Fire resistance of hot-dip galvanized steel constructions

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Introduction
Once a fire resistance rating of at least 30 minutes is necessary, it has to be proofed that the load bearing behavior of the steel construction, under the exposure of fire, still fits the static demands. To adjust steel constructions the state of the art is a passive fire protection. The high costs at this point lead to a common preference of concrete construction solutions. To optimize these expenses one verification method is to determine the critical temperature according to DIN EN 1993-1-2. For this purpose, positive effects of hot-dip galvanization on the temperature development of steel members in the accidental situation of fire exposure are investigated. The aim is thus to avoid additional passive fire protection for an R30 requirement through hot-dip galvanized steel members.

Approach
Heat transfer is based on thermal energy exchange between two systems. Heat is thereby distributed within a fire in three different ways: conduction, convection, and radiation. The most important process for this research is electromagnetic radiation, with its spread radiant energy. A measure of how much a material exchanges heat radiation with its environment is the emissivity $\varepsilon$. Emissivity depends on several surface characteristics and thereby to a decisive extent on the chemical composition, the roughness and as well on the degree of oxidization. With respect to this, different galvanized surfaces have to be tested with various weathering conditions to gain an optimized statement of realistic values of the emissivity of such surfaces. To get a representative statement, several specimens in different tests have to be examined: small-scale tests with explicitly defined surroundings and full-scale tests in a furnace according to the standard temperature-time curve ISO 834.

Small-scale tests
To define a variable emissivity, with a profound database, of hot-dip galvanized steel members in a fire exposure, the temperature dependent hemi-
spheric emissivity has to be determined under controlled conditions. The measurement of the hemispherical emissivity has to take into account the dependency of the wavelength, the polar angle, and the temperature.

A temperature development from room temperature to approximately 850°C is sought to depict an R30 fire exposure according to the standard temperature-time curve. To get a precise statement of the oriented emissivity the specimens are fixed on a self-built heating furnace and in addition on a rotatable frame which will be precisely controlled by a stepper motor in a range of at least -45° to 45° [2]. Two pyrometers measure the temperature of the surface at different wavelengths. Moreover, the samples are equipped with thermocouples to verify the temperature of the specimen.

During heating, processes like oxidation on the alloy layers take place and with that, a change of the surface occurs, accompanied by an emissivity change. For the hot-dip galvanized specimen the received emissivity varies in dependence of the temperature between 0.26 and 0.70 and is especially at the beginning of a fire smaller than the constant emissivity value of 0.7, given by the Eurocode DIN EN 1993-1-2 [1].

In figure 2 one can see the emissivity development (grey range) based on research tests including a newly gained emissivity curve (blue) in comparison with the \( \varepsilon_m = 0.7 \).

**Fig. 2: Emissivity measurement of the galvanized specimen (<0.04% Si) during a small scale test.**

**Full-scale tests**

In addition to the small-scale tests, the thermal behavior of hot-dip galvanized steel components under ISO fire scenario conditions are investigated experimentally in two large-scale tests in a fire laboratory in order to include the effects from convection and to verify the findings of the small-scale tests under conditions close to real fires.

**References**
