>>

Use of Unstressed Strands for Connections of Precast Concrete Members

"Use of Unstressed Strands for Connections of Precast Concrete Members" by Xiao Liang and Sri Sritharan, which appeared in the May–June 2021 issue of *PCI Journal*, includes both experimental and analytical programs to explore the bond behavior and overall performance of unstressed strands for seismic applications in positive moment connections of precast concrete girders. Background information was provided on the differences in bond behavior between unstressed and prestressed strand, including a discussion of the Hoyer effect. In addition, work by Salmons and McCrate[1] and Noppakunwijai et al.[2] was referenced.

The issue of bond between prestressing steel and concrete has received a lot of research attention in the past 30 years. In many of these studies, the bond properties of strands in concrete were found to vary widely, partly due to differences in concrete properties but also due to variable surface residues left on strands during manufacturing. In our opinion, any experimental test program that studies strand bond should at least characterize the bond properties of the strand according to ASTM A1081.[3] We did not see that this was done for this project. It also would have been appropriate, in our opinion, to fabricate and test the same cylindrical test specimens as ASTM A1081 using the grout mixture and the concrete member mixture. Alternatively, a strand bond qualification test in accordance with Peterman[4] would be appropriate.

The authors are to be congratulated for adding the variable of cyclic loading to the strand bond issue, showing that strand bond degrades under high cyclic interface stresses.

We believe that there are a number of other relevant and important studies that are not mentioned in this paper that further discuss the bond behavior of unstressed and stressed strand in concrete and would be beneficial to readers. These include experimental testing by Moustafa,[5] Moustafa pullout tests (large block pullout tests) by Logan,[6] North American Strand Producers (NASP) strand bond round robin testing conducted by Russell et. al.,[7–10] National Cooperative Highway Research Project (NCHRP) 603 report by Russell and Ramirez,[11] NCHRP 621 report by Osborn et al.,[12] the Kansas State University report by Polydorou et al.,[13] bond testing of stressed strand by Naito et al.,[14] and the due diligence report by Hawkins and Ramirez that summarize the results of these many studies.[15] There is also an ongoing PCI project on experimental testing of prestressing strand lifting loops by Chhetri et al.[16]

Andrew E. N. Osborn
Senior principal, Wiss Janney Elstner Associates Inc.
Boston, Mass.

Rachel Chicchi
Assistant professor of Structural Engineering, Department of Civil & Architectural Engineering & Construction Management, University of Cincinnati
Cincinnati, Ohio

References

1. Salmons, J., and T. McCrate. 1977. "Bond Characteristics of Untensioned Prestressing Strand." *PCI Journal* 22 (1): 52–65.
2. Noppakunwijai, P., N. Jongpitakseel, Z. Ma, S. A. Yehia, and M. K. Tadros. 2002. "Pullout Capacity of Non-Prestressed Bent Strands for Prestressed Concrete Girders." *PCI Journal* 47 (4): 90–103.

3. ASTM A1081. 2015. Standard Test Method for Evaluating Bond of Seven-Wire Steel Prestressing Strand. ASTM A1081/A1081M-15. West Conshohocken, PA: ASTM International.
4. Peterman, R. J. 2009. "A Simple Quality Assurance Test for Strand Bond." *PCI Journal* 54 (2): 143–161.
5. Moustafa, S. E. 1974. *Pullout Strength of Strand and Lifting Loops*. Technical bulletin 74-B5. Tacoma, WA: Concrete Technology Associates.
6. Logan, D. R. 1997. "Acceptance Criteria for Bond Quality of Strand for Pretensioned Prestressed Concrete Applications." *PCI Journal* 42 (2): 52–90.
7. Russell, B. W., and G. A. Paulsgrove. 1999. *NASP Strand Bond Testing Round One Pull-Out Tests and Friction Bond Tests of Untensioned Strand*. Final report 99-03. Norman, OK: University of Oklahoma Fears Structural Engineering Laboratory.
8. Russell, B. W., and G. A. Paulsgrove. 1999. *NASP Strand Bond Testing Round Two—Assessing the Repeatability and Reproducibility of the Moustafa Test, the PTI Bond Test and the NASP Bond Test*. Final report 99-04. Norman, OK: University of Oklahoma Fears Structural Engineering Laboratory.
9. Russell, B. W. 2001. *Final Report—NASP Round III Strand Bond Testing*. Stillwater, OK: Oklahoma State University.
10. Russell, B. W. 2006. *Final Report—NASP Round IV Strand Bond Testing*. Stillwater, OK: Oklahoma State University.
11. Russell, B. W., and J. A. Ramirez. 2008. *Transfer, Development, and Splice Length for Strand/Reinforcement in High-Strength Concrete*. NCHRP report 603. Washington, DC: National Transportation Board. http://www.trb.org/Publications/Blurbs/157097.aspx.
12. Osborn, A. E. N., J. S. Lawler, and J. D. Connolly. 2008. *Acceptance Tests for Surface Characteristics of Steel Strands in Prestressed Concrete*. National Cooperative Highway Research Program report 621. Washington, DC: Transportation Research Board. https://doi.org/10.17226/14206.
13. Polydorou, T., K. A. Riding, and R. J. Peterman. 2015. *Determination of Acceptance Criteria for Prestressing Strand in Pre-tensioned Applications*. Manhattan, KS: Kansas State University Transportation Center.
14. Naito, C., F. Cetisli, and T. Tate. 2015. "A Method for Quality Assurance of Seven-Wire Strand Bond in Portland Cement Concrete." *PCI Journal* 60 (4): 69–84.
15. Hawkins, N. M., and J. A. Ramirez. 2010. *Due Diligence Review of NASP Strand Bond Test Method*. Report created for PCI Technical Activities Council, Chicago, IL.
16. Chhetri, S., R. Chicchi, A. Osborn. 2021. "Experimental Investigation of 0.6 in. Diameter Strand Lifting Loops." *PCI Journal* 66 (2): 71–87.

Authors' response

The writers would like to thank the discussers, Osborn and Chicchi, for their special interest in the original paper. Their comments and wealth of suggested references are greatly appreciated.

The study presented in the original paper was motivated to establish cost-effective and easily implementable positive moment connections between precast concrete bridge girders and bent caps, making the use of precast concrete girders in seismic regions cost competitive to cast-in-place construction. In this effort, unstressed strands extending from the ends of precast concrete girders are used as the connecting reinforcement.[1] The writers agree with the discussers that the bond of strands is influenced by many factors, which has been shown in many studies, including those that the discussers cited. The writers did not perform bond tests in accordance with ASTM A1081[2] because the width of the bent cap mainly determined the anchorage length in our tests. Furthermore, the intent of the tests with straight ends was to determine the maximum force that the strand can develop and measure the corresponding slip as a function of the force. With this information, we were able to determine whether the provided strand embedment length was adequate for the particular connection demand and the required capacity of a supplementary mechanical connection if needed to ensure full development of the unstressed strand.

Using a shorter embedment length for strands extending from precast concrete components such as girders and relying on a combination of bond stress and mechanical anchorage for developing the strand capacity also minimizes transportation and construction challenges. In this regard, the work done by Salmons and McCrate[3] was valuable and was used as a reference. Considering that the objective of the original paper was to compare the responses of strands with different anchorage details and to determine the embedment length requirements for unstressed strands when used as connecting reinforcement between precast concrete members, the use of ASTM A1081 test was not deemed critical. Furthermore, our tests simulated the anchorage of the strands for our specific problem (anchoring the strands into a bent cap), creating a more realistic condition for the concrete with appropriate confinement effects. Finally, as presented in the original paper, we quantified the bond strength based on our test data, which is approximately five times the square root of the concrete compressive strength. This information would allow a designer to appropriately design the connection using unstressed strands and an appropriate supplemental mechanical anchorage. In cases where the strands can be anchored with a straight end, we expect the designer to follow the recommendations of the PCI Strand Bond Task Group[4] or other appropriate guiding documents.

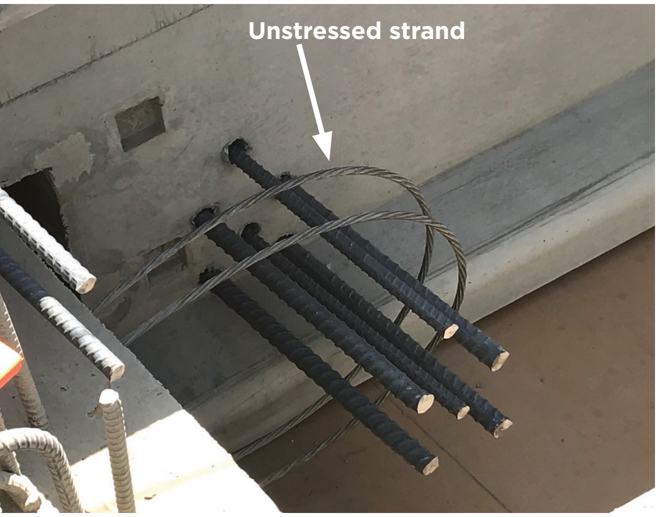

Figure 1. Use of unstressed strands in the positive seismic moment connections for precast concrete girders. Photo courtesy of Dorie Mellon, California Department of Transportation.

Although prestressing has been frequently used to establish connections between precast concrete members (for example, in Sritharan et al.[5]), unstressed strands in connections seldom have been used in practice. With a continuous emphasis on accelerated construction, we believe the use of the unstressed strands in connections, either as a new element or as an extension of pretensioned strands incorporated into precast concrete members, offers multiple advantages, as noted in the original paper. This is what we promoted in our study, which has begun to show deployments in field applications (**Fig. 1**). As suggested by the discussers, a more systematic study would provide many opportunities for the precast concrete industry to use unstressed strands for connecting prefabricated members in a variety of ways.

Xiao Liang
Lecturer, School of Civil Engineering, Tianjin Chengjian University
Tianjin, China

Sri Sritharan
Professor, Department of Civil, Construction and Environmental Engineering, Iowa State University
Ames, Iowa

References

1. Vander Werff, J., R. Peggar, Z. Cheng, and S. Sritharan. 2015. *Seismic Performance of Girder-to-Cap Connections for Accelerated Bridge Construction of Integral Bridges*. Department of Civil, Construction and Environmental Engineering, Iowa State University, Ames, Iowa.
2. ASTM A1081. 2015. Standard Test Method for Evaluating Bond of Seven-Wire Steel Prestressing Strand. ASTM A1081/A1081M-15. West Conshohocken, PA: ASTM International.
3. Salmons, J., and T. McCrate. 1977. "Bond Characteristics of Untensioned Prestressing Strand." *PCI Journal* 22 (1): 52–65.
4. PCI Strand Bond Task Group. 2020. "Recommended Practice to Assess and Control Strand/Concrete Bonding Properties of ASTM A416 Prestressing Strand." *PCI Journal* 65 (6): 33–34.
5. Sritharan, S., M. J. N. Priestley, and F. Seible. 1999. "Enhancing Seismic Performance of Bridge Cap Beam-to-Column Joints Using Prestressing." *PCI Journal* 44 (4): 74–91.

Comments?

The editors welcome discussion of the technical content of *PCI Journal* papers. Comments must be confined to the scope of the paper to which they respond and should make a reasonable and substantial contribution to the discussion of the topic. Discussion not meeting this requirement will be returned or referred to the authors for private reply.

Discussion should include the writer's name, title, company, city, and email address or phone number and may be sent to the respective authors for closure. All discussion becomes the property of *PCI Journal* and may be edited for space and style. Discussion is generally limited to 1800 words with each table or illustration counting as 300 words. Follow the style of the original paper, and use references wherever possible without repeating available information.

The opinions expressed are those of the writers and do not necessarily reflect those of PCI or its committees or councils.

All discussion of papers in this issue must be received by August 1, 2022. Please address reader discussion to *PCI Journal* at journal@pci.org.