By Kent A. Harries, Ph.D., FACI, P.E.
Contributing Author

# Patient J

## Study takes close look at how J-bars hold up in Pa.

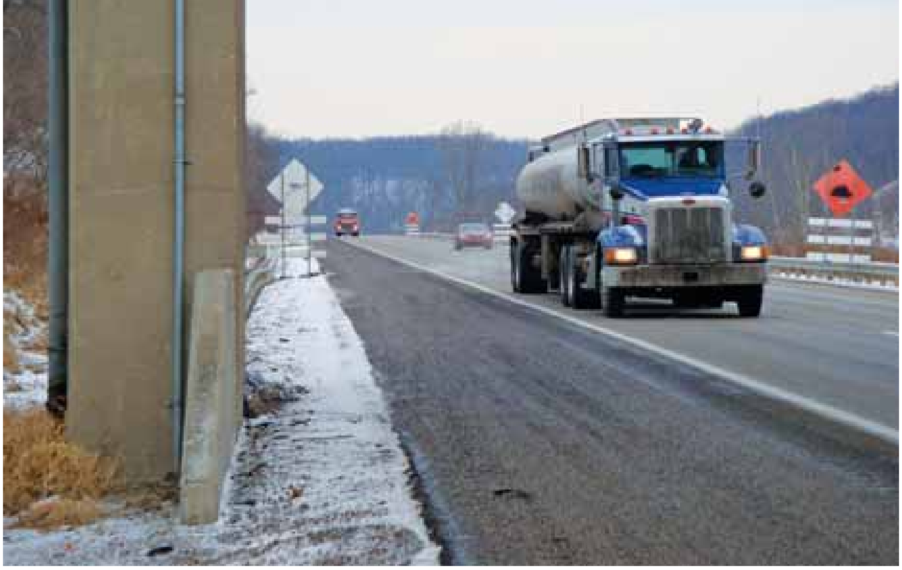
Deterioration and necking of reinforcing bars has been reportedly observed at the interface of the footing and stem wall during the demolition of older bridge piers, abutments and retaining walls.

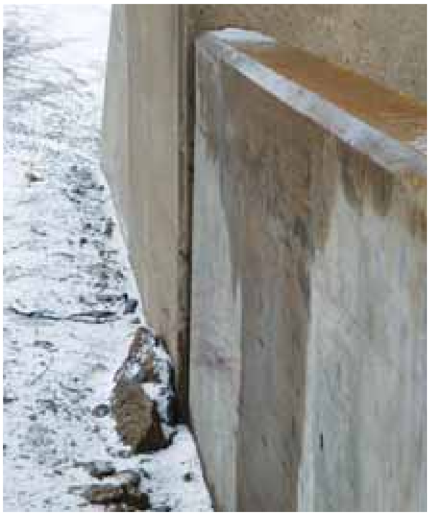
Any decrease in the area of steel at these interfaces may result in reduction of foundation capacity, and significant decrease in steel area may result in foundation instability and hamper efforts to rehabilitate or preserve existing foundations. A study was carried out to determine the extent and nature of deterioration and/or necking of interface reinforcing bars in existing bridge structures in Pennsylvania. The objective was to identify at-risk structures and appropriate methods of mitigating such deterioration.

Reinforcing steel crossing the footing-pier or footing-stem wall interface may take the form of "J-bars," typically small-diameter reinforcing bars having a 180° anchorage in the footing; dowel bars, usually large-diameter bars having a straight anchorage into the footing; or "L-bars" having a 90° anchorage. Together, these details are often referred to as "starter bars." The nature of the anchorage is not immediately relevant to the deterioration at the footing interface. With the exception of large-diameter dowel bars, embedment into the footing is typically more than adequate to develop the bar in tension at the footing interface. Again, with the exception of large-diameter dowel bars, straight bar embedment length above the footing interface also is typically adequate to develop the bar at the interface. Dowel bars, while not developed for tension, will usually have adequate embedment to be developed for compression.

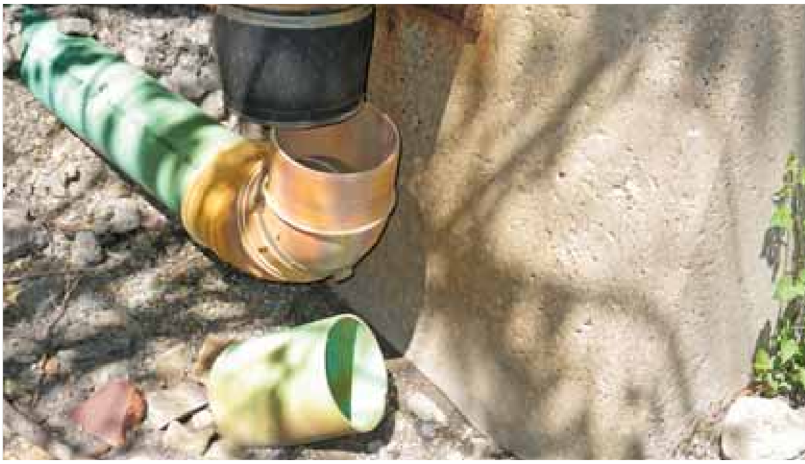
### Physical exam

Five decommissioned bridges located throughout western Pennsylvania were identified for study representing a reasonable snapshot of potentially affected bridges. The bridges ranged in age from 35 to 53 years at their time of demolition. Samples were taken from roadside piers and abutments, abutments immediately beneath (leaking) expansion joints and piers located on a creek flood plain. Samples of the interface reinforcing bars were





For both new construction and structural rehabilitation, requiring epoxy-coated or other corrosion-resistant reinforcement across the footing interface, coupled with waterproofing the interface, represents the current best practice for mitigating potential deterioration of J-bars or dowel bars near pier/stem wall-footing interfaces.



taken to assess the extent of corrosion and in order to determine the grade of steel used. Dry-drilled concrete core samples also were taken to permit the chloride profile near the interface reinforcing steel to be determined.

All samples were located at an interface of Class B (footing) and Class A (pier or stem wall) concrete. In all cases, this interface appeared to be well prepared, and when observable, sound bond between concrete lifts was evident. Samples included abutment walls having No. 4 or No. 5 J-bars and piers having No. 11 dowel bars. The samples included A615, Grades 40 and 60 bars, A408, Grades 40 and 50 bars, A431 Grade 75 bars and A432 Grade 60 bars. Beyond very minor surface corrosion, no evidence of corrosion at the pier-footing or stem wall-footing interfaces was observed in any sample.

Companion tests of acid-soluble chloride content (AASHTO T260) were conducted on samples taken from the footing side of the interface. There are a number of compelling reasons for this: (a) the footing is generally the lower-quality concrete (Class B, rather than Class A); (b) gravity will tend to result in the lower face of the horizontal interface having a greater chloride concentration; and (c) due to demolition practice, it is difficult to obtain samples above the interface. Powdered samples were recovered from each core at various depths—measured from the top of the footing—by drilling transversely through the core at the desired depth. In general, there was approximately a 2- to 2.5-in. cover to the reinforcing bars in all cases.

The acid-soluble chloride values indicated a relatively low susceptibility to chloride-induced corrosion. At the footing surface, values were consistent for all bridges considered, averaging about 0.26%. No measured chloride content values exceeded 0.37%. The few measurements taken at deeper concrete depths (4 in.) were likely indicative of chloride content of the original concrete mixes and found to be in the vicinity of 0.20-0.30%. This would be a typical value for concrete of this vintage. In cases where chloride content did not vary with depth, it is unlikely that there were chlorides being introduced from the environment. For those samples with a clear chloride gradient, it is likely that some chloride had been introduced from the environment, although the values were low in all cases. All recorded values are believed to fall below any reasonable value for the chloride corrosion threshold for a footing interface located below grade where oxygen diffusion will be limited.

These observations should be understood to represent a limited sample, although every effort was made to make this as representative of conditions in western Pennsylvania as possible. The absence of interface bar corrosion found in this investigation may be an indication that such corrosion is not endemic to the Pennsylvania bridge inventory. Nonetheless, the absence of evidence is not evidence of absence. Further observation of future demolition projects with some formal reporting (such as photographs) is warranted to expand the qualitative sample size.

Somewhat contrary observations were made in a related companion study, which sampled six bridges in central and eastern Pennsylvania. Both piers and abutment stem walls were sampled. In this study, three bridges exhibited "insignificant" deterioration. One bridge exhibited "moderate" deterioration, with the maximum bar section loss estimated to be 25%. The other two bridges exhibited "severe" deterioration, with a maximum bar section loss estimated to be 65%.

The moderate deterioration was observed in a stub abutment backwall, while the severe deterioration was observed in one stub abutment stem wall and one bent column. A significant observation in at least one case was that the top of the footing concrete had been finished in the interface, resulting in a relatively smooth joint, which would likely ease the ingress of (chloride-laden) water and oxygen along this joint. While poor construction practice, this appeared to be an isolated case. The results of the study indicate the possible variation of the phenomena considered and the need for further observation.

## Certain conditions

Site visits to each structure prior to demolition identified a number of conditions that have the potential to affect corrosion at footing-pier or footing-stem wall interfaces. Piers located in intermittent streams or on flood plains are subject to alternating wet-dry conditions, which may accelerate the corrosion process once it begins. Generally, however, these locations will not be subject to high chloride loading unless the structure is in a coastal environment. Piers, in particular, may be located sufficiently close to the roadway to receive regular exposure to deicing salt, either directly or indirectly from salt spray and deposition during plowing operations. Poor drainage in the vicinity of pier bases and/or broken or inoperable deck drainage also may channel chloride-laden water toward the pier base interface. Poor drainage also may wash out some of the soil cover. Similarly, damaged or deteriorated deck joints may lead to a concentration of chloride-laden water at an abutment wall.

During the demolition process, little reinforcing bar corrosion was noted at any bridge. Concrete, both above and below the footing interface, was sound in all observed cases. Steel, when exposed during demolition, was uncorroded and "black." Most bars retained a thin layer of adhered cement paste, an indication of continued passivity of the bar.

> **The absence of interface bar corrosion may be** an indication that such corrosion is not endemic to the Pennsylvania bridge inventory. Nonetheless, the absence of evidence is not evidence of absence.

## Possibilities of infection

While no interface bar deterioration was observed in this study, a number of factors that are believed to contribute to the potential for such corrosion were identified. While these may be used to screen existing structures for the potential for this type of deterioration, no factor has been found to correlate with interface bar deterioration:

1. The use of black steel (all cases in this study);
2. Lack of waterproofing membrane (all cases in this study);
3. Improperly prepared construction joints resulting in poor bond or a "smoother" interface crack surface. Anecdotal evidence tells of one such construction joint, which was trowel-finished; clearly such practice should be avoided (not observed in this study);
4. Construction joints having little or no soil cover or that are located in splash zones or other environments resulting in wet-dry conditions (one example in this study); and
5. Exposure to chlorides. This may result from proximity to a deck joint, deck drain or scupper or from proximity to a carriageway (splash zone). Topography also may lead to the potential for chloride-contaminated water ingress (all cases in this study).

Structures considered in this study exhibited all but condition 3 yet exhibited no J-bar deterioration. Thus these conditions alone are not correlated to deterioration; they are simply possible indicators that may be used to guide bridge inspectors during field views. All but condition 3 are knowable, and one would anticipate that compounding multiple conditions would result in a greater likelihood of deterioration; thus all such conditions should be noted in inspection reports.

Mitigation of the potential for interface bar corrosion amounts to addressing the five details described above. Conditions 1, 2 and 3 should no longer be an issue for new construction in Pennsylvania. Condition 1 was addressed in about 1995 by requiring epoxy-coated J-bars for all abutment and wingwall stems and pier/bent columns. Condition 2 was corrected more recently by requiring waterproofing details to be used at stem-to-footing construction joints for all abutments and retaining walls (2008), approach slab joints (2011) and pier/bent columns (2011). These requirements are believed to represent best practice for new construction. Condition 3 must be considered a construction error and is therefore rare. Construction joints should be roughened and free of latency when the upper concrete is placed. Soil cover over a construction joint is certainly desirable but not always possible. The provision for waterproofing should have a similar effect. It must be kept in mind that the presence of soil has the effect of limiting the ingress of oxygen rather than moisture and therefore works on a different principle than waterproofing. Finally, good maintenance of bridge-drainage systems should help to mitigate condition 5.

## Possible prescriptions

Because of the structure geometry, there are few practical ways to repair deteriorated J-bar regions. Section enlargement—essentially encasing a pier having deteriorated interface bars in a new reinforced concrete pier—is an option in cases where the pier must be maintained. Due to geometry, section enlargement is not likely practical for stem walls.

For local deterioration of a few bars, the installation of exterior straps, duplicating the deteriorated bars and anchoring into the core concrete can be used to control interface gap opening and transmit forces between footing and pier/stem wall. Such straps could be installed on the pier face or in a "near-surface-mounted" application, embedding the strap in the cover concrete (which should not be anchored to in any event). Transmitting forces across the interface without excessive distortion may be a challenge for large bars, requiring a stiffened angle at this location.

A final option when the J-bar region is accessible requires removal of cover concrete, drilling a new starter bar into the footing, reforming the cover concrete and providing external confinement to the region. This approach is likely only practical for piers, since confinement will likely be provided by an exterior jacket (fiber-reinforced polymer materials provide a reasonable option in this regard). For stem walls, drilled and epoxied hairpin confining bars may be an option, although these must be developed through the small thickness of the wall.

In any case, the cause and extant damage from existing corrosion should be mitigated as part of any repair. To the author's knowledge, there are no known applications of J-bar region repair.

## Not evidence of absence

For both new construction and structural rehabilitation, requiring epoxy-coated or other corrosion-resistant reinforcement across the footing interface, coupled with waterproofing the interface, represents the current best practice for mitigating potential deterioration of J-bars or dowel bars near pier/stem wall-footing interfaces.

For existing construction, there is no "one-size-fits-all" approach, and each structure must be addressed on a case-by-case basis. Summarized here, there is some degree of guidance for identifying, mitigating and repairing potential deterioration scenarios. Significantly, this report also provides guidance with respect to modeling deteriorated interface sections.

The absence of J-bar or dowel-bar corrosion found in this investigation may be an indication that such corrosion is not endemic to the Pennsylvania bridge inventory. Nonetheless, the absence of evidence is not evidence of absence. Further observation of future demolition projects with some formal reporting (such as photographs) is warranted to expand the qualitative sample size. R&B

---

Harries is an associate professor of structural engineering and mechanics, Department of Civil and Environmental Engineering, at the University of Pittsburgh.

**For more information about this topic, check out the Bridge Channel at www.roadsbridges.com.**