New Light on an Old Practice

by Hugh Ronald, RS&H

Simple-span bridges are often combined with pile-bent construction. Together, they provide one of the most cost-effective solutions for the design of short- or medium-span structures. But often overlooked, or not considered, is the longitudinal stiffness afforded to pile bents when the superstructure is continuous over multiple piers or pile bents and a double row of bearings over each pier/bent is used. Though each span is typically designed for simple-span behavior, the bridge deck may be cast continuously across multiple bents to avoid frequent expansion joints[1] or because continuous-span behavior is desired for live loads. A continuous deck over a double row of bearings provides a quantifiable stiffness. And the mechanism by which the pile-bent stiffness is acquired is fairly straightforward.

Consider the action of a 100-kip braking force on the deck of a four-span unit. If the substructure consists of five pile bents, all about the same height and embedded in the same strata, you would expect all bents to attract the same longitudinal load, or about 20 kips per bent. But that does not occur if each interior bent is provided with a double row of bearings and a continuous deck above. Instead of articulating as free cantilevers with increasing lateral displacement, the pile-bent caps at the interior bents will remain essentially level—that is, not rotating—due to the resisting moment developed from the couple generated between the two rows of bearings. The vertical load developed on the trailing row of bearings will be greater than the vertical load on the leading row of bearings.

This stiffening results from reverse curvature of the piles in the interior pile bents with two rows of bearings. It yields significantly improved strength, reduced displacement, and redistribution of the braking force to the stiffened interior pile bents. Quantitatively, reverse curvature of a pile leads to an effective halving of its *KL/r* ratio and can mean the difference between a stable or unstable foundation, or permit use of slender plumb piles without battering.

The effect of the stiffening is illustrated by the two identical bridges with four equal spans that are shown in the figure below; the top bridge has a single row of bearings on each bent cap (case 1), while the bottom bridge has a double row of bearings on each bent cap (case 2). Longitudianl displacements and bent reactions for the two bridges when subjected to the same 100 kip longitudinal braking force are also shown. These results were obtained using software that employs an iterative *p-y* analysis of the soil-structure interaction (including nonlinear structural effects). The behavior demonstrated by the software is well documented.[1]

Significance

So what does this mean? It means one can often eliminate battered piles. Battering of piles will seldom achieve the same result as stiffening of the pile bent with a double row of bearings. But the torsion generated by restraint of rotation must be accommodated by proper detailing for pile-to-cap fixity. Analysis is necessary to quantify the magnitude of the torsion that must be resisted between cap and pile, and uplift at bearings must not be permitted.

Reference

1. Podolny, W., and J. M. Muller. 1982. *Construction and Design of Prestressed Concrete Segmental Bridges*. New York, NY: John Wiley & Sons.

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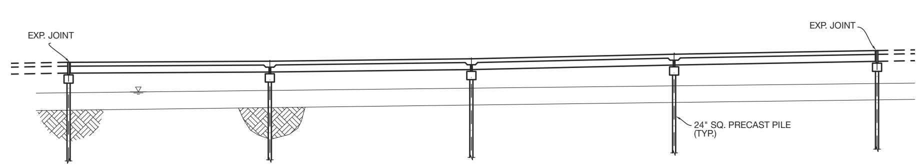
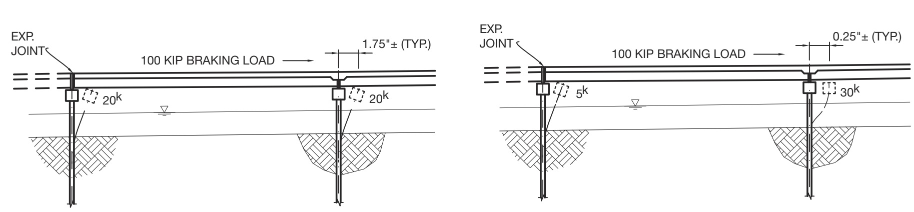


Example of a four-span continuous bridge.



Case 1
A single row of bearings on the centerline of each bent (or a double row of bearings without a continuous deck)

Case 2
A double row of bearings over the interior pile bents with a continuous deck

Comparison of stiffening behaviors of pile bents using single-row bearing versus double-row bearing. Figure: RS&H.