Study on Fire Resistance of Floor Structures in High-speed Train

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Abstract. According to the standard EN 45545, fire resistant tests of floor structures in high-speed train were carried out. Two typical floor structures which were placed in the passenger train were tested. Integrity and insulation are main performance criteria to evaluate fire resistance of floor structures. The furnace temperature is in accordance with the requirements in the standard ISO 834. The surface temperature and deflection were recorded with time. Glass wool and aluminium corrugated sandwich structure in two structures were burned through. The experiments were terminated at 30 minutes and 31 minutes respectively for the two structures. A large amount of smoke and the sound of cracking of the exposed surface of the test piece were produced, although the unexposed surface of test pieces did not reach the failure condition.

1. Introduction
As an important fire barrier, the floor structure of high-speed trains needs to meet the fire resistance requirements specified in the standard. At present, a large number of researches on the fire resistance of structures are focused on building components. The United States proposed fire test methods for panels, walls and other components in 1905. In 1916, the fire test method for components was revised and a standard time-temperature curve was proposed, which became the standard curve for fire research in the United States [1]. In 1976, the Portland Cement Association of the United States and the Canadian National Research Institute began to jointly complete the fire resistance test of full-size columns under loading. The United Kingdom has the world's most advanced fire research laboratory in building area. Japan, Australia, Canada, Sweden, Norway, New Zealand and a lot have also done extensive experimental research on fire resistance issues. The stress, deformation, and failure characteristics of structures and components under loading and high temperature are studied. The method of fire resistance analysis and design of various concrete components or structures are proposed.

However, there are currently few researches on the fire resistance of structures in high-speed trains. Some researchers have conducted fire tests on the structures of high-speed trains and subways based on the tests specified or recommended in the standard [2][3][4][5][6][7][8]. According to the standard EN1364-1/-2, this paper conducts an experimental study on the fire resistance of the typical floor structures in high-speed trains. The requirements for the fire resistance of the floor are shown in Table 1.
Table 1. Requirements of fire resistance

| Performance criteria | Content |
|----------------------|---------|
| Integrity            | This is the time in completed minutes for which the test specimen continues to maintain its separating function during the test without: a) causing the ignition of a cotton pad; or b) permitting the penetration of a gap gauge; or c) resulting in sustained flaming. The time of failure is the time at the end of the measurement; i.e. when the observation is finally made. |
| Insulation           | This is the time in completed minutes for which the test specimen continues to maintain its separating function during the test without developing temperatures on its unexposed surface which: a) increase the average temperature above the initial average temperature by more than 140 K; or b) increase at any location above the initial average temperature by more than 180 K. The initial average temperature shall be the average unexposed face temperature at the commencement of the test. |

2. Test specimen
The paper has carried out experimental research on two typical floor structures, both of which are 1.7m×1.7m in size. The floor composition and thickness are shown in Table 2. The two structures are both composed of floor surface, inner floor structure, glass wool and Train body, which can be seen in Figure 1. However, the component of inner floor structure is not the same. The inner floor structure in Structure 1 is composed of aluminium, wood and rubber, while that in Structure 2 is composed by honeycomb sandwich structure.

For Structure 1, it is mainly used for the end of the carriage to achieve good sound insulation and noise reduction. Structure 2 is mainly used in the middle of the carriage to achieve good load-bearing, heat insulation, and noise reduction effects. The honeycomb sandwich structure is composed of two upper and lower plates and a honeycomb core. The upper and lower plates and the core are welded or bonded to form a whole structure, which has the characteristics of light weight and high rigidity.

Table 2. Component of test specimen

| Test specimen | Component                                      | Thickness (mm) |
|---------------|-----------------------------------------------|----------------|
| Structure 1   | Floor surface (rubber)                        | 2.5            |
|               | Inner floor structure (aluminum, wood and rubber) | 22.0           |
|               | Glass wool                                     | 50.0           |
|               | Train body (aluminium corrugated sandwich structure) | 40.0           |
| Structure 2   | Floor surface (rubber)                        | 2.5            |
|               | Inner floor structure (honeycomb sandwich structure) | 22.0           |
|               | Glass wool                                     | 50.0           |
|               | Train body (aluminium corrugated sandwich structure) | 40.0           |
3. Fire Resistance Test

The test piece is placed horizontally on the top of the test furnace. The size of the exposed surface of the specimen is 1200mm×1500mm. Insulation wool made from ceramic fiber is placed around the test piece. The average temperature and furnace pressure in the test furnace are controlled in accordance with the requirements of the standard EN 1363-1. Five thermocouples for temperature measurement are arranged in the test furnace. A pressure tube is placed 200 mm below the furnace top to measure the pressure in the furnace. 5 min after the start of the test, the furnace pressure should be controlled at 10(±2) Pa based on the environmental conditions of the laboratory. Five temperature measuring thermocouples are arranged on the unexposed surface of the test piece. The position of measuring the deflection of the test piece and the position of thermocouples are shown in Figure 2.

4. Results and Discussion

For Structure 1, the furnace temperature is closer to the standard temperature curve which can be found in the standard ISO 834. During the experiment, although the unexposed surface of test piece did not reach the failure condition, a large amount of smoke and the sound of cracking of the exposed surface
of the test piece were produced. Therefore, the experiment was terminated in about 30 minutes. Train body and glass wool were completely burnt, part of the inner floor structure has been damaged, and the floor cloth has been deformed and bulged. The damage of the inner floor structure is shown in Figure 3. The maximum deformation is 4.5 mm at 30 min.

![Figure 3. The damage of the inner floor structure in Structure 1.](image)

For Structure 2, there was also a large amount of smoke produced during the experiment. The smoke first came from the position where there was no insulation cotton used. The experiment was terminated in about 31 minutes. Although the train body and glass wool were also burned through, and the lower surface of the inner floor structure faded, the inner floor structure seemed to remain good. The test piece after the experiment is shown in Figure 4. The maximum deformation is 3.0 mm at 31 min.

![Figure 4. The test piece after the experiment was seen from the exposed surface.](image)

It can be seen from the above experiment that the fire resistance of Structure 2 is better than Structure 1. Structure 1 has significantly higher toxicity and combustible gas production under fire condition than Structure 1, which can be judged from the experimental phenomena and the component of the structure. There are plywood and rubber in Structure 1 which can be easily burnt and produce toxic and
combustible gases, while Structure 2 is mostly composed of alloy. Therefore, it can be concluded from that Structure 2 is safer and more reliable than Structure 1 under fire condition.

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