ON HIGHER CIVIL ENGINEERING EDUCATION IN RUSSIA: A CASE OF A MASTER'S DEGREE ON STRUCTURE RELIABILITY & SAFETY

V. I. ANDREEV, O. V. MKRTYCHEV and G. A. DZHINCHVELASHVILI
Department of Strength of Materials, Moscow State University of Civil Engineering,
26, Yaroslavskoye Shosse, Moscow, 129337, Russia
e-mail: asv@mgsu.ru

EXTENDED ABSTRACT

Transition to the tiered system of education in Russia poses a workload problem for teachers, as it is associated with an increase in the number of master's programs related to the modern problems in construction. One of such problems is the safety and reliability of design of buildings in emergency situations, either man-made or natural. These problems are particularly relevant, considering the recent devastating earthquakes, tsunamis, numerous acts of terrorism, fires and other emergency situations. Moscow State University of Civil Engineering has developed a master's degree program on the subject of the "Reliability and safety of building constructions", aimed at training of experts in the analysis, in computational and experimental modeling, as well as in the development of building codes and standards for design and construction in special circumstances.

The developed master's program meets Federal State educational standard of Master in the field of "Construction", approved by the Ministry of Education and Science of the Russian Federation. The structure of the standard stipulates a percentage of about 30% of compulsory subjects (18 - 20 credits) for all master's programs in this field. The remainder, i.e. about 70% (40 - 42 credits), of the program consists of special courses reflecting the content of training for each individual program. Finally, 60 credits are allocated for research work and state certification. This masters program is described in Section 1 of this article.

In preparation for Masters, 8 of 10 special disciplines are required, while 2 of 4 subjects are optional. Optional disciplines permit students to advance their knowledge in topics such as general mechanics as well as numerical and experimental methods for mechanics of deformable solids. In Sections 2 to 9, the article gives a summary of the following eight disciplines of the aforementioned master's program "Reliability and safety of building constructions", as they are taught in this particular program:

- reliability and safety of technical systems, man-made risk;
- theory of reliability of structures;
- theory of seismic stability of structures;
- fire and explosion safety of structures;
- loads and effects on buildings and structures;
- design codes in civil engineering;
- multifactor structural analysis;
- structural survey and research.

KEYWORDS

Civil engineering education, Reliability, Man-made risk, Construction codes, Testing facilities, Earthquake resistance

1. INTRODUCTION

Transition to the tiered system of education in Russia poses a workload problem for teachers, as it is associated with an increase in the number of master's programs related to the modern problems in construction. One of such problem is the safety and reliability of design of buildings in emergency situations, either man-made or natural. These problems are particularly relevant, considering the recent devastating earthquakes, tsunamis, numerous acts of terrorism, fires and other emergency situations. Moscow State University of Civil Engineering has developed a master's degree program on the subject of the "Reliability and safety of building constructions", aimed at training of experts in the analysis, in computational and experimental modeling, as well as in the development of building codes and standards for design and construction in special circumstances.

Table 1 presents the contents of the program for master's degree in the subject of "The reliability and safety of building constructions".

Table 1: Program content

№	Name of subjects	Labor input (Credits)
M.1.	**General scientific cycle**	**30**
1	Philosophical problems of science and technology	2
2	Methodology of scientific research	2
3	Mathematical modeling	3
4	Special sections of higher mathematics	3
5	Reliability and safety of technical systems, man-made risk	4
6	Theory of reliability of structures	4
7	Theory of seismic stability of structures	4
8	Fire and explosion safety of structures	4
	Optional disciplines	
9.1	Sustainability and dynamics of structures	4
9.2	Plasticity and creep theory	
M.2.	**Professional cycle**	**30**
10	Foundations of pedagogy and adult learning	2
11	Business language	2
12	Information technology in construction	2
13	Methods for solving scientific and technical problems in structures	4
14	Loads and effects on buildings and structures	4
15	Design codes in civil engineering	4
16	Multifactor structural analysis	4
17	Structural survey and research	4
	Optional disciplines	
18.1	Computer-Aided analysis in mechanics	4
18.2	Experimental structural mechanics	
M.3	**Practice and research**	**57**
	Research work and practice	19.5
	Master's thesis	37.5
M.4	**Final state certification**	**3**
	Total workload	**120**

2. RELIABILITY AND SAFETY OF TECHNICAL SYSTEMS, MAN-MADE RISK

The reality is that technospheric (technosphere - the environment altered by people) human development leads to a deterioration of the environment. Man began to destroy the Earth before developing the ideas of cherishing and protecting it. The recent gradual greening of economic activity, aimed at reducing anthropogenic impact on the environment, is a source of optimism. An important role in this process can be played by education in general and education on "life safety" in particular. In our opinion, it is necessary to form a new specialized scientific field of knowledge, called "Health and Safety in Technosphere". In essence, this is a new form of technology, technology of risk management, which considers and solves a wide range of related issues (technical, environmental, socio-economic, informational, political, etc.). This approach allows us to identify "weaknesses" in the existing or emerging technospheric systems, in order to further optimize safety measures and reduce the likelihood of natural and man-made emergencies.

The discipline "Reliability and safety of technical systems and man-made risk" explores reliability of technical systems and safety as an integral part of technological security. Definitions of the basic terms in reliability of technical systems are provided and the basic dangers of technical systems are identified, thus proving the urgency of the problem of safety from the point of view of its social and economic importance. Substantive provisions of the theory of reliability of technical systems and man-made risk are considered. The basic methods of increase of reliability and examples of use of the theory of reliability for an estimation of safety of human-machine systems are formulated. The methodology of the analysis and estimation of man-made risk is considered. The basic qualitative and quantitative methods of an estimation of risk, methodology of an estimation of reliability, safety and risk with use of logical and graphical analysis methods, criteria of comprehensible risk, principles of management of risk are stated, and examples of use of the concept of risk in engineering practice are considered.

3. THEORY OF RELIABILITY OF STRUCTURES

So far, almost no attention has been paid to the issue of appropriate duration of maintenance of buildings. The pyramids were built for eternity. The same can be said about medieval cathedrals, and probably about the palaces of the Renaissance. In contrast, operation of aircrafts is limited in time - about 30 thousand flight hours or approximately 10 years. By 1920, it became apparent that most of the buildings have a finite lifetime. It was clear that sanitation facilities, which were excellent in 1870, became bearly satisfactory by 1920. Sometimes it was easier to tear down the building and build a new one than to improve the technical equipment of the old building. Consequently, industrial buildings, office buildings and apartment houses have a limited service life and the existence of structural foundations of a building, which outlasted its purpose, loses its meaning.

As a rule, the practical life of the building, depending on the expected changes in the area it serves, can be from 50 up to 100 years. Only some monumental buildings can be designed for longer existence.

One very important factor of enhancing the reliability and durability of constructions is to improve the methodology of calculation of building constructions on the limit states. Probability theory and mathematical statistics are theories of mass phenomena, which describe the possibility of recurrence of a random event in similar conditions. Application of methods of mathematical statistics in the study of design and construction failures meets difficulties in the respect that repeatability of the separate reasons that caused failures, takes place in some cases (for example, crash damage from the cold brittleness of steel, the loss of stability of constructions, etc.). However, uniformity of conditions of failure repetition, as a rule, is absent.

Failures are individual and are caused by a combination of different reasons. The onset of an emergency condition should not be considered as a homogeneous mass event. Tests for durability of a material and checks of the size of the applied load can be repeated many times, and in certain cases — working conditions of construction as well, such as crane load and its impact on the crane structure. In general, the working conditions of construction can't be considered as mass events. It is also impossible to consider an advance in the construction of the limit state as mass event.

4. THEORY OF SEISMIC STABILITY OF STRUCTURES

The development of theory of seismic stability of constructions has become increasingly important in the last decade. Various phenomena can lead to earthquake-like events, such as activity of volcanoes, explosions, hulling of arches over karst areas etc. From the engineering point of view, the greatest interest represent earthquakes of a tectonic origin, i.e. associated with the accumulation of stress over large areas of the earth's crust.

Assessment of seismic resistance of buildings, taking into account the spatial fluctuations, is associated with significant design challenges due to the complex dynamic processes occurring in the building, which depend on numerous factors. To solve this problem, you must have a correct idea of the actual mechanical properties of the support structure and take into account the spatial work of buildings under static and dynamic loads and have enough information about the seismic influence impact.

Application of seismic protection is one of the promising trends in earthquake engineering. This trend has resulted in a number of constructive suggestions, some of which haven't passed the necessary theoretical and experimental verification. The theoretical justification of an active seismic protection of a building is currently an important area of research.

The analysis of consequences of strong earthquakes shows that fluctuations of both separate structure elements, and buildings as a whole occur simultaneously in several directions, i.e. these movements are spatial and non-stationary. Ground movement during an earthquake is also a complex multi-dimensional random process and therefore there is a problem of accounting for the spatial nature of the seismic influence.

The seismic stability theory or **the seismic stability analysis** is the earthquake engineering tool that breaks this complex subject into a number of subsections for the best understanding of the behavior of buildings and constructions under seismic loading.

The seismic stability theory is based on principles of dynamics of constructions and antiseismic design. Within the present decade, the *response spectra* method has been the most common method of **seismic stability analysis,** which is being developed at present.

However, *response spectra* are only good for systems with one degree of freedom. Using the step of integration of real or synthetic accelerograms is more effective method for systems with many degrees of freedom and with significant non-linearity in the transition process of kinematic excitation.

5. FIRE AND EXPLOSION SAFETY OF STRUCTURES

The construction setup design should provide arrangements for labor, fire and explosion safety during the construction and reconstruction of existing enterprises, as well as measures providing stability of structures saved.

When determining conformity of frame constructions with fire and explosion safety, the following shall be established:

- fire resistance limits and limits of fire spread to walls, partitions, floors, coatings, elevator shafts, as well as for doors and gates;
- foundations or foundation beams with fireproof walls in frameless buildings;
- fire protection of walls separating the outer walls of combustible or hardly flammable materials and going beyond the plane of the exterior walls, ledges and overhangs roofs at 30 cm;
- fire protection of walls separating the outer walls of profiled metal sheets or asbestos-cement panels with heat insulation from hardly flammable or combustible material or with glazed and not going beyond the outer plane of the wall;
- separation of the outer walls of profiled or asbestos-cement sheets with synthetic insulation from hardly flammable or combustible materials, as well as tape glazing fire walls;
- the amount of the total openings in fire barriers;
- sealing of gaps between MEP systems and fire barriers;
- diaphragms in air gaps between walls and facing of non-combustible materials, as well as in air gaps in wooden coatings and floorings;
- presence of (tambour-gateways, exterior removable frame constructions, their space requirements to the fire code standards, as well as fire resistance and fire spread limits for constructions of tambour-gateways.

6. LOADS AND EFFECTS ON BUILDINGS AND STRUCTURES

The only source of data about loading conditions is the design standards, which don't give any explanation, but seem reasonable because of frequent use. However, the regulations of different countries often provide enough guidance on the different selection of loads and while working on foreign orders, when these instructions have to be performed, a lot of new issues arise, which are related to the fact that the "usual" domestic rates don't align with overseas. And the fact of differences between domestic and foreign approach provokes desire to correct "their erroneous point of view", though very convincing arguments may be the basis for this discrepancy.

However, there are scientific monographs devoted to particular kinds of loads, for example wind, but most of them are designed more for the reader-researcher than for the practicing designer. In addition, such books often require specialized knowledge that is missing from the experts with the usual training in civil engineering. Fairly typical is representation of the problem of loads and influences in reference books. Appeared to be a popular handbook of theoretical designer, released in 1960 under the editorship of professor. A.A. Umansky, the section *"Standards of loads and sizes"* disappeared from the second edition of this handbook, published in 1973.

Dynamic loads were luckier, they were adequately presented in three volumes of a handbook, edited by B.G. Korenev and I.M., Rabinovich and A.F, Smirnov. A recent excellent study guide by V.N. Gordeev, *"Loads and influences on buildings and constructions"* was published in Moscow in 2007.

The proposed discipline will be the first attempt of a comprehensive coverage of the issue of loads and influences taken into account when designing buildings and constructions. Principal views of loads and influences are described, including emergency and special load type. For each of the considered loads the description of its physical origin is resulted, and the basic information on characteristic parameters of these loads are supplied. Data from domestic and foreign standard documents are provided and compared.

The purpose of this discipline is to acquaint the future civil engineer (designer) with the properties, methods, definitions and characteristics of interaction with the design loads and influences of various types.

7. DESIGN CODES IN CIVIL ENGINEERING

The proposed discipline is expected to consider the methodology of creating and writing design standards and their application in the design and construction of buildings and constructions. It will also contain a section describing the current state of norm-setting in different countries.

8. MULTIFACTOR STRUCTURAL ANALYSIS

Elastic calculation methods are applied in most cases when calculating the buildings and constructions on operating load. Special effects, including seismic and emergency (such as explosion, impact, etc.) usually cause tension in structures close to the limit, lead to large deformations and displacements, failure of separate elements. Therefore, the calculation must be based on physical, geometric and structural nonlinearities. It should also be noted that almost all the special effects are dynamic. In order to adequately reflect the work of the structures in the calculation of the special effects nonlinear dynamical calculation methods should be applied. First of all it concerns main buildings and facilities constructions: high-rise and wide-span.

9. STRUCTURAL SURVEY AND RESEARCH

The development of this discipline in Russia is very promising, because currently there are practically no specialists able to completely carry out examination and test individual elements of the buildings - slabs, floors, foundations, columns, crossbars.

A survey of building designs of buildings is usually made to find out their bearing ability by identification and testing calculations of designs.

A survey of construction of buildings is necessary under the following circumstances:

- it is planned to increase the load on the floor when the functional purpose of the premises is changed, or the characteristics of the equipment and production modernization are planned;
- it is planned to move partitions (premise re-planning);
- growth of deformations is detected (increase in a deflection of overlapping plates, cracks in wall panels, etc.) and there is no information about bearing ability of structures (it is also unknown under what loading the structure was designed);
- time has come to replace structures (rotten wooden floors in structures of historic building);
- if there is an increase of a building deformation (generally, this means crack formation in the walls), which indicates problems with the foundations;

- if building foundation lifetime is depleted (and foundation reinforcement is scheduled);
- if there are regular roof leaks, wall depressurization, wall blotting or wall freezing;
- if a survey of building engineering network is required in connection with their malfunction.

Technical survey of buildings and constructions is the process of determining (control) technical state of operated building or structure and its components.

Technical survey of buildings and constructions may include:

- instrumental acceptance survey of completed building or capitally repaired structures , as well as reconstructed buildings or constructions; instrumental survey of technical condition of buildings and engineering equipment for maintenance of buildings or constructions;
- technical survey of residential buildings for a planned overhaul, modernization or reconstruction;
- technical survey of buildings and constructions with structural damage and accidents during the operation.

The technical survey of buildings include:

- objectives definition;
- receiving of baseline data from the customer;
- general technical survey of buildings;
- detailed technical survey of buildings;
- preparation of technical conclusion.

The monitoring of correct work or normal functioning of engineering structure or its elements require knowledge of the actual technical state of a building. It always contains a diagnosis of structures. The aim of the full-scale surveys is to obtain reliable data on the technical state of building constructions and engineering systems and identify the reasons behind this situation. The materials from a survey of technical condition of the building help to conclude the conditions of further operation of building elements, the activities to ensure their reliability and durability or replacement.

The need for technical survey of buildings and structures occurs if there is:

- defect or structure damage (e.g., due to stress, corrosion, temperature or other influences, including non-uniform foundation subsidence), which can reduce the strength, deformation characteristics of structures and degrade total operational condition of the building;
- increased operating load or influence on the structure by remodeling, modernizing and increasing the number of building stores;
- reconstruction of buildings, even without increase in load;
- lack of project design and as-built documentation;
- change in building and structure functionality;
- resuming of the interrupted construction in the absence of preservation or after three years after the termination of construction with preservation;
- need to monitor and evaluate the technical state of buildings, located near the newly built structures;
- need to assess the technical state of building structures which were exposed to fire, natural disasters of natural origin or man-made accidents, etc.

REFERENCES

1. Fundamentals of building structures reliability. Curriculum for the discipline "Applied Mathematics". Moscow State University of Civil Engineering, 2011.
2. Statistical mechanics and the reliability theory. Curriculum for the discipline "Applied Mechanics". Moscow State University of Civil Engineering, 2011.