

IMPLEMENTATION OF 0.7 IN. DIAMETER STRANDS AT 2.0 IN. BY 2.0 IN. SPACING IN PRETENSIONED BRIDGE GIRDERS

George Morcouc, Ph.D., P.E., University of Nebraska-Lincoln, Omaha, NE

Shaddi Assad, University of Nebraska-Lincoln, Omaha, NE

Afshin Hatami, P.E., University of Nebraska-Lincoln, Omaha, NE

Maher K. Tadros, Ph.D., P.E., e.Construct.USA, Omaha, NE

ABSTRACT

For several years, 0.7 in. diameter strands have been successfully used in cable bridges and for mining applications. Using these large diameter strands at 2 in. by 2 in. spacing in pretensioned concrete girders results in approximately 35% increase in the prestressing force compared to the same number of 0.6 in. diameter strands and 92% increase in the prestressing force compared to the same number of 0.5 in. diameter strands. This will, consequently, allow for longer spans, shallower structural depth, and/or wider girder spacing in bridge construction.

In this paper, the first application of 0.7 in. diameter strands at 2 in. by 2 in. spacing to precast/prestressed concrete bridge girders is presented in the construction of the Oxford South Bridge in Oxford, Nebraska. Twenty-six strand samples were tested to evaluate the breaking strength, yield strength, and modulus of elasticity of 0.7 in. diameter strands. Test results indicated that the tested strands meet the requirements of the ASTM A416-07. Also, transfer length measurements were taken at three different locations on two prestressed concrete girders at release and after 14 days using DEMEC gauges. Measurements indicated that the transfer length of 0.7 in. diameter strands can be conservatively estimated using the AASHTO LRFD Bridge Design Specifications. All fabricated girders were monitored for end zone cracking and camber growth and were found in compliance with current production tolerances, as specified by PCI and Nebraska Department of Roads.

Keywords: Bridge Girders, Precast Concrete, Prestressing Strands, Transfer Length, Camber, End Zone Cracking.

INTRODUCTION

For several years, 0.7 in. diameter strands have been used in cable bridges and mining applications in the United States and for posttensioning tendons in Europe and Japan. The 0.7 in. diameter strand has a cross-sectional area of 0.294 in.² and weighs 1 lb/ft. Prestressing one 0.7 in. diameter strand up to 75% of its ultimate strength results in a prestressing force of 59.5 kips, which is 35% higher than that of 0.6 in. diameter strand and 92% higher than that of 0.5 in. diameter strand. Also, for the same prestressing force, using 0.7 in. diameter strand results in fewer strands to jack and release, fewer chucks, and more efficient use of prestressing due to lowering the center of gravity of the strands.

The Pacific Street Bridge over Interstate 680 in Omaha, NE is the first bridge to use 0.7 in. diameter prestressing strands in pretensioned concrete girders¹. However, strands were spaced 2 in. horizontally and 2.5 in. vertically and tensioned at 64% of the ultimate strength, which does not fully utilize the advantage of 0.7 in. diameter strands. Since then, experimental investigations have been conducted to evaluate the bond strength of 0.7 in. diameter strands with different concrete strengths and degrees of bottom flange confinement². These investigations have concluded that 0.7 in. diameter strands can be tensioned up to 75% their ultimate strength and spaced at 2 in. × 2 in., while satisfying the transfer length and development length provisions of the 6th edition of the American Association of State Highway and Transportation Officials (AASHTO) *LRFD Bridge Design Specifications*³. The investigations have also addressed the challenges associated with handling, jacking, and depressing 0.7 in. diameter strands. Bridge producers may need to retool their facilities to accommodate 0.7 in. diameter strands.

The objective of this paper is to present the implementation of 0.7 in. diameter strands at 2 in. × 2 in. spacing in the Oxford South Bridge in Oxford, Neb. This is first application in the United States with 0.7 in. diameter strands tensioned at 75% of the ultimate strength at 2 in. spacing horizontally and vertically.

PROJECT DESCRIPTION

This project consists of a two-lane bridge that is 32 ft wide and 580 ft long. It consists of five spans (110, 110, 140, 110, and 110 ft). The bridge was initially designed as a reinforced concrete deck on four NU1600 precast/prestressed concrete girders (63 in. deep) spaced at 9 ft. The prestressing of these girders was forty-two 0.6 in. diameter strands per girder for the 140 ft span and twenty-six 0.6 in. diameter strands per girder for the 110 ft span assuming that the girders were simply supported for dead loads and continuous for live loads and superimposed dead loads. The design was revised to four NU1350 precast/prestressed concrete girders (53 in. deep) spaced at 9 ft as shown in Fig. 1. The prestressing of these girders was thirty-four 0.7 in. diameter straight strands and six 0.6 in. diameter depressed strands for the 140 ft span and twenty-four 0.7 in. diameter straight strands with no depressed strands for the 110 ft. The 0.7 in. diameter strands were not depressed due to the unavailability of hold-down devices for 0.7 in. diameter strands. Fig. 2 also shows the

reinforcement details and the location of debonded and extended strands for the 140 ft and 110 ft NU1350 girders.

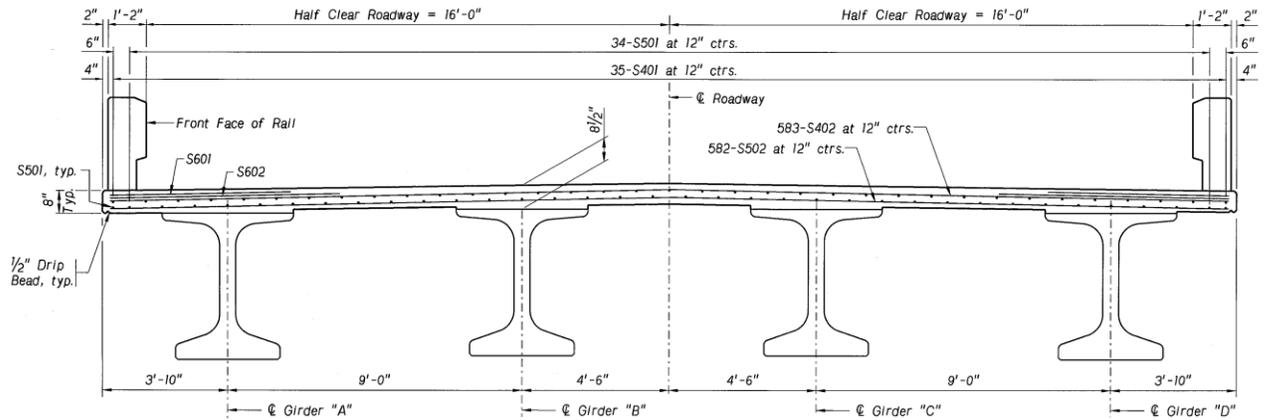


Fig. 1 Cross section of the roadway of Oxford South Bridge, NE

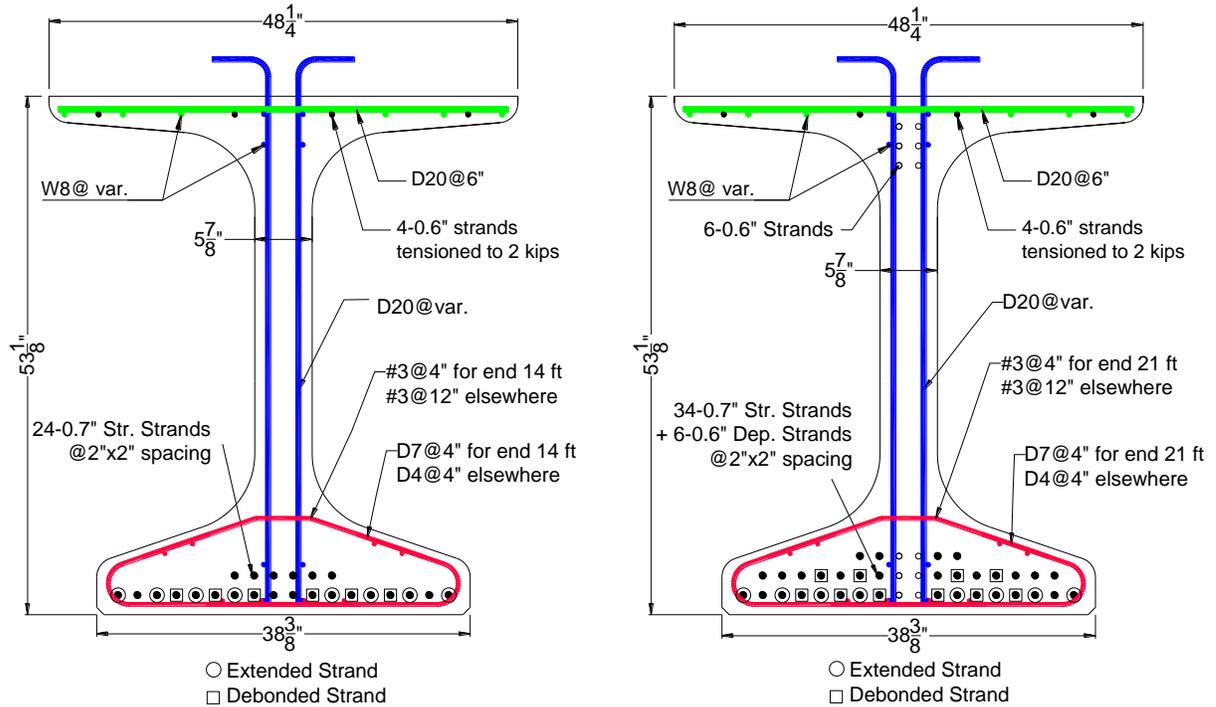


Fig. 2 Dimensions and reinforcing details of NU1350 used for 110 ft spans (left) and 140 ft span (right)

STRAND TESTING

Twenty-six 0.7 in. diameter prestressing strand samples were tested to verify that the currently produced strands conform to ASTM A416-06. Testing was performed according to ASTM A370-05 Annex A7. All tested strand samples were received in ideal condition free of lubricants, rust, and any visible defects. Two groups of strands obtained from separate

production heat or mill order were tested: group 1 (sample number 1 to 14) was tested on August 9, 2012, and group 2 (sample number 15 to 26) was tested on August 17, 2012. Fig. 3 plots test results of the two groups combined. This plot indicates that all strand samples met the minimum stress at 1% strain (243,000 psi) and minimum breaking strength (270,000 psi) requirements. It should be noted that all samples were tensioned until they reach the minimum required breaking strength and then released before rupture to avoid damage to the testing apparatus. Therefore, the actual ultimate load and extension were not determined. For more details on testing setup and procedures, refer to Morcous, et al.⁴.

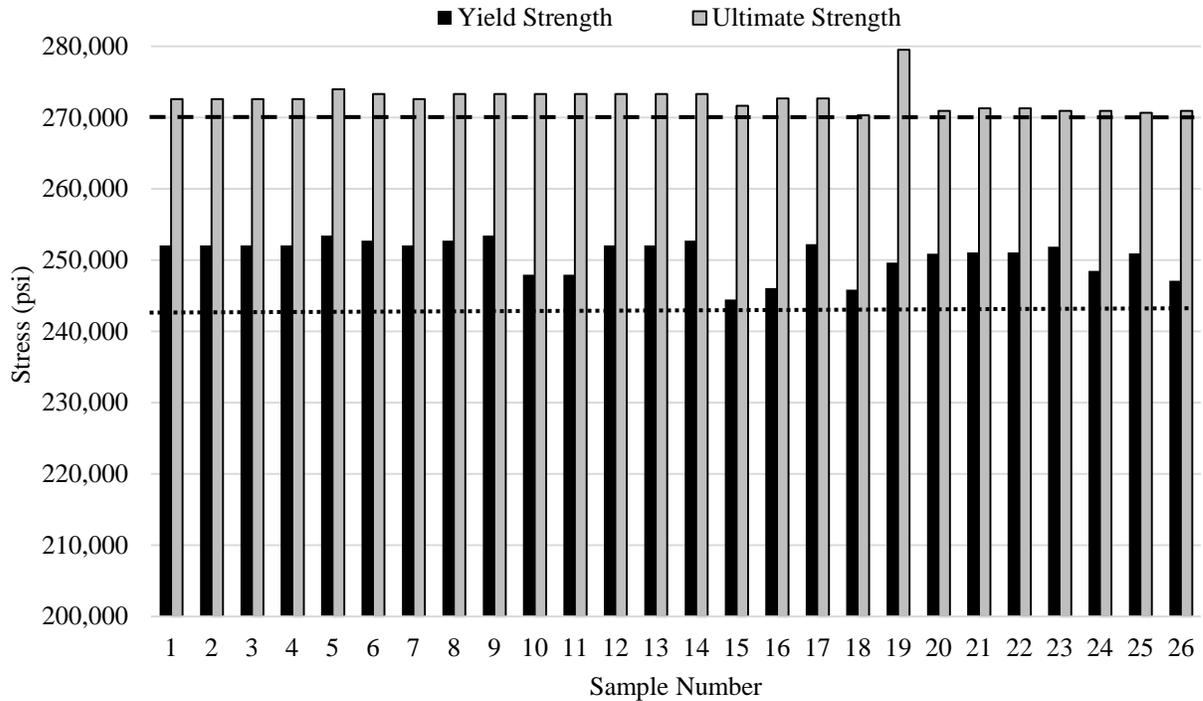


Fig. 3 Strand tension test results

CONCRETE STRENGTH

The specified minimum compressive strengths for the Oxford South Bridge girders were 6000 psi at release and 8,000 psi at 28 days for the 110 ft long girders; and 7,000 psi at release and 9000 psi at 28 days for the 140 ft long girders. Self-consolidating concrete (SCC) was used for all the girders with nominal maximum size of the aggregate of 1/2 in. and water–cementitious material ratio of approximately 0.35 to achieve an average spread of 27 in.

Fig. 4 plots the average concrete compressive strength at release and at 28 days for the 110 ft long girders and 140 ft long girders. Results indicate that the 28-day compressive strength of all girders exceeded 9,000 psi. The release compressive strength of all 110 ft long girders exceeded 6,000 psi and for all 140 ft (43 m) long girders exceeded 7,000 psi by keeping the

girders in the bed longer while using the same mixture. Fig. 5 shows the girder numbering and location in the bridge.

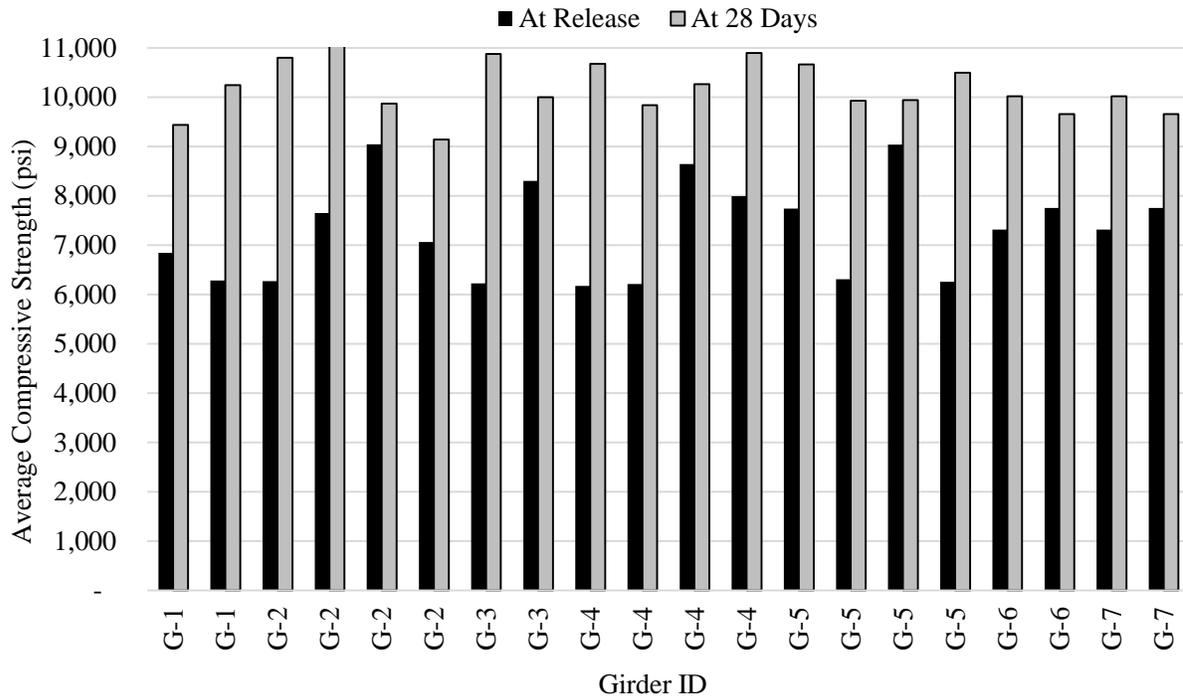


Fig. 4 Concrete compressive strength test results

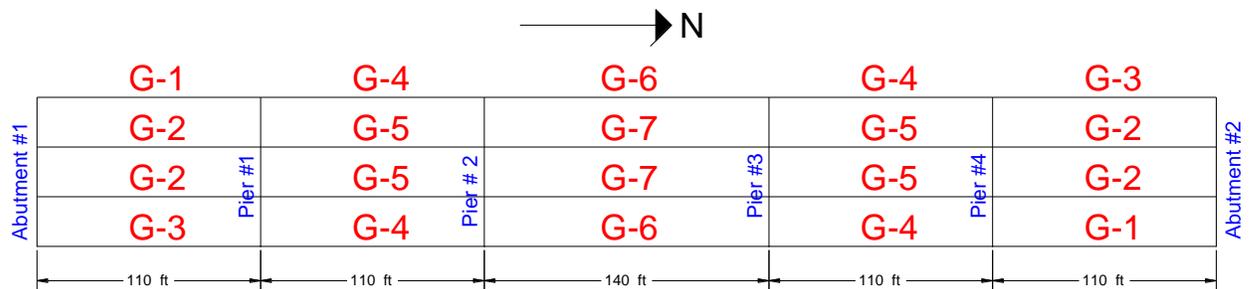


Fig. 5 Girder Numbering and Location in the Bridge

TRANSFER LENGTH

According to the AASHTO LRFD specifications, the transfer length of a fully bonded prestressing strand is estimated as 60 times the nominal strand diameter. Because this provision was developed for prestressing strands of 0.6 in. diameter or less, the transfer length of 0.7 in. diameter strands used in this project was measured to ensure that the previous equation is applicable. Detachable mechanical (DEMEC) gauges were used on three girder ends (two for 110 ft long girders and one for 140 ft long girder). Twenty DEMEC gauges were used on each side at 4 in. spacing to ensure accurate readings and cover the predicted transfer length of 42 in. DEMEC readings were taken at release and at 14 days using a caliper gauge. Transfer length was determined using the 95% average maximum

strain method⁵. Concrete strains increases with distance from the girder end. The point where the strain becomes constant indicates where all of the prestressing forces are transferred to the concrete. The transfer length was determined by measuring the distance from the end of the girder to the point where 95% of the maximum concrete strain is measured. Fig. 6 show the strain profile obtained from DEMEC gauge readings at the south end of the 140 ft long. According to DEMEC measurements, transfer length of 0.7 in. diameter strands at release and 14 days are approximately 30 in. and 37 in. respectively. This is slightly less than the values predicted using AASHTO LRFD specifications (42 in.).

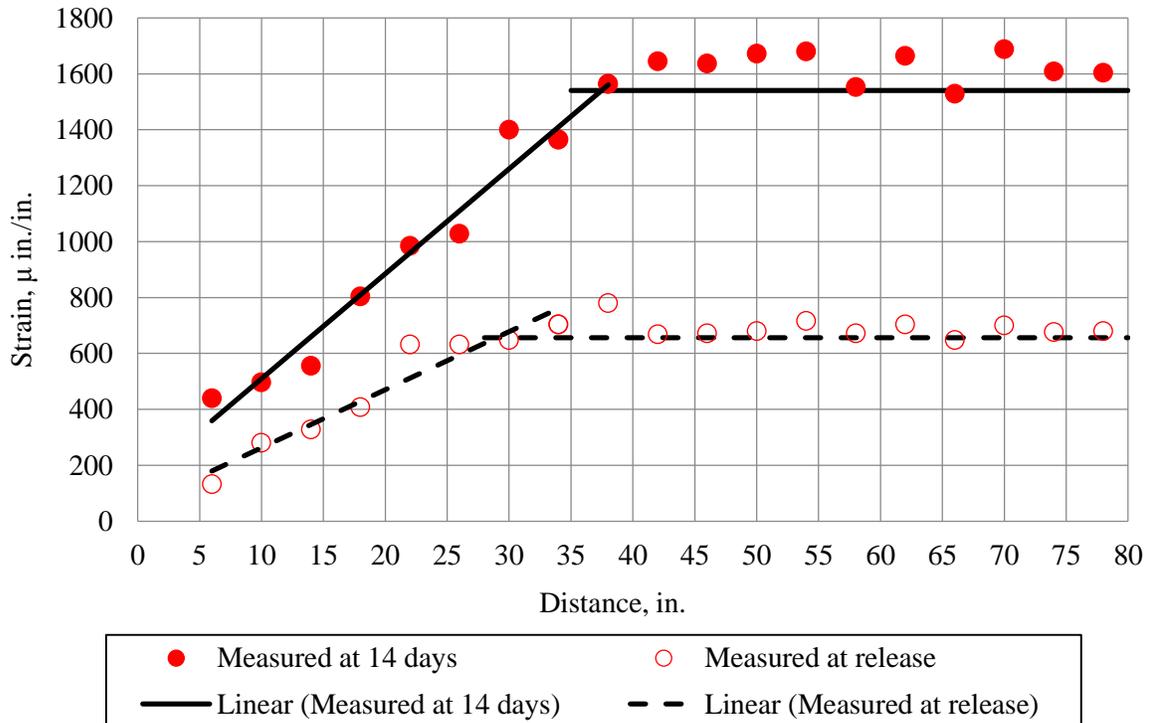


Fig. 6 Measured transfer length using DEMEC gauges

GIRDER CAMBER

According to the Quality Control for Plants and Production of Structural Precast Concrete Products⁶, for members with span-to-depth ratios less than 25, the tolerance for camber variation at release (within 72 hours from prestress transfer) from design camber is $\pm 1/8$ in. per 10 ft of girder length with a maximum of $\pm 1/2$ in. for girders up to 80 ft long and ± 1 in. maximum for girders over 80 ft long. This rule applies only to the 110 ft girders, as their span-to-depth ratio is approximately 25, while the 140 ft girder has span-to-depth ratio of approximately 32.

Fig. 7 plots the cambers measured at release and erection versus age to evaluate camber growth. This plot indicates the consistency in camber growth among girders of the same

length. It also shows higher rate of camber growth in longer girders than in shorter ones. The camber measured at release for 110 ft long girders varied from 1.5 in. to 2.25 in., and from 3.75 in. to 5.25 in. at erection. The camber at release is within the acceptable tolerance (± 1 in.) from the 2.2 in. predicted using the PCI method⁷. The camber at erection is slightly higher than the predicted value of 3.8 in. for some girders. The measured camber at release for 140 ft long girders varied from 2.75 in. to 3.0 in., and from 8.5 in. to 9.1 in. at erection. The camber at release is below the predicted value of 4.3 in., while the camber at erection is higher than the predicted value of 7.5 in. These deviations could be attributed to the high span-to-depth ratio and variations in concrete strength. Variation of measured camber at erection from predicted values was not an issue at deck placement as variable haunch thickness was used to achieve the required deck profile after considering the deflection due to deck weight (1.8 in. for 110 ft span and 4.7 in. for 140 ft span).

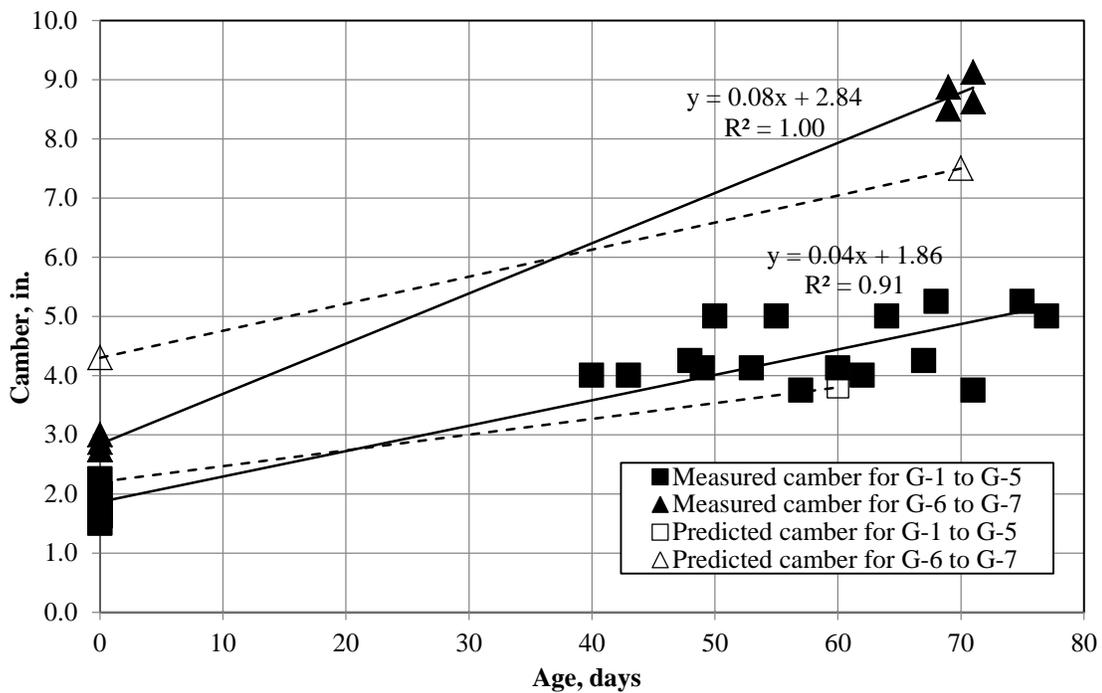


Fig. 7 Camber growth as measured and predicted for 110 ft and 140 ft long girders

END ZONE CRACKING

End zone cracking was evaluated by visual examination immediately after release and few days later. Fig. 8 shows photos of girder ends for 110 ft long girder and 140 ft long girder. These photos indicate that no cracks were observed by the naked eye at the girder ends or between strands due to bursting force of prestressing strands or due to using 2 in. spacing between strands, which proves that current AASHTO LRFD specifications for bursting and confinement reinforcement were adequate for designing these girders with 0.7 in. diameter strands.



Fig. 8 End zones of the girders.

CONCLUSIONS

This paper presented the first application of 0.7 in. diameter strands in prestressed concrete bridge girders at 2 in. \times 2 in. spacing for the Oxford South Bridge in Oxford, Neb shown in Fig. 9. Testing 26 strand samples indicated that they all conformed to ASTM A416. Transfer length measurements in three girder ends indicated that the transfer length of 0.7 in. diameter strands can be conservatively estimated using AASHTO LRFD specifications. Also, measurements of girder camber indicated that camber variability at release was within the specified tolerance. No end zone cracking was observed at girder ends due to the use of 0.7 in. diameter strands at 2 in. \times 2 in. spacing.



Fig. 9 Photo of the completed bridge

ACKNOWLEDGEMENT

The authors thank Nebraska Department of Roads (NDOR) for their financial and technical support of this project. The authors are also very thankful for CoreSlab Structures Inc. and InSteel Industries Inc. for their material donation and technical support.

REFERENCES

1. Morcou, G., K. Hanna, and M. K. Tadros., Use of 0.7 in. Diameter Strands in Pretensioned Bridge Girders, *PCI Journal* 56 (4), 2011, 65–82.
2. Morcou, G., and M. K. Tadros., Impact of 0.7 in. Diameter Strands on NU I-Girders, Nebraska Department of Roads (NDOR), Technical Report P311, 2011, Lincoln, NE.
3. American Association of State Highway and Transportation Officials (AASHTO), *AASHTO LRFD Bridge Design Specifications*. 6th ed., 2012, Washington, DC.
4. Morcou, G., Hatami, A, Maguire, M., Hanna, K., and Tadros, M. K., Mechanical and Bond Properties of 18 mm (0.7”) Diameter Prestressing Strands, *ASCE Journal of Materials in Civil Engineering*, 24(6), 2012, 735-744.
5. Ramirez, J., and B. Russell, Transfer, Development, and Splice Length for Strand/Reinforcement in High-Strength Concrete. NCHRP Report 603, 2008, Washington, DC.
6. Precast/Prestressed Concrete Institute (PCI), *Quality Control for Plants and Production of Structural Precast Concrete Products*. MNL-116. 4th ed., 1999, Chicago, IL.
7. Precast/Prestressed Concrete Institute (PCI), *PCI Design Handbook: Precast and Prestressed Concrete*, MNL-120. 7th ed., 2010, Chicago, IL.