Chronology and Context of the Hyatt Regency Collapse

By Gregory P. Luth[1]

Abstract: This paper presents a brief chronology of the events that preceded the collapse of the walkways at the Kansas City Hyatt Regency Hotel, including the prior failure that occurred during construction and the evolution of the detail that caused the catastrophe. Many of the facts surrounding the case were not publicized, due to the litigation. Some were not brought out during the litigation. No attempt will be made to affix responsibility, as these issues were resolved years ago. The chronology is followed by a discussion of the events that contributed to the collapse and of the changes that have been made in the industry toward preventing a similar occurrence.

INTRODUCTION

On July 17, 1981, two walkways at the Hyatt Regency Hotel in the Crown Center development in Kansas City, Missouri, collapsed during a ''tea dance.'' A full chronology of events is provided in table form (Table 1). The result of the collapse was that 114 people lost their lives and numerous others were injured. It is worthwhile to look back on the events leading up to the events of July 17 to determine what actions or omissions contributed to the tragedy and what actions might have averted the tragedy. The writer was a recent graduate working in the offices of the firm that performed the structural design of the Hyatt Regency. This paper presents a brief, objective, and factual summary of those events in chronological sequence in order to provide a context in which the profession might study and evaluate the lessons of the failure.

The project design was performed under the ''fast track'' method of delivery that came into vogue in the latter part of the 1970s. As with many projects delivered by this method, construction preceded design, structural design preceded architectural design, and both the design and construction phases were plagued by a lack of time and quality control. Thrown into the mix were multiple changes in personnel on both the construction and design sides.

Following the chronology is a subjective discussion of the lessons that were learned, lessons that were not learned, and changes to the practice that the writer has observed in the intervening years.

DESIGN PHASE

Master planning for the Hyatt Regency started in early 1976. By mid-1976 the elements of the concept had emerged. The hotel would consist of a 35-story, 750 guest-room tower topped by a revolving restaurant and a four-story function block area housing kitchen, restaurant, and support functions. The tower and the function block would be separated by a four-story tall, 36.6 m (120 ft) wide column-free atrium area. In July of 1976, the architect and owner began discussions with the structural engineer regarding the details and cost of the structural system. The schematic design phase commenced and would last until July, 1977. The details of the structure of the roof over the atrium area were fleshed out. An expansion joint would separate the roof structure of the atrium from the concrete structure of the function block. The primary structure support would be provided by deep trusses spanning 36.6 m (120 ft), supported on slide bearings that rested on concrete corbels on the function block end. One side of the atrium roof structure would be supported on a system of vertical frames that formed a ''sun screen'' and also functioned to support a four-story glass wall. Communication between the function block and hotel floors was provided by a system of walkways at the 2nd, 3rd, and 4th floors.

Production of construction documents was ongoing between July 1977 and January 1978. Because of architectural constraints, the sunscreen structure evolved into a vertical truss that picked up loads at the roof on one chord and dropped them off at the first floor at the other chord in order to avoid loading the concrete floor system at the first floor. The inside chord of the sunscreen truss, which functions as a column, was designed to be provided with lateral support by structural tubes that also supported the curtain wall. Early schemes called for the walkways to be supported on posts off of the concrete floor at the first level. Later, the decision was made to suspend the walkways from the roof structure to give a light and airy feel to the atrium space. Fig. 1 shows floor plans of the roof and walkways; Fig. 2 shows a section through the screen wall and bridges.

At the expansion joint, the ends of the walkways, and the ends of the wide flange beams holding up the east end of the roof structure, slotted holes were used to accommodate the anticipated movement. The design called for embedded knife plates welded to embedded plates at these connections.

In January 1978, the first bid package on the job was issued. It included the foundations and concrete substructure. At that point in time, the steel structure is assumed to be at ''design development'' level. The general contractor solicited preliminary pricing from a steel fabricator. Based on the first package, the owner contracted with the general using the ''fast track'' method of delivery. Construction of the foundations and substructure commenced shortly thereafter.

The contract for structural engineering services between the architect and structural engineer would not be signed until April of 1978.

The design continued to evolve between January and August of 1978. There were major changes to the screen wall and the curtain wall on the west side of the atrium. One of these changes moved the horizontal support elements in the wall. The splice locations for the inside chord of the screen wall trusses were not adjusted to reflect the new locations of the horizontals, leaving the column splices unsupported.

Part of the problem with coordination may have been due to the fact that both the project engineer and the senior project designer for the structural engineer left the firm in June of 1978. Both individuals had a deep knowledge of the design history. A typical team for a project of this size would include a project manager, a project engineer, a senior project designer (for large projects only), a couple of junior designers who may or may not be full time, a senior drafter, and several junior drafters who would not be full time. The project manager was the only remaining engineer with any history on the project.

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TABLE 1. Hyatt Regency Collapse, July 17, 1981—Chronology of Events

***1) Early 1976**	Owner commences master planning.
***2) July, 1976 - mid 1977**	Schematic design phase. Concepts call for a 35-story 750-room concrete guest tower topped by a revolving restaurant and a four-story function block area separated by a long-span (120') atrium structure.
***3) January, 1978**	First bid package issued. Owner contracts with general contractor using "fast track" method. Initial price from fabricator based on preliminary drawings is $350,000.
***4) April, 1978**	Architect contracts with structural engineer for "all structural engineering services" for hotel for design fee of $247,000.
5) January - August, 1978	Design continues, there are major revisions to the sunscreen framing.
6) June, 1978	Both the project engineer and the senior design engineer on the project leave the firm.
7) Mid 1978	First walkway connection detail shows eccentric hanger connection to angle mounted on the side of the W16 stringers. All purlins are W8x10.
8) Mid 1978	Architect requests that rods supporting the bridges be changed from 1-3/4" to 1-1/4" to "lighten up" the appearance of the bridges.
***9) Mid 1978**	Plans are revised to show 2-MC8x8.5 channels in lieu of W8x10 purlin at the hanger locations. Engineer's revised sketch of connection detail shows single rod with Fy=60 ksi centered on 2 channels placed toe to toe and an axial load of 22 kips. No weld is shown on between the channels.
10) August, 1978	Draftsman transfers sketch to final drawings leaving off the yield strength of the rod and the axial load.
***11) August, 1978**	Drawings and specifications are issued "for construction".
***12) December, 1978**	Contract between Category III fabricator and GC is signed for a revised amount of approximately $390,000 and fabricator starts shop drawings "in house." As part of preparation of shop drawings fabricator's in house engineers design heavy truss connections and all beam connections for forces shown on the drawings.
***13) January, 1979**	Fabricator requests (by phone) change from one continuous rod to two rods offset to facilitate erection. Engineer agrees provided request is forwarded "through channels."

Three events occurred in mid-1978 that had a direct impact on the eventual failure: The architect requested a change to the rods supporting the walkway, the project manager revised the configuration of the connection and the walkway framing, and the connection detail was redrawn and reissued.

The framing shown on the documents prior to the changes consisted of W8 floor beams spanning transverse to the walkway to W16 stringer beams on either side. The transverse beams had to be 8 in. in depth to allow building services to pass between the function block and the hotel in the ceiling below. The hanger rod was a 44 mm (1 3/4″) A36 threaded rod, and the hanger rod/walkway connection consisted of a bracket extended off the web of the W16 stringer, as shown in Fig. 3(a). Note that the original detail showed a rod terminating just below the bridge, showed a 9 in. (228 mm) dimension from the rod to the beam centerline, and indicated a load of 22 kips on the rod. There were actually three bridges and two conditions indicated on the plans. The walkways at the 2nd and 4th floors on the west side were situated one under the other. There was a single walkway at the 3rd floor just to the east, as shown in Figs. 1 and 2. The presence of the 22-kip load on the detail is significant because in those days it was an indication to the fabricator that the connection design was incomplete.

The architect requested that the rod be changed to 32 mm (1 1/4″) in order to give the walkway a ‘‘lighter’’ appearance. In the final structure, the rods were encased in 2 in. of plaster fire proofing and the 38 mm became 133 mm (5 1/4″) anyway. Nonetheless, the architect insisted that the change be made. At about the same time, the project manager decided to reframe

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TABLE 1. (*Continued*)

***14) January 12, 1979**	Due to unexpected increase in work load, fabricator sends partially complete shop drawings to outside detailer for completion. (Detailer is a licensed engineer with 28 years experience in designing connections and detailing steel.) Drawing showing double rod connection has been started. Outside detailer assumes connection has been designed and just adds tack weld to "hold channels into alignment."
15) February 7, 1979	Detailer checks erection and piece drawings for bridges.
16) February 16, 1979	Finished shop drawings for the entire atrium are received by the structural engineer. Checker asks engineer about rod strength and is told it is "high strength." Drawings are returned to contractor by courier on Sunday, February 26.
17) Summer, 1979	During erection of steel, connections along the expansion joint are made using expansion bolts because the embedded plates were not cast into the concrete when it was placed. The wrong number of bolts, with only 1/2 the specified embedment are used under one corner of the roof. Owner fires testing lab due to poor performance on the concrete portion of the project. Engineer requests field representation on three separate occasions but is ignored.
***18) October 14, 1979**	During first cold night of the fall season the deficient expansion bolt connection pulls out of the concrete and two bays of the roof collapse.
***19) October, 1979**	Field investigation reveals numerous design and construction deficiencies along the concrete/steel interface.
***20) October, 1979**	Owner retains outside engineering firm to investigate collapse and review the design along the concrete/steel interface.
***22) November, 1979**	Design errors discovered by in house check are corrected in field.
23) July, 1980	Hotel grand opening.
24) July, 1981	Bridges collapse

the structure in the area of the hanger to eliminate the eccentricity inherent in the bracket connection. He replaced the W8 at the hanger location with a pair of 8 in. channels turned toe to toe and extended these past the W16 to engage the hanger rod. At the same time, he resized the hanger rod to be 32 mm (1 1/4″), which required a grade 60 rod. The engineer's sketch, shown in Fig. 3(b), depicted the 60 ksi 32 mm (1 1/4″) rod, the relationship between the rod, the pair of channels (or ''box beam''), and the W16, and a load of 22 kips. Note that the sketch shows none of the welds or bolts nor any other detail of the connection other than the load and the spatial relationships among the connected members.

The draftsman transcribed the detail onto the contract drawings, as shown in Fig. 3(c). Note the information that is missing. Neither the yield strength nor the load is indicated on the detail. The series of events that led to the change in the detail from Fig. 3(a) to Fig. 3(c) were the first steps down the road to tragedy.

The detail was cross-referenced at all three floors where the walkways connected to the hanger rods. The dimensions on the plans (Fig. 1) indicated that the hanger rods between the 2nd and 4th floors were in the same location, implying a continuous hanger rod. At the 4th floor the detail was shown as ''SIM,'' indicating in industry shorthand that while there were differences in the details they were the same in all essential respects.

Although the focus of this paper is the design and construction of the steel structure of the walkways in the atrium, it should be realized that in the context of the project in 1978, this was considered to be a relatively insignificant part of the process. While the details of the walkway were being completed, the 35-story concrete tower was under construction and the details of the revolving restaurant at the top of the tower were also being completed. All of these elements were being subjected to the same process that caused fundamental changes to be made to the walkway structure in July of 1978. Understanding the context created by this project environment is

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TABLE 1. (*Continued*)

25) 1981 – 1983	Civil suit settled out of court by owner for more than $100 million
26) 1983	Grand jury investigation resulting in no true bill.
27) 1984	Administrative hearing results in revocation of licenses of both Engineer-Of-Record and project engineer.
28) 1985	Disciplinary hearing by the board of ASCE. EOR found vicariously responsible for error in shop drawing process, but not guilty of gross negligence nor of unprofessional conduct and suspends his membership for a period of 3 years. The action of the board is published, but the detailed findings are not, in accordance with ASCE policy.

Note: Items marked with an * are taken directly from findings of fact contained in the decision rendered in the administrative license hearing held in Missouri following the collapse.

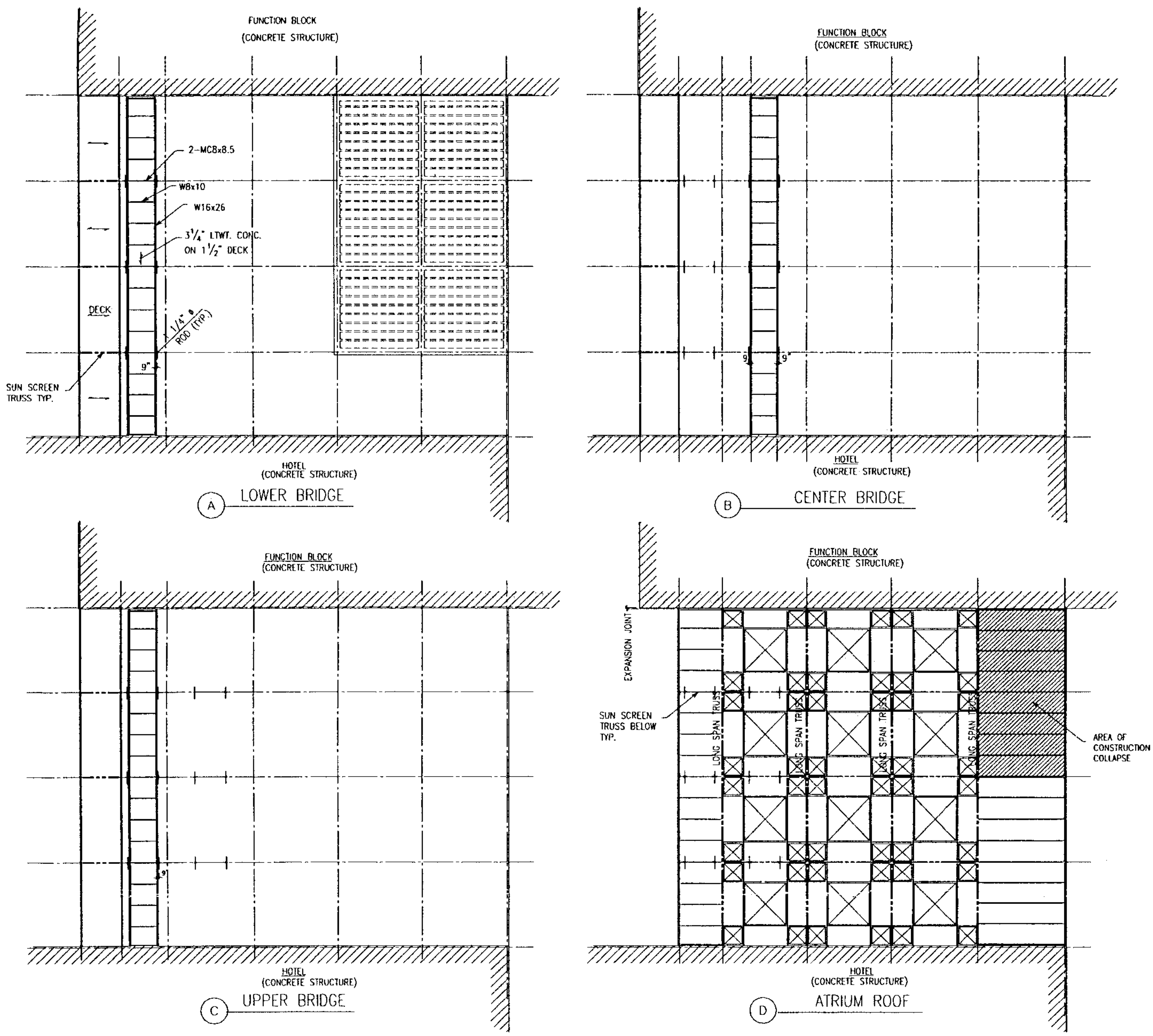

FIG. 1. Floor Plans of Roof and Walkways at Kansas City Hyatt

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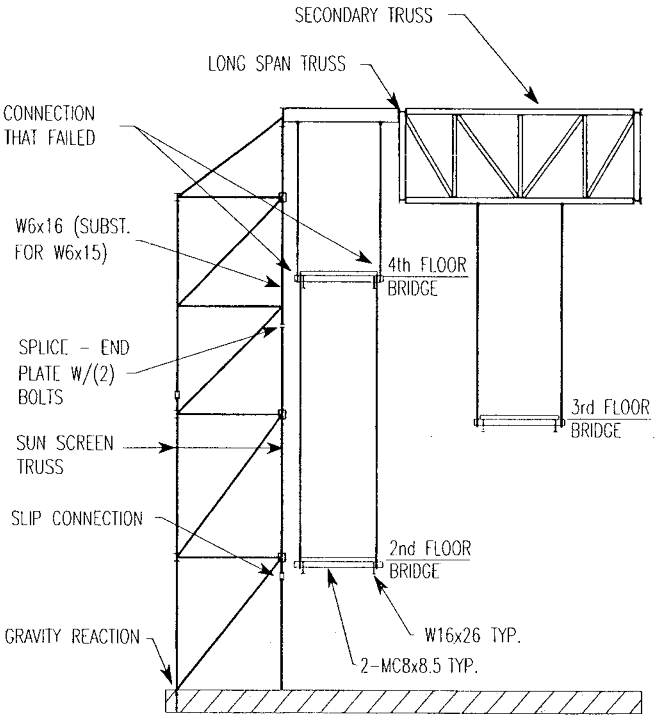

FIG. 2. Section through Bridges

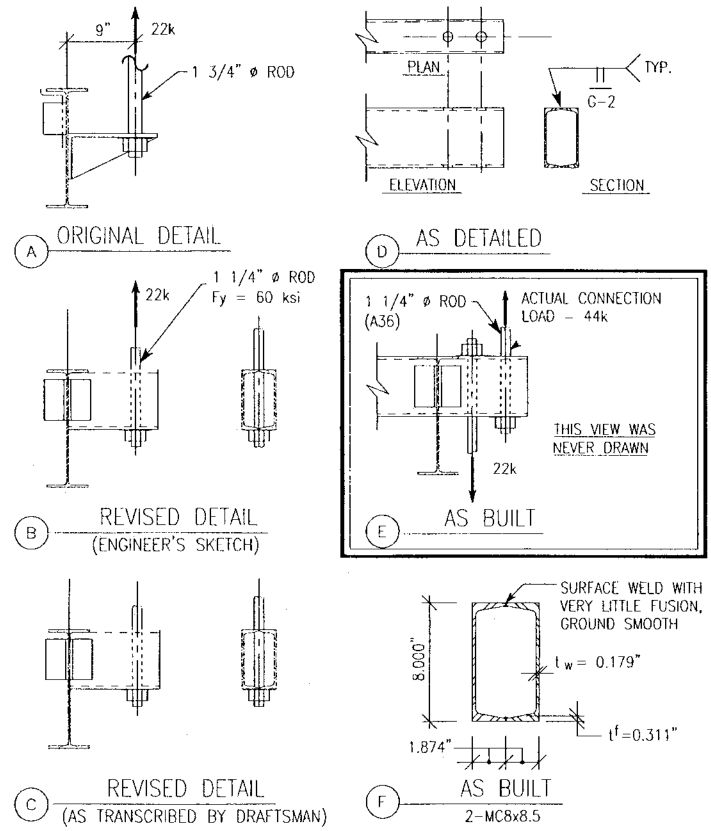

FIG. 3. Evolution of Walkway/Hanger Rod Connection

fundamental to understanding the human aspects of the process that led to the failure.

In August of 1978, the drawings and specifications were issued ''For Construction.''

CONSTRUCTION PHASE

By the time the drawings were issued ''For Construction,'' a significant amount of construction was already in place. Foundations had been completed and construction was well under way on the 35-story tower. From the outset, the construction site was plagued with quality control problems and ''bad luck.'' The owner contracted with an independent firm to provide testing and inspection services. The first testing agency was subsequently fired for nonperformance and a second one hired to take its place.

The general contractor negotiated a final price for the steel structure of the atrium and signed a contract in December of 1978. The fabricator was certified by AISC as Category III, which is a bridge and complex-steel-structure certification that requires in-house engineering capability. The $390,000 contract was not a large one for the fabricator. The fabricator and structural engineer had worked together three years previous to this on a high-rise steel structure in downtown Kansas City, and had a good working relationship. The engineering firm considered the fabricator's engineering manager to be an expert in the area of connection design and had used him as a consultant on other projects that involved complex or heavy steel connections.

Shortly after signing the contract, the fabricator commenced preparation of the shop drawings using its in-house engineering and detailing personnel. As part of its preparation of the shop drawings, the fabricator designed all of the gusset plate connections for the long-span trusses in the atrium roof as well as all of the beam connections. The ''custom and practice'' in the Kansas City area at the time the drawings for the Hyatt were prepared was to leave most of the details of the connections up to the fabricator, in order to let him tailor the details to suit his particular shop practice. Where connections were shown, they were generally drawn to the level of detail indicated in Fig. 3(b), unless the structural requirements or geometry were too complex to convey in the industry shorthand.

In early January 1979, the fabricator's engineering manager called the structural engineer's project manager to discuss the ''continuous'' rods supporting the 2nd and 4th floor walkways. He asked if they could be made discontinuous and offset at the 4th floor. The structural engineer checked the moment and shear in the box beam for the offset condition while on the phone, found them to be acceptable, and responded that the change would be acceptable from a structural point of view. He then asked the fabricator to submit the request through the channels of authority. This was never done, and a second step down the road to tragedy had been taken.

On January 12, 1979, the fabricator pulled the job out of his engineering department to make work for a large project that it had just landed. The partially complete shop drawings were sent to an outside engineering firm to be completed. The firm that was used for this had a long history of working with the fabricator. The principal of the firm was a licensed engineer who had 28 years of experience designing and detailing connections.

At the time the shop drawings were sent out to be completed, the drawing showing the box beam had been started. As is typical of shop drawings, no connection was shown. The connection configuration is implied by the details of the pieces. Thus the change to the offset rods, which was never submitted for ''official'' review, was implied by the piece shown on the shop drawings, shown in Figure 3(d). The outside detailer, upon unrolling the drawings and seeing detail [Fig. 3(d)], assumed that the connection design was done and simply added the weld symbol before sending the drawings out. (In later testimony he said that he added the weld to hold the two channels together for shipping and erection.) Standard practice would require that deviations from the contract drawings not be made on the shop drawings. Normal practice would be to submit the change under separate cover and then

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flag it for verification on the shop drawings. Neither of these was done in the case of the hanger rod/box-beam connection. The project was accelerating down the path to tragedy.

On February 7 the detailer performed his check of the erection and piece drawings for internal consistency and completeness. The box-beam details were not flagged and the first chance to change course was missed.

After the check of the entire atrium was completed, the drawings were sent to the structural engineer for approval. Meanwhile, pressure was building to get the steel into the field and get it erected as soon as possible. By the time the drawings landed on the engineer's desk on Thursday, February 16, the contractor was requesting expedited approval. Because of the departure of the project engineer and designer, there was no one left in the office who had experience with the project and could check the shop drawings. By this time the project manager was inundated and could not check them himself.

The shop drawings were assigned to a senior technician. Although he was educated as a structural engineer and had over 20 years of experience, he had never obtained a license. This was not that unusual, since in those days the owner of the company typically sealed all the drawings.

During the course of checking the drawings, the technician asked the project manager about the strength of the hanger rod, since, by his calculation, it didn't work as A36. The project manager responsed from memory that it was a high-strength rod. No attempt was made to verify this by looking at the drawings and specifications, and a chance to discover the missing information on the connection detail and the changed connection that was never designed or verified through channels was missed. The drawings were returned by bus on Sunday, February 27. No notation was made on the box-beam detail, and the fate of the project was all but sealed.

The weld symbol on the shop drawings indicated a groove weld between the toes of the channels ground flat. In reality, the dimensions that were used in detailing did not allow for a gap. The shop butted the two flanges together and a surface weld was applied to the outside of the two flanges. A bead was run on the interior of the channels as far back as the welder could reach with his stinger, although this was not explicitly called for on the shop drawings and was not required. The outside weld was ground smooth, leaving a razor-thin sliver of weld metal [Fig. 3(f)].

The as-built connection at the 4th floor bridge is shown in Fig. 3(e). This detail was never drawn, either on the shop drawings or the design drawings. In fact, the connection was never drawn or designed. The engineer assumed that the original single-rod connection would be designed by the fabricator, consistent with the standard practice at the time, for the force indicated on his detail. Because of a drafting error, that force was not on the design drawing. The change to two offset rods had the effect of doubling the connection force from 22 kips to 44 kips.

The change also resulted in two holes through the 100 mm (4 in.) wide box beam. The inner hole isolated the outer hole, limiting the effective length of weld that would be available to resist the concentrated reaction. The fabricator put the upper rod, which had double the reaction, on the outside hole. No stiffeners were provided and no closure plate was provided at the end of the box beam. The holes through the box beam were drilled after welding the two channels together. A standard washer was provided under the nut.

There would be one more opportunity to discover the problem with the hanger rod/box-beam connection.

THE CONSTRUCTION FAILURE, OCTOBER 1979

The steel for the atrium was fabricated and erected during the summer of 1979, but all did not go smoothly. The embedded plates for the connections of the beams to the concrete along the expansion joint were left out. The contractor requested a repair detail and the project manager sent a sketch showing a seat angle with four expansion bolts and a pair of slotted double angles with five bolts on each angle. When the contractor installed the connection, he could only get two of the four bolts in the seat angle. The others hit rebar, so they were left out. Only one of the web angles was installed, and that one had only three bolts. Of the bolts that were installed, several were shorter than specified. Of the 14 bolts specified, less than 5 were actually installed properly. Because of erection tolerances, the holes in the angles had to be enlarged. This was done with a torch, and the holes were left rough. The bolts were installed tight to the ends of the slotted holes.

The erection was completed, construction proceeded apace, and concrete (up to 1 ft thick in places to achieve the roof slopes) was poured on the roof. The second testing lab was fired for poor performance on the concrete testing. The owner opted to complete the project without a testing lab. On three separate occasions, the Engineer of Record (EOR) requested site representation but was turned down. The architect had a full-time representative and it was felt that that was sufficient.

During the night of October 14 there was a cold snap and the beam on the northeast corner of the atrium with the faulty connection pulled out of the wall. The end of the beam swung down and hit the first interior column, causing it to buckle, dropping two full bays of the roof. No one was hurt.

The response to the failure was swift. An on-site meeting was held at which the EOR called the construction quality an ''abomination'' and recommended that every connection in the atrium be inspected. The owner retained the services of an independent engineer to both inspect the atrium and perform a design check.

The EOR initiated an in-house check of the drawings relating to the connections between the steel and concrete along the expansion joint. The check was performed by a design engineer with three years of experience (the writer of this paper). During the design check, the issue of the strength of the rods came up once again. The project manager responded that the rod was high strength and that it was covered in the specifications. Once again, the opportunity to discover the drafting errors and the changes made during shop drawings was missed. There would be no more chances.

The design check revealed that the W6 $\times$ 15.5 members forming the inside chord of the sunscreen truss would be overstressed for the support condition and splice location shown on the drawings. The check of the shop drawings showed that the splice consisted of a two-bolt end-plate connection, a pinned connection by design standards although there would be some moment capacity due to bolt eccentricity and compression. What was more alarming was that a W6 $\times$ 16 had been substituted for the W6 $\times$ 15.5. The AISC was converting from the old sizes to the new, and the W6 $\times$ 15.5 was no longer available. The W6 $\times$ 16, although slighly heavier, had only a 100 mm (4 in.) flange compared with the W6 $\times$ 15.5, which had a 159 mm (6 in.) flange. The difference was sufficient to reduce the ''design'' capacity to a fraction of the existing dead load.

This problem was discovered at 10 p.m. and the project manager was called at home immediately. He felt that a calm orderly approach to fixing the problem would be best for the project, since nerves were already raw. The following day, the construction quality control coordinator returned from the field with a photograph showing the column kinked in the middle, at the splice point, and in a condition of what appeared to be incipient buckling. At that point, the project manager called the field and advised the contractor to evacuate the atrium area and cordon it off until a repair strategy could be devised. The

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unusual nature of the load path meant that shoring the structure by conventional methods from the ground up could trigger the failure that everyone was trying to avoid.

A suitable method of top-down shoring was devised and implemented, and the EOR provided the contractor with details for strengthening the splice. The other elements of the sunscreen truss had been designed with no provision for the loads that were imposed by the cladding and would be overstressed under design wind loads. Correction details were prepared for these as well. All of the corrections were completed in November of 1979. The general feeling in the engineer's office was relief. A fatal flaw had been discovered and corrected. Disaster had been averted. No further checking was done and the 2nd fatal flaw, the deficient connection at the hanger rod/box-beam connection, was not discovered.

The independent inspection and design check of the atrium steel was completed. No problems were uncovered by either the field inspection or the design check. The problems with the sunscreen truss were not uncovered by the independent check.

Prior to the completion of the project, the general contractor filed for bankruptcy. The owner took over the construction and finished the project.

The construction was completed, and in July of 1980 the grand opening of the hotel was held.

COLLAPSE OF THE BRIDGES

A year after the grand opening, during one of the regular Friday evening tea dances, one of the connections between an upper rod and the box beam failed, triggering a progressive collapse as the rest of the connections ''unzipped'' in sequence. Eyewitness reports indicated that there were people on all of the bridges at the time of collapse, but the loads were only a small fraction of the 100 psf design load. There were far more people on the floor of the atrium under the pair of bridges as they came down.

The local failure mechanism was similar at all of the 4th floor connections. Prior to the collapse, the reaction of the rod was carried by the flange of the box beam to the webs. The flange acted as a continuous beam, with both positive and negative moments under the concentrated force from the rod. The weld on the flange bearing on the upper rod ruptured, relieving the midspan moment, forcing the flanges to cantilever off of the 5 mm (3/16 in.) webs. The webs, which were likely in a yielded condition under the self-weight of the bridges, were incapable of resisting the overload; a plastic hinge formed, and the flanges rotated up until the nut and washer slipped through the resulting gap. A similar failure mechanism formed when the upper flange of the box beam hit the nut and washer, although by that time the momentum of the bridge carried it through the failure almost instantaneously.

POSTCOLLAPSE CHRONOLOGY

Following the collapse, numerous civil suits were filed. After two years of litigation, the owner settled the lawsuits for a figure in excess of $100,000,000.

In 1983 a grand jury was convened in Kansas City to investigate whether any illegal actions led to the collapse. The issue was whether the EOR at any time was aware of the deficiency and covered it up. The grand jury investigation focused on the events surrounding the failure that occurred during construction. The grand jury found no evidence of wrongdoing on the part of the design professionals and returned a verdict of ''no true bill.''

State of Missouri Administrative Hearing

In 1984, the State of Missouri convened an administrative hearing to determine if there had been any violation of State licensing laws. The State retained two law firms and a number of expert witnesses to prove that the EOR was guilty of ''gross negligence'' and ''unprofessional conduct.'' The records of the administrative hearing, in themselves, would make a fascinating study. The list of witnesses reads like a Who's Who of structural engineering at that time. Reputable engineers testified on both sides of the issue, indicating that there really was no consensus among structural engineers as to what constituted ''standard practice.'' Lawyers for the fabricator and the American Institute of Steel Construction (AISC) sat in on the hearings. There were no representatives of the professional societies in attendance.

The fabricator and the fabricator's engineer testified that they believed that the detail shown in Fig. 3(c) depicted a fully designed connection and that the change to the detail shown in Fig. 3(e) was a minor variation that didn't require formal approval. At least one principal of a structural engineering firm testified that he personally ran calculations for each and every connection on every shop drawing that came through his office. (He offered this testimony in order to ''improve'' the profession.) Other engineers testified that they relied on the expertise of the fabricator for the connection design and that they only spot checked the connection designs implied by the shop drawings.

Faced with such a disparate and contradictory testimony, the administrative law judge found against the EOR and upheld the charges of negligence, incompetence, and unprofessional conduct.

In coming to his conclusions, the administrative judge had to pick his way through the minefield laid down by the lawyers and expert witnesses. The mixture of mutually exclusive technical arguments, taken together with the legal arguments and filtered through the judges logic, led to some curious results, as reflected in the following excerpts:

On Professionalism

> The design team functions as an independent professional advisor to the owner without an entrepreneurial stake in the project. This is reflected in the fee paid for their services. Design team members do not ''bid'' for the work. They are retained at an hourly rate (with a maximum fee) and thereby retain their independence because any profit they derive from their contract is not realistically contingent on the amount of time and effort devoted to the endeavor.
>
> The general contractor ''bids'' the project work competitively and all of its subcontractors likewise bid for the work. Competitive bidding guarantees the owner the best price for the necessary trade skills, but it is clear that this system exposes the owner to the risk of shoddy workmanship at the hands of contractors who are businessmen, *bound ethically only by the rules of the marketplace*. No statute similar to 327 regulates their conduct. Licensed professionals may be employed by the contractors, but they are no less subject to the motive of profit on behalf of their employer than any other employee. This built in conflict of interest, therefore, makes suspect any system which leaves the performance of professional engineering or architecture to such individuals and acknowledges the wisdom of the statutory scheme and construction system which presumes the lack of any such involvement. (Emphasis added).

One would expect any professional engineer working for a contractor to be horrified at the slander on his profession promulgated by the decision of the administrative law judge. Unfortunately, the profession and the industry took this as vindication of the process by which buildings are designed and built. The AISC took the decision as *carte blanche* to implement the ideas expressed in the decision in its official Code

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of Standard Practice and in its written policies. The last paragraph above, which the writer finds exceptionally repugnant, was quoted verbatim in a 1990 AISC Policy Statement issued to owners, developers, and general contractors.

Other excerpts from the Administrative Decision include:

On Overlapping Responsibilities

> In this overlapping area communication between the engineer and fabricator becomes important. The design of connections is in this category and, initially, it is up to the structural engineer to determine which connections he will design and which will be designed by the fabricator.
>
> Upon seeing a drawing and section detail where nothing is called out and the pieces required to make the connection are absent, the fabricator will know he must supply the missing pieces to make the connection and, therefore, know his design responsibility.

On Shop Drawing Review

> The contract documents require that shop and erection drawings be submitted to the engineer of record for ''review and approval. . . . Engineers never use the term 'approved' . . . upon the dubious basis that . . . insurance carriers have directed that the word 'approve' not be used.
>
> This commission finds that the review stamp . . . functionally indicates review and approval.
>
> This commission finds . . . that the term 'design concept' when used to delineate the scope of shop drawing review, means review of both the members and connections to an extent necessary to give adequate assurances to the structural engineer that the interaction of the members and connections form a stable and strong structure.

More on Shop Drawing Review

> There is no single procedure prescribed by the engineering profession for review and approval of shop drawings. The ultimate objective of any such shop drawing review procedure is to provide assurance that all structural engineering work performed by others on connections is done in accordance with acceptable engineering practice and that a qualified design professional has either performed such engineering work or reviewed such work prior to its acceptance . . . Engineering and design work on such connections should be reviewed so as to determine that it is of such quality as to assure the engineer of record that such work was actually and properly performed or thoroughly reviewed by himself or another professional engineer.

On the Design of The Connection That Failed

> This commission finds that [the detailer] did not know it was to design the connection . . . and that no one at [the detailer] undertook to do such a design in the engineering sense.
>
> Selecting stiffeners for use in strengthening a member is an engineering function. Because stiffeners are structural steel members . . . they should have been designed by [the engineers].
>
> This commission finds that, in the absence of loads and other related design information, [the detailer] reasonably interpreted the connection . . . to be a completely designed connection.
>
> This commission finds . . . that [the detailer] reasonably interpreted [the structural drawings], in the absence of more specific information, to require a minimum assembly weld for the purpose of holding the two 8 × 8.5 MC channels in alignment.

On The Missouri Statute Regarding Use of The Seal

> Missouri Statute (in part): The personal seal of a registered architect or professional engineer or land surveyor shall be the legal equivalent of his signature whenever and wherever used, and the owner of the seal shall be responsible for the whole architectural or engineering project or for the survey, as the case may be, when he places his seal on any plans, specifications, estimates, plats, reports, surveys or other documents or instruments for or to be used in connection with any architectural or engineering project or survey, unless he shall attach a statement over his signature, authenticated by his personal seal specifying the particular plans, specifications, plats, reports, surveys or other documents intended to be authenticated by the seal, and disclaiming any responsibility for all other plans, specifications, estimates, reports, or other documents or instruments relating to or intended to be used for any part or parts of the architectural or engineering project or survey.
>
> *The structural engineer is, in fact and in law, the team leader bearing overall responsibility for structural design*.
>
> While the engineer may properly delegate the work of performing engineering design functions, he cannot delegate his responsibility for the structural engineering design where it concerns professional engineering functions. This responsibility is not delegable.

On The Role of Specifications

> While the Hyatt specifications are indeed part of the contract documents and the contractors are bound to follow them, they appear in a lengthy volume along with all other specifications, making a cumbersome reference for a fabricator's detailer interested only in structural steel. The general notes, on the other hand are not only concise and to the point of the fabricator's work but are sent to the fabricator as a structural drawing, sealed with the personal engineering seal of the engineer, and contain the basic information which he is likely to need. Fabricators generally deal primarily with these structural drawings. It seems somewhat doubtful that a detailer will spend much time plowing through the specifications in search of answers to questions he may not even have.

On the ''Custom and Practice''

> In summary, this Commission rejects [the engineers] evidence characterizing the role, duties and responsibility of structural engineers under custom and practice, wherein they contend that licensed professionals are merely additional contractors on a project. The custom and practice urged upon us by [the engineers] smacks of cost benefit analysis run amok and is improperly inserted out of place in a system requiring professional judgement and integrity. It imputes to the licensed professional the same financial and economic motives as are held by the construction team. This attempt by [the engineers] to join the construction team leaves the owner and public unprotected from a hazardous activity for no greater purpose than their own convenience and financial benefit. To the extent [the engineers] do and did perform their functions as professional engineers in accordance with such an unauthorized view of their role and responsibility, their practice is not in accordance with acceptable standards of engineering practice.

An engineer experienced in design and construction might be horrified at the blithe and seemingly cavalier manner in which the administrative law judge discarded or ignored years of tradition and practice. However, the administrative hearings in Missouri were not held to determine the facts of the case. Nor were they held to evaluate the process. The administrative

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hearings were legal proceedings in which advocates argued diametrically opposed positions. Facts that supported neither side were simply not presented. The ''whole'' truth had no advocate and many of the facts of the case presented here were missing from the proceedings.

ASCE Disciplinary Hearing

In 1985, the board of the American Society of Civil Engineers held a disciplinary hearing. The EOR was found vicariously responsible for error in shop drawing process, but not guilty of gross negligence or unprofessional conduct. His membership was suspended for a period of three years. The action of the board was published, but, despite the request of the EOR, the detailed findings were not in accordance with ASCE policy.

DISCUSSION

Historically, the design and construction process has relied for its success on the collaboration of a myriad collection of conscientious professionals working in all facets of the process, on both sides of the design/construction fence. The process was never rigidly defined and the lines of responsibility were never clearly delineated. Instead, the process evolved over time and was adapted to the unique conditions on each project. It relied on the professionalism of the parties to make sure that everything that needed to be done was done.

There has never been a hard line between design and construction. Anyone who has renovated a steel building that was built in the period that preceded the Great Depression can attest to the fact that much of the design of both the members and the connections was performed by the fabricator. As likely as not, the ''design'' drawings consisted of architectural elevations, architectural floor plans, and millwork details. It wasn't until some time later that structural engineering evolved as a distinct consulting role on a project.

Lessons Learned

Having studied the events that led up to the terrible tragedy of July 18, 1981, each professional will come away with a unique set of lessons based on his or her unique experience. Some of these lessons form a recurring theme, and therefore might be judged to be elements of ''good practice.'' Several of these are offered for consideration.

1. The connection that failed was never designed. Procedures must be implemented that can reasonably assure that every connection is indeed addressed at some point during the design/construction process. Every connection on every project should be designed by a competent professional. It is not sufficient for the connection to be ''developed'' by a detailer and then verified during the often rushed shop drawing process. If the capacity of each and every connection on the job cannot be verified without reference to the piece drawings, then this requirement has not been met.
2. A ''peer review'' should involve formal review of each and every detail on the structural drawings, as opposed to ''spot checking'' to get an overall feel for the quality of the design. The peer review should encompass connection details as well as primary structural systems and elements, even if this means that the peer reviewer must look at shop drawings.
3. The opportunity to discover the problem was missed on several occasions. When questions come up (i.e., the question regarding the strength of the rods) they should be answered by reference to the documents. What a person remembers and what is on the documents are quite often two different things. Also, if there is a question on one item it may be an indication that an area of design has not been completed. (This policy must be instituted and cultivated at the principal level, since principals are the ones who are most often ''taken at their word.'')
4. Changes in personnel interrupt the ''thought process'' on a project and create a much greater risk of errors creeping into the process. When such changes are unavoidable, special precautions should be taken to assure a smooth transition. Requiring an engineer—other than the EOR—to design connections builds in a formal obstacle to quality by requiring a change in personnel.
5. Changes in concept, however small or seemingly insignificant, should be handled through a formal process that forces the participants to focus on the issues involved. Changes should never be made over the phone or on shop drawings, unless they are clearly identified as such.

Lessons That Were Not Learned

1. The implications of structural failures, even though they are relatively rare, are far too serious for the scope of services to be defined through a ''low bid'' process.
2. City building departments do not—and cannot—provide adequate checking on major projects. A formal peer-review process on such projects should be mandatory. Peer reviewers should be excluded from liability by law and should be held to a higher standard of qualifications than ordinary engineers.
3. Structural engineers cannot continue to allow the legal profession to define the duties, obligations, and specific actions that constitute ''good engineering practice'' on a case-by-case basis after the fact.

Changes in Practice

The practice of engineering evolved differently in different areas of the country, and it continues to evolve in response to market and technology pressures; so it is difficult to attribute a particular change to the Hyatt collapse alone. The collapse is simply another element of the context in which the professional engineer operates. Perhaps it is less common for a principal to seal all of the drawings prepared by his or her firm. It is much less common nowadays for fabricators to have professional engineers on staff. The trend toward shedding responsibility seems to have promoted a bimodal distribution of fabricators: a few who offer professional services and a lot who do not. The discussion as to who performs the design of connections rages on—witness the evolution of Section 3.1 of the AISC Code of Standard Practice (Table 2)—with different flavors in different areas of the country. In the writer's firm, structural steel detailing is now offered along with structural engineering. This came from a realization that the only time all the connections are truly defined (designed) is when the detailing is completed.

CONCLUDING REMARKS

In the flurry of charges and countercharges that inevitably followed the tragic Hyatt collapse, the argument was made that structural engineering consultants had somehow been shirking their responsibilities and that the profession should return to the ''good old days'' when engineers truly designed everything. Since the collapse, the writer has had occasion to work on a number of steel structures that were originally built in the first few decades of this century. By and large, the structural drawings from that era showed much less detail than is common practice today. The inescapable conclusion is that a

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TABLE 2. Evolution of AISC Code of Standard

AISC Code of Standard Practice Seventh Edition (Blue Book) 1970

Section 1 (b) Plans and Specifications for Bidding

In order to insure adequate and complete bids, plans and specifications accompanying the invitation to bid show:

1) A complete structural steel design including any detached items such as loose lintels, clearly showing the work to be performed and giving sizes, sections and relative location of all members, with sufficient dimensions to convey accurately the quantity and nature of the structural steel.

2) Wind bracing, moment connections and other special details, in sufficient detail regarding parts, fasteners and welds so that they may be readily understood and supplied.

Section 4 Drawings and Specifications

4 (a) To enable the fabricator and erector to proceed expeditiously with the work, the owner furnishes as soon as possible a survey of the construction site or the lot lines and necessary sets of complete structural steel design drawings and specifications consistent with the original bidding plans and specifications. These show:

1. The design of the bridge or the structural steel framework establishing the location of all structural steel items, including detached items, and the location and size of all openings, holes, etc.

[. . . etc. . .]

4 (c) When shop drawings are made by the fabricator, prints thereof are submitted to the owner for his examination and approval. In order for the fabricator to commence shop work, the owner must return one set of prints to the fabricator (customarily within five days) with a notation of the owner's outright approval or approval subject to corrections noted. It is usual practice for the fabricator to make the corrections and to furnish one set of corrected prints to the owner.

AISC Code of Standard Practice Eighth Edition (Red Book) 1980

Section 3.1 Plans and Specifications

In order to insure adequate and complete bids, the contract documents provide complete structural steel design plans clearly showing the work to be performed and giving the size, section, material grade and the location of all members, floor levels, column centers and offsets, camber of members, with sufficient dimensions to convey accurately the quantity and nature of the structural steel to be furnished. Structural steel specifications include any special requirements controlling the fabrication and erection of the structural steel.

3.1.1 Wind bracing, connections, column stiffeners, bearing stiffeners on beams and girders, web reinforcement, openings for other trades, and other special details where required are shown in sufficient detail so that they may be readily understood.

3.1.2 Plans include sufficient data concerning assumed loads, shears, moments and axial forces to be resisted by members and their connections, as may be required for the development of connection details on shop drawings and the erection of the structure.

3.1.3 Where connections are not shown they are assumed to be in accordance with the requirements of the AISC Specification.

Section 4.2 Shop and Erection Drawings

The fabricator includes a maximum allowance of fourteen (14) calendar days in his schedule for the return of shop drawings. . . .

4.2.1 Approval by the owner of shop drawings prepared by the fabricator indicates that the fabricator has correctly interpreted the contract requirements. This approval constitutes the owner's acceptance of all responsibility for the design adequacy of any connections designed by the fabricator as part of his preparation of these shop drawings.

AISC Code of Standard Practice Ninth Edition (Green Book) 1989

Section 3.1 Plans and Specifications

Project specifications vary greatly in complexity and completeness. There is a benefit to the owner if the specifications leave the contractor reasonable latitude in performing his work. However, critical requirements affecting the integrity of the structure or necessary to protect the owner's interest must be covered in the contract documents. The following checklist is included for reference: (Followed by a list of codes, standards, etc.)

Section 4 Shop and Erection Drawings

4.1 The owner's responsibility for the proper planning of the work and the communication of all facts of his particular project is a requirement of the Code, not only at the time of bidding, but also throughout the term of any project. . . . [etc.]

4.2 In those instances where the fabricator develops the detail configuration of connections during the preparation of shop drawings, he does not thereby become responsible for the design of that part of the overall structure. The Engineer-Of-Record has the final and total responsibility for the adequacy and safety of a structure, and is the only individual who has all the information necessary to evaluate the total impact of the connection details on the structural design. The structural fabricator is in no position to accept such responsibility for two practical reasons:

a) The structural steel plans may be released for construction with incomplete or preliminary member reaction data, forcing a review by the Engineer at the time of approval.

b) Few fabricators have engineers registered in all of the states in which they do business

In practice the fabricator develops connection details which satisfy two basic criteria:

a) Suitable strength and rigidity [etc.]

b) Accommodates the fabricator's shop equipment.

Since each shop has different equipment and skills, the fabricator is best suited to develop connection details which satisfy the second requirement. However, the overriding first requirement necessitates acceptance of responsibility and approval by the engineer.

significant amount of the design work in those days was performed by engineers working on the construction side of the fence. The design drawings evolved as a mechanism for obtaining competitive pricing, and, as such, they needed to show only sufficient details to allow an accurate assessment of the scope by competent professionals working for the contractors. Design and construction was a collaborative effort of professionals working on all sides of the fence.

Structural engineers cannot continue to allow the legal profession to define the duties, obligations, and specific actions that constitute ''good engineering practice'' on a case-by-case basis after the fact. A formal definition of detailed standards for both design and drawings is a necessity. One of the reasons the profession finds itself in this predicament is that it has not paid sufficient attention to its history. There is no place for young engineers to go to learn how and why the custom and practice of structural engineering has evolved the way it has over time. The profession continues to pay a heavy price for this lack of historical perspective. Without a history, it can't be a profession.

Buildings are not like automobiles and airplanes. It is not possible to build and test prototypes to work out the bugs. Nor is it possible to design and draw every detail without overly constraining the construction activities. We are faced, then, with a system that requires building from less than complete drawings, working in less than ideal conditions, with laborers of uncertain skills. Such a system cannot help but produce more failures unless there are conscientious professionals working on all sides all the way through the project. To suggest otherwise is simplistic and unrealistic. The fact that there are so few failures is a credit to the professionalism of both the construction and the design professionals that design and build modern projects.

APPENDIX. BIBLIOGRAPHY

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