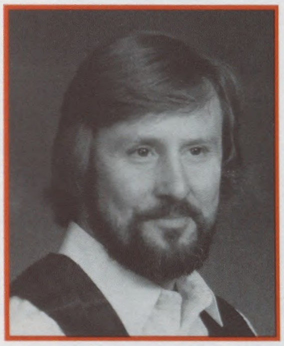
Elements of a Collapse

Abstract

Each study of a catastrophic fire or wind blow-off could begin with one question: What did the loss prevention agency (insurer) require in terms of construction? The same would be an appropriate starting point for investigation of collapse events; however, the governing building code may have as much to say about those requirements as does the loss prevention agency.

Delayed stormwater runoff may well be the event which precipitates a collapse. More insidiously, a structural framing system may have been overstressed and permanently deformed well in advance of actual failure. This study will review some common scenarios which can result in roof collapse. The review is offered to bring a heightened awareness to the matter.



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Roofing assemblies rarely make headlines until an event of significant non-performance. Structural failure is foremost among these (photos 1 and 2). The occurrence leaves owners panicked, occupants inconvenienced (if not injured), and reporters clamoring for more rolls of film.

As opposed to floor decks which are customarily sturdy, roof deck design does not anticipate such loading. Roof decks and framing members are comparatively light. Available load-carrying capacity is usually the sum of dead load (all permanent construction) and live load (anticipated temporary impositions), factored according to the method of design.

At the point of overloading, various structures behave in different manners. Concrete members tend to break abruptly, quickly releasing pent up energy. Fractions of broken concrete may separate violently. Similarly, wood structures may splinter and fail suddenly.

On the other hand, metal buildings and conventional steel structures may deform slowly. The shifting weights of drifted snow and stockpiled rooftop loads (Photo 3) may take several minutes to fail. It is not uncommon for steel structures to experience a "partial collapse", marked by extreme deformation of members yet falling short of complete failure.

One potentially perilous combination is a ballasted roof assembly on a poorly-drained surface. As shown in Photo 4, the 1-1/2 inch stone ballast disappears under water merely a few feet from the perimeter. At midspan, a depth of 4-1/2 inches of water was measured. The structural framing members below had gone into negative camber. At such a time, the deformed surface promotes ponding water which induces further concavity. This combination has resulted in a yielded structure on too many occasions.

A structural analysis should be performed prior to adding dead load to an existing assembly. For ballasted assemblies, the structural analyst may have based his or her calculations on 10 pounds per square foot of newly-imposed load. He or she may be thunderstruck to find how much stone may actually be placed from ordinary dispensing equipment. This writer has measured 23-28 pounds per square foot of stone ballast deposited on a roof. It was an overroof assembly on a deck exhibiting marginal drainage. (We carefully exited the roof.)

Site-specific drainage features (high scuppers, high drains, deformable roof decks, insufficient total drainage orifice, constricted drains, etc.) may combine to render the structural analysis dubious at best, irresponsible at worst. The prudent structural analyst will search for these features, evaluating their contribution, if any, to a potential collapse. Photo 5 depicts a sure contributor to ponding and roof loading which could go unnoticed both before and after collapse.

A simple review of structural framing plans is an inadequate structural analysis. The review must be matched against features now characterizing the project. The cumulative weight of internal process piping, sprinklers, light fixtures, and electrical conduits may sufficiently combine with other dead load components to result in overload and collapse. This is represented in Photo 6, where the collapse took upwards of

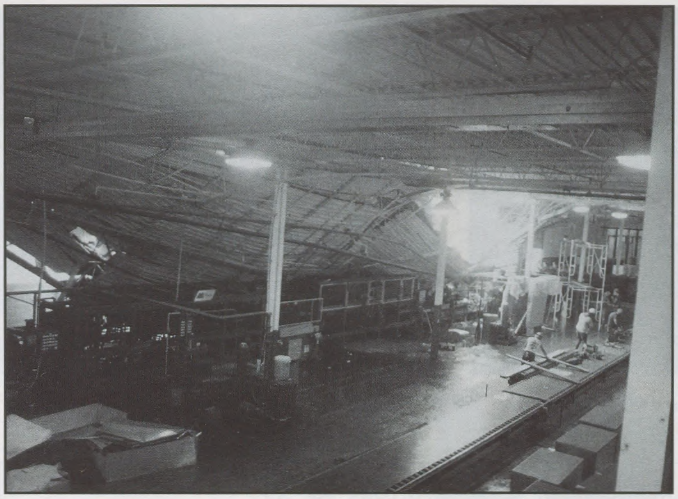

Photo 1

Photo 2

20 minutes, according to jolted onlookers.

Note that the weight of water in a pipe is significant. The water in virtually any size of PVC pipe flowing full weighs more than the pipe. With cast iron (schedule 40), the water is a lesser component of total weight per foot but figures prominently at greater pipe diameters.

More obscure perhaps is the diameter of the opening afforded at drain flashing.[1] Constriction there will violate the intent of the stormwater runoff rate when less than the diameter of the piping.[2]

Factory Mutual Corporation is fully aware of loss potential in this manner. Document 1-54 is dedicated to the subject of collapse and sets out requirements for considering drifting snow load potential among varying roof levels. Note that two buildings do not have to be connected for a drifting potential to exist.[3]

ASCE-7 (formerly ANSI A 58.1) addresses a "rain-on-snow" scenario. This recognizes the tendency of water to remain in snow much longer on relatively flat roofs than on those of steeper slope. A surcharge loading consideration is proposed, additive with ground snow loads for a given area.

In summary, several practices can prevent a partial or full collapse. The importance of regular roof maintenance is academic (Photo 7). Retrofitting a roof with supplementary scuppers may be wise in certain instances; it may be required in others.

Reroofing a building or significant portion may prompt structural enhancement. This prompting may be from the specific loss prevention agency involved or from the building code prevailing (latest revisions). The embellishments could proceed along many paths. Modern standing seam metal roofs are carried on a system of clips. This arrangement will not provide a shear diaphragm as would directly attached (panel rib-type) profiles. As with any other joist or beam, rotation of these cold-rolled purlins (Z's or C's) sharply

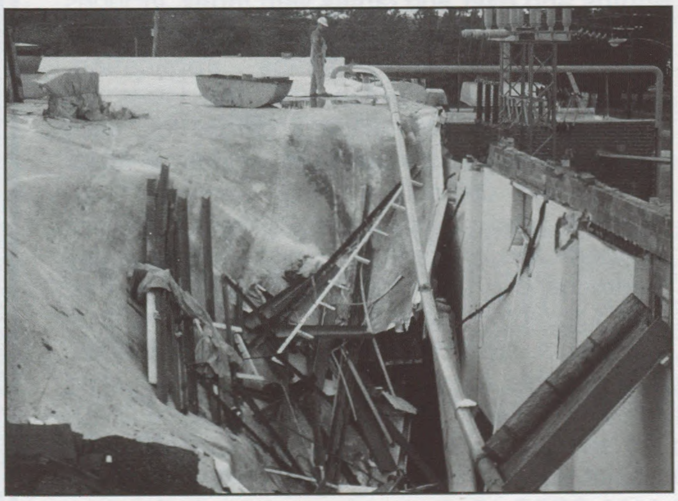

Photo 3

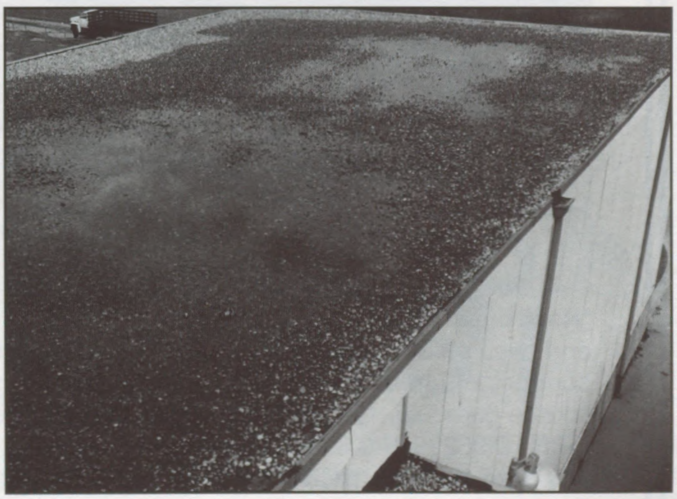

Photo 4

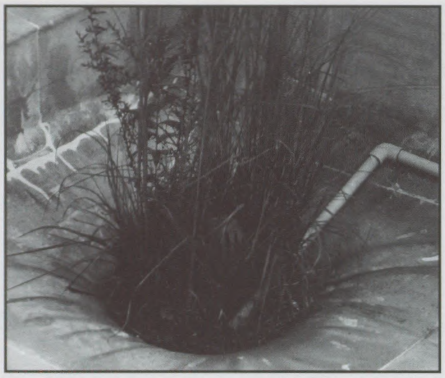

Photo 5

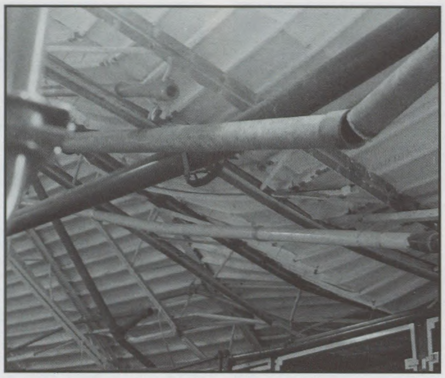

Photo 6

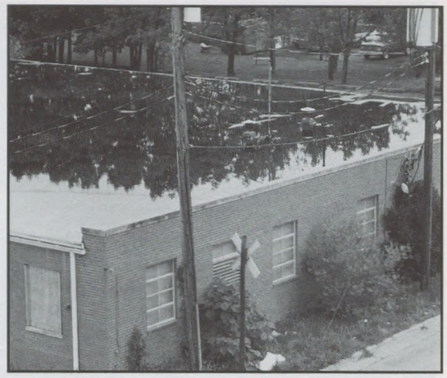

Photo 7

reduces load carrying capacity. One major insurer has mandated strengthening this type of construction with braces between outlying purlins.[4] Linking up the purlins in this manner induces better distribution of loading in a manner similar to the bridging used between floor joists of framed wood construction.

Wood structures might be stiffened by means of steel flitch plates sistered into place and bolted through existing joists. Steel joists may receive additional diagonal bracing; this improves load distribution among neighboring joists and reduces rotation of the members.

As always, replacement roof types which would result in a net loss in dead load are a worthwhile consideration.

References

1. Smith, Thomas L., "Tips for Avoiding Ponding-induced Roof Collapse", *Professional Roofing*, January 1995, pg. 42.

2. Hogan, Lyle D., "Providing Positive Roof Drainage", *Plant Engineering*, June 4, 1992, pg. 58.

3. Factory Mutual Research Corp., *Loss Prevention Data Sheet 1-54*, pp. 5, 6.

4. Allendale Insurance, letter dated September 6, 1994, and "Loss Prevention Alert" for metal roof systems.