LECTURES ON RAIL/ROAD BRIDGES

Dr. A. Shakoor Uppal
PhD, FICE, CEng, PEng

Under TOKTEN Programme

with

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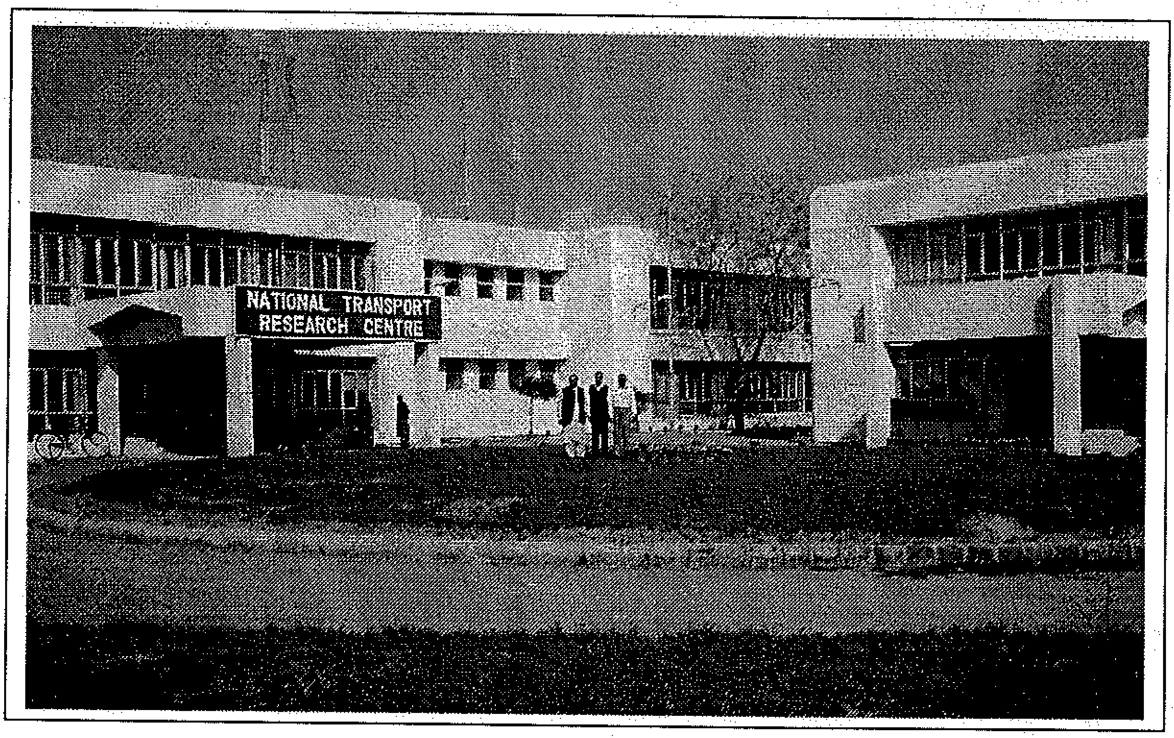

National Transport Research Centre (NTRC), Islamabad, Pakistan

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1. Introduction

The services of Dr. A. Shakoor Uppal were acquired by the National Transport Research Centre (NTRC) Islamabad for a period of four weeks during February - March 2003 under Transfer of Knowledge Through Expatriate Nationals (TOKTEN) program of the Government of Pakistan and sponsored by the United Nations Development Program (UNDP).

The objective of his original assignment was to train the NTRC staff by conducting a couple of lectures on topics as specified. In addition to that, to carry out studies on three different issues previously selected by the NTRC and to prepare reports of these studies with his findings and recommendations.

However, the NTRC in discussion with the TOKTEN consultant decided to modify the program to accommodate the request of its clients i.e. the National Highway Authority (NHA) and the Pakistan Railways (PR). This resulted in considerably additional workload on the part of the consultant but he accepted it.

The modified program now involved lectures on seventeen different topics at three locations and two study assignments. The lectures were well attended and the questions asked during these indicated a great deal of interest in the topics on part of the audience. Available data for the two study assignments was gathered in Pakistan for continuing analyses and drawing inferences and preparing reports in Canada. One report is complete now and is included herewith. The other report is in progress and will be submitted in the near future.

Hopefully, the efforts of the TOKTEN consultant would be fruitful to those for whom these were intended and in some small measure would meet with the UNDP broader aims and objectives.

The TOKTEN consultant would like to express his sincere thanks to the NTRC particularly Mr. Muhammad Kazim Idris, Mr. Bashir Ahmed, and Mr. Hameed Akhtar for their excellent cooperation and hospitality, the UNDP particularly Ms. Kaja Borchgrevink and Mr. Hicham Nahro for travel, security and other arrangements, the National Talent Pool (NTP) particularly Mr. Pirzada Riffat Nawaz, the PR particularly Mr. Ch. Abdul Aziz and Mr. Mohammad Amir Khan and to several NHA officials.

Finally, the TOKTEN consultant would be glad to answer any queries or questions on the subjects discussed during his assignment and the recommendations made in this or any subsequent reports.

2. Lectures

The outlines of different lectures by the TOKTEN consultant are given in this section.

1. Bridges General

Introduction

Brief History, Evolution of Bridge Construction, Tools and Techniques

Basic Types of Bridges – Girder, Arch and Suspension

Various Uses of Bridge Structures

Different Materials in Bridge Construction – Steel, Concrete, Timber and Others

Bridge Numbering System

Bridge Components and their Function

Bridge Decks – Railway and Highway
Bridge Spans
Bearings
Substructure and Foundations
Retaining Walls
Walkways and Refuge Bays
Utility Attachments

Railway and Highway Bridge Loadings

AREMA/ PR
AASHTO/ NHA

Different Types of Bridge Spans, Piers and Abutments

Load Dispersion and Load Paths

Forces in Bridge Components

Design Feature of Bridge Components

General Care of Bridges

Discussion

Recap

2. Concrete Structures

A. Types of Structures

B. Design Features

C. Causes of Deterioration

- i. Occurrences incident to Construction Operations
- ii. Drying Shrinkage
- iii. Temperature Stresses
- iv. Absorption of Water by Concrete
- v. Corrosion of Concrete
- vi. Chemical Reaction
- vii. Weathering
- viii. Shock Waves
- ix. Erosion (Abrasion)
- x. Poor Design Details, and
- xi. Error in Design

D. Preventive Maintenance

E. Diagnosis of Cause

1. Introduction

2. Steps
   - a) Check for an Error in the Basic Design
   - b) Relate the Potential Causes to the Three Basic Symptoms
   - c) Eliminate the Possibilities which are Readily Identified
     - i. Corrosion of the Reinforcement
     - ii. Shock Waves
   - d) Make a Detailed Investigation
   - e) Analyze the Available Clues
     - i. Where the Basic Symptom is Disintegration of the Surface
     - ii. Where there is Evidence of Swelling (Growth) of the Concrete
     - iii. Where the Structure is Spalling
     - iv. Where the Defects consist of Cracking
   - f) Finding out Why Deterioration has Occurred

3. Summary and Flow Charts for Diagnosis

F. Repairing Cracks

1. Introduction

2. Steps
    a) Determine whether the Cracks are Active or Dormant
    b) Determine the Cause
    c) Select a Method of Repair

3. Method of Repair

    a) Bonding with Epoxies
    b) Routing and Sealing
    c) Stitching
    d) External Stressing
    e) Blanketing
    f) Overlays
    g) Grouting
    h) Autogenous Healing
    g) Judicious Neglect
    j) What Not To Do

        i. Do Not Fill the Crack with New Concrete or Mortar
        ii. Do Not Use a Brittle Overlay to Seal an Active Crack
        iii. Do Not Fail to Relieve the Restraint causing the Crack
        iv. Do Not Surface - seal over Corroded Reinforcement without Encasing the Bars
        v. Do Not Bury or Hide a Joint so that it is Inaccessible

G. Repairing Spalls and Disintegration

1. General Requirements

    a) Preparing the Surface of Concrete, which is to be Repaired
    b) Existing Reinforcement
    c) Inspection before Placing New Concrete
    d) Compatibility of Materials and Sections
    e) Requirements for Good Quality Concrete and Mortar
    f) Cover
    g) Appearance
    h) Admixtures

2. Jacketing

    a) Description
    b) Forms
    c) Filling the Forms
    d) Finishing the Jacket
    e) Remarks

3. Pneumatically Applied Mortar

   a) Description
   b) Applications
   c) Preparing the Concrete Surface
   d) Materials and Proportions
   e) Mixing and Placing
   f) Remarks

4. Prepacked Concrete

   a) Description
   b) Application
   c) Composition
   d) Placing the Grout
   e) Remarks

5. Placement of Concrete

   a) Applications
   b) Preparing the Existing Concrete
   c) Proportioning the New Concrete
   d) Forms
   e) Placing and Curing

6. Drypack

   a) Applications
   b) Preparing the Existing Concrete Surface
   c) Mix
   d) Placing

7. Overlays

   a) Applications
   b) Preparing the Concrete Surface
   c) Materials
   d) Placing
   e) Remarks

8. Epoxy Resins

   a) Applications
   b) Preparing the Existing Concrete Surface
   c) Materials
   d) Mixing and Placing
   e) Remarks

9. Protective Surface Treatments

a) Oils
b) Silicones
c) Epoxies

H. Repairing Bridge Decks/ Pavements

1. Restoring a Disintegrated Surface

    a) General Consideration
    b) Method of Repair

2. Preventive Measures

    a) " Before the Fact " Considerations
    b) " After the Fact " Considerations

I. Correcting a settlement Condition

a) Restoring the Profile by Use of an Overlay
b) Compensating Profile
c) Mudjacking
d) Removing and Replacing the Slab
e) Correcting Deep-Seated Settlements

J. Masonry Structures

Weather, heaving or moving of substrata, the forces of ice and water and the effects of man-made environment are some reasons to cause maintenance requirements to brick or stone masonry structures.

a) Brick Masonry
b) Stone Masonry
    i. Types of stone substructures for bridges are;
        - Solid Cut Stone
        - Rubble Centre
        - Hollow Centre

    ii. Beside pointing masonry joints, other methods of upgrading or repairing stone masonry structures include;
        i. Drilling, dowelling and pressure grouting
        ii. Removing stones and replaced by pre-packed concrete into forms
    iii. Stabilizing the cracked stones - "dogging"
    iv. Harnessing part/all of structure to prevent moving/falling out of stones
    v. Enveloping part/all of structure and filling the envelope with pre-packed or ready-mixed concrete.

c) Tools and Methods

i. Raking the joints
Existing mortar, which is sandy, soft or crumby or has lost its bond, should be removed to a depth, point or chisel of the chipping hammer will allow.

ii. Chipping
Use of chipping hammer of pneumatic type

iii. Pointing
Joint leaks must be stopped before pumping grout. Pointing could be with trowel. Mortar of different strength is used for different purposes.

iv. Pressure Grouting
Location of holes depends on size and arrangement of stones. In piers - holes from top, angled holes from sides.

v. Repairing Broken Stones
Remove the broken stone and fill it with concrete or grout.

vi. Cinch Anchors
Drill hole and install

vii. Stone Bridge Seat Replacement
Splitting the stone with wedges

viii. Underpinning the Stone Structure
Clean the scoured area, filling with stones and grouting

ix. Dogging or Stitching Cracked Stone

K. Discussion

L. Recap

3. Use of Computers in Bridge Engineering Office

1. INTRODUCTION

Main Frame & Personal Computers

Programming Languages

FORTRAN
- PASCAL
- BASIC
- APL
- COBOL
- Others

DOS - Disk Operating System

- Symphony
- Lotus 123
- Freelance

Windows - Microsoft Packages
Word
Excel
Paint Brush
Power Point
Word Perfect
Designer
Project
Orgchart
Others

Graphic Packages for Windows

Autocad
Micrographic Designer
Others

Manual versus Computer

Manual
- Time consuming
- Some solutions are impossible
- Greater possibility of error
- Could not consider more options
- Good for non-repetitive work

Computer:
- Fast
- More accurate
- Numerous combinations of loads, material and shapes configurations could be attempted.
- Less expensive
- Good for repetitive work

Commercial versus Homemade

Commercially available:

- Made for specific application but marketed to recover development cost and to make profit.
- Commercial software are broad based and versatile.
- Not meant for specific use.
- Expensive.
- Need large computer memory.

Homemade:

- Railway is a unique industry.
- Better for specific needs
- Less expensive
- Does not require large memory
- Easy to modify
- Not broad based, not versatile.

User Friendly
- Prompting
- Icons

2. CHOICE OF BRIDGE

(a) Superstructures
(b) Substructures

3. DESIGN PARAMETERS

(a) Loadings
(b) Codes

Comparison

(c) Materials
(d) Method of construction
(e) Comparison of alternate designs

Cost vs. Benefits

4. STRUCTURAL ANALYSIS

   (a) Without Computer
   (b) Computer Software

5. STRUCTURAL DESIGN

   (a) Without Computer
       Structural Analysis
       Stress Analysis
       Ultimate Load/Stability Analysis

   (b) Computer Software

       Superstructure
       Substructure

6. MAINTENANCE DESIGN
7. ESTIMATES OF COSTS
8. JOB SCHEDULING
9. ACTUAL PROJECT COSTS
10. INVENTORIES
11. RESOURCE USE

    (a) Labor
    (b) Material
    (c) Equipment

12. PLANT MANAGEMENT SYSTEMS
13. FORECASTING
14. BUDGETING
15. RECAP

Numerous activities of Bridge Department of a railway or a highway could use computer software to obtain efficiencies and save time, energy and money. Several software are available which could be purchased. However, due to uniqueness of railway industry and differences in their practices, a good number of software should be developed in-house.

4. Quality of Concrete

1. **What is concrete?**

   Cement
   Aggregate – Coarse (Crushed rock, gravel etc.), Fine (Sand)
   Water
   Additives

2. **Types of cements**

3. **Types of aggregates**

4. **Types of additives (admixtures)**

   Workability
   Air entrainment
   Water reducing
   Accelerating or retarding setting time
   Sulphate resistance etc.

5. **Concrete mix design**

6. **Water Cement Ratio**

7. **Formwork**

8. **Placement of reinforcement**

9. **Pouring and vibration**

10. **Concreting in inclement weather** – cold, hot & humid

11. **Curing**

12. **Testing before/ during/ after concreting**

13. **Attributes of quality concrete**
    Weather resistant
    Watertight
    Wear resistant
    Adequate strength

14. **Discussion**

15. **Recap**

5. Inspection of Bridges

Purpose of Inspection

The Inspector

The Bridge Materials and Their Mechanical Properties

Wrought Iron, Cast Iron, Early and Present Steel and Steel Alloys
Mass Concrete, Reinforced Concrete, Prestressed Concrete
Hard and Soft Wood, Wood Products
Composite, Orthotropic and Membrane Construction
Miscellaneous Engineering Materials

Bridge Construction Techniques

Old
Current

Factors affecting the Service Life of Bridges

Traffic – Volume and Frequency
Deterioration – corrosion of metal and concrete, decay of wood etc.
Lack of Maintenance
Abuse – Overloading
Accidental Damage – Collision, Derailment, Fire, Flooding etc.
Erosion and Scour
Freeze and Thaw Cycles
Floating Matter and Environmental Toxities

Tools and Equipment for Bridge Inspections

Inspection Tools
Accessing Bridge Components
Safety Tools
Relevant Labor, Safety and Environmental Laws and Regulations

Forms and Reports

Identifying Emergencies

Condition and Priority of Needed Work

Evaluation Procedures

Weight and Speed Restrictions

Recommendation for Necessary Action

Handling Emergencies

Safety During Bridge Inspections

Discussion

Recap

References

6. Nondestructive Techniques for Bridge Inspection

1. Nondestructive techniques are employed to detect internal or external discontinuities, to determine structure of material, composition, and properties, and to measure geometric characteristics of an object or material, without affecting its form, fit, or function in any way.

2. NDE uses physical or chemical means to assist in detection and characterization of material deficiencies. Sound waves, electrical currents, magnetic fields, radiation, thermal waves, and tracer liquids are directed into and in most cases, penetrate the material being tested.

3. The basic NDE. i.e. visual inspection does not provide direct observation of the internal or hidden condition regarding internal flaws and internal fatigue cracks in the material. Some aspects of quality of fabrication and component stability are also not directly observable.

4. Therefore, there is a need to identify feasible NDE techniques that can help assess the complete condition of bridges. For a NDE technique to be successful for application in bridge evaluation, it should be able to provide the necessary measurements in a real time, be portable and practical to use, and have an affordable initial cost and operating cost.

5. The potential NDE techniques should complement the current visual inspection procedures and help improve the quality and efficiency of the condition information to be collected.

6. Any NDE technique identified for use in steel bridge inspection should focus on determining the following information:

   - Condition and service performance of bridges in the field; such as corrosion, cracks, stresses, deformations and dimensions.
   - Determination of physical properties of the structural components in laboratory, such as strength and.material quality.
   - Quality control purposes in fabrication shops, such as weldments (lack of fusion, lack of penetration, porosity) and lack of fit.

7. In civil engineering applications, the NDE methods may be employed for the following purposes:

   - Detecting internal flaws in metal and weld
   - Determining the remaining thickness of metal in corroded member
   - Measuring coating thickness
   - Detecting cracks, voids, their rate of growth and location, shape and size, and detecting reinforcing bars
   - Finding disbands in composite materials and lack of fit of coponents
   - Determining deformations and stresses
   - Determining dynamic behavior
   - Finding hardness and other material characteristics

- For quality control during fabrication of structural steel, inspection of steel bridges and testing bridge components or coupons in the lab.
- More recently to predict the performance and assessment of fatigue life of structural components.

8. There are numerous NDE techniques available. However, the most practical for use in steel bridges are;

- Penetrating Radian Methods
- Radiography

  Special Topics and Radiometry
  Neutron Radiography
  Image Enhancement
  X-Ray Computed Tomography
  Radiometry
  Other Areas

- Sonic and Ultrasonic Methods – Acoustics and Ultrasonics

  Active Techniques – Ultrasonic Pulse-Echo Inspection
  Passive Technique – Acoustic Emission

- Electromagnetic – Electronic Methods

  Techniques based on measuring magnetic fields

  Magnetic Particles Testing
  Magnetic Barkhausen Effect

  Techniques based on measuring electrical currents

  Eddy Current Testing
  Microwave Testing
  Other Electromagnetic Methods

- Visual Observation Methods

  Optical Enhancements
  Liquid Penetrants
  Metallographic Replication

- Methods Requiring Supplementary Conditions

  Leak Testing
  Optical Holography
  Thermal Infrared

- Discussion
- Recap

7. Bridge Bearings

1. Function of Bridge Bearings

- To transfer vertical loads from superstructure to substructure
- To resist lateral loads due to wind, nosing and hunting etc.
- To facilitate rotation of span due loads
- To allow change in span due temperature variations
- To prevent uplift of span
- To provide resistance against seismic forces

2. Changes in Bridge Spans due to Loads and Temperature Variations

- Elongation and shortening
- Rotation – longitudinal and transverse, deflection, and
- Torsion

3. Earthquake and Flood Forces

- Seismic – ground motion
- Uplift

4. Fixed Bearings and Expansion Bearings

5. Types of Bearings

(a) Metallic

Flat plates – slotted holes at expansion end
Plates with tongues and grooves
Rocker
Disc – circular, rectangular
Pintle
Rollers

(b) Elastomeric

Plain elastomer
Reinforced elastomer
Confined elastomer – pot bearing
Stainless steel - Fabreeka, Teflon, bronze or other types of sliding surfaces

6. Related Items

a) Castings and Shim Plates
b) Anchor Bolts
c) Slotted and Round Holes, Retaining Plates or Aligning Guides
d) Bearing Pads – Neoprene, Lead Sheet

e) Bridge Seats Deterioration

7. Problems

a) Seizing – rusting of components, deterioration of elastomers
b) Sinking or Dishing of bed plate
c) Cracked casting
d) Pumping under traffic – bent plates, space between plates, uneven surfaces
e) Loose, bent or sheared off anchor bolts
f) Flattening or wearing of pins and rollers
g) Dislocation or misalignment of components
h) Shoe Plate Weld Cracking

8. Maintenance

a) Periodic cleaning and lubrication
b) Resetting components
c) Shimming or removing shims – steel, wood, concrete shims or blocks
d) Adjusting expansion slots (account movement of substructure)
e) Machining pins and rollers that have lost roundness
f) Repairing/ extending/ replacing anchor bolts and nuts
g) Bearings for submerged superstructures

9. Bearing Replacement

- Verify loading, amount of movement/ rotation required. Also the height of the bearing required.
- Proprietary makes
- Specification for ordering

10. Installing Bearing

- Jacking of a span – off the bridge seats, off the adjacent span, off brackets installed on the piers/ abutments, off temporary supports (cribs, bents)
- Jacking locations on a span, jack capacities, hydraulic pumps, jack synchronization, traversing bases etc.
- Lifting span with a crane
- Jacking span by means of wedges

11. Discussion

12. References

8. Capacity and Maintenance Issues on Bridges

1. Purpose:

Safety: Can/ cannot operate on bridges, without/ with restrictions
Health of bridge plant: Is the overall condition of bridges – good, fair, poor, bad
Handling heavy or unusual shipments: prompt and reliable service to customers
Development of work programs: And in turn allocation of funds and resources
Upgrading needs:

2. Background information and its importance:

Before carrying out the load capacity (rating) of an existing bridge, gather up the following information:

(a) Plans of the original design, repairs, strengthening etc.
(b) Correspondence files dealing with the design, construction, and maintenance of bridge.
(c) Maintenance and problems or damage history
(d) Inspection reports particularly showing loss of material, mechanical damage if any, track eccentricity, excessive ballast etc.
(e) Photographs, and
(f) Future forecast of train loading and frequency

3. Definitions:

Normal rating – for regular equipment - $0.6f_y$
Maximum rating – for occasional equipment - $0.8f_y$

4. Areas of Possible Reserve capacity:

- Allowable stresses (tension, compression, bending, bearing etc.)
- Impact factors
  - Steam locomotive versus Diesel locomotive
  - Empirical formulas versus Test results – particularly short spans
  - Speed restrictions
- Train loading vs. actual train make-ups – prior to 1960's, unit trains, today's trains – long and more frequent freight trains
- Assumptions:
  - Structural behavior versus Method of Analysis
  - Simply versus continuously supported
  - Effective span length
  - Joints as hinges versus partial or fixed connections
  - Composite action
  - Load dispersion/ transfer
  - Passive pressures
  - Factor of safety against overturning and sliding

- Design
  - Working stress versus load factor
  - Available sizes versus required sizes (by computation)

5. Bridge Rating Procedure:

Design briefs – stress sheets are always required – to save time and effort.

(A) DECK PLATE GIRDER SPAN – Simply Supported

Note: For main girders, floor beams, stringers and bracing system in a given bridge span, work out the individual rating separately.

- Bridge plans for details and types of material used.
- If the material info. is not available, then coupons (specimens) are to be taken from the least damaging areas of the main members and are tested in a structural lab. to determine the ultimate and yield tensile strength, the elongation, the ductility, toughness (Charpy Vee Notch) as well as the micro-structure of the material.
- Information on the fabrication and erection techniques employed if any on files. Information on accidental damage or overloading situation or other condition that may affect the capacity.
- Review of plans (both the original and the repair or strengthening) for details of connections, general notes etc.
- Recent inspection reports for estimating condition such as corrosion resulting loss of section, change in geometry etc.

a) Determine the loading system for which a span rating is required?

Examples: In term's of Cooper's equivalent
Maximum weight limit for a given type of a car or locomotive
Railway's bridge classification

Whatever the purpose may be, the bending moments and shear forces are computed at the critical locations. Influence lines are used for finding the bending moments for moving loads.

b) Analysis

Loading: Dead Loads to include the weight of track, deck, walkways and other attachments and the self-weight of the span.
Live Loads to include train load, impact, wind, nosing, longitudinal forces, centrifugal forces, effects of track eccentricity, etc. in accordance to the specifications or codes being used.

Note: For some combinations of loads, codes allow increase of allowable stresses.

1. Establish the allowable stresses in tension, compression, bending, shear and bearing for the material of the bridge span. These may be computed from the lab test data, or from info. on the plans or files, or assumed.

2. Sectional Properties: Compute the gross and net (for tension members) cross sectional areas, moments of inertia and section moduli of full sections and for top and bottom sections separately.

3. Work out the bending moments; shear forces, reactions and deflections due to deal, live load, impact, wind, nosing, centrifugal force and track eccentricity etc. at critical locations of the span.

4. Using 2. and 3. above, work out the stresses at the critical locations. Compare them to the allowable stresses obtained in 1.

c) Ratings:

With (b) and (c) 4. above, and using live loads only, compute the ratings in bending and shear for full, three-quarter, one-quarter, and zero impacts.

Review bearing areas, stiffeners, web and flange splices, bracing system and connections for rating in a similar fashion.

Tabulate the rating information for all the components of the Deck Plate Girder Span in an orderly manner.

d) Action:

Review the computed ratings and determine if they are adequate for the applied loading or if, there is a need of weight and/or speed restriction for regular traffic on the span. Also if the span needs to be strengthened.

(B) THROUGH PLATE GIRDER SPAN – Simply Supported

a) The procedure is same as for the Deck Plate Girder Span except the floor system has to be rated as well.

(C) THROUGH TRUSS SPAN – Simply Supported

The procedure is similar to that of Through Plate Girder Span except for the following:

(a) Analysis:

Trusses could be analyzed as plane frames or space frames. The connections could be assumed as pins or hinges (riveted or bolted) or rigid or fixed (welded) or partially fixed. Similarly, the floor system could be assumed as simply supported or partially or fully fixed at ends.

Traffic should be assumed to be running in both directions in order to obtain the effect of stress reversal in certain members.

(b) Use of Computer in Bridge Rating Process:

- Structural analysis – numerous commercially available software
- Rating of rolling stock – new car to be built to run over bridges without restrictions
- Rating of different types of bridges
- Data base for verifying if a special shipment can be handled over a given route

(c) Use of Bridge Rating Information by Management:

- Marketing – What kind of traffic; cars, locos etc. that can be handled?
- Cost of Temporary Measures for Handling Special Shipments – Whether a bridge needs to be raised or strengthened to handle the shipment and its cost
- Competitive advantage with other modes of transportation – price fixing

6. Discussion:

7. Recap

9. Bridge Testing

- **Introduction**

- **Purpose of Bridge Testing**

  A. Static Tests

  B. Dynamic Tests

- **Measurements**

- **Instrumentation**

  Load Cells
  Shear Circuits
  Longitudinal Force Circuits
  Dial Gages
  Strain Gages
  LVDTs – String Potentiometers
  Accelerometers
  Pyrometers
  Thermisters

- **Signal Conditioning**

  Analog Signals
  Amplification
  Filtering
  Digitizing

- **Data Acquisition System**

- **Data Storage, Printing, Plotting**

- **Data Interpretation, Analysis and Manipulation**

- **Software Packages**

- **Discussion**

- **Recap**

10. Use of Continuous Welded Rail (CWR) on Bridges

Introduction

Effect on Rail of:

- Temperature changes
- Creep
- Curvature
- Traction and braking

Rail Break

Rail Buckling

Preferred Rail Laying Temperature Range

Stresses in rail due Anchoring and Other Restraints

What is a Continuous Welded Rail?

CWR on Bridges – Basic philosophies for

- Open deck bridges
- Ballast deck bridges

De-stressing

Rail Sliding Joints

Rail Anchoring and Locating Rail Joints on Bridges

Discussion

Recap

11. Railway Bridge Decks

1. Purpose of Bridge Deck

To transfer the axle and other loads from rails to the bridge spans.

2. Types of Bridge Decks

Bridge Components

Superstructure
Substructure

Typical Railway Bridge Spans:

Steel Spans
Concrete Spans
Timber Spans

Steel Spans:

Beam (BM)
Deck Plate Girder (DPG)
Through Plate Girder (TPG)
Through Truss (TT)
Deck Truss (DT)
Half Deck Plate Girder (HDPG)
Half Through Plate Girder (HTPG)
Poney Truss (PyT)
Arches (AR)

Concrete Spans:

Slab (RCS)
Girders - reinforced, prestressed (RCG, PCG)
Slab and Beams (RCBS)
Frame - portal (RCF)
Concrete or Stone Masonary Arches (CA, MA)

Composite - Concrete and Steel (CS Comp)

Timber Spans:

Stringers - Open Deck (ODPT)
Deck Planks on Stringers - Ballast Deck (BDPT)
Laminated Timber (SLD)

Deck Types

Open	- rail on transverse ties or bearing blocks
Ballasted	- rail on track ties and layer of ballast
Other	- rail directly supported on decking

Advantages and Disadvantages

Open

Lower initial cost
Fair amount of maintenance
Greater adoptability in temporary or emergency situations
Lower costs when renewal or repairs under traffic
Less dead weight
Service life; 20 - 40 years

Ballast

Relatively higher initial cost
Less maintenance
Greater ease in maintenance of track surface and line
Better train riding quality
Better performance under overloads
Better protection against damage due to fire
More dead weight
Service life; 30 - 60 years

Other

Rails directly supported on deck slabs using rail clips
Relatively moderate initial cost
High maintenance cost due to poor dispersion of axle load and the use of rail clips and anchored bolts
Service life; 10 - 20 years

Relative Dead Weights

Open deck: 0.75 to 1.60 Kips/foot
Ballast deck: 2.50 to 3.50 Kips/foot
Other decks: in between

3. Components

Open Decks

Running Rails: 85, 100, 115, 132 & 136 lbs. - Jointed, CWR

Tie Plates/ Bridge Plates: 11", 14", 18" & 22" etc.
Gauge Plates, Gauge Rods

Tie Pads:

To provide uniform bearing
To absorb impact
To prevent entry of moisture in wood
To prevent wood decay and fastener corrosion

Rigid versus Elastic Fasteners (Conventional versus Direct Fixation)

Rigid - work well with flexible ties and tie base.
Flexible - work well with both rigid and flexible ties and base.

Spikes/ Other Fasteners (Pandrols, Curv Lok, Sidewinder, Lag Screws)

Guard Rails Usually one size less than the running rail.
Spacing and Spiking Arrangement

Bridge Ties

Most Common Sizes: 10"x12", 8"x8"
Lengths: 10', 12', 13' and 16'
Softwood: Douglas fir
Hardwood: Red Oak
Concrete
Dapped/ Un-dapped

Structural Bridge Ties: Two supports
Four or more supports

Bearing Bridge Ties: Rails resting directly under the supports

Continuous Support under Rails

Bolts and Fasteners

Hook Bolts/Machine Bolts with Nuts and Spring Washers
Pandrols with Bridge Plates and Lag screws

Spacer Timber (Shock Blocks) or Steel Bar

Walkways

Refuge Bays and / or Water Barrel Stands

Other Attachments Utility Pipes and Cables

Fire Protection

Ballast Deck

Running Rails 85, 100, 115, 132 & 136 lbs. - Jointed, CWR

Tie Plates 11", 14", 18" & 22"

Tie Pads

Spikes/ Other Fasteners

Track Ties Softwood: Douglas Fir,
Hardwood: Oak
Steel
Concrete: Pre-stressed Concrete, Mono Block

Rail Anchors

Ballast 14" to 18" (Base of Rails to Top of Deck)

Guard Rails Usually one size less than the running rails
Spacing and Spiking Arrangement

Water-proofing

Drains & Drainage

Ballast Retaining Curbs

Decking Types

Timber Deck Planks - nailed to timber stringers
Laminated Timber Decks
Bunched Bridge Ties
Steel Decking - bolted/welded to steel stringers or floor beams
Concrete Slabs - composite or clamped to girders

Walkways

Design: Independent, monolithic
Timber/Steel/Concrete
End Treatment

Barrel Stands and refuge Bays

Other Attachments: Utility Pipes/Cables

4. Loads on Decks

Live Load
Impact

Wind Forces
Nosing
Centrifugal Forces

Deck Resistance provided by

Dead Weight
Live Load
Hold-down fastener

5. Dispersion of Axle Load

Open Deck	rail, tie-plate, ties and girder/beam/stringer etc.
Ballast Deck	dispersion through track ties and layer of ballast
Other Decks	rail directly supported on wood/concrete/steel

6. Structural Capacity of Deck

Design versus Traffic

Open Deck	Structural ties, Bearing Ties
Ballast Deck	Structural capacity - rail bound, center-bound conditions

7. Wood Science

Wood cells
Free and bonded water
Moisture content versus mechanical properties
Shrinkage, checking and splitting
Mechanical Properties

Deterioration of Wood

(1) Biotic Agents:
Decay Fungi
Insects and
Marine Borers

Control of Decay:

1. Moisture
1. Oxygen
2. Temperature
3. Food

Preservative Treatment

(2) Physical Agents:

Traffic
Stream Flows
Soil
Weather
Corrosion
Fire: Different ways of protecting the decks from damage by fire are:

Fire Retardant Coatings
Sheet Metal Coverings
Water /Sand Barrels
Sprinkle System

Poor Work Practices

8. Concerns

1. Checking and splitting of ties (vertical, horizontal & end checking)
2. Spike killing of ties missing and loose spikes/clips
3. Plate cutting of ties
4. Deteriorated tie pads
5. Decay in ties
6. Shimming tie plates
7. Over dapped ties; ties riding on flanges/gusset plates/bracings, checking at dap corners
8. Missing/broken hold-down bolts - causing weakness of lateral stability
9. Skewing/bunching of ties/damage caused by rail anchors
10. Mechanical damage/derailment/dragging equipment/rail handling etc.
11. Fire damage
12. Unsupported length of rails
13. Impact under rail joints
14. Crushing of ties
15. Centre-bound track ties
16. Fouled ballast
17. Poor deck drainage - puddle - plugged weep holes in concrete - spacing between planks filled up - result decay of timber, damage/corrosion to concrete/steel decking, poor track surface.
18. Excessive ballast
19. Insufficient ballast
20. Effect of track eccentricity
21. Water proofing of concrete deck slabs
22. Ballast retaining curbs
23. Decay/corrosion of deck planks/concrete slab/ steel plate or beams etc.
24. Corrosion of fasteners; spikes, clips, plates, cinch anchors, lag screws etc.
25. Poor bridge approaches; High/Low, hanging rails on deck/on approach, puddles, shims, high/loose/missing spikes or fasteners
26. Rails supported on dump walls
27. Approach ballast sections

9. Inspection of Decks

Purpose: ensure safety, evaluate capacity, determine maintenance and replacement needs, and update records

Tools:

Note book, straight edge, pens/pencils, camera and supply of films

Timber;

1. Drill 3/8" inch cap, pistol type
2. Drill bits 3/8" inch diameter
3. Electric extension cord *
4. Probe for measuring holes/voids
5. Treated hardwood plugs
6. Portable generator *
7. Safety gas can
8. Marking crayon
9. Measuring tapes
10. Testing hammer
11. Incremental borer

* Not required if gas operated drill is used.

Concrete;

1. Testing hammer
2. Knife
3. Dynamic concrete tester
4. Marking crayon
5. Measuring tapes
6. Core drill, core bits, power source
7. Core boxes

Steel;

1. Sand paper
2. Needle brush
3. Calipers
4. Micrometers
5. Magnifying glass
6. Marking crayon
7. Measuring tape

Frequency of Inspections

Visual : At least once a year
Detailed : As necessary - only suspect situations - do not waste time on clear cut cases.
Special : More often inspection of problem areas.

Safety during Inspections

Minimum two persons per team
Personal Wear; hardhat, safety goggles, safety shoes, dressed for the weather and work
Fall Protection; full body harness, proper tie-ups, scaffolding etc.
Protection against drowning
Positive track protection (CROR)
Buddy system - team members as lookouts
Public protection; barricades, warning signs etc.
Written procedures; safety, emergency, work etc.

Visual Examination of each component of the deck for condition
Sounding wood with hammer,
Observation under traffic,
Examining immediate surrounding for signs favourable to decay, high humidity or insect activities.
Identification of abnormal or suspect conditions etc.

Checklist for Decks:

Detection of Decay in Wood:

Exterior Decay
Interior Decay

Detailed Examination of Ties:

Test boring or coring of areas found suspect by visual inspection.
Examining wood shavings
Examining cores
Probing drilled holes with probe

Concerns Tie plate area, fastener holes, surfaces in contact, vertical and horizontal checks and splits, mechanical damage, fire damage and condition of fasteners etc.

10. Evaluation

Definitions

Reject tie: a tie incapable of
- holding rail gauge or alignment (spike killed, badly checked)
- carrying its intended loads safely (decayed or damaged)

Considerations:

(i) Original Design (Cooper E - Loading)
(ii) Age and Condition of Deck

(For Open Decks - location and extent of decay, percentage of rejects, bad spots, dimensional change; crushing, checking, splitting etc., condition of fasteners; loose, high, missing, presence of shims, pattern and condition of hold-down bolts, daps, bunching and twisting of ties, spacers, gauge, line and surface, super elevation, eccentricity etc. etc.)

(For Ballast Decks - as above for track ties plus center-boundness, thickness and condition of ballast, deck drainage, puddles, corrosion, waterproofing, deck clamping to girders, curbs etc. etc.)

Overall deck integrity and stability

(iii) Rated Capacity with Current Condition
(iv) Future Demand on Capacity - Heavy Axles ?

Restrictions:

Need for speed or weight restriction.

11. Maintenance

What maintenance activities?

- Removing splinters, frayed wood, tie pad edges, other combustible or decayed material from the deck.
- Spot renewal of ties.
- Tightening deck fasteners.
- Double spiking, plugging spikes, installing spike locks etc.
- Field treatment of open checks, spike/bolt holes and tie plate areas of ties.
- Reuse spike killed ties by turning on side or shifting existing holes.
- Replacing smaller tie-plates with larger tie-plates and tie-pads.
- Replacing fouled ballast.
- Repairing or reinforcing curbs.
- Waterproofing decking.
- Repairing walkway planks, railing, grating, deck planks, curbs, spacer bars and brackets for attachments etc.
- Correcting track eccentricity by lining rails.
- Raise or lower approaches to match deck elevation.

12. Replacement

Why replace?

- Deck capacity insufficient for the traffic loading.
- Maintenance has become very expensive and or very frequent.
- Considerations: Bridge needs raising.
- Conversion to ballast deck - may require strengthening of span.
- Addition of walkways.
- Increase in deck capacity.
- Added fire protection.

13. Discussion

14. Recap

12. Bridge Management System

Purpose

Means of controlling and manipulating bridge data for planning short and long-term work programs and for making various types of statistical inquiries and decisions for effective use of available resources including funds.

Sources needed for development

Highway or Railway network
Bridge location
Bridge basic data
Condition and priority of work
Information about problem bridges
Permanent and temporary speed restrictions
Bridge rating and bridge assessment record
Restrictions on bridges for different type of rolling stock – loads
Past maintenance/ improvement records

Some of the uses

Assessment of bridge condition on the network
Status of dimensional/ overload shipments
Maintenance programs – short and long-term – estimates of costs
Capital programs – short and long-term – estimates of costs
Forecasting bridge needs and budgets
Data for various engineering and economic studies
Response to bridge inquiries

Further

Data base could be expanded to include Maintenance of Way and
Signals and Communications
Bridge locations tied with GPS

Benefits

Powerful management tool
Paperless data on engineering plant inventories
Quick response to various inquiries
Forecasting and planning tool
Savings of labor, time and money

Discussion

Recap

13. Safety and Reliability of Bridges

Note: This was intended to be an assignment but due to the addition of lectures that considerably augmented the original workload of the TOKTEN consultant, it was decided by NTRC to turn into another lecture. The outline of the lecture is as below:

(a) Criteria for safety and serviceability

- The reliability of a structure or element is defined in a natural way by the probability of not achieving any of its limit states.
- Broadly speaking there are two types of limit states;
  1) Ultimate limit state – under which the structure or component is judged to have failed in its capacity to carry the load. Because it could have catastrophic effect, a low probability is assumed.
  2) Serviceability limit state – under which the function of the structure or component is judged to have impaired. Because it could have disruptions effect, a high probability is acceptable.

- Safety

  - There is no such thing as absolute safety in wake of uncertainties. Therefore there is the concept of probability of failure. Attempting to achieve an absolute safety entails enormous cost and still without surety.
  - Cannot prevent failure forever – therefore introduction of the time element.
  - Low probability of failure within a certain time frame may deemed to be acceptable criteria as this may entail catastrophic or fatal results.
  - Criteria has to be set by the governing authority based what is acceptable.
  - Example: 1. Culvert design based on 100-year flood – washout may result in loss of life.

    Example: 2. A derailment of a passenger train is happening every 10-years. A derailment of a goods train is happening every 2-years.

- Serviceability

  - There is no such thing as absolute serviceability in wake of uncertainties. Therefore, there is the concept of probability of disruption in service. Attempting to achieve an absolute serviceability requires very high costs.
  - Cannot prevent disruption or inconvenience forever – therefore introduction of the time element.
  - Relatively high probability of disruption within a certain time frame may deemed to be acceptable criteria, as it does not entail catastrophic events.
  - Criteria has to be set by the governing authority based what is acceptable.
  - Example: 1. Closing of a lane of a two-lane bridge for a month in a year.

    Example: 2. Ten bridges having weight or speed restriction in one year.

    Example: 3. Breakdown of a high rise building twice every month.

(b) Review of bridge inventory and bridge features

- Number and types of bridges – steel, concrete, timber, composite or other material
- Strategic or non-strategic – define strategic – based on traffic, replacement cost, no alternate route, overall length, type of traffic (rail and road, mixed, movable etc.).
- Bridges with special concerns:
    - Low clearance
    - Prone to flooding
    - Prone to fire damage
    - Subject to vandalism
    - Prone to trespassing
    - Possessing structural weakness or anomaly

⇒ Identify above features and characterize bridge inventory accordingly.

(c) Bridge designs versus traffic loading (including forecasts)

- Railways/ Highway – Design Loading:
    - Cooper E-loading/ PR – ML, BL, HM loading plus impact
    - Various Classes of Highway Loadings
    - Wind, Lateral loads (nosing, stream flow), Longitudinal loads (braking and accelerating), Centrifugal, Seismic etc.
- Railways, Highways – Actual Loading:
    - Magnitude and frequency – present, forecast for future
    - Establish probability of exceeding the design loads

- If the analysis is for serviceability then the exceedence is from the design or service loads and if the analysis for safety then the exceedence is from the maximum or ultimate loads.

- A similar criterion can be employed for the highway bridges.

(d) Maintenance practices and physical conditions

- Review the maintenance practices
- Review physical condition of bridges

(e) Examination of representative bridges

- Through field inspections, verify that the bridge condition and maintenance practices are as stated. This is to ensure the quality of the data for statistical analysis.

(f) Factors influencing safety and serviceability

Resistance Effect:

- Capacities of bridges differ depending on material, design and construction. Lab testing may be necessary sometimes to determine material properties. Field load testing may be necessary to determine factor α i.e. the ratio between the measured and theoretical stress.

- Maintenance practices – affects capacity
- Condition – affects capacity
- Age – material deterioration
- Accumulated traffic – remaining fatigue life
- Ultimate capacity, Maximum capacity, Operating (Service) capacity – also called resistance effect "R" to which appropriate resistance factor ϕ be applied to obtain effective resistance ϕR.
- Depending on the type of reliability analysis (safety or serviceability) determine the distribution curve of capacity or resistance of ϕR in a given line segment or for entire network.

Load Effect:

- Actual loads are determined by field surveys.
- Load (i.e. equipment) rating or Load effect "Q" is dependent on the length of the bridge. Load effects are multiplied by load factors γ to account for uncertainties.
- Depending on the type of reliability analysis (safety or serviceability) determine the distribution curve of load or rating of equipment of γQ for a given line segment or for entire network.

Unpredictability of maximum loads and resistances are represented by the distribution curves.

(g) Analyses and inferences, and

- The loads and resistances are assumed to be random variables.

  $\phi R_n \supseteq \Sigma\, \gamma_i\, Q_i$

  where:

  R_n = Nominal resistance for given failure mode calculated according to prescribed procedure using nominal material strength and dimensions,
  ϕ = Resistance factor,
  Q_i = Effects of prescribed nominal loads, and
  γ_i = Load factors.

  Load combinations are indicated by $\Sigma\, \gamma_i\, Q_i$

- Safety and serviceability checking involves the evaluation of above equation for each limit state or service state which can govern, for example, bending strength, buckling or excessive deflection.
- $\mathbf{R} = \phi R_n$ $\quad\quad$ $\mathbf{Q} = \Sigma\, \gamma_i\, Q_I$
- When $\quad$ $\mathbf{R} - \mathbf{Q} > 0$, the probability of failure can be given as:

$$P_f = p(\mathbf{R} > \mathbf{Q}) = \int_0^{\infty} F_R(x).\, f_Q(x).\, dx \qquad (1)$$

Where: F_R = cumulative probability distribution function (cdf) in R, and

f_Q = probability density function for Q

- If, **R** and **Q** both have normal distribution, then

$$P_f = \phi\,[\,-(\mathbf{R}^{bar} - \mathbf{Q}^{bar}) / \text{SqRt}\,(\sigma_R^2 + \sigma_Q^2)] \quad (2)$$

Where: $\mathbf{R}^{bar}$ and σ_R = mean and standard deviation (σ_R^2 being the variance) for **R** and similarly $\mathbf{Q}^{bar}$ and σ_Q are for **Q**.

- The reliability index β (in some studies, β is termed as safety index) is defined by;

$$\beta = (\mathbf{R}^{bar} - \mathbf{Q}^{bar}) / \text{SqRt}\,(\sigma_R^2 + \sigma_Q^2) \quad (3)$$

- If **R** and **Q** are normal and statistically independent, then **R** – **Q** is normal with mean $\mathbf{R}^{bar} - \mathbf{Q}^{bar}$ and variance $\sigma_R^2 + \sigma_Q^2$, then the probability of failure is;

$$P_f = P[\mathbf{R} - \mathbf{Q} < 0] = ???$$
$$= \phi\,[\,-(\mathbf{R}^{bar} - \mathbf{Q}^{bar}) / \text{SqRt}\,(\sigma_R^2 + \sigma_Q^2)] \quad (4)$$

From these the reliability index β is related to the percent point function of the standard normal distribution according to the following equations;

$$\beta = \phi^{-1}(1 - P_f) \quad (5)$$
$$P_f = \phi(-\beta) \quad (6)$$

β is a useful comparative measure of reliability, and can serve to evaluate the relative safety.

(h) Recommendations

- Consider bridges on the ML of PR for analysis or bridges on main highway segment for NHA for analysis.

(i) Discussion

(j) Recap

14. Assessing Residual Life of Railway Bridges

INTRODUCTION

REASONS FOR ASSESSMENT

1. Verify capacity for Existing Traffic
2. Need to increase the Current Speed
3. Need to increase the Current Loads
4. Need to increase both Speed and Load
5. Determine Residual Fatigue Life

WHAT IS FATIGUE?

EXISTING STRUCTURES

1. Original Plans
   Look up the plans for design details, repairs and maintenance or damage information that would affect the evaluation.

2. Design Criteria
   Check the design and impact loading used and compare it to the current and proposed loading.
   If the bridge rates good with the last reported condition, then it may not be necessary to carry out further strength analysis.

3. Materials and their Properties
   Look up the old records for the type of material. Determine whether open-hearth or Bessemer steel or whether wrought iron.
   If not available, take three specimens from the main members, test them for tensile stress, V-notch test for toughness and identify the structure by microscopic examination.

4. Workmanship - Fabrication and Construction
   Review plans to pick up the critical members or details that are prone to fatigue damage. This may require a thorough examination of the detailed drawing as well as the field conditions. In particular, look for copes, rivet holes, re-entrant corners, nicks, poor welds, cracks, corrosion, knife-edges etc.

5. Age and Past Load History
   This is required to establish the accumulated traffic cycles that would affect the remaining fatigue life

6. Maintenance and Service History

Gather information on past repairs and on any problem that could affect the strength and fatigue evaluation.

7. Inspection Reports

(a) Loss of Material
(b) Fatigue Cracks
(c) Mechanical Damage
(d) Deficiencies
(e) Maintenance Required
(f) Movement under Trains
(g) Eccentricity of Loads
(i) Loss of Camber
(j) Added Dead Weights
(k) Changes from Original Design
(l) Miscellaneous

8. Results of Theoretical Analysis

(i) Methods of Analysis

Plane Frame
Space Frame
Finite Element

(ii) Use of Calculators
(iii) Computer Softwares

In-house developed

Commercially available

Carry out analysis as needed and determine the stress ranges in members having critical details, for different equipment (past, present and future).

9. Results of Material Tests

(i) Microscopic Examination

(ii) Chemical Analysis

(ii) Mechanical Tests

Tensile Test

Impact Test

10. Results of Field Tests

(a) Static

(b) Dynamic

BASICS OF BRIDGE VIBRATIONS

RESONENT FREQUENCIES

Avoid speeds that would result in resonant frequencies on the bridge.

PAST, PRESENT, AND FUTURE TRAFFIC

Past traffic is used to determine previously accumulated load cycles. Future traffic is assumed to determine the remaining fatigue life.

LOAD SPECTRA AND HISTOGRAMS

STRESS RANGES AND LOAD CYCLES

If the max live load stress range (SR) is below the allowable fatigue stress, then do not bother with fatigue analysis.
However, if the live SR is greater than the allowable fatigue value then follow the procedure described below.

VARIABLE AMPLITUDE VERSUS CONSTANT AMPLITUDE

STRESS CONCENTRATION/ STRESS RAISERS

FATIGUE PRONE DETAILS

Examine fatigue critical details and group them into different fatigue categories.

MINER'S HYPOTHESIS OF CUMMULATIVE DAMAGE

One of the stress cycles counting methods such as rain-flow or reservoir method is used to determine the accumulative damage.

Miner's rule is used to determine the effective stress range Sreff and the effective number of cycles, Neff for different fatigue critical details.

STRESS RANGES VERSUS NO OF LOAD CYCLES (S-N CURVES)

Plot the SReff and Neff on the S-N curves given in the AREMA Manual and thereby determine remaining number of cycles to failure.

ASSESSMENT OF CAPACITY AND RESIDUAL LIFE

The remaining number of cycles is used to estimate the remaining fatigue life. If run-out of these values is encountered, then the following options are available:

- **Replace the bridge and/ or the member with critical detail as the economics warrant or**
- Load Test the bridge – first a thorough stress analysis – using different models – such as plane frame, space frame, with or without joint fixity (partial or full) or support continuity etc
  This would provide information and pinpoint areas of strain gauging. Approximately 48-72 hours of testing can provide sufficient data.
- Compare the computed information with field results and thereby determine the actual behavior of the span.
  Attempt to determine the fatigue life with the test behavior of structure (Quite often the test stresses are lower than computed stresses in a structure).
- If the structure has reached its useful life – and it is uneconomical to retrofit, then replace the structure.

POSSIBLE RETROFIT STRATEGIES

- Control stress concentration

1. Drill hole at the crack tip – a temporary measure
2. Enlarge radius at the copes
3. Grind welds
4. Smoothen by grinding any rough cuts or nicks
5. Peening
6. Ultrasonic impact treatment
7. Ream rivet holes
8. Replace rivets with HS bolts

- Reduce Stresses

1. To below those allowed by fatigue consideration by reinforcing members
2. Replace member

DISCUSSION

RECAP

3. Discussions with Pakistan Railways' Officials

Had a brief discussion with Mr. Mohammed Amir Khan, Deputy Chief Engineer – Bridges, Railway Headquarter, Lahore, (Tel: 9201705 Office, 9201617 Home) on AM of 25 Feb 2003 in Islamabad. The discussion was originally held in the NTRC office at Islamabad and continued with PR staff at meetings in the PR academy, Lahore.

1. Welding of Track on Bridges

   a) Recommendation of track welding on short and long span steel bridges merits and demerits, practice in Canada and World wide, its application on Pakistan Railways.

   Explanation: **For spans less than 40-ft in length on brick masonry, in certain cases, the masonry piers are settling and cracking. It is being thought this is happening due to impact caused by the rail joints.**
   Question is can welded rail be installed on the bridges and how. Also, how one is to deal with welded rail on larger bridges.

   Answer: **Welded rail is installed on bridges. I can certainly relate to the practice of a couple of railroads in North America.**

2. Track on Bridges

   a) Presently timbers on bridges are 30" center to center and thickness 6" for hard wood and 8 ½" for soft wood are being used on Pakistan Railways. Can reduction in the spacing help in reducing stresses on older girder bridges or add to the safety of running trains.
   b) Revision in size of timbers if recommended (present size of timbers 10'x10"x8").
   c) Any change in fastenings as the existing bearing plates generally become loose, resulting in additional impact.

   Explanation: Accident of derailment took place at approach to the bridge. However, when the first car landed on one of the sleepers (sleeper spacing being 30 inches) it broke and created a wide gap between the sleepers causing the axles (wheel diameter being 48") to get stuck thus resulting in one of the worst railway accident with several fatalities.

   Answer: **The sleepers on PR bridges are acting like bearing pads rather than structural elements. Reducing spacing will certainly help safety in case of derailment. However, it should be realized that the capacity, condition and hold-down fasteners also play a significant part in carrying the loads and in maintaining the integrity of deck.**

   I would like to suggest that the sleeper design should be verified for safely carrying the forces generated by derailed wheels and if necessary, their design and spacing and the hold-down fasteners be adjusted/ modified accordingly.

Suggest that you attend my presentation on " Railway Bridge Decks".

3. Pads under Bearings

   a) **Presently C.I. boring pads are being provided (1:1 Cement and Iron borings). Any recommendation could be to improve these pads?**
   b) **Use of Rubber or Elastomeric bearing pads on steel girder bridges.**

Answer: **There are several designs for bearing pads available these days that could be employed, both for replacement of existing bearings and for new span bearings. I would suppose that the bearing pad that you are referring to would not provide elastic properties that are desirable.**

Suggest that you attend my presentation on "Bridge Bearings".

4. Creep

   a) **Effect of creep on bridges**
   b) **Types of track fastenings to arrest creep on bridges and on approaches.**

Answer: **This question is related to your first question and deals with the use of welded rails on bridges. We will discuss these two questions together.**

5. Masonry Arches

   a) **The brickwork in arch bridges is loosing strength due to the old lime-surkhi mortar being decomposed. Recommendations for its rehabilitation?**
   b) **In arch siphon seepage is being observed any sealing recommended to stop the seepage.**

Answer: **Without knowing the site conditions, I would think that the existing mortar be removed where it has lost its strength or has loosened and the joints be re-pointed with cement mortar or joints be grouted under some pressure. Similarly, siphon barrels could be sealed with jelly, cement or epoxy grout.**
I would like to see some actual sites for appraising the situation. If you like I could obtain some literature on the grouts and sent it to PR.

6. Soundings

   a) **During floods soundings are taken manually to find the scour in river during flood and in big canals, which are considered not effective. Is any electronic device to check scour during peak floods?**

Answer: **There are some sonar type equipments available for finding the depth of water in streams. I would try to obtain literature on it for PR.**

7. Well Foundations

a) **Brick masonry of deep wells is about 100 years old. These wells are still safe or not, means for checks, and examination in use in Canada and Worldwide.**

Explanation: **Well foundations are made up of brick masonry in-filled with sand. Question is related to determining their condition.**

Answer: **Brick masonry is rare in North America. I would like to see a typical drawing of the well foundation. Since there is no means of access to the wells, some sort of scanning equipment may be possible to use for detecting any internal weakness. This could then be supplemented by external visual above or below water inspections. One needs to investigate if such tools are available and their costs.**
I would think that normally some signs would be visible on the outside for any major abnormality that may be developing inside.

8. Speedy Temporary Arrangements

a) **Presently sleeper cribs, steel staging, steel service spans are being used as temporary arrangements, which require long intervals of traffic blocks. Any speedy lightweight and handy arrangements to pass traffic for construction of new or damaged bridges for reconstruction.**

Explanation: **Currently PR uses 40-ft girders or Callender Hamilton spans? and for 300-ft truss spans (assembled by bolting together at site) for pier construction. Is there any faster way of putting together a support structure that would taker shorter time?**

Answer: The following temporary arrangements could be made during construction / repair of substructure.

Alternate route – where possible
Shoofly or diversion
Temporary falsework span on temporary crib work or pile bents

Where cribwork is not possible or is difficult to build and time consuming, building pile bents could be expedious. A locomotive pile driver, pile driver on barge or pile driver mounted on a truck (on tires or crawler type) may be used.
Similarly, depending on the size of opening required, a rail falsework or a low clearance span could be used.
I would like to see the arrangements that the PR is currently using for such situations.
I could gather more information for PR on the pile driving equipment.

9. RCC Jackets

a) **The old brickwork of piers of such bridges has various defects, which need rectification. Whether RCC Jackets around such structures would increase the life of bridges, the existing brickwork may act as filler.**

4. List of Participants

A. List of the NTRC and NHA Participants

At NTRC Offices, Islamabad on 24, 25 and 26 March 2003

No.	Name	Title	Posted at
1.	Mr. Shahzad Sarwar	AD (Eng'r)	NHA Quetta
2.	Mr. Ibrar Hussain	Asstt, Director	Karak (M)
3.	Mr. Fateh Ullah Khan	Asstt. Director –GM Office	Peshawar
4.	Ms. Ruqqaya Shahani	AD (Opr) RAMD Section	NHA-HQ
5.	Mr. Sajjad Ali Shah	AD (Mai) Khi	Karachi
6.	Mr. M. Jehanzeb Khan Niazi	AD (Plg)	Islamabad
7.	Mr. Abdul Qudoos Sheikh	AD (M-2)	Lahore
8.	Mr. Zubair Mirza	RE (CNACP), A.A. Associates	Khairabad
9.	Mr. Asif Ali Shah	AD (Eng)	Karachi
10.	Mr. Col. Mohd Iqbal	Structural Expert NHA	Islamabad
11.	Mr. Col. Gulfam (NIT)	DD & C, E in C Branch	GHQ
12.	Mr. Khalid Ayub	AD (Design)	Islamabad
13.	Mr. Jehangir Lasik	Asstt Director MCRP NHA	Karachi
14.	Mr. Muhammad Amir Khan	Dy. C.E.N./ Bridges	PR - Lahore
15.	Mr. Muhammad Kazim Idris	Chief NTRC	Islamabad
16.	Mr. Farrakh Taimur Ghilzi	D. E. N.-2/RWP	PR-Rawalpindi
17.	Mr. Mohammed Naeem	AC NTRC	Islamabad
18.	Ms. Fozia Saleem	AC NTRC	Islamabad
19.	Mr. Khizer Javaid	RO NTRC	Islamabad
20.	Mr. Hameed Akhtar	RO NTRC	Islamabad
21.	Mr. Bashir Ahmed	Dy Ch NTRC	Islamabad
22.	Mr. Naeemullah	Dy Ch NTRC	Islamabad
23.	Mr. Sayyar Khan	RO NTRC	Islamabad
24.	Mr. Hassan Syed	RO NTRC	Islamabad
25.	Mr. Mushtaq Mahmood	Dy Ch NTRC	Islamabad
26.	Mr. Sajjad Mehdi	Director Materials - NHA	Islamabad
27.	Mr. Aijaz Ahmed Buria	AD (Design) – M-3	
28.	Mr. Khalid Bangash	AD (Design) -NHA	Islamabad
29.	Mr. Mohammed Tahir Shah	AD (M-1)	Barbanda

B. List of PR Participants

Attending the Workshop on 5th & 6th of March 2003 On Railway Bridge Related Subjects at Walton Railway Academy, Lahore

No.	Name	Title	Organization
1.	Mr. Hafeez Ullah Khan	Director General/ Walton Academy	PR
2.	Mr. Abdul Aziz Chaudhary	Chief Engineer	PR
3.	Mr. Shahid Baig	PD	RAILCOP
4.	Mr. Anjum Pervaiz	Dy. C.E.N./ S&C	PR
5.	Mr. Chiragh Din	PD	RAILCOP
6.	Mr. Shakeel Ahmed	PD	RAILCOP
7.	Mr. A. M. Zafar Khan	Rtd CEN/ Design	PR
8.	Mr. Dost Ali Laghari	D. E. N.-I, Multan	PR
9.	Mr. Akhtar Mehmood Khatak	D. E. N. – II, Lahore	PR
10.	Mr. Farzand Ali	Dy. C.E.N./N	PR
11.	Mr. Sabir Ali	AFX/ Tower	PR
12.	Mr. Munir Ahmed	X.E.N./ B/Tech	PR
13.	Mr. Atiq-ur-Rehman	Dy. C.E.N./ Design	PR
14.	Mr. Muhammad Amir Khan	Dy. C.E.N./ Bridges	PR
15.	Mr. Shah Rukh Afsher	X.E.N./ CSF	PR
16.	Mr. Farrakh Taimur Ghilzi	D. E. N.-2/RWP	PR
17.	Mr. Azeem Sakhani	X.E.N./ G	PR
18.	Mr. Mustansar Ahmed Khan	AFX/ Tech	PR
19.	Mr. Munir Iqbal	A.W.M./JMR	PR
20.	Mr. Muhammad Sabir	A.E.N./ Design-III	PR
21.	Mr. Shahid Abbas Malik	A.E.N./ Bridges/ MUL	PR
22.	Mr. Muhammad Amin Akhtar	A.E.N./ B/ LHR	PR
23.	Mr. Zulfqar Ahmed Qureshi	A.E.N./ Bridges/ SUK	PR
24.	Mr. Muhmmad Anjum Masood	A.E.N./ Bridges/ PSC	PR
25.	Mr. Irfan Naeem Mangl	X.E.N./ Design	PR
26.	Mr. Saleem Mehmood	D.E.N.-I/ LHR	PR
27.	Mr. Ali Muhammad Afradi	D.E.N./ PSC	PR
28.	Mr. Qamar-ul-Zaman Bhatti	A.E.N./ W	PR
29.	Mr. Irfanullah	D.E.N./ W	PR
30.	Mr. Nadir Rafi	A.F.X./ RWP	PR
31.	Mr. Muhammad Arif	X.E.N./ HQ	PR
32.	Mr. Aamir Nisar Chaudhry	D.E.N.-III/ LHR	PR
33.	Mr. Muhammad Shafi Tahir	AFX/ QTA	PR
34.	Mr. Bashir Ahmad	Dy. Chief	NTRC

C. List of Participants

Attending the Workshop on 11th of March 2003 On "Safety & Serviceability of Bridges" and "
"Bridge Management System" at NTRC Lecture Room, Islamabad

No.	Name	Title	Organization
1.	Mr. M. Kazim Idris	Chief	NTRC
2.	Mr. Bashir Ahmad	Deputy Chief	NTRC
3.	Mr. Hameed Akhtar	Research Officer	NTRC
4.	Mr. Mohammed Naeem	Assistant Chief	NTRC
5.	Mr. Khizar Javed	Research Officer	NTRC
6.	Mr. Sayyar Khan	Research Officer	NTRC

8. Distribution of the Report

1. Mr. Pir Zada Riffat Nawaz
   Director General – NTP
   National Project Director (TOKTEN)
   Ministry of Labor, Manpower and Overseas Pakistanis
   Post Box No. 1095
   Plot 39, Sector H-9
   Islamabad, PAKISTAN
   Tel: 92-51-9257107
   Fax: 92-51-4436580
   E-mail: tokten@ntp.sdnpk.undp.org
   Internet: tokten@isb.comsats.net.pk

2. Mr. Bashir Ahmed
   Deputy Chief - National Transport Research Centre (NTRC)
   Ministry of Communications – Govt. of Pakistan
   Sector H-8/2
   Islamabad, PAKISTAN
   Tel:9257793

   Mr. Mohammad Kazim Idris
   Chief - National Transport Research Centre
   Ministry of Communications – Govt. of Pakistan
   Sector H-8/2
   Islamabad, PAKISTAN
   Tel: 9257189
   Fax: 9257334

3. Ms. Kaja Borchgrevink
   Program Officer (SL Unit)
   UNDP
   Islamabad
   Tel: 2800133-42 Ext. 2244
   Fax: 2800031-34
   E-mail: kaja.borchgrevink@undp.org

4. Mr. Hicham Nahro
   Fellowship Associate – Training and TOKTEN Section
   United Nations Office for Project Services (UNOPS)
   The Chrysler Building, 4th Floor
   405 Lexington Avenue
   New York, NY 10174
   USA
   Tel: 212-457-1094

Fax: 212-457-4048
E-mail: HichamN@unops.org

5. Ms. Maria Ejaz
Section Officer (UN)
Economic Affairs Division
Islamabad

6. Mr. Ch. Abdul Aziz
Chief Engineer – Pakistan Railway
Railway Headquarters
Lahore

7. Mr. Mohammad Amir Khan
Dy Chief Engineer – Bridges
Pakistan Railways
Railway Headquarters
Lahore
Tel: 9201705