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Forensic Engineering Investigation of a Long Span Wooden Truss Failure During Erection

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Abstract

With about one third of the long span wood trusses in place for a 60' by 100' building being constructed as a convenience store, the trusses already erected fell over like dominos injuring three laborers. The three workers sued a number of parties involved in the project including the crane rental company and the manufacturer and supplier of the trusses, claiming that they shared responsibility for the accident and that they should have taken action to prevent the collapse. The author was retained as an expert witness for the crane rental company. Investigation and analysis of available facts established that the crane rental company was not responsible and should have had no liability.

Keywords

Forensic Engineering, Construction Safety, Construction Accident, Long Span Wood Trusses, Construction Management Responsibility.

Background

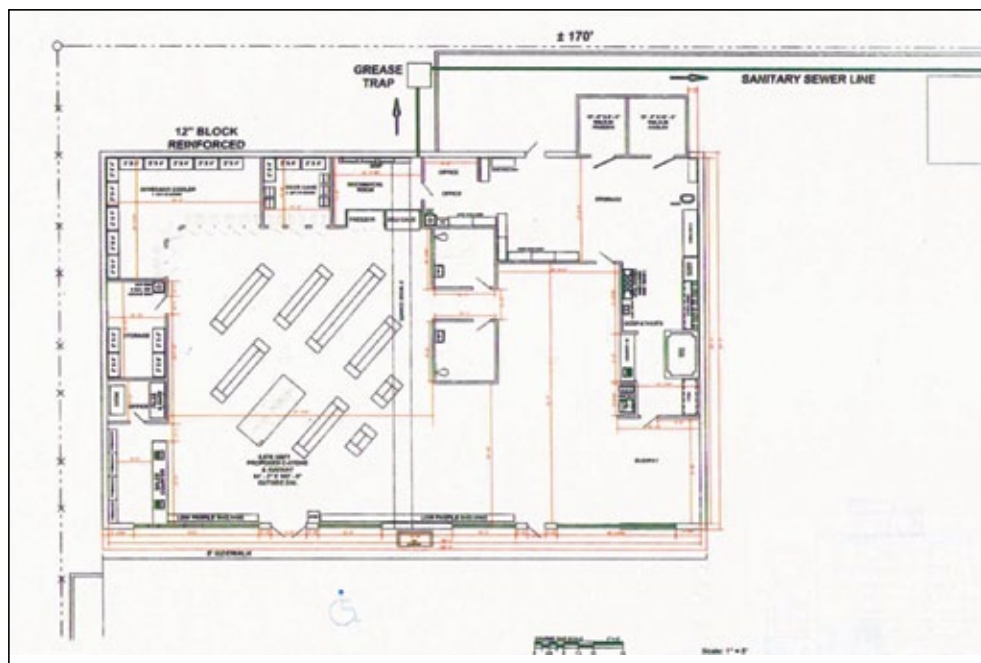
A Mid-Atlantic corporation that owned a chain of convenience stores decided to establish one in a small town that lacked such a facility. The normal practice for the corporation was to buy or lease the property for their stores and build the structures themselves, performing as their own general contractor using subcontractors for specialty work. Due to the geography of the area there were few suitable sites, but after reconnaissance one was located. However, the owner of the property was not willing to sell or lease the property so the corporation could build on it. Instead, the owner of the property wanted to build the facility himself and then lease it to the corporation.

Agreement was reached between the corporation and the property owner. The facility would be built "according to plans and specifications" that were to be provided by the corporation. The corporation provided two drawings to the owner as a concept submittal, an architectural front elevation and an interior floor plan showing partitions and equipment layout, see below. The owner retained his father as prime contractor to build the project, including obtaining all necessary permits and approvals. The contractor told the owner and the corporation that the two provided drawings were sufficient for his purposes and that he did not want any further detail.

The contractor applied to the local building authority for the construction permit without including any drawings except perhaps for the two below (there is no record of any drawings being submitted). When the building authority was contacted during investigation a year and a half after the accident, there were no drawings in the approval file. Among the missing documents were foundation, structural, plumbing, electrical, and civil plans. The building authority granted the permit upon the contractor's promise that the necessary drawings would be provided. They never were, in spite of several requests by the building authority's inspectors for them. According to the building authority's records, the contractor also failed to call and request compliance inspections at key points during construction, including footing inspections, buried plumbing inspections, electrical inspections, etc. As a result, no inspections were conducted during the early phases of construction.



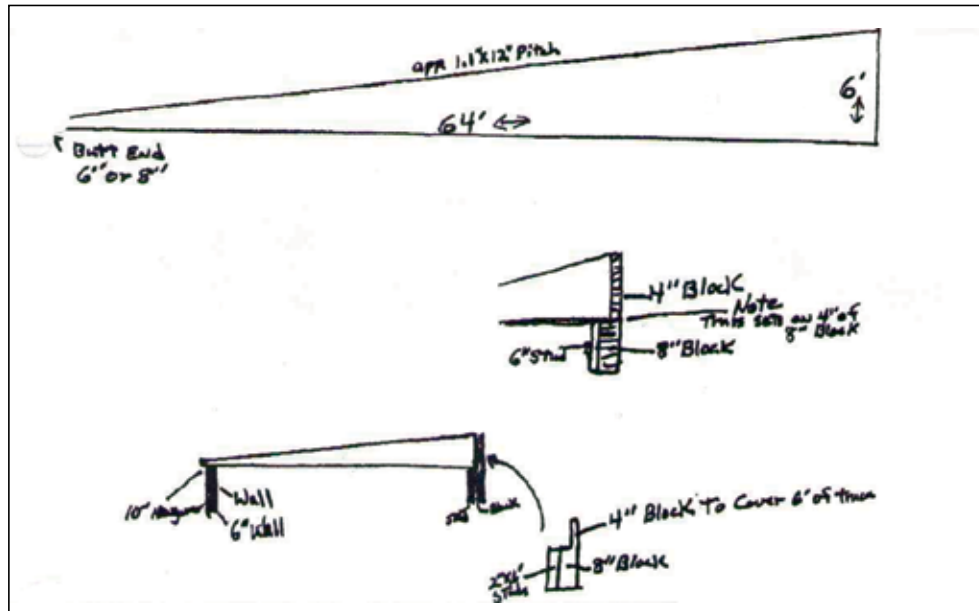
Front Elevation



Interior Plan View

Standard practice of the corporation was to have an architectural/engineering firm produce a full set of construction drawings. All previous similar facilities were built with reinforced concrete masonry unit (CMU) walls and lightweight steel roof trusses. Early in the construction effort the contractor said he was having difficulty hiring masons to erect the CMU walls so he asked for and obtained permission from the corporation to build only the front wall with CMUs and the other three exterior walls with wood framing. He also asked for and received concurrence to build the roof system using wood trusses.

With the assistance of the wood truss supplier, the contractor prepared a sketch of the roof cross section. The supplier used that sketch to order the wood roof trusses from the manufacturer who designed, manufactured and shipped them to the construction site. See the contractor's sketch of the roof cross-section below.



Roof Cross-Section and Details

The Incident

In June 2010, the long span wood roof trusses were being placed on the exterior walls. A rental crane company had provided the mobile crane and its operator to a subcontractor who was installing buried fuel tanks for the facility. When the tanks were in place, the prime contractor approached the crane operator and asked if he could assist with setting the 60 feet long wood trusses in place. After checking with his supervisor by telephone, the crane operator had the contractor sign a short contract for rental crane services and proceeded to lift the wood trusses into place, where they were aligned, temporarily fastened in place, and disconnected from the crane's slings.

When the trusses were delivered to the jobsite, the prime contractor signed for them on a page that included the statement, "Failure to follow instructions and or consulting (sic) a registered professional engineer for installing & bracing requirements, will most likely result in serious injury or death or damage to structures." The prime contractor admitted that he had neither read the installation instructions nor retained the services of a professional engineer to assist with the safe installation of the trusses.

The prime contractor himself was supervising this operation and directing activities during the roof erection using local laborers he had hired two days before the incident. When about two thirds of the trusses were in place, the trusses fell over like dominos, injuring three workers who had been spotting, fastening, and disconnecting them from the crane or supporting the operation from the floor of the building. Photos 1 and 2 show the structure after the collapse. Note the lack of bracing of exterior walls.



Photo 1
Front of Building After Collapse of Trusses

The incident triggered an OSHA investigation the following day that resulted in a number of citations for SERIOUS violations:

1. “The employer did not furnish employment and a place of employment which were free from recognized hazards that were causing or likely to cause death or serious physical harm... employees were exposed to crushing injuries...”
 - a. “...there was no top chord and bottom chord temporary diagonal bracing...”
 - b. “...there were no ground braces leading up to each temporary lateral brace...”
 - c. “...there were no lateral braces and diagonal braces in the front and rear deep ends of the trusses...”
 - d. “...the employees installed only one nail per connection...(in) the short top chord lateral bracing in lieu of using two nails as required...”

“ABATEMENT NOTE: AMONG OTHER METHODS, ONE FEASIBLE AND ACCEPTABLE METHOD OF ABATEMENT WOULD BE TO FOLLOW THE MANUFACTURER’S RECOMMENDATION OF ROOF TRUSS ERECTION OR THE BCSI B1, B2, & B3 GUIDELINES ISSUED BY THE WOOD TRUSS COUNCIL OF AMERICA AND THE TRUSS PLATE INSTITUTE.”

2. “The employer did not develop, implement, and/or maintain at the workplace a written hazard communication program...”
3. “A safety and health program was not initiated and maintained...”
4. “The person designated as the competent person did not ... identify hazards of the job site, materials and equipment... (including) ensuring the wood mono trusses were properly braced and...”



Photo 2
Back of Building After Collapse of Trusses

- (insuring) employees wear appropriate personal protective equipment such as hard hats...”
5. “The employer did not instruct each employee in the recognition and avoidance of unsafe conditions and the regulations applicable to his work environment to control or eliminate any hazards such as... instructing the employees to follow the BCSI Guide Lines for Temporary Bracing...”
 6. “Toilets were not provided for employees...”
 7. “Employees working around a crane while it was lifting the trusses into position were not wearing hard hats...”
 8. “Compressed gas cylinder(s) were not secured in an upright position.”
 9. “”The 2 acetylene cylinders in the upright position were stored with(in) inches of 3 oxygen cylinder(s)...”
 10. “There was no ground fault circuit interrupter protection for (the temporary wiring used during construction)...”
 11. “Extension cord sets used with portable electric tools and appliances were not of the three wire type...”
 12. “The 12-3 SJTW yellow extension cord that was providing energy to the Craftsman saw was cut severely exposing bare wires of the individual conductors...”
 13. “Supported scaffold poles, legs, posts, frames and uprights did not bear on base plates and mud sills.”

14. “Each employee on a walking/working surface 6 feet (1.8 meters) or more above lower levels was not protected from falling by a guardrail system, safety net system, or personal fall arrest system... Employees were exposed to a fall of approximately 10 feet 6 inches while working up inside/between the wooden trusses...”

The OSHA inspector concluded his report with the statements:

1. “The wood mono trusses... collapsed due to... no top chord and bottom cord (sic) temporary diagonal bracing...”
2. “there were only 5 lateral braces in lieu of installing the top chord lateral bracing on 4 foot centers (approximately 16) (per truss)...”
3. ...there were no ground braces leading up to each temporary lateral brace...”
4. “...there were no lateral braces and diagonal braces in the front and rear... of the trusses...”
5. “...more than 50% of the time the employees installed only 1 nail per connection... in lieu of using two nails as required for top chord lateral braces...”
6. “The trusses failing caused the front masonry wall to partially fail and kick outward.”
7. “The employees were not trained to erect these long wooden trusses in a safe manner...”
8. “Due to the number and the nature of the hazards addressed it is evident that the competent person was not identifying hazards.”

A civil suit against a number of the parties involved in the project was filed on behalf of the three injured workers in the County Circuit Court in 2011, alleging that all of the defendants were responsible for the collapse and should have taken action to prevent the incident. The defendants in the suit were the owner (later settled the suit), the convenience store corporation to whom the finished facility would be leased, the prime contractor (also later settled the suit), the designer and manufacturer of the wood trusses, the local lumberyard which sold the trusses to the contractor, and the rental crane company that placed the trusses on the building.

Among the allegations in the complaint were:

1. “...defendant(s)... intentionally exposed plaintiff(s)... to a high risk that (they) would be seriously injured or killed through the improper erection and/or installation of roof trusses.”
2. “...the defendants were responsible for the safety of personnel working on the property during the installation of roof trusses, including adequately designed and/or constructed walls to support the installation of trusses.”
3. “...defendants failed to adopt and follow adequate safety precautions, such as ensuring that the subject roof trusses were properly installed, secured and supported...”

4. "...defendants... allowed numerous unsafe conditions to exist..."
5. "By failing to ensure that proper safety precautions were followed, the defendants failed to provide a reasonably safe work environment..."
6. "... (defendants failed) to ensure that proper safety equipment and safeguards were being utilized to brace the supporting walls during the roof truss installation..."
7. "The defendants... negligently manufactured, fabricated, designed, packaged, shipped, sold and/or distributed the subject roof trusses in such condition that they failed to perform in the manner for which they were intended...(and the roof trusses) could not be installed safely."
8. "The defendants... failed to warn, instruct or provide installation plans and as a result, the subject roof trusses could not be safely installed."
9. "The subject roof trusses were not reasonably safe for their intended purpose..."
10. "The failure to provide warnings and installation instructions rendered the roof trusses not reasonably safe for their intended purpose..."
11. "The manufacturing and design of the subject roof trusses were not reasonably safe for installation inasmuch as there was a lack of support and/or planning to install same..."
12. "Defendants' acts and/or omissions in failing to exercise the highest degree of care further demonstrates a callous disregard for the health, safety and lives of all individuals, such as the plaintiff(s), at the defendants' premises."
13. "The acts and/or omissions of defendants demonstrate a gross indifference for the safety of the plaintiff(s) by virtue of the known risk presented by the inherently dangerous undertaking of the installation of the subject roof trusses and the defendants' failure to take even the most basic safety precautions."

In other words, the convenience store corporation, the truss manufacturer, the lumberyard that sold the trusses, and the crane company were being held responsible for the collapse of the roof truss system and the resulting injury to the plaintiffs.

Site Investigation

A year and a half after the incident a visit to the site was made in the company of attorneys representing all parties to the suit along with engineering expert witnesses for the plaintiff and the manufacturer of the wood trusses. The debris from the collapse in June 2010 had all been removed and a finished store was in place and operating. There were, however, a stack of unused or recovered trusses and a pile of broken concrete masonry unit (CMU) debris adjacent to the operating store.

The wood trusses were intact and showed no signs of damage, except that they had been cut in half,

presumably to make them easier to handle, and had been left in a pile where they had weathered for the year and a half since the incident. See photo 3 below. The CMU rubble contained no evidence of any reinforcing, an opinion shared by the plaintiff's expert, a structural engineer. See photo 4 below.



Photo 3
Wood Trusses



Photo 4
CMU Rubble Pile

Analysis

The temporary bracing system used for the trusses during erection was totally inadequate. The OSHA report indicates that too few braces (five per truss instead of 16) were used to support the trusses and also states that there was only one nail used in the end of 50 to 60 percent of the braces that were installed. The prime contractor corroborated this statement by testifying during his deposition that many of the temporary braces for the truss system were secured with an insufficient number of nails. The lack of proper, sufficient bracing of the trusses and the use of only one nail in the ends of half of the truss braces caused the trusses to fall.

Based on analysis of the photographs taken shortly after the incident, it is apparent that the wood stud exterior walls were only partially sheathed and insufficiently braced. The concrete masonry unit (block) walls also appeared to be insufficiently braced, and there is no evidence of reinforcing steel being present in the block wall, a fact substantiated by observation of the masonry block rubble during the site visit. These factors contributed to the instability of the perimeter walls of the building and are consistent with the findings of the OSHA report.

Much of the documentation reviewed recommends retaining a professional engineer to provide erection guidance and temporary bracing details for long span (greater than 60 feet) trusses. In deposition the prime contractor/superintendent admitted that a professional engineer was not retained for the project before the incident.

Both the prime contractor and the crane operator testified that there was no bowing of the roof trusses when they were lifted and set in place. The fact that the trusses were not permanently deformed as a result of being lifted indicates that the lifting process was appropriate and adequate. Even if there had been some temporary bowing of the trusses during the lift, this temporary bowing would have been removed during a proper installation. Proper installation and bracing of the trusses would have rendered the bowing inconsequential.

OSHA regulations require prime contractors to be responsible for the safety of all the workers at a work site (29 CFR 1926.16). Therefore the general contractor was responsible for ensuring the safety of all the individuals at the work site and for seeing that the trusses were installed properly and braced securely. His failure to have the trusses properly braced resulted in their collapse. According to OSHA regulations and industry practice, subcontractors assume responsibility only for their portion of the work (29 CFR 1926.16). Accordingly, the crane company's specific responsibility was limited to its portion of the work, during the period of time when the trusses were connected to the crane, being lifted and moved into position, until the trusses were disconnected from the crane's lifting cable (or slings).

After the incident the facility was rebuilt. Photo 5 shows the completed facility at the time of the site visit.



Photo 5
Completed Store Front

Conclusions

The truss manufacturer and crane company were accused of being responsible for the temporary bracing of the trusses as they were being placed. The truss manufacturer and crane company had nothing to do with creating the temporary bracing system and were not responsible for it.

It was not the responsibility of the crane operator to ensure that the trusses were stable and secured prior to the crane hook being disconnected. According to OSHA regulations (29 CFR 1910.180(h)(4)), and industry practice (U. S. Army Corps of Engineers Safety and Health Requirements Manual, EM385-1-1), the crane operator is required to remain in his crane at the operator's station whenever there is a load suspended from it; therefore, the operator could not get out of the crane to inspect the way the trusses were being secured. Furthermore, installation of trusses simply was neither the crane operator's duty nor his area of expertise. The responsibility for determining when it was safe to disconnect the trusses from the crane appropriately rested not with the crane operator but with the project manager, the rigger and the crew chief at the installation location.

In accordance with the applicable regulations and industry standards and practice, the crane company was responsible for lifting the trusses and moving them safely to their installation location; it was not responsible for securing the trusses once they were in place on top of the building. The truss manufacturer and supplier were responsible for supplying a safe product for installation, not setting the trusses in place.

As is common in tort litigation, settlements were reached. For the crane rental company, this settlement was nominal.

References

1. Safety and Health Standards for the Construction Industry (29 CFR 1926.16).
2. 29 CFR 1910 OSHA General Industry Regulations (29 CFR 1910.180(h)(4))
3. Safety and Health Requirements Manual, U. S. Army Corps of Engineers EM385-1-1, 15 September 2008, Section 16.G.04

