

Zeitschrift: IABSE reports = Rapports AIPC = IVBH Berichte
Band: 77 (1998)

Artikel: Damage of reinforced concrete structures exposed to violent thermal gradient
Autor: Cioni, Paolo / Croce, Pietro / Salvatore, Walter
DOI: <https://doi.org/10.5169/seals-58285>

Nutzungsbedingungen

Die ETH-Bibliothek ist die Anbieterin der digitalisierten Zeitschriften auf E-Periodica. Sie besitzt keine Urheberrechte an den Zeitschriften und ist nicht verantwortlich für deren Inhalte. Die Rechte liegen in der Regel bei den Herausgebern beziehungsweise den externen Rechteinhabern. Das Veröffentlichen von Bildern in Print- und Online-Publikationen sowie auf Social Media-Kanälen oder Webseiten ist nur mit vorheriger Genehmigung der Rechteinhaber erlaubt. [Mehr erfahren](#)

Conditions d'utilisation

L'ETH Library est le fournisseur des revues numérisées. Elle ne détient aucun droit d'auteur sur les revues et n'est pas responsable de leur contenu. En règle générale, les droits sont détenus par les éditeurs ou les détenteurs de droits externes. La reproduction d'images dans des publications imprimées ou en ligne ainsi que sur des canaux de médias sociaux ou des sites web n'est autorisée qu'avec l'accord préalable des détenteurs des droits. [En savoir plus](#)

Terms of use

The ETH Library is the provider of the digitised journals. It does not own any copyrights to the journals and is not responsible for their content. The rights usually lie with the publishers or the external rights holders. Publishing images in print and online publications, as well as on social media channels or websites, is only permitted with the prior consent of the rights holders. [Find out more](#)

Download PDF: 06.02.2026

ETH-Bibliothek Zürich, E-Periodica, <https://www.e-periodica.ch>



Damage of Reinforced Concrete Structures Exposed to Violent Thermal Gradient

Paolo CIONI

Assistant Professor

Univ. degli Studi di Pisa

Pisa, Italy

Pietro CROCE

Assistant Professor

Univ. degli Studi di Pisa

Pisa, Italy

Walter SALVATORE

Researcher

Univ. degli Studi di Pisa

Pisa, Italy

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.