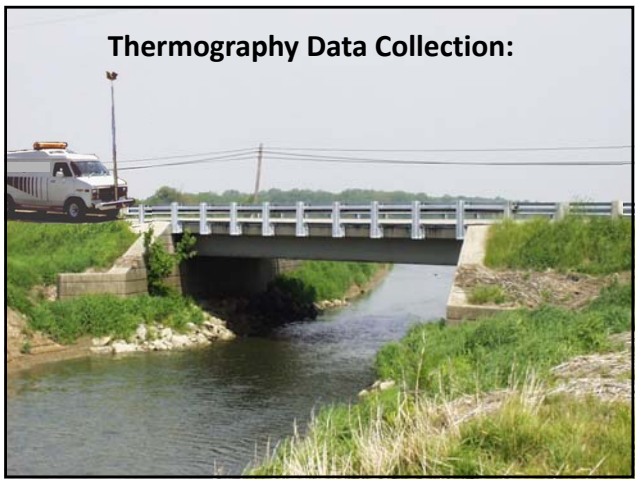
+ Chloride Test Results



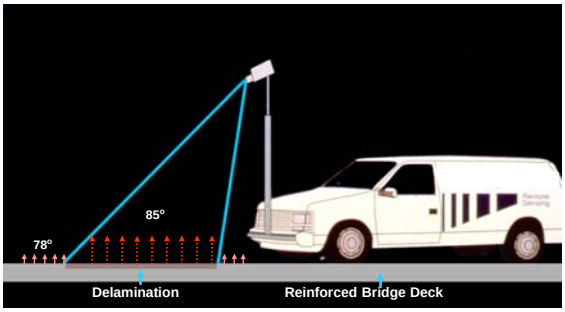
Other Level II Inspection/Testing Methods for Concrete Bridge Elements:

- Thermography
- Ground Penetrating Radar (GPR)
- Schmidt Hammer
- Coring
- Linear Polarization

Thermography Data Collection:

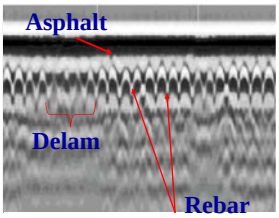


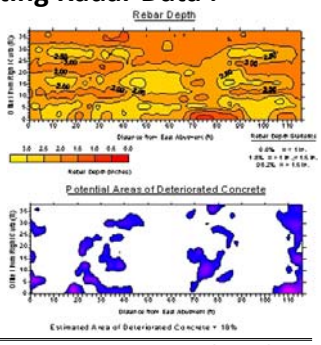
Thermography



Ground Penetrating Radar Data Collection:

Ground Penetrating Radar Data :





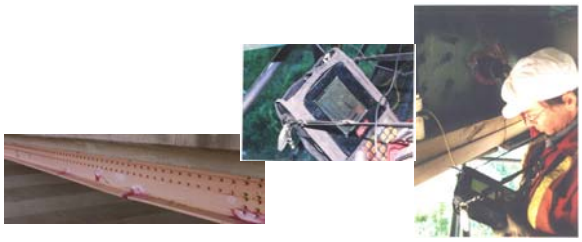
Schmidt Hammer:

Coring:

Linear Polarization Testing:

QUESTIONS ???

Advanced Inspection of Steel Elements



Methods of Inspection

- Level II inspection in steel elements is made if cracks or potential for cracks or faults is present.

Visual

- Important for detecting degradation
- Logical and systematic procedures
- Used to establish non-destructive testing (NDT) techniques

Methods of Inspection

Non-Destructive Testing

- To supplement visual inspection
- To define the extent of faults

Non Destructive Test Methods

Dye Penetrant Inspection

- Surface requires mechanical cleaning
- Low viscosity, high capillary fluid containing red dye is sprayed and allowed to penetrate the cracks and surface defects
- Excess fluid is wiped from the surface after a penetration time
- Surface sprayed with a developer
- Cracks and faults will be apparent by drawn red dye on a surrounding white background

Non-Destructive Test Methods

Dye Penetrant Inspection

- Advantages: Low cost, requires minimal skills, portable, not time consuming, can identify extent of surface cracks
- Disadvantages: Limited to surface defects

Non-Destructive Test Methods

Magnetic Particle Inspection

- Yoke is used to produce a magnetic field in the steel
- Fine iron powder is sprayed on the surface
- Field is distorted by surface or near surface discontinuities causing concentrations of magnetic lines
- Iron powder is drawn to these lines

Non-Destructive Test Methods

Magnetic Particle Inspection

- Advantages: portable, requires minimal skills and can define tight cracks
- Disadvantages: limited to the inspection of cracks and surface defects near the surface. Depth of cracks cannot be determined and element may become magnetized.

Non-Destructive Test Methods

Hardness Testing

- Used to determine if mechanical properties have changed. System can be used for determining degradation after fire damage.
- Telebrineller system principle is comparing hardness of a known test bar to the bridge element hardness
- Equipment: Anvil, steel impression bar, microscope, hammer

Non-Destructive Test Methods

Hardness Testing

- Anvil is placed on the element and struck. Impact is transmitted to the test bar and the specimen element.
- Steel ball makes an impression in the test bar and the element
- Diameters are measured and read through a microscope to within 0.05 mm

Non-Destructive Test Methods

Hardness Testing

$$\left(\frac{\text{Dia of Impression In Bar}}{\text{Dia of Impression In Metal}}\right)^2 \text{ x BHN of Test Bar = BHN of Specimen Material}$$

- BHN has a correlation to the tensile strength of steel
- Advantages: equipment is light weight, portable, reasonably accurate and requires no special training

Non-Destructive Test Methods

Eddy Current

- Similar to MPI, except a defect is detected by disturbances in an electrical field
- Technique involves the use of a coil carrying an alternating current, which produces an eddy current in the part being examined
- Eddy current creates an impedance in the exiting coil
- Impedance depends on the nature of the part being tested and the exiting coil, magnitude and frequency of the current and the presence of discontinuities in the part
- Change is read from a meter

Non-Destructive Test Methods

Eddy Current

- Advantages: size and depth of defects can be estimated reasonably and surface conditions such as paint do not affect scanning
- Disadvantages: changes in geometry affect the impedance and recalibration is required
- Limited use but has potential

Non-Destructive Test Methods

Radiography

- Used to detect macroscopic defects and discontinuities
- Testing is based on the ability of radiation such as gamma rays to penetrate metal and other opaque materials to produce an image on sensitive film
- Gamma rays are produced by the disintegration of radioisotopes or radium of which cobalt or iridium are common sources

Non-Destructive Test Methods

Radiography

- Source is housed in a lead capsule to avoid radiation danger when not in use
- Amount of radiation getting through section being tested depends on section and density
- Defects result in less steel to pass through and more radiation gets on to the film placed behind the section
- Defect size and shape shows up as a dark area on the film

Non-Destructive Test Methods

Radiography

- Planar defects are only detectable if they are parallel to the source axis due to radiation absorption
- Accuracy is dependent on the section and location of the crack
- Fatigue cracks to 2% of thickness can be detected

Non-Destructive Test Methods

Radiography

- Advantages: permanent record and size and shape are determined
- Disadvantages: cannot detect planar defects and depth of cracks, hazardous and government licensing is required

Non-Destructive Test Methods

Ultrasonics

- Uses high frequency sound waves to detect flaws
- Discontinuities act as a reflector for high frequency vibrations
- Sound waves are produced by a wave generator and receiving pulses are displayed on a cathode ray oscilloscope
- Ultrasonic frequency is 2 MHz or approximately 9500 ft/sec.

Non-Destructive Test Methods

Ultrasonics

- Sound waves are transmitted by contact through a crystal and an intervening couplant
- Depth, size and nature of the defects are determined from the return signal on the oscilloscope
- Signal corresponds to elapsed time between transmission and reception

Non-Destructive Test Methods

Ultrasonics

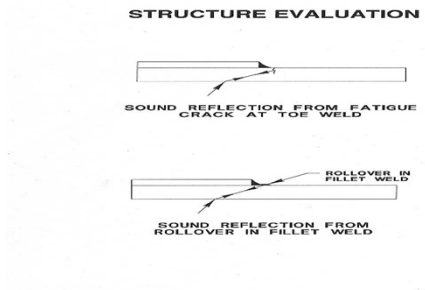
- Time can be converted to distance because the angle and velocity are known
- Sensitivity is influenced by the sound frequency, design of the unit, instrumentation processing of the return signal on the oscilloscope and operator skill

Non-Destructive Test Methods

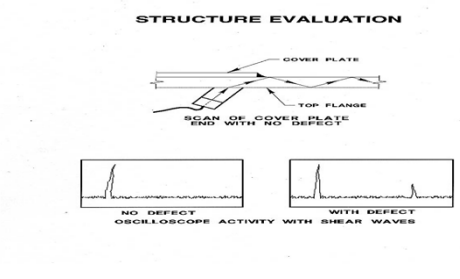
Ultrasonics

- Advantages: portability, sensitivity, ability to detect locations and depth of defects
- Disadvantages: influenced by operator ability, no permanent record of the display and it can be too sensitive displaying very minor defects

Non-Destructive Test Methods



Non-Destructive Test Methods



Methods of Inspection

- It is important for the inspector to evaluate the damage and recognize the potential faults.
- The visual assessment can be used to establish non-destructive testing (NDT) techniques to supplement the visual inspection and define the extent of faults or damage.
- Assess the significance of damage on the load carrying capacity.

Questions??

Sign Structure Inspection and Rating

Introduction

- Signing for Interchanges
- Naming Convention
  - Site file number 75760
  - Visual identifiers
    Z = sign structure
    N,S,etc = direction of approach
  - Structure number
    2= 2nd structure (travelling north)
  - Example 75760-ZN-2
- Rating and Recording same as for other structures

Inventory Data

- Verify and update

Utilities

- Note and record
- Most structures have lights

Approach Road / Safety Features

- Horizontal and vertical alignment
  - rate same as Chapter 6 of BIM
- Traffic Safety Features
  - refers to all flashing lights, barriers, signs, etc. (not guardrail)
  - rate function and condition
- Guardrail
  - rate according to Chapter 6 of BIM
  - record length
  - meets standard Yes / No
    - W-Beam 550mm above road, 1950 post space & turn down end
  - guardrail termination type

Substructure

Substructure			
Bridge Component	**Last**	**Now**	**Explanation of Condition**
Pedestal			
(Total number :)			
(Type :)			
(Offset from Shoulder (m) :)			
Column			
(Type :)			
Connections			
Coating			
Substructure General Rating			

- Substructure accommodates
  - DL of sign structure
  - LL such as wind etc.

Substructure (Cont'd)

- Pedestal
  - base for column attachment (usually concrete)
  - check for scaling, spalling or corrosion (light scaling not serious)
  - record number and type (concrete or steel)
  - measure and record offset
- Column
  - carries bridge loads to pedestal
  - generally steel; susceptible to deicing salts and vehicle damage
  - check surface condition, welds, connections, etc.

Substructure (Cont'd)

- Connection / Bearings
  - refers to column-to-pedestal connection
  - loss of section , missing or loose nuts, rate 4 or less
  - check all welds for cracks
- Coating
  - refers to coating on column and pedestal
  - top coat deteriorated, primer intact rate 5
  - pitting and / or loss of section rate 4 or less

Superstructure

Superstructure			
Bridge Component	**Last**	**Now**	**Explanation of Condition**
(Sign Type :)			
Special Features			
Special Feature			
(Type :)			
Special Feature			
(Type :)			
Truss Members			
Bottom Chord			
Diagonals			
Verticals			
Connections			
Access Platform			
Coating			
(Type :)			
Touch-Up (Y/N)			
Span Alignment Problems			
Vertical (Y/N)			
Horizontal (Y/N)			
Superstructure General Rating			

- Refers to portion spanning the road

Superstructure (Cont'd)

- Special Features
  - refers to high load indicators, special lighting, hazard signs, flashers, etc.
- Truss Members
  - rating details Chapter 7 of BIM
    - bottom chord
    - diagonals
    - verticals
    - connections
  - check lower members for collision damage
  - tension members fatigue cracks
  - rate section loss 4 or less

Superstructure (Cont'd)

- Access platform
  - refers to platform and rail (servicing)
  - Level I from ground with binoculars
  - Check connections
  - high load damage
- Coating
  - rating same as 15.6.5 Substructure
- Span alignment problems
  - check for bows, sags, buckles, twists, etc.
  - alignment of columns

Signs

Sign			
Bridge Component	Last	Now	Explanation of Condition
Sign Board			
(Type :)			
Connections			
Coating			
Readable (Y/N)			
Illumination			
Sign General Rating			

- Refers to signs on the superstructure
- Should be clear, clean and readable

Sign (Cont'd)

- Record type of sign
- Sign Board
  - damage from wind, high load, etc.
  - fasteners, and connections
  - coating damage or deterioration
  - lighting
- Coating
  - damage, difficult to read
  - rate 4 or less
- Connections
  - loose or missing bolts
  - rate 4or less

General Ratings

- App Road / Safety Features
  - Hor. And Vert. align
  - Safety concerns
- Substructure
  - Pedestal, Column and Connection ratings
- Superstructure
  - Load carrying elements
  - Safety concerns
- Sign
  - Sign board, Connections, Coating, Illumination

Major Superstructure Inspection and Rating

Wearing Surface

- Bonded or fastened to the deck
- In direct contact with the traffic
- Not part of the "structural" deck
- Purpose
  - ➢ Protects the bridge deck
    - traffic wear
    - salt and water infiltration
  - ➢ Provides a smooth wearing surface
  - ➢ Provides skid resistance

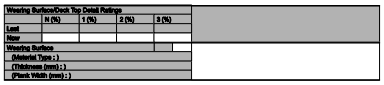
Wearing Surface

- Types
  - ➢ Asphalt
  - ➢ Timber
    - untreated
    - treated
  - ➢ Polymer membranes
  - ➢ Concrete overlay
    - silica fume
    - high density
    - latex modified
    - other (Pyrament)
    - fibre reinforced
  - ➢ May have more than one type
    - i.e. polymer membrane on concrete overlay

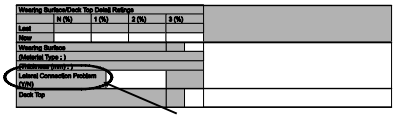
Wearing Surface

- Drive over deck at design or posted speed
- Observe traffic crossing bridge
  - ➢ Look for deflections or movement
  - ➢ Listen for unusual noises
- Look for defects common to the material
- Look for debonding, loosening or loss of wearing surface
  - ➢ Sound for debonding using hammer if suspected
- Look for protruding nails in timber wearing surfaces
- Look for loss of aggregate from polymer wearing surfaces or seal coats
- Look for polishing of concrete overlays especially high density

Wearing Surface



- TT, TH and PT forms



PCS and PSR only

- PCS, PSR, SG, SS, DT and CON forms

Wearing Surface

- Record or verify type
- Record or verify
  - Thickness
  - Size (TH & PT only)
- Record or verify the presence of Lateral Connection Problem (Y/N)
  - PSR and PCS only
  - Rate under girders
- If no wearing surface, rating is for Deck Top
  - TH, PT and TT only

Wearing Surface

- Record in *Explanation of Condition* location, severity and extent of
  - Wear
  - Scaling / raveling
  - Cracks
  - Debonding
  - Wearing surface loss

Wearing Surface

- Rate according to existing condition and functionality
- If wearing surface does not have sufficient skid resistance
  - rate 4 or less
- If wearing surface does not cover the entire deck (curb to curb)
  - rate 4 or less
  - rate 2 if traffic hazard
- Exposed nails or other fasteners
  - rate 4 or less
- If speed has to be reduced due to potholes, missing planks, ruts or other deterioration
  - rate 3

Wearing Surface

Concrete Overlay Rating Guide

Rating	Scaling	Cracks	Debond	Spalls / Patches
7		H/N ≤ 1/30 m/m^2		
6		H/N ≤ 1/10 m/m^2 M/W ≤ 1/30 m/m^2	≤ 1%	
5	Light	H/N ≤ 1/3 m/m^2 M/W ≤ 1/10 m/m^2	≤ 3%	
4	Moderate	H/N ≤ 1/1 m/m^2 M/W < 1/3 m/m^2	≤ 10%	≤ 1%
3	Heavy	H/N > 1/1 m/m^2 M/W ≤ 1/1 m/m^2	≤ 30%	≤ 3%
2	Severe	H/N > 1/1 m/m^2	> 30%	≤ 3%

- Crack definitions
  - Hairlines <0.1 mm
  - Narrow ≥0.1 mm and <0.3 mm
  - Medium ≥0.3 mm and <1.0 mm
  - Wide ≥1.0 mm

Wearing Surface

Asphalt Pavement Condition Severity Guide

Rating	Ravelling	Cracking
5	Some loss of Material	Less than 10mm interconnecting cracks
4	Shallow disintegration of surface, open texture	10 to 20mm Alligator pattern, corners of polygons fracturing
3	Shallow disintegration of surface, small potholes, open texture, loose material	20 to 30mm no ravelling Alligator pattern, spalling of polygon blocks
2	Deep disintegration of surface, numerous potholes. Very open texture, loose material	Greater than 30mm ravelling edges Alligator cracking, blocks lifting, potholes

Wearing Surface

Asphalt Pavement Condition Severity Guide (Part 2)

Rating	Flushing	Slipperiness	Rutting and Surface Distortion
5	Variable color, localized veining	Skid number 40 to 50	Under 10 mm
4	Distinct color, free asphalt	Skid number 30 to 40	10 mm to 25 mm
3	Wet look. Traffic leaves tire marks and noise	Skid number 20 to 30	25 mm to 50 mm
2	Excess free asphalt, wet look, footprints	Skid number under 20	Over 50 mm

Wearing Surface

Wearing Surface Rating Guide - ACP

Rating	Alligator / Cracking, Ravelling, Rutting and Surface Distortion, Flushing, Slipperiness	Longitudinal / Transverse / Random Cracking	Loss (potholes and patches)	Debond
6		< 1/30 m/m^2		< 1%
5	Light	< 1/10 m/m^2	< 1%	< 3%
4	Moderate	< 1/3 m/m^2	< 3%	< 10%
3	Heavy	< 1/1 m/m^2	< 10%	< 30%

Wearing Surface

Wearing Surface Rating Guide

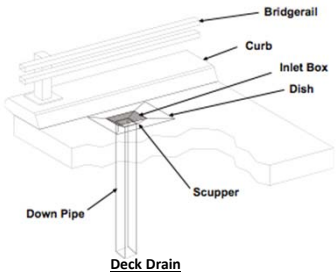
Polymer / Seal Coat

Rating	Seal Coat Loss	Polymer Debond / Loss	Polymer Cracking	Slipperiness
7	≤ 1%			
6	≤ 3%	≤ 1%	≤ 1/30 m/m^2	
5	≤ 10%	≤ 3%	≤ 1/10 m/m^2	Light
4	≤ 30%	≤ 10%	≤ 1/3 m/m^2	Moderate
3	over 30 %	≤ 30%	≤ 1/1 m/m^2	Heavy
2		> 30%	≥ 1/1 m/m^2	Severe

Deck Drainage

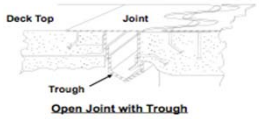
- Not included on TT, PT or TH forms
- Poor drainage
  - Common cause of deck deterioration
  - May cause a hazard due to hydroplaning or icing
  - Caused by inadequate design, construction or maintenance practices
  - May affect other bridge elements
    - superstructure
    - substructure
    - headslopes and sideslopes
- Drainage system includes
  - gutters, inlet boxes, scuppers, downpipes and catch basins
  - drainage problems at deck joints
    - sealed
    - with plumbing
    - non-watertight

Deck Drainage

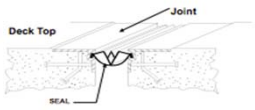


Deck Drain

Deck Drainage



Open Joint with Trough



Sealed Joint

Deck Drainage

- Check for:
  - plugging of inlet boxes, scuppers, downpipes and joint plumbing
  - corrosion of metal components
  - gouges, cracks, breaks or tears
    - joint seals
  - integrity of attachments and connections
    - loose or missing bolts
    - cracked or broken welds
    - loose or open connections
  - length of downpipes

Deck Drainage

- Check for:
  - signs of ponding on the deck
  - damage to the deck, curbs, girders and substructure
    - staining (water and rebar corrosion)
    - scaling
    - freeze-thaw
    - delaminations
    - spalling
  - erosion below downpipe

Deck Drainage

Deck Drainage			
Drains Clogged (Y/N)			

- Record or verify if drains or joint plumbing is clogged

Deck Drainage

- For timber decks or steel grating
  - not on TT, TH & PT forms
- water ponded on the deck rate 4 or less
- water ponding is a hazard rate 2
- drains leak or downpipes too short rate 4 or less
- ponding, leakage or discharge causes significant deterioration of deck, curbs, girders or substructure rate 3 or less
- erosion on sideslopes or headslopes from discharge rate 4 or less
- Deck joint leakage causing damage - reduce rating

Deck Top/Underside

- Purpose
  - Carries traffic loads
  - Transfers loads to main structural members
  - Can be in direct contact with traffic in the absence of a wearing surface
- Types
  - Cast in place concrete
  - Precast concrete
  - Timber
  - Steel grate
- Separate ratings for top and underside
  - Except for PCS, rate underside with top and girders
- May not be inspectable from the top
  - Wearing surface
  - Snow, ice or gravel

Deck Top/Underside

- Drive over deck at design or posted speed
- Observe deck under traffic
  - Listen for unusual noises
  - Look for deflections or movement
- Look over deck top and underside for problems with material
- On concrete decks, sound suspect areas with a hammer to detect delaminations
  - Birdbath locations
  - Stained areas
  - Badly cracked areas or adjacent to large cracks

Deck Top/Underside

- Deck Top rated separately except for PT, TH and TT where Wearing Surface / Deck Top combined

Sub Deck/Deck Underside		
(Material Type :)		
(Plank Thickness (mm) :)		
(Plank Width (mm) :)		
Defects (Percent Area)		

- Applies to PT, TH and TT only

Deck Underside		
Stains (Percent Area)		
(Snow Slots Filled :)		

Applies to DT and SS only

- Remainder applies to SG, PSR, CON, DT and SS

Deck Top/Underside

- Record or verify subdeck type and size for TH, PT& TT
- Record or verify deck underside
  - % defects for TH, PT & TT
  - % stains for all others
- Record if snow slots filled for DT & SS
- Record location, severity and extent of
  - Staining
  - Scaling
  - Cracks
  - Delaminations
  - Spalling

Deck Top/Underside

- Rate according to existing condition and functionality
- Speed reduced due to deterioration
  - rate 4 or less
- Surface does not have sufficient skid resistance
  - rate 4 or less
- Steel grating
  - connections are loose or broken rate 4 or less
  - improper bearing or support on girders rate 4 or less
- Timber
  - minor splitting in non-adjacent planks - rate 5 or more
  - any rot - rate 4 or less
  - broken planks - rate 4 or less
  - connections loose or broken - rate 4 or less

Deck Underside

Concrete Deck Rating Guide

Rating	Scaling	Cracks	Delams	Spalls / Patches	
7		H/N ≤ 1/30 m/m^2			
6		H/N ≤ 1/10 m/m^2 M/W ≤ 1/30 m/m^2	≤ 1%		
5	Light	H/N ≤ 1/3 m/m^2 M/W ≤ 1/10 m/m^2	≤ 3%		Light
4	Moderate	H/N ≤ 1/1 m/m^2 M/W < 1/3 m/m^2	≤ 10%	≤ 1%	Moderate
3	Heavy	H/N > 1/1 m/m^2 M/W ≤ 1/1 m/m^2	≤ 30%	≤ 3%	Heavy
2	Severe	M/W > 1/1 m/m^2	> 30%	> 3%	Severe

- **Crack definitions**
  - Hairline <0.1 mm
  - Narrow ≥0.1 mm and <0.3 mm
  - Medium ≥0.3 mm and <1.0 mm
  - Wide ≥1.0 mm

Deck Underside

Concrete Staining Deck Rating Guide

Severity Rating	Description
5	Efflorscence or exudation at cracks. Light grey damp appearance
4	Dark grey damp appearance
3	Efflorescence or exudation in satined areas Light rust stains
2	Heavy rust stains

Concrete Girders

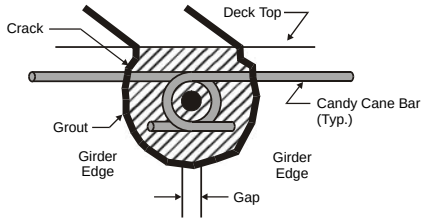
- Purpose
  - Receive the loads from the deck
  - Transmit the loads to the substructure (through the bearings)
- Three types
  - Cast-in-place standard reinforced
  - Standard reinforced precast
  - Prestressed or post-tensioned precast

Concrete Girders

- Inspection is primarily visual, looking for
  - Staining
  - Scaling
  - Cracks
  - Delaminations
  - Spalling
- Observe girders under traffic and look for unusual deflections or movement
  - Independent movement on laterally connected girders
- Evidence of grout key or lateral connection failure
  - Cracking or loss of grout in grout key
  - Cracking in pavement
  - Corrosion, or missing, loose or broken bolts at channel connectors
  - staining on underside of keys

Concrete Girders

- **Grout key failure**



Concrete Girders

- On post-tensioned girders check end anchorage zones
- Check for corrosion of prestressing or post-tensioning cables
  - rust stains or cracking along sides of girders
  - leakage onto ends of girders with staining from ends of cables
- Cracking in end anchorage zone of prestressed girders
- High load damage which breaks the concrete around the pre- or post-stressed cables
  - Look for damaged or broken cables

Concrete Girders

Girders		
Cracking (Y/N)		
Spalling (Percent Area)		

- Record or verify the presence of cracking
  - PCS, PSR & CON
  - Not hairline/narrow flexural on PCS or CON
- Record or verify the amount of spalling in %
  - PCS and PSR
  - Corrosion induced spalling on bottoms and sides over stirrups only
  - % of total leg or girder length
- Girder Detail Ratings on PCS forms only

Concrete Girders

- Record in *Explanation of Condition* location, severity and extent of
  - Staining
  - Scaling
  - Cracks
  - Delaminations
  - Spalling
  - Grout Key failure

Reinforced Concrete Girder Rating

- Applies to all plain reinforced concrete girders
  - Not prestressed or post-tensioned
- If curb girder ***only*** affected, can increase ratings by one
  - Has lower load carrying function
  - Does not apply to shear cracks

Reinforced Concrete Girder Rating

Spalling or Longitudinal Cracking on Bottom of Legs

RATING	DESCRIPTION
5	Medium crack & sound concrete - anchor zone Wide crack/spall - other zones
4	Medium crack - anchor zone Wide crack/spall sound concrete - other zones
4	Moderate section loss on main bars or stirrup bends up to 10%
3	Wide cracks or spall with sound concrete - anchor zone
2	Spall with unsound concrete - anchor zone
2	Severe loss of section on main bars or stirrup bends greater than 20%

*Increase rating one point for:
-PG and PA girders **OR** cracking limited to one leg
-Defects limited to curb girder only

Reinforced Concrete Girder Rating

Shear Cracks

*Must be 60 degrees or less from horizontal

RATING	DESCRIPTION
5	Narrow*
3	Medium*
2	Wide or growing*

*Reduce by one if wide longitudinal crack or spall in anchorage zone

Reinforced Concrete Girder Rating

Other Defects

RATING	DESCRIPTION
No effect	Hairline or narrow flexural cracks
6	End diaphragm spall Narrow map cracks
5	Top slab transverse crack
4	Medium or wide map cracking or any map cracking with staining
4	Medium flex or narrow grout key cracks

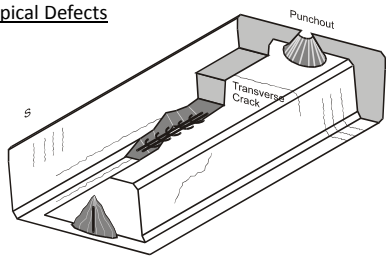
Reinforced Concrete Girder Rating

Other Defects

RATING	DESCRIPTION
4	Small (150mm max) punchouts
3	Medium or wide grout key cracks
3	Other punchouts
3	Failed girder connectors
2	Wide flexural cracks
2	End diaphragm spall extending into legs

Reinforced Concrete Girder Rating

Typical Defects



Prestressed Concrete Girder Rating

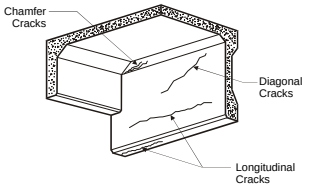
- Applies to all prestressed and post-tensioned concrete girders
- Reduce as needed to reflect condition & function
- If curb girder only affected, can increase ratings by one
  - Has lower load carrying function
  - Does not apply to shear cracks

Prestressed Concrete Girder Rating

RATING	DESCRIPTION
4	Hairline cracks*
3	All other cracks*
3	Corrosion stains from strands
2	Cracks with corrosion in webs, flanges or bottom of boxes
2	Any cracks that are growing
1	Cracks opening and closing or with slippage

*Some cracks are acceptable and don't affect rating

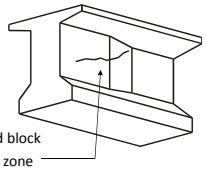
Prestressed Concrete Girder Rating



- Chamfer crack at girder ends: N=5, M/W=4
- Longitudinal crack in bottom half of leg at girder ends: H/N= 5 M/W=4
- Longitudinal crack underside of leg: H/N=5, M/W=4
- Diagonal crack in web transition: =5

Prestressed Concrete Girder Rating

DBT Girders

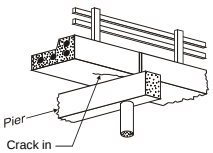


Crack in girder end block through transition zone

- Diagonal crack in end block area - rate 5
  - Not extending into bottom 1/4 of girder
  - No staining
  - Reduce by 1 if into flange or thin web section

Prestressed Concrete Girder Rating

SM,VS, SC, RD, RM,PM,VM Girders



- Longitudinal crack on underside- rate 5
- Longitudinal crack curb fascia- rate 5
- Crack in fascia at pier connection- rate 5
- Bottom diagonal crack in ends - rate 5
  - Not longer than 0.5m from cap or seat
  - No corrosion staining
  - With corrosion staining- rate 3

Diaphragms / Cross Frame

- Purpose
  - Distribute loads between girders
  - Resist torsion forces
  - Support the compression flange of the girder
- Generally made out of the same material as the girder
  - If not, usually steel
- Rate according to condition and ability to function as designed
- If diaphragms contribute to defects in the girder - rate 4 or less

Steel Girder

- Purpose
  - Receive loads from the deck
  - Transmit loads to the substructure
- Two types
  - Rolled beam
  - Welded plate girders
- Usually I-shaped
  - Web
  - Flanges
- Each part of girder rated separately
- Stiffeners
  - Vertical at bearings & along span
  - Horizontal in high bending stress areas
- Cover plates
  - Extra plates welded to flanges to increase capacity in high bending areas

Steel Girder

- Cracks
  - Tension areas
  - End of cover plates
  - Stiffeners welded to bottom flange
  - Re-entrant corners
  - Changes in section
  - Stiffener welds that cross the weld from flange to web
  - Gouges, nicks, holes, collision damage
- Buckling
  - High stress areas such as at bearings

Steel Girder

- Alignment
  - Twists, bows, bends, sags
- Corrosion
  - Top of bottom flange
  - Around connections
  - Under joints
- Connections
  - Loose or missing bolt or rivets
  - Poorly fitted connections
  - Misaligned bolt holes
  - Deformed bolt holes
  - Corrosion between plates
    - warping of plates
- Collision damage
  - Grade separations

Steel Girder

- Notches or stress raisers in tension areas
  - rate 4
- If corrosion is causing a loss of section
  - rate 4 or less
- If any signs of distortion or misalignment
  - rate 4 or less
- If fatigue cracks or signs of distortion
  - rate 4 or less
- Elements with visible cracks
  - rate 3 or less
- Fatigue cracks in bottom flange extending into web
  - rate 2 or less

Steel Truss Members

- Purpose of truss as a unit is to:
  - Receive loads from deck
  - Transmit loads to substructure (through bearings)
- Three types of trusses
  - Through
  - Pony
  - Deck
- Member types are rated separately
- Includes stringers and floor beams
- Truss members in tension or compression
  - Inspector must identify each
  - Different concerns

Steel Truss Members

- Check alignment of trusses
  - top chord alignment especially important because it is in compression
- Check for wide or high load damage
  - If any present, indicate "YES" and explain in *Explanation of Condition*
  - Especially look at portal bracing and sway bracing
  - Wide or high load damage will affect the rating of the member(s) damaged
    - compression members rating are especially lowered by bends
    - tension members by cracks or nicks
  - Check connections and members adjacent to damaged member

Steel Truss Members

- Check each truss member in an orderly fashion
  - On tension members or collision damaged members look for cracks at connections
    - crack will most often be at first bolt hole on the member side
    - light members with significant stress or stress reversal
  - On compression members look for kinks or bows
  - Look for welds or torch cuts
    - crack prone
  - Look for fatigue prone details
    - sharp radius corners
    - notches
    - light members - especially with stress reversal
  - Check which members govern load capacity
    - *Allowable Load* on first page of form

Steel Truss Members

- Check each connection in an orderly fashion
  - Loose or missing bolt or rivets
  - poorly fitted connections
  - misaligned bolt holes
  - deformed bolt holes
  - corrosion between plates
    - warping of plates
- Check for Corrosion
  - Between Built up members
  - Splash zone
  - bottom chord, especially channel section

Steel Truss Members

- Corrosion causing a loss of section
  - rate 4 or less
- Distortion or misalignment on a tension member, no other defects - rate 5
- Minor misalignment or damage to cross-bracing or portal - rate 5
- Cracks in a tension member - rate 3 or less
- Cracks in a compression member - rate 4 or less
- Any fatigue cracks - rate 4 or less
  - Cracks on bottom flange of floor beam or stringer extending into web - rate 2 or less

Rating Grade Separations

Grade Separation

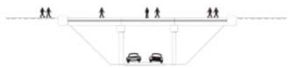
The grade separation section applies to structures which have the following "Structure Usage" as classified in the BIS inventory:

GS - vehicular grade separation
PS - pedestrian grade separation
RO - railway overpass
RU - railway underpass
SP - stockpass or cattlepass

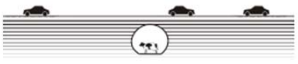
RO - Railway Overpass

RU - Railway Underpass

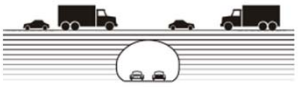
GS - Vehicular Grade Separation



PS - Pedestrian Grade Separation



SP - Stockpass or Cattlepass



GS - Culvert Vehicular Grade Separation

Grade Separation

The grade separation section of the BIM inspection form replaces the channel section for structures that are not over streams. The grade separation section is different for bridges and culverts as shown:

Bridge Section - Chapter 10

		Structure Usage		
		Last	Now	Explanation of Condition
Grade Separation				
Road Alignment				
Traffic Safety Features				
Type				
Slope Protection				
(Type :)				
Bank Stability				
Drainage				
Grade Separation General Rating				

Grade Separation

Culvert Section - Section 13.8

		Structure Usage		
		Last	Now	Explanation of Condition
Grade Separation				
Road Alignment				
Roadway Surface				
(Type :)				
Icing (Y/N)				
Traffic Safety Features				
Type				
Lighting				
Barrel Leakage (Y/N)				
Drainage				
Structure In Use (Y/N)				
Approach Road / Embankment General Rating				

Road Alignment

This element refers to road vert.& horiz. alignment below or through the bridge or culvert and condition of the road surface surface. The limits of evaluation are 1 km in each direction

Inspection and rating considerations include:

- vertical and horizontal alignment that may contribute to damage to the bridge
- look for indications for reduced vertical clearance
- railway alignments should be rated "X"
- alignments that can be safely driven and do not contribute to collision with the structure should be rated "5" or higher
- bridge structures include condition of road, cracks, heaves etc. that may lead to damage of the bridge.

Traffic Safety Features

For the purposes of the BIM system this item refers to safety features such as:

- curbs or barriers
- medians
- guardrails
- energy attenuators
- vertical clearance signs
- advance warning signs

The type of safety features are to be noted on the BIM form.

Traffic Safety Features

Inspection and rating considerations for safety features are as follows:

- do not rate standard of safety feature… rate functionality and condition as per original design
- rating should include all components of the safety feature, including connections
- if elements are missing but there is evidence that they were previously there, then rate "4" or less
- use "explanation of condition" to further describe features or to indicate concerns, maintenance required, etc.

Slope Protection

This item refers to the slope protection system used on the headslopes of bridges to prevent erosion damage and provide an aesthetic finish (graffiti).

Some considerations for inspection and rating include:

- look at abutment front for evidence of settlement
- for concrete treatments, look for cracking, surface deterioration, crushing, settlement or heaving
- look for signs of undermining at the toe or by loss of soil material below the protection system
- significant movement or settlement should be rated "4" or less
- if maintenance required it should be rated "4" or less and a description provided
- Good condition but somewhat unattractive rate 7

Bank Stability

This refers to the stability of the headslopes and transitions. It is influenced by factors such as:

- type of backfill material
- construction techniques
- degree of compaction
- drainage system
- underlying soil stratigraphy

Consequences of instability may range from minor settlement to major structural distress .

Bank Stability

Considerations for inspection and rating of bank stability include:

- look for evidence of damage to bridge components
- look for evidence of settlement and shifting of substructure elements
- check for evidence of soil bulging at toe of slopes
- record locations of wet and slumping areas
- instability affecting bridge elements rate "4" or less
- instability that requires monitoring rate "4" or "3"

Drainage - Bridge G/S

This item refers to the handling of water that reaches the toe of the headslopes and its transitions. Sources of water include:

- deck drainage
- approach road drainage
- highway ditch drainage
- weep holes in abutments and concrete slabs

Considerations for inspection and rating include:

- Drainage functional not causing damage rate 5 or more
- if drainage causes safety concerns or damage, rate "4" or less
- ponding or icing causing hazard on travel lanes below rate 2 or less

Drainage / Barrel Leakage

This item refers to disposal of water that reaches culvert roadway surface.

- Considerations for inspection
  - look for ponding in culvert
  - gutters clogged or not functioning
  - damage caused by roadway drainage
- Record "Y" if there is barrel leakage and explain
- Drainage functioning, rate 5 or more
- Ponding causing a hazard, rate 2 or less

Roadway Surface

This item is limited to culvert structures and refers to the condition and functionality of the roadway through the structure. The purpose of the roadway surface is to provide a suitable surface for vehicular or other traffic. Considerations for inspection and rating include:

- record the type (pavement, concrete, gravel, etc.) of roadway surface on the inspection form
- evaluate the condition of the surface and its ability to function as designed
- roadway surfaces requiring maintenance to provide the required level of service should be rated "4" or less
- roadway surfaces that are hazardous due to icing should be rated "2" or less and icing should be indicated on the inspection form
- if there is leakage of water through the barrel onto the roadway, indicate "Y" and explain

Lighting

This item refers to the lighting system used in the culvert to enhance visibility and to provide for safe passage through the culvert. Some considerations for inspection and rating include:

- if the lighting is not operational, rate "4" or less
- check guardrail and safety features for damage as this may indicate visibility problems in the culvert
- check all connections and features to determine condition and functionality
- no lighting (cattlepass) rated "X"
- inadequate lighting or no lighting and hazardous situation for the user should be rated "2" or less with "explanation of condition".

Structure In Use

This item refers mostly to cattlepasses and stockpasses but may also apply to other uses. If there is evidence that the structure is no longer in service, then circle "N" and make a note in the "explanation of condition" regarding the circumstances.

General Rating

The general rating of the grade separation section of the BIM inspection should reflect the significant structural and safety concerns relative to the items being inspected and rated. Governed by:

- Bridge G/S
  - road alignment
  - traffic safety features
  - bank stability
  - drainage
- Culvert G/S
  - road alignment
  - roadway surface
  - traffic safety features
  - drainage

Level II Inspection

Introduction

- Level I
  - primarily visual with standard tools
  - no special access
  - in accordance with BIM manual
- Level II
  - specialized knowledge / training and equipment
  - detailed information on a particular component or components
  - supervised by certified bridge inspector

Level II Inspection Types

- Copper Sulfate Electrode (CSE Testing)
- Chloride Testing
- Concrete Deck Inspection
- Ultrasonic Truss Inspection
- Culvert Barrel Measurements
- Vertical Clearance Measurements

Types of Level II Inspection

- Concrete Girder Inspection
- Paint Inspection
- Timber Coring
- Scour Monitor
- Special Structure Monitor
- Underwater Inspection
- Steel Culvert Corrosion Testing
- Pin and Hanger Connection Testing
- Steel Girder Cover Plate Inspection

General Principles

- BIM condition rating system
- Quantifies rating categories
- Provides technical data / measurements
- As required / ordered by Level I Inspector
- Regular / predetermined schedule

When Required?

- Special access required
  - swing stages or manlifts
  - dewatering culverts
  - underwater (scour or foundations)
- Overall assessment for rehabilitation or major maintenance
  - deck or paint inspections
  - condition evaluation
  - CSE, timber coring, ultrasonic

Level II Inspection Forms

Bridges

(Primary Span : **FC, Spans: 1,2,3, Lengths(m): 29-16.2-29**)
(Total Length : **29-16.2-29 = 74.2**)

Culverts

Bridge Culvert Information

Pipe #	Design Span/Diam. & Rise	Type	Length	Corr Profile	Pl. Thickness	Number of Rings	Top Arc Radius	Side Arc Radius	Bottom Arc Radius	Corner Arc Radius
1	1810	SP	65.800	152X51	2.8	30	kN			

Level II Inspection Forms – Common Inventory Information

Alberta Transportation — Bridge Inspection & Maintenance System (Web 2005) — 07871 -1 Bridge

Level 2 Inspection - Concrete Deck

Bridge File Number	07871 -1 Bridge	Form Type	CDK
Year Built/Year Supstr	1958/1958	Lot No.	
Bridge or Town Name	MANNVILLE	Inspector Name	John Doe
Located Over	VERMILION RIVER, 6.5, WATERCRS-ST	Inspector Class	BR CLS A
Located On	881:08 C1 4.791	Assistant Name	
Water Body Cl./Year		Assistant Class	
Navigabl. Cl./Year		Inspection Date	20-May-2014
Legal Land Location	SW SEC 6 TWP 51 RGE 8 W4M	Arrive Time	15:46
Longitude, Latitude	-111:10:28, 53:22:21	Depart Time	17:19
Road Authority	Alberta Transportation (AIT)	Data Entry By	Jane Doe
Contract Main. Area	CMA15	Data Entry Date	03-Dec-2014
Clear Roadway/Skew	7.9 /	Reviewer Name	Joe Blow
AADT/Year	300 / 2013 (A)	Review Date	13-Dec-2014
Road Classification	RCU-209-110	Dept. Reviewer Name	John Snow
Detour Length (km)	43	Dept. Review Date	13-Mar-2015
		Follow-Up By	
		Visual Inspection?	Y
		CSE Testing?	Y
		Chloride Testing?	N

Allowable Load (t):	Single	CS1 39 GIRDER	Semi	CS2 49	Train	CS3 62	---> On Critical Spans ---> Critical Member
Design Loading:		HS20					---> Primary Span

(Primary Span : **PO, Spans: 1, Lengths(m): 25.9**)
(Total Length : **25.9 = 25.9**)

Level II Inspection Forms – Inspection Scheduling Information

Previous Level 2 Inspector's Name		Previous Level 2 Insp Date	18-Aug-2008
Next Level 2 Insp Date	20-May-2020	Discontinue Level 2 Insp? (Y/N)	No
Level 2 Insp Previously Completed	7	Level 2 Insp Cycle (Default) (Months)	72
Detailed Report/Diagram? (Y/N)	Yes		
Level 2 Insp Comments	There is erosion at the northeast corner of the bridge, beginning to encroach into roadway (0.5m x 0.1m)		
Next Level 2 Inspection/Test	Concrete Deck Insp? (Y/N) Yes	CSE Testing? (Y/N) Yes	Chloride Testing? (Y/N) No
Department Reviewer Comments			

Level II Inspection Forms – Inspection Scheduling Information

Structural Condition Rating (%)	**55.6**	**Sufficiency Rating (%)**	**61.0**	Est Repl Year	2030		
Level 1 Insp Date	28-Oct-2014	Next Level 1 Insp Date	28-Jan-2018	Current Level 1 Insp Cycle (Default) (Months)	39		
Special Comments for Next Insp							
Snooper? (Y/N)	No	Lift? (Y/N)	No	Traffic Control? (Y/N)	Yes	Boat? (Y/N)	No	Ladder? (Y/N)	No
Other Special Requirements Comments							

Level II Inspection Forms – Maintenance Recommendations

Alberta Transportation Bridge Inspection & Maintenance System (Web 2005) 07871 -1 Bridge

Maintenance Recommendations

Inspector Recommendations	Year	Inspector Comments	Department Comments	Target Year	Est. Cost	Cat #
SEAL CURBS						
PATCH DECK						
SEAL DECK						
OVERLAY DECK						
REPAIR/REPLACE DECK JOINTS						
WASHING						
OTHER ACTION						
CRACK REPAIRS/TREATMENT						
PATCH CURBS/PARPETS						
OTHER ACTION						
OTHER ACTION						
OTHER ACTION						

Concrete Deck Inspection

- Primarily visual with standard tools
- Measurement of damage / condition
- Components inspected are
  - wearing surfaces
  - concrete overlay
  - concrete deck
  - concrete edge elements
  - deck joints

Concrete Deck Inspection – Wear Surface Inventory and Condition

Concrete Deck Inspection

		Last	Now	Explanation of Condition
Wearing Surface				
Polymer? (Y/N)		N		
ACP? (Y/N)		N		
Chip Seal Coat? (Y/N)		Y		

	Type	Year Installed	Avg. Total Thickness (mm)	Area (m²)
Seal Coat	CHIP SEAL COAT	1999		1298.1

Polymer Rating (% Area)

	9-7	6/5	4	3	2/1	N/X
Last	0	0	0	0	0	100
Now	0	0	0	0	0	100

ACP Rating (% Area)

	9-7	6/5	4	3	2/1	N/X
Last	0	0	0	0	0	100
Now	0	0	0	0	0	100

Chip Seal Coat Rating (% Area) — Chip seal coat has all but worn off.

	9-7	6/5	4	3	2/1	N/X
Last	0	0	10	90	0	0
Now	0	0	10	90	0	0

Polymer Total Debonded /Lost Area (m²)		X	X
ACP Total Debonded /Lost Area (m²)		X	X
ACP Average Measured Depth (mm)		X	X
ACP Crack Frequency (m/m²)		X	X
Chip Seal Coat Total Lost Area (m²)	999	999	1099 m² of lost seal coat (~85 %)

Concrete Deck Inspection – Concrete Overlay Inventory and Condition

Concrete Overlay

Overlay? (Y/N)	Y
(Span Type : CT)	
(Span Numbers : **1, 2, 3, 4**)	

	Last	Now	Explanation of Condition
(Overlay type : **CONCRETE (HIGH DENSITY)**)			
(Area(m²) : **1298.1**)			
(Year Installed : **1978**)			
(Thickness(mm) : **50**)			
(Average Cylinder Strength(Mpa) :)			

Overlay Rating (% Area)

	9-7	6/5	4	3	2/1	N/X
Last	0	70	10	0	0	20
Now	0	65	15	0	0	20

Partially covered by chip seal coat.

There is widespread cracking along the overlay. Several core patches are deteriorated.

Total Crack Length - Medium/Wide (m)	371	453
Total Scaled Area - Light (m²)	0	0
Total Scaled Area -Moderate/Heavy/Severe (m²)	0	0
Debonded Area (m²)	84	30
Spalled Area (m²)	1	1.5
Patched Area (m²)	0	0
Average Measured Cover Depth (mm)	100	102
Standard Deviation of Measured Cover Depth (mm)	14	15

Concrete Deck Inspection – Concrete Deck and Underside Inventory and Condition

Deck

(Span Type : CT)	
(Span Numbers : **1, 2, 3, 4**)	
(Deck Type : **CONCRETE (CLASS C)**)	
(Area(m²) : **1298.1**)	
(Year Constructed : **1957**)	
(Year Widened :)	
(Thickness(mm) : **150**)	
(Average Cylinder Strength(MPa)) :)	

	Type	Size	Design Cover (mm)	Spacing (mm)
Long. Reinforcing	REINFORCING STEEL	10	25	750
Trans. Reinforcing	REINFORCING STEEL	15	25	190

Deck Top Rating (% Area)

	9-7	6/5	4	3	2/1	N/X
Last	0	0	0	0	0	100
Now	0	0	0	0	0	~100

Total Crack Length - Medium/Wide (m)	N	N
Total Scaled Area - Light (m²)	N	N
Total Scaled Area - Moderate/Heavy/Severe (m²)	N	N
Delaminated Area (m²)	N	N
Spalled Area (m²)	N	N
Patched Area (m²)	N	N
Average Measured Cover Depth (mm)	N	N
Standard Deviation of Measured Cover Depth (mm)	N	N

Deck Underside Rating (% Area) — Could not inspect span 3 due to water levels.

	9-7	6/5	4	3	2/1	N/X
Last	0	74	1	0	0	25
Now	0	75	1	0	0	25

Staining between G1/G2 on the south span.
There is flexual and shear cracking along the CT girders.
There are narrow to medium wide transverse cracks in the deck underside. Isolated spalled patch between G2/G3 S4 (north span).

Total Stained Area - Moderate (m²)	0	1
Total Stained Area - Heavy/Severe (m²)	0	0
Total Crack Length - Medium/Wide (m)	140	175
% of Medium/Wide Cracks Stained	80	85

Concrete Deck Inspection – Edge Elements Inventory and Condition

Edge Elements

Curbs? (Y/N)	Y
Parapets? (Y/N)	N

	Last	Now	Explanation of Condition
Medians? (Y/N)	N		
Sidewalks? (Y/N)	N		
Curbs			
(Type : **CONCRETE**)			
(Total Length(m) : **175.8**)			
(Height(mm) :)			
(Width(mm) :)			
(Average Cylinder Strength(MPa)) :)			

Reinforcement Type	Size	Design Cover (mm)	Spacing (mm)
	10	50	600

Curb Rating (% Length)

	9-7	6/5	4	3	2/1	N/X
Last	0	100	0	0		
Now	0	~100	0	0	0	0

Transverse cracking.

Isolated areas of exposed rebar due to insufficient concrete cover along the west curb.

Total Crack Length - Medium/Wide (m)	38	56
Total Scaled Length - Light (m)	4	6
Total Scaled Length - Moderate/Heavy/Severe (m)	0	0
Delaminated Length (m)	0	0
Spalled Length (m)	0.1	0.1
Patched Length (m)	7	8
Average Measured Cover Depth (mm)	64	73
Standard Deviation of Measured Cover Depth (mm)	21	14

Level II Inspection

Concrete Deck Inspection – Deck Joint Inventory and Condition

Deck Joints			
(Type : **GLAND (WABO-MAUER, TRANSFLEX, ETC)**)			
(Number of Joints : **2**)			
(Expansion / Fixed? : **EXPANSION**)			
(Location : **A1, A2**)			
% Inspected	100	100	Inspected joints after a hard snow/rain, no leakage was observed.
% Joints Leaks	0	0	
% Joint Length Leaks	0	0	There are horizontal cracks in the abutments. There are vertical cracks along the piers.
Superstructure Damage Rating	6	6	
Substructure Damage Rating	6	5	
Level 1 Joint Rating	7	7	

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BIM
Bridge Inspection and Maintenance

Concrete Bridge Decks

- Large Percentage of All Bridge Decks (over 90%)
- Two Main Mechanisms of Deterioration
  - freeze thaw damage
  - corrosion of rebar – delamination of concrete
- Prevention of Freeze Thaw Damage
  - proper concrete mix design/air entrainment

Concrete Bridge Decks

- Prevention of Corrosion Damage
  - prevent moisture/chloride entering concrete
  - ensure concrete around rebar remains passive
  - use non-corrosive rebar
- Deck Durability – New Construction
  - membrane and ACP
  - epoxy coated rebar
  - stainless steel/stainless steel clad rebar
  - corrosion inhibitors

Deck Rehabilitation - Timing

- Optimum timing gives best life cycle cost
- Too early
  - existing deck protection still working
  - no significant damage to deck
  - future life of deck/bridge not shortened if rehabilitation delayed
- Too late
  - significant corrosion damage to deck
  - rehabilitation costs have significantly increased
  - high chlorides or other factors have significantly shortened life of deck/bridge
- Great deal of experience and judgement to determine optimum timing

Methods/Options for Rehabilitation

- Concrete Overlays
  - provides durable long lasting wearing surface
  - less permeable – reduces moisture in deck
  - reduces rate of corrosion
- Membrane/ACP
  - waterproofs deck surface
  - stops additional moisture getting in deck
  - significantly reduces corrosion
  - membrane/ACP not as long lasting wearing surface as concrete

Methods/Options for Rehabilitation

- Thin Polymer Overlays
  - membrane without protection of ACP
  - does not add significant dead load
  - existing concrete deck in good condition
  - need very good bond with concrete
  - subject to damage from snow plows, vehicle wear, UV rays

Methods/Options for Rehabilitation

- Cathodic Protection
  - electric potential over deck surface prevents additional corrosion
  - use when existing corrosion activity very high
  - need power source at site
  - generally needs to be used with concrete overlay
  - monitoring and maintenance required to ensure system is working

Types of Concrete Overlay

- High Density Concrete
  - started using in mid-1970's
  - low water/cement ratio – low slump
  - site batched with mobile mixer
  - placed with special finishing machine
  - very good durability
  - less permeable than normal concretes
  - still relatively high permeability

Types of Concrete Overlays

- Latex Modified Concrete
  - also started using in mid-1970's
  - latex used to replace some of the water in mix
  - also site batched
  - low permeability/high slump
  - difficult to finish and cracks easily
  - can be used for thin overlays < 40 mm
  - section of overlay can become loose if bond problem

Types of Concrete Overlays

- Pyrament Cement Concrete
  - cement with high fly ash content – 35%
  - on market in early 1990's
  - pre-bag mix – water added at site
  - fast setting, high strength, low permeability
  - hard to finish – shrinkage cracks
  - AAR problems – reduced bond

Types of Concrete Overlays

- Silica Fume Concrete
  - started using in late 1980's
  - small amount of silica fume in mix (7.5%)
  - early use – pre-bag mix – water at site
  - presently mostly transit mix
  - low permeability – good durability
  - little more difficult to finish
  - more sensitive to shrinkage cracks

Types of Concrete Overlays

- Silica Fume Concrete with Steel Fibres
  - steel fibres added to mix
  - increases tensile strength
  - reduces/controls shrinkage cracks
  - holds overlay together if debonded
  - presently most commonly used overlay by AT

Types of Concrete Overlays

- Modified Silica Fume Concrete
  - small amount of fly ash in mix
  - fog curing immediately behind finishing machine
  - seven day wet curing
  - increase strength – reduces cracks
  - can be used with and without steel fibres
  - will be more widely used by AT in future

Types of Membrane/ACP

- Hot Applied Rubberized Membrane/Protection Board/ 2-40 mm Layers ACP (90 mm)
  - used on new construction
  - dead load limits use for rehabilitation
- Sheet Membrane with 50 mm ACP
  - repair any damage to deck
  - requires fairly smooth surface
  - bond with concrete and joints between sheets main concerns
  - top of sheet rough surface to protect from and provide bond with ACP

Types of Membrane/ACP

- Polymer Membrane with 50 mm ACP
  - requires relatively smooth surface
  - good bond with concrete decks
  - bond with ACP problem unless some aggregate in top layer
  - aggregate can affect permeability of membrane

Thin Polymer Overlays

- Flexible Epoxy Overlays
  - two components - must be mixed properly
  - can be multi-layer system
  - very low permeability
  - requires very good preparation of concrete surface
    - rough texture but clean
  - very sensitive to weather conditions
    - concrete internally dry
  - even flexible epoxy is a relatively brittle material

Thin Polymer Overlays

- MMA Overlays
  - more flexible, thicker material
  - single layer
  - somewhat more expensive than epoxy
  - also requires very good concrete surface preparation
  - works better on more flexible decks
- Urethane Overlays
  - use in parking garages
  - not durable enough for highway traffic

Cathodic Protection Systems

- Conductive Titanium Wire Mesh in Overlay
  - requires concrete overlay
  - must eliminate all shorts between mesh and deck
  - requires monitoring
- Under Deck Conductive Coating
  - do not require concrete overlay
  - still must eliminate all shorts
  - requires monitoring
  - long-term performance not proven
  - coating system appears to dry out and become non-conductive with time

Lateral Connection Between Girders

- AT has a number of concrete girder types that are placed side by side and connected together by grout-keys or connector bolts
- These grout keys have not stood up well over time
- During rehabilitation of these girder bridges the lateral connections are usually upgraded and supplemented (underslung beams, lateral post-tensioning)

Typical Shear Key – PM Girders

Girder Shear Keys

Lateral Connection Between Girders

- Short Span Girders with Bolted Connector Pockets (HC,VS,SM)
  - reinforced concrete overlay (nominally 150 mm)
  - hair pin bars and grouting
- Longer Span Girders (FC, VF, FM) – Continuous shear keys
  - lateral stressing
  - underslung beams
  - combination of both

Lateral Stressing and Underslung Beam – FC Girders

Bridge Deck Joints

- Pre – 1975 Bridges
  - lots of simple spans
  - lots of non-waterproof joints
- Existing Practice
  - continuous spans, eliminate deck joints where possible
  - joints waterproof or with drainage systems

Types of Deck Joints

- Strip Seal Joints
  - waterproof
  - a rubber/neoprene seal attached to metal extrusion
  - moderate thermal movements (up to approx. 75 mm)
  - make sure installation fills all voids behind extrusions
  - work well but seals must be replaced from time to time

Types of Deck Joints

- Finger Plate Joints
  - non-waterproof
  - sliding finger plates with plumbing/drainage system
  - works for large thermal movements (> 75 mm)
  - careful to fill all voids behind plates when installing
  - mis-alignment of fingers due to dead load creep and abutment rotation
  - plumbing/drainage systems need to be cleaned out from time to time

Types of Deck Joints

- Small Movement Joints
  - small movements due to live load deflection, etc.
  - compression seals
  - types of caulking materials

Specifications for Bridge Construction

- Link to Specifications for Bridge Construction
- Section 4 - Cast in Place Concrete
- Section 15 - Polymer Overlays
- Section 16 - Bridge Deck Waterproofing
- Section 20 – Deck Overlays and Concrete Rehabilitation

- https://www.transportation.alberta.ca/4753.htm

Major Maintenance and Rehabilitation of Concrete Bridge Decks

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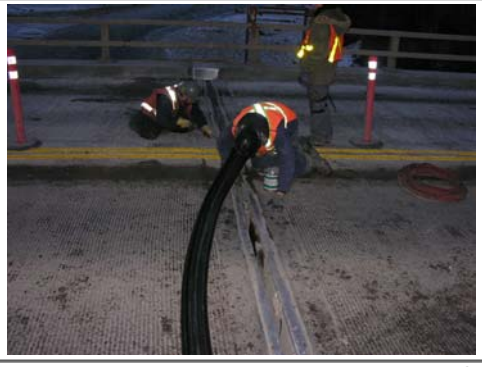

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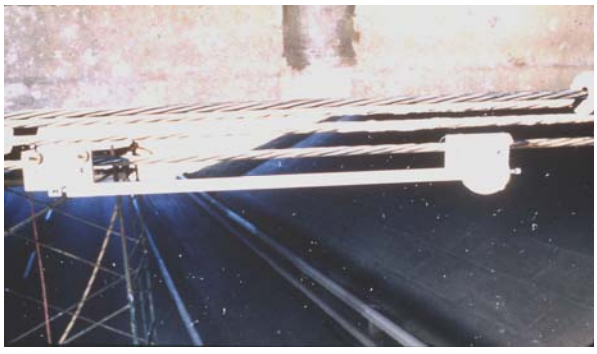

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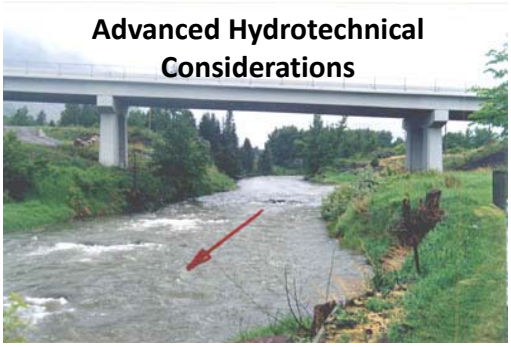
Questions

Advanced Hydrotechnical Considerations

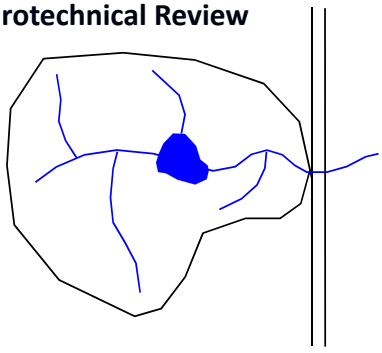


Overview

- Hydrotechnical Review
- Pier Scour Inspection
- RPW Inspection
- Case Study

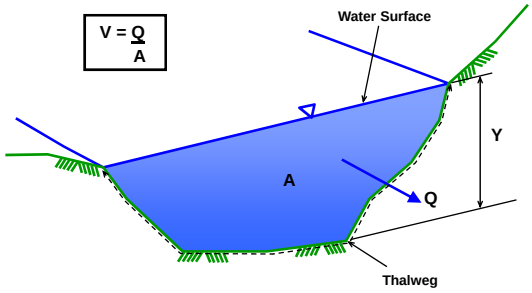
Hydrotechnical Review

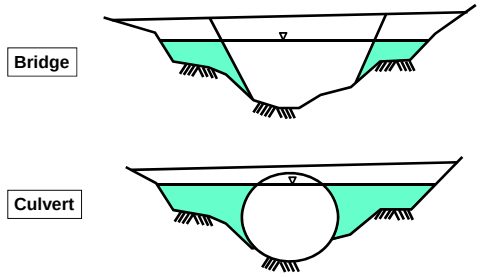
- Area
- Shape
- Slope
- Channel
- Storage
- Density
- Vegetation
- Soil Type
- Initial Moisture

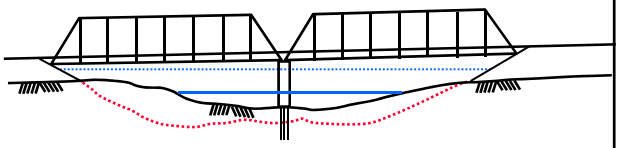


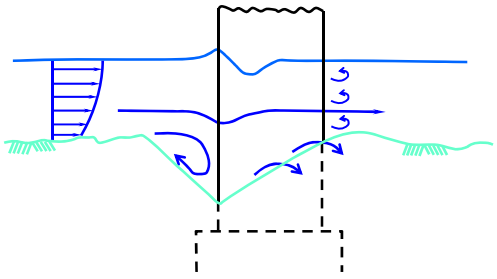
Hydrotechnical Design Guidelines:

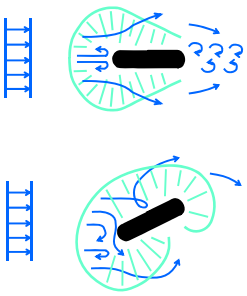
- Channel Capacity
- Historic Highwater Data
  - Drift, debris
  - Scars, erosion
  - Locals, photos
- Runoff Potential

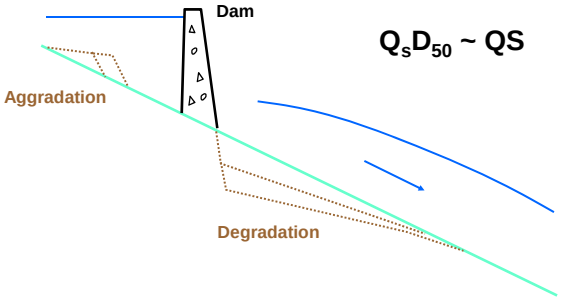

V = Q
A
Water Surface
Y
A
Q
Thalweg

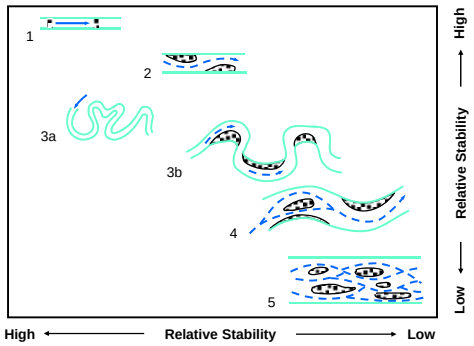

Bridge
Culvert



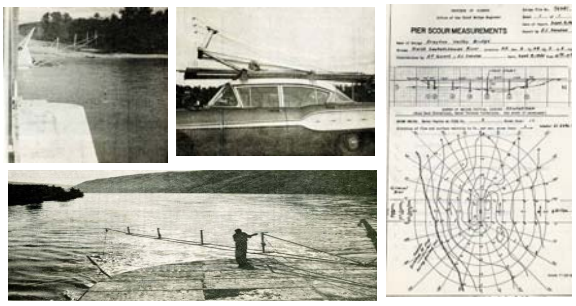



Flow Parallel to Pier
Flow on Skew to Pier


Dam
Q_sD_{50} ~ QS
Aggradation
Degradation

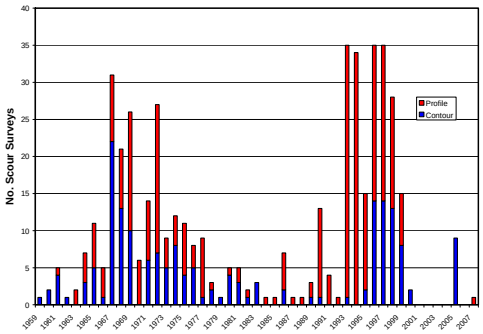


Pier Scour Survey



Advanced Hydrotechnical Considerations

Advanced Hydrotechnical Considerations



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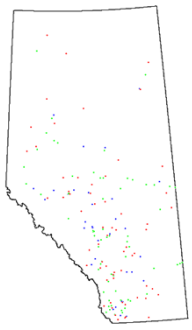

	Number Of Structures	
Priority	Initial	Latest
1	60	38
2	68	70
3	41	65

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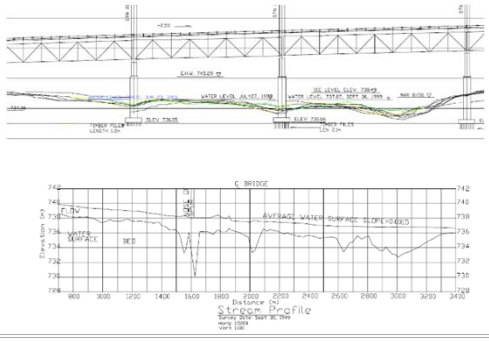


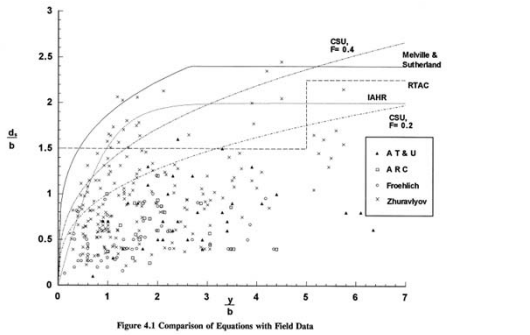
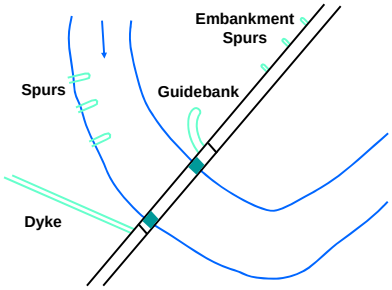
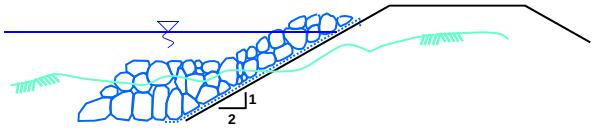


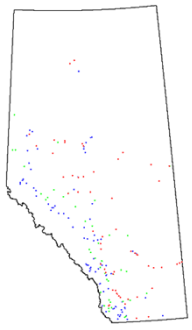
Figure 4.1 Comparison of Equations with Field Data

RPW Inspection



Typical Rock Riprap Section





Priority	Description	No. Sites
1	Multi-channel Gravel Bed	93
2	Active Gravel Bed	48
3	Active Meander	66

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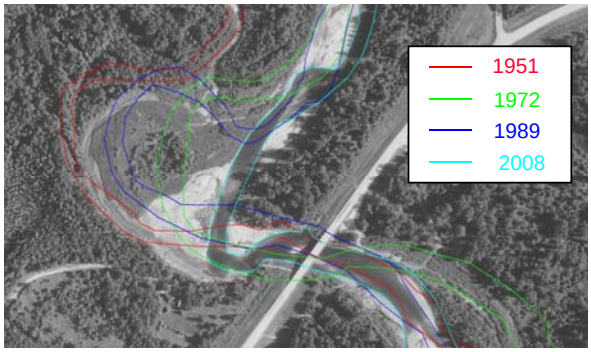

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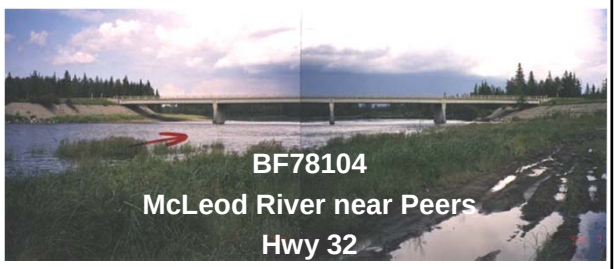
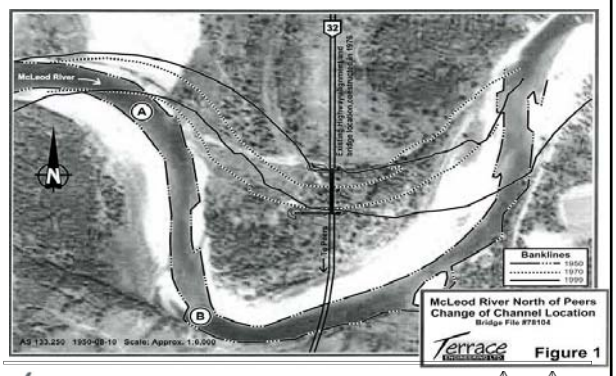
Case Study


BF78104
McLeod River near Peers
Hwy 32


McLeod River
32
A
B
N
Banklines
1950
1970
1999
McLeod River North of Peers
Change of Channel Location
Bridge File #78104
Terrace
Figure 1


McLeod River
33
N
Flow Centerline
1950
1961
1970
1982
1999
McLeod River North of Peers
Historic Channel Locations
Bridge File #78104
Terrace
Figure 2

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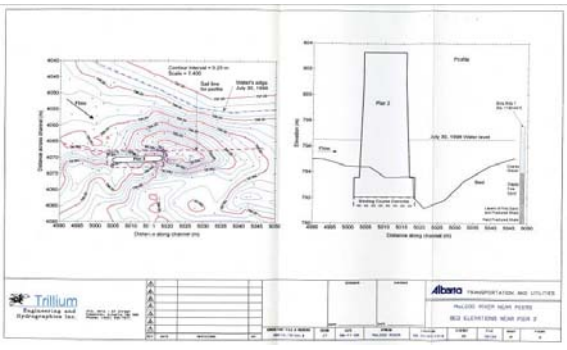

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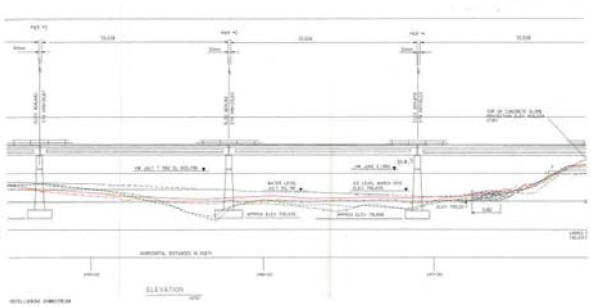

Class A Bridge Inspection Course
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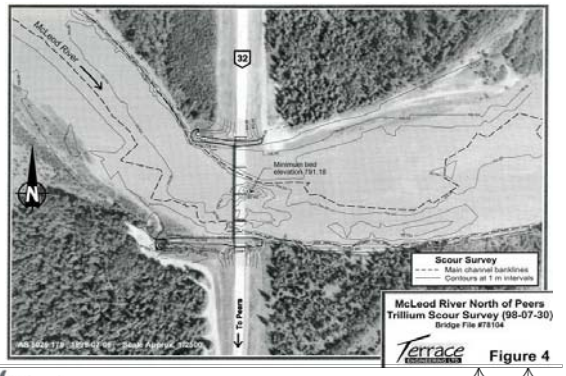
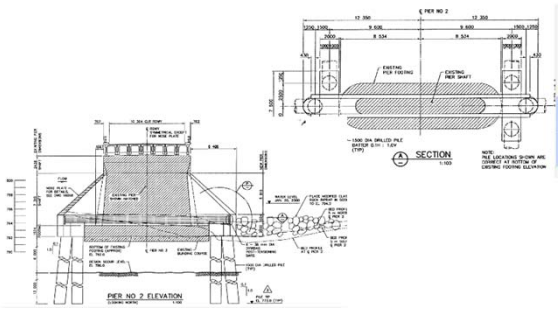

McLeod River
32
N
To Peers
Scour Survey
Main channel baselines
Contours at 1 m intervals
McLeod River North of Peers
Trillium Scour Survey (98-07-30)
Bridge File #78104
Terrace
Figure 4


SECTION
PIER NO 2 ELEVATION

…Questions?

Maintenance and Rehabilitation of Culverts

Introduction

- Widely used, started in 1950
  - low cost alternative to bridges
  - road system expansion in 60s and 70s
- Installed by road builders
  - local road authorities
  - district forces
- Designs by Bridge Engineering then Regional Bridge staff

Technical Developments

- Early history - many problems
  - spectacular uplift failures
  - undersized
  - deformation and cracking
- Need for quality backfill and compaction not recognized
- Importance of end treatments

Culvert Inspection

- Regular inspection initiated in mid-80s
  - before major problems or failures reported
- inspection provides early detection of changes
- most defects develop slowly
- poor backfill often detected at first inspection
- As constructed records shape at ends, quarterpoints and middle

Structural Problems

- Include:
  - Deformation
  - Cracked seams
  - Corrosion
- Usual causes
  - poor quality backfill
  - frozen backfill
  - poor compaction
  - poorly prepared foundation
  - corrosive environment
  - piping

Structural Problems
Deformation

- Heaving floors
- Bulging walls
- Sagging roof
- Severity measured as percent of design shape
- Contributing factors
  - backfill low shear strength
  - culvert material low bending strength
  - load carried in ring compression and soil-steel interaction

Structural Problems
Cracked Seams

- Primary cause is deformations
  - sometimes deformations small; 5%
  - may occur at one or more seams
- Contributing factors
  - incorrect laps
  - Over or under torquing bolts
  - improperly curved plate
- Severity measure
  - number of seams cracked
  - location of seams
  - remaining steel between cracks

Structural Problems
Corrosion

- Corrosion
  - electrochemical process that converts metal to natural state
- Environmental requirements
  - differences in potential
  - electrolyte
  - oxygen
- Corrosion types
  - electrolytic
  - galvanic
- Severity measure
  - percent rust pitting or perforation
  - static potential

Waterside Corrosion on Culvert Floor

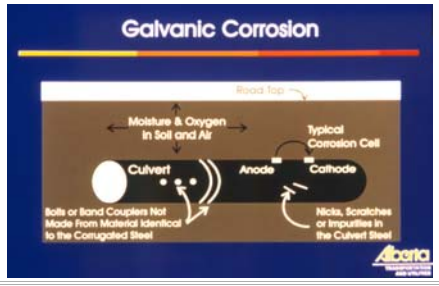
Soil-Side Corrosion Damage

Corrosion

- Electrolytic corrosion
  - caused by external stray currents
  - other cathodic systems
  - overhead power lines
- Galvanic corrosion
  - materials of different potential in an electrolyte
  - impurities in metal
  - differences in coatings
  - surface defects
  - moist soil good electrolyte
  - generates own current

Electrolytic Corrosion Mechanism

Galvanic Corrosion Mechanism



Repair and Maintenance

- Monitoring
- Strutting
- Liners
- Crack repairs
- Cathodic protection
- Concrete Floors
- Extensions
- Scour/Piping Repairs

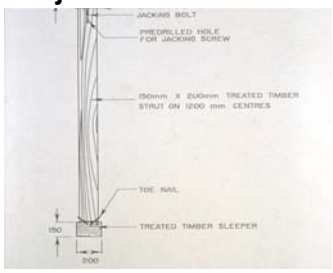
Monitoring

- First option, low cost
  - structure may stabilize
  - Review BIM history
- Provides ongoing record
  - mark ends of cracks
  - measure magnitude and location of deformations
  - establish reference points
  - photographs

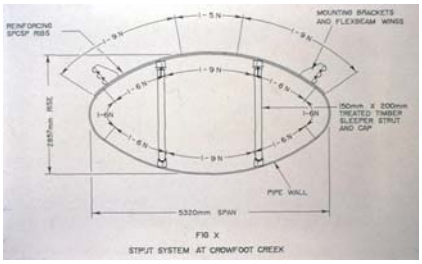
Strutting

- Oldest, often cheapest method
- Effective for extreme distress
- Not suitable for drift and ice locations
- Components
  - vertical struts between sleepers
  - cut to length, jacked in place
  - timber or steel
- Life 25 years

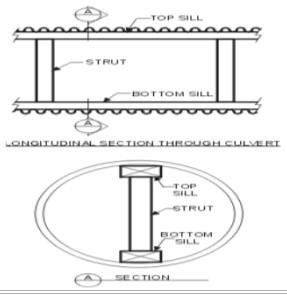
Timber Strut with Adjustable Turn-screw



Strut Layout for Horizontal Ellipse Culvert



Timber Strutting of Metal Culverts



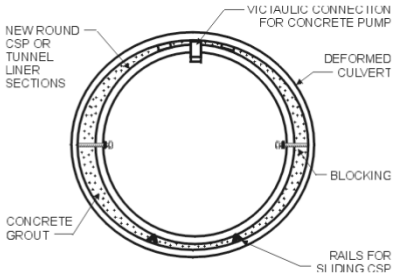
Installing Struts

Completed Installation

Liners

- Used when culvert cracked or corroded
- Reduces hydraulic capacity
- May increase velocities, back water
- Not suitable for large deformations
- Life 30 to 60 years

Culvert Liners



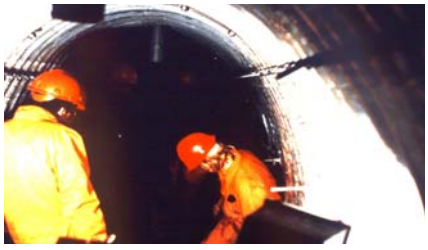
Liner Types

- CSP culvert
  - 1.5m to 3.0m culverts
- SPCSP
  - larger than 3.0m culverts
  - limited length
- Tunnel liner
  - large culverts and long length
- Smooth wall pipe
  - Generally less than 1.5m culverts

Installing CSP Liner into Existing SPCSP Culvert

Pulling Assembled SPCSP into Concrete Box Culvert

SPCSP Liner Inside Concrete Box



Victaulic Connector for Concrete Pump

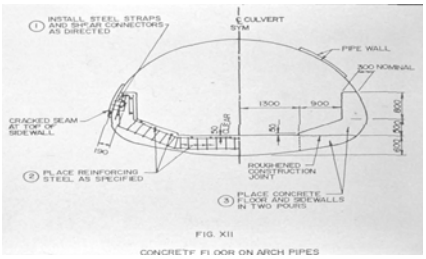
Installing Tunnel Liner Inside Culvert

Tunnel Liner Ready for Grouting

Concrete Floors

- Repair severe perforations of invert
- Reinforce cracked seams and sidewall deformation of arch culverts
- Reduces hydraulic capacity

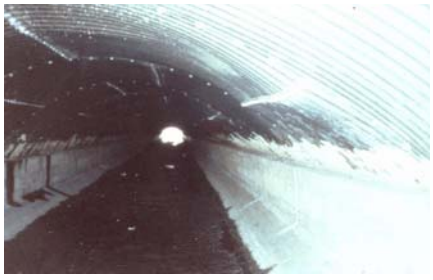
Details of Concrete Floor for SPCSP Arch



Reinforcing Steel Arrangement

Concrete Floor Casts

Floor and Sidewall in Place



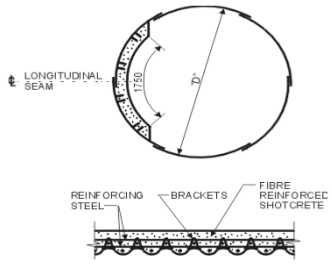
Crack Repair Methods

- Stop drilling crack ends
- welding cracks
- reinforcing plates
  - welded
  - bolted
- reinforced concrete
  - arch culverts
- shotcrete

Shotcrete Reinforcing

- Preferred method for repairing cracks
- Stiffens joint and transfers ring compression
- Sprayed over shear connectors and rebar
- Not suitable for:
  - small cracks
  - severe corrosion
  - large deformations

Longitudinal Seam Reinforcing

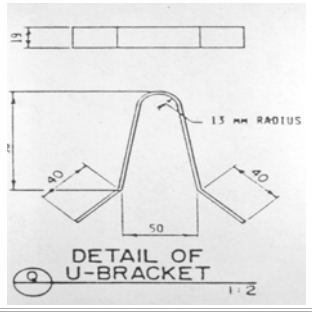


Longitudinal Cross Section

Pump and Mixer for Prewetting

Detail of Reinforcing and Shear Connectors

U-bracket Shear Connector



Sandblast Equipment

Heaters

Reinforcing and Shear Connectors Ready for Shooting

Shooting Concrete Mix

Completed Crack Reinforcing Beam

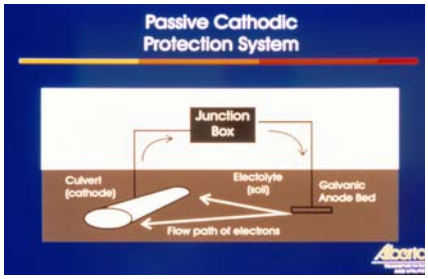
Cathodic Protection

- Prevents corrosion
  - impressed uniform potential
  - anode sacrificed to protect structure
  - soil side corrosion only
- System types
  - impressed current system
  - passive system

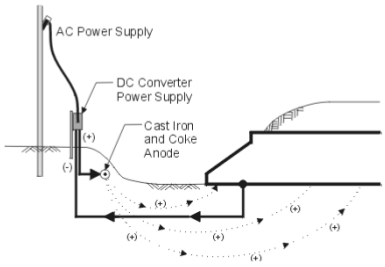
Cathodic Protection

- Impressed current system
  - 20 to 60 volts and 4 to 16 amps
  - available power on site, 120/240 AC
  - power supply, anode bed, electrolyte
  - life - 15 to 25 years
- Passive system
  - dissimilar metals create current and potential
  - many magnesium anodes sacrifice to protect structure
  - 1 to 2 amps and 1 to 2 volts
  - life - 15 to 25 years

Passive Cathodic Protection

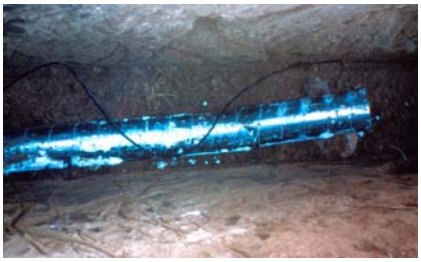


Impressed Current System



Anodes

Anode in Trench



Culvert Extension

Cut-off Wall - Piping

Downstream Restoration

Downstream Restoration

Jacking Culvert Under Highway

Environment Controls - Siltation Fence

Questions??