Available online at www.sciencedirect.com

ScienceDirect

Procedia Engineering 195 (2017) 120 – 126

Procedia Engineering

www.elsevier.com/locate/procedia

18th International Conference on Rehabilitation and Reconstruction of Buildings 2016, CRRB 2016

Determining the Condition of Reinforced and Prestressed Concrete Structures Damaged by Elevated Temperatures

Iva Rozsypalova[a,b], Pavel Schmid[a,b], Petr Danek[b] *

[a]*Brno University of Technology, Faculty of Civil Engineering, AdMaS, Purkyňova 139, 612 00 Brno, 602 00, Brno, Czech Republic*
[b]*Brno University of Technology, Faculty of Civil Engineering, Institute of Building Testing, Veveří 331/95, 602 00, Brno, Czech Republic*

Abstract

This paper focuses on the effect that high temperatures generated during a fire have on reinforced and prestressed concrete structures. Fire is one of the common reasons for rehabilitations and reconstructions during the service life of a building. Before these can be started, however, it is necessary to assess the structure's technical condition. It is therefore necessary to know the physico-chemical changes occurring in the concrete due to fire. Rising temperatures effect the evaporation of all water contained and cause the dehydration of CSH compounds. Transformations in the crystalline structures of siliceous aggregate minerals result in an increase of volume and crack formation. The decarbonation of limestone aggregate produces escaping gases which damage the concrete as well. Additional mechanical stress caused by the sum of the volume changes is another important factor. In addition, the different thermal expansion of steel and concrete severs the bond between the two. Changes in the material structure are then detrimental to the mechanical parameters. Concrete sees significant changes at temperatures as low as 300 °C. A structure's load-bearing capacity is often determined by reinforcement bars or prestressing tendons, which reach their critical limits at temperatures lower than concrete. The paper draws on knowledge about the condition of materials damaged by elevated temperatures and discusses the assessment of a concrete skeleton structure after a fire. The main problem was presented by the ceiling, which was built from Spiroll prestressed ceiling slabs. The grouting between the slabs had disintegrated, the bottom faces of the slabs fell off and the prestressing tendons often lost tension. A renovation procedure for the structure was suggested.

Peer-review under responsibility of the organizing committee of the 18th International Conference on Rehabilitation and Reconstruction of Buildings 2016

* Iva Rozsypalova. Tel.: +420-541-14-7829 .
E-mail address: rozsypalova.i@fce.vutbr.cz

Peer-review under responsibility of the organizing committee of the 18th International Conference on Rehabilitation and Reconstruction of Buildings 2016
doi:10.1016/j.proeng.2017.04.533

Keywords: Concrete; structural assessment; high temperatures; fire

1. Introduction

Fire is one of the most common hazards that steel-reinforced and prestressed structures are facing today. Prior to commencing renovation and remediation of a structure damaged by a fire, it is necessary to assess its current structural and technical condition. The effects of fire on each part of load-bearing steel-reinforced structures are subject to a large number of influences. The most significant one is the duration of the thermal load, water content of the concrete, type of aggregate and mineral composition. Apart from material properties, the eventual behaviour of the structure after a fire is also affected by the type of structure, since the forces inside a constrained structure often cause irreversible damage during a fire due to thermal expansion. In addition, the extinguishing of the fire can have a strongly detrimental effect when the hot structure comes in contact with a large quantity of a cold extinguishing medium (typically water), which results in additional thermal shock [1,2,3,4].

As concrete becomes warmer, the volume of the aggregate increases while the hardened cement paste surrounding the aggregate shrinks. Due to these counter-acting processes, the bond between the cement matrix and aggregate (known as the transition zone) becomes the weakest point in the composite and the concrete then suffers damage by cracking [1,3,4]. The volume changes in the cement matrix and aggregate are a result of a combination of physico-chemical changes, which occur in concrete during thermal loading. The most important changes are listed in Tab. 1 below.

Table 1.Overview of the main effects of fire on concrete [1,5]

Temperature inside concrete *θ [° C]*	Process taking place
20 – 100	Hydration (free water becoming chemically bound) produces calcium hydro-silicate (CSH) and calcium hydroxide ($Ca(OH)_2$, i.e. portlandite).
100	Start of cement matrix dehydration – decomposition of hydrates and release of free water.
150	Peak of the first phase of CSH decomposition.
200 - 300	Release of chemically bound water.
300 -550	Continuing decomposition of CSH and portlandite causes frequent formation of cracks.
550-600	Beginning of aggregate damage; siliceous aggregate is first to suffer damage.
700-750	Phase transformation of quartz (occurring in siliceous aggregate) from the triclinic to hexagonal system, increasing the volume of aggregate. This effect, together with different thermal expansion of aggregate and the cement paste leads to the severing of the bond on the interface between the two phases.
800 and more	Peak of the second phase of CSH decomposition.
900	Transformation of hydraulic bonds in the matrix to ceramic bonds.
1000 and more	Decarbonation of limestone aggregate producing carbon dioxide (CO_2); the expanding gas causes damage to the concrete structure.
1200 and more	Total decomposition of the cementitious binder.

These physico-chemical changes have an important effect on the load-bearing function of a structure as they significantly reduce the strength of concrete, see Figure 1 [6,7]. It is apparent that the first significant strength losses occur as early as when the temperature of 300 °C is reached. Higher temperatures reveal the influence of aggregate used in the concrete formula as almost the entire temperature range described in Eurocode 2 shows a lower degree of degradation of concrete with limestone aggregate compared to one with siliceous aggregate [6,7,8,9,10].