ANALELE UNIVERSITĂȚII
"EFTIMIE MURGU" REȘIȚA
ANUL XXV, NR. 1, 2018, ISSN 1453 - 7397

Consideration of Active Fire Protection and Coating for Commercial Buildings

Md Azree Othuman Mydin

For buildings and other constructions, fire protection is a must. The fear of uncontrolled fires and the desire to avoid their consequences is as ancient as human civilization. This fear has obvious enduring roots: unwanted fire is a destructive force that takes many thousands of human lives and destroys large quantities of asset. The primary objective of fire protection is to limit loss of properties and lives in the event of unexpected fires. Active fire protection is effective and efficient in most situations. However, passive fire protection, which includes the use of fire-proofing materials, provides an on-site fire resistance measure to prolong the longevity of load-bearing structures. Certainly, the nature, causes and scope of such events have changed considerably over millennia but fear and avoidance have remained as a primary human reaction and as an important human objective, respectively, for virtually every society. This paper will discuss on risk posed by fire, the passive fire protection components, conventional protection materials and thermally reactive materials. From the review, it can be concluded that active fire protection is effective and efficient in most situations passive fire protection, which includes the use of fire-proofing materials, provides an on-site fire resistance measure to prolong the longevity of load-bearing structures.

Keywords: *fire protection, active fire, coating, construction, building technology*

1. Introduction

The fear of uncontrolled fires and the desire to avoid their consequences is as ancient as human civilization. This fear has obvious enduring roots: unwanted fire is a destructive force that takes many thousands of human lives and destroys large quantities of asset. Certainly, the nature, causes and scope of such events have changed considerably over millennia but fear and avoidance have remained as a primary human reaction and as an important human objective, respectively, for virtually every society (Vandersall, 1971). In the United Kingdom, for example, more than 400,000 fires occur every year in which about 800 people are killed and 15,000 sustain non-fatal injuries. Fires in the UK cost more than £1,000 million per year in direct fire damage. In addition, some fires cause indirect and consequential losses arising from loss of production, of profits, of employment and of exports and thus destroy a significant percentage of the economic wealth of a country.

To control the risk posed by fires, careful education and prevention is necessary but not enough, and fire protection measures have to be adopted. Fire protection involves the study of the behaviour, suppression and investigation of fire and related emergencies. It also includes research and development, production, testing and application of suitable fire protection systems (Taylor, 1992). Fire protection system is an integral part of the building environment. The primary goal of fire protection is to limit the levels of fatal and non-fatal injuries, of property losses to be acceptable, in an unwanted fire event.

There are two generic types of fire protection: active fire protection and passive fire protection. Active fire protection commonly involves automatic devices and human direct actions to control and extinguish the fire. Although active fire protection is effective and efficient in most situations, some problems still remain (Shuklin et al., 2004). For example, an automatic sprinkler system, which sprays deluge agents over a local area under the activated sprinkler head, is a good form of active fire protection. However, a sprinkler system must operate early in a fire to be useful because the water supply system is designed to extinguish only a small size of fire (Purkiss, 1996). Similarly, fire-fighters can actively control or extinguish a fire, only if they arrive in time before it gets too large (Buchanan, 2001). Therefore, the most critical problems of using active fire protection are: (1) it needs time to respond, a very short delay will lead to hugely different consequences; (2) it relies on the supply systems, such as water, inert gas, foam. These conditions may not be met.

Passive fire-protection system is built as a part of the whole building. Not requiring operation by people or automatic controls, it can be considered as an onsite protector with instant response to fire. The primary reason for using passive fire protection is identical to that of all fire protection: life safety. This is mainly accomplished by maintaining structural integrity during the fire, and limiting the spread of fire and the effects thereof. While active fire protection aims to reduce life and property losses, passive fire protection design usually considers property protection as the secondary objective (Buchanan, 2001). According to the design requirements, in most cases passive fire-protection is used in conjunction with appropriate active systems, and it has been increasingly used and developed. By use of a suitable balanced protection system, the human and economic costs of fire damage can be significantly reduced (Anderson and Wauters, 1984).

2. Passive fire protection

Passive fire protection means insulating systems designed to deter heat transfer from a fire to the protected structures, or preventing combustion of flammable materials (Purkiss, 1996). For pre-flashover fires, passive control includes selection of suitable materials for building content and interior linings that do not support rapid flame spread in the growth period (Buchanan, 2001). In the fire protection literature, this aspect is referred to reaction to fire performance. In post-flashover fires, passive control is to provide, by using additional structures and assemblies, sufficient resistance to prevent fire spread through the building construction, which may occur as a result of excessive temperature rise, integrity failure (opening) or structural failure. Prevention of fire spread through the building construction is referred to as fire resistance. For example, walls and floors, structural steelwork and plant can all be protected either by the application of protective material to the substrate, or by the enclosure in a protection system (Buchanan, 200).

There are numerous fire protection technologies currently available for protecting structural elements during a fire and providing sufficient fire resistance. These technologies use different methods to achieve their fire resistance ratings. Fireproofing materials range from conventional inorganic mineral based products to thermally reactive organic formulations.

3. Conventional protection materials

Application of insulating materials is one of the most common measures to protect the structure from direct fire exposure. The conventional materials, including concrete, brick, tile, and asbestos, have been quite prevalent because they perform well at elevated temperatures (Anderson et al, 1988).

In the past, mineral fiber asbestos was used with a cementitious binder and sprayed onto structural elements to provide fire protection. It was also combined with other materials to make asbestos board and asbestos wood. Due to proven health hazards associated with construction and occupancy periods, asbestos has been banned (Purkiss, 1996).

Gypsum (Figure 1) is a good and relatively inexpensive fireproofing material. It contains a high percentage of water that is chemically combined with the calcium sulfate (gypsum) base, and a large amount of energy is required to dehydrate and evaporate this water (Anna et al., 2002). It is typically attached to metal or wood framing, which is then attached to the structural member. However, gypsum products have durability problem in corrosive environment and are subject to loss of integrity in long term service. Loss of water also adversely impacts the strength of the remaining gypsum board (Purkiss, 1996).

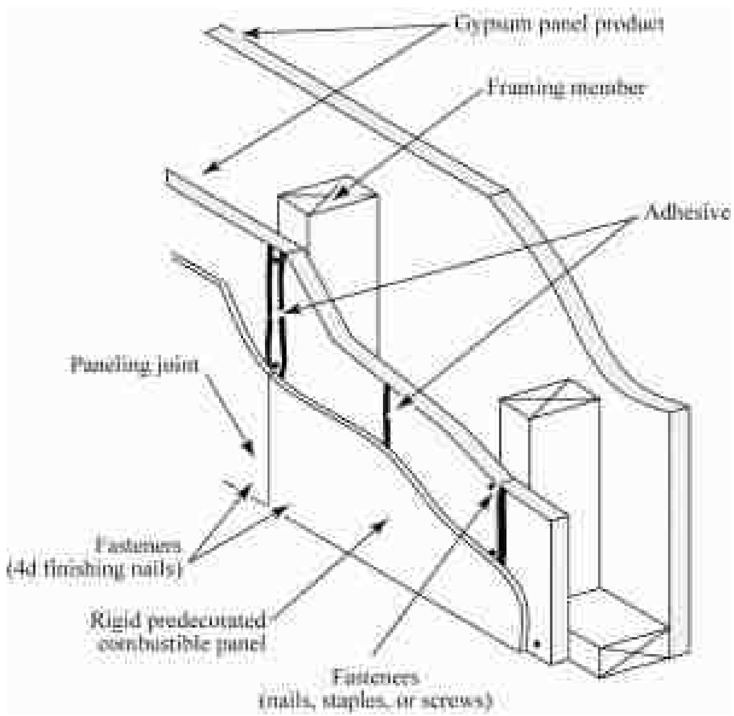

Figure 1. Gypsum panel system

One of the more traditional methods of protecting structures involves encasing the steel member in concrete as shown in Figure 2. Similar to gypsum, concrete is an endothermic material which absorbs heat by evaporation of water content. Concrete is also a good thermal insulator with low thermal conductivity and high thermal capacity (Bourbigot et al., 2000). It therefore delays heat transmission to adjacent structural elements. Increasing the thickness of the concrete increases the time required for heat to transfer to the steel. A distinctive advantage of concrete is that this technology is well established and the required thickness of concrete to achieve sufficient fire resistance can be easily calculated (Buchanan, 2001). In addition, concrete has excellent durability in corrosive conditions. It performs well where resistance to impact, abrasion, weather exposure, and corrosive agents is important.

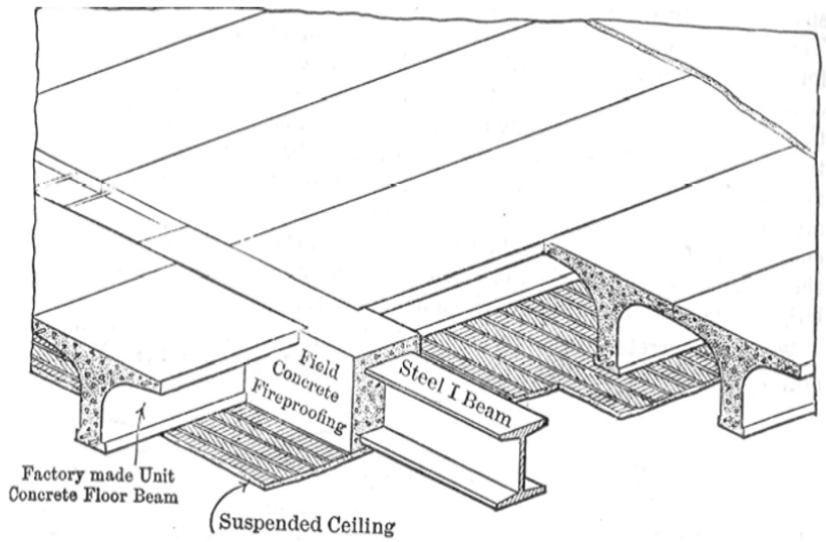

Figure 2. Encasing the steel member in concrete

However, unless it is considered as a so-called "Steel Reinforcement", concrete encasement has some notable disadvantages: poor aesthetic quality of concrete; concrete may take up valuable spaces around structural elements; concrete encasement is time consuming to install; concrete is heavy and can increase the overall weight of the building; transport and handling for off-site materials are difficult; concrete encasement is relatively expensive; concrete is susceptible to spalling (Branca and Di Blasi, 2002). These disadvantages can frequently limit the application of concrete encasement for protective purposes.

Spray applied fireproofing materials are typically cement-based products or gypsum with a light weight aggregate (vermiculite, perlite or expanded polystyrene beads) that have some cellulosic or glass fiber reinforcement as shown in Figure 3. Some of the earliest spray applied fireproofing materials contained asbestos, which is no longer allowed due to health issues (Buckmaster et al., 1986). This method is easy to protect detailed features including connections, bolts, etc. However, protecting on-site areas from overspray is typically required. Rough surface finish makes it not easy to meet aesthetic requirements. Intensive labor works are needed to adequately control quality.

Hollow structural elements can be filled in order to increase the heat capacity of the element, to act as a heat sink. Figure 4 shows an example of hollow slab. Typically, they are filled with either concrete or water (Buchanan, 2001). When filled elements are exposed to fire, the heat passes through the steel and begins to heat the fillings. This method allows use of exposed steel and does not increase thickness of the structural element. As the yield strength of the heated steel column is reduced, the load is transferred to the concrete fillings. However, this method significantly intensifications the weight of structural components (Buchanan, 2001).

Figure 3. Spray applied fireproofing

Figure 4. Hollow slab

4. Thermally reactive materials

The conventional methods have some obvious drawbacks. These materials are heavy, lack of good appearances, hard to apply and need plenty of space. They are liable to shatter and spall when subject to fire. In addition, some of these products are with the potential hazards of mineral fibers. The alternative is to use fire retarding coatings, which are one of the easiest, one of the oldest and one of the most efficient ways to protect a substrate against fire (Buckmaster et al., 1986). Three major forms of thermally reactive materials are available, halogenated fire retardant coating, ablative/subliming coating and intumescent coating [Camino, 1988]. Some years ago, the majority of the commercially used fireproofing materials were traditional halogenated fire retardants. These materials provide chemicals to act as flame poisons by interfering with the atmosphere immediately surrounding the coating, and hence inhibiting combustion (Taylor, 1992). These coatings have shown their highly effective performance. But on burning they generally evolve halogen acids and metal halides whose proven efficiency as fire retardants has to be balanced against their known potential effect in increasing the formation of obscuring, toxic and corrosive smokes (Buckmaster et al., 1986). In recent years, the use of these materials has been limited on account of the possible impact to the environment.

Ablative/subliming compounds are usually added to provide an additional layer for insulation. These coatings have active ingredients that absorb heat during exposure to a fire due to changing from the virgin solid coating into a gas phase. This action prevents heat transmission to the material that these coatings are applied to (Buchanan, 2001). The effectiveness of these compounds is a function of various elements including the coating material thickness, compounds' reactive temperature and enthalpy at thermal reaction, heat capacity of the substrate, and fire exposure. These coatings are similar to intumescent paints. However, the application procedure is complex and this results in relatively high costs for pplication. Furthermore, the fire depletes the protection compounds. Therefore once exposed, the protection provided by the compound is reduced or eliminated (Anna et al., 2002). This can be a major disadvantage during long fires that exceed the designed exposure period.

The above disadvantages associated with various types of passive fire protection materials have resulted in intumescent coating being increasingly favored by architects and becoming dominant in the passive fire protection market in the UK.

5. Conclusion

In conclusion, it can be summarized that fire protection is essential for buildings and other constructions. The main goal of fire protection is to limit damage of properties and lives in the event of unforeseen fires. Active fire protection is effective and efficient in most situations. However, passive fire protection, which includes the use of fire-proofing materials, provides an on-site fire resistance measure to prolong the longevity of load-bearing structures. A broad selection of fire-proofing materials are available, however intumescent coating has become increasingly dominant in the fire protection market in recent years.

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Address:

- Sr Dr Md Azree Othuman Mydin, Senior Lecturer, School of Housing, Building and Planning, Universiti Sains Malaysia, 11800, Penang, Malaysia, azree@usm.my