

All Fall Down: The Hartford Civic Center Roof Collapse

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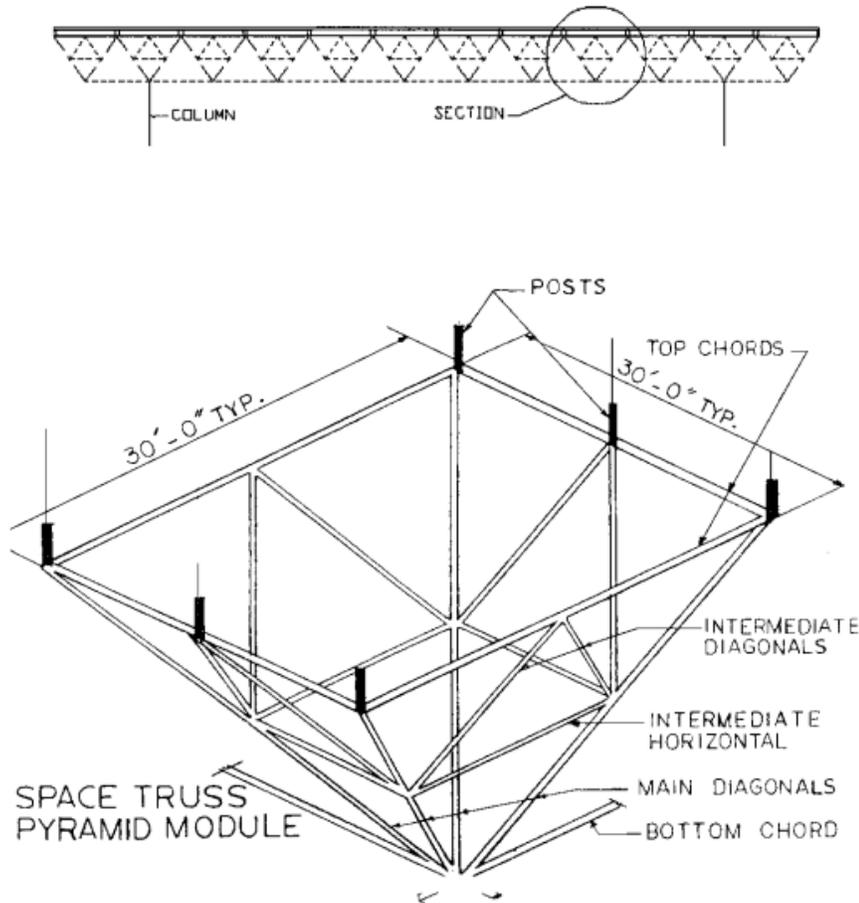
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A catastrophic event in the early morning of January 18<sup>th</sup>, 1978 proved to be a chilling near miss for thousands of citizens in the city of Hartford, Connecticut. The previous night, nearly 5000 fans had been inside the Hartford Civic Center cheering on the University of Connecticut basketball team's victory (Gammell, 2012). Mere hours later, the entire roof collapsed into the empty arena. While a record breaking snowfall had fallen over the course of the night, it was only the straw that broke the camel's back. Several key design flaws and unethical decisions doomed the Civic Center's roof before construction was even completed. The examination of the design errors involved lends an important dimension to the prevention of future structural failures. A close study of the decisions behind the construction process and ultimate collapse emphasizes the repercussions of unethical engineering.

The design of the Hartford Civic Center roof was highly innovative for the time. The Fraoli, Blum, and Yesselman engineering firm proposed a design using a space frame roof measuring 300 by 360 feet. This roof would eliminate the need for columns inside the arena in order to improve visibility from all sections. The roof was formed by an upper and lower layer of horizontal steel bars separated by 21 vertical feet (Martin & Delatte, 2001). They were connected by diagonal beams braced by additional bars in the center, forming an inverted pyramid support structure. The bottoms of the pyramids were connected in a cross formation to create the bottom layer of the roofing structure. A schematic of the design is shown in Figure 1.



**Figure 1.** The space frame roof design consisted of two layers of steel bars connected by pyramidal trusses with the lower layer in cross formation (Martin & Delatte, 2001).

The roof structure was considered to be on the cutting edge of design, but several key flaws were present. The cross formation of the bottom layer was known to be incapable of carrying highly compressive loads and was prone to buckling. Compressive forces press down on the structure while tension forces act to pull the structure apart (Krishnamurthy, 2007). The usage of posts at each corner of the top layer of bars supported the roof but concentrated the weight at points instead of along the entire bar, increasing the pressure on the corners, or nodes. These initial structural errors, while serious, could have been corrected with careful calculations

by structural engineers before the final design was submitted. However, the usage of a complex computer model to test the roof design gave a false sense of security to the safety testing process.

The computer model was assumed to be highly accurate by the design engineers; in reality, the model oversimplified the forces associated with the roof design. Forces along the intermediate braces were not considered, and connections at the corners and outside edges of the structure were incorrect; in addition, a buckling scenario was not examined (Krishnamurthy, 2007). The dependence of the design engineers on a flawed model led to the approval of a dangerously unstable roof design.

The construction process began in 1972, with the assembly of the roof completed at ground level in order to save money. The roof was then lifted into place using hydraulic jacks. At this point, serious deflections, or displacement of beams under the presence of a heavy load, were detected at several of the nodes (Martin & Delatte, 2001). The design engineers were contacted and said the deflections from the original design were expected. The construction manager then urged last minute fixes to connect displaced beams in order to assembly on time. In addition, the design plans were not followed at the corner connections on the top layer of bars; the diagonal beams were connected several inches lower rather than firmly in the corner, which led to insufficient bracing that was unaccounted for (Krishnamurthy, 2007). The severely compromised roof was completed in 1973, and began showing signs of progressive collapse such as bending of the members for the next five years leading up to the incident.

The city of Hartford appointed Lev Zetlin Associates to determine the causes of the roof collapse. The report listed the main causes as excessive overloading of the compressive forces on the top layer of the truss structure by as much as 852% (Krishnamurthy, 2007). The overloading was due to the corner connections being less braced due to the changes to the diagonal bracing

design during construction and several missing midpoint braces throughout the structure, as well as a low estimation of the actual weight of the roof. When the snowfall occurred, several overstressed beams on the top layer buckled, which changed the forces acting on the lower layer from tension to compression. The diagonal beams were unable to brace the structure and the roof collapsed. The Hartford Civic Center is shown on the day of the incident in Figure 2.



**Figure 2.** An aerial view of the Hartford Civic Center after the roof collapsed on January 18th, 1978 (Gammell, 2012).

An examination of some of the key decisions and lack of action present in the construction process of the Hartford Civic Center roof highlights the importance of engineers holding safety of the public paramount and ethics in the highest regard. The first error in ethical decision making was the failure of the design engineers to perform hand calculations to check the computer model's calculations. The engineers trusted the computer optimization and failed to comprehend its limitations. Grievous ethical errors were also made during the construction process; when the architects of the roof recommended hiring structural engineers to oversee

assembly, the construction project manager refused in order to save money (Martin & Delatte, 2001). As a result, no one realized the implications associated with the large deflections during assembly, which should have immediately alerted a structural engineer of the construction and design flaws. Several of the ironworkers on the project had said they knew the bowing in some of the members spelled disaster for the roof; their concerns seem to have been left unaddressed (Martin & Delatte, 2001). The multiple ethical failures during the building of the roof contributed greatly to the eventual collapse.

Several lessons can be learned from the engineering mistakes in Hartford. In light of the incident, Connecticut is one of the few states that require peer reviews of structural designs for public buildings (Gammell, 2012). Safety checks should be increased for buildings with higher occupancies to prevent similar disasters. In addition, the presence of structural engineers' inspections during construction is crucial to the success of buildings. Finally, dependence on computer modeling should be monitored, with room for error allowed rather than a narrow optimization with no redundancies in the design for safety purposes.

The Hartford Civic Center roof collapse highlights the duty of engineers to act ethically under all situations and to protect the public. Engineers face a huge responsibility to create safe products to improve the lives of their communities; this responsibility should not be taken lightly when faced with difficult decisions such as cutting costs or admitting mistakes. The catastrophic combination of structural and ethical issues leading to the roof collapse in Hartford should serve as a lesson to future engineers to act with the ultimate caution and respect for the public who must trust in their decisions.

## References

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