Rapid, Reliable, Repeatable Assessment of Transport and Main Roads’ Bridges

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Outline

1. Definition of Assessment Ratios
2. Tier 0 Assessments
3. Tier 1 and Tier 2 Assessments
4. Transport and Main Roads Bridge Assessment Tool
5. Priority Bridges.
Definition of Assessment Ratios
Network

- Large, varied bridge network

Access

- 1000s of requests for heavy vehicle access
- Need rapid method of assessing requests

Assessment

- Development of Scalable Assessment Ratios
What are they?

- **Three Assessment Ratios:**
  - SAR – Strength Assessment Ratio
  - ERT – Equivalence Ratio Traffic
  - ERB – Equivalence Ratio Bridge

- **Assessing access:**
  - permit vehicles
  - as-of-right heavy vehicles (network)

- **Short span simply supported bridges (95%).**
AS 5100 General Strength Equation

ULS Capacity \geq ULS Load Effects

\phi R_u \geq G^* + Q^* + S_p^* + S_s^* + S_t^*

\phi R_u \geq G^* + Q^*
Strength Assessment Ratio: SAR

\[ SAR = \frac{\text{ULS Capacity}}{\text{ULS Load Effects}} \geq 1 \]

\[ SAR = \frac{\phi R_u}{G^* + Q^*} \geq 1 \]

- Helps quantify the risk
- Not scalable
Terminology

RV
Equivalence Ratio Traffic: ERT

\[ ERT = \frac{\text{Available ULS Capacity for LL}}{\text{ULS load effects applied by LL}} \geq 1 \]

\[ ERT = \frac{\phi R_u - G^*}{Q^*_{RV} + Q^*_{RAV}} \geq 1 \]

- Scalable to obtain ERT for \( Q^*_{PV} + Q^*_{PAV} \) using line models
- Assessment of as-of-right heavy freight traffic (LL)
Equivalence Ratio Bridge: ERB

\[ ERB = \frac{\text{Available ULS Capacity for RV}}{\text{ULS load effect applied by RV}} \geq 1 \]
\[ = \frac{\phi R_u - G^* - Q_{RAV}^*}{Q_{RV}^*} \geq 1 \]

- Scalable to obtain ERB for \( Q_{PV}^* \) using line models
- Assessment of permit vehicles (PV)
ERB vs ERT

- MCV = Multi-combination vehicle (as-of-right freight vehicle)
Interpretation of ERB

20 t / axle HLP 320

ERB = 0.6

0.6 × 20 = 12 t / line

12 t / axle HLP 192

ERB = 1.0
Tier 0 Assessments
Tier 0 – Assumptions

1. Capacity of bridge to resist live load = Design Class Effect

2. HLPs
   - Two lanes
   - 50% of each lane
   - AVF = 1.0

3. RV & RAV mimic Design Class
   - RV = RAV
   - RV and RAV – same load factor & DLA
   - Drivelines as per design
Tier 0 Assessments

Reference Vehicle

Span, Articulation

Global Effect (M, V, R)

Design Class
• Available LL Capacity

ERT$_0$
Worked example: $ERT_0$

<table>
<thead>
<tr>
<th>Group</th>
<th>Span 1 (m)</th>
<th>Span 2 (m)</th>
<th>Effect</th>
<th>$Q^*_DC$ T44 (92)</th>
<th>$Q^*_RV$ HML Type 2 Road Train</th>
<th>$ERT_0$</th>
</tr>
</thead>
<tbody>
<tr>
<td>A1-2</td>
<td>16</td>
<td></td>
<td>Reaction</td>
<td>1713 kN</td>
<td>1679 kN</td>
<td>1.02</td>
</tr>
<tr>
<td>P1-2</td>
<td>16</td>
<td>20</td>
<td>Reaction</td>
<td>1893 kN</td>
<td>2975 kN</td>
<td>0.64</td>
</tr>
<tr>
<td>S1,3</td>
<td>16</td>
<td></td>
<td>Shear (end)</td>
<td>1713 kN</td>
<td>1679 kN</td>
<td>1.02</td>
</tr>
<tr>
<td>S1,3</td>
<td>16</td>
<td></td>
<td>Moment (sag)</td>
<td>6105 kNm</td>
<td>5456 kNm</td>
<td>1.12</td>
</tr>
<tr>
<td>S2</td>
<td>20</td>
<td></td>
<td>Shear (end)</td>
<td>1806 kN</td>
<td>2002 kN</td>
<td>0.90</td>
</tr>
<tr>
<td>S2</td>
<td>20</td>
<td></td>
<td>Moment (sag)</td>
<td>8279 kNm</td>
<td>8675 kNm</td>
<td>0.95</td>
</tr>
</tbody>
</table>

$ERT_0 = \frac{\gamma_{Q, DC}(1 + \alpha_{DC})(1 + AVF_{DAV})Q_{DC,LM}}{\gamma_{Q, RV}(1 + \alpha_{RV})(1 + AVF_{RAV})Q_{RV,LM}}$
Tier 0 Assessment: B-Double and Road-train network

Excludes timber and continuous bridges

![Graph showing the percentage of bridges vs. (Design Load Effect)/(As-of-right Freight Vehicle Load Effect) with curves for Substructure and Superstructure]
Span versus time and design load
Pier ERT₀ 1950 to 2010 (HML BD)

Design loads lighter and shorter than B-Doubles and the average span increased with time.

Increase in Design Class

Introduction of Limit State Design

Nominal Capacity / HML B Double Effect

Year Designed

Average Span
Tier 1&2 Assessments
Calculate ERBs, ERTs and SARs for each component of the bridge:
Tier 2 Assessments

Apply advanced methods to potentially structurally deficient components:

- Span, articulation, structure
- Travel Restriction
- Local Effects (M, V, N)

ERTs, ERBs, SARs

Assessed capacity $\phi R_u$
## ERT$_0$ versus ERT$_{1/2}$

<table>
<thead>
<tr>
<th>ERT$_0$</th>
<th>ERT$_{1/2}$</th>
</tr>
</thead>
<tbody>
<tr>
<td>Quick</td>
<td>Time consuming</td>
</tr>
<tr>
<td>Reliable</td>
<td>Subject to calculation error</td>
</tr>
<tr>
<td>Bridge specific</td>
<td>Bridge specific</td>
</tr>
<tr>
<td>Implement across network</td>
<td>Families / similar bridges</td>
</tr>
<tr>
<td>Cannot identify design errors / reserves</td>
<td>Identifies design errors / reserves</td>
</tr>
<tr>
<td>Global</td>
<td>Local</td>
</tr>
<tr>
<td>Identifies potentially higher risk bridges</td>
<td>Refines the risk</td>
</tr>
</tbody>
</table>

**Complementary**

Closely related – scalable using line models
TMR Bridge Assessment Tool
Tier 0 – Tier 1/2 Relationship

\[ ERT_1 = \chi \ ERT_0 \]

Where \( \chi \) is a calibration factor which depends on:

- Design Class and methodology
- Distribution to component
- Element Capacities including material properties and factors
- Accompanying Vehicle Effect
- Live Load Factor
- Dynamic Load Allowance
- Dead and superimposed dead load effects
Tier 0 – Tier 1/2 Observations

It can be observed that $\chi$ is:

- Independent of the Reference Vehicle
- Dependent on choices of factors (Can be post processed)
- Dependent on Accompanying Vehicle (Can be decoupled)
- Dependent on vehicle drivelines and distribution factors

These dependencies help define bridge “families”
Bridge Families

Working Stress designs differ from Limit State designs (e.g. T44)

Superstructures

• Deck Units
• PSC I Girders
• Steel Girders with Composite Concrete Decks
• Concrete Deck Slabs
Bridge Families

Substructures

• Portal Frames
• Portal Frames with Cantilevered Headstocks
• Single Columns with Cantilevered Headstocks
• Headstock on Piles
• Headstock on Multiple Columns (3 or 4)
• Not Sensitive to Live Loads (Blade walls, girders directly over columns, etc)
ERT₁ versus ERT₀

Portal Frame (Bridge Component Data) DU Bridges - Portal Bending

ERT₁ vs ERT₀ graph showing data points and trend lines for different percentage scenarios.
Estimated Assessment Ratios

1. Calculate $\chi$ for each family to obtain a lower (5%), upper (95%) and mean estimate

2. Based on Tier 0 for each bridge, calculate lower, mean and upper ERT estimates for each bridge.

3. Estimates can be post-processed to obtain ERB estimates.

4. Results can be “scaled” to assess a new vehicle (Permit Vehicle or MCV) and change the LLF, DLA and AVF
Observations

1. Bridges designed to working stress approximately 20 - 25% stronger than cousins designed using Limit States
2. Lower estimate for ERT tends to approximate ERT0
3. Some bridges plot very low cf family ⇒ assessment error or design error (Priority Bridge; exclude from calibration)
4. Variations in designs and assessments
5. Assessment NOT Design in reverse!
TMR Bridge Assessment Tool

1. Assessment ratios (ERT and ERB) for all bridges on freight network except continuous bridges and some “specials”

2. Contains key bridge data necessary to scale vehicles, change factors (LLF, DLA & AVF) and travel restrictions

3. Provides rapid, reliable, repeatable assessments for TMR’s freight network bridges (20 s approx)

4. Can assess access for a particular vehicle (e.g. crane - ERB) or network access for a particular class of vehicle (e.g. HML A-double - ERT)
Priority Bridges

• Approximately 270 bridges have insufficient theoretical capacity for as-of-right freight vehicles = Priority Bridges. However these bridges appear to perform satisfactorily in the field.
• Shear capacity in portal frame headstocks
• Hogging moment and shear capacity in cantilevered headstocks
• Shear capacity in PSC I girders
• What to do about these bridges is the driver for today’s sessions
Conclusion

• Assessment Ratios are a simple yet complex and essential component of an efficient network bridge assessment program

• Some bridges have insufficient theoretical capacity for current freight vehicles but appear to perform satisfactorily in the field. Priority for further investigation.

• Assessment ≠ Design
Thank you