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S.S. Bula, R.O. Boiko
Lviv Polytechnic National University
Department of Building Constructions and Bridges

HISTORY AND FUTURE OF FULL-SCALE FIRE TESTS

The given article concerns the analysis of full-scale fire-tests existing in Ukraine and abroad. Development trends in full-scale fire tests are considered in the article.

Key words: full-scale fire tests, trends.

Проведено аналіз натурних вогневих випробувань як в Україні, так і за кордоном. Наведено тенденції розвитку даного методу випробувань.

Ключові слова: повномасштабні вогневі випробовування, тенденції розвитку.

Introduction

Nowadays, much attention is paid, both in Ukraine and abroad, to the research of methods aimed at determination of fire resistance. One of the major directions of the given research consists in comprising joint work of particular constructions of a building, that is, studies of the overall construction system and not its particular constructions. An important research method in the given direction is full scale fire tests of buildings or its parts.

Analysis of the Current State of the Issue

Determination of fire resistance of buildings and structures by fire tests is a complex and ambivalent issue. However, the complexity of modern technical solutions and constructive systems makes the use of the given method necessary. In this case, the use of results determining fire resistance of particular constructions for estimation of fire resistance of the whole building is not correct and, in some cases, absolutely impossible. The analysis of fires of recent years (Table 1) illustrates the gravity of consequences of fires occurring in modern multistory residential, public and industrial buildings.

Table 1

Fires in multistory buildings [1,2]

Name of the building, its purpose and number of floors	Location and date of the fire	Design system, materials and fire protection of buildings	Destructions
1	2	3	4
One New York Plaza, office, 50	New York, USA August 5, 1970	Steel framing with reinforced concrete core, fire resistive with no sprinklers.	Connection bolts sheared during fire, causing several steel filler beams on the 33-34thfloors to fall and rest on the bottom flanges of their supporting girders
Andraus Building, office, 31	Sao Paulo, Brazil February, 24 1972	Reinforced concrete	Spalling of exterior walls, joists, and columns, exposing reinforcing.
Hotel “Vendome”, residential, 5-6	Boston, USA June 17, 1972	Masonry with cast iron	All five floors of a 40 by 45 ft section collapsed
Military Personnel Record Center, office, 6	Overland, USA July 12, 1973	einforced concrete, without expansion joints, no sprinklers above 2nd floor	Roof and supporting columns partially collapsed 12 hours after fire began
Joelma Building, office, 25	Sao Paulo, Brazil February 1, 1974	Reinforced Concrete	Spalling of exterior walls

1	2	3	4
Katrantzos Sport Department Store, commercial, 8	Athens, Greece December 19, 1980	Reinforced concrete	Partial collapses of 5-8th floor, together with various other elements, during a 2-3 hour fire
Alexis Nihon Plaza, office, 15	Montreal, Canada October 26, 1986	Steelframe with composite steel beam and deck floors; fire resistive without sprinklers	Partial 11th floor collapse
CESP, office, 21	Sao Paulo, Brazil May 21, 1987	Reinforcedconcrete frame, with ribbed slabs; no sprinklers	Partial, full height interior core collapse
First Interstate Bank, office, 62	Los Angeles, CA, USA May 4, 1988	Steel frame with composite steel beam and deck floors; fire resistive; sprinklers not operational	Fire lasted for about 3.5 hours, causing major damage to four floors
Broadgate Phase 8, office, 14	London, UK 1990	Steel composite trusses and beams; mostly not fire protected and without sprinklers	During construction, 4.5 hour fire duration and temperatures reached 1000 ºC
Mercantile Credit Insurance Building, office, 12	Churchill Plaza Basinhstouk, UK 1991	Steel frame with composite floor beams; fire resistive, but no sprinklers	Fire burnout of 8th to10th floors
One Meridian Plaza, office, 38	Philadelphia, USA 23-24 February 1991	Steel frame with composite steel beam and deck floors; fire resistive, but sprinklers not operational	Started Saturday and burned for a total of 18 hours, causing significant structural damage to 9 floors
Central Square Apt. Massachusetts Ave. and Douglas St., residential, 8	Cambridge, USA October 1, 1993	Brick	Collapse of several floors
Apartments, Brooke Ave and 138th St., residential, 8	Bronx, New York, USA April 5, 1994	Brick	Rear of the building collapsed.
Coeur de Royale Condominium, residential, 4	Creve Coeur, USA August 25, 1994	Unknown	Partial collapses of roofs
Effingham Plaza Nursing Home, residential	Portsmouth, USA April 6, 1998	Unknown	Roof collapsed in places
Commercial complex, commercial, 4	Newton, USA February 9, 2000	Brick/masonry	Collapse started at upper story and progressed
Apartment in Vandergrift, residential, 6	Pittsburgh, USA May 7, 2000	Wood	Back wall fell, initiating progressive collapse
Textile Factory, commercial, 6	Alexandria, Egypt July 21, 2000	Reinforced Concrete, no sprinklers	Total
Faces Nightclub and Memories Lounge Bar, commercial residential, 4	Motherwell, Lanarkshire, UK February 27, 2001	Unknown	Total
WTC 7, office, 47	New York, USA November 11, 2001	Steel moment frame with composite steel beam and deck floors; fire resistive with sprinklers	Total
WTC 2, office, 110	New York, USA November 11, 2001	Structural steel tube lateral system with composite floor truss system; fire resistive with retrofitted sprinklers	Total

1	2	3	4
WTC 1, office, 110	New York, USA November 11, 2001	Structural steel tube lateral system with composite floor truss system; fire resistive with retrofitted sprinklers	Total
WTC 5, office, 9	New York, USA November 11, 2001	Steel moment frame with composite steel beam and deck floors; fire resistive with sprinklers	Partial collapse of 4 stories and 2 bays
Pentagon, office, 5	Washington, DC, USA November 11, 2001	Reinforced Concrete	Partial collapses of floors and other elements
Jackson Street Apartments, residential, 21	Hamilton, Ontario, Canada February 8, 2002	Concrete	Partial collapse of concrete floor-ceilings
Apartment block, residential, 19	St. Petersburg, Russia June 3, 2002	Concrete	Total
Santana Row, Bldgs., commercial\ residential, 5	San Jose, California, USA August 19, 2002	Wood frame, still under construction, fire protection and sprinklers not completed/functional	Total collapse and destruction
Parque Central, office, 50	Caracas, Venezuela October 18, 2004	Unknown	Burned 20 upper floors of the building
National Bank, office, 45	Chicago, USA December 7, 2004	Unknown	Slight damage
Vinzdor, office, 32	Madrid, Spain February 2005	Reinforced concrete building with a stiffness core	Partly destroyed
Altitude 220 m	Madrid, Spain September 5, 2006	During the construction fire ignites on floors 42-43	Slight damage
Deutsche Bank, office, 40	USA August 19, 2007	Unknown	Unknown
Residential House, 34	New York, USA February 9, 2008	Unknown	Unknown
House of China Central Television, office, 54	Peking, China February 9, 2009	Metal frame	Burned 80% of the building
50 storey residential building	Nanjing, China April 19, 2009	Unknown	Significant damage to the entire building
52 storey skyscraper	Abu Dhabi, UAE October 19, 2009	Unknown	Slight damage
Hotel "Ukraine" residential	Moscow, Russia November 14, 2010	Unknown	A fire ignites in an apartment on the 29th floor in the fireplace hood
Residential, 28	Jinan, China November 15, 2010	Was on repair	Significant damage to the entire building
Hotel "Dynasty Wanxin", residential	Shenyang, China February 3, 2011	Unknown	Damaged façade of 2 towers in hotel complex
Tower "Vostok" commercial residential, 93	Moscow, Russia April 2, 2012	Reinforced concrete frame building	Fire was on floors 66-67 during the construction of the building
Tamweel Tower, residential, 40	Dubai, UAE November 18, 2012	Reinforced concrete	Significantly damaged 10 apartments and frontage
Triumph Palace, residential, 50	Moscow, Russia January 25, 2013	Reinforced concrete frame building	-
Grozny City, residential, 42	Grozny, Russia April 3, 2013	Reinforced concrete frame building	Completely burnt facade of the building

At present, the normative document regulating the performance of fire tests on buildings or its parts in Ukraine is DSTU B.V.1.1 – 18:2007 entitled "Structures and Parts of Buildings. The Method of Full Scale Fire Tests. General Requirements." [3] This document establishes general requirements to the method of fire test on building objects or their parts by temperature regime approximating the standard one.

According to the above document the following basic principles concerning tests performance are distinguished. A real building object is used for tests and it must conform to the project documentation. In case if it is impossible to test a real building object due to technical and economic reasons, it is allowed to use part of a building to be constructed taking into account requirements of this standard. To create a fire load a simulated fire is used, the burning of which provides the temperature regime approximating the standard one.

The construction of building part must meet the following requirements: to have no less than three floors in case of multistory building objects; the volume-project solution must be made basing on the project documentation for the building; according to the project documentation the bearing and enclosing constructions must have the lowest fire resistance among similar constructions; static loads on the bearing constructions of building part must be equivalent to static loads on the real building; construction solutions of connections must conform with those accepted in the project documentation for the building; the place where the simulated fire is to be located must be enclosed according to the project solutions of the building.

Similar normative documents exist in other countries: NPB 233-96 "Buildings and Parts of Buildings. Method of Full Scale Fire Tests. General Requirements." [4] (Russia), BS 476-32:1989 "Fire Tests on Building Materials and Structures. Guide to Full Scale Fire Tests Within Buildings" [5] (Great Britain), ASTM E119 – "Standard Test Methods for Fire Tests of Building Constructions and Materials" [7], "Methods for Fire Tests on Building Materials, Components and Structures" [8] (Australia), EN 1363-1:2012 "Fire Resistance Tests. General Requirements." [9] (EU countries), etc.

Statement of the Problem

For a successful full scale fire testing to be carried out it is necessary to analyze the already existing performed tests and to understand the development trends of the given tests.

Statement of the Main Principles

The main principles concerning studies of fire testing started to be developed in the late 19th century. The first method of fire tests was adopted at the conference held by the International Organization for Fire Protection in 1903. In the former USSR fire tests on building constructions was carried out in 1936 on the basis of methodological approaches developed by VNIIPO MVD and other organizations. The major tests are quoted in Table 2.

Table 2

Full Scale Tests in the Former Soviet Union [10,11]

Place and year of test	Type of building	Design scheme of the building	Destruction
1	2	3	4
Moscow, 1959	Series P-32, 5 floors	With transverse bearing walls	Local
Moscow, 1960	Series K-7-2-4 with cluster panels, 5 floors	With beam-walls	Local, general
Leningrad, 1962	Series E-1-58 (E-32-60) with the cluster and ribbed panels, 5 floors	With longitudinal bearing walls	Local
Krasnodar, 1962	With monolithic expanded clay lightweight concrete volume elements 5 floors	With transverse bearing walls	No damage
Minsk, 1963	Series 1-OPB-5-60 monolithic concrete block-box, 5 floors	With monolithic volume blocks	Local
Kyiv, 1965	With monolithic expanded clay lightweight concrete block-rooms, 5 floors	With monolithic blocks of bulk-type cap	Local, general
Kyiv, 1967	Series BC-3 with monolithic block-rooms, 5 floors	With monolithic blocks of bulk-type cap	Local
Minsk, 1970	Series 30PB-108 with monolithic blocks, 9 floors	With monolithic blocks of bulk-type cap	Local
Caucasus, 1988	Two store fragment of 5-storey residential building with blocks of heavy concrete	With monolithic blocks of landfill volume manufacturing	Local

Table 1 shows that fire tests in the former Soviet Union were mostly conducted on large block buildings due to general development trends of the building industry at that time.

The first fire tests targeted the floor systems of the building and the effects of fire on it [12]. The given tests were performed in Denver in 1890. In 1894 the first stations for fire testing of building constructions and materials were set up in the USA.

Two methods are distinguished in fire testing, namely: small scale and full scale methods.

The development of construction solutions of that time allowed performing tests of small construction elements. The following fire tests were based on tests conducted in special furnaces at standard fire regime.

In the 1980s, the main objections to fire testing in furnaces using standard fire regime were the following:

– the standard fire curve does not reflect a real fire in a real building, conversely, it contradicts physical and fire dynamic laws;

– loads and fixing of constructions during furnace testing do not reflect real work conditions of constructions in the building;

– fire tests are performed on particular constructions of diminished size (scale factor);

– as a rule, fire exposure occurs only on one side (except for columns and beams);

– tests are over before the construction is destroyed (as a rule, before the norm fire resistance is reached or before the loss of insulating ability and construction rigidity);

– a small number of data and measurements to understand the work of the construction system.

Therefore, full scale fire testing simulating real fires has been developing in Europe and the USA since then. The main performed tests are quoted in Table 3.

Several trends are distinguished in the development of full scale fire testing:

– improvement of fire protection system in buildings;

– performance of fire testing on buildings with the design load;

– reduction of size scale of tested objects which provides true results for full scale buildings;

– studies of development dynamics of real fires in real buildings.

Table 3

Full Scale Tests across the World [13-15]

Place and year of test (organization)	Type of building	The test results
1	2	3
1976 (Pettersson)	Unknown	Time-temperature curves of gas in different fire compartments
1977 (Wittveen)	Rigid and non-rigid metal frame	Stability of rigid and non-rigid frames in case of high temperatures
USA, 1980	Hangar for large aircraft such as Boeing 707	The investigation of fire dynamic in case of aircraft fires
USA, 1982 (AISI / NBS)	Two storey, four bay steel frame with concrete slab (9.75 × 12.2m), fire exposure using a ASTM E119 furnace curve.	Validated the computer modeling program, FASBUS
Germany, 1985, (Stuttgart-Vaihingen Univ.)	Water and concrete-filled columns with composite steel concrete construction, fire exposure using timber cribs.	Demonstrated the performance-based refurbishment of building post fire
1985 (Latham)	Unknown	Time-temperature curves for unprotected steel structures
1986 (Anon)	Unknown	The behavior of steel and composite structures under fire
1987 (Cooke and Latham)	A steel frame was fully loaded, fire exposure using timber cribs.	The investigation of the behavior of whole the building

1	2	3
Australia, 1992 (BHP)	Steel concrete composite frame (4 × 4 m compartment), fire exposure using office furniture.	Demonstrated use of sprinkler system to prevent collapse, suggested fire protection was not necessary for underside of composite slab.
Australia, 1994 (BHP)	Steel concrete composite frame (8.4 × 3.6 m), fire exposure using office furniture.	Test argued no fire protection for beams and external steel columns were necessary.
Cardington, UK, 1996, (British Steel and BRE)	Steel concrete composite frame. Test 1 of restrained floor beam assembly (9 m), fire exposure using a purpose built gas furnace.	Test observed tensile failure of connections during cooling.
Cardington, UK, 1996, (British Steel and BRE)	Steel concrete composite building, Test 2 of long pane frame (21 m), fire exposure using a purpose built gas furnace.	Non protected column portions buckled locally, shear failure of bolts in cooling.
Cardington, UK, 1996, (British Steel and BRE)	Steel concrete composite building, Test 3 of floor compartment (9 × 6 m), fire exposure using timber cribs.	Test observed membrane actions and load path changes, structure behaved ‘well’.
Cardington, UK, 1996, (British Steel and BRE)	Steel concrete composite building, Test 4 of floor compartment (9 × 6 m), fire exposure using timber cribs.	Test observed interaction between exposed and non-exposed structure.
Cardington, UK, 1996, (British Steel and BRE)	Steel concrete composite building, Test 5 of large compartment (18 × 21 m), fire exposure using timber cribs, though not as severe as tests 3 and 4.	Test observed connection failures in cooling.
Cardington, UK, 1996, (British Steel and BRE)	Steel concrete composite building, Test 6 of floor compartment (162 m^2 not square), fire exposure using office furniture.	Cracking around columns developed during cooling.
Japan, 1996 (Building Research Institute of Japan)	Three storey wood frame building with height of 12.7 m	The research of fire dynamic in the building and its influance on neighboring buildings
France, 1998 (CTICM)	Car park building, unprotected composite steel concrete frame (16 × 32 m), fire exposure using 3 cars, beams reached a temperature of 700ºC with no collapse.	Tests highlighted beneficial membrane actions.
Cardington, UK, 1999, (BRE)	Timber frame building, compartment fire (24.1 × 12.4 m). fire exposure using timber cribs	Global behavior assessed as well. Some worries over potential for fire spread in adjoining compartments and vertically through the windows.
Cardington, UK, 2001, (BRE)	Concrete frame building, Compartment floor fire (2 × 2 bays, 225 m^2), fire exposure using timber cribs.	Compartment failed and most instrumentation lost, beneficial membrane action demonstrated in building, spalling observed.
Cardington, UK, 2003, (BRE)	Eight hollow core concrete frame building tests (12 × 12 m), fire exposure using timber/plastic cribs.	Tests studied fire dynamics of growth, burning, and cooling stages of fire studying effect of Insulation, openings, and fuel load.
Cardington, UK, 2003, (Czech Technical University)	Steel concrete composite building, of large compartment (11 × 7 m), fire exposure using timber cribs, loaded to 56% of its ambient temperature capacity	Cracking occurred at column heads, sustained greater deflections than earlier tests.
Ostrava, Czech Republic, 2006 (CTU)	Steel concrete composite building (3.8 × 6 m), fire exposure using timber cribs.	Only gas and steel temperature measured. No structural implications discussed.

1	2	3
Tsukuba, Japan, 2006 (Institute of Construction Engineering of Zurich)	Three storey wood building, size 6,935 × 6,935 m, fire load in the form of residential furniture and timber cribs	The research of fire dynamic in the building and caused damage
China, 2007 (Harbin Institute of Technology)	Steel concrete composite frame (2, 3.6 × 3.6 m bays), fire exposure using four oil fired burners.	Beam to column connections failed in cooling, tensile cracking of slabs observed near ends.
UK, 2007 (BRE)	Hollow core prestressed concrete slab building (18 × 7 m), fire exposure using timber cribs.	Test demonstrated that properly designed and detailed buildings would behave well in a fire, with some cooling phase fractures though
Mokrsko, Czech Republic, 2008 (CTU)	Steel concrete composite building (12× 18 m), mix of different components and structural systems, fire exposure using timber cribs.	Various localized failure modes were observed using a variation of instrumentation.
Metz, France, 2008 (FRACOF)	Steel concrete composite sub frame (8.8 × 6.7 m), corner compartment fire, fire exposure using gas furnace.	Insulation integrity failure due to improper mesh lapping, though system behaved well in heating and cooling
Metz, France, 2008 (CROSSFIRE)	Steel concrete composite sub frame (6.7 × 9 m), corner compartment fire, fire exposure using gas furnace.	No global collapse despite flexural failure of secondary beam, rated building achieved its standard fire rating time.
China, 2010 (Hong Kong Polytechnic University)	Reinforced concrete (7.8 × 4.8 m), fire exposure using ethanol pool fire	Spalling and associated protection of concrete columns emphasized from tests
Australia, 2010 (CCAA-CESARE)	Multi strand post tensioned slabs on high strength columns (6 × 5 m), fire exposure using timber cribs	Spalling primarily observed with some remedial design suggestions regarding polypropylene fibres.
UK, 2010 (University of Ulster)	Composite steel (cellular)-concrete building (15 × 9 m), fire exposure using timber cribs	Unprotected cellular beams demonstrated beneficial membrane action
Russia, 2011 (TSNYYSK)	Fragment of the facade of the two storey building	Research the spread of fire on the facade of the building
Munich, Germany, 2011 (TU)	Steel-concrete composite (5 × 12.5m), fire exposure using timber cribs	Unknown
Vienna, Austria, 2011 (TU)	Reinforced concrete frame abutment, fire exposure gas burners	Demonstrated benefits of polypropylene fibres to prevent spalling and give unusual structural shape data for model development.
Roorkie, India, 2011 (University of Edinburgh/ Indian Inst. of Tech.)	Reinforced concrete building (9 × 12 m), fire exposure using kerosene pool fire, frame was pre damaged to simulate fire after a earthquake without collapse	No spalling observed
Ottawa, Canada, 2011 (NRC)	Single reinforced concrete column, fire exposure using gas furnace, realistic transient support conditions were replicated using the Hybrid Fire Testing (HTF) approach	Test demonstrated the successful implementation of HTF
Veseli, Czech Republic, 2011 (CTU)	Steel-concrete composite (10.4 × 13.4 m), fire exposure using timber cribs	Uknown

Fire testing necessitates the existence of large fire testing centers which can provide quality performance of tests. The material and technical base of fire testing centers should be provided with: special measurement apparatus, means of application and measurement of force and temperature loads, stands for constructions of full scale building parts with modeling of connections and fixing, etc. The existence of such centers contributes to the development of studies of full scale fire testing. Table 4 provides a list of the major world research centers of fire resistance.

The development of full scale fire testing is held up by the economic situation, an imperfect normative base and a need for large financing of testing centers. Namely, the major testing centers in Ukraine are the “TEST” (Brovary town, Kyiv region) and NVC “Eurostandard” (Cherliany village, Lviv region), Limited Responsibility Company “POZHTEST” (Kyiv). However, no information about full scale fire tests conducted by them is available.

A number of fire tests in Ukraine have been conducted as part of research work of National University “Lviv Polytechnic” (Table 5).

A partial solution of the existing complex situation is carrying out fire tests on models of construction systems, which is a kind of compromise between small scale testing of particular constructions and full scale testing of building parts.

Such tests do not solve the situation in overall, but they provide a basis for trial of numerous methods and definition of their adequacy in respect to the real work of the construction system. Presently, this kind of tests is of scientific character [17-19], and notwithstanding scale factor uncertainties, it yields positive results.

Table 4

List of the Major Fire Testing Centers across the World [1]

Laboratories	Country
Underwriters Laboratories Inc, Armstrong World Industries, Southwest Research Institute, Factory Mutual Research Corporation, SGS/US Testing Laboratory – LA, Omega Point Laboratories, 3M Company, Carboline, US Forest Product Laboratory, Western Fire Center, US Gypsum – Research Facility, Guardian, NGL Testing Services, VTEC Labs, Commercial Testing, UC Berkley, Intertek – WI	USA
Underwriters Laboratories of Canada, National Research Council	Canada
DITUC, IDIEM	Chile
Intertek Testing – US & Canada	USA/Canada
INTI	Argentina
IPT	Brazil
REDCO, Univ. of Ghent	Belgium
SP	Sweden
Danish Institute of Fire Technology	Denmark
VTT	Finland
SINTEF	Norway
Institute for QC of Bldg	Hungary
Lorient, BRE, Warrington	UK
Warrington, Lorient, CSIRO	Australia
Tianjin Fire Research Institute, China Nat. Center for QC & Testing of Bldg, Sichuan Fire Research Institute	China
Architecture & Building Research Institute	Taiwan
PSB/SISIR	Singapore
SIRIM	Malaysia
CTICM, CSTB	France
Building Res. Institute, Res. Institute of Marine Engineering, Gen Building Res. Corp, Japan Testing Center for Building Const.	Japan
Fire Research Institute	Czech Republic
Univ. of Canterbury, BRANZ	New Zealand
BAM, MPA – Materialprufungsamt	Germany
TNO	Holland
Institute of Building Technology	Poland
ДОНСТРОЙТЕСТ, Лаборатория противопожарных исследований, сертификационных испытаний и экспертизы в строительстве, МГСУ, ПожСтандарт, НИЦ “Строительство”, ЦНИСК DONSTROYTEST, Fire research laboratory, testing and certification expertise in construction, MGRS, PozhStandart, SIC "Construction", TSNISK	Russia

Table 5

Full-scale fire testing in Ukraine [11, 16]

Place and year of test	Type of building	The test results
1	2	3
Vinnitsa, 1996 Demchyna B. G.	The five storey building with HOLDPLAN system, size 24,25 × 21 × 17,1 m, fire exposure using timber cribs	Study of closed volume blocks during the fire
Lviv, 2008 Shnal T. M.	Fragment of a panel building, size 7,3 × 7,5 × 7,5 m, fire exposure using timber cribs	Research of the general behavior of the building during a fire

Conclusions

Small scale fire tests aimed at determination of fire resistance of particular constructions have been used for many years, and they really provide for some safety, as in most cases a fire does not lead to the destruction of the building. This is due to the following factors: limited area of fire expansion, redistribution of forces over elements not exposed to fire, activation of fire protection measures, etc. But, notwithstanding a certain success in this trend, damages caused by fires still occur, and considering the dynamics of such fires (Table 1), they will occur in the future, as well.

Incidents of destruction of buildings in a fire prove that methods for determination of fire resistance of construction systems must be based on their real work. In this case, the data base of performed small scale tests will serve as a basis for further studies of real large scale constructions. Finally, these studies will become a basis for development and improvement of numerous methods for determination of fire resistance of different construction systems.

Adoption of the normative base conforming to Eurocodes, improvement of the economic situation, will, undoubtedly, contribute to resuming of full scale fire tests. Presently, however, attention should be focused on the development and improvement of numerous methods based on tests with models of construction systems and buildings.

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Ivo Demjan, Michal Tomko
Technical University of Košice
Civil Engineering Faculty
Institute of Structural Engineering

CALCULATION OF THE DYNAMIC RESPONSE OF REINFORCED CONCRETE STRUCTURES SUBJECTED TO THE FFECTS OF HEAVY TRANSPORT

A 3D model of a reinforced concrete building was created using a dynamic analysis which focused on the spectral response of the object represented by a random excitation experiment found in records in the form of load spectra.

Key words: experiment, spectral analysis, modeling.

Створено 3D модель залізобетонної будівлі з використанням динамічного аналізу, спрямованого на спектральну характеристику об’єкта через запис випадкових збурень у вигляді змінних навантажень.

Ключові слова: експеримент, спектральний аналіз, моделювання.

Introduction

In order to create a model of a building structure for dynamic analysis, it is necessary to specify the analysis model in terms of dynamic properties of the object as the same methods cannot be consistently applied to the substructure as those used in the structural analysis of the superstructure. When conducting a diagnosis of the current condition of the structure, the stiffness of the whole support system is generally unknown, but by experimental analysis of natural frequencies, it can be re-expressed in terms of computational model debugging and confirmed numerically.

The conciseness of computational models should be verified based on experimental investigations of the structure. Verification is made possible by comparing measured and computational model characteristics. The model may be optimized by the results of the diagnostic methods (experimental model analysis). Experimentally determined model characteristics describe the current status, properties and spatial behaviour of the structure, respectively certain elements of the structure at the time of experimentation. Such a model facilitates the calculation of the response of time courses of tested specimens to dynamic effects.