INFLUENCE OF ZINC COATING TO A TEMPERATURE OF STEEL MEMBERS IN FIRE

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Abstract

This paper describes effect of hot dip galvanizing of steel structure surfaces to temperature of steel members during the fire. Temperature in a set of specimens was measured during the second fire test at experimental building in Veseli nad Luznici. Experiment results show, that the zinc coating can reduce temperature in steel members especially in first fifteen minutes of the fire. The paper describes the process of experiment and analytical evaluation.

Keywords: zinc coating, surfacing, emissivity

INTRODUCTION

Influence of surfacing to the fire resistance is not currently described. A value of surface emissivity of galvanized components for calculations of the fire resistance of steel structures is not specify in Eurocode EN 1993-1-2. Conservatively, the value of surface emissivity $\varepsilon_m = 0.7$ is considered. This value is used for all steel components.

Surfacing by zinc coating is applied by dipping in zinc bath at a temperature about 450 °C. Therefore, it can reduce emissivity of the surface until the temperature of steel structure reaches this value. After reaching of the temperature about 450 °C, surfacing begins runoff and surface emissivity returns to the value for steel without surfacing. Due to the temperature reduction of a steel member in the initial time of a fire, a temperature curve is moved and fire resistance of steel member 15 or 30 min can be reached without the fire protection.

Experimentally determined value of surface emissivity of galvanized steel members is only valid for the duration of the fire exposure when the temperature of steel member is not higher than approximately 450 °C.

TEST SPECIMENS

For verification of the effect of surface emissivity of galvanized steel structure to a temperature of steel members in the real fire conditions specimens were placed into compartment in full scale fire test, see Fig 1. The zinc coated specimens were during the second fire test at the first floor of experimental building monitored. The calculated surface emissivity of galvanized elements was verified on the results of fire experiments in a horizontal furnace in 2011. The zinc specimens were hung on logs with a diameter of 10 mm, see Fig 1 under the ceiling structure, in the compartment area with expected highest gas temperature. The arrangement of specimens inside the compartment eliminated an uneven temperature distribution. Members were arranged in pairs, always galvanized and without zinc coated surface. Specimens were isolated at both ends by mineral fiber wool so that the sample simulated the endless element and the heat transfer occur its outer surface only.

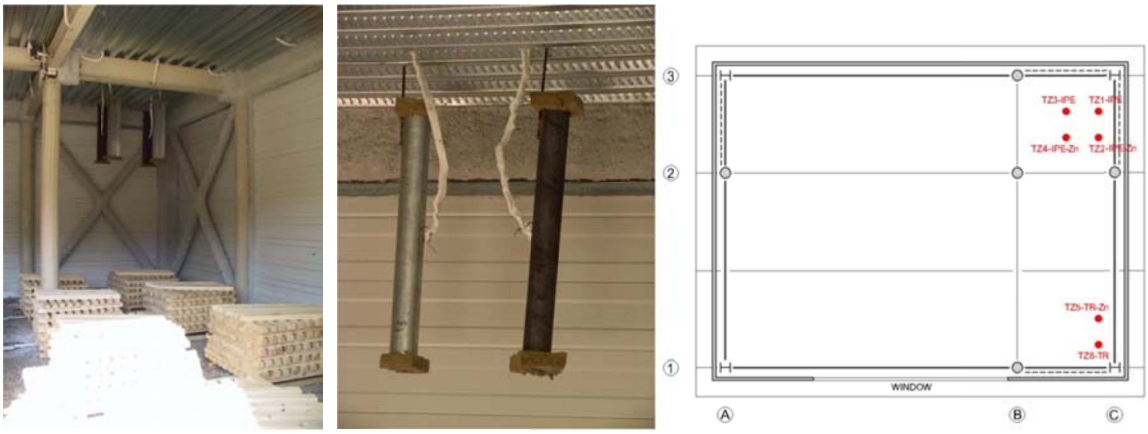

Fig. 1 Specimens under the ceiling of the compartment and location of specimens in the compartment

For the specimens open and closed cross-sections length 1 m were used, see Tab. 1

Tab. 1 Specimens

Specimen	Cross section	Surfacing
TZ1 - IPE	IPE 200	No
TZ2 - IPE	IPE 200	Zn
TZ3 – IPE	IPE 200	No
TZ4 – IPE	IPE 200	Zn
TZ5 – TR	TR 114,3x4	Zn
TZ6 – TR	TR 114,3x4	No

First half of the specimens was done without surfacing – the samples TZ1 - IPE, TZ3 - IPE, TZ6 - TR and second half was galvanized – the specimens TZ2 - IPE, TZ4 - IPE, TZ5 - TR. Identical technology of galvanizing for the both IPE specimens was chosen. Galvanizing temperature reached 447 ° C, average coating thickness 157.8 μm, max 171.4 μm, min 138.4 μm. A conventional galvanizing bath without additional chemical elements such as Al, Pb, Bi, Sn, etc. with the chemical composition prescribed for products intended with permanent contact with drinking water was used. A conventional bath for galvanizing of the circular closed cross sections profile TR 114.3 x4, temperature of galvanizing was 458 ° C, average thickness of the coating 110 μm was also used.

Specimen´s temperature measuring

Temperature of each specimen was measured by one 2 mm diameter thermocouple. This was placed at half height of each specimen. The gas temperature in the fire compartment was measured by twenty 3 mm thermocouples and seven plate thermocouples.

Fig. 2 Detail of surface of zinc coated member after fire

Evaluation of the fire test

Step by step method (EN 1993 – 1 – 2, 2005) was for evaluation of the fire test modified. Results are summarized in Tab. 2. Total heat flux increase for galvanized elements was from known gas and steel temperature calculated. Than was a heat transfer coefficient as constant value $\alpha_c = 4$ W/m^{2}K for the specimens without surfacing from the total heat flux and known radiative heat flux calculated. The radiative heat flux of zinc coated specimen and subsequently surface emissivity of zinc coated members from known value of heat transfer coefficient and temperature increase of zinc coated specimen was than derived.

$$h_{net.r} = h_{net} - h_{net.c} \tag{1}$$

where h_{net} total heat flux [W/m^2]
$h_{net.r}$ the radiative heat flux [W/m^2]
$h_{net.c}$ convective heat flux [W/m^2]

The calculated values of emissivity for each specimen are shown in the Tab. 2. Resulting emissivity value of zinc coated members was determined as the average from all specimens, ε_m = 0.32. On Fig 4, 5 and 6 are calculated temperatures with measured with considering an uniform surface emissivity ε_m = 0.32 for all specimens compared. This value is valid until the temperature of steel member reaches the application temperature of zinc coating.

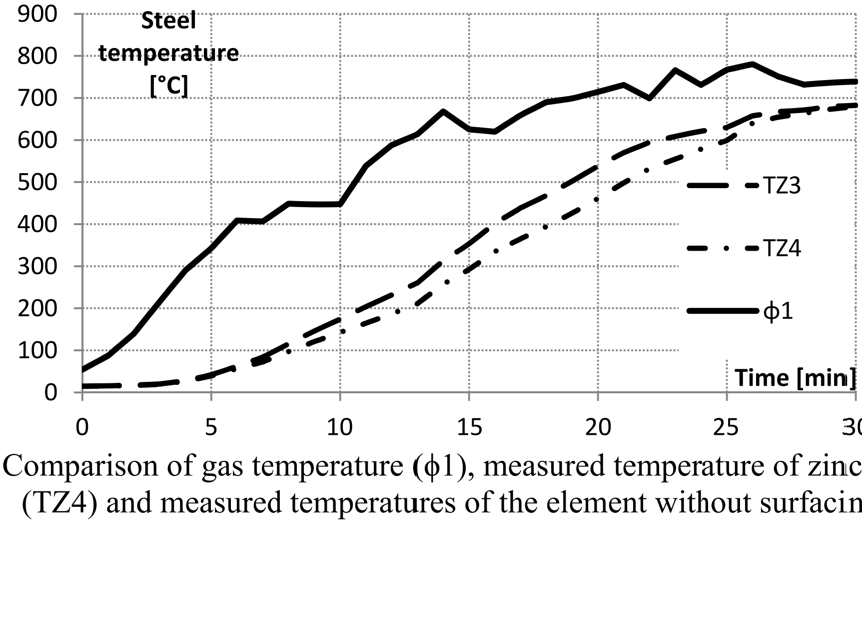

Fig. 3 Comparison of gas temperature (ϕ1), measured temperature of zinc coated member (TZ4) and measured temperatures of the element without surfacing (TZ3)

Tab. 2 Calculated surface emissivity of galvanized members

Specimen	Surfacing	Surface emissivity
TZ2 - IPE	Zn	0,290
TZ4 - IPE	Zn	0,280
TZ5 - TR	Zn	0,400

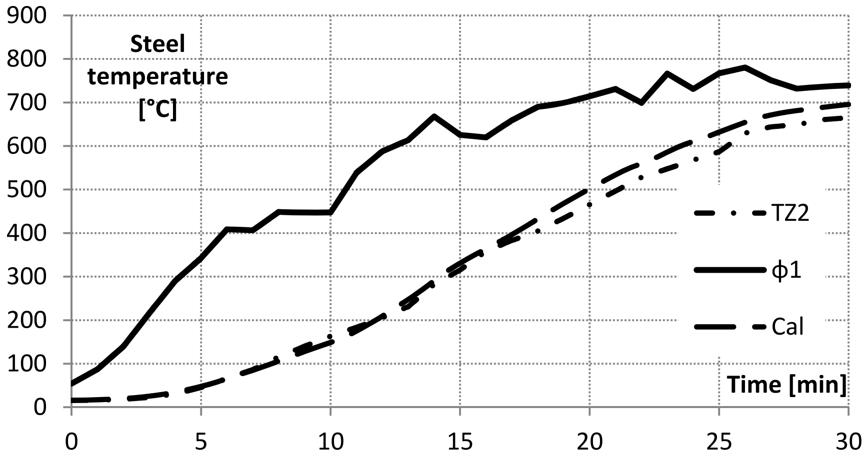

Fig 4 Comparison of gas temperature (ϕ1), calculated (Cal) and measured temperature of zinc coated member (TZ2), emissivity 0.32

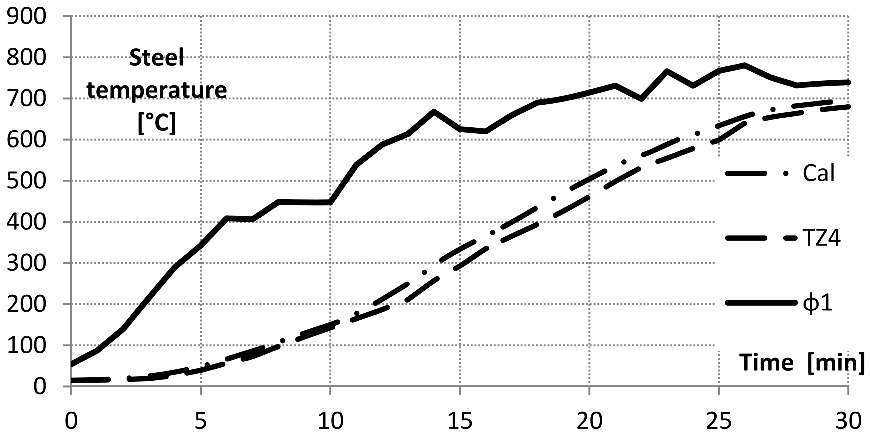

Fig 5 Comparison of gas temperature (ϕ1), calculated (Cal) and measured temperature of zinc coated member (TZ4), emissivity 0.32

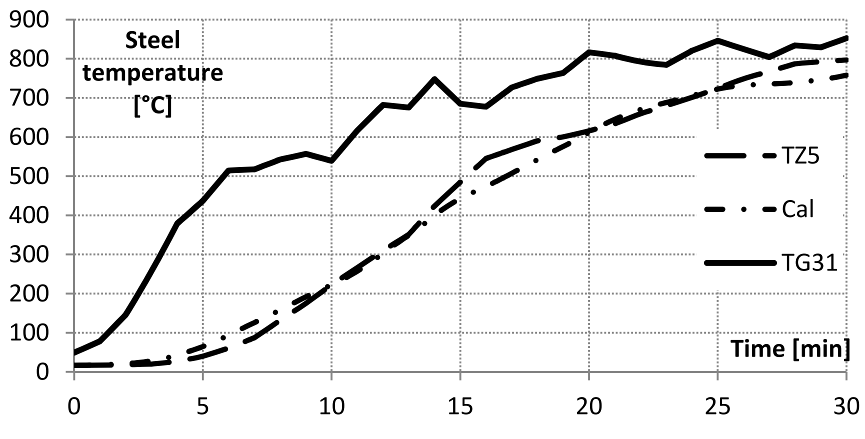

Fig 6 Comparison of gas temperature (TG31), calculated (Cal) and measured temperature of zinc coated member (TZ5), emissivity 0.32

SUMMARY

Experiment on the real structure shows significant decrease of temperatures of steel members with zinc coated surface in first fifteen minutes of fire. Surface emissivity of zinc coated steel element in the fire (0.32) is less than half of the value of emissivity for steel elements without surfacing (0.7). Next set of specimens is focused on testing influence of zinc coating aging and its effect to surface emissivity in the fire.

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