Report No. CDOT-2013-1
Final Report

SELF-CONSOLIDATING CONCRETE REPAIRS ON INTERSTATE 25 BRIDGE ABUTMENTS NORTH OF MEAD

Panos D. Kiousis
Brent L. Whitcomb

July 2013

COLORADO DEPARTMENT OF TRANSPORTATION
DTD APPLIED RESEARCH AND INNOVATION BRANCH

Technical Report Documentation Page

1. Report No.	2. Government Accession No.	3. Recipient's Catalog No.
CDOT-2013-1		

4. Title and Subtitle	5. Report Date
SELF-CONSOLIDATING CONCRETE REPAIRS ON INTERSTATE 25 BRIDGE ABUTMENTS NORTH OF MEAD	July 2013
	6. Performing Organization Code
7. Author(s) Panos D. Kiousis, Brent L. Whitcomb	8. Performing Organization Report No. CDOT-2013-1
9. Performing Organization Name and Address Colorado School of Mines 1500 Illinois Street Golden, Colorado 80401	10. Work Unit No. (TRAIS) 11. Contract or Grant No.
12. Sponsoring Agency Name and Address Colorado Department of Transportation - Research 4201 E. Arkansas Ave. Denver, CO 80222	13. Type of Report and Period Covered Final 14. Sponsoring Agency Code

15. Supplementary Notes

Prepared in cooperation with the US Department of Transportation, Federal Highway Administration

16. Abstract

In August of 2011 CDOT performed maintenance on Interstate 25 bridges D-17-DA and DB on I-25 north of Mead, CO. The maintenance was performed using self-consolidating concrete (SCC), and the methods were based on a study performed by the Colorado School of Mines under contract number 09 HTD 00027, and published in a CDOT 2007 report titled “Study on the Use of Self-Consolidating Concrete for the Repair of the Mead Bridges on I-25.”

The concrete abutments at the Mead Bridges on I-25 deteriorated in recent years due to unexpected freeway embankment movements. In many places the concrete had spalled off and exposed the steel reinforcement. The north abutments were especially affected by the embankment progressive movement towards the bridge. This movement forced the abutment against the steel girders, and progressed to the point where the abutment cover was crushed and the girders came in direct contact with the abutment reinforcement. It also resulted in buckling of the concrete deck, which was lifted off of the girders, resulting in a gap between the deck and the girders.

To mitigate the problems described above, CDOT decided to “lock” the girders to the abutments with the use of SCC. The intent to use SCC was based on the need to have a flowable, yet stable concrete that could encapsulate the ends of the steel girders and the space in between them, without leaving voids at the interface of the new concrete and the existing deck slab, and without the need to vibrate the new concrete during placement. To achieve these goals, a high flowability concrete was designed with the intent of placing it through a number of holes at the deck within the encased area.

One year after completion of the repair, inspections of the abutments were made in order to verify the performance of the repair after a full cycle of seasonal temperature changes. The inspection found that the concrete placed around the girders is performing as intended. No significant cracking or other indications of concrete failure were seen.

Implementation

The long-term performance of the repair is yet to be determined, but the inspection after one year of seasonal thermal cycles has not revealed any detriments to the concrete or steel girders. It is recommended that the long-term behavior of the repair concrete, steel girders, deck, and abutment movements be monitored in order to ascertain that no problems arise.

17. Keywords:	18. Distribution Statement
SCC, mechanically stabilized earth walls (MSEW), seismic design, connection details, finite element analysis, I-25	This document is available on CDOT’s website http://www.coloradodot.info/programs/research/pdfs

19. Security Classif. (of this report)	20. Security Classif. (of this page)	21. No. of Pages	22. Price
Unclassified	Unclassified	21	

Form DOT F 1700.7 (8-72) Reproduction of completed page authorized

SELF-CONSOLIDATING CONCRETE REPAIRS ON INTERSATE 25 BRIDGE ABUTMENTS NORTH OF MEAD

by

Panos D. Kiousis
Brent L. Whitcomb

Report No. CDOT-2013-1

Sponsored by
Colorado Department of Transportation
In Cooperation with the
U.S. Department of Transportation
Federal Highway Administration

July 2013

Colorado Department of Transportation
Research Branch
4201 E. Arkansas Ave.
Denver, CO 80222

ACKNOWLEDGEMENTS

The authors of this report wish to express their appreciation to the Colorado Department of Transportation for the opportunity to contribute to the improved construction in Colorado. Special appreciation must be given to Aziz Khan, as well as Roberto de Dios, Richard Griffin Ahmad Ardani, Richard Osmun, and Jake Kononov for their thoughts and dedication towards this research project.

EXECUTIVE SUMMARY

This report presents the outcomes of a Colorado School of Mines (CSM) study on the research project, "Self-Consolidating Concrete Repairs on Interstate 25 Bridge Abutments North of Mead."

Twin bridges D-17-DA and D-17-DB on Interstate 25 (I-25) north of the town of Mead, CO, developed support problems, deterioration of abutments, and degradation of the deck due to foundation movements. The original design of the bridges utilized three (3) spans of steel girders simply supported on concrete abutments, founded on steel H-piles. It was observed that the abutments moved into the steel girder superstructure. This resulted in significant deterioration of the abutments, including complete degradation of their cover, as they came in contact with the steel girders. To mitigate this problem, it was decided to "fix" the girders to the existing abutments by encapsulating the steel girders and the abutments in concrete, essentially creating an integral abutment.

In order to encapsulate the girders in concrete and limit disturbance to traffic, self-consolidating concrete (SCC) was selected to surround the ends of the girders. Using SCC allows the concrete to be placed through small holes drilled in the deck above the abutments and flow between the girders, filling all voids. SCC utilizes specific proportions of water, cement, fly ash, sand and pea gravel, along with superplastizer chemical admixtures, such as High Range Water Reducers (HRWR) and Viscosity Modifying Agents (VMA) in order to produce a flowable concrete, allowing it to consolidate, encapsulate all reinforcement and fill completely the formwork without the aid of external vibration.

In the first phase of this project, CSM measured the vibrations of the bridges under normal use traffic loads. The vibration patterns and subsequent displacements due to the traffic loads were replicated in the laboratory and transferred to smaller scale model steel beams curing in fresh SCC. After curing for 24 hours under the replicated displacements, the bond strength of the vibrating beams was measured and compared to identical beams cured under normal conditions. The loss of bond strength between the vibrated beams and the static beams was determined to be sufficiently small to accomplish the desired effect of locking the Mead bridges to create an

integral abutment. This first phase of research was published in the report "Study on the Use of Self-Consolidating Concrete for the Repair of the Mead Bridges on I-25" (CDOT -2007-1).

The second phase of this project was the placement of the SCC on the I-25 bridges north of Mead. Due to the bridge configurations and the repair plan decided upon by CDOT and the contractor, the southern abutments were encapsulated with SCC. The northern abutments, which contained the elastomeric expansion joints, were repaired using normal concrete. The northern expansion joints were removed, along with a small portion of the deck and a portion of the roadway pavement. This concrete was finished to the existing deck and approach pavement elevation to create a new driving surface. The southern abutments of the twin structures were locked up with SCC by drilling holes in the deck between each girder bay to pour concrete into these holes, allowing the SCC to flow between and under the girders and within the confining formwork.

During the repair procedure, traffic was diverted to the opposite bridge to allow for placement and curing. As recommended by the preliminary study, sufficient time for initial setting of the concrete was needed before opening the repaired bridges to full traffic. In addition, heavy truck loads were diverted for a minimum of 24 hours, while light vehicle traffic was allowed on the bridge following a few hours of initial set.

After one year of service, the CSM team inspected the encapsulated abutments. The duration of normal use with live traffic loading and seasonal temperature changes, allowed for examination of the repair performance. Based on the inspection of the repair it can be stated that the performance of the SCC is acceptable. There is minor evidence of local cracking near the bottom flanges of the embedded girders, but there is no evidence of significant cracking in the concrete mass between the girders.

In summary, it cannot be determined at this point if the encapsulation of the girders has resolved the root problem of abutment displacement, but the performance of the SCC and normal concrete has successfully encased the ends of the steel girders. There is no evidence of concrete cracking due to girder deflection under typical service loading.

TABLE OF CONTENTS

LIST OF FIGURES

1.0 INTRODUCTION

In August of 2011 CDOT performed the maintenance of the Interstate 25 bridges D-17-DA and DB on I-25 north of Mead, CO. The maintenance was performed using self-consolidating concrete (SCC), and the methods were based on a study performed by the Colorado School of Mines under contract number 09 HTD 00027, and published in a CDOT 2007 report titled "Study on the Use of Self-Consolidating Concrete for the Repair of the Mead Bridges on I-25."

The concrete abutments at the Mead Bridges on I-25 have deteriorated in the recent years due to unexpected freeway embankment movements. In many places the concrete had spalled off and exposed the steel reinforcement. The north abutments were especially affected by the embankment progressive movement towards the bridge. This movement had forced the abutment against the steel girders, and progressed to the point where the abutment cover was crushed and the girders came in direct contact with the abutment reinforcement. It also resulted in buckling of the concrete deck, which was lifted off of the girders, resulting in a gap between the deck and the girders.

To mitigate the problems described above, CDOT decided to "lock" the girders to the abutments with the use of SCC. The intent to use SCC was based on the need to have a flowable, yet stable concrete that could encapsulate the ends of the steel girders, and the space in between them without leaving voids at the interface of the new concrete and the existing deck slab, and without the need to vibrate the new concrete during placement. To achieve these goals, a highly flowable concrete was designed with the intent of placing it through a number of holes at the deck within the encased area. In the original approach, in order to accommodate the large volume of traffic on I-25, it was decided that the bridges must have at least one lane open at all times during the repair. The material research performed at CSM was designed to accommodate this plan. For long-term performance and safety reasons during construction it was eventually decided that it was preferable to divert all traffic during the bridge repair operations for 24 hours.

2.0 EXECUTION OF REPAIRS

Aggregate Industries, Inc. provided the SCC concrete for the repair work. For the repair, the contractor used two separate operations to encase the ends of the steel bridge girders in order to "lock" their end rotations. In the first operation, normal concrete was used to encase the ends of the bridge girders on the north abutment, where the expansion joint needed replacement. As shown in Figure 1, approximately ten feet of the concrete deck and approach slab were removed, followed by placement of normal concrete into the voids between the girders up to the deck profile elevation. This operation eliminated the expansion joint and integrated the abutment, girders and approach pavement. Normal concrete was used because the removal of the expansion joint allowed workers to access area with vibrators and the normal concrete was deemed to be a more cost effective alternative.

Figure 1: Southbound Bridge, North Abutment

The second repair operation aimed, similarly, to encase the girder ends in the southern abutment. This task was accomplished by placing SCC through the existing deck, and filling the abutment area between the girders. Holes were cored through the deck into each of the bays between the girders and above the overhangs. SCC was then poured from the trucks down into the holes, through the funnel system shown in Figure 2, filling up all bays with SCC.

Figure 2: SCC Placement Funnel

Due to the cross slope of the deck and abutment, it was decided to begin placing the SCC near the transverse center of the bridge, allowing it to flow outwards in both directions. The east-side holes were at slightly higher elevation. Placing the SCC at the eastern-most hole and allow gravity and the concrete flowability to fill up all space was considered. However, it was decided to start the placement of the SCC at the central hole to reduce flow travel and avoid potential segregation. At the early stages, the SCC flowed both towards the lower end, as well as the higher end. As the space between the girders filled, the SCC leveled itself until the SCC began to rise out of the hole at the low end overhang. Once the SCC began to flow out of the lowest hole, the hole was "plugged" with plywood and sand bags to prevent further outflow. The small head difference between the highest and lowest slope (only a few inches), made this process possible.

After the SCC reached the top of the placement hole, the funnel was moved to a hole at a higher elevation and placement resumed. During the relocation of the funnel, the covered holes were checked for SCC height and it was found that the SCC had lowered below the height of the deck. It was then decided to continue pouring until all holes were filled, including the highest elevation hole over the eastern overhang.

When the eastern overhang hole had SCC at its brim, the placement through the funnel was stopped. Each hole was checked for SCC height. It was found that all of the holes had a small drop of the SCC level. This was expected due to the self-leveling of the SCC. However, the placement hole (at the highest elevation) was full and no further SCC could be poured without spilling and getting the SCC to push up in the other bays. Thus, it was decided to finish off the tops of the lower holes by placing SCC in from the top AFTER tamping with a rod to avoid the formation of a cold joint between the two different concrete placements. It should be point out here, that SCC has a thixotropic characteristic, where it appears to set fairly quickly (within a few minutes). However, a small vibration or disturbance by rodding returns it into its more fluid state. This property was used when the holes were topped off to avoid cold joints.

The following tests were performed on the fluid SCC:

1) Air content (ASTM C231/C231M-10 Standard Test Method for Air Content of Freshly Mixed Concrete by the Pressure Method);
2) Slump flow (ASTM C1611/C1611M-09be1 Standard Test Method for Slump Flow of Self-Consolidating Concrete),
3) Slump flow through a J-Ring (ASTM C1621/C1621M-09b Standard Test Method for Passing Ability of Self-Consolidating Concrete by J-Ring),
4) The L-Box test, which is a common test of fresh SCC, but is not currently part of an ASTM standard.

This slump flow test is used to monitor the consistency of fresh, unhardened self-consolidating concrete and its unconfined flow potential. The slump flow test through the J-Ring (Figure 3) gives an indication of the SCC's ability to flow through confined spaces while maintaining its required flow circumference. The J-Ring tests of SCC typically should not show excessive amounts of aggregate trapped behind the vertical bars, which is an indication of the SCC being susceptible to segregation. The SCC tested on the Mead Bridge repair showed minor amounts of aggregate being left behind the J-Ring bars, as demonstrated in Figure 4. However, it was judged that the amount remaining behind did not indicate that the SCC delivered would not perform as intended.

The average slump flow of the SCC measured without a J-Ring was 27 inches, while the slump flow with J-Ring measured on average 26 inches, both of which were acceptable under the project specification minimum of 24 inches. The small difference of slump flow between the unobstructed and obstructed conditions (27 inches vs 26 inches) is a reliable indicator that the flow of SCC through bars will not result in significant segregation.

The L-Box test is used as another indication of SCC ability to pass through tight spaces and retain its self leveling attributes. As demonstrated in Figure 5, the SCC delivered for the project did not show any indication of being restricted in the L-box test and was approved on-site.

Figure 3: SCC Slump Flow Test with J-Ring

Figure 4: SCC J-Ring Aggregate Left Inside the Ring

Figure 5: SCC L-Box Test

The SCC placement was successfully completed for the southbound bridge on the same day, and the bridge was open for traffic the next day, with the overall process being declared successful. The following weekend allowed for the northbound repairs to commence, which also was completed in the same day and considered a successful repair.

3.0 INSPECTION OF REPAIRS IN SERVICE

A follow-up visit and close inspection approximately one year later, indicated that the intended locking of the bridge to its abutments was performed successfully, without the new concrete showing significant signs of distress. The one year wait period allowed for the repairs to perform in service through all types of seasonal cycles, which would indicate potential problems with thermal expansion and contraction of the girders.

The surfaces of the repaired abutments were coated in a white wash. There are a few areas beneath the bottom flanges of the steel girders where minor cracking was observed. Figure 6, taken at the deck overhang area, shows the typical surface finish of the SCC on the south abutment of the northbound bridge.

Figure 6: South Abutment of NB Bridge with SCC

Figure 7 shows the typical surface finish of the SCC on the Southbound Bridge between the girders. Note that the thermocouple used during construction to monitor the strength gain during the repair is still in place in this photograph.

Figure 7: SB Abutment Typical SCC Finish

The northern abutments of both bridges, cast in normal concrete, also appeared to be performing satisfactorily in the service conditions. No significant cracking was observed near the girders or in the bays between the girders. Figure 8 shows the typical surface finish and performance of the normal concrete used.

Figure 8: Typical Surface Finish of Normal Concrete

4.0 CONCLUSIONS

After the initial SCC study, observation of the concrete placement, and inspection of the service performance, it is concluded that the repair of the I-25 bridges north of Mead was successful in meeting the original objectives of locking the girders to the abutments. The long-term performance of the repair is yet to be determined, but the inspection after one year of seasonal thermal cycles has not revealed any detriments to the concrete or steel girders. It is recommended that the long-term behavior of the repair concrete, steel girders, deck, and abutment movements be monitored in order to ascertain that no problems arise.