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Damage of Reinforced Concrete Structures Exposed to Violent Thermal Gradient

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Summary

The evaluation of the actual damage suffered by reinforced concrete buildings exposed to fire is necessary to decide if rebuilding is more advantageous than repair or vice versa. An original assessment technique is proposed, in which thermal and stress theoretical analyses are combined together to study a posteriori fire damaged structures, being the maximum temperature attained by the actual fire deduced by searching, using spectroscopy, temperature dependent mineralogical transformations of basic components of the concrete aggregate. A worked example, concerning a fire damaged existing industrial building, demonstrates the efficacy of the method.

1. Introduction

The refurbishment of reinforced concrete buildings exposed to fire is a problem of great topicality. In fact, since in many cases the buildings are not significantly destroyed, it is necessary to decide when rebuilding is more advantageous than repair or vice versa. In making such a decision, the evaluation of the actual damage suffered by each structural element becomes crucial, in order to distinguish the structural parts to pull down from those that can be repaired. Unfortunately, fire injuries are often not restricted to the external surfaces of beams and columns and penetrate deeply into their core, so that appropriate diagnostic procedures, combining non-destructive testing methods with theoretical thermal and structural analyses, are required. Moreover, non destructive testing methods result not yet satisfactory, and therefore, at present, it seems quite impossible to estimate exactly inner damages, unless a posteriori exhaustive information, like the knowledge of the maximum temperature attained on the surface of each structural element, to be deduced by multidisciplinary analyses, is available. On these bases an original method for the assessment of existing building subjected to fire has been developed.

2. A refined combined method for damage diagnosis

The procedure consists in the preliminary localisation by non destructive testing methods of the most damaged areas, to be analysed in most refined way. Subsequently, analysing cores taken out from the elements themselves, the internal crack patterns is mapped while the maximum fire temperature is deduced, resorting to spectroscopy, checking the penetration depth of characteristic mineralogical transformations, affecting certain mineral components of the aggregate, subjected to high temperatures, like the one concerning dolomite, which originates, at 832 °C, brucite and periclase. In this way the maximum temperature attained on the external surface during the fire can be evaluated, allowing the calibration of the input fire curve for transient thermal and stress FEM analyses.

3. Diagnosis of existing structures exposed to fire: a worked example

The validity of the procedure sketched out before has been proved studying the damage of an existing industrial building, a paper-mill located near Lucca (I), which was seriously injured by fire in the spring 1997.
In fact, the coring of the columns permitted to stress the internal crack pattern of the damaged column, characterised by cracks propagating perpendicularly to the exposed face, while the spectroscopic analysis has proved that the transformation of dolomite in brucite and periclase affects a 6 mm thick layer of concrete, so that the FEM transient thermal analysis of the reinforced concrete column shown that the maximum temperature on the heated face of the column during the fire was about 957 °C.
The results of the stress analysis show that tensile stresses parallel to exposed surface occur, which are much higher than the tensile strength of concrete, and this explains the reason of the opening of the detected cracks.

4. Conclusions

An original procedure to assess fire damaged existing reinforced concrete buildings, making use of multidisciplinary knowledge, has been developed. The method is based on preliminary non destructive tests, mainly ultrasonic, which allow to establish the most damaged elements on which further investigations must be focused. Beside that spectroscopic analyses are carried out in order to discover, studying suitable mineralogical transformation of the aggregate components, some characteristic temperature, that will be used to locate the position, inside the element, of the corresponding isotherm. This information, by means of an appropriate theoretical analysis, leads to fix the maximum temperature attained on the exposed surface during the fire, in such a way that the appropriate input data for thermal and stress analysis of the building can be set up.
A worked example, concerning an industrial building severely injured by fire, is fully developed, demonstrating the flexibility and the powerfulness of the proposed method, also explaining the complex crack pattern discovered in the damaged columns.
The development of the method, still in progress, is mainly addressed toward the improvement of non destructive investigations to calibrate the input data.