Load Rating Arch Culverts

Mid-West Peer Group Conference

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Load Rating For Deterioration

- **Buried Structure Rating Criteria**
  - LRFD 12.5 – Limit States and Resistance Factors
    - Metal Structures
    - Concrete Structures
    - Thermoplastic Pipe
    - Tunnel Liner Plate
    - Fiberglass Pipe
    - Steel-Reinforced Thermoplastic Pipe

Load Rating For Deterioration

- **Buried Structure Rating Criteria**
  - MBE 6A.5.12.2
    - Flexure, Shear, and Thrust

6A.5.12.2—General Rating Requirements

Culvert ratings should recognize that these structures experience several loadings that are not applicable to most bridge superstructures, including vertical and horizontal soil loads and live load surcharge.

Culvert structural members shall be evaluated for flexure, shear, and axial thrust. Load ratings at several critical sections for the culvert structure must be calculated for each load effect in order to establish the lowest load rating.

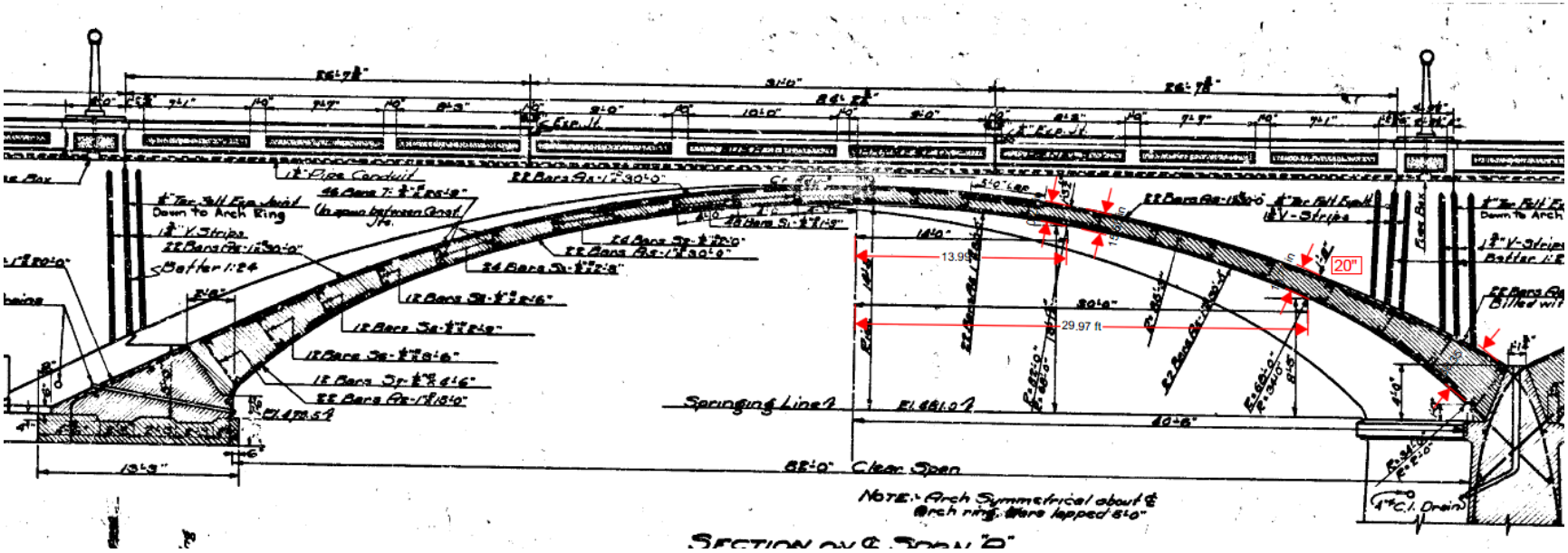
Water load on interior walls may be neglected in load rating calculations.

Load Rating For Deterioration

- **INDOT Buried Structure Rating Process**
  - Flat Top
    - BrR – Vertical Loads (i.e. Soil arching is neglected)
  - Arch Top
    - Develop Loads: MathCAD
    - Analyze Structure: CANDE
    - Load Rate: Excel Spreadsheet

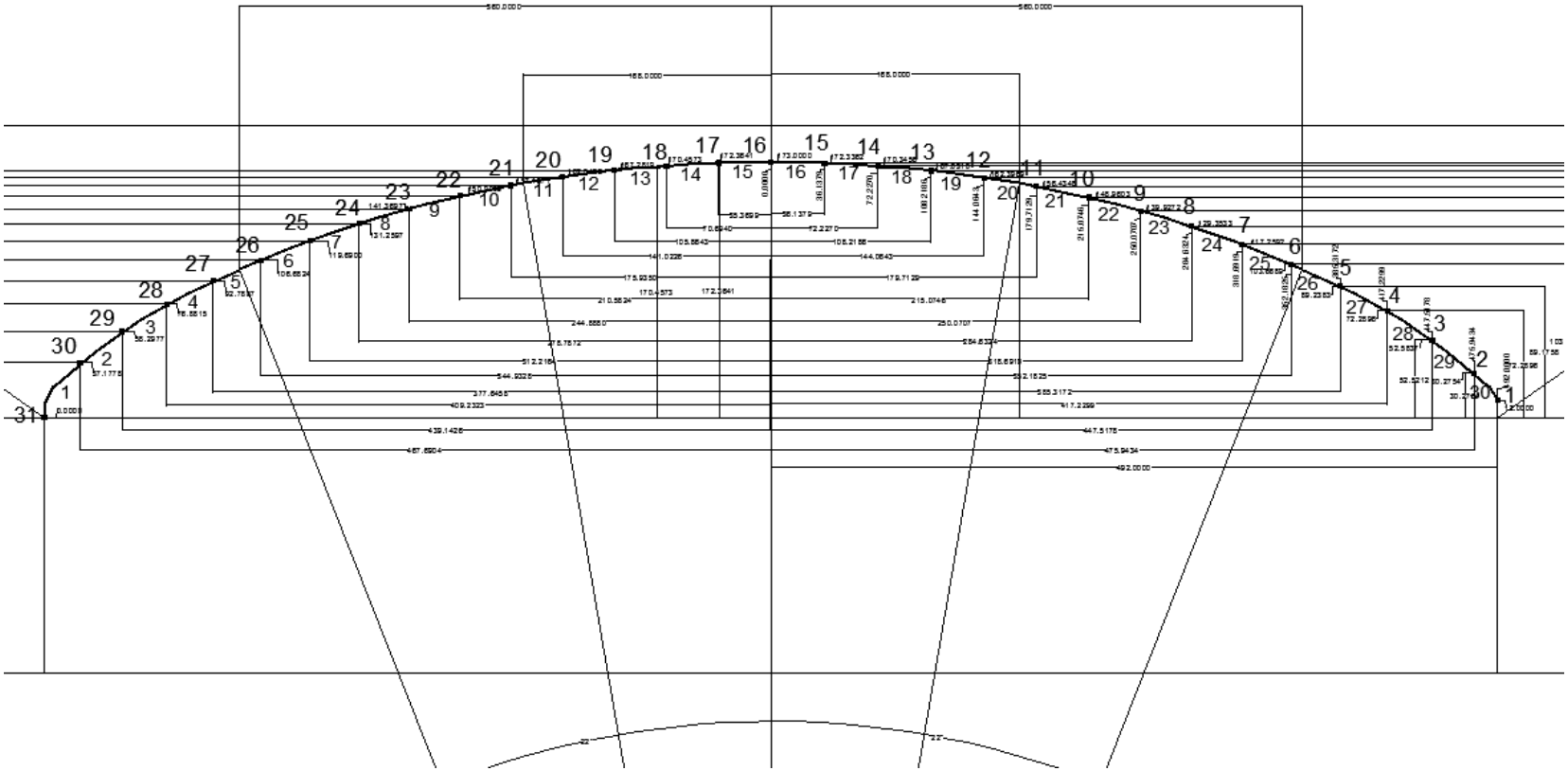
Load Rating For Deterioration

- **Buried Structure Rating**
  - Example Buried Concrete Arch Structure



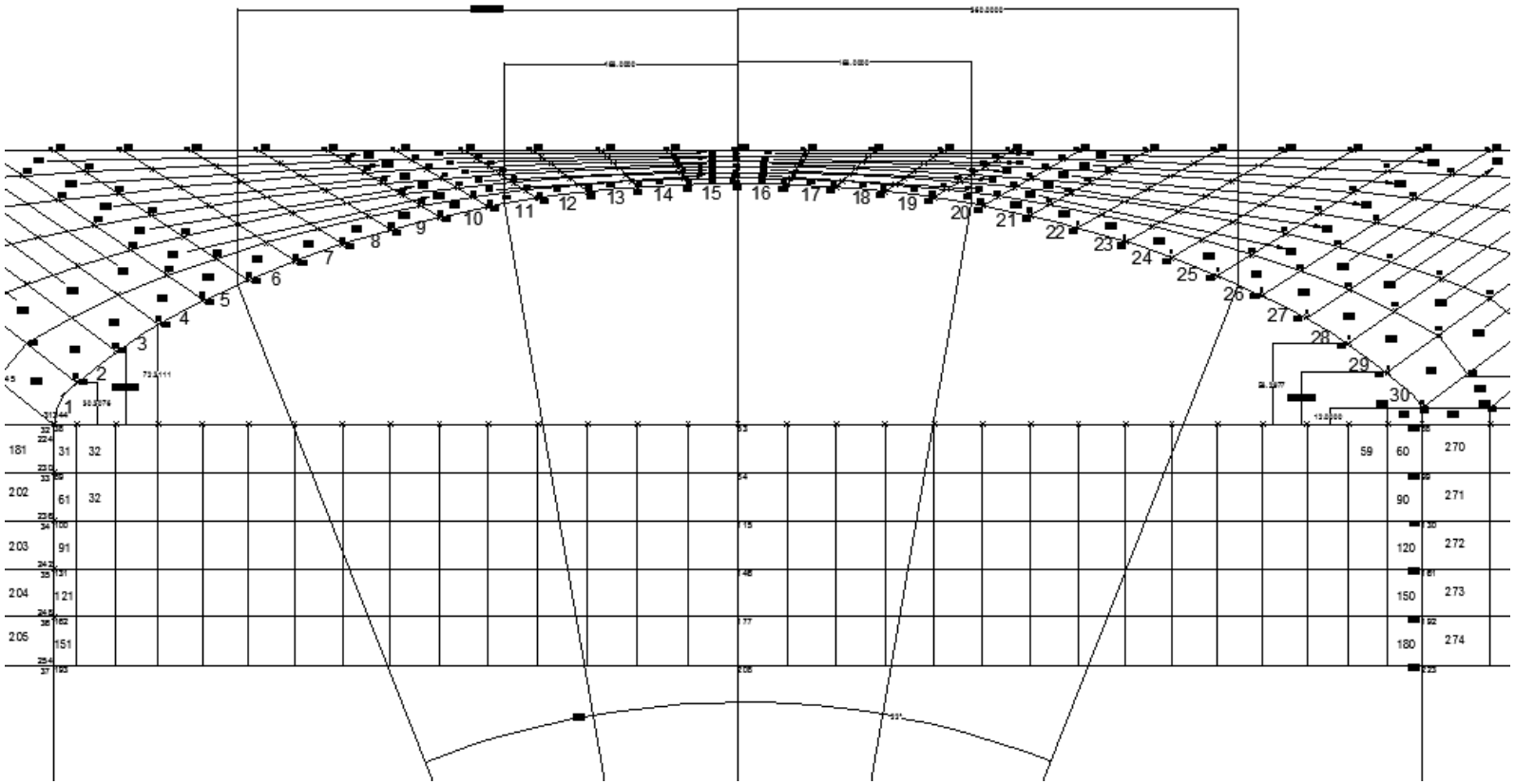
Load Rating For Deterioration

- **Buried Structure Rating**
  - Model Geometric Coordinates



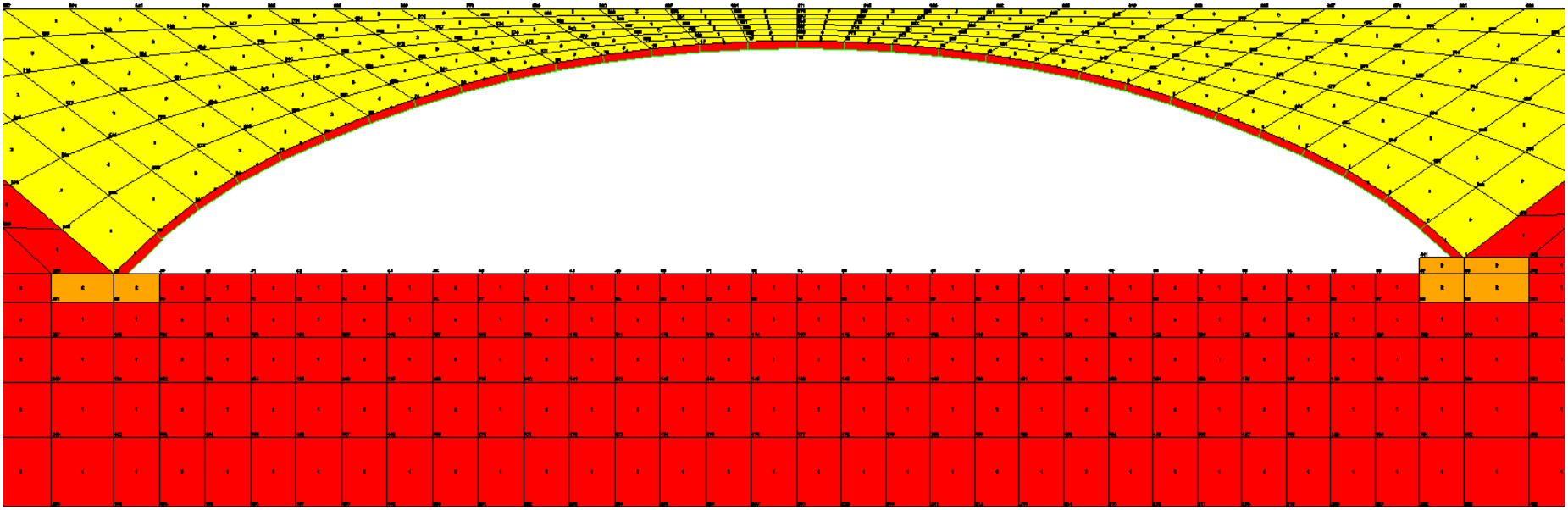
Load Rating For Deterioration

- **Buried Structure Rating**
  - CANDE Model Elements



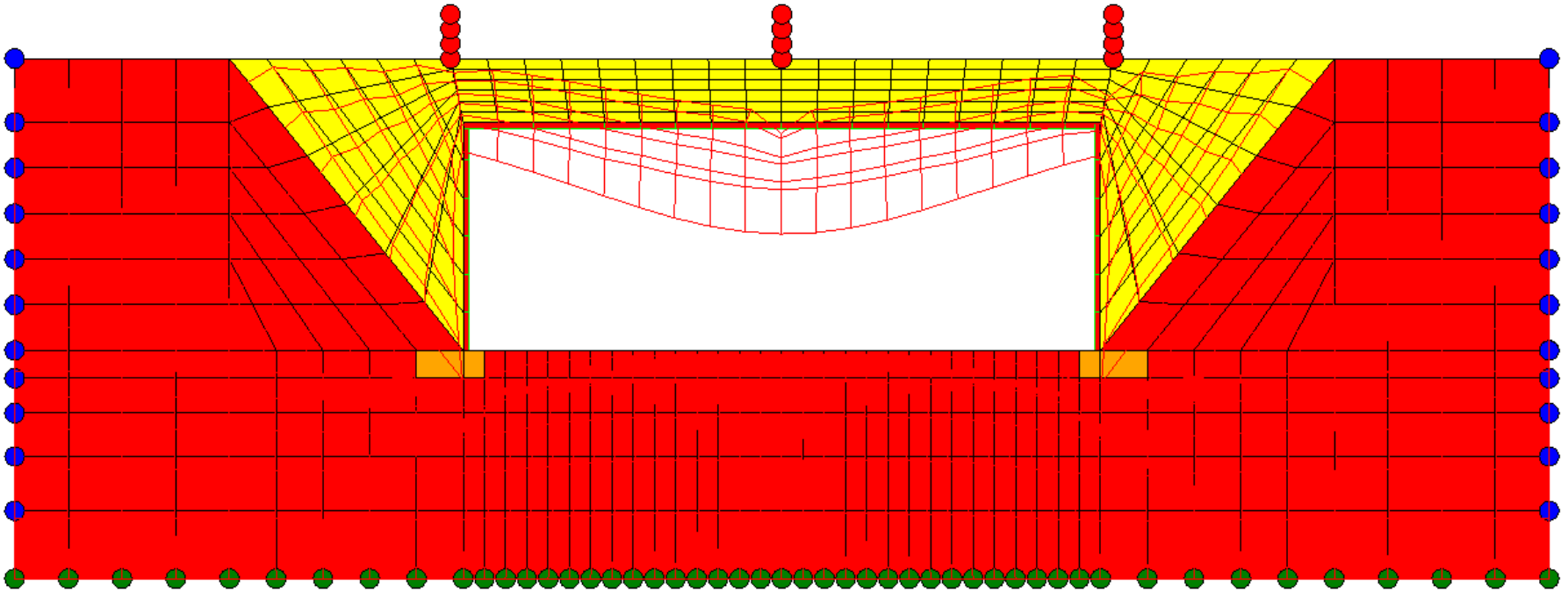
Load Rating For Deterioration

- **Buried Structure Rating**
  - CANDE Model Elements



Load Rating For Deterioration

- **Buried Structure Rating**
  - Example Flat Top Structure – Showing Live Load Effects



Load Rating For Deterioration

- **MBE Compressive Element Load Rating**

APPENDIX G6A—RATING OF CONCRETE COMPONENTS FOR COMPRESSION PLUS BENDING

Steps for Obtaining Rating Factors (see Figure C6A-1)

1. Develop the interaction diagram, by computer or manual methods, using as-inspected section properties.
2. Point A represents the factored dead load moment and thrust.
3. Using the factored live load moment and thrust for the rating live load, compute the live load eccentricity ($e_1 = M_{LL}/P_{LL}$).
4. Continue from Point A with the live load eccentricity to the intersection with the interaction diagram.
5. Read the ultimate moment and axial capacities from the diagram.
6. Moment $RF = \dfrac{\text{Moment Capacity} - \text{Factored } M_{DL}}{\text{Factored } M_{LL+IM}}$

   Axial $RF = \dfrac{\text{Axial Capacity} - \text{Factored } P_{DL}}{\text{Factored } P_{LL+IM}}$

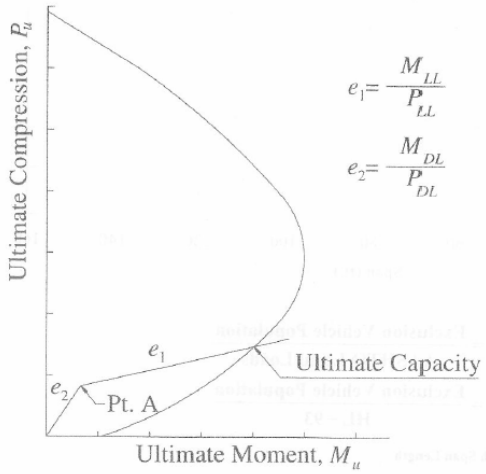


Figure G6A-1—Axial Plus Bending Interaction Diagram for Concrete Structures

Load Rating For Deterioration

- **Arch Element Load Rating**

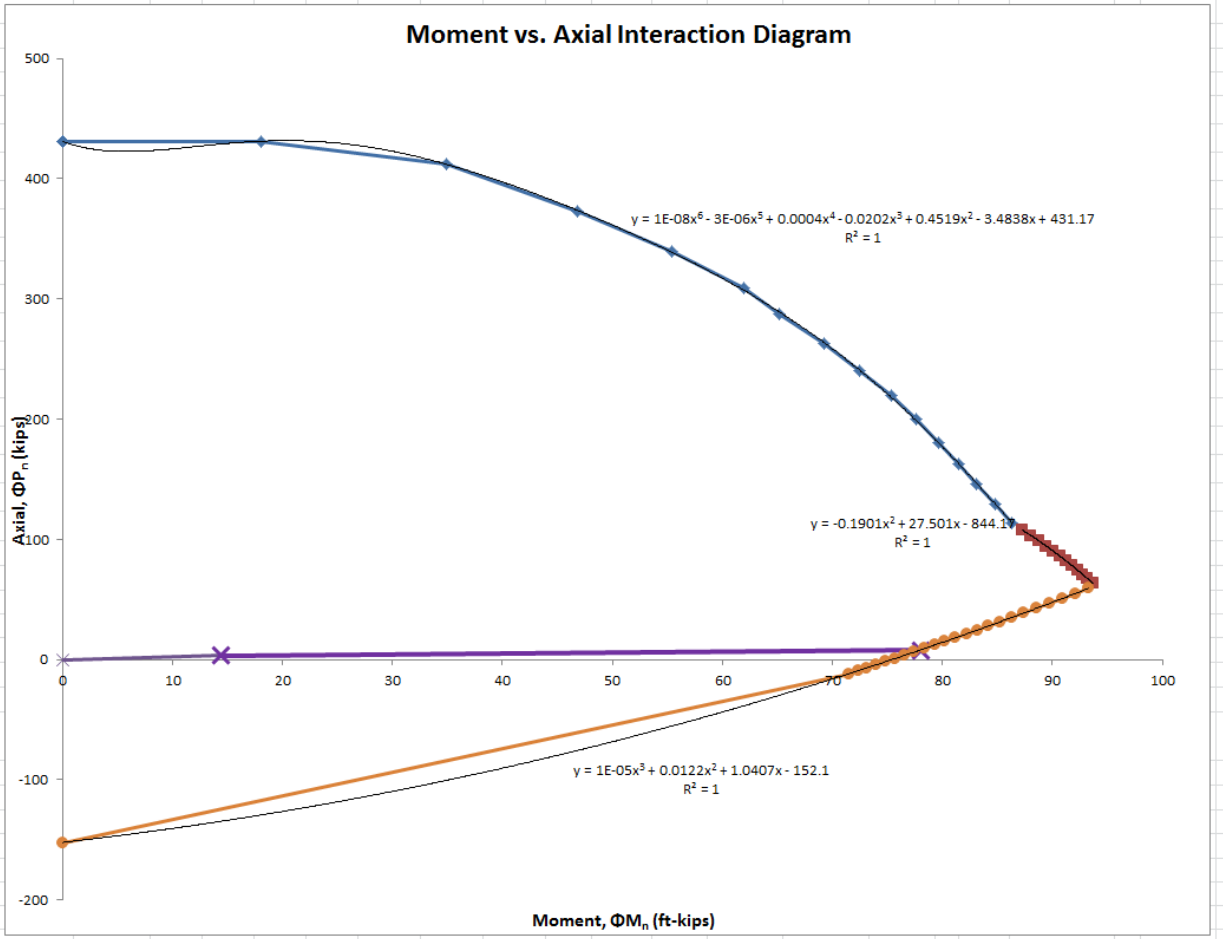
Element17	
Input Variables	
b=	12 in.
h=	12.00 in.
A_g=	144 in2
A_s=	1.720 in2
A'_s=	0.880 in2
Φ_{bar1} =	0.750 in
Φ_{bar2} =	0.750 in
Cover 1	1.50 in.
Cover 2	2.00 in.
f'_c=	5,000 psi
F_y=	65,000 psi
E_s	29,000,000 psi
ε_y=	0.00224
ε_c=	0.003
β_1=	0.8
$\phi P_{n,max}$	431.17 kips
d_1=	9.63 in.
d_2=	1.88 in.

Factored Forces		
	Moment	**Axial**
Dead	14.38	3.19
Live	25.85	1.97

Projected Capacities	
Moment (ft-kips)	**Axial (kips)**
78.01	8.03

DL Slope	0.222
LL Slope	0.076

*Plotted points and slopes are absolute values



Load Rating For Deterioration

- **Buried Structure Rating**
  - Final Result: Rating Factors at Arch Nodal Coordinates For:
    - Shear
    - Combined Moment and Axial Force (P-M Analysis)

Load Rating For Deterioration

- **Buried Structure Rating**
  - Research:
    - JTRP SPR-3816: Steel Multi-Plate Arch
      - Wall Area Yielding
      - Buckling Strength
      - Seam Resistance