Steel Pipe Pile/Concrete Pile Cap Bridge Support Systems: Confirmation of Connection Performance

Authors: Lenci Kappes, MS, PE
Michael Berry, PhD
Jerry Stephens, PhD, PE

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Background

Typical Bent Configuration and Advantages:
- Series of concrete-filled steel pipe piles embedded in a concrete pile cap
- Fast and efficient to construct
- With proper design, improves the ductile response and overall strength of the structure

Benefits of Concrete-Filled Steel Tube (CFT):
- Concrete inside steel tube has several advantages:
  - Increase thermal capacity and ductility, and delay buckling of the steel tube
  - Compressive strength of column is increased
  - Plastic-hinging of the CFT is a preferable failure (opposed to deterioration of the cap)
  - Proper design of the connection between CFT and concrete cap is necessary for benefits

Approach Methodology

Test Setup:
- Test specimens based on a subsection of a typical bridge bent
  - Approximately 1:4 scale

Overall
- 9 monotonic test specimens —
  - 4 without U-bars encircling the embedded pile
  - 5 with U-bars encircling the embedded pile
- 2 cyclic test specimens
- Both include U-bar reinforcement

Test Methods:
- Initial monotonic testing without U-bars (labeled PC1, PC2, PC3, PC3a)
- Remaining monotonic testing included U-bars (labeled CT1, CT2, VT1, VT2, VT2.5, VT3)
- 3 unique cap reinforcement configurations (VT1 cap was reused for VT2.5)
- Loaded in a single direction until failure, with extensive cap deterioration observed
- The loading was reversed and increased until the tip of the pile reached the same displacement as the lateral load
- CFT tip deflection, applied CFT tip deflection and reinforcement strains were recorded
- Cyclic testing included U-bars (labeled CT1L, CT2): 9 different cap reinforcement configurations (one was similar to VT2, second was enhanced)

Test Observations:
- Connection capacity increases with increased CFT embedment, increased concrete strength, the addition of U-bar reinforcement, etc.
- CFT tip deflection, applied CFT tip deflection and reinforcement strains were recorded
- Cyclic testing included U-bars (labeled CT1L, CT2): 9 different cap reinforcement configurations (one was similar to VT2, second was enhanced)

Test Results

Observed Limit States:
- Initial Cracking
- Concrete degradation/crushing
- Yielding of the CFT:
- Connection capacity increases with increased CFT embedment, increased concrete strength, the addition of U-bar reinforcement, etc.
- CFT tip deflection, applied CFT tip deflection and reinforcement strains were recorded

Results Focus:
- Test results presented herein focus on VT and CT test series with U-bar reinforcement

Summary and Conclusions

U-bar Benefits:
- Provide local concrete confinement around CFT
- Direct steel reinforcement capable of resisting CFT rotation
- Splitting of the cap:
  - Inclusion of interior U-bars delayed deterioration
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Yielding of the CFT:
- Two crushing regions — interior and exterior
  - Concrete confinement around the embedded CFT
  - When U-bars are included in exterior confinement, failure is limited at the exterior
  - Inclusion of interior U-bars delayed deterioration

Concrete degradation/crushing:
- Provide local concrete confinement around CFT
- Direct steel reinforcement capable of resisting CFT rotation

Spalling of the cap:
- Reduced geometry of CFT creates transverse forces that may cause the cap to split
- Transverse stress needs these forces and provides concrete confinement for the compression regions resist the pile rotation
- Possibly rely on empirical relationship for transverse reinforcement or use forces from a more robust analytical model

Supporting Documents

Kappes, L., M. Berry, and J. Stephens. 2013. Performance of Steel Pipe Pile-To-Concrete Cap Connections Subject To Seismic Or High Transverse Loading: Phase II—Confirmation of Design Performance. Montana Department of Transportation. (Accepted by DOT in 2013)
Berry, M., and H. McDonald. 2005. Final Report: Performance Of Steel Pipe Pile-To-Concrete Cap Connections Subject To Seismic Or High Transverse Loading, Montana Department of Transportation. (Accepted by MDT in 2005)

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