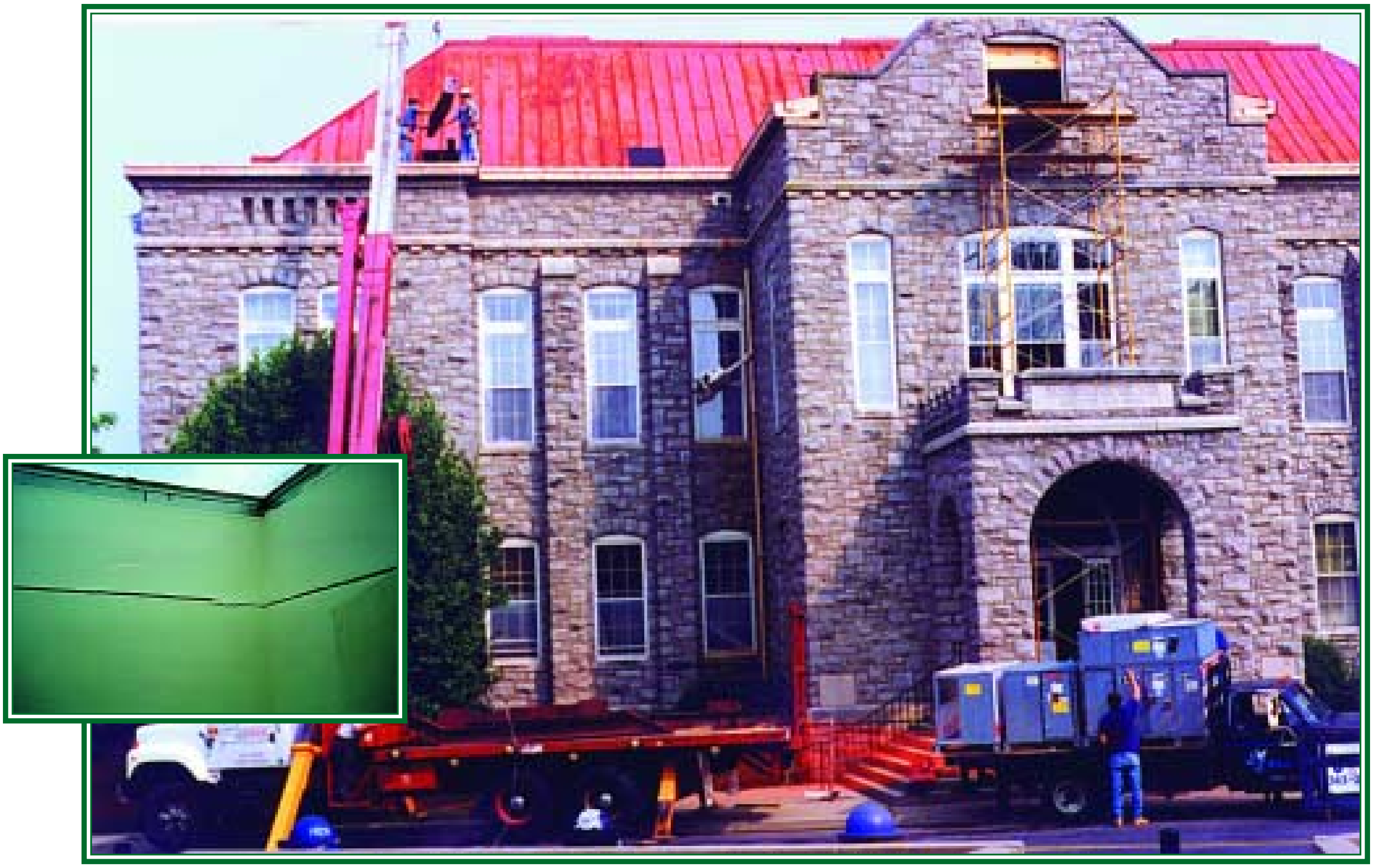


REBUILDING WOOD TRUSSES WITH STEEL

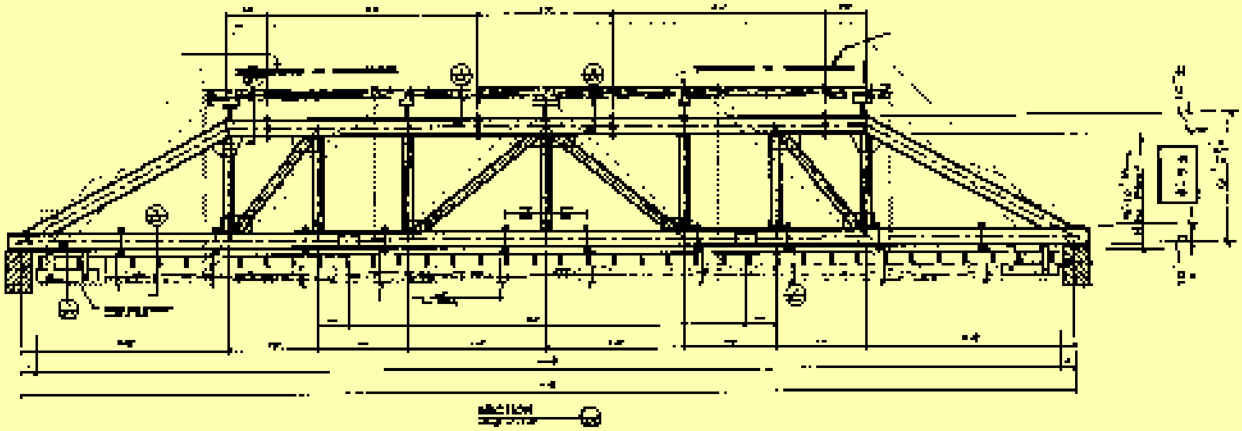
Moisture damage to structural elements required an innovative solution to preserve a historic structure

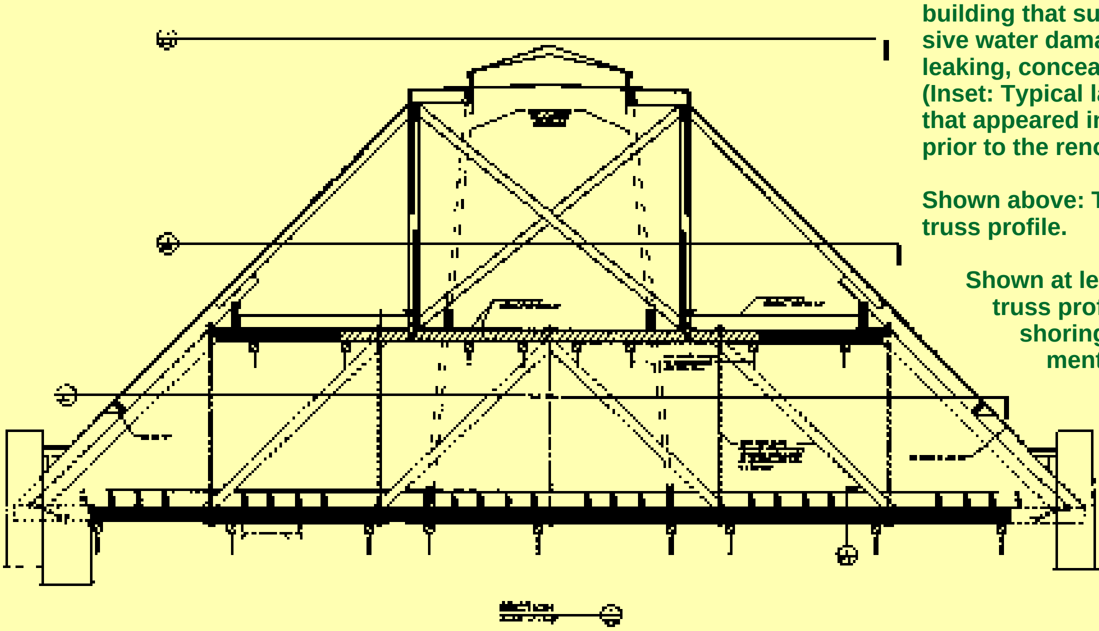
By Ethan Buell, P.E., and David Carroll, P.E.

Despite a major renovation only a few years earlier, Kentucky State University's prominent administration building was showing signs of severe distress in its roof and ceiling structure. After investigation, the culprit was discovered to be a continuous concealed gutter designed into the original roof system that was now allowing moisture to deteriorate wood trusses and finishes. Subsequently, it was discovered that the original wood trusses were creeping and deflecting, causing large cracks in the drywall of the second floor and ceiling.

The building houses the university's president, vice presidents and all supporting staff. Perhaps more significantly, the structure, which was designed around 1909 by William Sidney Pittman—an early black American architect—was on the National Historic Register.

The structure has load-bearing exterior walls (approximately 20" thick of cut stone) with a





Pictured opposite: The front of Hume Hall, a historic building that suffered massive water damage from leaking, concealed gutters. (Inset: Typical large cracks that appeared in light wells prior to the renovation.)

Shown above: The new steel truss profile.

Shown at left: Existing truss profile showing shoring requirement.

blend of interior bearing walls and sporadic steel framing, primarily where main corridors were relocated during a previous renovation.

Though the original design drawings were not available, we were told that the second floor was originally used as an auditorium or large classroom. As a result, the interior space was free of support columns and the roof structure was supported with six equally spaced overhead wood trusses spanning roughly 52'. On top of these trusses were placed a series of stick framing wood posts, beams and rafters so as to extend the main roof profile. The truss bottom chord served to support the wood-framed attic or mechanical floor. As previously mentioned, a concealed gutter ran the perimeter of the building. Leakage from this gutter caused damage to the roof structure.

The building had undergone a major renovation in 1983-84. This renovation included installation of a sprinkler system and a new mechanical system with large fans in the previously unoccupied attic space. In addition, three large light wells with skylights were created between the trusses. During this construction, a pipe fitter's torch caused major fire damage to a significant portion of the roof structure, including several trusses. These damaged truss elements were either replaced or repaired, as needed, at that time.

Around 1990, the owner's representative, Don Jeffers, contracted our office to investigate some significant separations of the high roof support columns above the roof trusses. At that time, it was determined that the structure was safe, but needed to be monitored regularly in order to determine if repairs or rein-

Note the large separation in the roof framing.

forcement would be necessary. In 1995, we were called back to the site by Charles Porter of the architectural firm of Coblin Porter Associates to examine some new drywall cracks in the walls of two light wells—with some of the cracks exceeding 1" in width.

PRELIMINARY FINDINGS

Using a surveying level and sighting over existing mechanical equipment, we immediately began a visual inspection of the roof framing in an attempt to determine differential bottom and top chord elevations along each truss. Simultaneously, we were: interviewing previous contractors that were involved in the 1983 renovation; searching through the owner's construction files for vendor drawings, change order instructions, changed conditions, etc.; and running a stress analysis on the existing wood trusses. Our findings indicated that:

- A significant amount of additional load had been added to the roof trusses over recent years.
- Because of the previously mentioned fire, many components were either replaced or reinforced.
- Because of load increases and truss repairs, significant increases in truss stresses had occurred.
- Original and subsequently added lateral bracing on the trusses was inadequate, which created large lateral (sweep) and differential movement in the trusses.
- Nearly all of the trusses have had moisture decay to some degree, particularly near the bearing ends where the original concealed gutter was leaking (as a side note, many of the exterior walls had experienced significant water damage).
- The existing attic was very poorly ventilated due to insufficient louvers and a dysfunctional exhaust fan motor; this high temperature and moisture level in the attic contributed to the deterioration of the wood trusses.

During our investigation and fact finding phase, other activities were being carried out. The owner, through the State's Architect, was exploring avenues for emergency funding, scheduling of time to vacate the property for repairs, finding areas to relocate administration personnel, and at the same time doing two separate projects—a re-roof, including replacement of the built-in gutters and a mechanical system retrofit. Meanwhile, our office was performing in-house brain-storming sessions seeking out and refining viable alternate solutions of repair methods.

One of the first questions that had to be answered was: "Is there imminent danger of the roof collapsing without any further warning?" After our initial survey and after running some preliminary calculations, we assured the owner that a catastrophic collapse was not imminent; however, we were beyond the monitoring stage and corrections had to be planned and implemented within the next 12 months. A detailed milestone schedule was jointly developed and became a part of the bidding instructions. Also, a lengthy list of unit costs had to be developed because of the existing damage inside the building. Among these items was expensive trim, including case work type finishes that wrapped around the bottom chord of the existing wood trusses extending down below the existing ceilings. Finally, it was anticipated that additional damage would be done in the course of construction. Therefore, a detailed video tape of existing conditions was made with both the owner and the contractor immediately after contract signing so as to document the level and location of existing damages.

SELECTING THE FINAL REPAIR SCHEME

A variety of repair options were considering during our in-house brainstorming sessions. Unfortunately, there was no clear-cut answer since it seemed as though each had its pros and cons.

The first idea was to completely remove and replace one truss at a time. This scheme would require removing a large section of roofing, temporarily protecting this opening every night, and having a large lay down area for the prefabricated truss. Also, a very large crane would be required to erect this prefabricated truss; thus, this scheme

Pictured is a close-up view of a truss member as it is transported to the interior of the structure.

was rejected early because of the limited space around the building, building accessibility and high risk for rainstorm damage.

The next concept to be explored was to design a new pair of steel trusses to fit around and support each of the existing wood trusses. A benefit of this scheme was that the new trusses could be built so as not to require cutting out large sections of the roof. Carrying this idea further, however, led to some very cumbersome details of picking up the deteriorated wood truss and, at two locations, developing adequate truss bearings was essentially impossible. Therefore, this scheme also was rejected.

The third idea, which ultimately was accepted, was to build a new steel truss inside the chords of the existing wood truss after first carefully shoring the existing trusses' top and bottom chords (from the second floor). Since the trusses could be done one at a time, the shoring could therefore be reused. Additionally, shoring only one truss at a time would serve to limit the load to the second floor. After the shoring was installed, the contractor would then remove the existing trusses' web members. The new steel trusses would be prefabricated with bolted connections and dismantled in the shop. The truss would then be stick built in the field.

The new trusses incorporated adjustable supports to hold up the existing wood top chords and adjustable hangers for the existing wood bottom chords (which could not be removed since they were integral with the roof and ceiling). We developed preliminary sketches and met with two general contractors to get their comments and to collectively arrive at a budget cost figure. Once this method gained the constructability approval and we felt safe with our construction cost estimate and schedule, we then arranged for a meeting the owner and architects. We presented our concept, along with the cost and schedule estimates. We also discussed how only a small roof cut near each truss would be required for letting materials in, thereby minimizing the chances of storm water damage. Our method was reviewed in detail and approved. We then proceeded into final design documents.

Construction

Falcon General Contractors was the successful bidder and energetically came on board with suggestions and ideas for the project. Gary Wright, project manager, and Jerry Jeffers, superintendent, made more detailed dimensions for their shop drawings and proceeded into fabrication. During this activity, they had contacted with an independent structural engineer, Paul Haggard, according to Project Specifications, to verify their anticipated shoring loads and placements. Since this structural rehabilitation project was combined with a major mechanical retrofit, there was subsequently two general contractors on site. Naturally, this required significant coordination and a bit of give and take by both contractors, since the attic floor was the main mechanical level for the building.

The first truss erection started in late May of 1996 and the last (sixth) truss was finished in mid-August of 1996. Construction went very smoothly, beginning with shoring, then removal of the ends of the wood trusses, installation of special grout at the new truss ends, and then stick building of the new steel trusses.

Because of the concealed damage, a lot of additional general building renovation was required for this project. For example, a big percentage of the upper story walls were repaired. This included repairing of existing window headers and repointing of the stone walls, plus replacing water damaged plaster, vinyl and fabric wall coverings, and also finish painting. A good percentage of the ceiling drywall had to be replaced or repaired. And extensive scaffolding inside the building (interior shoring) caused some accidental damage. The second and first floor was riddled with cracked tile because of an inferior light weight leveling material that shrank extensively over the years. Several floor joists under the first and second floors had been damaged due to redistribution of loads that occurred when the non-loadbearing walls at the second floor started supporting roof loads when the existing trusses began failing. The framing was severely overstressed and had to be reinforced.

Additionally, the high roof over the trusses had some "dips" in two places due to the large deflections of the old wood trusses and the roof needed to be trued. The entire project was completed in February 1997. It should be noted that after the new steel trusses were installed and the existing truss supports were adjusted, most of the all of the separation in the remaining wood roof structure closed.

The project was very cumbersome at times and during the early stages it seemed like it couldn't be completed within a reasonable period of time or for a reasonable cost. But with perseverance and good team work, the project was successfully completed.

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