Fire Hits the Deck

In parking garage fires, the framing system never takes the most heat.

DALE F. DENDA'S INVESTIGATORY work over the last 18 years has been both focused and unique. Denda is the director of research for Parking Market Research Co., McLean, Va. Today, after studying more than 550 fires, his findings likely constitute the largest single body of field evidence of fire behavior in open multi-level parking structures in this country. *Modern Steel Construction* editors recently spoke with Denda about this body of knowledge and the lessons it holds, especially for designers and code officials.

Q: Do we really know more today than we did a decade ago in terms of designing a better fire-safe parking structure?

DD: The short answer is yes. We now know that we don't have a huge or even significant issue, from a fire-fighting perspective, in terms of sustained structure-threatening fires in parking garages. Non-crash vehicle fires simply don't behave the way other combustibles do in building fires. Vehicle fires are largely contained, self-limiting events. Most garages actually are over-designed for the worst probable event.

Q: That touches on a couple of different issues. In what way do garage fires, or at least vehicle fires, represent a different type of event than found in a normal building occupancy?

DD: A non-crash vehicle fire is, in relative terms, a tame event in that it doesn't develop, or spread, quickly. Our research shows that's very significant in terms of life safety, and directly corresponds to the superior life safety record in garage fires relative to other types of structures. Vehicles also don't burn very long at exterior elevated temperatures—say above 800°—affecting exposed structural members. Very rarely does a vehicle fire burn that hot for more than 15 to 20 minutes.

Opposite page: Although fire code provisions for parking garages assume greater risk of fire damage to larger parking structures, historical information show the opposite to be true—those with larger floor areas create a relatively larger margin of safety.

Q: How rare are the longer vehicle fires? Can you be specific?

DD: Fires in larger-floor area garages show combustion to be quite limited both in relative and absolute terms. Only about 8% of events affect an area beyond the footprint of the vehicle of fire origin. Thus, 92% of the events take in a floor area of about 200 sq. ft. The maximum impact is actually a smaller area, perhaps 50 to 70 sq. ft, directly beneath the area of origin in the vehicle. We found this to be the case in several hundred single-vehicle fires. Fire incidents spreading beyond the vehicle of origin are progressively rarer and take in proportionately more, but still limited, slab areas. So considering that larger garages have on average about 70,000 sq. ft of floor area, typical fire exposure and spread are quite limited.

Q: How often does structural damage occur from vehicle fires in these structures?

DD: According to fire department records it is very rare—less than 1% of events. In terms of damage to the structural frame, it's on average negligible. As far as properly designed, built and maintained floor slabs are concerned, damage is limited to the immediate area above, and sometimes beneath, the vehicle of origin. Damage occurs in only a fraction of the larger events and, even with multiple-car fires, the damage is limited in area.

Also on average there is no difference between concrete framed- or steel-framed structures, given that steel-framed garages as a system are typically of composite (i.e. concrete deck) construction. One wouldn't expect much difference, and in fact there is none in terms of statistical significance.

Q: What do you mean by no expectation of differences between steel and concrete garages?

DD: Well, first remember that we are talking about fire events as recorded by fire departments and insurance companies. I'm a researcher and we report on what we find in the paper trail. Deck exposure to the heat of the fire is the greatest danger, and the decks are concrete regardless of whether garage framing is concrete or steel. In other words, structural damage measures in our research are in whole dollars per fire defined by the cost of repairing the damage, including both the beam and slab members. When damage does occur, it is mostly in the areas that are most exposed—the concrete slabs.

Q: But aren't beams the critical elements?

DD: Yes, fire resistance of beams, whether steel or concrete, is critical to preventing catastrophic collapse. But understand that there have been no documented situations, or even reported occurrences, where structural collapse occurred or where civilians could not be safely evacuated, firefighters inserted to combat the event, or inspectors or even repair crews sent in after the event. In short, we have seen no catastrophic failures associated with fires in parking garages. At any rate, fires in larger garages are too small and don't burn long enough for concerns of structural frame stability to come into play.

Q: Are you saying that the composite concrete deck slabs are at a greater risk in steel framed garages than the steel members?

DD: Yes, that's exactly what the evidence shows.

Q: How often does this type of slab damage occur?

DD: Again, rarely. Relatively serious damage, say in excess of $300,000, may occur once every few years.

Q: What do you see as a worst case scenario?

DD: A worst case scenario is defined in one sense by events yet to happen. Witness, for example, how the World Trade Center redefined such a scenario. However, as far as my research is concerned, we have definitively outlined the probable worst case event. We call it a probable worst case three-year event, because it likely will occur only once every three years in a single garage somewhere in the U.S.

It would be about a six-car fire load, like the one that occurred in a large airport parking structure in 2003. The total burn time there was well over 90 minutes, and probably closer to two hours due to complicating circumstances. Damage immediately above the vehicle in which the fire originated ranged from severe spalling to crazing in cast-in-place, post-tensioned slabs. That cost something less than $1 million to repair. Even under those extreme conditions, damage was limited 1,400 sq. ft in a 600,000-sq.-ft garage with parking for 1,800 cars—and there was no threat of structure failure.

In that case it's also notable that the fire investigation report was able to document how long the structure was exposed. Quoting from the report, "According to the surveillance tape

After years of studying vehicle fires in parking structures, Dale Denda says today's building fire code assesses the risk from such fires exactly opposite of what fire department reports show it to be.

there was a one-hour delay from the time cameras lost picture and the time the fire department was contacted. The time period that the fire burned freely prior to extinguishment was a significant contributing factor to the extent of fire damage to the vehicles and to the parking structure itself."

Q: Has your research resulted in any changes in garage design?

DD: None that I have heard of. Changes in the building code have been proposed, discussed and passed citing our findings. Unfortunately, those changes have been at the margins and have not, to date, addressed all issues.

Q: You raised an interesting issue when you said most garages actually are over-designed for the worst probable event. In what way is that so?

DD: Our research shows that there are several specific discrepancies between assumptions upon which the parking structure building fire codes are based and actual field experience. The findings clearly point to a typology, or categorization, of potential fire severity by garage size. Evidence shows that larger structures—those with larger floor areas—create a relatively larger margin of safety. By that I mean they militate against personal injury and conflagration-like events, which also correspond to super-heated conditions. In the first instance that is due to the limited nature of the event. Vehicle fires in large parking garages are relatively limited and relatively contained combustion in an otherwise non-combustible structure.

We not only don't see structural failure, we also don't find significant losses in larger garages due to the fact that they are over-designed for the fire events occurring in them. And by that I mean IBC Type I & Type II structures, both of which are comparable in fire resistance even without superfluous fire protection coatings, special rated assemblies or sprinklers and the like presently required in the latter. These requirements are redundant.

However, the fire code paradigm holds exactly the opposite to be true. That is, it sees larger floor area equating to greater potential combustion, translating to greater probability for structural failure due to prolonged exposure to high temperatures. Based on those unsupported assumptions, the fire codes further posit a risk at parking levels above a certain height. However the same "limited combustion" logic means these provisions are also unsupported.

That is the gap between code assumptions and real world fires. However, our data plainly show there can be complications and greatly increased risk in certain vehicle fires in smaller floor area garages. For example, consider the three-year event I mentioned earlier occurring in a 180-car, multilevel garage rather than in an 1,800-car garage. With an average floor area of only 20,000 sq. ft, the same six-car fire load could become a serious, structure-threatening fire, if given enough time. Potentially even greater risk arises if non-vehicle combustibles come into play. These are the conditions present fire codes address as if they applied to larger floor areas and heights, but they should actually be applicable only to small garages.

Q: Is over-designing really all that much of an issue? And if so, in what ways?

DD: About 35% of the garages in design or starting construction in 2008 were of a size or configuration that would trigger unnecessary fire code requirements—but only if the garages were of steel construction. And these projects are by definition the larger ones, so in 2008 code-related over-design affected as many as 195,000 spaces or the potential use of well over 200,000 tons of steel.

Q: What would you say are the most significant aspects of your work concerning parking garage fires?

DD: There are two problematic issues in terms of basic assumptions in the fire code as applied to parking garages. The flaws in the code are fundamental, not details at the margin. One, field evidence does not support any difference whatsoever in structural fire-resistance between any type of larger concrete parking structure and any kind of steel-framed parking structure. And the evidence is pretty straightforward—the fires are too limited in extent and duration, and therefore degrees of exposure and temperature in that area are below any threshold where there are differences between steel and concrete. The fire code recognizes garages as a low fire hazard building type, creating, ironically, an internal contradiction in applying higher standards for heat resistance for steel in an environment that, as I just said, it also classifies as low hazard.

But, again, the bigger issue is a more fundamental flaw concerning the assumed relationship between area, or size, and structural risks. The present building fire code posits risk assessment exactly opposite of what fire department reports show it to be, namely, that large steel or concrete garages are more risk prone to collapse than smaller ones. The evidence to support this proposition does not exist. MSC

When damage does occur as a result of a vehicle fire in a parking garage, Denda says, it is mostly in the areas that are most exposed—the concrete slabs.

Photos by Bill Pascoli, AISC, in the offices of AISC Member Kinsley Manufacturing, York, Pa.