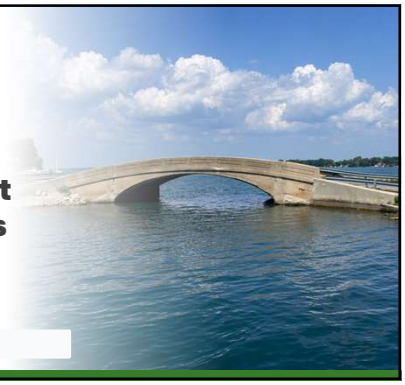
Load Rating of Concrete Arch Bridges without Available Plans



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Edgar Nunez, P.E.

Learning Objectives

- Necessary information required to perform a complete load rating of a concrete arch bridge when no plans are available.
- How to combine inspection data, analysis results, and engineering judgement into a load rating that is accurate yet conservative.
- Insight learned from developing a concise and repeatable analysis and load rating method.

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Arch Bridge Load Ratings - Overview

Project 1

Great Lakes Naval Station, Sampson St. – Fall 2024

Project 2

City of Gibraltar Bridge Inspection Program – Spring 2025

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Structure Background – Project 1

- Great Lakes Naval Station, Great Lakes, IL
- Originally constructed in 1926
- Three-span reinforced concrete closed spandrel deck arch bridge
- Sidewalks and one lane of traffic closed in 2010
- Posted to 12 tons, single lane

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Structure Background – Project 2

- Horse Island, Gibraltar, MI
- Original construction date unknown, assumed 1920s
- Supports single lane of traffic
- Load posted from a previous load rating
- Collins tasked to verify the load carrying capacity

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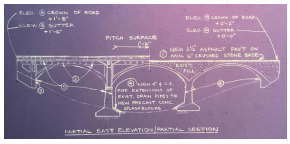
Field Inspection/Testing

- Goal of inspection
- Goal of testing



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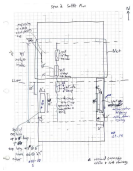
Field Inspection

- Structure condition
- Geometry and Loading



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Testing

- Coring
  - Concrete Compressive Strength
- Ground Penetrating Radar Scanning
  - Rebar Spacing

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Additional Assumptions

- AASHTO Manual for Bridge Evaluation (MBE)

Table 6A.5.2.1-1—Minimum Compressive Strength of Concrete by Year of Construction

Year of Construction	Compressive Strength, f'_c, ksi
Prior to 1959	2.5 5.0
1959 and Later	3.0

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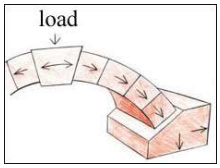
Modeling the Structure

- Inputs
  - Geometry
  - Loading
    - » Dead Load
    - » Live Load
- Outputs
  - Axial Forces
  - Bending Moments
  - Shear Forces



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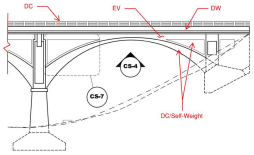
Modeling the Structure – Dead Loads

- DC
  - Self-Weight
  - Applied Dead Load
- DW
  - Asphalt roadway surface
- EV
  - Soil Fill



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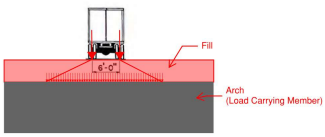
Modeling the Structure – Live Loads

- AASHTO 3.6.1.2.6



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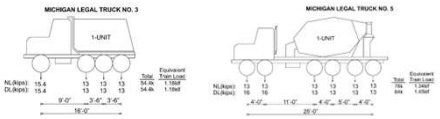
Modeling the Structure – Live Loads

- Rating Vehicles (AASHTO MBE)
- Rating Vehicles



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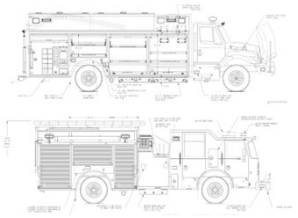
Modeling the Structure – Live Loads

- Additional vehicles at owners request



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Modeling the Structure – Appropriate Software

- Accurate Results
- Usable Results
- Verifiable Results

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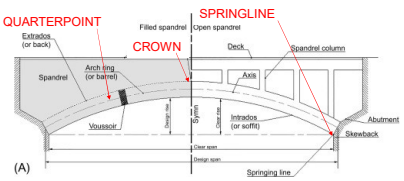
Parts of an Arch Bridge



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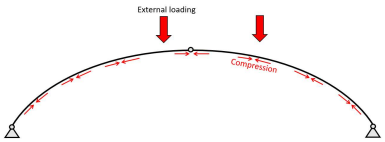
Bonus – Arches, How Do They Work?



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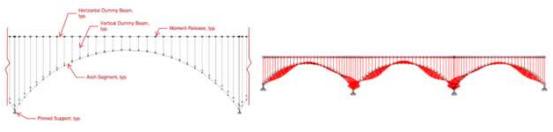
Modeling the Structure – Frame Analysis

- Modeled as a 1-ft strip



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Load Rating the Structure

- Critical Points – Crown, Quarter Point, Springline
- Dead and live load results from model – moment and axial forces
- Capacity determined from AASHTO and MBE

$$RF = \frac{\text{Capacity - Dead Load = Remaining Capacity}}{\text{Applied Live Load}} > 1.0$$

6A.4.2.3—Condition Factor: φ_c

Use of Condition Factors as presented below may be considered optional based on an agency's load-rating practice.

The condition factor provides a reduction to account for the increased uncertainty in the resistance of deteriorated members and the likely increased future deterioration of these members during the period between inspection cycles.

Table 6A.4.2.3-1—Condition Factor: φ_c

Structural Condition of Member	φ_c
Good or Satisfactory	1.00
Fair	0.95
Poor	0.85

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Load Rating the Structure

Φc=0.85	Per MBE table 6A.4	
	M, (ft*k)	P, (kips)
Axial	0.00	533.56
Balanced	108.60	312.64
Flexure	10.56	0.00

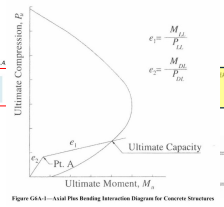

Figure G6A-1—Axial Plus Bending Interaction Diagram for Concrete Structures

$e_1 = -\frac{M_{LL}}{P_{LL}}$

$e_2 = -\frac{M_{DL}}{P_{DL}}$

(AD+LIVE LOAD)	LINE TO DETERIME CAPACITY		
P (kips)	26.03	110.39	
110.39	69.82	127.56	60
e=	0.39		

$= \frac{M_{LL}}{P_{LL}}$

$= \frac{M_{DL}}{P_{DL}}$

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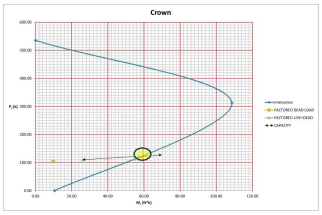
Load Rating the Structure



Moment Capacity from Interaction Diagram =	58.0	ft-kip
Axial Capacity from Interaction Diagram =	120.0	kip

Moment RF= Moment Capacity-Factored Dead Load Moment / Factored Live Load Moment

Moment RF = 2.97

Axial RF= Axial Capacity-Factored Axial Dead Load / Factored Axial Live Load

Axial RF = 2.51

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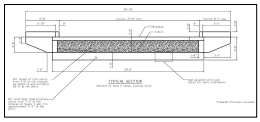
Project Conclusion

- Inspect structure to determine geometry and loads
- Test structure to determine material properties
- Conservatively reduce material strength and structural capacity
- Analyze structure and verify behavior
- Assemble results (rating factors and posting)



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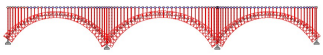
Takeaways

- Focus your inspection – know what you need
- Consider field observations, fundamental structural analysis, and relevant engineering manuals
- Verify behavior
- Method should be concise, easy to follow, and repeatable



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Questions

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