Autoroute 19 de la Concorde Overpass Structural and Ethical Failures

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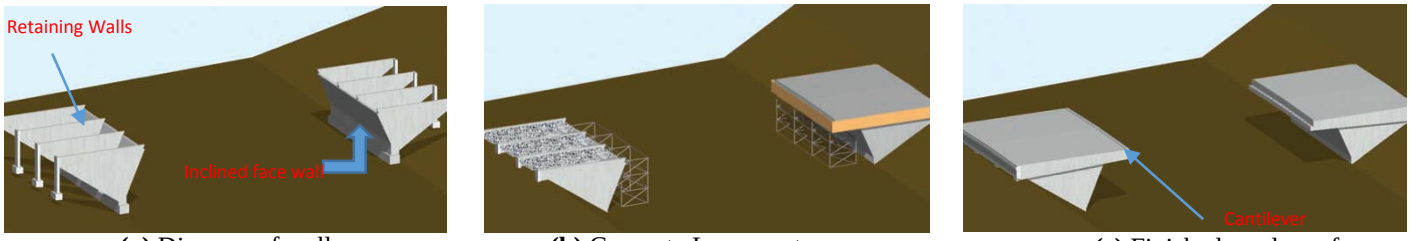
(Commission of Quebec, 2007)

During the afternoon of September 30, 2006, three lanes of the Concorde Overpass buckled onto six lanes of Quebec Autoroute 19. Unfortunately, this horrific incident claimed the lives of five people and critically injured six (“Canada Overpass Collapse”, n.d.). The collapse managed to completely crush two cars and sent three others and a motorcycle 20 feet below the overpass. However, surprisingly, the three westbound lanes remained intact. Analyses done before and after the collapse, make it clear that the deteriorated concrete and the lack of proper placement of supports led to the eventual downfall of the Concorde Overpass. This horrific situation could have been avoided if these failures were noticed at the times of regular inspection, or better regulations were laid out at the time of construction.

Since the time the overpass was conceived in the 1960’s there had been many problems leading up to this fatal disaster. As far back as the 1980’s inspections found that there were cracks in the bridge, but it was not a sufficient enough of an issue to be dealt with. In 1992, the joints in the bridge were replaced, but large amounts of concrete had to be removed to do this; hence severely weakening the structure. Finally, in 2002 the condition of the bridge was downgraded from “good” to “acceptable” but, strangely, it was again upgraded in the reverse without any changes being made (“Papineau Autoroute Historic Overview”, n.d.). Eventually, according to Dennis Mitchell, a civil engineering professor at McGill University, the concrete was in such a poor state that only 20% of the concrete retained structural integrity. The cracks found in 2004 should have served as a warning sign to make changes to the bridge and prevent its ultimate collapse.

There is not one overarching factor that contributed to the downfall of the bridge. Based on the report published by the Commission of Inquiry, the collapse of the bridge can be attributed to a chain of physical events. To understand these mechanical failures that resulted in

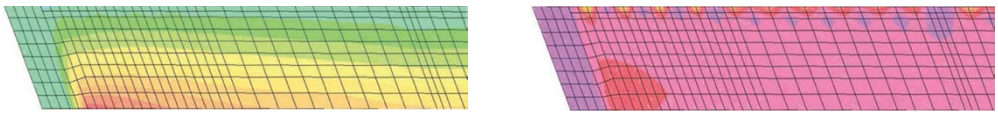
issues for the bridge, one must understand the main structure. The bridge was made up of two abutments, as shown in the three components of Figure 1, which are supporting walls at the sides of the overpass. Each abutment consisted of an inclined wall and four retaining walls. The latter had a thick layer of concrete, some of which extended over the inclined face, forming a cantilever.



(a) Diagram of walls **(b)** Concrete Layer on top **(c)** Finished product of abutments

Figure 1: Construction of abutments (Commission of Quebec, 2007).

A bending moment is the result of the forces on a section causing it to rotate about a point or bend inwards. A shear force is the forces in play within beams to balance an external load ("Analysis of Beams Shear Force and Bending Moment Diagram", n.d.). Figure 2(a), shown on the bottom left, shows the bending moment, and 2(b) on the right shows the shear force under the pressure of a dead load, or the weight of all of the structural components. The darker red/pink areas in figures 2(a) and 2(b) below indicate the greater force. This additional force was mainly due to the sidewalks, which created stress at the edges of the cantilever. It was concluded from this stress analysis that additional reinforcement would be needed to counteract the load that would be present on the cantilever portion of the overpass. This added support could have come in the form of vertical bars anchored to the top and bottom of the cantilever slab (Commission of Quebec, 2007).



(a) Bending Moment Distribution **(b)** Shear Force Distribution

Figure 2: Moment and Force Pressures on Various areas of bridge (Commission of Quebec, 2007).

During the construction of the de la Concorde, the designers assumed that there was an equal load distribution over the entire overpass. This analysis was done using a unit slice of overpass that was assumed to be representative of the entire structure. Hence, engineers did not realize the effects of the structure being skewed at the southeast and northwest corners of the abutments. This was an error that could have been caught by way of the regular inspection. This skew created sharp stress concentrations at the corners of the cantilevers. Since this skew was underestimated at the time of construction, the load concentrations were not accurately calculated (Commission of Quebec, 2007). This concept can be understood by a simple force analysis. The load on the overpass is distributed over the various portions of the bridge, but, not equally. Hence, the force acting down on the edges of the overpass could not be counteracted by the normal force, or the force acting on the load by the bridge in the cantilever region. This can be compared to a simple wood table that cannot sustain the weight of everyday objects being placed upon it due to improper construction.

Another major issue could be attributed to the specific bars placed within the cantilever. For example, the #8 and #6 bars were not properly anchored to the top bar (see Figure 3). This faulty anchoring created a weak zone that could not handle a large load, as described previously (Commission of Quebec, 2007). This error, though it may seem small, effected the daily use of the bridge.

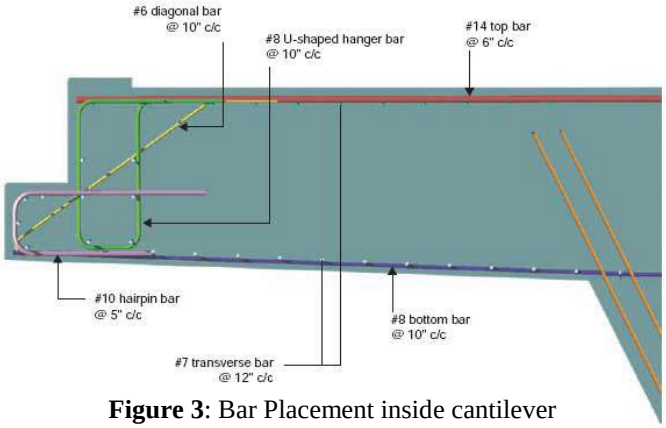


Figure 3: Bar Placement inside cantilever (Commission of Quebec, 2007)

However, there were other issues that factored in to the collapse. This includes the usage of poor quality concrete, or concrete that wore. Tests showed that the bridge barely had the strength it should have had after 36 years, only 28 days after construction. This is especially a problem considering that concrete should get stronger over time. In addition, further tests revealed that the condition of the concrete deteriorated with the use of de-icing salts, which are widely used in the snowy Canadian winters. By some accounts the degradation of the concrete was so bad that water was able to surge deep under the pavement (Commission of Quebec, 2007). The contribution of the additional stress and weak zone sums up the main issue with the construction of the overpass.

With the structure failing structurally in almost every possible way, it would seem to be the only possible problem surrounding the incident. However, the ethical troubles that came with the collapse are almost as bad. An inspection within just ten years after construction of the bridge revealed surface cracks, but nothing was done about it. In addition, a report released on the failure of the bridge showed that there were lackluster procedures used during inspection. For example, in an examination in 2004, the investigation was completed in approximately two hours, and not all of the abutments were looked at. Also, the Commission found evidence in their investigation that security personnel were aware of the unorthodox design of the bridge, but essentially did not collaborate with the Ministry to come up with better standards (Commission of Quebec, 2007). From the investigation it was evident that there were many missed opportunities in fixing the bridge However, the code was one of the biggest problems of the entire fiasco. The code used during the construction became so outdated over time that the people who constructed the bridge and those who were inspecting it also could not be fully blamed (Commission of Quebec, 2007).

The collapse of the de la Concorde overpass is an extremely tragic event, resulting in the loss of lives. One of the biggest challenges in finding an answer to the collapse is locating the many factors that contributed to its demise. It is hard to lay blame on one person or one specific flaw; but, the faulty design of the cantilevers and the bars within, which were not enough to carry the load, would be a place to start. The failure of the overpass brought out many ethical failures surrounding the inspection of the bridge, especially dealing with code regulations that made it very difficult to analyze the true situation of the bridge. However, it is safe to say that a better design at the time of construction would have not resulted in the same scenario.

The result of the Autoroute 19 de la Concorde Overpass collapse exposed many engineering flaws, and simple ethical failures that should not be repeated. “No one knows a machine or its failure modes as well as the engineers who created it…” (Petroski, 2003). If the engineers inspecting the overpass had a better understanding of what could be done to improve the condition of the bridge, this catastrophe may not have occurred. Unfortunately, however, bridge collapses continue to occur on a fairly regular basis. This shows that many ethical discrepancies are, even to this day, not controlled. The only way to fix this problem would be to lay down strict guidelines, and have thorough checks of the bridges more regularly. The fact that this structure was constructed in a faulty manner to begin with shows that it was not just a simple case of deterioration over time, but just a disregard for the regulations, or lack thereof, from the start. These mistakes, some of which may seem minute, can have serious consequences, including the loss of lives, as evidenced by this collapse.

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