REDUCTION OF CONNECTION RESISTANCE DURING VESELÍ FIRE TESTS

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Abstract

The paper is focused to the temperature distribution in the reverse channel connections to concrete filled tubular column during two fire tests on an experimental building in Veselí nad Lužnicí. Temperatures of connections without fire protection as well as fire protected connections were investigated. The connected beams and columns were without fire protection.

Keywords: reverse channel, fin plate, heat transfer, fire design, fire test

INTRODUCTION

The fire design of structures is based on member fire tests in furnaces and connection behaviour is usually neglected. Connections have lower temperature than the adjacent structure during the fire which is caused by the concentration of the material in the connection area and they are protected by a similar thickness of the fire protection as connected members. During the heating and cooling, the connections are subjected to different forces which were not taken into account in the design for the ambient temperature. The connection behaviour is based on the change of mechanical properties of the steel and on the interaction between different parts of the connection. To determine the degradation of the mechanical properties is necessary to find out temperature distribution which can be used in the component method.
The temperature in the connection can be predicted by two methods. According to the first of these methods, the temperature of the beam-to-beam and beam-to column connection with a concrete slab above the connection is calculated from the temperature of the bottom beam flange in the mid-span (CESTRUCO, 2003). The second method is based on the concentrated mass and the temperature is predicted by using the section factor A_m/V for the each component of the connection. Numerical (Franssen, 2002) and experimental studies (Wald et al., 2006) show necessity to improve the temperature prediction in order to achieve the acceptably accurate description of the connection behaviour during the fire.
The real temperature field in the structure can be obtained from a test on a real object only. Therefore two fire tests on the two-story building with real fire scenarios create the part of the European project COMPFIRE – Design of Joints to Composite Columns for Improved Fire Robustness. The tests enabled to obtain the temperature developments in the reverse channel connections.
Connections in the partially fire protected steel/composite structure at the fire cannot be critical part of this structure. Heat transfer into the connections can be reduced by fire protection. Temperatures during the fire reach significantly lower values compared with temperatures of unprotected connections. Therefore the selected connections in the experimental building were fire protected.

1 EXPERIMENTAL STRUCTURE, CONNECTIONS, FIRE PROTECTION

A two-storey composite steel-concrete experimental structure on the area 10.4 x 13.4, with the height of 9 m was designed and represented a part of an administrative building. Composite ceiling slabs consisted of simple trapezoidal sheets with the rib of 60 mm and 60 mm of reinforced concrete C30/37. Beams under the slabs designed as IPE 220, 240, 270 and IPE 330 (steel S355) were supported by hollow section columns (TR 245/8, steel S355) filled with concrete and by columns of sections HEB 200. The lateral stiffness of the building was provided by two cross bracings in the both directions. Steel cladding with thermal insulation was used. In each floor there was one window with dimensions 5 x 2 m, see Fig. 1 and (Wald et al., 2011).

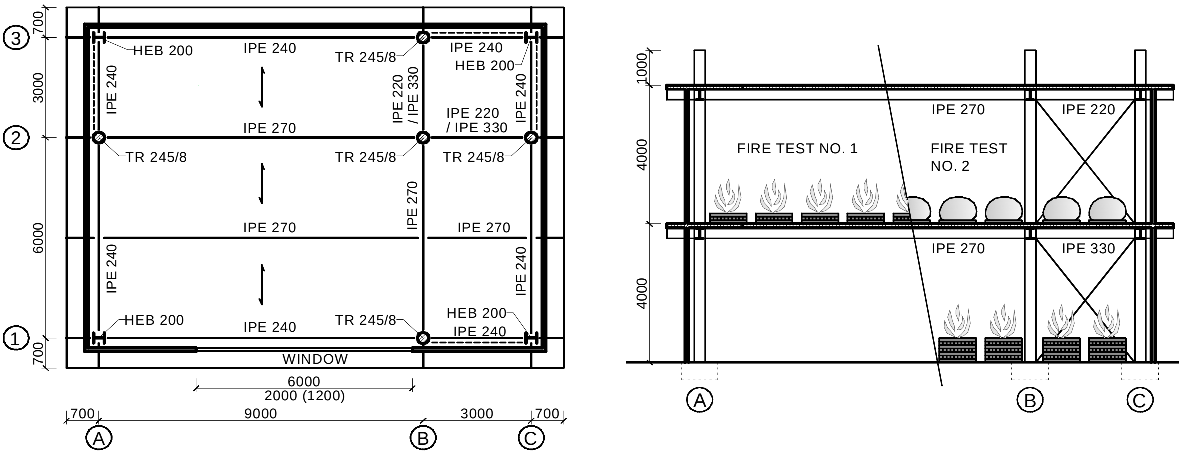

Fig. 1 Experimental structure

Connections were designed according to (EN 1993-1-8, 2005) to resist shear force at ambient temperature and were checked in accordance with European guidelines (ECCS) and (SCI/BCSA). The reverse channel connections connected beams with the cross-sections IPE 220, IPE 270 and IPE 330 to the composite circular tubular column. The reverse channel was formed by standardized rolled section UPE-DIN or by bent sheet metal of the thickness 8 mm. The thickness of the end plates was also 8 mm in all cases. Size of bolts, M12, M16, M20, corresponded with the size of the connected beam. Tab. 1 summarizes the arrangement of the connections which were observed during the fire tests.

Tab. 1 Arrangement of connections

Designation of connection	**Beam cross-section**	**Column cross-section**	**End plate**	**Reverse channel**	**Bolts**	**Designed thickness of fire protection**
First fire test (2nd floor)						
A2-B2 to A2	IPE 270	TR 245/8	165/160/8	sheet 165/200/8	4x M16	20 mm
A2-B2 to B2				UPE 160		
B2-C2 to B2	IPE 220		135/120/8	UPE 120	4x M12	-
B2-C2 to C2				sheet 135/160/8		
Second fire test (1st floor)						
A2-B2 to A2	IPE 270	TR 245/8	165/160/8	sheet 165/200/8	4x M16	-
A2-B2 to B2						
B2-C2 to B2	IPE 330		200/180/8	sheet 200/220/8	4x M20	60 mm
B2-C2 to C2				UPE 180		

Some connections were protected by the fire protection of the thickness 20 mm in the second floor at the first fire test. In the first floor at the second fire test, the fire protection of the thickness 60 mm was applied on the some connections. The reverse channel connections were protected in the length of 250 mm from the edge of the column in the both cases and a mixture of mineral fibres and a cement binder was used as the fire protection.

Fire load was created by piles from softwood dried to moisture of 12 %. The first fire test in the second floor had a character of traveling fire without flashover (fire load was 173.5 MJ/m^2), the development of the gas temperature at the second fire test in the first floor corresponded with fire scenarios with flashover in a fire compartment of the ordinary administrative building (fire load was 520 MJ/m^2). The main objective of the fire tests was a monitoring of the heat transfer into the composite structure and a subsequent determination of mutual influence of the fire unprotected and protected parts of the structure. Temperature distribution in the structure and gas temperature in the compartment was measured during the both tests by 120 thermocouples. Typical temperature fields in the reverse channel connections are shown thereinafter.

2 TEMPERATURES OF FIRE UNPROTECTED CONNECTIONS

2.1 Reverse channel connection B2-C2 to B2 at the first fire test

Fig. 2 shows three-metre beam to central column connection with six thermocouples. Thermocouple TC13 was placed into mid-height of the beam web, 100 mm from the end plate, TC14 was installed into the upper bolt, TC15 into the lower bolt. TC16 was placed into mid-height of the end plate between both bolts, TC17 measured temperature in mid-height of the reverse channel flange and TC18 temperature in the steel tube of the column. The connection was not fire protected.

Fig. 2 Fire unprotected beam-to-column connection (B2-C2 to B2) in the 2nd floor

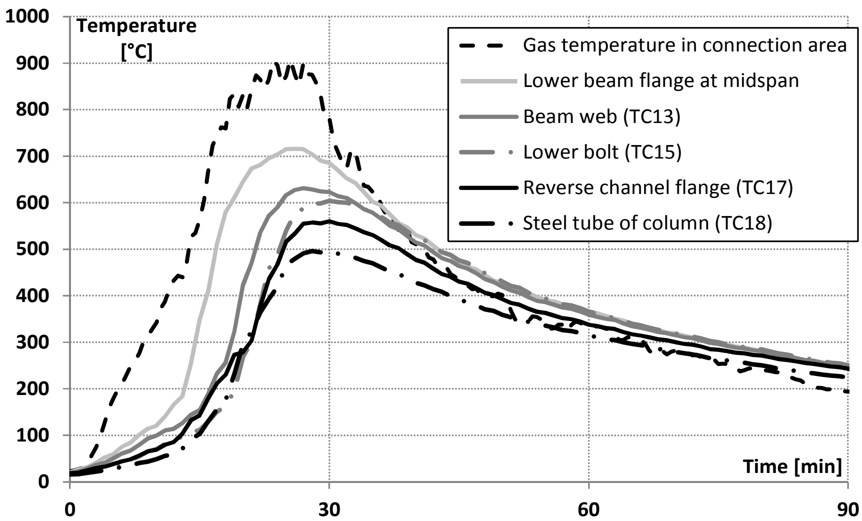

Fig. 3 Comparison of the measured temperatures in fire unprotected reverse channel connection (B2-C2 to B2) with the gas temperature and beam flange temperature in mid-span

In Fig. 3, there are compared the measured temperature in different parts of the connection with the temperature of the bottom beam flange in the mid-span and with the gas temperature. You can see that the connection temperatures were lower than the temperature of the flange and the parts of the connection close the composite column were lower temperature than the connection components more distant from the column. That shows a positive impact of the great heat capacity of the concrete in the column to reduce the component temperature in the fire unprotected connections.

2.2 Reverse channel connection A2-B2 to B2 at the second fire test

The seven thermocouples were on the nine-metre beam to column reverse channel connection without fire protection. The thermocouple TC56 was placed into mid-height of the beam web A2-B2, 150 mm from the end plate, TC57 was installed into the upper bolt, TC58 into the lower bolt. TC59 was placed into mid-height of the end plate between the both bolts, TC60 and TC61 measured temperatures in the middle of the reverse channel flange surface and TC 101 temperature in mid-height of the end reverse channel weld, see Fig. 4.

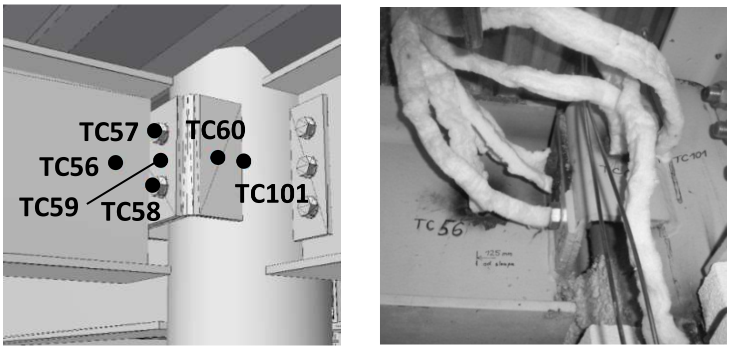

Fig. 4 Fire unprotected beam-to-column connection (A2-B2 to B2) in the 1st floor

Temperature distribution of the connection during the second fire test is shown in Fig. 5. Analogous to the temperatures at the first fire test, measured temperature of the each connection component is again significantly reduced in the direction from the beam to the composite column. The connection temperatures are also lower than the temperature of the bottom beam flange in the mid-span.

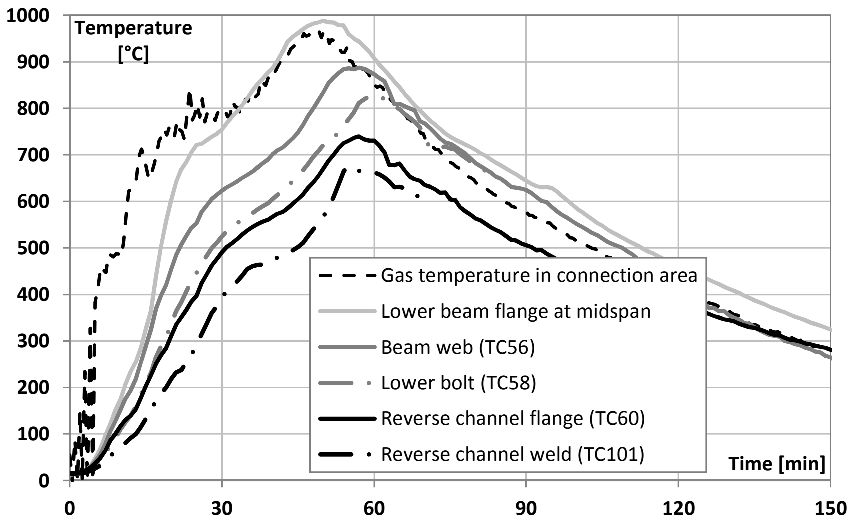

Fig. 5 Comparison of the measured temperatures in fire unprotected reverse channel connection (A2-B2 to B2) with the gas temperature and beam flange temperature in mid-span

3 TEMPERATURES OF FIRE UNPROTECTED CONNECTIONS

3.1 Reverse channel connection B2-C2 to B2 at the second fire test

In three-metre beam to column connection, temperature was monitored by five thermocouples. TC62 was placed into mid-height of web of beam B2-C2, 150 mm from end plate, TC63 was installed into upper bolt, TC64 into lower bolt. TC65 was placed into mid-height of end plate between both bolts, TC66 measured temperature in mid-height of reverse channel flange, see Fig. 6. The connection was protected by the fire protection in a length of 250 mm from the edge of the column.

Fig. 6 Fire protected beam-to-column connection (B2-C2 to B2) in the 1st floor

Measured temperatures in the fire protected reverse channel connection during the second fire test are shown in Fig. 7. Compared with temperatures in the similar connection without fire protection the applied fire protection with average thickness of 60 mm was able to reduce the temperatures in the connection about 400 °C.

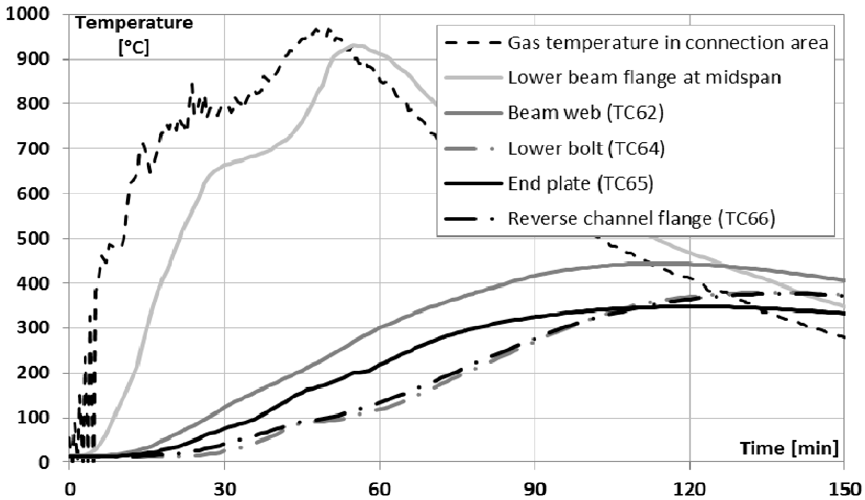

Fig. 7 Comparison of the measured temperatures in fire unprotected reverse channel connection (B2-C2 to B2) with the gas temperature and beam flange temperature in mid-span

4 CONCLUSION

Temperature distribution in the connection influences its mechanical behaviour principally through the change in material properties. Steel resistance reduce at elevated temperature. It may be accounted by a factor expressing the ratio between the property at elevated temperature and its ambient temperature value (EN 1993-1-2, 2005).

In Fig. 8 is comparison of the reduction factors for components of reverse channel connection based on the measured temperatures during the second fire test. The figure shows a significant reduction of the mechanical properties of the connection without fire protection unlike fire protected connection. For example at the 45th min the value of the reduction factor calculated from the measured temperature in the fire unprotected lower bolt is 16 %, while the calculated value of the reduction factor is 97 % in the fire protected connection. Utilization of the fire protected connections and beams without fire protection allow to consider the membrane action of a composite ceiling without fire resistance reduction of the connections.

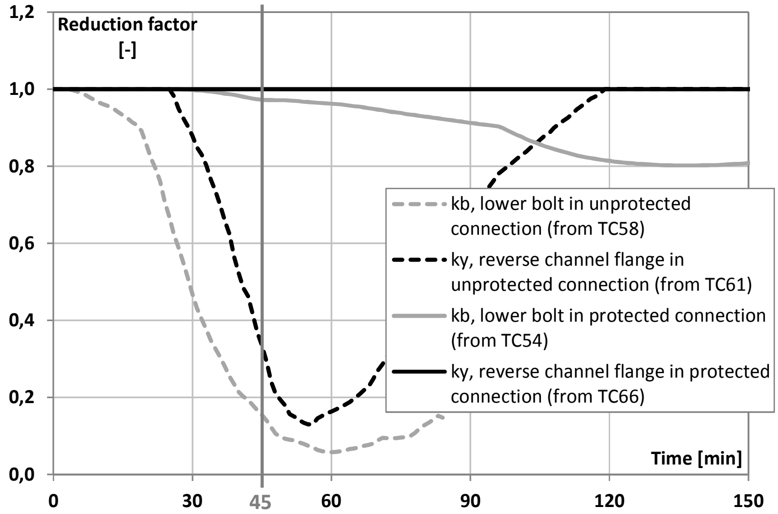

Fig. 8 Reduction of connection resistance through the components in fire unprotected connection (A2-B2 to B2) and fire protected connection (B2-C2 to B2)

ACKNOWLEDGMENT

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