I-35W Highway Bridge Collapse

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On the fateful evening of Wednesday, August 1st, 2007, the interstate highway bridge I-35W over the Mississippi River in Minneapolis, Minnesota catastrophically failed resulting in 13 deaths and 145 injuries (National Transportation Safety Board, 2007). In the aftermath, Figure 1 shows that nearly 1,000 feet of the 1,907 foot-long bridge (deck truss) collapsed with nearly 50 percent of that portion (458ft) falling into the river (National Transportation Safety Board, 2007). After the bridge's collapse, the subsequent investigation that was conducted by the National Transportation Safety Board (NTSB) would go on to detail a long-standing history of negligent maintenance performance by the bridge's developer and overall disregard by federal and state authorities to proactively address the concerns of what many engineers expressed. In addition to the substantial list of ethical lapses that contributed to this disaster, the design firm expressed considerable shortsightedness in the final design of the bridge, which if addressed properly, could have prevented a failure of this magnitude.

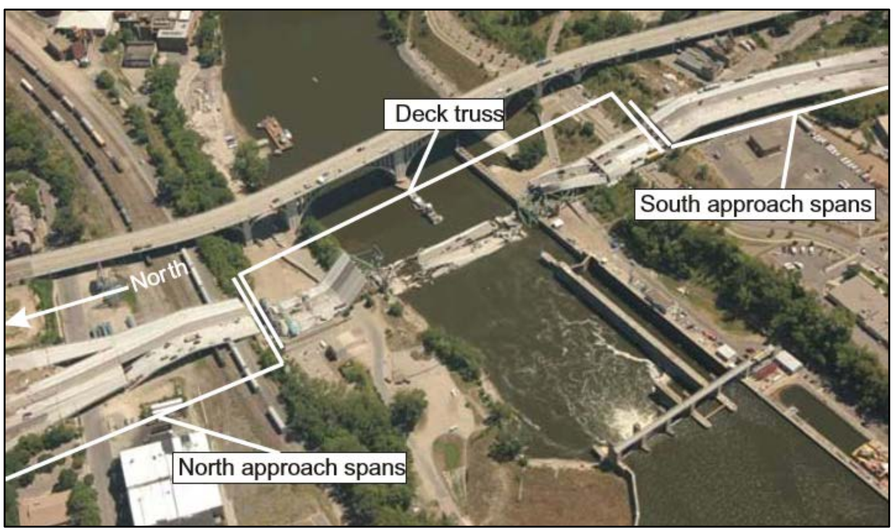

Figure 1: Aerial view of the I-35W Bridge after the collapse
(National Transportation Safety Board, 2007)

In order to begin to comprehend the failures that occurred that day, it is crucial that one understands several key features of the bridge as well as a few fundamental engineering concepts relating to the construction of any bridge. Designed in 1964 and commissioned for use in 1967 by the St. Louis based engineering consulting firm, Sverdrup & Parcel and Associates, the warren-type deck truss was utilized in an effort to somewhat simplify the overall design calculations and reduce costs (National Transportation Safety Board, 2007). Simply put, a truss bridge is, "composed of straight structural elements connected to form triangles. In large structures, the ends of the members are connected with gusset plates which are essentially, "metal plates used to unite several structural members in order to withstand heavy load (weight) on the bridge deck" (National Transportation Safety Board, 2007). The following figures (2 and 3) are utilized to display how a deck truss and gusset plate are configured. In addition, another very important feature of this bridge is that the structure was known as "fracture critical", meaning that the failure of any one of its supporting structural members could result in the collapse of the whole bridge (LePatner, 2007). However, during the era in which this bridge was constructed, these types of bridge designs were not uncommon to see. In fact, according to a 2008 article, nearly 12,600 bridges of this same design are still in use today (LePatner, 2007).

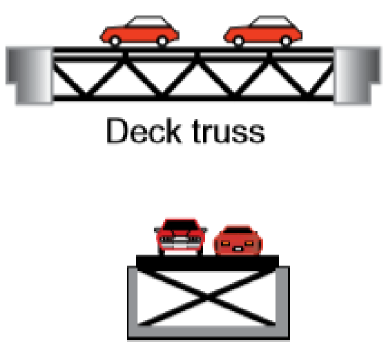

Figure 2: Representation of a Deck Truss Bridge
(National Transportation Safety Board, 2007)

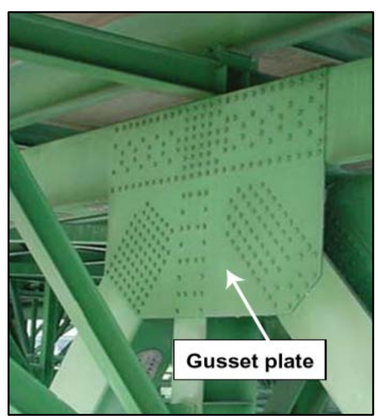

Figure 3: Actual Gusset Plate from I-35W Bridge
(National Transportation Safety Board, 2007)

After an extensive investigation of the bridge's failure, the NTSB concluded that the collapse of the I-35W Bridge was the result of design errors made by the consulting firm in the gusset plate at the U10 position (seen in Figure 4). The thickness of the U10 gusset plate was determined to be far too thin to withstand the combined effect of the self-weight of the bridge, vehicle traffic, and construction loads (Robles Lora, 2013). As of today, it is still unclear why this gusset plate was improperly designed, but several theories point toward an overall failure in design process by the consulting firm. Ultimately, the excessive bridge load present on the day of the collapse is what would eventually expose this fatal design flaw.

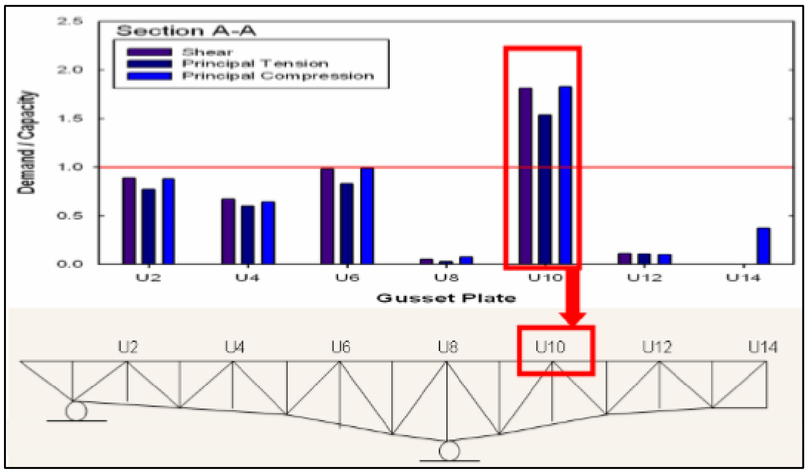

Figure 4: Bridge Capacity/Demand with respect to each Gusset Plate
(Holt & Hartmann, 2008)

The conclusion from Figure 4 is quite simple to understand. By focusing on the U10 gusset plate (highlighted in red), it is obvious that the force on the bridge (demand) was far greater than the capacity for which it was built to handle. This is clearly seen by the indication of the maximum demand to capacity ratio indicated by the solid red horizontal line. On the day of the collapse, several pieces of construction equipment and aggregate (crushed rock, sand or gravel) were brought onto the bridge and positioned directly above the U10 gusset plate in attempt to resurface the bridge deck (road surface). As the NTSB would later report, the appropriate placement of construction loads on the bridge during repair or maintenance activities was never discussed due in large part to a severe lack of guidance between bridge officials

(Robles Lora, 2013). Unfortunately, this lapse in judgment would be prove to be the initiator in the bridge's collapse.

While the explanation for this bridge's collapse may seem obvious up to this point, it would not be complete without understanding Sir Isaac Newton's third law of motion. By definition, the law states that for every force exerted on an object, there is an equal and opposite reaction force. In essence, this means that in order for an object to reach and maintain equilibrium (stable condition), the forces must balance each other out in both the *x*, *y* and even *z* directions. Nowhere is this law more evident than what is shown in the following figure. According to Figure 5, there is indisputable evidence that the U10 gusset plate was experiencing such an excessive force in the downward (z)-direction that it had actually began to bow outward prior to the collapse. The subsequent upward force in the (z)-direction of the bridge was not nearly enough to keep the bridge in equilibrium, resulting in catastrophic failure. For convenience, a red line was added to indicate the original position of the plate if it had been properly designed in accordance with Newton's third law.

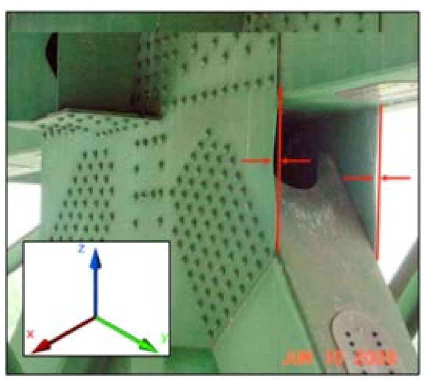

Figure 5: Bowing of Gusset Plate U10 Prior to Collapse
(Hao, 2010)

Shockingly, Sverdrup & Parcel's inadequate design of the I-35W Bridge was only the beginning of a story riddled with ethical lapses in judgement. In looking back through extensive reports which detailed the events leading up to the collapse of the bridge, there was overwhelming evidence to suggest that there was an ongoing failure by the Minnesota Department of Transportation (MnDOT) to provide the necessary maintenance for a bridge that had been deteriorating for many years (LePatner, 2007). In fact, according to a book published in 2010 by Barry LePatner, “in 1991, based upon a litany of reported signs of deterioration, I-35W Bridge inspectors downgraded the bridge’s previous rating of “satisfactory”, to “poor” or “structurally deficient” (LePatner, 2007). Of course, one would have expected that with such a drastic drop in the bridge’s rating, MnDOT would have absolutely obliged in making the necessary corrections. This, however, could not be farther from the truth of what occurred. For nearly 16 years until the collapse in 2007, MnDOT continued to treat the bridge as if it was “structural safe”, despite not only receiving millions of dollars in federal funding, but repeated warnings of catastrophic conditions from outside engineering firms (LePatner, 2007). All in all, it may never be known officially why the people at MnDOT exhibited such gross negligence, however, it is apparent that this event could have otherwise been avoided if proper caution and procedures were utilized in a serious and ethical manner.

In light of the findings which almost explicitly place the collapse of the I-35W Bridge on the officials at MnDOT, it should go without saying that the ethical implications of this tragedy are shared throughout all the associated parties. Despite repeated attempts by several engineering consulting firms to shed light on the deteriorating condition of the bridge, it was clear that MnDOT’s personal agenda would never align with the news they were receiving from outside entities. As Henry Petroski once described NASA in his 2003 article “Failure Is Always an Option”, perhaps the actions of MnDOT officials could also be better understood by examining the culture that arises from the inevitable tension between management and the outside engineers tasked with the actual completion or maintenance of a project (Petroski, 2003). As the United

States began to shift its efforts towards providing more safety redundancies in all of its infrastructure design, it left the I-35W Bridge in a peculiar spot. It either had to be fixed at expense of millions of dollars or, be left to deteriorate beyond reasonable limits. As a result of this predicament, it is likely that the two parties fought immensely over whether or not the capital expense required to fix the bridge was necessary or not. Sadly, the eventual fate of the I-35W Bridge was left to the overwhelming influence of cost saving measures.

While it is deeply concerning that such egregious errors were made for so long, it is important to reiterate that in the face of all these obstacles, engineers must continue to uphold their highest integrity and ethical obedience in whatever endeavors they happen to encounter, regardless of political or managerial backlash that may ensue. Had this sense of morality prevailed, engineers would have spent more time in designing a properly sized gusset plate. Furthermore, they would have never approved the deployment of the construction equipment on to the bridge without carefully analyzing the potential effects that it would cause.

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