Bearing Zone Tearing and Spalling in Precast, Prestressed Concrete Girders

by Hugh Ronald, Reynolds, Smith and Hills

If there is one thing you can count on: it's that engineers will push the envelope to achieve longer spans with fewer members. What used to be an industry dominated by standard American Association of State Highway and Transportation Officials (AASHTO) girder shapes, is now an industry that has a range of new bulb tees designed to more effectively utilize higher concrete strengths and larger-diameter strands. From Florida to Washington state, new standard wide flange I-girders have been developed and are growing in use. These girders may be as deep as 10 ft and can use not only more strand, but larger (0.6-in.-diameter) strand, than was typically used in the standard AASHTO shapes.

Surface Treatment	Coefficient of Friction, μ
Concrete on Steel (Unlubricated)	0.51
Oil Lubricant	0.46
Teflon Pad	0.27
Wax Lubricant	0.23
Steel Plate (on Steel Soffit)	0.23
Steel Plate with Oil Lubricant	0.21

Note: Adapted from Kelly, Patrick and Lawrence F. Kahn. 2007. "Bearing Zone Cracking of Precast Prestressed Concrete Bridge Girders," Final Report Research Project No. 05-14, Office of Materials and Research, Georgia Department of Transportation, Atlanta.

Use of these new shapes is leading to new challenges in the casting process and may require new details to produce precast concrete girders that are both strong and durable, particularly given the need to increase the service life of bridges to 75 or 100 years.

One of the challenges to girder fabrication has been the advent of tearing (cracking) and spalling of the concrete in the girder bearing zones, a phenomenon that occurs during prestress transfer. Girders that experience tearing are generally longer, heavier, and/or more highly prestressed than their older counter parts.

Bearing Zone Tearing and Spalling

The primary causes of tearing and spalling are girder shortening and camber that occur as the prestressing force is transferred to the concrete during detensioning. As a highly prestressed girder cambers, the bearing reactions concentrate at the ends of the girder, producing a knife-edge loading condition. At the same time, the girder contracts and slides due to elastic shortening. If the girder is long, the bearing reactions will be proportionately high, and the friction that develops between the girder and casting bed soffit will produce tension along the longitudinal axis of the girder.

The magnitude of this tension is directly proportional to the friction force that develops at the ends of the girder. If not adequately addressed, this force may crack and possibly spall the concrete at the ends of the girder. Unfortunately, the strands in the bearing zone are not fully developed so they cannot mitigate the problem.

Remedial Countermeasures

To address the problem, a number of countermeasures have been employed with varying levels of success. The first countermeasure employed has generally been to lubricate the soffit pan using oil or wax at the ends of the girder (over a distance roughly equal to the strand transfer length), or to place polytetrafluoroethylene (PTFE) or plywood sheets, compression tape, or steel sheets under the bearing zone. The intent is to lower the coefficient of friction between the girder and soffit, thus reducing the magnitude of the tension associated with girder camber and shortening. The table shows that the friction coefficient is reduced from as high as 0.51 on an unlubricated soffit to 0.23 for a wax lubricant. Still, when soffits are lubricated, cracking and spalling are generally not eliminated, but are only reduced in frequency and magnitude.

The second approach has been to embed and anchor steel plates or angles in the bearing zone at the ends of the girder where the knife-edge loading occurs. Use of embedded angles anchored to the girder with headed studs decreases the frequency and magnitude of the cracking and spalling more than use of lubricants alone, but test results show that cracking may still occur. Embedded plates, adequately sized to extend from the end of girder across the bearing zone, have been used successfully to virtually eliminate bearing zone tearing. This detail has been adopted by several owner agencies.

The Florida Department of Transportation employs galvanized bearing plates in all of their new Florida I-beams, one of the new generation of wide flange girders designed for long-span, pretensioned concrete girder construction. Galvanized plates are less susceptible to corrosion and will provide the durability needed for a long service life.

A cracked and spalled girder in the location of the bearing zone for the case of an untreated soffit. All Photos: Lawrence Kahn.

A cracked and spalled girder in the location of the bearing zone. In this case, a Teflon pad was placed between the girder and the soffit.

A cracked and spalled girder in the location of the bearing zone where wax was applied to the soffit.

Steel angle positioned to be embedded in girder end.

Are Bearing Plates the Bottom Line?

There is good reason to believe that not every girder needs a bearing plate to protect it from tearing and spalling. Recall that the problem was not prevalent when AASHTO girders were the predominant shapes in use, but developed with the advent of deep bulb tees and the use of 0.6-in.-diameter strand. There appear to be several variables that contribute to the problem. These include

- the initial prestress force applied to the girder, considering the effect of debonded strands,
- the eccentricity of the prestress force, and
- the weight of the girders (or more precisely the bearing reaction and stress due to friction between soffit and girder in the bearing zone).

The advent of spalling and tearing are directly related to these variables. Alternatively, tearing is resisted by strand development and the tensile strength of the concrete in the bearing zone, so there appears to be an inverse relationship between these variables and incipient tearing and spalling.

Tearing and spalling may also be affected by the method of strand detensioning. Two methods are used to transfer the prestressing force to a girder: flame detensioning and gang detensioning. Flame detensioning, which is used more often, transfers the prestressing force more abruptly, possibly introducing a shock load in the bearing area that may aggravate the tearing mechanism.

Gang detensioning has long been used by a number of precasters, and continues to be used to this day. When gang detensioning is used, all strands are detensioned slowly and evenly by retracting hydraulic jacks. Several fabricators who employ gang detensioning indicate that through the use of lubricants, compression tape, or plywood slip planes, there has been no need for embedded plates in their girders.

At the very least, there is probably a threshold for length, weight, or prestressing force below which girders no longer need to incorporate bearing plates to avoid cracking or spalling. There may also be a threshold below which tearing cracks will not penetrate the bottom row of prestressing strands, allowing repairs to be made by routing and grouting cracks. Further research may be needed to quantify these thresholds.

Summary

In summary, bearing zone tearing cracks will not occur in every girder, only those in which the friction force exceeds the tensile strength of the concrete. The problem can be eliminated using bearing plates, but there are likely thresholds that can be quantified to avoid the problem in less heavily stressed girders. Gang detensioning of the prestressing force may also prove to be as effective at eliminating these cracks as steel bearing plates—a choice which may be left to the fabricator when bidding a job.

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