STRUCTURAL ENGINEERING'S
TOP TEN LIST

#1. Two Story Commercial Building – Collapsed After 2 Years

We investigated a 2 story commercial building collapse. The entire building collapsed to the ground. Fortunately no one was in the building at the time.

There were numerous failure points on this structure

- Tack welds instead of fillet welds at butt joints for steel pipe columns

- Only 2 of the bolt holes in the base plate had anchor bolts in them

- Anchor bolts failed, were covered with epoxy, indicating that the dust was not cleaned out of the holes

- 24" deep LVL girder beams were secure to steel saddles with 3" long x 5/8" diameter lag bolts.

  (These lag bolts were found throughout the site, looked like a box of lag bolts were dumped on the ground. Did not find a single lag bolt still in place on all of the steel saddles).

- Top row of masonry block not poured solid. Wood plate straps pulled out of masonry block.

- First floor walls were not balloon framed to 12'. Had 4' wall stacked on 8' wall. Exterior plywood sheathing was broken at the top of the top plate. A perfect hinge.

- LVL girders were under designed, but there was little load on these girders.

What caused the failure ?

It wasn't wind or snow loads. Turns out that the back wall was constructed as a 4 foot tall masonry retaining wall with no vertical rebar or horizontal ladder wire. Heavy rains (20+ inches) flowed into a garage bay door, puddle in the rear and blew out the masonry wall.

The building never experienced winds greater than 40 mph. We estimate that the building could not have withstood a 60 mph gust.

#2 Commercial Building – Collapsed While Under Construction

A commercial storage building with 24 foot tall masonry walls from snow and rain loads. Fortunately no one was in the building during the collapse. The building had mono wood roof trusses that had sheathing and a single ply membrane in place. GC was in the process of installing permanent bracing the day before the collapse. There was an interior 2x8 stud wall that ran down the middle of the building.

The main cause of the collapse was the buckling of the 2x8 stud wall in the middle of the building. There was no sheathing on the stud wall at the time of collapse, but there was blocking. Engineering calculations indicate that the studs would have failed in buckling even if both sides were sheathed.

Other weak points in the structure were:

- The wood stud wall was not secured to the masonry walls in any manner.

- Owner changed the width of the opening in the interior wall but did not increase the size of the LVL door header. The door header was undersized.

- Vertical rebar in the masonry walls was not specified on the plans with respect to the vertical expansion joint locations. Some of the masonry "wall panels" only had 1 piece of vertical rebar on one edge of the panel.

- The detail for the "L" rebar with respect to the vertical rebar did not match. So in many cases the vertical rebar was not tied to the footing via an "L" rebar.

- The owner tried to control everything to reduce costs. His lack of specific construction knowledge of roof trusses and masonry did not detect other problems. If this building had been erected and obtained a Certificate of Occupancy, there were many ways for this structure to collapse in the future.

- The County Building Code officials accepted an inferior set of engineering plans and roof truss submittal drawings. Even a quick look at the plans would have been enough to reject the permit from a lack of connection details. While during the concrete footing inspection the job should have been stopped because of the changes being made by the owner that obviously did not match the building plans.

The truss manufacturer sold a set of roof trusses to the owner that had agricultural design loads instead of commercial loads.

#3 Large Church Building – No Failure

A local large church was under construction. The construction was a combination of steel framing and wood framing. The roof structure was metal plate connected wood roof trusses.

As the 60+ foot scissor trusses were being erected, the supporting steel beams began deflecting laterally.

Observations during the Investigation

- The 45+ foot long steel beams could not support the lateral thrust from the scissor trusses. The truss engineers designed the truss for both pin-roller and pin-pin to let the Structural Engineer of Record know what the possible lateral forces would be if the truss was not allowed to roll. The roof trusses were supported by the lower flange of the W shaped beam.

- Not only was there no lateral support for the steel beams but the top flange was not braced to prevent buckling.

- The wood framing portion of the church was not fastened to the steel structure. No details of this connection were in the plans, GC did not know how to fasten wood to steel.

- There were no shear diaphragms in the large open church space. Horizontal and vertical shear walls had to be added to the wood framing structure.

#4 Large Church Building – No Failure

A large church was constructed of metal stud perimeter walls and metal plate connected wood roof trusses.

Observations

- The metal studs in the corners of the building were not secured/fastener at all. There was no transfer of lateral wind pressures to the perpendicular walls.

- There were no vertical or horizontal shear diaphragms in the large open building. There was no resistance to racking or lateral loads. Vertical and horizontal shear diaphragms were added to the structure.

5. Wood Deck Failure

A two story deck on an apartment complex building failed while 8 students enjoyed grilling outside. Besides broken ankles, twisted knees and a broken hip, two of the students were burns from the charcoal inside the grill. Fortunately the lower deck caught the upper deck so the fall was only 9′ instead of 22′.

The investigation found that the design of the deck was inadequate. The framing involved the floor joist running parallel to the building. Then beams carrying the floor joists were supports at the building (point load) and on posts at the perimeter of the deck.

The problem was the connection of the beam to the band board. The band board was secured to the building band board with 5/8″ diameter through bolts spaced 16″ o.c. Unfortunately there was only 1 bolt near the beam connection into the building. The point load was large enough that the wood failed around the bolt and the deck band board failed.

#6 Church - Roof Truss Collapse During Erection

A church with metal stud walls and metal plate connected wood roof trusses was being constructed. Structural Engineer of Record required a meeting with the GC and the truss erector on site. The engineering plans called for 63′ long scissor trusses on metal stud walls. The truss specifications required that the chords be Southern Yellow Pine #1 lumber.

The roof trusses were mono scissor trusses that were spliced together on the ground with a "saddle truss". These saddle trusses are made of 2x4 or 2x6 dimensional lumber and are plated together. The saddle trusses are then sandwiched and nailed to the two mono scissor trusses on the ground prior to erection.

The erector stated that he had experience with 63 foot long scissor trusses. The truss erector did have 3 rows of top chord bracing on each side of the roof. The erector had erected 19 roof trusses before the failure occurred. The braced metal stud walls did not fail. Three men were injured on the job site.

During the investigation the following items were discovered:

- The truss erector stated that the trusses "moved" or were more flexible than previous roof trusses.

- The truss erector explained the difference between temporary and permanent bracing.

- The truss erector was only installing 24" long 2x4 temporary bracing. He stated that he was going to install 14′ long permanent braces after the crane left the site.

- The engineering shop drawings were examined. The truss manufacture constructed the trusses out of Spruce Pine Fir – mechanically graded lumber, not SYP.

- The truss manufacture never designed the truss for clear spanning the 63 feet. The truss was only designed as a mono truss of 31+ feet. Therefore the chords, webs and metal connector plates were undersized for a 63 foot clear span.

- The Modulus of Elasticity between the SYP #2 and SPF mechanically graded lumber is 1.6 x 10^6 versus 1.1 x 10 ^6 pounds per square inch. Euler buckling calculations indicate that the buckling force created by the dead load of the roof truss would have require 5 rows of top chord bracing and 3 rows on the bottom chord.

#7 Church - Roof Truss Collapse – After Truss Erection

Again, a large open church design. Metal stud walls supporting 64' metal plate connected wood scissor roof trusses. The sanctuary was being added onto an existing church building. The roof trusses had been erected. Roof sheathing was added to one side of the roof only. Everyone went home of the 3 day weekend. On Tuesday morning there was a light rain. The framing crew assembled at the site, then decided (because of the rain) to go down the street for coffee and breakfast. One hour later they returned to the site and the entire structure (trusses and walls) was flat on the ground.

The debris was cleared up. New roof trusses were brought to the site. We were brought in to develop a truss bracing plan.

Observations and Discussions

- Framers complained about the quality of the collapsed set of roof trusses. State that the new trusses where a high quality of lumber.

- The new roof trusses were examined and a few cracks chords were discovered along with two large knot holes. The knot hole for #2 grade 2x6 were within code allowance. But it left only about 1 ½ inches of lumber that would be in tension on the bottom chord. These trusses were repaired on the ground.

- The trusses were mono scissor trusses and connected with plywood sheathing on both sides.

- Engineering calculations were performed concerning the first collapse. Placing the sheathing on one side of the roof truss increased the dead load, so that additional rows of bracing would have been required to brace the truss.

- A bracing plan was designed. We stayed on site while the attic frame trusses were installed up against the existing building. The walls and floor of the attic frame trusses were sheathed with plywood. Then the roof plane of the attic framed trusses was installed back to the existing building. Some addition frame was installed to create the valley between the new building that was perpendicular to the existing building. This rigid box acted as the "foundation for the scissor roof trusses.

- We allowed the truss erector to install 5 scissor roof trusses using 2' temporary bracing on the top chord and the bottom chord of the trusses. Then the erector installed 14' long braced back the attic framed trusses (already sheathed). Then they were allowed to continue installing 5 trusses, stop, add 14 foot permanent bracing and repeat the process.

- The following day, while at another site, we received a frantic call from the site about the walls coming apart. After arriving back to the site, the plans were reviewed and the wall section sheet was examined. The building plans were developed by an architect. However, the wall section did not have the architects title block or seal on it. It turns out that the wall sections were designed by a guy in the GC's office.

- We examined the entire sanctuary framing design. The sanctuary did not have sufficient shear walls.

- More specifically, the 14 foot tall sanctuary walls were not structurally adequate to support the VERY SMALL lateral loads from the pin-roller scissor trusses. So a horizontal beam was inserted in the soffit and supported by exterior pilasters.

8. Fire-Explosion Investigation

A house had an explosion and a fire in it. The owner claimed to the insurance company that someone threw two Maltov cocktails into the house. The claimant stated that the explosion blew the front wall outward (about 9 inches).

Our investigation found accelerants in small quantities on the floor in room other then where the Maltov cocktails were.

This was an old house and had unconventional wood framing. The roof rafters bore on a wood plate that was tied into the wall studs. The nails were driven downward through the wood plate and into the end grain of the wall studs. We observed of that these nails were not bent. This indicated that the roof structure HAD to go up vertically. Once the roof was up in the air, the front wall fell away from the house (into the front yard). The roof structure coming back down caught the ends of the wall and held it in place.

If an explosion were to have occurred, the pressure acts as a scalar, outward in all directions. The Maltov cocktails were located in the kitchen, not in the front living areas where the wall was falling away from the house.

We had heard that they owners were performing some renovations weeks before this explosion took place. There are two false framing structures on each side of the front door entrance. They

structures are along the ceiling, a dropped sort of box beam, to help identify foyer from living room and foyer from family room. These were both noticeably sagging.

Our final theory was that the owner tried to jack up the dropped ceiling box beam. This acted as the pivot of a teder-toter. The front end sprang upward when the nails gave away, the front wall fell outward and then they lower the ceiling back down. We assume that for a few days that they tried to reverse the process but could not push the wall back into place. So they started a fire.

9. Bank Explosion

An entire single story bank building blew up one day. The bank building was a wood framed stud wall structure with a metal plate connected wood roof truss system. Robbery was ruled out.

Several theories were investigated. But a camera video tape from a gas station across the street showed a white plumb coming up from behind the bank. Occasionally cars cut through the back of the bank building to avoid a busy intersection. Apparently a car hit the gas meter in the rear of the bank. The theory was that the gas leaked out of the gas line connection at the meter and rose upward. The bank roof design had a large roof overhang with a flat soffit. The theory was that the gas accumulated in the open truss roof structure over the weekend. Then when the gas filled up enough of the roof and started filling up the office area space, a thermostat kicked in and ignited the gas.

10. Too Many Bug Bombs

A single story residence had a problem with bugs in the kitchen. The owner decided to set off some bug bombs in the kitchen and left for the day. The owner placed 4 bug bombs in the small kitchen and closed the door to the kitchen. The aerosol from the cans filled up the kitchen and when the aerosol density was thick enough and reached the level of the pilot light in the gas stove, the explosion blew out the kitchen windows and caught fire to the house. Fortunately neighbors were able to contain the small fire and save 95% of the house.