nyrej

Aging trusses and structural repair projects: Sagging diagnosis

February 13, 2012 - Design / Build

We have been responding to reports of sagging trusses in the living space of buildings which were built over the past 30 years. Over the past decade and continuing through today, Falcon Engineering has observed various deflection conditions. Our findings are that many structures investigated have deflections which exceed design criteria and are in need of repair. Repairs are relatively simple, but costly to the owners/association having responsibility for the structural components of these buildings. Because of the need for financial planning, co-ops, condominiums and owners want to understand the factors which influence the failures of these aging structures. For the purposes of this discussion, we are talking about sagging failures which occur due to unknown origin, rather than catastrophic failures of excessive wind or snow loads, or abuse from excessive loads that the trusses were not designed to accommodate (such as water beds or heavy stone finishing materials).

Wood trusses have been widely-used in residential construction since the mid 1960s. Trusses that we commonly see are frames of triangulated lumber fastened with galvanized steel connector plates, referred to as truss plates. Typically, they are constructed with 2x4s with the lumber oriented flat to provide a wider, more stable, platform to fasten sub-flooring and ceiling drywall. The advantages are that framing is both lighter and more efficiently manufactured, floor plans are more flexible with longer spans, and the open web design of the trusses make convenient runs for plumbing, electrical cables and mechanical ducts.

Wood trusses are anticipated to perform for the service life of the buildings, yet we are beginning to find evidence of creeping failure now that the buildings are approaching a life of 30 years. While there is not a standard which is utilized to define a "failure" based on the deformation of a wood truss assembly in an aging structure, we have utilized the design criteria for allowable deflection of new structures as it relates to spans. For a combination of live and dead loads, deflection shall not exceed length of span divided by 240 for new structures as defined by building codes. In many instances which we have observed, an example would be the span of 18 feet and allowable deflection would be 0.9 inches. We have observed that conditions which exhibit deflection exceeding 1 inch typically are accompanied with cracked drywall and noticeable sagging of the floors above. As deflection exceeds 20% greater than allowable deflection for a new structure, the loss of function is typically evident by the observed damages.

In the scenario with a span of 18', ceilings which exhibit deflection up to 1-inch are no more than 10% greater than allowable deflection for a new structure and should be monitored over time because deflection can continue to creep to the extent where repair will be necessary. At this level of deflection, we typically have not yet observed significant damages to the ceilings or floors above.

The evidence of truss deformation which triggers a need for repair can be described by ceiling deflections greater than 1", with creaking and springy floors above, coupled with drywall failure to the ceilings. In the extreme cases, trusses have deflected to the extent that plumbing failures have occurred within the floor/ceiling assembly.

During our research into truss "failures," we found the most relevant commentary to be that regarding the design of MPC joints (truss plates or connector plates with "teeth"). Laboratory studies by researchers and the author indicate that, as tension load is incrementally applied to a connector plated joint, wood members tend to slip past the connector plate. The "slip and slide" action is manifested by incrementally increasing force of wood against the teeth, forcing the teeth out away from the wood into an "arch" configuration, also described as "peeling" or "plate back-out." The mode of failure noted most often was withdrawal of the teeth from the wood combined with plate bending. One of the prime contributing factors for "peeling" is repeated cycles of wetting and drying.

This often coincides with our observations of wood trusses without apparent defects except that small gaps between webs and chords indicate "peeling" of the connector plates. We often found more significant separation on the occasions where we found splices in the bottom chords which are secured with connector plates.

The progressive nature of these failures manifests as deflection of a truss or truss "creeps" over time. The point in time that a specific truss or joint has actually "failed" can be defined when the resident suffers a loss of function of the structure and it must be considered that continued use of the structure past the point of function could be unsafe. In many circumstances that we observed, truss deflections were so severe that plumbing failures occurred and caused significant damage to the drywall ceilings.

Patterns of failure can be observed in buildings with standardized floor plans where joint failures occur in near-identical trusses at near-identical locations. This coincides with examples we have seen where deflection is maximum underneath washer and dryer locations, with the associated vibration. Circumstances with repetitive cycles of wetting and drying are significant indicators of potential problems. Examples may include locations underneath bathroom floors where leakage from tubs and showers, or poorly maintained flooring, may be the source of unnoticed water that infiltrates into the floor/ceiling cavity. Other circumstances may occur where warm, humid, outdoor air can be exposed to air conditioning ducts in the summer, with condensation and high humidity becoming the source of wetting.

It is not cost-effectively feasible to adequately predict the incidence of truss failures. It can be suggested that suspicious locations with excessive deflection be investigated by a qualified licensed engineer. It should be noted that deflection will creep over time and, when truss deflection exceeds design criteria, there is increasing danger that plumbing damage will occur, followed by more severe failure. We have noted that deflections are normally associated with drywall cracks. When residents explain that drywall cracks have been repaired, only to reappear, this is an indication of the nature of failure where the structure "creeps" over time.

The recommended method of repair for trusses which are less than 24 inches deep is to remove the ceiling drywall and install plywood plates on both sides of the truss to fortify the structure. The plywood must be fabricated on-site with the necessary cut-outs for plumbing, cable and ducts. The plywood is often fabricated in convenient-sized segments to fasten to the trusses in-place, by gluing and screwing the plywood into position. In effect, the trusses are redesigned in place as box beams.

Repairs are essentially fortifying the failures that result from "peeling" of the truss plates. Deflections may also occur when web or chord members split or have a failure due to knots in the wood. In these circumstances, the wood members can be fortified by attaching "sistered" components with dimensional lumber. It is often necessary to have plans prepared by a licensed engineer which detail the repairs for building permit application, depending upon local ordinance; however, proper design is recommended by a licensed professional that understands the truss design regardless.

Buildings have a tendency to "settle" into the deflection of structural components. It isn't always feasible to restore the floor/ceiling assembly without affecting other components of the residence. The repairs should be accomplished under watchful eyes throughout the building to ensure that efforts to level the ceiling aren't causing costly damages in other areas. As always, the repair effort has to be undertaken with reasonable care and diligence. Repairs will extend the service life of the existing trusses so as to avoid far more costly replacement of flooring systems in the future.

Scott Wilton, P.E., is senior engineer for The Falcon Group, Bridgewater, N.J.