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A TEMPERATURE EFFECT ON SHEAR CONNECTORS OF STEEL-CONCRETE COMPOSITE STRUCTURE

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1. INTRODUCTION

Steel-concrete composite girder bridges are widely used as highway bridges nowadays. However, practical experience indicates that when these highway bridges are subjected to severe fires due to vehicle accidents, it may cause damage to the bridge; thus, leading to traffic closure and even disfunction to the entire transportation network, severe economic losses may be received. The structural response of steel-concrete composite girder bridges under severe vehicle fires still remain incompletely understood. Studies of environmental factors, such as fire location, spatial form on structural response are limited and mainly focused on thermal inertia since steels have higher thermal conductivity and lower specific heat. The temperature of steel rises quickly, and the yield strength and Young's modulus, etc. will decrease rapidly with the rise of temperature in a fire. However, only when the temperature is very high, the surface of the concrete will explode and spall, which will expose the internal rebars and the strength will greatly decrease. As a result, the load carrying capacity of the structure will also be significantly reduced. Currently, study on composite structure under fire almost only consider the occurred location under the bridge, so the temperature of the surface of concrete will not be very high, in fact, there were many accidents of fire on the bridge.

In this paper, referring to the specimen used in paper[2)], the target structural element is considered. Fig.1 showing the dimensions of the structure, studs have been considered but steel rebars are neglected in this analysis for simplicity this time. It is assumed that the fire location is same with reference paper[2)] this time, and then used finite element software to simulate heat transfer of steel-concrete composite structure under the standard external fire curve.

2. FEM ANALYSIS

According to previous study[2)], a finite element model was established by ABAQUS. The thermal coefficients of concrete and steel were taken as recommended by the reference paper, steel is as shown in Table 1, specific heat of concrete is as shown as Eq. (1) and thermal conductivity is shown as Eq. (2).

$$C_c = -4\left(\frac{T}{120}\right)^2 + 80\left(\frac{T}{120}\right) + 900 \tag{1}$$

$$\gamma_c = 1.6 - \frac{0.6}{850}T \tag{2}$$

Where, C_c is specific heat of concrete， γ_c is conductivity of concrete, T is temperature。

The ambient temperature is 20°C. The target heating curve of the reference paper is the standard external fire curve specified by Eurocode, as shown in Fig. 2. The heating was carried out from 0 to 90 min according to the external fire curve, and the natural cooling was carried out in the next 210 min.

Table 1 Thermal coefficients of steel

Temperature (°C)	0	100	200	300	400	600	800
Specific heat (J/kgK)	462	496	512	525	540	577	604
Density (kg/m³)	7872	7845	7816	7740	7733	7669	7578
Conductivity (W/mK)	45.9	44.8	43.4	41.4	38.9	33.6	28.7

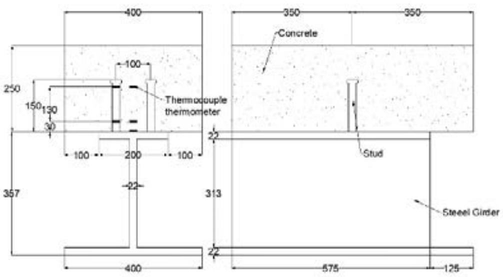

Fig. 1 Dimension of structure & Site of Thermocouple

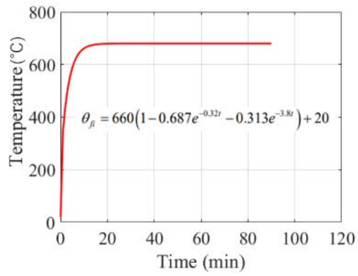

Fig. 2 External fire curve

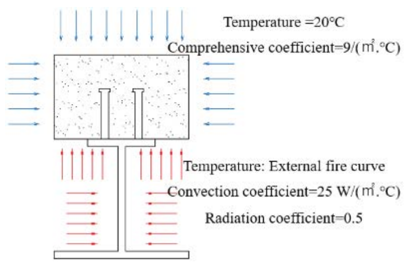

Fig. 3 Thermal conduction

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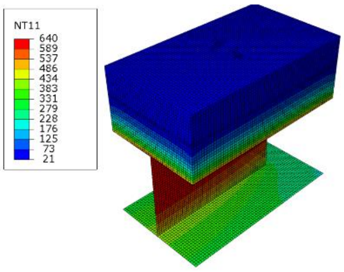
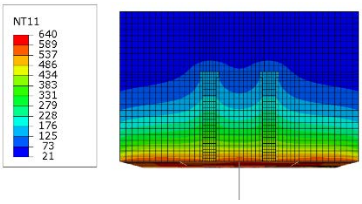


Fig. 4 Temperature distribution of the integral structure



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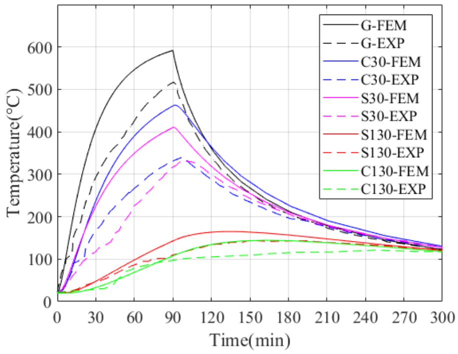

Fig. 6 Comparison of temperature-time relationship curves

Table 2 Comparison of results

	Top flange	Stud 30mm	Stud 130mm	Concrete 30mm	Concrete 130mm
Experiment	518°C	332°C	144°C	341°C	121°C
Model	591°C	410°C	165°C	462°C	144°C
Relative Error (%)	14.1	23.4	14.5	35.4	19.0

According to the experiment, the upper flange of the steel girder, the web and the lower surface of the concrete not in contact with the steel girder are subjected to fire on one side. The coefficient is shown in Fig.3, where comprehensive coefficient includes convection and radiation coefficient. The upper flange of steel girder is connected to lower surface of the concrete by tie constraint, and the studs are also connected to the concrete by tie constraint.

3. RESULTS AND DISCUSSIONS

The temperature distribution when the fire is under the structure is shown in Figure 4 and 5. The same five locations as the reference[2)] are taken as the output data, which are the upper flange of the steel girder, the concrete and steel at a distance of 30 mm and 130 mm from the upper flange, as shown in Figure 1. The comparison of temperature variation with time at the five locations in simulation to test results are shown in Figure 6. It can be found that the temperature change trend is consistent with the experimental results. However, the maximum temperature of each point is higher than the experimental results, and the slope of each curve obtained by FE analysis is also larger than that of experiments. The comparison of highest temperature and time of appearance with the experimental results is tabulated in Table 2.

There are mainly three reasons for this disagreement. Firstly, the standard external fire curve is idealized and the heat input is a stable, low value compared to experimental and actual fire conditions. Secondly, the variation of the thermal properties of the material with temperature cannot be accurately simulated. Lastly, heat conduction between different materials, such as studs and concrete, steel girder and concrete slab is the main cause of high temperatures in concrete and studs at the location of 30mm. After comparing analysis results from FEM models used various interaction, it is found that the case using the interaction way of tie is closer to the experimental results.

4. CONCLUDING REMARKS

In this paper, modeled is the heat transfer in steel-concrete structural elements comparing with the existing experimental results, where the temperature distribution of the steel-concrete composite structure and the temperature variation at specified locations with time according to standard external fire curve are obtained. Compared with the highest temperature of the experiment, the difference of the temperature on the straight fire surface and the upper surface of the steel beam is 14.1%, and the difference around studs and concrete after heat conduction is between 14.5-35.4%, which is large, In order to improve the prediction accuracy to the experimental results, it is necessary to assess more accurate analytical models based on considering the material's thermal properties depending on temperature and interactions between structural members in future work.

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