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ABOUT THE NATIONAL SOFTWARE SYSTEM FOR STRUCTURAL ANALYSIS

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Abstract: As is known, design solutions for the load-bearing systems of buildings and structures, as well as individual structural elements, are based on the results of a design analysis, which is usually performed by numerical methods using software systems. The same is true for structural analysis of construction objects at the stages of construction, operation, reconstruction. The distinctive paper is devoted to the current task of developing the Russian national software system for adequate determination of loads and impacts, stress-strain state, strength, stability, reliability and safety of buildings, structures and complexes at significant stages of their life cycle.

Keywords: national software system, structural analysis, finite element analysis, buildings and structures, stress-strain state, strength, stability

О НАЦИОНАЛЬНОМ ВЫЧИСЛИТЕЛЬНОМ КОМПЛЕКСЕ ДЛЯ СТРОИТЕЛЬНОЙ ОТРАСЛИ

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Аннотация: Проектные решения несущих систем зданий и сооружений, а также отдельных конструктивных элементов базируются на результатах проектного анализа, который выполняется, как правило, численными методами с применением вычислительных комплексов. То же справедливо и для расчетного обоснования объектов строительства на стадиях строительства, эксплуатации, реконструкции. Настоящая статья посвящена актуальнейшей задаче разработки российского национального вычислительного комплекса (НВК) для адекватного определения нагрузок и воздействий, напряженно-деформированного состояния, оценки прочности, устойчивости, надежности и безопасности зданий, сооружений и комплексов на значимых этапах их жизненного цикла.

Ключевые слова: национальный вычислительный комплекс, расчеты строительных конструкций, здания и сооружения, напряженно-деформированное состояние, прочность, устойчивость

Currently, the following specialized (problem-oriented) software systems are used in the Russian Federation for analysis the strength, stability and deformability of building systems and foundations, which to some extent implement the requirements of the current Russian design codes: LIRA-SAPR, LIRA-SOFT, SCAD-SOFT, MICRO-FE, Stark ES, PLAXIS [1-3].

In some cases, more powerful software systems are also used (ANSYS, NASTRAN, SIMULIA Abaqus, etc.). These software systems, as a rule, are not used in the practice of mass design, but are used for the purposes of scientific research, for example, within the framework of scientific and technical support for the design and construction of unique and especially critical facilities (buildings, structures, complexes).

All the main modules of these software systems (first of all – solvers) are developed outside the Russian Federation. At the same time, formally majority of above mentioned software systems (LIRA-SAPR, LIRA-SOFT, SCAD-SOFT, MICRO-FE, Stark ES) are distributed (with copyright) by legal entities registered in the Russian Federation. However, due to historical reasons, the actual developers of LIRA-SAPR, LIRA-SOFT and SCAD-SOFT are deployed in Kyiv (Ukraine). Besides, MICRO-FE and Stark ES are based on solvers developed by Germany. The PLAXIS geotechnical software system was developed at the Delft University of Technology (Netherlands).

The most important (from the point of view of the functioning of the construction industry) foreign software systems are discussed below.

SIMULIA Abaqus software system is widely used for computational justification of complex load-bearing systems, assemblies and structures. It is the main one in the line of the International Atomic Energy Agency (IAEA), where the calculation justifications of structures of nuclear power plants (NPP) made using this software system are accepted. Within the framework of sanctions analysis performed in the updated version of the software system, which will be banned, can be required.

PLAXIS is the main software system for computational research and computational justification in the direction of geotechnics. It is widely used in the design of civil and industrial facilities, transport infrastructure facilities. The IAEA also requires the use of this software system to justify design solutions for bases and foundations for nuclear power plants. This software system can be used without upgrade option. Within the framework of sanctions analysis performed in the updated version of the software system, which will be banned, can be required.

Tekla is the main software system the computational justification of steel structures and load-bearing systems. It is widely used in the design of industrial buildings and technological complexes (petrochemistry). This software system can be used without upgrade option. For individual objects, requirements for computational justification may be established in the updated version of the complex, which will be banned.

LIRA-SAPR, *LIRA-SOFT*, *SCAD-SOFT* and *MICRO-FE* are the main professionally oriented software systems with advanced post-processors that take into account the provisions of design codes of the Russian Federation. These software systems can be used without the possibility of updating.

ANSYS is the main software system for analysis of construction (building) aerodynamics. This software system can be used without upgrade option.

NASTRAN software system is normally used for research purposes with minimal use in industrial purposes. This software system can also be used without upgrade option.

Practice shows that in recent years sanctions instruments have been actively used in international relations, which in some cases can lead to significant delays in industrial processes, and in some cases, to the inability to perform certain procedures. Thus, several years ago, in the sanctions regime, access to updates of the PLAXIS software system was closed for some time, which led to delays in the performance of computational studies and the impossibility of performing individual computational procedures.

Due to the fact that the most important modules (solvers) of problem-oriented software systems are de facto developed outside the Russian Federation, there is a risk that they will fall under sanctions. The situation with the denial of access (in the case of sanctions) to a single or several simultaneously problem-oriented software systems for analysis of building systems and foundations can lead to blocking of the most important component of the construction process – the analysis of design solutions for construction objects.

In addition, the mentioned building-oriented software systems have a number of limitations that can be explained 10-20 years ago, but which constrain the construction industry today: a relatively poor set of finite element types, a selective and small set of types of nonlinearities (physical, geometric, structural, geometric), weak implementation of modern dynamic algorithms, etc.

We believe it is expedient to consider in a short time the issue of developing a national problem-oriented software system for adequate determination of loads and impacts, stress-strain state, strength, stability, reliability and safety of buildings, structures and complexes at significant stages of their life cycle. It will be vital to ensure state ownership of such national problem-oriented software system.

The development of a national software system can be carried out on the basis of the National Research Moscow State University of Civil Engineering (MGSU) in collaboration with Universities that are members of the Industry Consortium "Construction and Architecture" (established in 2021) and partner companies with successful experience in development and verification in related industries (organizations with all the necessary competencies and highly professional specialists). The international practice of developing problem-oriented software systems shows the validity and effectiveness of using the potential of leading universities for such work.

Stages of development of the national software system are described below.

The first stage includes development and approval of the concept and architecture of the national software system, development of Terms of Reference. In particular it includes the following items:

– analysis of the problem-oriented software systems of the construction profile; formation of goals and objectives for the development of the national software system;

– development and approval of the concept and architecture of the national software system;

– development and approval of the Terms of Reference for the development of the national software system.

The second stage includes the development of the basic version of the national software system for the analysis of construction objects (so-called, "Engineering level"). In particular it includes the following items:

– development of a basic library of finite elements;

– development of basic models of physical, geometric, structural and genetic non-linearities;

– development of basic effective (direct sparse and iterative with preconditioners) "solvers" of systems of linear algebraic equations (SLAE);

– development of "solvers" of the partial eigenvalue problem;

– development of methods for solving problems of explicit and implicit schemes for direct integration of dynamic equations, including seismic analysis (for earthquake accelerograms) and progressive collapse analysis;

– development of methods for tasks of the linear-spectral approach for seismic analysis;

– development of a preprocessor (the first ("basic") level);

– development of a post-processor (the first ("basic") level);

– development of two-way communication with information modeling systems (CAD, BIM, information (digital) twins) (the first ("basic") level);

– development of user documentation for the second stage of development of the national software system;

– verification/validation of the national software system (the first ("basic") level) according to the rules and in the system of the Russian Academy of Architecture and Construction Sciences (RAACS).

The third stage includes advanced development of the national software system (so-called "Research level"). In particular it includes the following items:

– development of an extended library of finite elements (the second ("advanced") level);

– development of advanced models of non-linearities (the second ("advanced") level);

– development of advanced non-linear static and dynamic "solvers" (the second ("advanced") level);

– development of effective superelement schemes, including methods for dynamic synthesis of substructures;

– implementation of parallel procedures on systems with distributed computing for high-dimensional problems;

– implementation of quantum algorithms for particular problems of computational mechanics and data processing;

– development of a preprocessor (the second ("advanced") level);

– development of a post-processor (the second ("advanced") level);

– development of user documentation for the third stage of development of the national software system;

– verification/validation of the national software system (the second ("advanced") level) according to the rules and in the RAASN system.

Implementation of parallel development of separate stages is planned as well.

We invite all interested persons and organizations to collaboration in development of the Russian national software system for adequate determination of loads and impacts, stress-strain state, strength, stability, reliability and safety of buildings, structures and complexes at significant stages of their life cycle.

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