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ABSTRACT

A test facility to determine the fire resistance of columns was built at the Tianjin Fire Research Institute. This facility was constructed mainly for the purpose of providing testing for the fire resistance of building columns found in China. The test results indicate that this facility is reliable and produces comparable results with those at the facility at the National Fire Laboratory of the Institute for Research in Construction, National Research Council of Canada.

COLUMN FIRE RESISTANCE TEST FACILITY AT THE TIANJIN FIRE RESEARCH INSTITUTE

1 INTRODUCTION

As a part of a joint research project on the "Fire Resistance Evaluation for Housing (China)" between the Tianjin Fire Research Institute (TFRI) of the Fire Bureau of the Public Security Ministry of China, and the Institute for Research in Construction (IRC), National Research Council of Canada, a testing facility to determine the fire resistance of columns (which will be called the "column furnace" for short) was constructed at TFRI. The column furnace was designed and installed jointly by TFRI and the National Fire Laboratory (NFL) of IRC.

The main purpose for the construction of the column furnace at TFRI was to provide a testing facility for the fire resistance of building columns, commonly used in China. In the joint project, experimental studies on the fire resistance of three reinforced concrete columns were carried out at TFRI.

A photograph of the column furnace at TFRI is shown in Figure 1. Details of the column furnace are described below.

2 Main Characteristics of Column Furnace at TFRI

The column furnace at TFRI consists of a loadbearing framework, furnace chamber, combustion system, hydraulic loading system, instrumentation system, and data acquisition and processing system. The main characteristics of this column furnace are given in Table 1.

The column furnace was designed to meet the ISO-834 Standard and the China National Standard GB-9978. In addition, the test furnace can also produce some non standard conditions to which a column may be exposed during the course of a fire with regard to temperatures, structural loads and heat transfer.

2.1 Loadbearing Framework

The loadbearing framework comprises a bottom beam, a upper beam and four steel columns. The bottom beam is fixed to the base of the furnace; the upper beam is supported by the four steel columns which are connected to the bottom beam. The dimensions of the loadbearing framework are 5.90m in width, 4.73m in depth and 9.80 m in height.

Since the outer dimensions of the loadbearing framework, which is designed to meet the required conditions of stiffness and strength, are relatively, small the loadbearing framework was easily manufactured and installed. Because the loads applied to a test column in the furnace are carried by the loadbearing framework, only the weight of the furnace is carried by the base. Therefore, a solid and deep base was not needed.

2.2 Furnace Chamber

The furnace chamber, whose floor area is 2.6 x 2.6 m, is made of an insulating material that will give a high heat transfer to the specimen. Since this insulating material has a low heat conductivity, the temperature rise on the outside of furnace chamber was found to be only 8 °C after a 6 hour test.

The roof of the furnace chamber can be moved upwards or downwards in a range that will provide furnace chamber heights varying from 3.0 m to 4.2 m and enables testing of columns of different lengths. The roof functions as a blow-out panel as a safety measure against explosions.

2.3 Combustion System

There are 16 diesel oil burners in the furnace chamber arranged in four columns containing four burners each. The total capacity of the burners is approximately 4187 kW, which should be sufficient to simulate any fire severity encountered in practice. In order to simulate different temperature conditions, the oil supply to the burners can be controlled by a programmable controller. In addition, each burner can also be adjusted individually, which provides a high degree of temperature uniformity in the furnace chamber. The accuracy in controlling the furnace temperature is ± 10 °C.

The pressure in the furnace chamber is also adjustable and is set somewhat lower than atmospheric pressure.

2.4 Hydraulic Loading System

The hydraulic loading system consists of one axial loading jack, two eccentric loading jacks and two lateral loading jacks. The axial loading jack was designed for a maximum load of 5000 kN. This capacity is sufficient to subject most of columns, used in China, to their design loads. The capacity of the two eccentric loading jacks is 300 kN at an eccentricity of 500 mm. The other two jacks exert lateral loads at the top of the column, to simulate the loads and displacements due to floor expansion during a fire. The capacity of the lateral loading jacks along the x-axis is 400 kN; the capacity along the y-axis is 150 kN.

The loads are measured by pressure transducers that send electric signals to a load controlling system, controlled by hydraulic servo valves.

2.5 Instrumentation System

The furnace temperatures are measured with the aid of eight Chromel-Alumel thermocouples installed 0.1 m from the test specimen at various heights. There are two thermocouples placed opposite each other every 1 m along the height of the furnace chamber, starting from the floor. The eight temperatures, measured by these thermocouples, are averaged automatically and the average temperature is used as the criterion for controlling the furnace temperature.

The axial deformation of test columns is measured with a SONY digital linear potentiometer. The accuracy of this measurement is ± 0.001 mm.

2.6 Data Acquisition and Processing System

The data acquisition and processing system is a FLUKE Helios-I data acquisition system and a microcomputer. The Helios-I data acquisition system can acquire analog and digital data (i.e., temperature, voltage, current, strain, displacement, pressure). The Helios-I data system uses LABTECH NOTEBOOK software with the microcomputer. During a test, the test data can be stored, displayed, printed and saved by the system. After a test, LOTUS 1-2-3 software is used to process the test data saved on a hard disk.

3 Conclusion

Since the column furnace was built, three fire resistance tests on reinforced concrete columns, identical to three columns tested at the NFL, have be carried out. These results are given in Table 2.

The test results indicate that the newly built column furnace at TFRI is reliable, and comparable with the column furnace at the NFL. The TFRI furnace can carry out fire resistance tests on columns, used in China, according to the ISO Standard, the China National Standard or other testing standards, including North American Standards.

4 Acknowledgments

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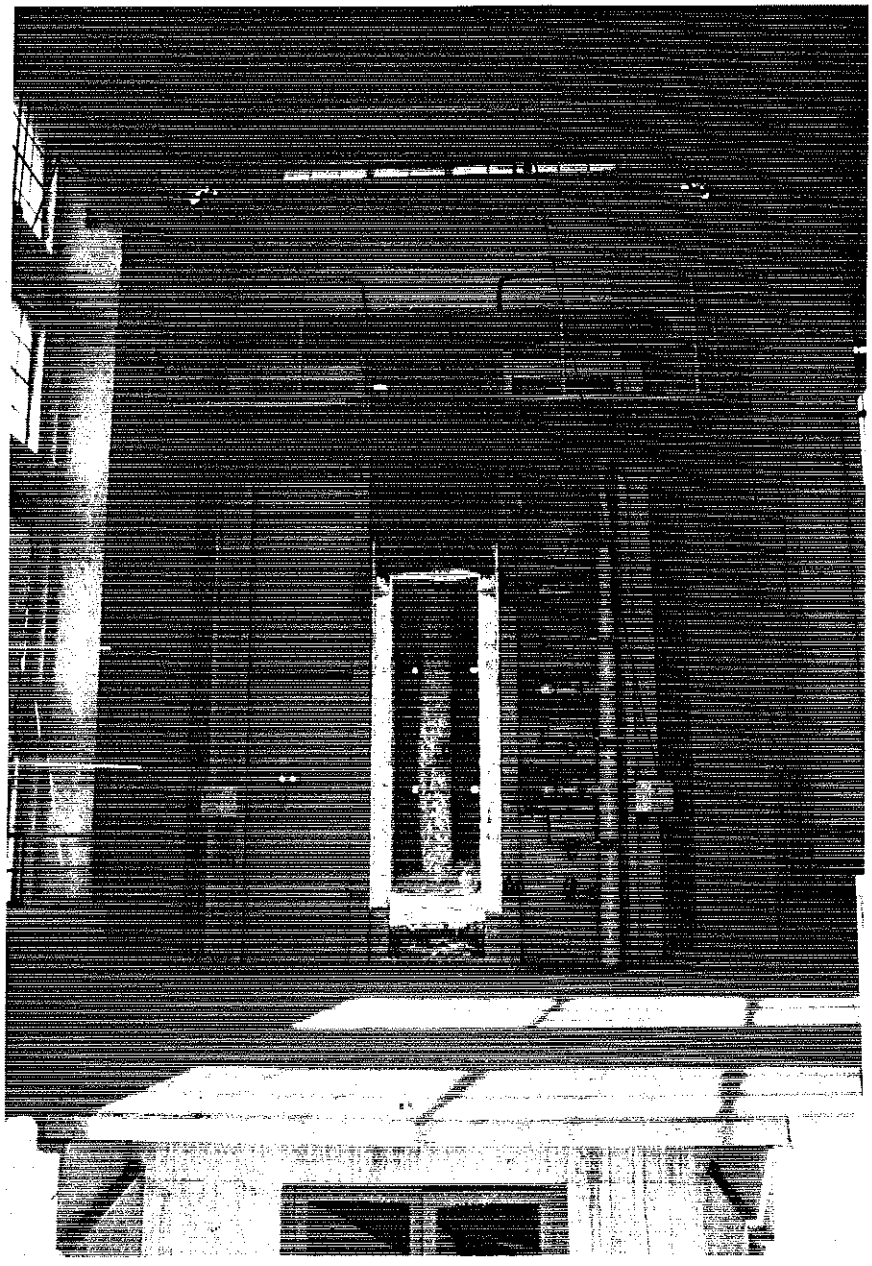

Figure 1. Column furnace and specimen at TFRI

Table 1. Main Characteristics of Column Furnace at TFRI

Characteristics	Details
Floor area of furnace chamber	2.6 m × 2.6 m
Inner height of furnace chamber	up to 4.2 m
Fire exposure height of specimens	from 3.0 m to 4.2 m
Size of loading frame	5.9 m × 4.73 m × 9.8 m
Maximum pressure of hydraulic loading system	3.2 MPa
Accuracy of controlling and measuring loads	± 2 %
Accuracy of measuring displacements	± 0.001 mm
Capacity axial load	5000 kN
Maximum movement of axial jack	400 mm
Maximum speed of axial jack	22 mm/min
Capacity of eccentric load	300 kN (eccentricity 500 mm)
Maximum movement of eccentric jack	450 mm
Capacity of lateral load along x-axis	400 kN (to be installed)
Capacity of lateral load along y-axis	150 kN (to be installed)
Fuel	diesel oil
Number of burners	16
Capacity of 16 burners	approximately 4187 kW
Oil consumption of 16 burners	191 to 214 kg/hour
Ignition of burners	Pilot flame lights oil burners.
Pressure of fuel oil supply system	49 to 294 kPa
Pressure of air supply system	6.9 kPa
Type of thermocouples for temperature measurement	Type [K]

Table 2. Comparison of Results of columns tested at TFRI and NFL

Column No.	Dimensions (mm)	Aggregate	Loads (kN)	Failure Time (min)	
				Test at TFRI	Test at NFL
1	305 x 457 x 3810	Carbonate	1585	256 (24-08-1992)*	232 (21-04-1992)*
2	305 x 305 x 3810 (with brackets)	Siliceous	910 (axial) 49 (eccen.)	120 (01-09-1992)*	41** (03-06-1992)*
3	305 x 305 x 3810	Carbonate	1180	177 (12-06-1993)*	164 (08-05-1992)*

* Test date

** Not comparable because of premature failure