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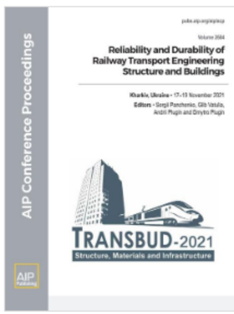

RELIABILITY AND DURABILITY OF RAILWAY TRANSPORT ENGINEERING STRUCTURE AND BUILDINGS
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Improvement of means for assessing fire resistance of fragments of reinforced concrete structures

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There are errors in experimental and computational methods for determining fire resistance, respectively, the improvement of methods and tools is an urgent issue. Based on the results of the work, a prototype of a small-sized fire installation was created and the results of test starts were analyzed, in particular, the temperature distributions in the fire furnace chamber and the possibility of achieving the temperature regime of a "standard" fire. The method of conducting an experimental study to determine the fire resistance of load-bearing structures was revealed. The distribution of temperatures over the entire area of the fire furnace was checked and the results were analyzed. The created prototype of the fire furnace allows to determine the fire resistance of load-bearing building structures by means of fire tests. The results of the experiment showed that this tool and method of testing building structures for fire resistance allows you to reproduce the standard temperature in the furnace chamber and to assess the fire resistance of structures.

Topics
Cement, Computational methods

Improvement of Means for Assessing Fire Resistance of Fragments of Reinforced Concrete Structures

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Abstract. There are errors in experimental and computational methods for determining fire resistance, respectively, the improvement of methods and tools is an urgent issue. Based on the results of the work, a prototype of a small-sized fire installation was created and the results of test starts were analyzed, in particular, the temperature distributions in the fire furnace chamber and the possibility of achieving the temperature regime of a "standard" fire. *The method of conducting an experimental study to determine the fire resistance of load-bearing structures was revealed. The distribution of temperatures over the entire area of the fire furnace was checked and the results were analyzed. The created prototype of the fire furnace allows to determine the fire resistance of load-bearing building structures by means of fire tests. The results of the experiment showed that this tool and method of testing building structures for fire resistance allows you to reproduce the standard temperature in the furnace chamber and to assess the fire resistance of structures*.

INTRODUCTION

Over the last 5 years, the number of fires has increased, in particular in buildings and structures for industrial and residential purposes. Due to the peculiarities of the design solutions of the above buildings, it is important to ensure fire resistance of both individual elements of building structures and their fire resistance in general.

Various theoretical, experimental, computational, modeling methods for determining the limit of fire resistance of building structures are constantly being developed, which make it possible to determine the fire resistance of a significant number of structural systems without costly and time-consuming fire tests. However, it should be considered that experimental studies of fire resistance of building structures make it possible to determine the fire resistance of a very large number of structures with real dimensions for various fire effects that can be simulated in a fire chamber.

ANALYSIS OF RECENT ACHIEVEMENTS AND PUBLICATIONS

In the field of fire safety, abroad, in the European standard EN 1363-1:1999 "Fire resistance tests – Part 1: General requirements and in the international standard ISO 834-1: 1999 "Fire resistance tests –Elements of building construction – Part 1: General requirements to determine the limit of fire resistance of building structures, a test method is used, the content of which is to determine the time interval from the start of the test to the onset of one of the normalized for this structure limit states of fire resistance under standard temperature [1].

After analyzing the literature [2-4], it was found that there are large furnaces in which you can conduct research to determine the fire resistance of building structures of standard size. However, these furnaces have a significant disadvantage in terms of efficiency: their tests are time consuming, expensive and non-ecological.

In the work [5], with the help of a furnace for thermophysical tests of small fragments of building structures and individual components of their butt joints [6], the temperature change in the thickness of the building structure was investigated during heating and the limit of fire resistance was established. However, the design of the furnace involves the use of only one burner to heat the chamber, which can affect the uniformity of heating of the studied structures. In addition, this stove can only be used to test walls and it runs using liquid fuel. This in turn indicates the imperfection of the design. This work takes into account design solutions to create a more versatile installation.

Now in Ukraine there is DSTU B V.1.1-4-98* [7], which defines the requirements for testing to assess the fire resistance of building structures, as well as means, methods and techniques of conducting. According to researchers [2-4], the standard is somewhat outdated and needs to be revised. However, to date, the requirements specified therein are mandatory for fire resistance tests. The disadvantage of this is that the quality control of the tests is insufficient: the non-uniformity of the temperature field is not controlled as a factor influencing the sample in the chamber of the fire furnace. The temperature difference of 100 °C or more in the furnace during the tests of homogeneous samples of the building structure leads to the establishment of different limits of their fire resistance (the difference can be tens of minutes) [8]. This feature is not taken into account by the installation described in the work [5].

PURPOSE

This article describes the stages of creating a prototype fire installation on the basis of the Training Complex of practical training of specialists of the Operative and Rescue Service of Civil Defense of ChIFS named after Chornobyl Heroes of NUSD of Ukraine and the analysis of the results of test launches of the installation, in particular the temperature distributions in the chamber of the fire furnace and the possibility of achieving the temperature of the "standard" [7] fire.

To solve the goal, such tasks are set:

- To describe the stages of construction of a prototype of a compact installation for testing reinforced concrete and reinforced concrete building structures to simulate the thermal effects of fire.
- To determine technical characteristics of the prototype of the fire installation, to conduct tests for fire resistance.
- To analyze the temperature regime and to measure the possible maximum temperature in the firebox chamber.
- To make a conclusion about expediency of application of a prototype of a fire installation, for carrying out tests on fire resistance of reinforced concrete constructions.

CONSIDERATION ON METHODS AND RESULTS

To conduct the experiment, a prototype of a small-sized fire installation was created to test the possibility of achieving a standard temperature in the chamber of the fire furnace.

In fig. 1 there is a photo of the created prototype of a small fire installation.

FIGURE 1. Prototype of a compact installation for testing reinforced concrete and reinforced concrete building structures under the thermal effects of fire:
1- n-shaped box; 2-3- removable covers; 4- thermocouple; 5- power floor (foundation); 6- gas installation; 7- chimney for the output of combustion products; 8- hole for installation of burners.

The model of the installation for testing the fire resistance (Fig. 1) is able to provide standard conditions of fire exposure in terms of thermal exposure and pressure. The main stages of construction of a prototype fire installation are described below.

Stages of creating a fire installation:

Filling the foundation under the fire furnace: a pit was dug for the foundation under the furnace, formwork was installed, a sand-rubble layer was leveled and laid, a reinforced concrete slab was installed and filled with liquid cement mixture;

The fire furnace is built of refractory brick, which provides sufficient thermal insulation of the chamber and meets the standards [6];

The furnace chamber has 4 holes for burners (during the field test only 2 holes out of 4 are used, and the other 2 are closed with mineral wool, which provides insulation of air flow from the outside) and 1 hole for combustion products;

The chimney is built of 2 parts: a built-in pipe with a diameter of 20 cm, which is laid with bricks in one row;

Removable covers consist of: a welded metal frame in which mineral wool is placed, on top of which, on the side exposed to temperature, stainless steel sheets are fixed.

The fire furnace was made on three sides, U-shaped, one side of the structure was not built, which will help to investigate a fragment of a reinforced concrete wall in a real fire.

The characteristics of the fire furnace chamber are given in table. 1.

TABLE 1. Characteristics of the Fire Furnace Chamber

Parameter	Units of measurement	Value
Power	kW	100
The maximum temperature of heating of space of the chamber	°C	1050
Working chamber volume	m^3	1

Overall dimensions (internal space of the furnace chamber):		
Width	mm	1000
Length	mm	1000
Height	mm	1000
Maximum heating rate of the camera	°C/min	85

Before the start of the test, the date of the study and the ambient temperature is recorded.
3 Thermocouples are placed in the chamber of the fire furnace to determine the temperature distribution.
The location of thermocouples in the walls of the fire furnace chamber is shown in Fig. 2.

FIGURE 2. The Location of Thermocouples in the Walls of the Test Installation for the Study of Temperature Distribution in the Furnace Chamber: 1-3 – Thermocouples of TCA Eype.

The burners are placed so that the flame of their flame is not in contact with each other and is 80 cm to the test specimen.

In Fig. 3 the hole for the output of combustion products is shown, it is indicated by the number 1, 2-5 - holes for burners.

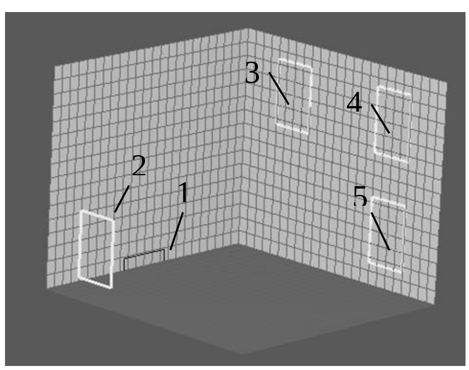

FIGURE 3. Layout of the Hole for the Output of Combustion Products and Holes for Burners.

The placement of burners and holes for the removal of combustion products affects the uniformity of temperature distribution on the heating surface of building structures.

There is a technical possibility to change the size of the hole for the removal of combustion products, which allows you to further regulate the process of heating the furnace chamber and provide the required temperature of the fire.

To check the possible temperature in the chamber of the fire furnace and create the appropriate temperature in it, 2 burners were connected to 2 gas cylinders. Gas heating, although contrary to the requirements [7], is more environmentally friendly and less expensive. Therefore, it was decided to test the possibility of reproducing the test conditions using propane-butane [7].

Thermocouples TCA-2388 with a wire diameter of 1.25 mm which can be used to measure temperature in the range from 0 to 1300 ℃ were used to measure the temperature in the furnace.

To obtain digital values of temperature in the installation of the thermocouple the module of analog-to-digital conversion (ADC) of the thermocouple signal is used, this module was specially developed at the institute, it allows to conduct temperature measurements with a sensitivity of 0.25℃. The module is based on the chip max. 31855, which allows you to convert the analog digital signal of thermocouples into digital with a maximum temperature up to 1350℃. This module takes into account the temperature of the cold junctions and automatically corrects the temperature measurement values.

All analog-to-digital converters of a signal of thermocouples and thermistors were placed in the block of the combined calculation of temperatures (fig. 4.)

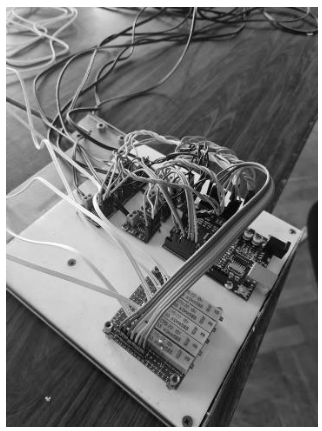

FIGURE 4. Combined Temperature Calculation Unit.

To process the obtained data, the PLX DAQ plug-in for Microsoft Excel was used, which allows you to see numerical temperature values in real time and build appropriate graphs.

In Fig. 5 A Graph of Temperature-Time Dependence of the Heating Chamber of the Fire Furnace Is Shown.

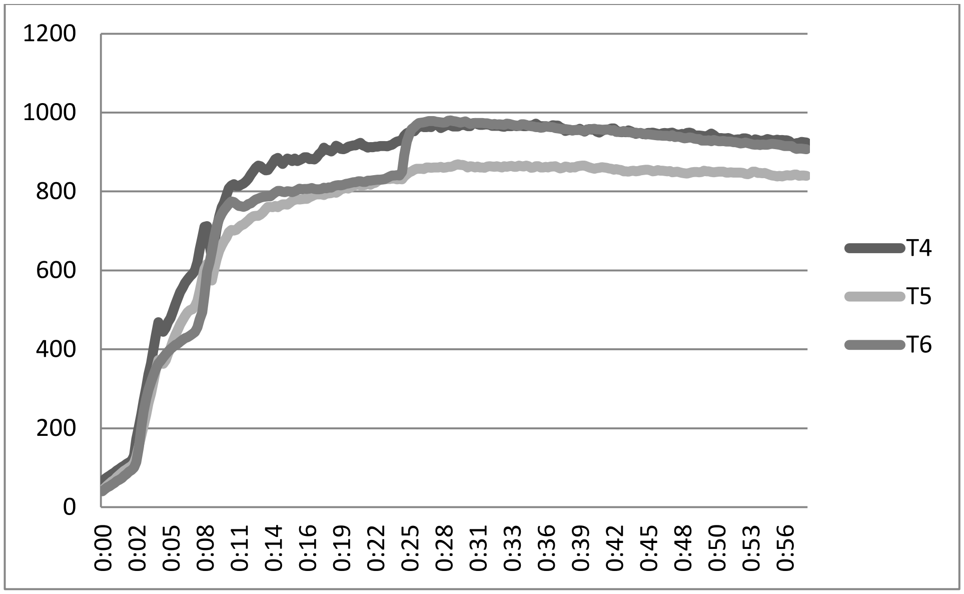

FIGURE 5. Linear Heating Rate of the Furnace Chamber: Temperature-Time Dependence in the Fire Furnace Chamber: T4 – Temperature Sensor, Which is Located Closer to the Opening for the Output of Combustion Products, T5 – Temperature Sensor, Which is Located Closer to the Installed Vertical Removable Cover; T6- Temperature Sensor, Which is Installed in a Parallel Wall to the Sensors T4 та T5.

The linear heating rate of the furnace chamber was 35 °C/min. When the value reached 975 C stationary mode was set by adjusting the heating power of the furnace. The test lasted 60 minutes (Fig. 5).

During the test, the temperature in the furnace met the requirements regulated by the standard.

Analyzing the performance of thermocouples in the process of conducting a fire test, it became possible to state the following:

- maximum temperature in the study room for 9 minutes was 630 ºC, and the average temperature at this time was 600 ºC and it was stable for 15 minutes;
- in 24 minutes from the beginning of the fire the power of burners was increased as a result of which the temperature increased to 975ºC and it was stable for 10 minutes;
- fire test and temperature rise in the furnace chamber corresponded to the temperature rise when using a standard fire temperature curve [7].

CONCLUSION

1. The prototype of the fire furnace which is constructed in the size of 1 m × 1 m × 1 m is created for definition of fire resistance of vertical bearing building designs. It gives the chance to carry out fire tests according to the standard temperature mode.
2. The stages of construction of a fire furnace with flare combustion are described and the peculiarities of creating a prototype of a compact installation for testing reinforced concrete building structures under the thermal effects of fire are shown..
3. According to the conducted experimental test, in the chamber of the fire furnace there is a uniform distribution of temperatures on all area of the furnace, the maximum temperature in the furnace reached 975℃ that corresponds to the minimum possible temperature of carrying out tests for 80 minutes, according to requirements. [7].
4. Given the above and in conclusions 1-3, the prototype of the described installation should be used for testing the fire resistance of reinforced concrete building structures, but only as an element of the experimental calculation method. The development of the method is a prospect for further research in this work.

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