PCI Advisory on I-Girder Stability during Handling and Construction

by Chris D. Hill, John S. Dick and Maher K. Tadros

This advisory has been prepared to inform owners, designers, fabricators, and girder erectors about issues affecting long-term sweep of pretensioned concrete girders during manufacturing, shipping, and erection. Jobsite incidents have been reported involving excessive deformations and, in extreme cases, failure. The use of increasingly long, slender girders made possible by stronger concrete and larger prestressing strands may render the issues discussed below more significant in modern design and construction of I-girder bridges.

This alert is not intended to alarm or discourage bridge designers from using long, slender I-girders. They have proven to be significantly less expensive than alternative steel plate girders, which are even more slender. When concrete I-girders are constructed with due care and in accordance with published guidelines, there should be no concern about stability problems. Numerous examples exist of good practices. A bridge in Calgary, Alberta, Canada, utilized 65-m (213-ft)-long, 2.8-m (9-ft 3-in.)-deep girders. In many states including Nebraska, Oregon, and Washington, long-slender girders are increasingly being used.

For the purposes of this discussion, two fundamental terms must be understood.

Initial Sweep (IS)—lateral midspan deviation from a straight line measured at or close to the time of strand release and removal from the form.

Long-Term Sweep (LTS)—lateral midspan deviation from a straight line occurring after IS and until the time the deck is cast on the girders.

Effects of Sweep

Sweep should be considered for all precast concrete products, keeping in mind that the effects are magnified as girder length and slenderness increase.

The core issue is the performance of the system consisting of girders seated on bearings in any given span, before the deck is placed and cured. The interaction between girders and bearings must be considered for all projects.

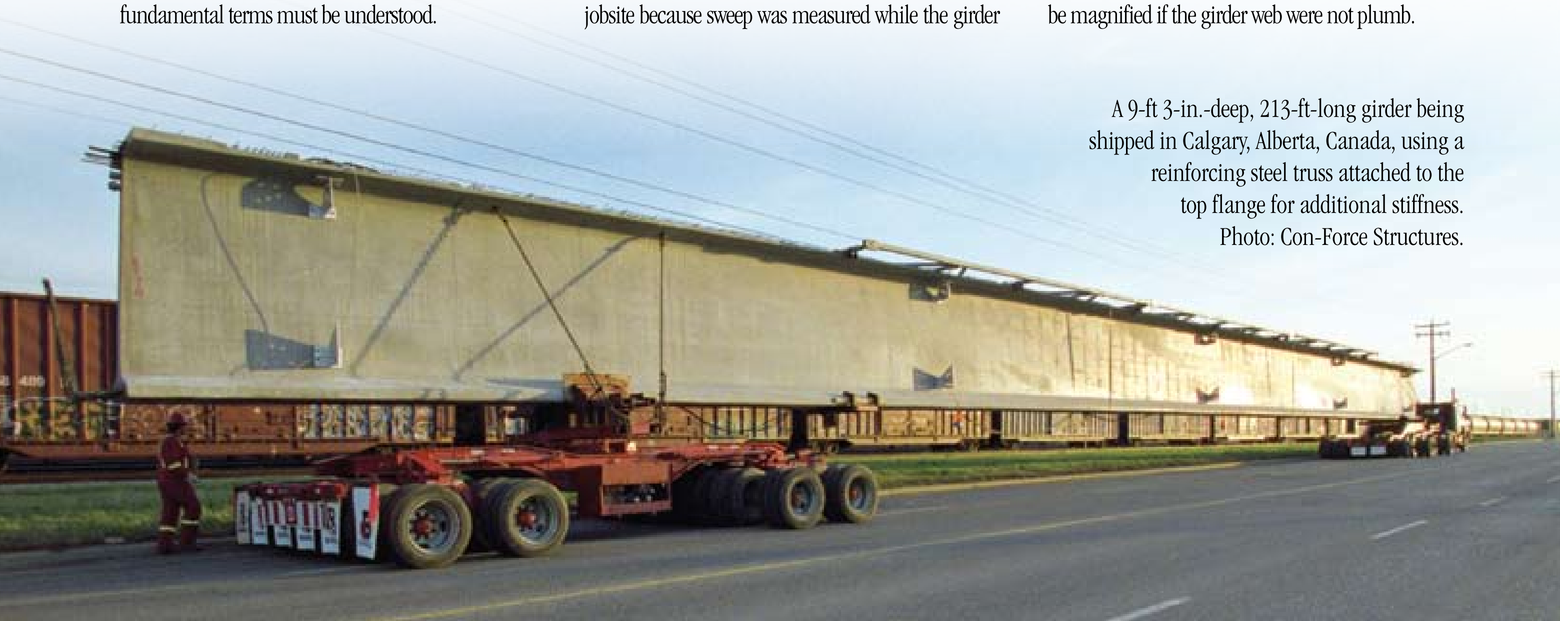
Recent Events

I-girders are much weaker and more flexible about their vertical axis than about their horizontal axis. In some instances, the ramifications of IS and LTS have been experienced with a general lack of understanding of this behavior. There are examples where girders have been rejected on arrival at the jobsite because sweep was measured while the girder was on a truck sitting on unlevel ground. In other cases, girders have been rejected and removed from the bridge. In other instances, remedial action at the jobsite has been permitted to straighten girders. In rare situations, girders have become unstable and fallen from their supports after being erected. This is obviously a potential danger to people and property.

Bearing Design Concerns

Some bearing types such as cotton duck pads and relatively stiff steel-reinforced elastomeric pads (SREPs) have demonstrated superior performance. They have a minimal first cost impact on the overall project and require practically no maintenance. However, current design specifications for SREPs can produce a wide range of solutions, some of which can lead designers to select relatively soft and thick bearings that could be also be considerably narrower than the width of the girder's bottom flange. Any IS or LTS that is present in a girder will likely be amplified when seated on such bearings.

When a girder is placed on a narrow bearing and not exactly centered, slight eccentricity would create significant lateral stress about the girder's weak axis, and significant additional LTS. This situation would be magnified if the girder web were not plumb.



A 9-ft 3-in.-deep, 213-ft-long girder being shipped in Calgary, Alberta, Canada, using a reinforcing steel truss attached to the top flange for additional stiffness. Photo: Con-Force Structures.

An NU2000 (6-ft 7-in.-deep), 183-ft-long girder used for the construction of the Riverview Road Bridge over I-80 in Omaha, Neb. The bearing pads are 36 in. wide, 8 in. long and $1\frac{5}{8}$ in. thick. The wide, thin, pads provide stable support for these long girders. This bridge has steel mid-span diaphragms but no diaphragms on the piers. Photo: Coreslab Structures (OMAHA) Inc.

Initial Sweep versus Long-Term Sweep

IS is a function of production means and methods. IS of precast, prestressed concrete girders is generally limited to a tolerance on straightness of $\frac{1}{8}$ in. per 10 ft of length. Measurements of IS must be made just after form stripping and strand release in a "plant controlled" environment with the girder sitting plumb, on rigid dunnage, and lateral rotation at support locations is restrained. It is a quality-control measurement that can be indicative of the prestressing force eccentric to the vertical axis. Reliable measurements can only be made before the beam is exposed to direct sunlight. A "straight" girder subjected to uneven sunlight exposure will deform laterally in the direction of the warm side. Prior to shipment, LTS measurements should be made to quantify elastic and time-dependent effects of storage conditions on sweep in relation to tolerances.

Gravitational load effects and relevant details such as "roll-axis," "shear-center," and girder symmetry result in changes in the behavior of the girder as it is handled. Simply stated, from the time of loading the girder on the truck until the girders are integrally joined by bracing and/or by a rigid concrete slab, the girders are flexible elements that will deform in various ways in response to the combination of forces and restraints to which they are subjected. Such forces are principally the heat of the sun, gravity, and wind. The restraints are principally the girder supports at the different phases of construction, including dunnage rigidity, eccentricity of lifting inserts, and bearing pad rigidity. Additional LTS may develop as a result of these effects.

It is not possible to measure IS at a jobsite. It may only be measured at the time of strand release and stripping from the forms in the plant. A measurement of LTS under jobsite conditions may include a combination of the original IS due to production, and the additional cumulative effects of storage, shipping, and erection. LTS is beyond the control of the precast concrete manufacturer.

An important condition exists when the girder is being handled by a crane using the girder's lifting devices. If the lifting devices are slightly eccentric relative to the vertical centerline of the girder, an otherwise straight girder will deform laterally. As the laterally deformed girder is set on "soft/narrow" bearings, the IS/LTS will remain or be amplified by unequal deformations in the bearing. Conditions may be made considerably worse if the girder is inadvertently seated off-center of the bearing. A girder seated on a wide, rotationally rigid support, such as cotton duck pads or hardwood blocking, will tend to self straighten. In the absence of a rotationally rigid support there must be some other means available to "force" the girder to a plumb, straight configuration.

Consequences of Initial Sweep and Long-Term Sweep

Excessive IS can become a source of subsequent LTS. The ramifications of LTS are of broader concern since the forces producing the LTS are seldom self-correcting once the girders are set in the bridge. Methods must be provided to balance external forces and prevent lateral movement and transverse rotation of the girder ends. Without such methods, LTS can lead to girders rolling off their supports. Should LTS be present, the cause and significance must be immediately investigated and remedied if needed. Otherwise, the risk exists that it will be further magnified by creep effects, creating the potential for failure.

An informative article on lateral stability by Robert F. Mast was published in the *PCI JOURNAL*, Vol. 34, No. 1, January-February 1989, pp. 34-53.

The simplest treatment of girder erection to avoid excessive LTS, irrespective of bearing type, is to:

1. Confirm that the girder is plumb at the bearings, and
2. Lock the girder ends in a fixed condition preventing lateral and rotational movements through the use of rigid, unyielding bracing before releasing the girder from taunt crane lines.

After the deck is constructed, or the girders are otherwise integrated in a manner that prevents the girders from rolling off their supports, temporary bracing may be removed.

This photo shows long-term sweep. The LTS was subsequently removed by straightening, plumbing beam ends, and reattaching cross bracing to the straightened girders.

Example of a narrow, tall bearing pad that must be given attention by all project stakeholders and avoided by designers.

Precautions Suggested by PCI

Personnel involved in various design stages should not hesitate to refer questions regarding the suitability of specified details affecting LTS, such as handling and bearing details, to their local girder producer. All concerned should be involved in this process, including owners, designers, design checkers, and personnel involved in the drafting of contract plans or shop drawings. Ultimately, contractors must be aware of bearing details. They must formulate careful girder erection procedures that minimize LTS. Bearing components should be stiff in the transverse rotational direction. Girders must be centered on the bearings. The girder webs must be in a plumb position at the time they are fully seated on their supports. Full rotational restraint must be provided at girder supports. The first girder to be erected in a span should be braced to the substructure. Subsequent girders can be braced against previously erected girders.

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EDITOR'S NOTE

This article was reviewed and approved by the Committee on Bridges, the Transportation Activities Committee, and the Technical Activities Committee of the Precast/Prestressed Concrete Institute.

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