Evaluating the experiences with real fire load. Case studies in Hungary

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Abstract. The initiation and the development of fire are strongly influenced by the choice of construction materials. In addition their mechanical properties, their behaviour in elevated temperature is also of high importance. Present paper deals with the effects of fire attack on concrete of fire attack in concrete structures in Hungary. Material and structural behaviour is analysed at high temperatures, which, based on practical observations, could reach even 800°C in some cases. The fire cases of an industrial hall (2014), of the Athletic Hall of the University of Physical Education in Budapest (2015) and of two types of slab-interjoists systems (with concrete as well as brick interjoists) are summarized in our paper. By the analysis of these fire attacks important information can be obtained that can be used in subsequent fire safety design.
Key Words: concrete, structural behaviour, fire, temperature dependent material properties, spalling.

Introduction. Due to the large number of fire cases, the design of structures against fire has become more and more important. There are some Hungarian studies to focus on the problem of managing fire prevention (Pantya at al 2014) or fire extinguishing in concrete buildings (Restas 2011, 2014).

Concrete is a composite material that consists mainly of mineral aggregates bound by a matrix of hydrated cement paste. The cement matrix is highly porous and contains a relatively large amount of free water. Concrete has excellent properties regarding of fire resistance compared to other constructions materials (Balázs & Lublóy 2015).

At high temperatures, the strength of concrete decreases due to physical and chemical changes. During the cooling process concrete is not able to regain its original characteristics. Deterioration of concrete at high temperatures has two forms: (1) local damage in the material itself, and (2) global damage, resulting the failure of the structural elements (Restas 2011, 2014).

The following typical changes can occur in reinforced concrete structures during fire (Balázs & Lublóy 2015):

- changes in concrete material, which may be due to: different thermal expansion of the hardened cement paste and the aggregate, internal water vapour pressure, different temperature in the cross-section as well as along the length of the element;
- extreme deflections (including the creep caused by high temperature and increased deflection caused by specific (relative deformations);
- excessive cracking;
- decrease of bond and anchorage between the concrete and reinforcement;
- spalling of concrete cover (Rossino et al 2014; Yining et al 2017);
- reduction of load bearing capacity.

The reduction of the strength capacity of building materials and the effects of linear thermal expansion leads to deflections and deformation in the structure. The structures which are not subjected to direct fire can be damaged because of the cumulative deformations. Furthermore, explosive spalling of concrete structures may occur in case of rapidly increasing temperature. The protection of the reinforcement can disappear due to explosive spalling of the concrete cover and the reinforcement can warm up fast (Figure 1). The reduction of the strength of the reinforcement may occur at high temperatures and the static system of the structure may change. In our paper the behaviour of concrete and reinforced concrete in fire is represented by case studies in Hungary.

Figure 1. Explosive spalling of the concrete cover by reinforced concrete beam.

Case study: fire in an industrial hall. A small room (area: 14.7 m^2 and clear height: 2.5 m) of a reinforced concrete frame warehouse was subjected in 2014 in Kecskemet to a real fire load test (Figure 2). The slab of the test building was cast-in-situ reinforced concrete with nonloadbearing brick walls. We put large amount of combustible materials (paper, rubber, wood) in the test area in order to simulate a real building fire. Thermocouples were placed in the tested area, so we could measure the temperature at 0.3 m distance from the slab. Opening and closing of the door, and influence of a broken window on the fire scenario were also considered. Behaviour of the various building materials and the structural elements were studied during the fire.

Figure 2. Frontage of industrial hall during the fire test (Lublóy at al 2015a).

The damage of the joint of concrete beam and pillar was observed far from the centre of the fire caused by cumulative deformations *(*Figure 3a). Cracks were observed around the longitudinal reinforcements and stirrups on the concrete cover of the lintel (Figure 3b). The carbonation zone was less than the concrete cover. The test of the carbonation zone is important for fire cases because of the decomposition of $Ca(OH)_2$ at 500°C. This means that the temperature of the reinforcement was lover than 500°C. It may be explained by the thick concrete cover and the relatively short fire effect.

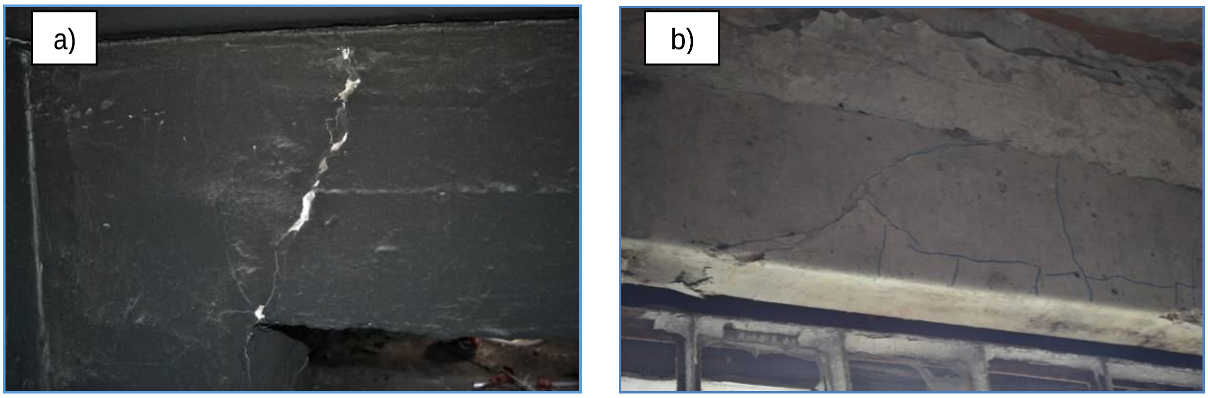

Figure 3. Damaged concrete elements, a) effects of cumulative deformation the joint of the concrete beam and pillar, b) cracks on the lintel (Lublóy at al 2015a).

Case study: fire case o Athletic Hall of the University of Physical Education in Budapest. At about 5 o'clock early morning of 15 October 2015 the Athletic Hall of the University of Physical Education in Budapest, Hungary caught fire. The fire — in the nearly 3000 m^2 hall — could only be extinguished in the early afternoon. The steel truss roof system completely collapsed. The hall became unusable.

At some locations the temperature of the reinforced concrete was higher than 500°C (Lublóy at al 2015b). Explosive spalling of the concrete cover was observed on the pillars and the beams (Figure 4a). Stability failure of precast concrete wall elements and slab elements occurred, due to the failure of the steel elements (Figure 4b and Figure 4c).

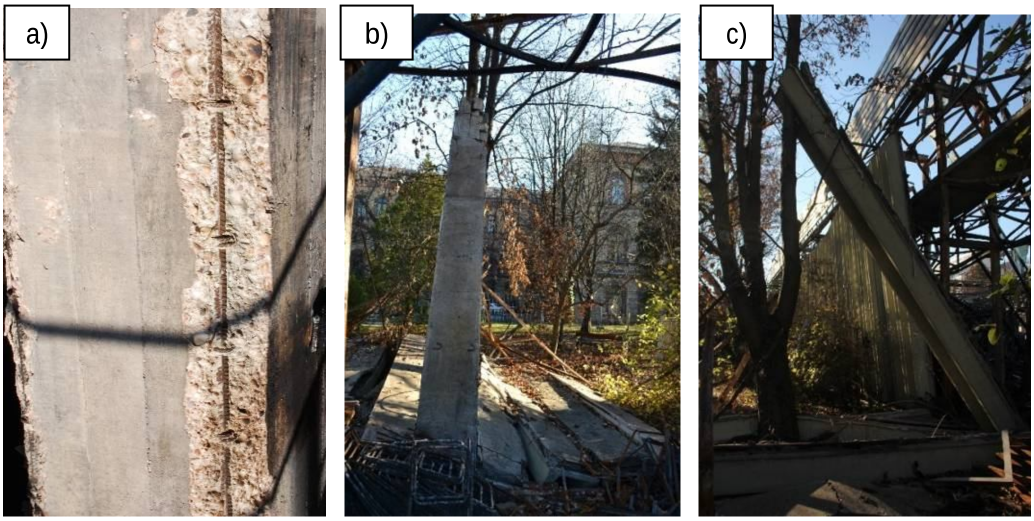

Figure 4. a) Explosive spalling of the concrete cover, b) and c) stability failure of concrete elements (Lublóy at al 2015b).

Case studies: slab-interjoists systems. The slab in our case studies consisted of pretensioned E type girders and concrete interjoists were made without reinforcement. Due to the fire the slab was damaged (Figure 5) some of the pretensioned E-girders were cracked (Balázs & Lublóy 2015). The concrete became red-coloured, indicating that the maximum temperature was around 500°C. The bottom parts of concrete interjoists fall down.

Figure 5. Fire damage of the girder-slab with concrete interjoists (Balázs & Lublóy 2015).

During the fire case in one furniture store, the concrete cover of the pretensioned E type girders was spalled (Figure 6). The concrete was white-coloured and strongly cracked indicating that the temperature reached about 800°C. The bottom parts of brick interjoints fall down.

Figure 6. Fire damage of the girder-slab with brick interjoists (Balázs & Lublóy 2015).

Conclusions. Our paper deals with the engineering consequences of the fire attack in concrete structures in Hungary. The typical failure modes of concrete structures were demonstrated with real fire cases. At high temperatures the strength of concrete decreased due to physical and chemical changes. The structures which are not in direct fire can be damaged by cumulative deformations. Furthermore, explosive spalling of concrete structures may occur in case of rapidly increasing temperature.

In case of fire in an industrial hall, cracks were observed far from the centre of the fire caused by cumulative deformations and cracks were observed around the longitudinal reinforcements and stirrups on the concrete cover of the lintel.

In case of the Athletic Hall of the University of Physical Education in Budapest, explosive spalling of the concrete cover was observed on the pillars and the beams and stability failure of precast concrete wall elements and slab elements was caused by the failure of the steel elements.

In case of slab-interjoists systems, the slabs were damaged due to the fire. Some of the pretensioned E-girders were cracked. The concrete became red-coloured, indicating that the maximum temperature was around 500°C. The bottom parts of the concrete and the brick interjoists fall down.

References

Balázs G. L., Lublóy É., 2015 Fire resistance for thin-webbed concrete and masonry elements. Applications of Structural Fire Engineering, 15-16 October 2015, Dubrovnik, Croatia, 6 pp.

Lublóy É., Czoboly O., Balázs L. Gy., Mezei S., 2015a [Experiences with real fire load]. Vasbetonépítés, ISSN 1419-6441, online ISSN: 1586-0361, 17(1), pp. 17-23. [in Hungarian]

Lublóy É., Czoboly O., Hlavička V., Oros Zs., Balázs L. Gy., 2015b [Experiences of the fire case of athletic hall of the University of Physical Education in Budapest 15 Oct. 2015]. Vasbetonépítés, ISSN 1419-6441, online ISSN: 1586-0361, 17(3):50-55. [in Hungarian]

Pántya, P., Restás, Á., Horváth, L., 2014 Preparing for Firefighter's Interventions during Designing Buildings: basic planning requirements in Hungary; In: The Main School of Fire Service Faculty of Fire Safety Engineering; VIII. International Conference "Fire Safety of Buildings". Warsaw, Poland (Szkoły Głównej Służby Pożarniczej), pp. 1-8.

Restás Á., 2011 Modelling of fire managers' decision making method; In: D. X. Viegas: Advances in Forest Fire Research. Coimbra: 2014a. pp. 892-902 (ISBN:978-989-26-0884-6)

Restás Á., 2014 How Firefighter Managers Make Decisions at the Scene; In: Karol Balog, Jozef Martinka (Ed.) Advances in fire and safety engineering, pp. 196-203. ISBN:978-80-8096-202-9.

Rossino C., Lo Monte F., Cangiano S., Felicetti R., Gambarova P.G. (2014): „HPC Subjected to High Temperature: A Study on Intrinsic and Mechanical Damage", Key Engineering Materials, No. 629-630 pp. 239-244.

Yining Ding, Cong Zhang, Mingli Cao, Yulin Zhang, Cecília Azevedo, Influence of different fibers on the change of pore pressure of self-consolidating concrete exposed to fire, Construction and Building Materials, Volume 113, 2016, Pages 456-469, ISSN 0950-0618, http://dx.doi.org/10.1016/j.conbuildmat.2016.03.070.

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