“The building is your enemy”

1 Introduction

The title of this article is a well-known quote in the US. The legendary chief (officer) “Frank Brannigan” has made it his life’s work to ensure firefighters are aware of the dangers inherent to structures on fire. Structural collapses (either full or partial) are not uncommon at fire scenes.

Buildings are very diverse. In the US there are more buildings with wooden structures than in Belgium. And buildings with a wooden (read: flammable) structure behave differently during fires than our traditional brick buildings. However, an increasing number of “wood structures” is being built in our parts nowadays. In passive housing construction, more and more wooden frames are being used. Often the interior finishing is done with wood paneling. Housing like that contains a lot of extra fuel load. Wood paneling as an interior finish also means there’s a very large surface of contact. The comparison can be made to a CFBT container in which typically wooden boards with a total surface of 10-12 m² are used as fuel load. In a room of 4 m by 5 m there’s easily 45 m² of wall present. If these walls are finished using a flammable material, a different kind of fire will develop here than in rooms made of brick and plaster. A second important difference between the new wood frames and the traditional building is strength. Modern construction often uses thin wood elements. The fire resistance of these building elements is usually rather limited.

However even in our traditional buildings we sometimes face difficulties. Wall collapses have caused plenty of injuries to firefighters. After the incident it’s often stated that “We didn’t see this coming”. Therefore this article will focus on buildings and more specifically on structural collapse.

1.1 Cases

1.1.1 Church fire

On March 9th of 2004 a fire starts in the Koningkerk of Haarlem (The Netherlands). The massive wooden roof structure is quickly engulfed in flames. Because of both the large surface of the roof and the size of the church, an interior attack is no longer possible. The decision is made to operate from the outside. The fire scene grows immensely. An exterior attack is by definition not very efficient. A lot of water is flowed into places where it can’t do much good. Unfortunately, there simply is no better alternative available. After the roof structure has collapsed or burned away, the large walls of the church are still standing. Inside these walls a heavy fire is still burning. The incident commander realizes that the free standing walls pose serious risks. He orders one of the roads next to the church to be closed down because the risk of an outward collapse is too high. Even the fire service is prohibited from using the road. The fire scene is very large however, meaning that there are numerous firefighters present. Not everyone receives the command that a specific road is prohibited to all personnel. About an hour after arrival of the fire service, one of the side walls caves in. The wall collapses – as expected – outward. Three firefighters, apparently unaware of the issued command, are caught underneath the wall collapse and perish.

1.1.2 Dormer

On May 16th of 2012 the fire service of Waregem (Belgium) is fighting an apartment fire. During extinguishment a side wall of a dormer collapses completely unexpected. The debris falls onto a firefighter wearing SCBA. Even though his helmet and BA partially deflect the blow, the firefighter is still severely injured. After months of revalidation, he remains paralyzed from waist down. So aside from known risks ("walls collapse at fire scenes" as described in the Dutch case) there's also a less known or even unknown risk for collapse ("a dormer can collapse as well"). It's the responsibility of every commanding officer to watch for any potential collapse scenarios. By discussing incidents, the knowledge of such scenarios should increase. Hopefully this will reduce the chance for accidents.

1.2 Why does a building collapse?

In the US dr. Richard Gasaway is working on a campaign on "situational awareness". He's trying to teach firefighters that it's important for them to be aware of their surroundings. His website, www.samatters.com, hosts a number of interesting articles on how we are aware of our surroundings. In one of his articles, he formulates the hypothesis that each and every building is in the process of falling down.

Everyone knows gravity. Gravity tries to force everything down. Gravity is also acting on every building. In these buildings there are "structural" elements designed to counteract that force. Aside from gravity, other forces will act upon the building as well. Wind can execute a tremendous force on an exterior wall. Through all the structural elements (floors, walls, beams, columns,…) the different forces are transferred onto the foundations.

As long as the structural elements function as they are supposed to, the building will remain standing. When the structural elements are weakened as a result of a fire, the building can (partially) collapse. Sometimes this is hard to predict, but in some other cases (e.g. a wall falling over) the risk is known long beforehand.

1.3 Building materials

Underneath is a description of a few building materials commonly used in construction and often prone to collapse. It is a very concise and simplified description. The goal is to highlight some of the collapse mechanisms.

1.3.1 Brick

Brick is very widely used in construction. Most of the time it's used for building walls. Brick walls are well suited to counteract vertical forces. They transfer the weight of the floor onto the foundation. They don't stand up well to sideway force however. Masons know very well that recently laid brick walls can topple when there's a strong wind blowing. The wind exerts a large pressure on the surface formed by the wall. When this force becomes too large, the wall will fall over. It's not until there's a floor on top of the wall, that this risk is cancelled. The floor absorbs the horizontal force of the wind and distributes it to the different walls on which it's resting. The same goes for gables on buildings. Only after there are rafters attached to them, do they become sturdy.

In a fire there are two different effects that may lead to collapse. The first is the burning up of the wooden rafters. This usually takes some time. First the fire needs to be fully developed. Then gradually the fire will burn through the rafters until they collapse and burn up completely. At some point in time the gable will be standing on its own. If in that case there's a strong wind blowing, the free standing gable will become a risk. Dependent on the wind the gable might fall inward or outward. This can happen during extinguishment, during overhaul or even long after the fire's been put out. As long as the wall isn't supported, it may fall over.

Figure 1 The fixation points of the bales have been partially burnt through. When wind conditions are fierce, these gables may collapse. The chimney is probably attached to the rafters as well. There may be damage at this point also. *(Photo: unknown)*

A second effect that's happening is the heating up of the wall. A fire that has burned through the roof usually means that temperatures are very high. The free standing wall is subjected to these temperatures. On the inside of the wall, these may exceed 1000 °C. The outside of the wall will not be that hot. Objects that are heated up have a tendency to expand. The inside of the wall will want to expand while the outside doesn't. The result is that the wall will become warped. The bottom end of the wall is fixed onto a foundation or a floor so it can't move. The top end of the wall is loose, so it will move outward. The wall will take on the shape of a banana. By assuming this form, the hot inside can expand while the cooler outside won't have to. If this process will continue, the wall will eventually fall over. A free standing wall that falls over because of a fire will always fall outward (away from the fire).

1.3.2 Steel

Steel is also widely used in construction. It's a very strong material and will also stretch very far before it breaks. Typically you will see a steel construction bend before it collapses. Steel is also a material that transfers heat extremely well. When steel is heated, it will expand just like any other material. Steel beams and trusses can therefore exert a tremendous horizontal force onto the walls to which they are attached. This force may become so high that the wall will be pushed over. So in this scenario, walls can fall outward as well.

New building legislation regarding industrial construction ("bijlage 6" in Belgium) requires structures to be designed so that they will fall inward in the event of a collapse. For modern industrial buildings this means the risk is eliminated beforehand.

1.3.3 Wood

Wooden beams are also frequently used in construction. Historically these were massive wooden beams. Even though wood is a flammable material, these beams had rather good fire resistance. A beam supporting a floor, will be “attacked” by the fire from three different sides. At the bottom and the two sides, wood will burn. This will reduce the load capacity of the beam. This will continue until the fire’s been put out or the beam collapses. For old, massive wooden beams it would take some time for the fire to sufficiently weaken them.

Figure 2 Wooden trusses *(Photo: NIST)*

In modern construction, more and more light weight wooden elements are used. These types of constructions have long since been used for roof structures. Most of the time, a “common rafter” is used. These are wood planks of about 3,5 cm by 18 cm. During a violent fully developed fire these rafters burn up quickly. The width is only 3,5 cm after all. Recently these boards are also being used to support flooring. It goes without saying that these floors collapse quickly when there’s a fire on the underlying levels.

In North-America, light weight construction is taken a step further. Here, wooden trusses are being used (see Figure 2). The strength of the element is partially dictated by the diagonal joints between the upper and lower wood of the truss. It’s clear to everyone that these diagonal joints will burn away very quickly during a fire. Research done in Canada indicated that the fire resistance of such a construction is less than ten minutes.

1.3.4 Prefabicated concrete

In industrial buildings, prefab concrete is often used (see Figure 4). Wall elements made of concrete are attached to a steel frame. During a fire the joints connecting the wall elements to the steel frame will be severely strained. It’s possible that these joints will buckle and the wall elements will come crashing down. Especially when elements with a large vertical size have been used, then the debris can fall quite far from the original wall.

1.4 Avoiding accidents

It’s not always possible to avoid collapses during a fire. After all a fire weakens the load bearing capacity of constructions. However it is important for commanding officers to be aware of the risk and also to take it into account. It should never happen that firefighters perish under a collapse that could have been foreseen.

1.4.1 *Collapse zone.*

Every firefighter should know what the term collapse zone means. The collapse zone is the area in which debris ends up when a wall falls over or a building collapses. The rule of thumb usually says that the size of the collapse zone is equal to one and a half times the height of the wall.

After a wall has collapsed, fire crews often advance through the rubble to get closer to the fire. After the wall has fallen over this isn't such a big problem. The risk is gone after all. Before the wall has collapsed, it's extremely dangerous to enter the collapse zone. In the event of a collapse, you would then get caught be falling debris.

1.4.2 *Deployment of personnel*

It's the job of the officers in charge to be wary of possible collapse during firefighting operations. In those first hectic minutes on the fire ground there more often than not isn't any time to check for this. Then again most of the time collapse doesn't happen in the beginning of a fire ground intervention. The exception to this are light weight wood frames that are more and more commonly used in construction.

In longer fire ground operations fire crews will all have been deployed at some point in time. Chief and company officers should then ask themselves: "Can something collapse? What could possibly collapse? Where will the falling debris end up?" If the answers to any of these questions indicate to possible injury of fire crews, other emergency aid services or civilians, preventive measures have to be taken.

Figure 3 After a fire only the walls are left standing. Using crowd barriers and barricade tape the collapse zone is outlined. *(Photo: Herman De Wit)*

The correct deployment of personnel (see Figure 4) can prevent a lot of problems. Firefighters set up outside the collapse zone will probably remain unharmed in the event of a collapse. When a crew is placed at a certain distance from the building, it is important to tell them why they have to stand "this far". It may also be useful to communicate to all firefighters that a certain area is off limits. In extreme circumstances a sentry can be posted. For example when a passage way has been open for the crews during a long period and now can no longer be used. This may seem like an extreme measure and the firefighter assigned to perform the task probably won't be happy doing it. But if we compare that to a severely injured or deceased fireman, it has to be said that it is an efficient measure that is also easy to implement.

1.4.3 *Preventive collapse of walls and gables*

When, after the fire's been knocked down, it becomes clear there's a risk for collapse, the necessary measures have to be taken. The best option is to remove the danger completely. The fire service may opt to let the wall collapse or they can requisition heavy cranes to have the wall partially broken down before overhaul is started. Forcibly collapsing a gable is not something home owners like to see happening, but the cost of rebuilding is small compared to the cost of an injury or fatality caused by a collapse.

Figure 4 A fire in an industrial building made up out of prefab wall panels. Because of the risk for collapse, distance to the wall is kept. Afterwards, any loose panels are removed to eliminate the any risk for collapse. *(Photo's: Peter Vangierdegom)*

Sometimes the choice is made to leave walls standing in an unstable position during overhaul. This is done because the building has architectural value. In such cases an area needs to be outlined in which crews can no longer come (if this hasn't already been done during extinguishment). In some fire services abroad, barricade tape with a different colour combination is used (e.g. yellow/green). Firefighters tend to ignore the classic red/white tape. The rule in such services is that the classic red/white tape is used to deny access to civilians, while the alternative colour combination is used to indicate immediate danger and is off limits to everyone.

1.4.4 To shore

Shoring a wall is a last and important way to eliminate collapse danger. Especially when the choice has been made to leave unstable walls standing, these walls need to be stabilized. Sometimes this can't be done until after firefighting operations have been completed. This is preferably done by specialised firms. Especially after extinguishment, it isn't wise to take risks while professionals are often better trained and equipped to shore walls and buildings.

1.5 Final thoughts – "I have a dream"

I would like to finish this article with a quote from Martin Luther King. The first case in this article, the fire at koningskerk, was thoroughly investigated after the incident. The final report by public safety inspection ("Inspectie voor openbare orde en veiligheid") was 220 pages long. A full reconstruction of the timeline of the fatal intervention was attempted. Numerous people present on scene at the time were interviewed. An analysis was made of how the accident was able to take place. A study was done on how things can be done better in the future. Recommendations were made and an instructional course was developed.

On May 9th of 2008 the infamous fire took place in De Punt in the Netherlands. In this fire three firefighters lost their lives. A team was gathered consisting of fire officers, a professor and an expert on occupational safety. On June 18th of 2008 (only 1 month later) this group produced a preliminary rapport with their initial and most important findings. On April 15th of 2009, a final analysis rapport of 256 pages was presented. Again the focus of the group was "what can be done better next time?" instead of "who is to blame?" An instructional video was distributed to offer everyone active in the Dutch fire service the chance to learn from this unfortunate incident. Firefighters course contents are adapted. New operating guidelines are developed.

The Dutch fire service is trying to learn from incidents.

Can we finally start doing the same in Belgium? For large scale catastrophes like the train calamity in Wetteren as well as smaller incidents like a firefighter perishing or getting seriously injured. *I have a dream.*

2 Bibliography

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