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EFFECTIVE THERMAL CONDUCTIVITY OF FIRE PROOF MATERIALS AND THE MEASURING METHOD

Jun HAN [a], Guo-Qiang LI [b], Guo-Biao LOU [b]

[a] College of Civil Engineering, Tongji University, Shanghai, 200092, China

[b] State Key Laboratory for Disaster Reduction in Civil Engineering, Shanghai, 200092, China

1. Introduction

Proposed the concept of effective thermal conductivity and developed measuring method and test setup based on steel components standard fire test, in order to reflect the actual performance of fire insulation in fire. In total, 15 steel specimens with 5 different schemes of layer thickness were fire tested in the new-developed furnace of Tongji University.

Comparison of experimental results and theoretical calculations will be presented to show that the effective thermal conductivity can accurately model the performance of steel members protected with fire proof material in fire.

2. Effective Thermal Conductivity

1. Calculation of thermal conductivity:

$$T_s(t+\Delta t)-T_s(t)=\frac{\alpha}{\rho_s c_s}\cdot\frac{F_i}{V}\cdot[T_g(t+\Delta t)-T_s(t)]\Delta t$$

$$T_s=\left(\sqrt{5\times10^{-5}\times\frac{1}{R_i}\cdot\frac{F_i}{V}+0.044}-0.2\right)t+20$$

$$R_i=\frac{5\times10^{-5}}{\left(\frac{T_s-20}{t_0}+0.2\right)^2-0.044}\cdot\frac{F_i}{V}$$

$$\lambda_i=\frac{d_i}{R_i}$$

2. Definition of effective thermal conductivity:

Def.1: the average of thermal conductivities when the specimen temperature was 400~600℃;

Def.2: the thermal conductivity when the specimen temperature was 540℃ (1000℉).

3. Test Setup and Specimens

The furnace for small-scaled test of fire coating is shown in Fig.1. As shown in Fig. 2, steel plate specimens with dimensions of 16mm×200mm×270mm were chosen in the test.

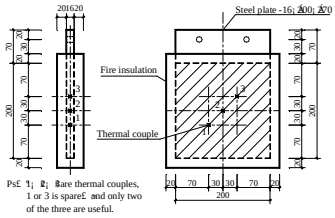
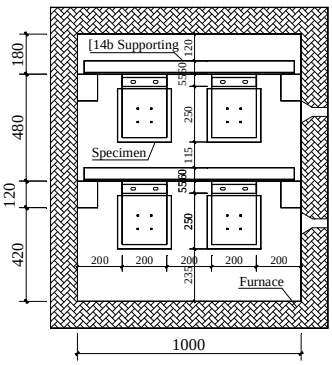


Fig. 2 Dimensions of specimens and arrangement of thermal couples

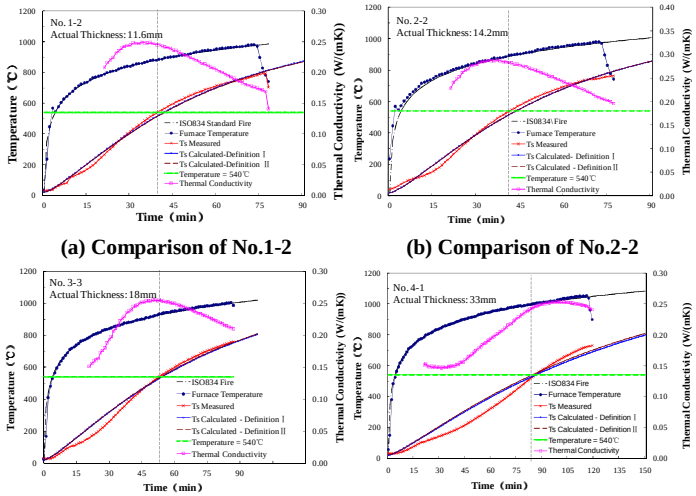
(a) Furnace



(b) The cross-section and the arrangement of specimens

Fig. 1 Testing furnace and the arrangement of specimens

Fig. 3 Reaction of spray coating in fire



(a) Comparison of No.1-2

(b) Comparison of No.2-2

(c) Comparison of No.3-3

(d) Comparison of No.4-1

Fig. 4 Comparison between Ts calculated and Ts measured

4. Testing Results

The fire insulation showed peace performance with no obvious change and the temperature of the steel member rose steadily in fire. Cracks appeared on the surface of the insulation after fire, as is shown in Fig. 3.

Fig.4 shows the temperature-time curve of steel members, furnace temperature-time curve and the thermal conductivity of fire insulation.

5. Conclusions

Proposed the concept of effective thermal conductivity and developed measuring method and test setup based on steel components standard fire test. The deviation between calculated temperature and measured temperature met the engineering requirements, indicating that the test-based method is available. The conclusions may be drawn as follows.

1. Proposed a measuring method suitable for thermal conductivity of fire proof materials and developed the corresponding test setup.
2. Proposed two definitions of thermal conductivity.
3. Verification and comparison of the two definitions were proposed. Comparison between the calculated temperature and the measured temperature indicated that the two definitions met the engineering requirements. In practice, the second definition is suggested for its more convenience than the first one.
4. The thickness of fire insulation has little effect on the effective thermal conductivity. 20mm was chosen as typical thickness taking actual use into consideration.