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Diagnosis and Repair of Buildings Damaged by Fire Exposure

Évaluation et réparation de bâtiments endommagés par un incendie

Diagnose und Reparatur von Gebäuden mit Feuerschäden

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SUMMARY

This paper summarises the philosophy and procedures to be adopted in assessing the damage by fire to structural elements. It describes the design and execution of the repairs necessary on the basis of such assessment, especially to restore the structure so that it will fulfil its original performance requirements, including fire resistance.

RÉSUMÉ

Cette communication présente un sommaire de la philosophie et des procédures pour évaluer le dommage dans les structures sous l'effet du feu. La réparation des structures endommagées, et le calcul nécessaire, sont décrits afin d'atteindre la performance originale et satisfaire les réglementations, spécialement en ce qui concerne la résistance au feu.

ZUSAMMENFASSUNG

Der Aufsatz beschreibt die Philosophie und das Verfahren, welches bei der Beurteilung von Feuerschäden an Gebäuden angewendet werden soll. Es wird die Bemessung und die Ausführung der auf Grund der Beurteilung notwendigen Reparatur beschrieben, mit dem Ziel die ursprünglichen Anforderungen, insbesondere der Feuerfestigkeit zu erfüllen.

1. INTRODUCTION

The objective of a rapair is to restore the original functions of a structure in the most economical way. Before the repair of a building can be started, the damage must be carefully investigated. It must be known which part of the structure or structural element is damaged and to what extent.

It may be useful to discribe what kind of damage are to be expected after a fire, in order to know to what to look for. Therefore, a classification system is useful for the grading of the damage.

There are a number of publications which give advice on the assessment and repair of fire damaged structures. The most comprehensive is Conseil International du Batiment (CEB W14) Report "Repairability of Fire Damaged Structures", 1990 [4].

Though this paper concentrates mainly upon reinforced concrete structures as these are most readily repaired, consideration is also given to damage and repairability of other types of engineering structures and materials.

2. MATERIAL DAMAGE

The deterioration of material properties occuring during a fire exposure, may, in many cases, not be fully restored after the cooling down to normal temperature conditions.

Residual mechanical properties of the materials used in concrete structures, after cooling depend on a number of parameters, such as: kind of steel reinforcing, maximum temperature attained, stress-level during the manufacturing process, rate of heating and cooling, and duration of maximum teperature level.

2.1 Concrete

The residual strength of concrete can be tested by the well known measures. The dependance of decreased strength on the temperature reached before as well as on the cooling down conditions can be taken from Fig. 1-a. As a rough solution, the decrease of the elastic modulus versus temperature may be taken as equal to that of strength.

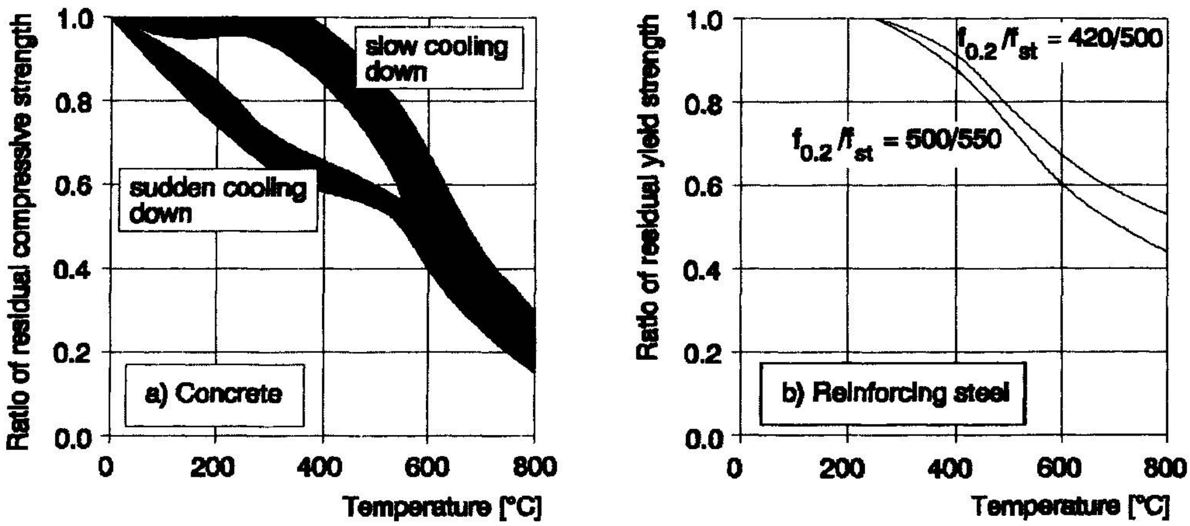

Fig. 1 Residual strengths of concrete and reinforcing steel as a function of temperature reached

2.2 Reinforcing Steel

Hot rolled reinforcing steel recovers its original yield stress if the temperature does not exceed approx. 700°C. With cold worked steel, the work-hardening effect which increases the strength of such typed of reinforcement under normal temperature, surffers regression if exposed to temperatures > 400°C. With temperature lower than 400°C, a residual hardening due to an ageing effect may be observed. Hardening effects, possibly accompanied by a loss of ductility also may be caused by sudden cooling down.

The reduction of the modulus of elasticity may roughly be taken to be in the same range than for the yield stress, Fig.1-b.

3. TEMPERATURE DEVELOPMENT IN CONCRETE CROSS-SECTIONS

The parameters influencing the development of a fire in a compartment, and in consequence the temperature development in concrete elements, are documented in reference [2]. However, a reliable re-construction of the time-temperature process which may have affected the load bearing structure in the individual case to be judged, will very often not be possible.

4. DAMAGE ASSESSMENT

The load-bearing capacity of structural members made from reinforced concrete is reduced through the action of elevated temperatures, because the strength of the concrete as well as that of the steel and the bond between the two materials are diminished. The reduction in load-bearing capacity can be estimated from the maximum temperature, the temporal temperature change and the duration of the heating period.

If the reinforcement has lost strength or ductility, additional reinforcement must be provided to ensure the function of the structure. The design of the repaired members as well as the size and spacing of the additional reinforcement must comply with the code of practice. They must also be practicable in respect of thickness of the concrete cover required.

One special problem can be the placement of the shear reinforcement. There will be no problems for free standing columns or beams, but difficulties will occur in complying with the normal code of practice when additional stirrups have to be placed on reinforced floor beams. To make closed stirrups it is necessary to drill holes through the floor slab at each side of the beam at sometimes very short distances. This will reduce the compression zone of the beam and also affect the shear capacity of the slab. It will also mean that a number of reinforcing bars in the slab are cut.

5. REPAIR TECHNIQUES

It is essential that a repair must restore any loss of strength, maintain durability and fire protection. In situations where, following a fire, there is still sufficient strength and cover for durability then a thin hand or spray applied material could be used to restore a loss in fire protection. Equivalent thickness of concrete cover for various materials may be found from manufacturers. Some information is given in reference [3] and in BS 8110 [1].

5.1 Resin Repair

As a result of the study, it has been necessary to make particular comment on resin repairs. These are commonly used to overcome problems of reinforcement corrosion but may not provide the necessary protection in the event of a subsequent fire.

Resin repairs may consist of a variety of configurations of patch or infill of Epoxy, Polyester and Acrylic mortar. Resins are often used for repairs to lightly spalled areas and, though they may perform quite satisfactorily in normal service, there is no comprehensive information on the performance of such repairs or that of the materials when subject to heat or an actual fire test. What information does exist, including some published papers documented in Ref.[4], indicates that these materials may soften at relatively low teperatures (80°C). As a consequence, it is possible that some resin repairs may not provide adequacy in compression zones. Accordingly it is recommended that resin repairs only be used when either :

- performance data can be supplied to show that the particular formulation has adequate fire resistance and retains its structural properties under the envisaged fire condition, or
- the material is adeqately fire protected by other materials and retains its structural properties at the expected fire temperatures at the relevant depth in the section, or
- loss of strength or other properties of the material will not cause unacceptable loss of structural section or fire resistance.

The designer should refer to the manufacturers literature for details of the performance of the various materials available. A wide variety of materials exists and their specifications are liable to changes at relatively short notice. In general, the materials will be capable of providing good bond and compressive strengths, the flexural and tensile strengths may exceed that of concrete but the thermal expansion is considerably larger than concrete and this may be a point to be considered where the temperature range is large. For further information, the designer should refer to the Concrete Society Technical Report No.26, "Repair of concrete damaged by reinforcement corrosion" [5].

5.2 Polymer Modified Mortars

In many instances, hand repairs of small areas can be effective by use of polymer-modified cementitious mortars. These repairs will generally be to areas or patches of between 12 mm and 30 mm depth. In particular, styrene butadiene rubber (SBR) modified mortars appear suitable. There is limited test information on such mortars but it is expected that they will be satisfactory in a fire as they should behave as a cementitious product. It is to be expected that the use of a small sized aggregate will improve the performance of mortars compared to concretes due to a lesser tendency for damage caused by aggregate splitting in the event of a subsequent fire. In other respects, these mortars are also described in the Concrete Society Technical Report No.26, "Repair of concrete damaged by reinforcement corrosion" [5] to which the designer should refer.

5.3 Cement Mortars

These may be hand applied to damaged areas but great care in surface preparation is necessary in order to ensure adequate adhesion. Generally, mortars will be applicable to well-defined areas placed in layers using good rendering practice, up to a total 30 mm thickness.

5.4 Plaster

This may be readily applied to both plain and roughened concrete surfaces. It can restore a degree of fire resistance but will not replace cover requirements for durability.

5.5 Sprayed Mineral Preparations

This technique will not assist where strength restoration or replace cover requirements for durability are required. Where internal repairs of a minor nature are necessary, these systems will restore fire resistance and shape to damaged members. For particulars, the designer should consult specialist contractors.

5.6 Alternative Supports

The designer can consider the use of alternative supports such as further columns or new beams to sub-divide floor spans. Such schemes may be well prove economic as they may allow lesser restoration to damaged members. Ideally, new supports would be in reinforced concrete but there is no reason why steel, timber or masonry should not be used providing the required strength, fire resistance, durability and appearance are achieved.

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