

Exploring “Creep” Behavior in Building Construction

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BROADLY DEFINED, CREEP is a time-dependent strain of solids caused by stress. Simplified, it is the permanent deformation of a structural surface or member from long-term service loads. It can occur in wood, concrete, under-designed retaining walls, bowing and cracking basement walls, some polymers/plastics, downslope movement of rock and soil on a hillside berm, and many other construction materials and systems; even glacier flow is considered a form of creep.

It is rather common in exposed lumber (decks), rail fences, old timber structures, floor framing beneath a refrigerator, and roof ridge beams where elevated attic temperatures assist in the permanent distortion. It is also the condition by which old ceilings may begin to sag. Creep can even be experienced with some roof membranes, such as lap splices under

tension. It is a gradual deformation, and it is irreversible—meaning the condition does not rebound when the physical load is removed; such is the distinction between plastic and elastic deformation. When it occurs at or near room temperature, it is known as cold flow.

WOOD ROOF DECKS AND LUMBER FRAMING COMPONENTS

Wood can experience long-term creep deformation when subjected to long-term loads, and it has much to do with the internal moisture content.¹ If not fully seasoned (that is, dried), plastic deformation can be a problematic behavior, and it can generally advance for years without risk to occupants. For example, when a split-rail fence sags between posts, it is not because an overweight cowpoke perched there for a while. In that instance, there will either be rupturing/splintering of the top rail or there will be harmless rebound once that person removes himself. If permanent deformation is observed without such loading, it is because the spacing between posts exceeds span relationships for the size and species of wood used.

Figure 1 illustrates a sagging roof ridge beam in residential stick-built lumber framing. The condition did not occur from a singular loading event. Outward bowing of walls (**Fig. 2**) is a frequent consequence of misbehaving ridge beams. Both of these are textbook examples of long-term creep where lumber size and span relationships were substandard.

Agricultural structures (for example, poultry houses, farm equipment sheds, and barns) seem especially prone to creep. Similarly, **Fig. 3** depicts sagging of wood roof supports between



Figure 1. Sagging ridge beam in residential stick-built roof framing; this did not occur from a singular loading event.

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Figure 2. Extreme sagging of roof ridgeline and outward bowing of walls; this is a textbook example of long-term creep where lumber size and span relationships were substandard.

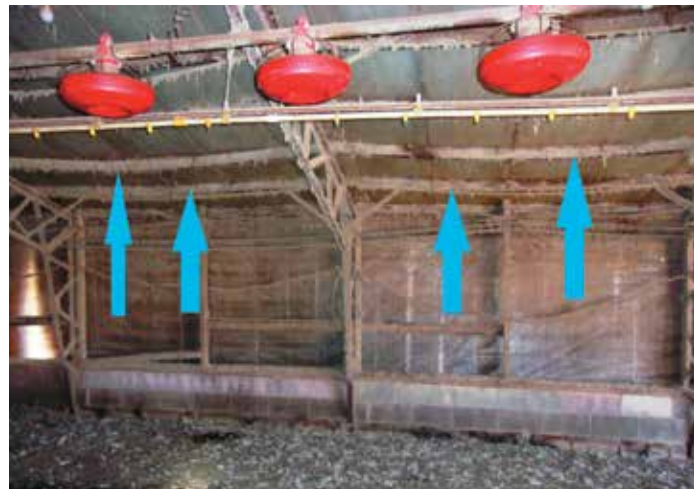


Figure 3. Sagging of wood roof supports between iron joists of a large poultry confinement house. The span and spacing were far too great for the size of lumber used.



Figure 4. Another poultry confinement house (400 ft [122 m] long) experiencing extreme out-of-plumb leaning. Support posts and engineered roof trusses were 5 ft (1.5 m) on center, and ordinary shear diaphragm bracing was absent throughout.

iron joists of a large poultry confinement house. Span and spacing were far too great for the size of lumber used. **Figure 4** illustrates another poultry confinement house, which was 400 ft (122 m) long, experiencing extreme out-of-plumb leaning. Support posts and engineered roof trusses were 5 ft (1.5 m) on center, and ordinary shear diaphragm bracing was absent throughout. Radical auxiliary bracing was necessary just to stabilize the leaning. Structures of this variety are governed under a separate classification in the building code, as no one would consider building a residential



Figure 5. Outward bowing of walls of a church fellowship hall. Two large columns within had been removed, and the roof ridgeline slowly began sagging while walls responded by displacing outward at the top.

dwelling in this manner; it is perplexing to consider why a different service behavior is expected with agricultural framing stretched to these dimensions.

In another instance involving the outward bowing of walls of a church fellowship hall (**Fig. 5**), parishioners had carried out removal of two interior columns to accommodate more dining tables. The roof ridgeline slowly began sagging while walls responded by bowing outward; the behavior was so slow and gradual that occupants were unaware of it. Had there been legitimate structural overloading, other distress would have been generated, such as broken or splintered framing members. Absent that, however, the slow progressive distortion of the roof and walls signals creep behavior.



Figure 6. Severe deflection on a hollow-core concrete plank deck. High and dry region is that portion occurring above inside partition walls.

THE OCCURRENCE AS FOUND IN CONCRETE

When relatively brief intervals of ponding water or heavy, wet snow occur, roof deflection tends to be elastic, with the surface rebounding to its original profile. However, if there is prolonged excessive loading from any source, permanent deflection may result. Such is why the definition of *creep* specifies that it is time dependent. **Figure 6** depicts severe deflection of hollow-core concrete deck planks. The high and dry regions are above interior partition walls of this classroom building. Yet the hollow-core planks were arranged absolutely flat, were spanning too far for the capacity of the section properties, and the roof surface was often loaded with prolonged ponding water beyond its live-load allocation. Surface deformation of this nature

is permanent and unrelated to any singular loading event.

Even large concrete tee-beams can sag during service life, especially if any internal reinforcing steel has been broken or loosened. This can manifest as a curious pattern of ponding water occurring only in a specific zone, such as with long-span tee-beams on a pulp/paper mill. Similarly, post-tensioned concrete can experience abrupt snapping of embedded steel tendons. As explored in Part XI of the author's "Roof Decks A to Z" article series, roof and floor slabs of the post-tensioned type are thinner in section than some other concrete decks, and broken tendons may violently rupture the concrete cover or topping. While abrupt "rupturing" of internal steel is not the best illustration of creep, the rupturing can be prompted when long-term surface deformation of a post-tensioned concrete deck has been experienced and unaddressed for long periods during service; that is, sagging-type movement exceeds the strength of the steel reinforcement.

INSTANCES OF CREEP IN STEEL FRAMING

Unlike "brittle fracture" (such as with a glass rod loaded to failure), creep deformation accumulates with time. Often, the collapse of a steel structure can take hours to reach its conclusion. Pre-engineered metal buildings usually have bracing tendons to serve as the horizontal shear diaphragm. But steel rope, rods, and wire may experience creep (that is, relaxation of original tension). Accordingly, turnbuckles are used in this type of construction—and they may need to be adjusted on occasion, such as after severe wind, seismic events, or other times when "racking" of the structure may have been experienced.

The orientation of internal drain lines (relative to the direction of bar joists) may be a factor in observed creep. It should be noted that large drain lines are a considerable structural load when flowing full. The horizontal pipes running parallel in **Fig. 7** caused concentrated loading on one or two joists, as opposed to being distributed across several joists. There was rooftop ponding water in this region only, and permanent surface deflection was present even during dry conditions. The same can occur when a single joist is loaded with large ductwork, process piping, a suspended conveyor line, or related burden. This loading arrangement can often be addressed with modification to joist spacing or by sharing the load among adjacent joints.



Figure 7. Internal drain lines running parallel to the direction of bar joists. This explains ponding only in a specific region on this roof; ponding had been present for decades.

OTHER INSTANCES OF CREEP

Sagging ceilings: The author has been party to scores of sagging/fallen ceiling investigations, including one over a newborn baby's room, multiple church sanctuaries, and several fellowship halls having long-span wood trusses.

Figure 8 illustrates severe ceiling sagging of an occupied restaurant (unknown to diners or the owner). Some instances of ceiling collapse are so abrupt and loud that witnesses have described an "explosion" in the attic. One instance of a slamming door set off a collapse of plaster finishes, but distress was clearly underway prior to the door's influence. On multiple occasions, elaborate shoring/bracing was necessary to stabilize and control propagation of a ceiling loss. Many fallen ceilings had an astounding unit weight when examined in the debris pile (especially those having old plasterboard backing). It should be noted that fastening relationships are crucial in overhead work. Some collapses had as many as three layers of materials and support grids, installed during decades of building use and renovations. In contrast with vertical gypsum drywall or plaster, the entire mass of a ceiling must be restrained against gravity. Fastener type, configuration, and spacing are all pivotal in the performance of a ceiling, as is the arrangement of support lath.

Curving chimneys and meandering parapets: A curving chimney is not the same thing as a *leaning* chimney—the latter being associated with inadequate footing projection and the fact that the chimneys are eccentrically loaded on a footing. **Figure 9** illustrates radical curving of a brick masonry chimney. Remember that creep can occur from both mechanical loads and persistent thermal loading. Curvature of a chimney stems from environmental influences over a long period (for example, wind or solar exposure). There are conflicting theories regarding what prompts the curving of



Figure 8. Severe ceiling sag in an occupied restaurant. Some instances of ceiling collapse are so abrupt and loud that witnesses have described an "explosion" in the attic.



Figure 9. Radical curving of a brick masonry chimney, not from structural loading, but rather stemming from environmental influences over a long period.

a chimney. One theory holds that curving occurs *toward* the direction of the prevailing wind, as it is the quickest-drying face; the slow-drying side experiences widening of mortar joints from expansion of the internal salt crystals. The other theory holds that curving is *with* the direction of wind-driven rains. It remains debatable whether wind direction or solar exposure is the prime influencer for long-term curving, as the prevailing direction of wind may or may not be the same face experiencing the quickest drying. In any event, it is a long-term behavior, and the two theories share the notion that unequal deterioration of mortar joints is the primary driver to cause curving.²

One-ply membrane lap splices: The one-ply membrane market has been rich with experimentation—and for good reason. The early days of one-ply roofing were characterized by a plethora of failures, and many were associated with poorly performing laps and related flashings. Specifically for ethylene propylene diene monomer (EPDM),

TABLE 1. Development changes to ethylene propylene diene monomer products and systems

Years	Development changes to products and systems
1985–1986	Butyl-based splicing cement replaces neoprene, which had poor resistance to heat and moisture (for example, trapped water, wet roof insulation).
1985–1987	Ethylene propylene diene monomer—based flashing material replaces neoprene. The latter had poor resistance to heat and ozone.
1987–1989	Uncured tape laminates replace adhesive seams at perimeters and on batten bars.
1988–1990	Metal battens, screw fasteners, and stress plates replace beveled wood nailers at base tie-ins.
1991–1993	Reinforced membrane flashing strips introduced as alternative to metal battens for base tie-ins.
1992–1993	Vulcanized seam tape and “high-solids primer” replace liquid adhesives in lap splices.

Source: IECC 2021, Table C402.1.3



Figure 10. Older variety of structural insulated panel used for the walls and roof deck of a midwestern freezer facility. Severe deflection resulted from long-term ponding plus the mass of two roof layers (the outermost being stone ballasted). This behavior may be years in the making and well exemplifies creep.



Figure 11. Downslope migration of bituminous flood coat and aggregate surfacing. The softening point of the bitumen was incompatible with the roof slope.

Table 1 highlights some of these changes in materials and practices.

The table is by no means a complete list of changes through the years, and it is no particular indictment of rubber roofing. Thermoplastics enjoyed a host of problems of their own—as did uncured elastomers and early modified bitumen. Meanwhile, as tapes were gaining acceptance, groundbreaking work was carried out at the National Institute of Standards and Technology. Regarding EPDM laps, the “time to failure” under sustained loading (that is, creep rupture) was evaluated for lap splices using a variety of tapes, primers, and temperature combinations.³

Structural insulated panels (SIPs): Severe roof deflection shown in **Fig. 10** resulted from long-term ponding plus the mass of two roof layers (one being stone ballasted). While this midwestern freezer facility had a quite early

variety of SIP, the slowly sagging behavior was years in the making and well exemplifies creep. Modern SIP products are vastly improved over this 1960s construction, but they still should not be stretched out or overloaded. Roofs are experiencing creep when their surface deformation does not rebound after snow and water are removed.

Downslope migration of old built-up roofs: **Figure 11** illustrates downslope migration of bituminous flood coat and aggregate surfacing. The softening point of the bitumen was incompatible with the roof slope. Five decades ago, this behavior was known as slippage, and all manner of construction disputes grew from it. The seasoned reader may recollect a practice known as back nailing, the purpose of which was to control downslope creep of bituminous roofing materials. The slow-acting load being applied here is simple gravity.



Figure 12. Unit masonry slumped vertically and eventually kicked out of plane. Decades in the making, it originated from a substandard connection to the backup plane.

Unit masonry walls (usually but not always brick): **Figure 12** is an example of unit masonry that had slumped vertically and eventually kicked out of plane. Probably

decades in the making, it originated from a substandard connection to the back-up plane. Bow and sweep observed in basement walls are often accompanied by water seepage. The perception by some property owners is that wall cracks are getting worse with time, and they may well be. Proprietary movement gauges are available to evaluate whether or not cracks are indeed widening. Cracks that are deemed to be "dynamic" should be closely scrutinized, with emphasis on remedial measures.

SUMMARY REMARKS

Every time there is deflection of a roof deck, it does not portend creep behavior. But the point remains that a slowly deforming building components, eventually falling or failing after years of service life, should not be confused with a singular episode of unusual weather

activity. This can be shocking to some owners who assert that their building was fine for decades until it inexplicably failed during a storm. Creep can certainly be aggravated by extreme weather events, but its origin is usually from something undersized, overextended, or poorly connected. 

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