Structural Failures

investigating failures, along with their consequences and resolutions

Hyatt Regency Skywalk Collapse Remembered

By Randall P. Bernhardt, P.E., S.E.

It was a time of celebration at the Kansas City Hyatt on July 17, 1981, 35 years ago. Between 1,500 and 2,000 people were in attendance at the Tea Dance, enjoying the band, the music, the food, the drink and the dance contest. Unfortunately, what began as an evening of celebration would be remembered for the tragic deaths resulting from the most catastrophic failure of a structural connection in the United States. The collapse caused the death of 114 people and the injury of more than 180, and traumatized countless others. The effects were felt throughout Kansas City and the United States and served as a wake-up call to the engineering community.

This event highlights the importance of following appropriate procedures and processes involved in structural engineering. The consequences of a structural failure can be catastrophically high – and can be the result of inattention to details, inadequate quality reviews, and lax shop drawing reviews. The following article describes the events leading to the construction and failure of the Hyatt Regency Skywalks, post-event actions, and lessons learned – especially about quality reviews.

Background

Planning for the Hyatt Regency project started in 1976. The plan for the hotel included a 35-story tower with sleeping (guest) rooms and a four-story conference center. A walkway spanning across the atrium at the second, third and fourth stories connected the two buildings. Initially, the walkways were intended to be supported from columns at the ground level. In a later design change, the walkways were suspended from the roof (Luth 2000).

In the final configuration, the fourth-floor walkway was positioned directly above the second-floor walkway. The third-floor walkway was offset from the other two (*Figure 1*). The distance that the walkways spanned from the tower structure to the conference center was approximately 120 feet. The 120-foot length was split into four equal spans of approximately 30 feet each, using two (2) W16x26 longitudinal stringers per walkway. The ends of the walkways were supported by the tower and conference center structures, but each interior span support consisted of a built-up box beam suspended from the roof structure by two steel hanger rods. The box beams consisted of two MC8x8.5 channels welded toe to toe. The hanger rods were 1¼-inch diameter steel with a yield stress of 36 kips per square inch (ksi) (Marshall et al. 1982). The roughly 8-foot wide walkway was comprised of 3½-inch thick lightweight concrete on 1½-inch steel form deck that spanned longitudinally between W8x10 floor beams (*Figure 2, page 26*).

This was a "fast track" project intended to provide the owner with a completed product in the shortest amount of time. Speed was of the essence, where construction often preceded a completed design and structural design preceded architectural design (Luth 2000). While this method became popular in the 1970s, the coordination of all the processes under these conditions to ensure quality was not fully developed. At the time of the project, it was customary in the Kansas City area to delegate design of most of the typical steel connections to the steel fabricator (Luth 2000).

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Figure 1. After the event; the fourth-floor hanger rods remain next to the intact third-floor walkway.

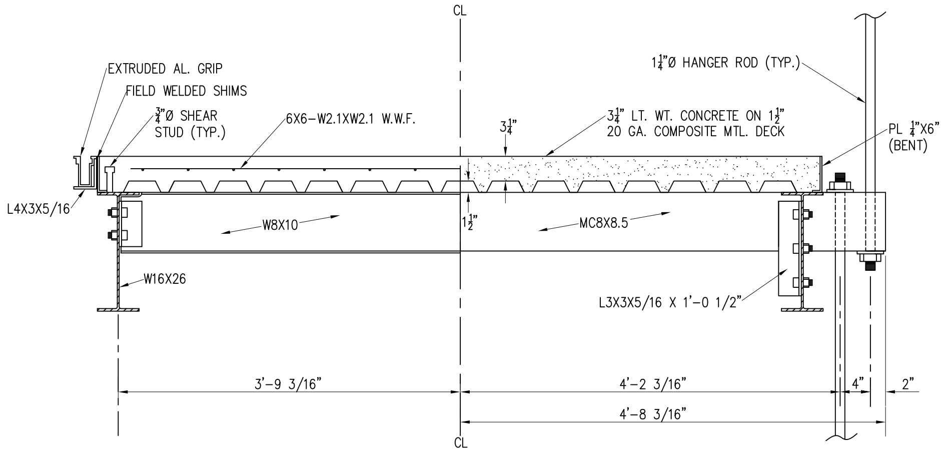

Figure 2. Cross section of the walkway. (Marshall, R.D., et.al, 1982. Page 26.)

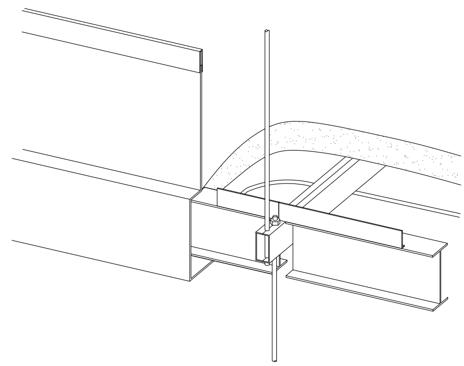

Figure 3. The perspective of the critical connection showing the double rod configuration. (Marshall, R.D., et.al, 1982. Page 30.)

Chronology

The following important points and missed opportunities can be found in Luth's chronology of events (Luth 2000).

1) The initial project engineer and senior designer, who were familiar with the background of the design, left the structural engineering firm early in the design process. Their departure impeded the communication of the original design intent to those who completed the design.
2) Similarly, the fabricator transferred incomplete shop drawings to an outside detailing firm for completion, further impairing the flow of information. The outside detailer assumed the connection had been designed because it was shown on the shop drawings and not flagged for design check, as no loads were provided in the initially drafted sketch.
3) The project manager conditionally approved a change request from the fabricator to use a double rod configuration in lieu of a single continuous rod (*Figure 3*). This essentially doubled the load on the rod-to-box-beam connection at the fourth-floor walkway. The structural engineering manager requested it be submitted as a formal change request, delaying the final review until a later date. The fabricator did not formally submit the change from one continuous to two offset rods as requested by the structural engineer.
4) The structural engineer's technician reviewed the shop drawings and questioned the yield stress of the steel hanger rod. The project manager did not give the question his full attention but responded from memory. If the question had drawn the structural engineer's focus, the deficiencies in the design might have been noticed.

Expansion bearing connections for the steel atrium roof failed early during construction due to erection deficiencies. This failure prompted an internal check of the atrium roof design. During this internal check, the grade of steel hanger rod was again questioned, but no follow-up was made.

At approximately 7:05 pm on July 17, during the Tea Dance, with less than 10 people on the fourth-floor walkway and less than 60 people on the second-floor walkway, the bottom flange weld connecting the two MC8x8.5 toes ruptured. The rupture was caused by the force of the fourth-floor walkway-to-roof hanger rod nut on the bottom surface of the box beam. Before the rupture, the welded channel flanges acted continuously between the webs. After the rupture, the flanges were cantilevered. They rotated upward from yielding in the web which allowed the bolt and nut to slip through the hole (*Figure 4*). The impact from the bolt and nut on the upper flange of the box caused failure of the upper flange, with the bolt and nut slipping through the hole in an instant at that point. The fourth-floor walkway became disconnected from the roof support, and both walkways collapsed onto over one hundred people standing below (*Figure 5*) (Luth 2000).

Figure 4. Deformed box beam failed connection.

Figure 5. The collapsed second- and fourth-floor walkways on the floor of the atrium after the rescue operation.

Fourth Floor Hanger Rod to Box Beam Force	Total Unfactored Load (Kips)
Code Required Loading	40.7
Actual Loading at Collapse	21.3
Actual Tested Ultimate Capacity	18.6

Post-Event Investigation

After the collapse, the National Bureau of Standards conducted an exhaustive investigation (Marshall et al. 1982). The following conclusions can be drawn from their report:

1) The loads on the hanger rods and hanger-rod-to-box-beam connections at the time of the collapse were significantly less than the loads required by the Kansas City Building Code as seen in the *Table*.
2) According to the applicable AISC Specification (1969), the 1¼-inch hanger rods with a yield stress of 36 ksi had an allowable tensile capacity of 20.9 kips. If the 60 ksi rods had been used as intended, they would have had an allowable tensile capacity of approximately 34.9 kips. This is still less than the code required dead and live load on the fourth-floor-to-roof hanger rod of 40.7 kips that would be imposed for both the single continuous rod configuration or the offset double rod configuration. The original 1¾-inch diameter hanger rods would have an allowable tensile capacity of 41.0 kips using 36 ksi steel and would have satisfied all load requirements. Though the failure of the hanger rods was not the cause of the walkway collapse, they were still under-designed.
3) The dynamic effects of walking or dancing on the walkways did not significantly increase the load effect on the walkways.
4) The box-beam-to-rod connection detail did not satisfy the requirements of the 1969 AISC provisions, i.e., it was not a typical detail that could be designed by the fabricator: No bearing stiffeners to accommodate concentrated loads were provided and web crippling requirements were not met through the use of distribution plates. Further, the AISC provisions did not anticipate significant eccentricities of the load from the plane of the web as were actually used where the rod load was applied at the flange toe.
5) Though the original continuous rod configuration did not meet the requirements of the Kansas City Building Code, the hanger rod connection to the box beams under that configuration would have had the capacity to resist the actual loads estimated to have occurred at the time of the collapse.
6) Poor quality of workmanship and materials did not contribute to the collapse.
7) The critical portion of the structure, and where the collapse initiated, was at the fourth-floor hanger rod to fourth-floor box beam connection. This connection had a tested ultimate capacity of 18.6 kips, with a code-required load demand of 40.7 kips.

Legal and Professional Actions

The damages awarded to victims and families of victims exceeded $100 million. A grand jury found no evidence of illegal action on the part of the design professionals.

The Missouri Board for Architects, Professional Engineers and Land Surveyors investigated and brought charges of gross negligence and misconduct against the structural engineer of record and the structural engineering project manager from the firm that had provided the structural design of the Hyatt. An administrative judge found them guilty of the charges. Both engineers lost their licenses (Roddis 1993) (Pfatteicher May 2000)

Lessons Learned

Many lessons can be drawn from this tragedy, including the following (Luth 2000):

1) Connections should be designed by a qualified engineer at some point in the design and construction process.
2) An internal quality review should be thorough – more than spot checking – and should include a formal check of details on the structural drawings
3) Questions posed during design and construction should not be disregarded, but should be given the utmost attention on a project with an accelerated schedule.
4) When there are changes in personnel, steps should be taken that ensure a smooth transition and full transfer of knowledge about the design activities leading up to the personnel change.
5) Even small, seemingly insignificant changes in concept should be handled through a process that compels the participants to focus on potential issues.
6) Engineers in city building departments should not be depended upon for finding errors in the design. Internal quality reviews should catch any errors before documents are issued for construction.

Discussion

Additionally, many more valuable lessons can be extrapolated from the Hyatt Collapse including issues about communication during the project, design quality control, design responsibility, shop drawing review, construction inspection, and structural observation (Delatte 2009) (Morin 2005). These issues were also discussed in House Report 98-621, *Structural Failures in Public Facilities*, that was prepared in part as a result of the Hyatt tragedy and other structural failures in the United States (House Committee on Science and Technology, 1984) and other papers.

Structural engineers can be pulled in many different directions on projects, but in particular on a project with an accelerated schedule and tight budget. There may be temptations to skip steps in normal procedures and not give the focused attention that design or construction issues require. Some say that if you have quality and speed, the cost will be high. If you want speed and low cost, the quality will suffer. When faced with a high-pressure project, many have been tempted to relax the guard on quality. Like the engineering mistakes made in the Hyatt, "There but for the grace of God, go all of us." It is essential that there be an independent checking process, a conviction to follow the process, and a focus on protecting the public by providing safe designs.

Comprehensive quality control reviews during the design, effective shop drawing reviews, and vigilant structural observation during construction are three significant steps that structural engineers can use to ensure that the design conforms to accepted practice and that the fabricator and constructor understand and deliver a final product that meets the engineer's design intent.

Quality Review Process during Design

Every project should have a clearly documented quality review process for design deliverables. Project engineers should be instructed about its importance and procedures, and should demonstrate a commitment to adhere to it. Given the magnitude and complexity of the Hyatt construction, which included a revolving restaurant on top of the tower, the walkways were a relatively small part of the project (Luth 2000). It would be easy to focus on the complexity of the tower and revolving restaurant, and pay less attention to the details of the atrium.

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Some takeaways from the Hyatt event and the author's experience with different firms regarding quality control are:

1) The originators of calculations and drawings need to provide a self-check of their work.
2) An independent internal review should be required for calculations and deliverables. This may be completed by the structural engineer of record or a senior engineer in the firm. Some firms require drawings to be highlighted for compliance and red lined for disagreements.
3) The reviewer should have a commitment to quality for the firm's deliverables and should assume a sense of responsibility. It should be required that the reviewer's comments be resolved by the originator of the work product.
4) The review should not focus on only the details on the structural plans, but should envision the "big picture"– how the discipline specific design fits into the whole project. Coordination with other disciplines is necessary to provide fewer change orders during construction.
5) The engineering firm should not depend on the client or a government agency to find errors. The design and plans should be correct when delivered for a permit or issued for construction.
6) Corrections made by a drafter need to be thoroughly reviewed to ensure that the corrections are accurate before submittal to the client.

This review process is intensive, but essential, especially for more complex or innovative projects. Only by adhering to this process can effectiveness and a high degree of accuracy in the final product be provided. Self-check is important but equally important is that another set of experienced eyes review design calculations and details on a project. ASCE's *Quality in the Constructed Project, A Guide for Owners, Designers and Constructors* provides useful information on different facets of quality reviews for civil engineering projects.

Shop Drawing Review

Shop drawing review is another step in the process of delivering a quality project. The fabricator or vendor should submit detailed fabrication drawings and information for the materials that meet the designer's intent. These submittals need to be approved by the engineer of record or a delegate before construction. The reviewer needs to be someone who is familiar with the design and who is knowledgeable in the structural engineering requirements. Shop drawing review should not be depended on as a quality review to find the designer's errors. Rather, it is a step to ensure accurate communication of the design for fabrication before construction. Like quality reviews, the ASCE guide, *Quality in the Constructed Project*, has useful information on shop drawing submittals and review.

Structural Observation during Construction

Having a site presence during construction was requested by the structural engineer of record at the Hyatt three times. Presence at the site by a qualified structural engineer may have finally prompted the attention to the critical detail that was required and the tragedy could have been averted. As with shop drawings, observation of the construction by a structural engineer should not be used as a tool to find errors in the design, but it can be another layer of the safety net to ensure that the structural details are constructed as the engineer intended in the design. The House Report 621 suggested that building codes require structural inspections of critical components. This is currently included in the *International Building Code*, Chapter 17.

Conclusion

Many factors could have affected the outcome of this tragedy. Imagine if the structural project manager and engineer were not overloaded – or, the original project engineer and designer had not left the firm. Consider what might have happened had the project manager and engineer realized the critical nature of the detail when questioned. Our clients and the public at large should be aware of the importance of high-quality structural engineering on all projects. We, as structural engineers, should operate with a heightened level of discipline and conviction to ensure that projects are not deemed, or delivered, as complete without adherence to a proper quality control process. Additionally, we should not avoid our responsibility to provide quality in our structural reviews of construction submittals and observation in the field during construction.▪

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