Study of the Fire Resistance Performance of a Kind of Steel Fire Door

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Abstract

A fire resistance test was carried out for a no infill steel fire door, base on the test data analysis and the observation, combined with relative standard to evaluate the fire resistant performance, this fire door has good integrity performance, but with poor insulation performance.

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1. Preface

Fire door generally located in fire compartment, fire separation or evacuation passage; it’s one kind of active fire partition. Except for ordinary door’s function, it also can prevent the fire spread and smoke diffusion together with its framework in a certain period of time. Fire resistance is a performance that building unit to withstand fire and maintain its structure and function, and (or) the ability to limit the fire in a certain space. And the fire resistance performance is judged by the fire endurance time for the fire resistance test \cite{1-3}.

In this paper, a fire resistance test was carried out for a no infill steel fire door, base on the test data analysis and the observation, combined with relative standard evaluate the fire resistant performance of this uninsulated fire door.

2. Fire-resistance Test

2.1. Specimen Description

This specimen was a fire resistant steel double door. It was assembled by two steel leaves, a steel doorframe, eight hinges and a lockset. The entire doorframe and the panel of the leaves were made by 1.0mm thick cold-roll steel sheets, and with no infill insulation material inside the leaves. The dimensions of doorframe were 2,400 mm width by 2,400 mm height, and the thickness of the door leaves was 45mm. The exposed face of the door is the face which containing hinges and door closer. The constructional detail and the photograph of the exposed face of the specimen see Fig. 1 and Fig. 2.
2.2. Test Process

As a process of the fire endurance test, the fire door should install in an opening vertical furnace test frame before the test. The test exposes a test specimen to a standard fire controlled to achieve specified temperatures throughout a specified time period, evaluated the fire resistance performance of the specimen through the measurements, observations and the temperature rising record on the unexposed surface[4-5]. In addition, a hose stream test would carry out after the fire endurance test immediately, the exposed surface of the test assembly was subjected to the impact, erosion, and cooling effects of a hose stream described in the test standards. The specific procedure of this test is as follow:

2.2.1. Installation

The steel fire door was mounted in a standard supporting construction in advance, and the specimen had been cured for a standard condition, and moved in front of the furnace for the fire exposure before tested. The temperature of the unexposed face of the specimen was measured by means of 6 chromel/alumel thermocouples.

2.2.2. Fire endurance test

The furnace employ gaseous fuels to ignite the burner to providing the standard fire exposure conditions with respect to thermal exposure, and the furnace temperature is measured by means of 16 thermocouples distributed evenly in the furnace. During the test period, the temperature of burner will be controlled by adjust the gas proportion; insure the mean of the 16 thermocouple readings followed as closely as possible the time/temperature curve. The furnace pressure is controlled by frequency modulation air fan; insure the furnace pressure is relative to atmosphere at a location 1,000mm above the sill, and use 3 pressure sensors which locate at vertical direction of the furnace to insure the pressure gradient conform to the standard [6].

2.2.3. Hose stream test:

The hose stream test is mainly inspects the integrity of a fire door which to be subjected to the impact, erosion, and cooling effects of a hose stream immediately after the fire endurance test. As the test process, the specimen shall be hanged out of the furnace after and within 90 seconds of the end of the fire endurance test, and hose stream test shall be applied on the exposed surface immediately. The hose stream test shall be applied according to the requirements of the located distance, water pressure and duration of application and the hose stream pattern must also comply with relevant standard.

2.2.4. Performance criteria

The fire resistance performance of the fire door is mainly considered with integrity and insulation. Integrity: Failure is deemed to occur:
a) When collapse or sustained flaming for not less than 10s on the unexposed face occurs;
b) When cracks, gaps or fissures allow flames or hot gases to cause flaming or glowing of a cotton fiber pad;
c) A 6mm-diameter gap gauge can penetrate through a gap into the furnace and be moved in the gap for a distance of at least 150mm;
d) A 25mm-diameter gap gauge can penetrate through a gap into the furnace.

Insulation: Failure is deemed to occur:
a) When the mean unexposed face temperature increases by more than 140ºC above its initial value;
b) When the temperature recorded at any positions on the unexposed face is in excess of 180ºC above the initial mean unexposed face temperature.

Besides, the fire door shall withstand the hose stream test, and shall be determined to comply with the requirements for performance when it remains in the opening during hose stream test and without developing openings anywhere through the door.

3. Test data and analysis

The fire endurance test was terminated after a period of 3 hours, and a hose stream test carried out immediately with a 184 seconds period. Base on the test recording data and the results analyses, and combined with the standard at home and abroad, evaluation of the fire resistant performance of this steel fire door as below.

3.1. Furnace temperature

The temperature rising of fire endurance test in general is reference hydrocarbon fire temperature rise curve; present a characteristic as initial heating rapidly and heating slow down gradually in later period, and there are some differences in details in different national standards [7-9]. Fig.3 shows the compare of the differences between Chinese, European and American standard in time/temperature curve. From the figure can see that the furnace temperature rising of this test was close to the time/temperature curve of standards mentioned above, and through calculation, the tolerances between furnace temperature and the standard curve also in line with the standards tolerance range.

![Fig.3 Furnace Temperature Curve](image)

3.2. Furnace pressure

This test belongs to positive pressure fire endurance test. The specimen shall be subjected to a pressure condition similar to that which would apply if a linear pressure gradient of 8 Pa per 1,000 mm height, and after the first 5 minutes of the test the furnace pressure was maintained at 0 Pa at 1,000 mm from the notional floor level. The test furnace pressure curve (see Fig. 4) show that the pressure condition of this test all can meet above requirement during the test period, and it also can be controlled in range of ±2 Pa of the pressure specified in the standard.

Analysis above indicated that, the furnace temperature condition and the pressure condition for this test are completely accord with Chinese, European and American positive pressure fire endurance test standard requirements.
3.3. Insulation

The unexposed surface temperature curve (see Fig. 5) shows that, at 10 minutes from commencement of this test, the mean temperature rise of the unexposed surface was more than 140 °C, and the maximum temperature rise of the unexposed surface was more than 180 °C. Judge according to the standard requirements, the insulation performance only for 10 minutes. Normally, the steel leaves and hardware are with good thermal conductivity, the insulation performance of steel fire door mainly depends on the infill insulation material with high strength and low thermal conductivity. In this test, the steel fire door is assembled by steel panel only, with no infill insulation material at all. As soon as the test began, high temperature easily transferred to the unexposed face of specimen, made the unexposed surface temperature rise up so quickly that met the insulation criteria very soon.

3.4. Integrity

During the test period of 3 hours, there was no collapse of this specimen, no sustained flaming on the unexposed surface and no loss of impermeability. The integrity of this steel fire door was not failure. The photograph of the unexposed face of the specimen sees Fig. 6. Because of steel panel has great fire resistance and is not easy to burn through, ensure the door leaves can barrier high temperature from furnace during the test period. Therefore, in the choice of thick and with excellent performance cold-rolled steel sheet as door panel material can basically to prevent cracking or peeling which results
integrity failure. In this door, the entire doorframe and the panel of the leaves were made by 1.0mm thick cold-roll steel sheets, and assembled with fire-resistant hardware. Adjustment of gaps dimension between leaves and doorframe had made strictly before the test, which ensured that in the process of test, hot gas or flames would not overflow from the gaps of burn through the door panel, or hardware damage melt, or the gaps between the leaves and doorframe that cause flaming or glowing of cotton fibre pad. Further, since the leaves had no infill insulation material, the temperature difference between exposed surface and unexposed surface was less; thereby reduced the stress which caused by internal and external temperature difference, there was no obvious warping occur on the door leaves, and just slight deflections was observed at the middle joint of the double door, thus ensuring all of the gaps and joints of the fire door remain tight.

3.5. Hose stream impact endurance performance

In this test, the steel fire door was subjected to a hose stream impact; the water pressure at base of play pipe was 310kPa, and duration of application of exposed surface for 184 seconds. Photograph of the exposed face of the specimen after the hose stream test see Fig. 7. As the result, the fire door could still remain in the opening during the hose stream test and with no developing openings anywhere through the specimen. It proved that after endure 3 hours high temperature effects, this steel fire door’s panels still keep in good condition, and the hardware which equipped on the door still maintain normal function, there was no collapse or perforate occur on the specimen, the fire door kept tightly closed and passed the hose stream test successfully.
4. Conclusion

In summary, this no infill steel fire door has good integrity performance (integrity ≥ 3.00 hours), but due to its non-filled insulation material structure, result in its poor insulation performance (insulation 10min). This test result indicates that this steel fire door is in line with the uninsulated fire door performance requirement for C3.00 Class as integrity ≥ 3.00 hours which mention in the Chinese fire doors standard GB 12955-2008[10]. Also, this steel fire door performance is in line with the fire endurance test requirements of exposure chosen as 3 hours fire door which mention in American standard UL 10C-2009, and pass the hose stream test successfully.

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References

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