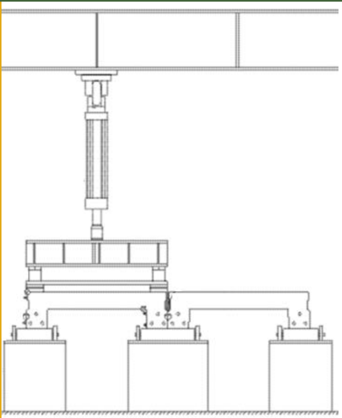
UHPC Shear Keys in Concrete Bridge Superstructures



Investigating the use of ultra-high performance concrete as a grout to fill shear keys between pre-stressed girders in concrete bridge superstructures

Highlight | Jan. 2019

Project No. 18CNMS01

PI: Dr. Craig Newtson, Dr. Brad Weldon (NMSU)

POP: March 2018 – November 2019

Shear keys are used between bridge superstructure elements to provide load transfer from one girder to an adjacent girder. Shear keys are produced by forming recessed keys into the sides of precast girders so that when the girders are placed on site, the recessed areas in adjacent girders align to form a void that can be grouted to achieve interlock between the girders. Repair of deteriorated shear keys requires chipping open portions of the shear key, removal of the original grouting material, and re-grouting in a manner that successfully re-seals the joint. This research investigates the use of ultra-high performance concrete (UHPC) produced with local materials to fill shear keys between girders. UHPC has been shown to have exceptional durability and strength properties that have the potential to greatly extend the service lives of shear keys. Research activities consist of a comprehensive literature review to identify best practices for traditional grouting materials that might also be used for UHPC grouts, slant shear and direct tension testing to evaluate bond strength, shrinkage testing to assess cracking potential of the bonded interface, and full-scale laboratory testing to assess structural performance.

Background

Shear keys are used between bridge girders to provide load transfer from a loaded girder to one or more adjacent girders. The ability of the shear key to transfer load to adjacent girders is a function of many variables that include the strength and stiffness of the grout in the shear key as well as the conditions of the grout and it's bond to the girders. Shear keys are produced by forming recessed keys into the sides of precast girders. When the girders are placed on site, the recessed areas in adjacent girders align to form a void that can be grouted full to achieve interlock between the girders. In service, shear keys often deteriorate in a manner that starts with loss of bond between the grout and the superstructure elements. Once bond is lost, a path for water to seep into the shear key is provided. Infiltration of water into the damaged shear key can cause degradation through freezing and thawing, leaching, and corrosion of reinforcing steel. As degradation progresses, less load transfer occurs between the girders which reduces the load carrying capacity of the bridge. To restore load transfer between the girders, repair of deteriorated shear keys involves chipping open portions of the shear key, removing the original grouting material, and re-grouting in a manner that re-seals the joint, establishing a strong bond with the girders on both sides of the shear key.

Project Summary

The major objectives for this project are:

- Conduct a comprehensive literature review on grouting materials, grouting techniques, and technologies related to rehabilitation of shear keys between superstructure elements in concrete bridges.
- Characterization of the bond between the UHPC grout and the substrate concrete through direct tension and slant shear testing with different surface preparation. These tests are performed by constructing bonded specimens that are tested as shown in the photographs at the end of this section. The slant shear specimens are tested in compression to induce shear stress on the inclined bonded surface.
- Characterization of the bond between the UHPC grout and the substrate concrete through scanning electron microscopy.
- Characterization of UHPC shrinkage under expected field conditions through shrinkage testing. UHPC shrinkage is being measured in both the fresh and hardened states.
- Assessment of cracking potential in UHPC grouted shear keys through shrinkage and thermal modeling.
- Full scale testing of repaired shear keys between channel girders to assess shear transfer and grout performance. An illustration of the full-scale testing is provided in Section A. Twenty-five foot (7.62

m) long channel girders recovered from a bridge demolition project are being used in the full-scale tests.

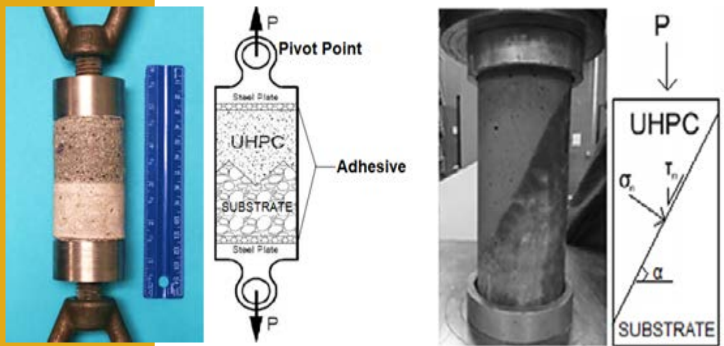


Figure 1. Testing specimen and set-up for bonding between UHPC and the substrate.

Status Update

Results from slant shear and direct tension testing have shown that surface preparation methods have substantial influence on the bond strength. It appears that bond strengths achieved on formed surfaces is minimal when the surface is not wetted prior to grouting, which could lead to immediate cracking of the shear key bond unless lateral constraint is provided by post-tensioning or other methods. Reasonable bond strengths for repair concrete has been achieved when the substrate surface has been properly prepared by wetting and texturing, even when the surface texture is minimal. This provides confidence that field surface preparation methods will produce suitable bond between the grout and the superstructure concrete.

Table 1. Slant shear test results.

Texture	7 Day Strength		28-Day Strength	
	MPa	psi	MPa	Psi
Formed	22.8	3300	18.5	2680
	9.7	1400	19.8	2870
	20.0	2900	11.7	1700
	28.7	4160		
Chipped 0.221 mm (0.008 in)	29.4	4730	33.7	4890
	23.8	3450	29.9	4340
	35.9	5200	35.9	5200
Chipped 0.701 mm (0.0276 in)	28.7	4160	35.4	5130
	25.8	3740	32.3	4690
Chipped 1.26 mm (0.0496 in)	29.4	4270	25.8	3740
	15.7	2270	22.1	3210
	15.1	2190	27.4	3980

The shrinkage tests have demonstrated that the free-shrinkage of the UHPC mixture being used in this study is consistent with the shrinkage of other UHPC mixtures described in the literature.

Analysis of the interaction between bond strength and the combined temperature and shrinkage strains that are expected to occur in the UHPC grout have indicated that there is a reasonable likelihood that a UHPC shear key will lose bond with a formed face of the shear key if lateral restraint is not provided.

Table 2. Direct tension test results.

Texture	7 Day Strength		Average Strength	
	MPa	psi	MPa	psi
Formed	0.88	127	1.14	166
	0.66	96		
	1.54	223		
	0.96	139		
	1.63	237		
	1.57	228		
	1.07	154		
	0.85	123		
Chipped 0.128 mm (0.00503 in)	1.34	194	1.17	170
	1.00	145		

Testing of channel girders with a UHPC shear key has been prepared, and preliminary tests have been performed for troubleshooting purposes. This testing currently on-going.

Impacts

This project is one of the first attempts to use UHPC as a grout for bridge superstructure shear keys with the intent of extending service lives of rehabilitated bridges. This project is also one of the first studies to include full-scale laboratory testing of UHPC shear keys. The development of this technology expands the body of scientific knowledge in transportation engineering bridge engineering. Additionally, this work could easily lead to other novel applications of UHPC or new practices for grouting shear keys.

Since UHPC shear keys are expected to extend the lives of rehabilitated bridge superstructures, this would provide a significant reduction in bridge maintenance costs.

Tran-SET

Tran-SET is Region 6's University Transportation Center. It is a collaborative partnership between 11 institutions (see below) across 5 states (AR, LA, NM, OK, and TX). Tran-SET is led by Louisiana State University. It was established in late November 2016 "to address the accelerated deterioration of transportation infrastructure through the development, evaluation, and implementation of cutting-edge technologies, novel materials, and innovative construction management processes".

Learn More

For more information about Tran-SET, please visit our website, LinkedIn, Twitter, Facebook, and YouTube pages. Also, please feel free to contact Mr. Christopher Melson (Tran-SET Program Manager) directly at transet@lsu.edu.

Tran-SET