# Failures Resulting from Inadequate Design-Construction Interface

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## Summary

From a forensic perspective, errors that contribute to failures are almost always obvious after the fact, generally result from human error, and could have been avoided. This observation is particularly true for failures that occur during construction where procedural inadequacies, poor coordination, unauthorized changes from design to as-built conditions and poor inspection can and often do contribute to failures. This paper examines three case studies, and demonstrates the need for better communication between design and construction professionals.

Keywords: construction failures, lateral stability, temporary falsework, glue-laminated timber arch, horizontally curved steel girder, erection procedures, responsibility

## 1. Introduction

More structures fail during construction than in service, and many construction failures occur due to poor communication between the engineer responsible for the design of the permanent structure and the contractor charged with building this structure. There have been serveral initiatives in recent years to develop or improve construction standards and disseminate the information learned from construction failures. In light of recent high profile construction failures, however, it is evident that there is a need for improvement.

## 2. Case Studies

### 2.1 Rosemont Horizon

The Rosemont Horizon, a sports arena in suburban Chicago, collapsed while under construction. Five workers were killed and sixteen were injured. The erection of the glue-laminated timber roof arches was about ninety percent complete when the collapse occurred.

The primary cause of the collapse was that the partially completed roof structure did not have adequate lateral stability to support its own weight. The arches are braced by buttresses at the east and west ends of the arena. At the time of the collapse, however, the structural system was not yet connected to the buttresses. The final lateral bracing systems were essential to maintain stability of the roof system.

The subsequent claims related to this collapse focused on the responsibilities of the various parties involved with the project. Virtually all of the parties involved in the design and construction of the arena contributed to the settlement.

### 2.2 Cline Avenue Ramp

The Cline Avenue Ramp in East Chicago, Indiana collapsed while under construction. Twelve workers died and seventeen were injured when sections of the falsework-supported ramp collapsed during a concrete pour.

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The ramp has a cast-in-place post-tensioned concrete superstructure, which was constructed in segments. Prior to post-tensioning, all construction loads including the self-weight of the ramp were carried by the falsework system. The formwork rested on longitudinal stringers, which were supported by transverse beams. The transverse beams were, in turn, supported by shoring towers located at the piers and at the third-points of the spans. The legs of the towers rested on individual concrete pads.

The collapse was initiated by the cracking of concrete pads supporting the falsework towers. Cracking of the pads increased the longitudinal displacement of the top of the tower, which in turn increased the relative flange displacement of the transverse beams. The relative flange displacement produced high bending moments in the screw jacks supporting the crossbeams. Due to their poor quality, the screw jack weld connections fractured, the underlying transverse beams lost support, and the resultant instability caused the total collapse of the concrete superstructure.

Contributing factors included the omission of specified wedges between stringers and beams; and an inadequate factor of safety in the design of the concrete pads. If any one of the preceding deficiencies had not existed, it is unlikely that the collapse would have occurred.

### 2.3 Centre County Bridge

Unlike the prior two case studies, this failure did not result in a collapse or loss of life. The Centre County Bridge and several others like it have generated considerable debate regarding their design and constructability. In this case, as is common in the US, the erection plan and procedures were assigned to the contractor and subject to submittal. The contractor failed to develop an adequate erection plan.

Construction of horizontally curved bridges is more complex than the construction of comparable straight girder bridges. The problems with curved girder bridges are generally related to fabrication and assembly procedures, or deformations that occur during construction but not accounted for in design. These considerations are generally “means and methods” left to the contractor. However, the successful execution of these projects is very dependent on the contractor’s experience and sophistication.

The most common problems that occur during the erection of steel bridges can be prevented by the following:

- Verifying horizontal and vertical alignment during erection;
- Installing sufficient crossframes to maintain geometry and girder stability during erection;
- Providing temporary falsework or additional cranes as required; and
- Prescribing and following proper pinning, bolting and tightening procedures.

## 3. Conclusions

The failures cited in this paper resulted, wholly or in part, from a breakdown in communication between the engineer and contractor. Both the engineer and contractor have a vested interest in the success of the project. However, their respective responsibilities on how this success is achieved is not always well-defined. The technical complexity of some projects and the method of delivery of these projects can exacerbate this problem.

The engineer should provide specific guidance to the contractor and particularly in regards to the sequence of construction and the temporary bracing and support of the partially completed structural system during the transient stages of construction. While the Structural Engineer of Record can be the most qualified person to perform this analysis, the assignment of this responsibility to the contractor is more common.

Improvements in specification, review and inspection will invariably translate to improved standards of construction and a reduction in construction failures. There have been several initiatives in recent years to develop or improve these standards and disseminate the lessons learned from these failures. However, given the recent occurrence of other high-profile failures, it is evident that there is still a need to improve communication between the design and construction team.