Fire resistance and simple storey buildings

According to the fire parts of the Structural Eurocodes, the 3 main construction materials- concrete, steel and timber- do not have the same behaviour when exposed to fire.

Concrete structural members, which need to rely on reinforcement steel or prestressing steel to deal with tensile forces, are fire resistant as long as the steel temperature is below a critical value of about 500/600°C for rebars and 400°C for prestressing bars. Conside ring an average concrete cover of the steel bars of 20 to 30 mm, concrete structures have an intrinsic fire resistance rating of 60 to 90 min, provided no spalling phenomena has occurred. Fire rating of 180 to 240 min can be achieved by increasing the concrete covering. However, from an economical point of view, it is generally cheaper to use fire protection material to reduce the heating rate of these elements.

Due to their high conductivity, the temperature of steel structural members is quite close to that of the surrounding fire. In this respect, and considering a critical temperature similar to the one of rebars (500/600°C), the fire resistance rating of steel me mbers is about 10 to 20 min. To achieve fire ratings of 60, 120 and up to 240 min, it is generally necessary to use fire protection coating, the thickness of which will vary from a few millimetres to 50/60 mm, depending on the type of material and on other relevant parameters.

Massive or glued-laminated timber structural members, depending on the size of the cross-section, can achieve fire ratings of 60 min, provided, however, that the elements ensuring the overall stability have the same fire resistance. For higher fire resistance ratings, the use of fire protection material is generally needed.

Clearly, using a fire protection material leads to an increase in the cost of the structure. This increase could be as much as 30/40 % of the total cost.

This short summary on the feasibility of some construction materials is only valid in the context of a standard fire exposure (so-called « ISO fire ») which is still the basis for prescriptive regulations as far as fire safety is concerned. So we need to bear in mind that R60 structural elements will not have an actual fire behaviour of 60 min in the event of a real fire and indeed could be very different. In addition, when dealing with the behaviour of a real building, which is the aim of any fire regulation, other parameters need to be considered, such as the interaction between structural elements and, consequently, the fire behaviour of connections. Expertise on this subject is not consistent between the various materials: some calculation methods like EN 1993-1.2 (steel structures) or EN 1995-1.2 (timber structures) give elevated temperature design rules when others such as EN 1992-1.2 (concrete structures) do not.

In such conditions, for those national regulations which are not performance-based, levels of fire resistance required by prescriptive regulations (or deemed-to-satisfy provisions) will have various economical consequences, depending on the material used for the structural elements. Consequently, it is absolutely necessary for any requirement to be justified in terms of its need to achieve required levels of safety for the building or civil work under consideration.

If there is no doubt that a high level of fire resistance is needed to avoid premature collapse of multi-storey buildings, particularly for tall buildings, the fire resistance rating for single storey buildings is generally unnecessary. This latter type of building is not governed by the principle: the higher the fire resistance rating, the better the level of safety; it needs to be assessed using fire safety engineering tools to avoid costly but ineffective methods of fire protection to reduce the level of risk.

When regulations require the strengthening of fire resistance for multi-storey buildings, it is to ensure the life safety of people (occupants and firefighters) located above the fire level and also to protect property. However, for single storey buildings, there are no people or property above the fire level. For this type of building, risk analysis has to take into account the following:

- First of all, we need to bear in mind that, if there is an increase of temperature in the fire room, it is due to combustible content and, sometimes, to combustible materials used for the structure and fabrics. It is never the only structural combustible element, if any, which can lead to a very severe fire that might endanger people and property. Consequently it would be wrong to suppose that it is possible to protect property by increasing the fire resistance of the loadbearing structure.

- Secondly, when dealing with life and health safety, only relevant parameters should be considered and not appropriate simplistic rules such as "egress time" or "time for firefighters' operation" lower than "the fire resistance time of the single storey building ". For people, the metric for hazard should not refer to time but to toxic gas yield and the amount of heat flux in the vicinity. It is important to remember that a hot gas layer at 500℃ leads to the rmal flux of about 20 kW/m^2 and at 700℃ to 50 kW/m^2 or so; under such thermal conditions skin burn will occur after about 1 minute. Generally, it is agreed that the tenability threshold is 2.5 kW/m^2, much lower than heat flux emitted when structural members fail.

- Likewise, regarding fire service operations, it is not the fire resistance duration which will be the harmful parameter, since the risk of failure of the structure will occur at a level of temperature which cannot be withstood by firefighters. It is the extent to which the fire has developed when the fire service is ready for action which is the key factor determining whether or not they can enter a single storey building.

- In particular, the overall stability of the structure needs to be accurately considered. In the event of a localized fire, a local failure of the building should not lead to a progressive collapse which could endanger lives or even property in areas which are away from hot gases and smoke. .

A lot of national regulations have taken into account this specification for single storey buildings by not requesting fire resistance rating for such works but by concentrating requirements on egress facilities and early fire detection and/or suppression. No information, resulting from the large number of real fires that occur every year, has shown that these kinds of prescriptive requirements are unsafe and could endanger people. However it does appear in some countries that regulators in charge of maintaining fire safety regulation have forgotten these basic principles and are requesting fire resistance ratings of up to 120 min for an ISO fire for such single storey buildings.

It is always detrimental to request inefficient methods to decrease the level of risk, since such an investment should be put to much better use on more productive fire protection methods. This is more and more pertinent when considering the current economical situation and, in particular, sustainable development.

Since it is not possible to cover all fire safety issues with a performance-based code (which could refer to the forthcoming ISO 23932 standard on General Principles for fire safety engineering) and the usefulness of prescriptive codes will last for decades, it is however necessary that any prescriptive requirement is developed in such way that :

- the required objective is clearly expressed,
- next, prescriptive measures relevant to this objective are given,
- and, most importantly, it can be accurately demonstrated in which way the prescriptive measures fulfil these objectives, not only in a conventional manner, in the context of a standard fire and isolated elements, but for the overall behaviour of the entire structure subjected to real fire, which is the sole aim of any regulation.

Regulators in charge of drawing up such regulations need to be careful not require inconsistent fire protection methods which have not proved adequate in reducing risks. Any other approach would be detrimental for the construction economy by forcing building owners to invest in inefficient methods while introducing intentional bias into the competition between construction materials.

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