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Bolted Connector Failure as a Result of Improper Construction Procedure/Management

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The case study below serves to illustrate how construction practice and management played a significant role in a failure.

Bolted connections in prefabricated structural members are commonly used to assemble a building steel structure, which supports floors and the exterior facade. The steel erector is employed to assemble a steel structure by aligning prefabricated sections, inserting bolts into prefabricated sections and applying the proper torque to the bolts.

Prudent construction practice includes inspecting all bolted connections for proper installation. Bolted connections can fail for a variety of reasons resulting in the collapse of the structure with economic loss or personal injury. One way in which a bolted connection can fail is directly related to construction practice and management. The following case study serves to illustrate how construction practice and management played a significant role in a failure.

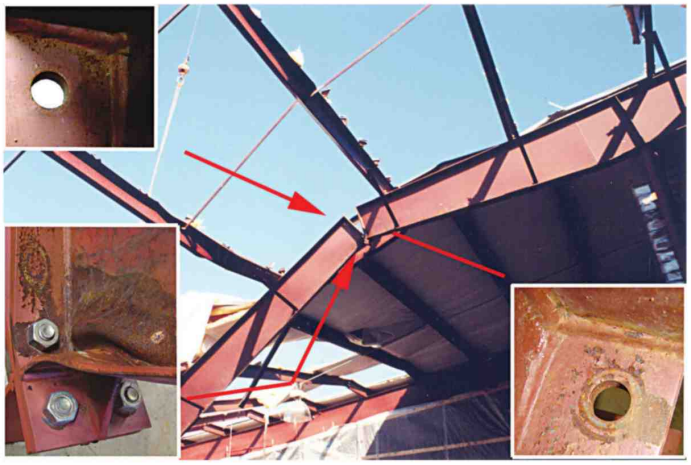

Fig. 1 — View of a bolted connection that failed as a result of snow loading on a roof.

Case Study: Roof Support Failure

Figure 1 is a view of a bolted connection that failed as a result of snow loading that should have been within the capacity of the roof to support. The building was approximately six years old. The bottom portion of the beam connection that failed had four bolts properly installed. The upper portion of the connection flange was designed to have two bolts installed. There was evidence of a bolt having been installed in one of the holes (lower right in **Figure 1**), but no evidence of a bolt having been installed in the other upper flange hole (upper left in **Figure 1**).

Figure 2 shows the fracture surface of the fastener (*ASTM A325* Type 3 high-strength structural bolt) that failed at the upper flange. Analysis of the fracture surface showed evidence consistent with an excessive load applied to the fastener. No deficiencies were found in the bolt metallurgy that could have caused or contributed to a failure. Only one failed bolt was found at the scene.

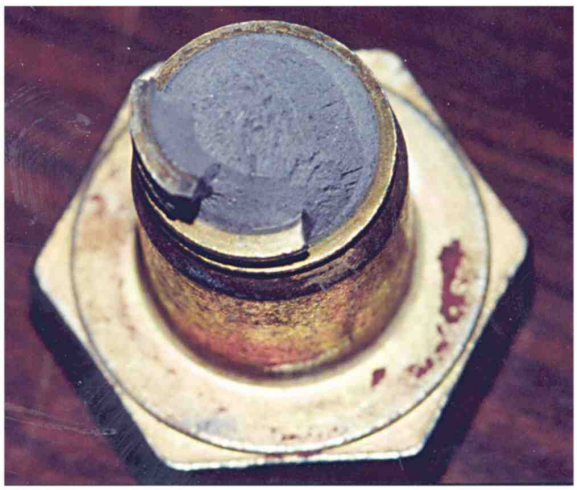

Fig. 2 — Fracture surface of the fastener that failed at upper flange.

Figure 3 aids in reconstructing the probable cause of the failure. Wear patterns on the upper holes of the flange connection suggest that one bolt was installed, while the other bolt was not installed.

Figure 3B shows the connection under uniform loading, before failure, such that the lower bolts are in tension and the upper bolts in compression (also called sagging). With the missing bolt, the connection will support the designed uniform load along the beam since the bottom bolts are in tension while the upper bolt is carrying very little load other than the pre-load. As long as the sagging bending moment is applied to this connection, it will remain stable within design parameters.

In **Figure 3A**, the snow loading at the time of the failure is shown, which applied bending moments to the beam and connection such that the upper bolts were in tension and the lower bolts in compression (also called hogging). With the onset of a hogging bending moment as experienced in this particular unsymmetrical snow load, the lower bolts are not carrying much tension, but the upper bolt is, and in an unsym-

metrical fashion, because of the bolt offset (**Figure 3C**). This over loaded the bolt, resulting in failure of the upper part of the connection (**Figure 3D**) and roof collapse. Structural calculations showed that if both of the upper bolts had been installed properly, the failure would probably not have occurred.

The absence of the fastener was the probable cause of failure, suggesting a problem with construction procedure/management. During steel erection, bolts are often installed with nuts that are hand tightened to make sure the connections all fit. They are then tightened to the proper torque before normal loading is sustained by the structure.

In some instances, only a few of the flange bolts are inserted to align the structure before final assembly, which can result in missing bolts if no inspection is performed. Occasionally, flange connection holes do not line up and some fasteners cannot be installed, which should be reported to management. The purpose of an inspection is to verify that all bolts have been installed.

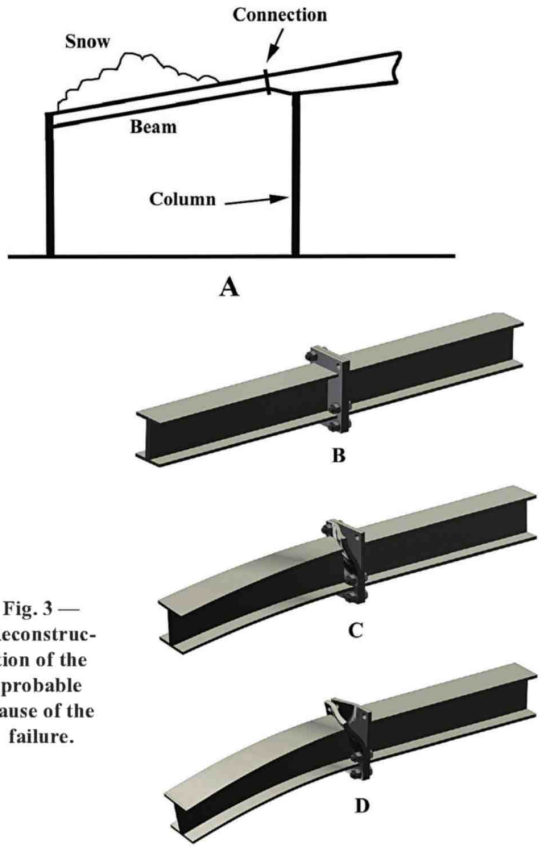

Fig. 3 — Reconstruction of the probable cause of the failure.

Apparently no inspection was performed or only a cursory inspection was performed, resulting in a missing bolt at a critical part of the structure, which was not rectified. Clearly the fastener itself was not at fault in this case.

For further discussion or for additional technical information, contact the author via email at:
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