Contemporary Digital Technologies in Construction Part 2: About Experimental & Field Studies, Material Sciences, Construction Operations, BIM and "Smart" City

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Abstract. Digital technologies in experimental and field studies are considered, the interrelation with mathematical modelling is shown, digital technologies in production of materials, products and structures are presented, the brief analysis of development of computer material science is given. BIM and digital technology in the construction economy are under consideration as well. Paper also explains the concept of so-called "smart" home, "smart" district, "smart" city, "smart" region and "smart" country, which are normally used by smart professionals in terms of current realities, long-term and medium-term prospects. Besides, the expediency of development of design codes in the field of information technologies is assessed.

1. Digital technologies in experimental and field studies are considered, the interrelation with mathematical modeling

The most important stage of structural survey is creation of adequate drawings and models [2-5,12] of the existing object with the use of laser systems. As an example, it should be noted that the Shukhov tower (Figure 1), built in 1922 and in operation, needs urgent reconstruction, but the original project of the tower and its reconstruction in 1937 has not been preserved. Special ground-based pulsed laser scanning system was used for creation of the drawings of the tower. This system allows scanning at a distance of up to 600 meters with an accuracy of determining distances up to 5 millimetres. The result of the scanning was a point cloud, which is a three-dimensional point model of the space area around the scanner. After office work full three-dimensional point model of the tower (about 50 million points) was created.

Figure 1. About field tests of Shukhov tower.

Then a digital three-dimensional frame model of the tower was built. Besides, a digital three-dimensional solid-state model of the Shukhov tower was created, on the basis of which the measurement drawings of the tower and corresponding computational model were created and all necessary design work was performed.

As for the problem of structural health monitoring (SHM) [1, 3], there are four methods of instrumental monitoring: geodetic measurements; engineering-geological observations of the state of the soil mass of the base; measurements of loads and deformations in the structures of the foundation and the above-ground part.

A promising direction is the use of building structures with embedded sensitive elements connected to an artificial neural network, which will allow accurate identification of the type and location of damage on the basis of pattern recognition technology. The seismometric method, which allows to examine the building as a whole and to reveal significant changes in load-bearing structures without tool influence and visual inspection of each structure, deserves attention. This method provides an acceptable definition of the accuracy of natural frequencies and modes that identify local changes in the state of structures (including failure). For example, by changing the values of the measured high frequencies, it is possible to determine the beginning of the destruction of any load-bearing structure.

Figure 2 shows the elements of computational studies of the stress-strain state, strength and stability of the load-bearing structures of the “Evolution” tower [6] of the “Moscow-City” complex (Moscow, Russia) with allowance for the actual position of reinforced concrete structures. Only the system of instrumental monitoring based on results of finite element analysis in comparison with the measurement data, will allow to draw conclusions about the state and possibility of further operation of the building.

2. Digital technologies in production of materials, products and structures

Perhaps additive manufacturing (3D printing) is the future of construction [10]. It is possible that a 3D printer in the future will finally solve the “housing problem”. On a 3D printer, all objects are printed in layers, synthetic resins, concrete and steel can be used as a material.

Currently, the development of 3D printing of buildings is constrained by the scale. Very expensive and really huge printer is required for building of a large house with a height of at least two or three floors. An alternative is to teach a three-dimensional printer to move through special scaffolding, erecting walls in accordance with the given program.

Figure 2. Elements of computational studies of the stress-strain state, strength and stability of the load-bearing structures of the "Evolution" tower of the "Moscow-City" complex with allowance for the actual position of reinforced concrete structures: construction stages and finite element models.

That is why so far all the printed buildings are either very small, or consist of separate modules, or are assembled from finished parts. Opinions of experts on the future of three-dimensional printing of buildings differ. Many experts believe that the whole building in this way will never be built, it is unprofitable. In the meantime, printing on 3D printers is more like a race for records than the beginning of really mass and cheap construction of buildings. At the same time, in the Netherlands, a steel bridge with a span of 12.5 meters, a width of 6.3 meters and a weight of 4.5 tons was built in 6 months.

The three-dimensional printing technology allows significantly simplify the manufacture of different objects. In particular, 3D printers allow the use of different materials to create structures of arbitrary shape in the form of a single part, which is impossible to do with conventional production technologies. This reduces material consumption.

In recent years, in Russia there has been a practice of using three-dimensional automatic control systems installed on concrete pavers and have significantly increased productivity (laser 3D technology of concrete pouring (Figure 3)).

3. Development of computer material science

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In recent years, in the development of problems of building materials science, the foundations of the theory of synthesis and design of composite structures have been determined and developed, which are correlated with the study of physicochemical and mechano-chemical problems of formation of hardening systems, with the development of methodology, principles and procedures for analytical and experimental modelling of the "structure of materials" of a new generation, with the solution of theoretical and engineering issues of management of the operational properties of composites based on the optimization of their structures, with the improvement of traditional and the creation of new high-tech production of construction companies.

Figure 3. Laser 3D technology of concrete pouring.

In the near term as the current perspective is taken, inter alia, the following:

- development, research and development of the theory of synthesis and design theory of optimal structures of building composites of a new generation, including the development of models, algorithms and computer programs for the optimization design of high-efficiency resource-efficient building composites, as well as the implementation of the obtained data in solving the issues of creating heavy-duty structural conglomerate composites for special purposes based on crystalline submicro-structural and nanostructural matrices;
- development, research and development of problems of mathematical modelling, development of algorithms and programs, information technologies in the problems of computer materials science and optimization of variable structures of building composites (superdense, extra high strength, ultra-lightweight, ultra-resistant to the action of the operating environment, etc.).

4. BIM – the idea of "information economy" in construction and the current state (advertising and realities)

The turn of the end of the 20th century – the beginning of the 21st century, was marked by the emergence of a fundamentally new approach in architectural and structural design, which consists in creating a computer model of a new building that carries all the information about the future object. Besides, this model is a tool for monitoring its life cycle-Building Information Model (BIM). BIM is called our future.

However, through PR it is important to see the real state of affairs, which indicates that it is often marketing, not reality, forms a BIM-view, and most people operate rather advertising slogans than understanding real technologies. BIM [8] is good for solving problems of shaping, space utilization and project presentation. Its features include excellent visualization tools and conflict resolution of the relative position of objects.

Figure 4 shows a three-dimensional model of the Lakhta Center (Saint-Petersburg, Russia) [13] and one floor with a full set of engineering equipment. At the same time, at other design stages, for example, the need to form computer models specifically designed for specific types of computational justification comes to the first place. In almost all cases, these models are in principle impossible to obtain from the BIM database automatically, and hence the specified problem area is effectively excluded from the integrated design process.

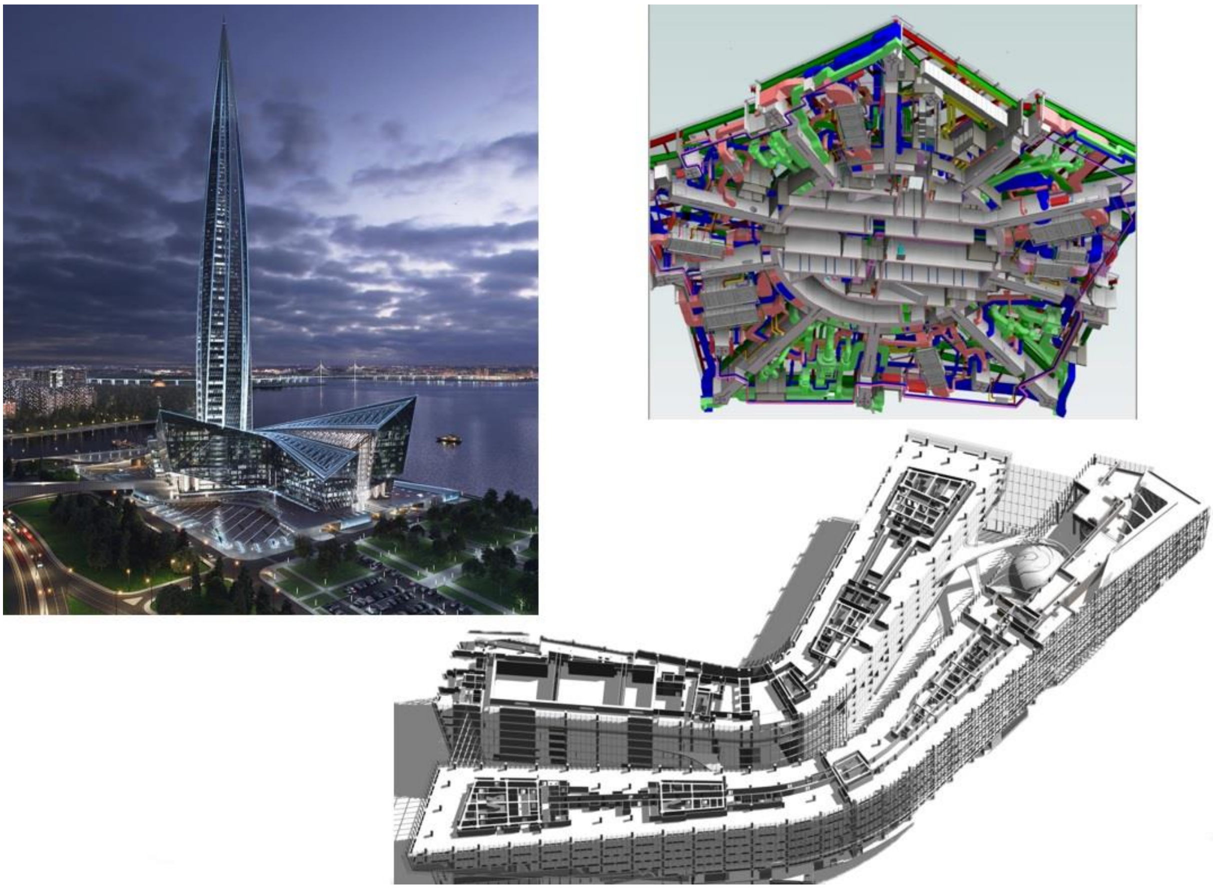

Figure 4. Three-dimensional model of the Lakhta Center and one floor with a full set of engineering equipment.

The implementation of adequate control over the life cycle of an object within BIM is also fraught with a number of fundamental difficulties. For example, for a sufficiently large object information about the existing defects can have a huge amount.

In classical methods, this information is simplified in engineering reports for easy review and decision-making, but “embedding” it in a BIM model can be time-consuming and inefficient.

Another problem is to obtain a reliable assessment of the technical condition of existing construction projects based on the results of their surveys and diagnostics. Digital technologies have allowed to apply fuzzy logic to the creation of expert systems that allow to obtain reasonable conclusions about the state of objects and their suitability for further operation.

5. Digital technologies in construction economics

Modern development of digital technology allowed to create two new Federal information system in the Russian Federation – the Federal state informational pricing system in construction and the Federal state system Unified state register of expert opinions of design documentation of capital construction projects.

The main task of the Federal state informational pricing system in construction is to monitor the cost of construction resources for each subject of the Russian Federation. This system allows to increase the precision of estimates due to the transition to a resource method for preparation of cost estimates. System uses a new classifier and codifier of construction resources, which consists of almost 69 thousand items (materials, products, structures, equipment, machinery).

The Unified state register of expert opinions of design documentation of capital construction projects will provide access to the consolidated information on the expert opinions in respect of capital construction projects, including cost-effective design documentation for reuse, which will increase the information openness of the activities of expert organizations.

6. "Smart" home, "smart" district, "smart" city, "smart" region and "smart" country

"Smart home" [11] or smart buildings [9] gradually or constantly help to save operational resources and increase the comfort of people in such buildings.

"Smart city" [7, 14] is a strategic concept for the development of urban space, implying the joint use of information and communication technologies for the management of urban infrastructure.

Through the use of sensors integrated with a real-time monitoring system, data are collected directly from the relevant devices and residents, and then processed and analyzed.

However, the idea of creating a comprehensive urban infrastructure, managed from a single center by local authorities, reflects the model of vertical urban governance, brought to the extreme. The possibility of connecting people or devices directly stimulates the emergence of new behaviours in which there is no need for a single coordinator of everything. It is predicted that with the development of new systems and behaviors, such a concept of "smart city" will be a thing of the past.

7. About design codes (regulatory documents) in the field of BIM

Generally, we regret to note not always the high quality of design codes (regulatory documents) regulating the use of information technologies and related research works in our opinion. To remedy this situation in the Russian Federation, it is advisable to involve The Russian Academy of Architecture and Construction Sciences (RAACS) not only in the examination of draft regulatory documents and completed research and development works, but also in the formation and evaluation of applications for the relevant competition held by the Federal center for standardization, standardization and technical conformity assessment in construction. The expert community, coordinated by RAACS, should formulate a list of the main directions and topics of the urgently needed design codes (regulatory documents) and relevant research and development works for the Federal center for standardization, standardization and technical conformity assessment in construction, as well as, possibly, recommend the teams of developers of these documents.

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