

The mechanical activation accelerates a role of microsilica in bonding substance. In 28 – and day-time age the durability of hydrated cement by mechanoactivated bonding substance with additive of 10 % of microsilica is higher in 1, 4 in comparison with a control [2] . So that, it may be affirmed that directional structural modification leads to increasing of durability of consolidated cement compositions.

Conclusions

1. The insertion of microsilica in a composition of bonding substance contributes to the formation of solid connections among the products of hydration of cement that is confirmed by the facts on a formation of lowly basic calcium hydrosilicate.

2. The mechanical activation of grains of cement and microsilica assures the increase of mechanical characteristic of cement stone in diapason from 26 to 40%.

1. Gorelik S. S., radiographical and electro-optical analysis/ S. S. Gorelik, L. N. Rastorguev, J. A. Skakov // Tutorials for students. – 3 rd ed. comp. alt. - M.: MISSIS, 1994. - 328 p .2. Ksenschkevich L. M. Physico-chemical and physico-mechanical methods of research of hydrated cement with an additive of microsilica/ L. M. Ksenschkevich, I. V. Barabash // Herald OSAEA. - Odessa: OSAEA. - 2010. – Writ. № 40. - P.161 -167.

UDC 624.042.5

S. S. Bula, R. O. Boiko, S.A. Lysiuk, Y. Kurtyak, Y. Fall

Lviv Polytechnic National University,

Department of building constructions and bridges

ANALYSIS AND IMPLEMENTATION OF NEW MODELS OF FIRE FURNACES

© Bula S. S., Boiko R. O., Lysiuk S.A., Kurtyak Y., Fall Y., 2014

This paper analyzes existing furnaces for fire testing of building constructions both in Ukraine and abroad. A new model of fire furnace was designed, which allows to test models of structural systems.

Key words: furnace for fire testing, the fire resistance of building construction.

Здійснено аналіз вогневих печей, що використовують для випробування будівельних конструкцій як в Україні, так і за кордоном. Розроблено нову модель печі, що дасть змогу проводити випробування моделей конструктивних систем.

Ключові слова: вогневі печі, вогнестійкість будівельних конструкцій.

Introduction

Determination of the fire resistance of different constructive systems is a complex and time-consuming scientific problem. One of the main methods for determining fire resistance, which gives accurate and reliable data about building's behavior during a fire, is a fire test: a full-scale imitation of the real fire in buildings or their fragments and tests in fire furnaces on building constructions of diminished size. The full-scale experiments provide the most accurate data about the behavior of a building during a fire, but they require significant economic and a labor costs. According to the difficult economic situation in Ukraine, this type of fire testing is not used. Therefore it is necessary to pay attention to the fire tests in furnaces on models of constructive systems, which give base for the development of numerical methods for determining the fire resistance.

Analysis of the Current State of the Issue

General requirements for construction of the fire furnaces are listed in DSTU B V.1.1-4-98 "Protection against fire. Building construction. Test methods for fire resistance. General requirements"[1]. Relevant foreign counterparts is ISO 834-1:1999 "Fire-resistance tests. The elements of building construction. Part 1: General requirements"[2] and GOST 30247.0-94 "Building constructions. Test methods for fire resistance. General requirements"[3]. The furnace for the fire testing must create a temperature regime and an overpressure in the furnace according to paragraphs 6.1, 6.2 [1] and provide the fixing condition and loading of the sample in the furnace in accordance to paragraph 6.3 [1]. Also a number of regulatory documents [4-7] contain additional requirements for construction of the fire furnaces according to the type of construction that is tested.

Statement of the Problem

An important issue of present days is to conduct experiments in according to real conditions of a building operation. It means to consider a common work of particular constructions of a building. Requirements for the fire furnaces are fixed the existing regulatory documents only for testing of a particular construction. So it is necessary to conduct analysis of the existing fire furnaces and develop new ones for continuous building constructions or models of constructive systems on this base.

Statement of the Main Principles

Fire furnaces in the world. In 1894 the first stations for fire testing of building constructions and materials were set up in the USA [8]. Further fire tests were mostly conducted in special furnaces using standard fire regime.

In 1970es in Canada, series of the fire experiments were conducted in special furnaces [9]. There were developed and manufactured special furnaces for fire testing of columns, slabs and beams in the NRC. The experiments were carried out on columns height 3.89 m. A mechanical load on testing columns in the furnace was created by hydraulic system. For testing slabs was used furnace of CTL laboratory. Its size was 18x14 ft (5,4864 x4, 2672 m). For these tests were used free-supported slabs. The load was created by using of 16 vertical frames. Testing of the free supported beams of different shapes (rectangular, T-profile, double T-profile) was performed in the CTL laboratory. The fire furnace for the testing beams has dimensions of 12,2x6,1x3 m and is shown in figure 3. The mechanical load in this furnace was created by hydraulic system.

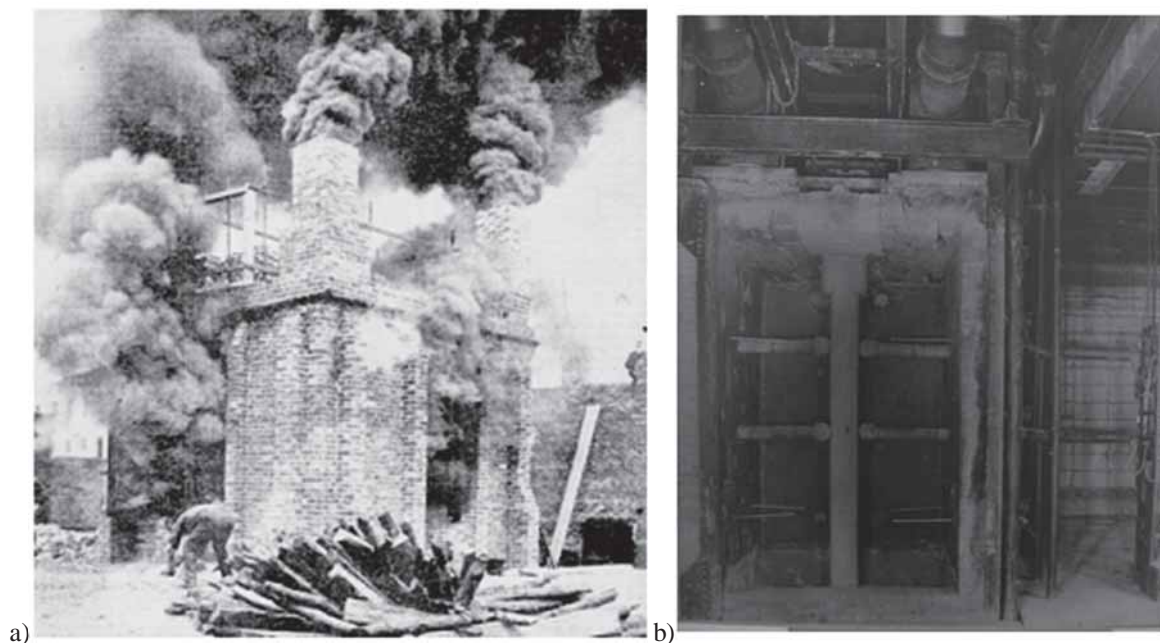


Fig. 1. a) Fire testing about 1902; b) Fire furnace for testing columns in 1920es

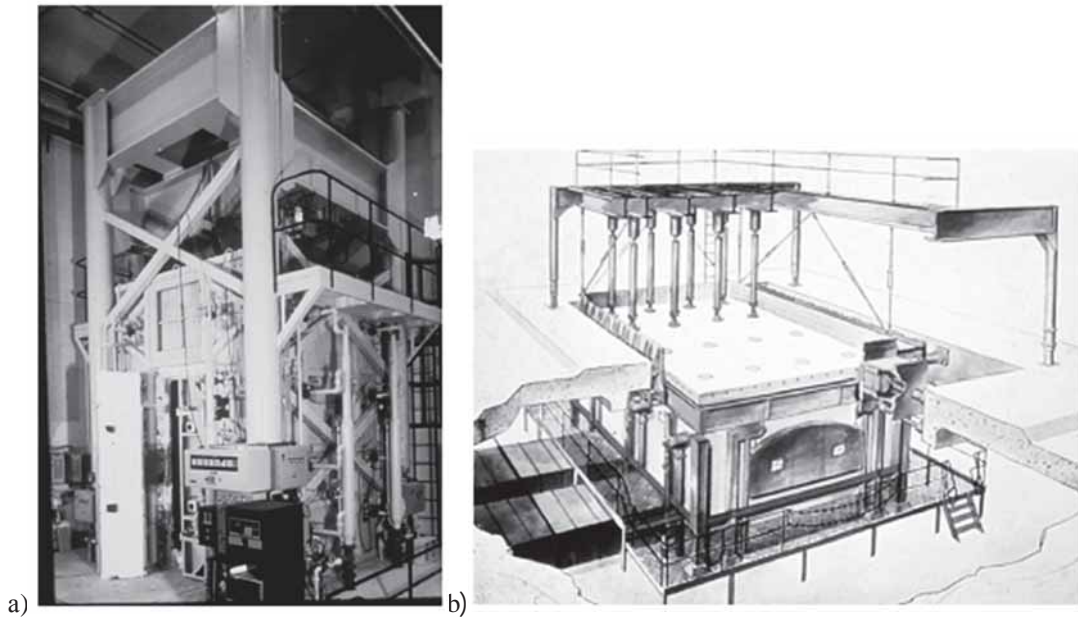


Fig. 2. a) Fire furnace for testing columns, NRC, Canada; b) Fire furnace for testing slabs, CTL, Canada

One of the currently functioning fire laboratories in Canada is RINA, which has a fire furnace with dimensions of 3040x3040x1000 mm [10]. This furnace can be used in both positions horizontal and vertical. The maximum temperature that produces furnace is 1200 °C.

One of the main laboratories in England is Fire Testing Technology Limited, which has the fire furnace for horizontal full-scale experiments. This furnace allows testing any of horizontal elements and columns. The dimensions of the furnace are 3000x4000x1000 mm. More than 20 burners can be used in this furnace at the same time [11].

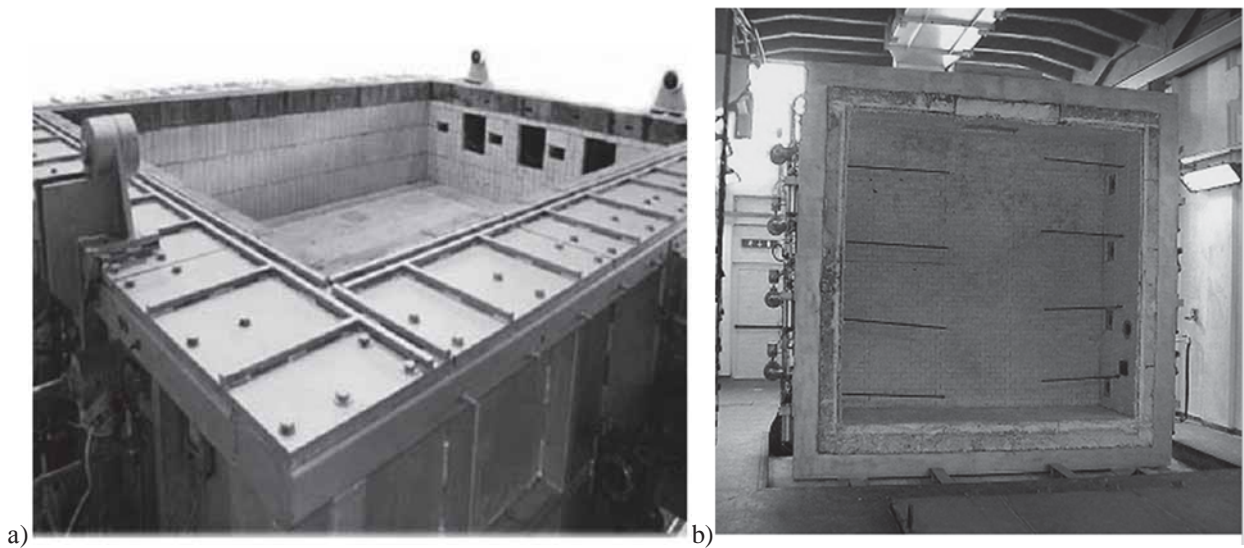


Fig. 3. a) Fire furnace in the Fire Testing Technology Limited laboratory, England; b) Fire furnace in the RINA laboratory, Canada

The “Fire resistance testing laboratory” of the United States has two fire furnaces [12]. The first furnace is for vertical tests with dimensions of 12x12 ft and 6 special burners. The mechanical load up to 100 000 lbs can be created in this furnace. The second furnace is for horizontal tests with dimensions of 12x16x6 ft, and mechanical load up to 130 000 lbs. The maximum operating temperature in fire furnaces is 2500 °F.

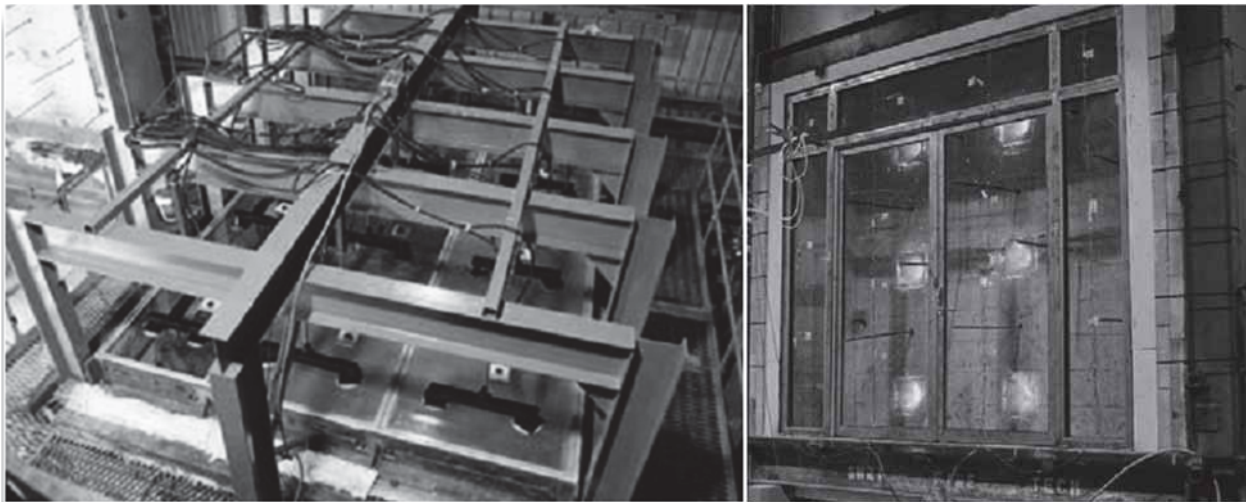


Fig. 4. Fire furnaces in the fire resistance testing laboratory, the USA

Also in the USA there is NGC Testing Services laboratory, which has three fire furnaces [13]. The first furnace with dimensions of 14x18 ft is for full-scale horizontal testing, mainly for floor slabs. The second one with dimensions of 5x5 ft is for small-scale fire tests, mainly for floor slabs, ceiling, entrance doors and safes. The third one with dimensions of 10x10 ft is for full-scale vertical tests, mainly for testing walls, partitions, doors, windows.

There is located Grifitlab laboratory in Poland. It has three fire furnaces [14]. The first one is for full-scale horizontal tests furnace with dimensions of 4x3 m. The second one is for small-scale fire tests with dimensions of 2,5x1,5 m. The third one is for full-scale vertical tests with dimensions of 4x4 m.

There is the fire furnace for testing columns in the University of Coimbra, in Portugal [15]. The mechanical load in this furnace is created by using a hydraulic jack. The additional frames were made in this furnace to ensure the stiffness of the system. Dimensions of the furnace are 1500x1500x2500 mm. The maximum temperature in the furnace is 1200 °C.

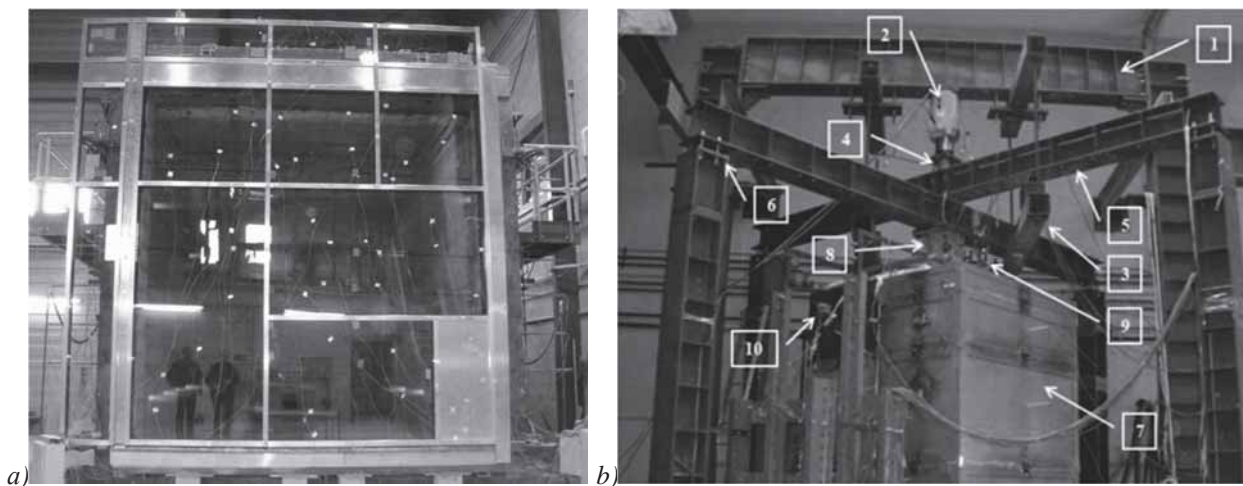


Fig.5. a) Fire furnace in the Grifitlab laboratory, Poland; b) Fire furnace at the University of Coimbra, Portugal

The fire furnace for full-scale fire tests is located in Applus laboratory in Spain. Dimensions of the furnace are 5x3 m. This is the biggest fire furnace in Spain [16].

The fire furnace located in Fire laboratory in Belgium has dimensions of 3x3x1,2 m [17]. The fire load is created by kerosene burners and static mechanical load with a help of using a hydraulic system.

In New Zealand there were tested slabs in the BRANZ Ltd laboratory, in 2002 [18]. Dimensions of the furnace in this laboratory are 4,3x3,3 m. It is designed for full-scale fire tests of horizontal elements. The mechanical load was created by using barrels of water.

A fire laboratory was opened in the University of Tokyo, Japan, in March 2005 [19]. There were built two fire furnaces to test building constructions. The first furnace is made for medium scale testing. Its dimensions are 1,5x1,5x1,5 m. This furnace is designed for testing columns, beams, slabs, walls. The second furnace is designed for full-scale fire tests of vertical planar elements. The dimensions of the furnace are 3,5x3,5 m. The fire load is provided through 20 burners.

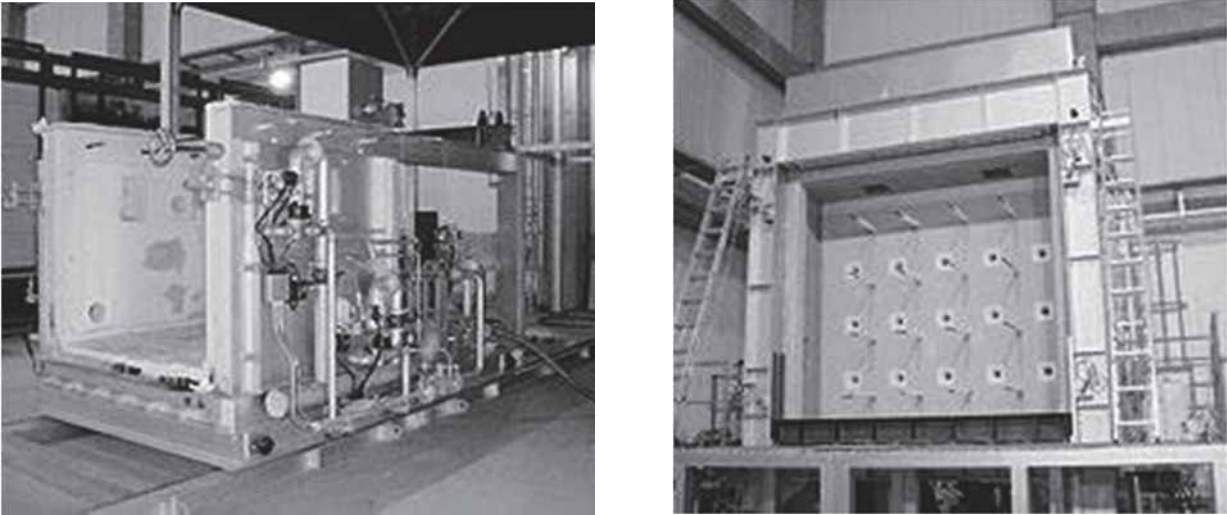


Fig. 6. Fire furnace at the University of Tokyo, Japan

Fire furnaces in Ukraine. One of the interesting ideas of fire furnace is filed in the patent of Demchyna B.G., Polovko A.P., Fitysk V.S., Peleh A.B., Demchyna H.B. "Furnace for thermal and physical investigations of small-scale building constructions and their separate joints" [20].

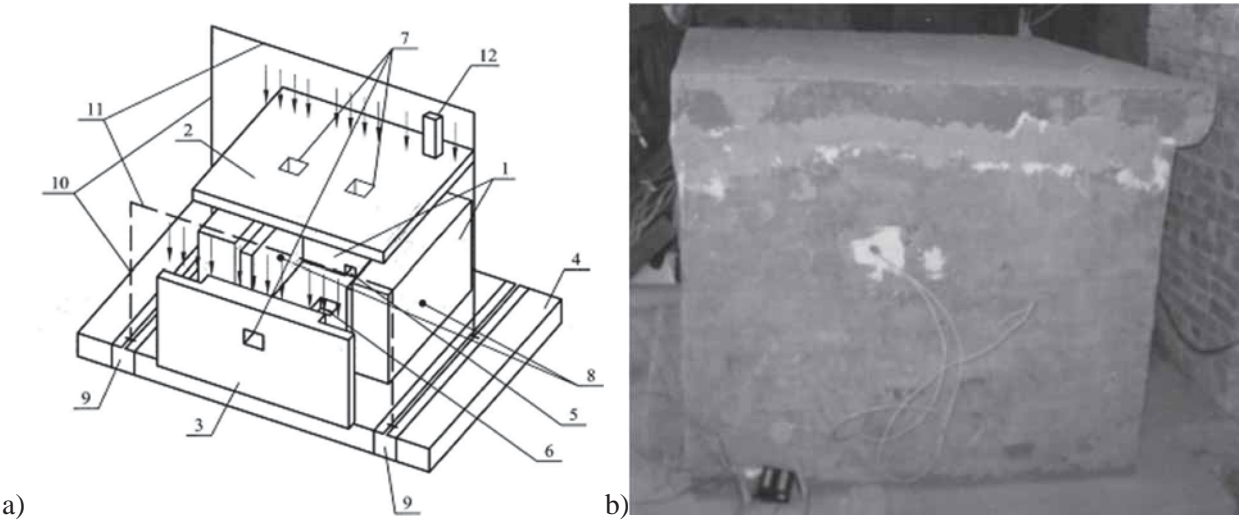


Fig. 7. a) The design of fire furnace according to the patent; b) Executed the fire furnace in fire laboratory of Lviv Polytechnic National University

This fire furnace is designed as a box with holes for burners and measure instruments, and it has a removable top slab and a side wall with viewing windows, a bottom has got holes for ventilation. This oven is used for testing plate horizontal and vertical elements, linear elements and the particular joints of building constructions. During testing of horizontal plate elements the removable side wall is mounted to form a box, and during testing of vertical plate elements the removable top slab is mounted to form a box too.

There are some testing centers in Ukraine is "TEST" (Brovary, Kiev region), NVC "Eurostandart" (village Cherlyany, Lviv region) and "POZHTEST" ltd. (Kyiv). However, there is not proper information about the fire furnaces in these laboratories in the public domain.

The presented analysis of the fire furnaces shows that the fire furnaces made abroad allow testing of continuous building constructions or models of constructive systems, but their construction requires significant financial cost that does not reply to the difficult economic situation in the country. The existing furnaces in Ukraine are not suitable for testing such type of structures. Therefore is necessary to develop a new models of furnaces that do not require significant financial costs and allow fire testing on continuous building constructions or models of constructive systems.

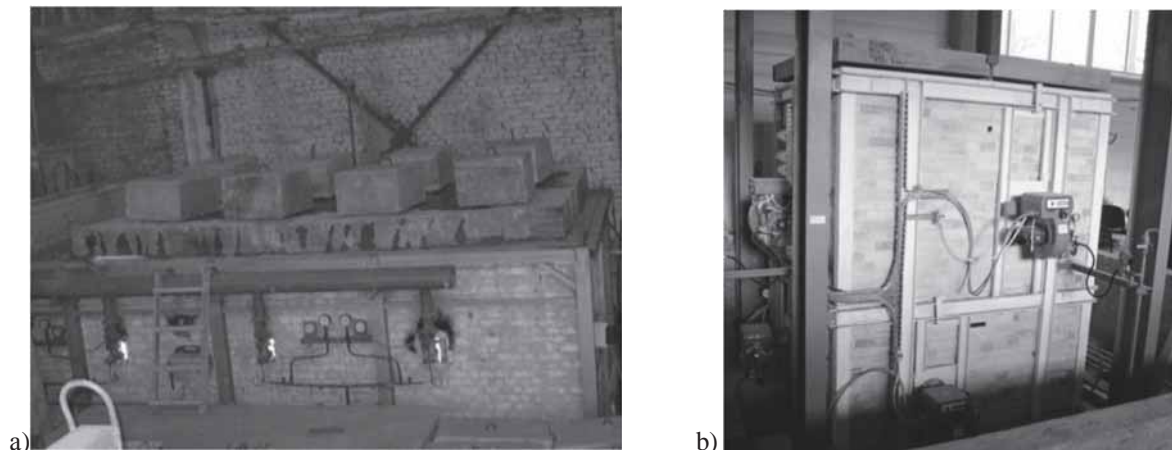


Fig. 8. a) Fire furnaces in the "POZHTEST" laboratory, Kyiv; b) Fire furnace at NVC "Eurostandart", village Cherlyany, Lviv region

Fig. 9 shows the furnace that is patented by authors of this article for fire tests of building structures and thermal testing of materials, which is a box that consists of walls 1 and removable partitions 2. The holes 3 are made in the longitudinal walls 1 for fuel systems and holes 4 for instrumentation, transverse walls 1 have got viewing window 5. The bottom 6 has holes 7 for ventilation, embedded parts 8. On both sides of the furnace are power rails 9, in which the lower ends of the bands 7 are fixed in the desired position and between their upper ends the beam 8 is rigidly fixed.

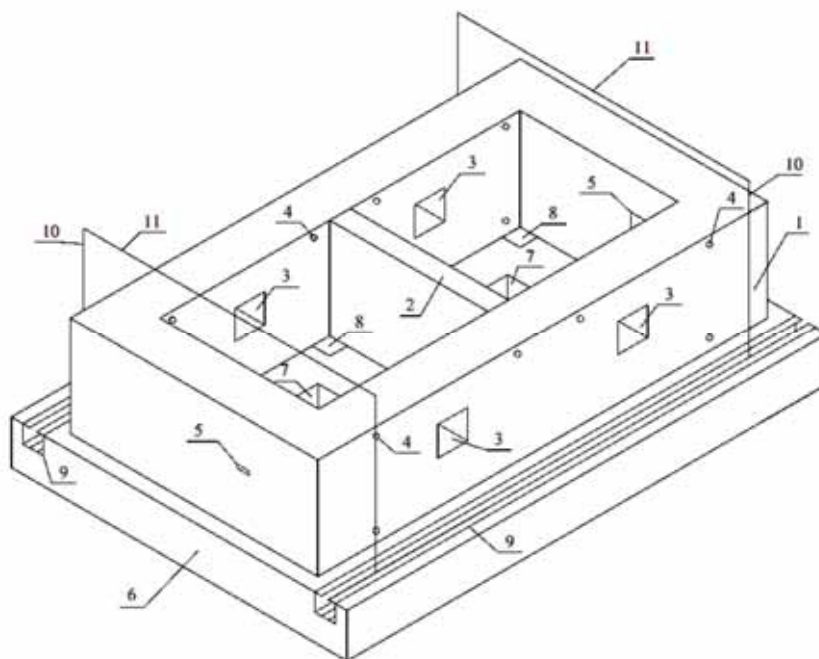


Fig. 9. The construction of the fire furnace for the fire testing of models of frame-wall buildings

Here is a description of the furnace work. The building construction under testing is mounted on the furnace construction to embedded parts 8. Horizontal plate elements building construction under testing are furnace top. The burners are mounting in holes for fuel equipment 3, which are made in the longitudinal walls 1. These burners create the temperature regime in the furnace volume. The products of combustion are discharged from the fire chamber of the furnace through holes for ventilation 7. The process of combustion and external changes of the sample can be observed through the viewing window 5. In the bottom 6 on both sides of the furnace are power rails 9, in which the lower ends of the bands 7 are fixed in the desired position and between their upper ends the beam 8 is rigidly fixed, which are used to create the mechanical load on the studied building construction, if it is necessary. During a joint action of mechanical load and thermal impact several changes of physical parameters of the sample through holes for instrumentation measurement 5 is recorded, such as strain, temperature, deformation and development of cracks, the pressure in the furnace, spread of fire and so on. To study the indirect effects of fire in the furnace is setting partition 2 and temperature load is created in only one combustion chamber.

The design of the furnace provides the opportunity to explore the fragments continuous building constructions or models of constructive systems including the indirect effects of fire. This allows testing in accordance with the actual conditions of building operation and increasing the reliability of models of physical processes.

1. *Protection against fire. Building construction. Test methods for fire resistance. General requirements.: DSTU B V.1.1-4-98 – [Effective since 28.10.1998]. – Kyiv: State Building, 2007. – 21 p. – (National Standard of Ukraine).* 2. *Fire-resistance tests. Elements of building construction. Part 1: General requirements.: ISO 834-1:1999 - [Effective since 28.10.1998]. –Switzerland: International organization for Standardization, 1999. – 25 p. – (International standard).* 3. *Building constructions. Test methods for fire resistance. General requirements.: GOST 30247.0-94 - [Effective since 23.03.1995]. – Moscow: MNTKS, 1994. – 11 p. – (National Standard of Russia).* 4. *Beams. Method of test for fire resistance.: DSTU B V.1.1-13:2007 – [Effective since 22.06.2007]. - Kyiv: Ukraine Ministry of Regional Development, 2007. –15 p. – (National Standard of Ukraine).* 5. *Fire retardant coatings for building bearing metal. Method of determining the fire retardant ability.: DSTU B V.1.1-13:2007 – [Effective since 22.06.2007]. - Kyiv: Ukraine Ministry of Regional Development, 2007. –60 p. – (National Standard of Ukraine).* 6. *Floors and covers. Method of test for fire resistance.: DSTU B V.1.1-20:2007 – [Effective since 26.10.2007]. - Kyiv: Ukraine Ministry of Regional Development, 2007. –14 p. – (National Standard of Ukraine).* 7. *Columns. Method of test for fire resistance.: DSTU B V.1.1-14:2007 – [Effective since 22.06.2007]. - Kyiv: Ukraine Ministry of Regional Development, 2007. – 8 p. – (National Standard of Ukraine).* 8. *J. R. Lawson A History of Fire Testing / J. Randall Lawson. – Gaithersburg : U.S. Department of Commerce, 2009. – 41 p.* 9. *Lin T. D. Building Fire Safety, Structural Fire Tests, and Performance Based Codes / T. D. Lin // Fire Science and Technology Vol.25. – 2006. - №2. – p. 133-146.* 10. *Rina test laboratory [electronic resource]: Laboratory brochure – Mode of access: http://lab.rina.org/_files/brochure_rinalab_EN.pdf.* 11. *Fire testing technology [electronic resource]: Horizontal Fire Resistance Test Furnace – Mode of access: <http://www.fire-testing.com/horizontal-test>.* 12. *Southwest Research Institute [electronic resource]: Fire Resistance Testing Flyer – Mode of access: <http://www.swri.org/3pubs/brochure/d01/FireRes/FireResTestFlyer.pdf>.* 13. *NGC Testing Services [electronic resource]: Facilities and Equipment – Mode of access: <http://www.ngctestingservices.com/fire.html>.* 14. *Grifitlab [electronic resource]: Fire testing laboratory – Mode of access: http://gryfitlab.pl/FIRE_TESTING_LABORATORY.html№!prettyPhoto[pp_gal]/7/.* 15. *Fire resistance tests on concrete columns / João Paulo C. Rodrigues, Cristina C. dos Santos & Tiago A. Pires // International Conference on Experimental Mechanics – 2012. - №15 – 12 p.* 16. *Applus laboratories [electronic resource]: New 15m² furnace for fire resistance testing – Mode of access: http://www.appluslaboratories.com/en/new/New_15m2_furnace_for_fire_resistance_testing-1340215032489.* 17. *Fire test equipment [electronic resource]: Fire Resistance Furnacesg – Mode of access:<http://www.fire-eu.com/article/135.html>.* 18. *Linus Lim Experimental Fire Tests of Two-WayConcrete Slabs / L. Lim, C. Wade. - Porirua City, New Zealand., 2002 – 95 p.* 19. *Forum on fire safety in Asia [electronic resource]: Laboratory units – Mode of access: http://www.tus-fire.com/?page_id=120.* 20. *Pat. 49549 UA MPK (2009) F23M 5/00 Furnace for thermal and physical investigations of small-scale building constructions and their separate joints [text] / Demchyna B.G., Polovko A.P., Fitysk V.S., Peleh A.B., Demchyna H.B.; applicant National University "Lviv Polytechnic". – № u200912903; application 14.12.2009; published 26.04.2010; bulletin № 8, 2010.*