

HUB-GIRDER BOLT ASSEMBLY WITHOUT AN INTERFERENCE FIT IN BASCULE BRIDGES

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Motivation

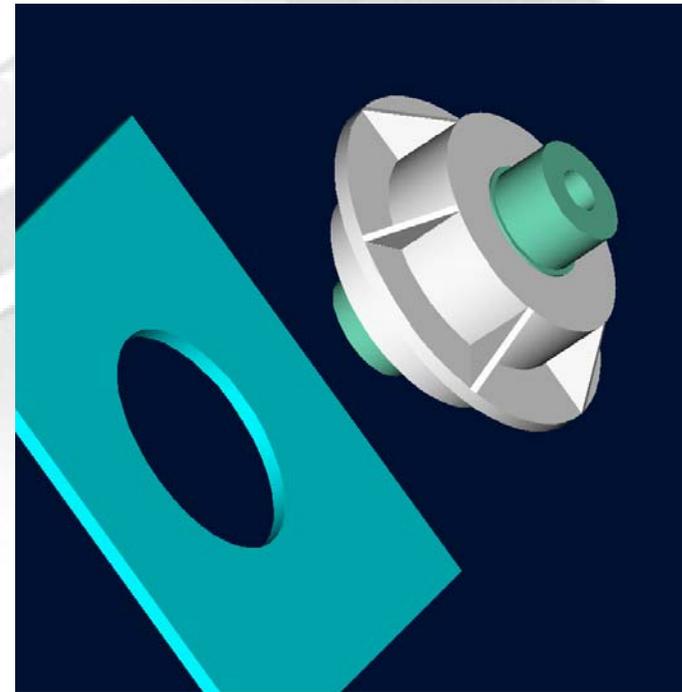
- Failures during shrink fitting trunnion-hub into girder (Christa McAullife and Brickell Avenue Bridges)
- Cracks & Shrink defects (Miami Avenue Bridge)



**TYPICAL TRUNNION-HUB-GIRDER
ASSEMBLY**

Task

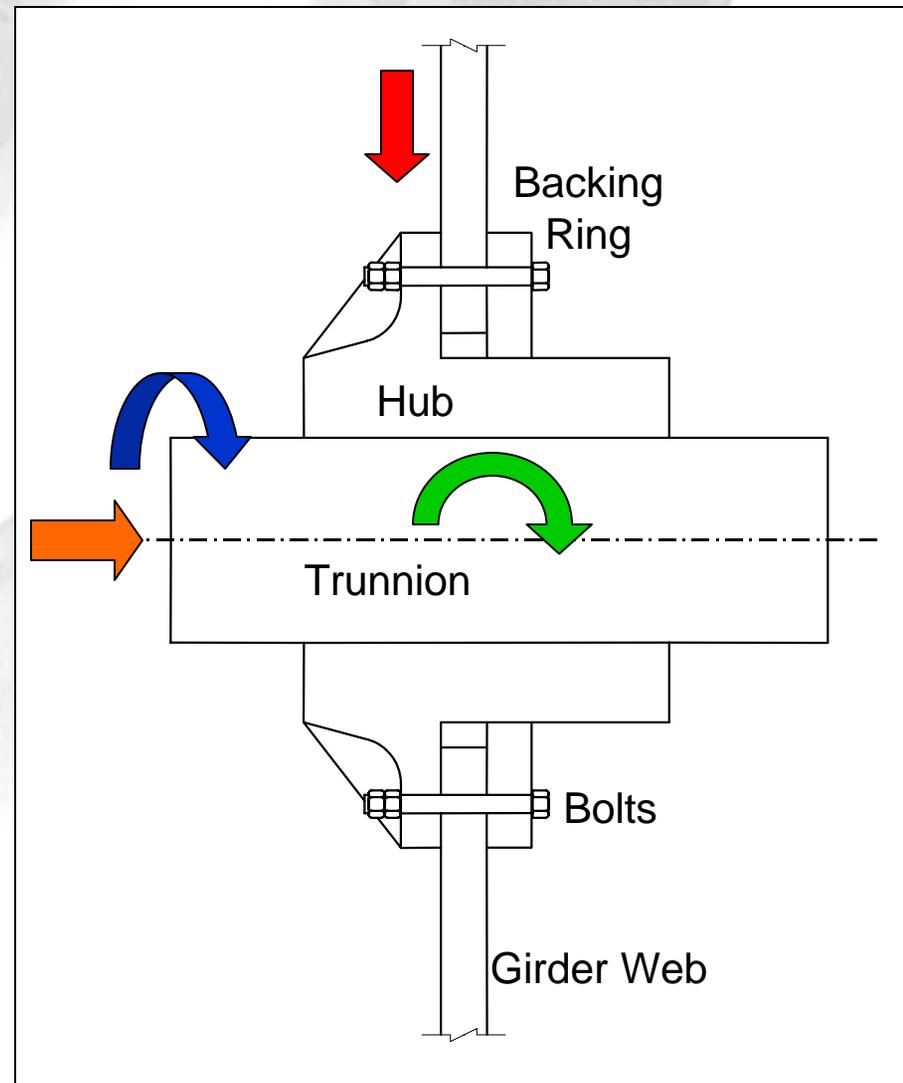
- Design the trunnion-hub to girder assembly as a slip critical joint without interference fit



**TRUNNION-HUB TO GIRDER
ASSEMBLY**

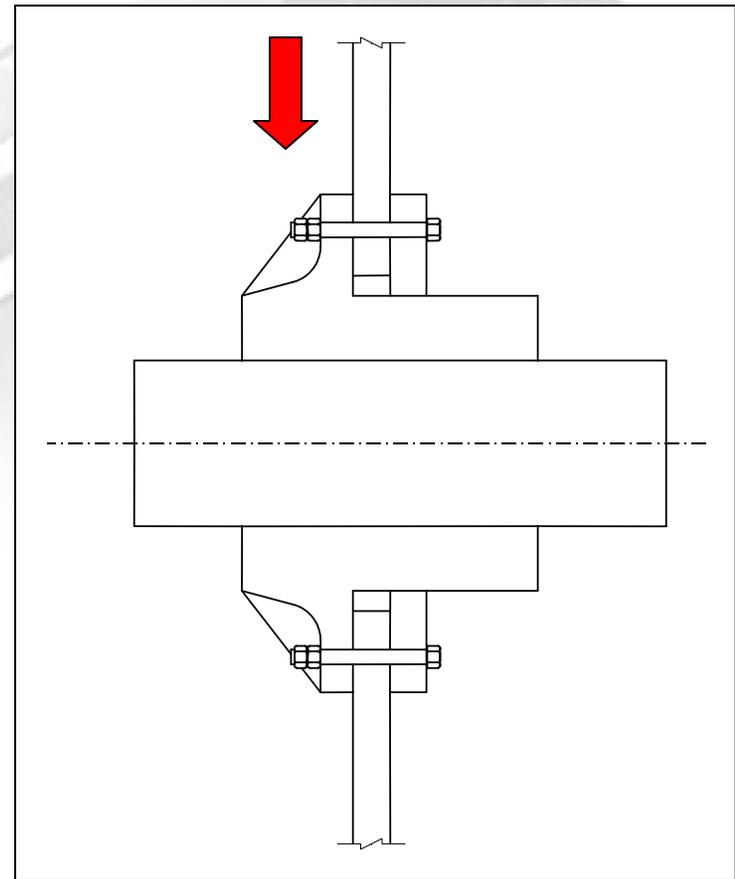
Basic Design & Loading

- Shear
- Torsion
- Axial Loads
- Bending Moment



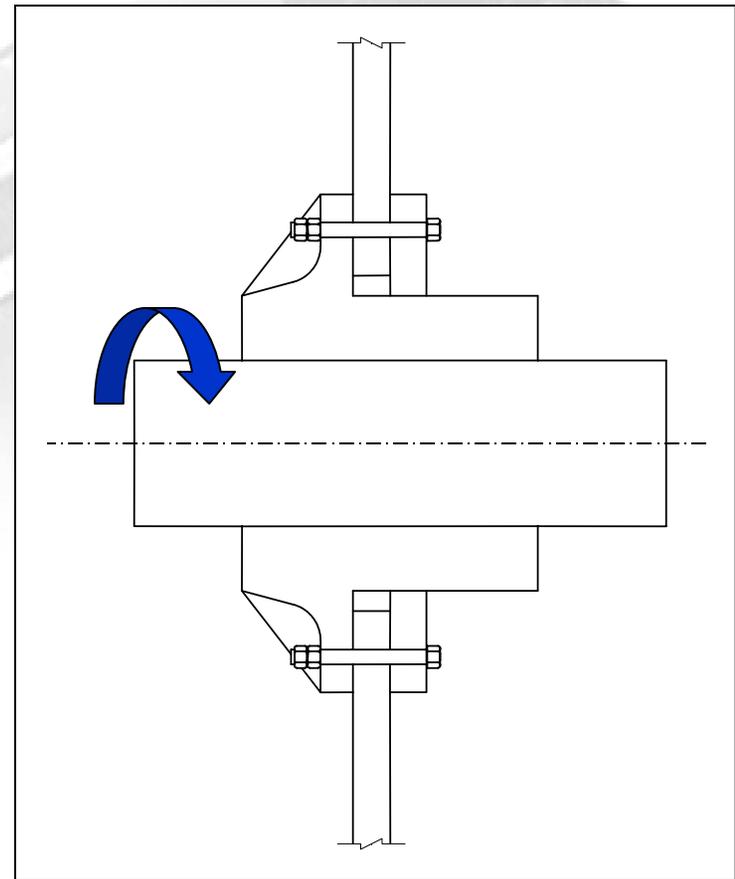
Shear

- Transferred from girder to the trunnion bearings
- Mainly dead load, wind, live load + impact
- Obtained from various Load Case combinations specified in AASHTO



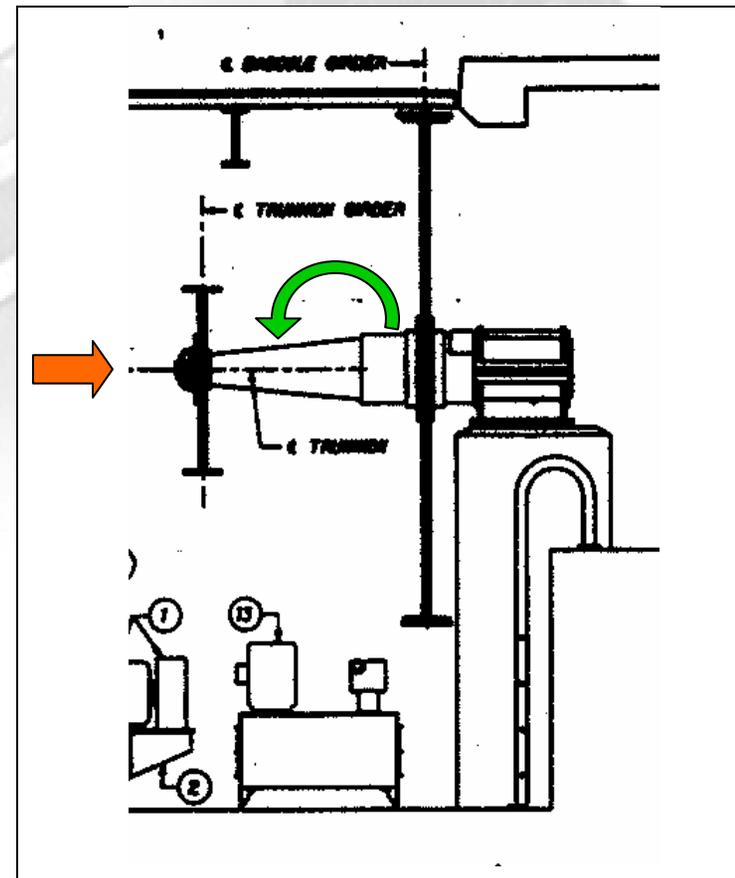
Torsion

- **Torsion** loads caused due to friction at trunnion bearings
- Specified as 6% radial load acting on trunnion outer diameter for bronze bushing
- For anti-friction bearings, 1/100 of maximum radial load



Axial Load & Bending Moment

- These do not generally control
- **Axial load** specified as 15% of shear load (AASHTO)
- **Bending moment** checked for Hopkins trunnion



HOPKINS TRUNNION

Design Procedure

Following items are considered -

1. Slip resistance of the joint
2. Shear strength of fastener (in bearing)
3. Bearing strength of girder
4. Bearing strength of the hub
5. Bearing strength of the backing ring

Slip Resistance

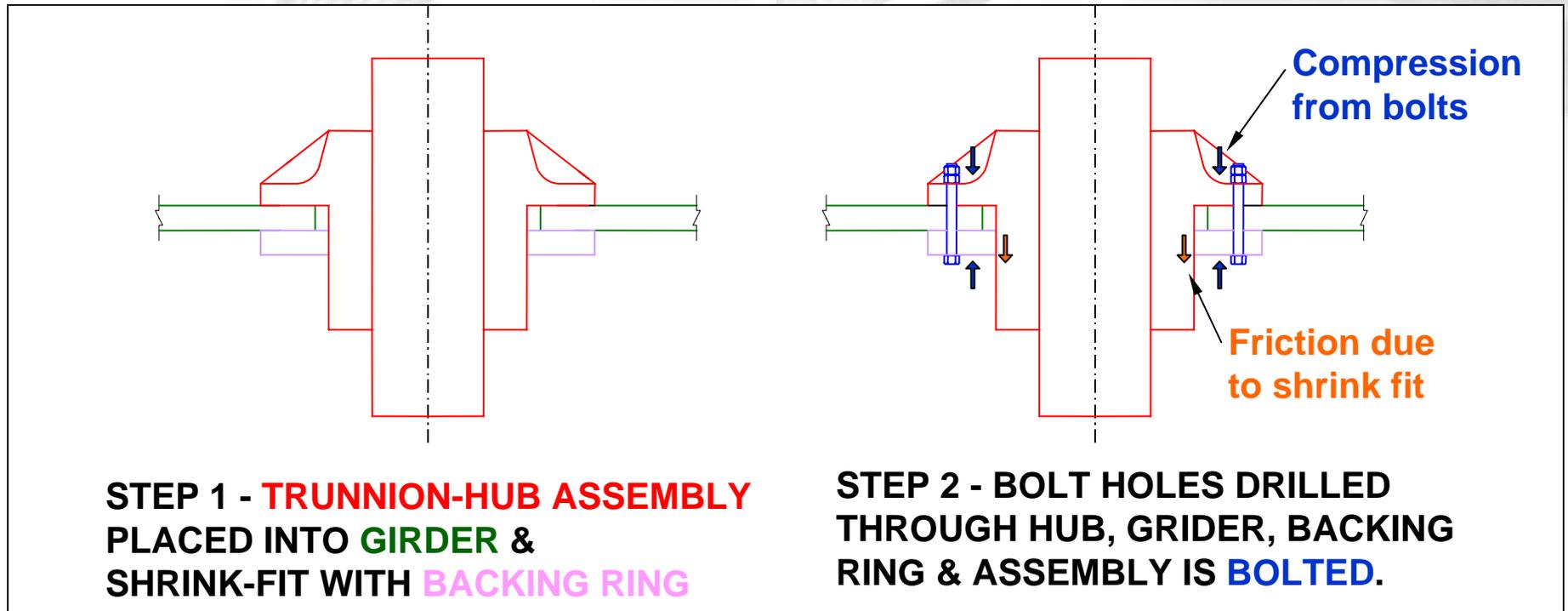
- LRFD Equation

$$R_n = K_h K_s N_s P_t$$

- K_h = hole size factor (1)
- K_s = surface condition factor (0.33 or 0.5)
- N_s = no. of slip planes (2)
- P_t = min. required bolt tension (?)

Bolt Tension Requirement

■ $P_T = P_{\text{shear}} + P_{\text{torsion}} + P_{\text{axial}} + P_{\text{backing ring friction}}$



ANTICIPATED ASSEMBLY SEQUENCE

Bolt Tension for Shear & Torsion

- Shear

$$P_{\text{shear}} = \frac{V}{K_h K_s N_s}$$

- Axial $P_a = P$

- Torsion

- Conservative estimate assuming a uniform pressure distribution due to bolting

$$P_{\text{torsion}} = C_b \frac{3T(R_{\text{out}}^2 - R_{\text{in}}^2)}{2K_s K_h N_s (R_{\text{out}}^3 - R_{\text{in}}^3)}$$

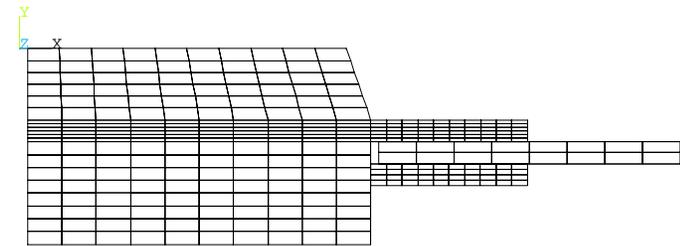
- Refining final design

$$T = \sum_{n=1}^{n_b} K_s K_h N_s P_{tn} r_{bn}$$

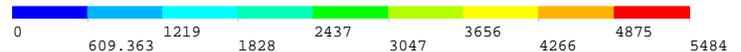
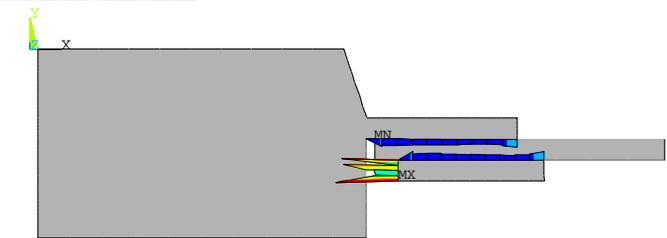
Backing Ring Friction

- Axisymmetric FEM used to determine significance
- For bridge considered (Royal Park), backing ring friction was about 7% of total preload
- Can be conservatively estimated using theory of elasticity (about 10% of total preload for above case)

$$P_{bpf} = \mu_{bp} \frac{E\delta(r_{bo}^2 - r_t^2)}{2r_t r_{bo}^2} A_{bpc}$$



FE MESH



CONTACT PRESSURES

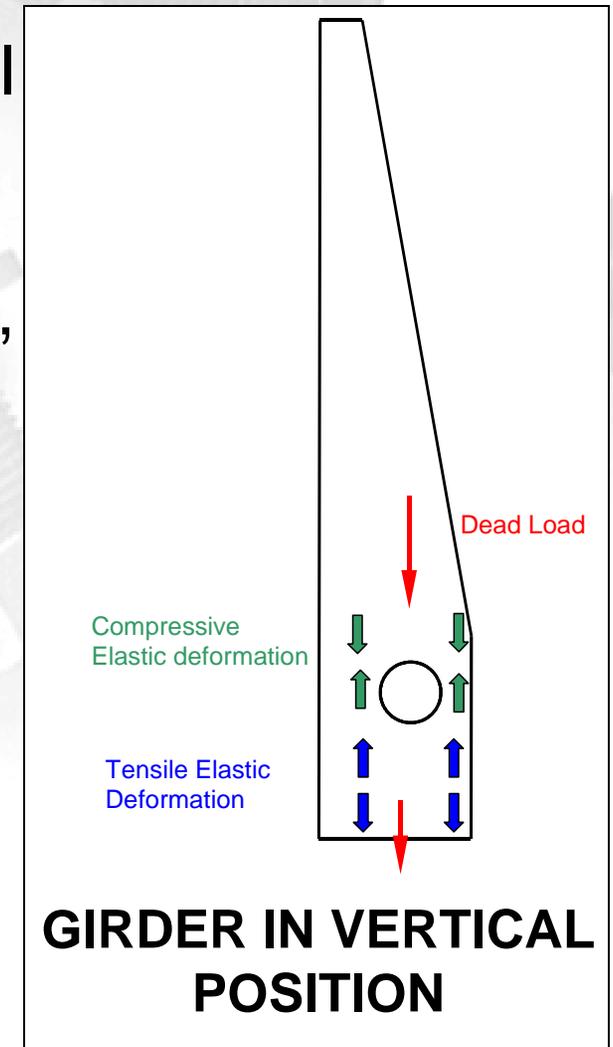
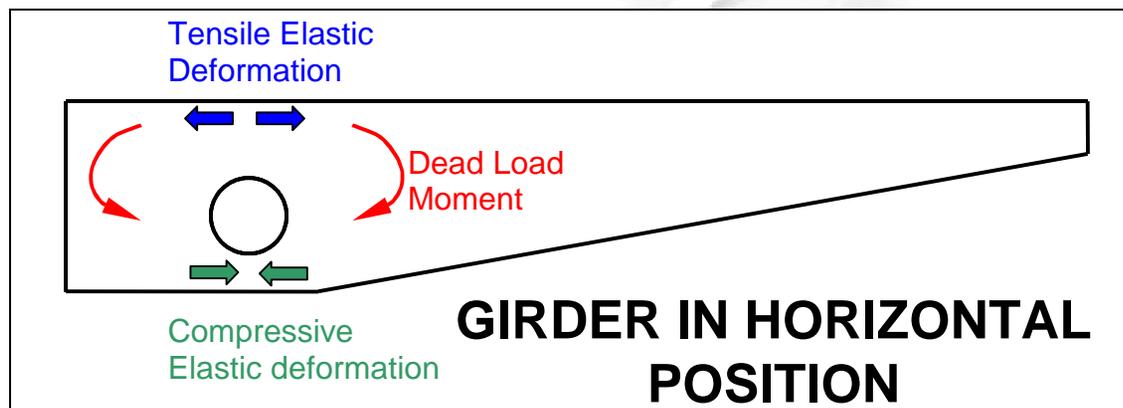
Other Checks

These are used in current design and must be checked as specified in section 6.13.2 (Steel Structures) in AASHTO LRFD

- Shear strength of fastener (in bearing)
- Tensile strength of fastener
- Bearing strength of members (girder, hub & backing ring)

Other Considerations

- Slip can occur from reduced frictional resistance resulting when elastic deformation changes at the contacts
- Here slip is restricted by bolt bearing, so tight clearance (LC6) recommended with turned bolts
- **Dowels** with interference fit might also prove useful to prevent slip



Design Tools

- The procedure has been used to develop design tools using Microsoft Excel & Visual Basic for Application
 1. **Design** - Different bolt patterns can be obtained for given loads, material & geometry.
 2. **Analysis** - Specified bolt pattern can be checked for given loads, materials & geometry.

Impact of Removing Interference

- Joints with interference fits are designed for bearing strength, which resist the load using 0.38 or 0.48 times the bolt tensile strength
- Slip critical joints utilize 0.23 to 0.35 times the tensile strength of bolts and also need to overcome collar friction
- Net impact is to **nearly double** the numbers of bolts, which means larger hub diameter
- Also, **tighter fit** is required between bolt and hole or dowels must be provided to avoid small slip caused by elastic deformation

Final Phase

- Analyze 5 different bridges (perhaps different types - simple trunnion, Hopkins, box girder)
- Verify designs with simple FE models
- Miscellaneous issues
 - Slip due to elastic deformation from temperature loading & span rotation
 - Effectiveness of dowels in preventing slip
- Schedule – Above tasks will be completed by end of June 2003.