Competence "Engineering design" – a platform for developing the skills of designing an object of capital construction

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Abstract. The construction industry is undergoing a change in approaches to the design of capital construction projects due to the preparation of consolidated digital models in the course of designing and working with the information placed therein. This requires updating the content and changing the format of training students in the fields of study and specialties related to the design of capital construction projects and their engineering systems. Based on the comparison of the current format of training engineering students to the format of professional activities of engineers involved in the design of capital construction projects, it is shown that today's training system does not fully take into account the specifics of team work of engineers of various profiles in the course of project development. The necessity of using methods of cross-discipline team training is substantiated. It is proposed to use the best practices in competence R94 "Engineering Design" of the WorldSkills Russia "Young Professionals" national championship as a methodological basis for organizing such training format.

1 Introduction

In the construction industry, an evolutionary transition is proceeding from "conventional" design methods to the creation of consolidated digital models of buildings and engineering systems in the course of design. While the "conventional" method resulted in detailed design and cost estimate documentation, in the conditions of digitalization of processes, the result, in addition to this documentation, is the most detailed consolidated digital model, which is used and periodically updated at all subsequent stages of the life cycle of the capital construction project (hereinafter referred to as the CCP).

The application of software packages that implement the principles of collective development and information modeling improves the quality of output documentation and

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automates transfer of data about the CCP between all the participants of object's life cycle, including the repeated use of information during reconstruction and overhauls.

The industry develops requirements for a new way to organize storage, generation and use of information about the CCP in its digital model. This also entails requirements for new knowledge, skills and abilities of design engineers and university graduates, as well as the need to supplement the content and change the format of training.

2 Formats of training and professional activity of a design engineer

A digital model includes a set of interrelated data, documents and materials about the CCP generated in electronic form at the stages of engineering surveys, architectural and construction design, construction, reconstruction, overhauls, operation and decommissioning of the CCP. The design of CCP using information modeling technologies and working with a digital model determine the need for a modern design engineer to possess three groups of skills:

- hard-skills, professional specialized skills in the field of engineering design (heat and power engineering, electrical engineering, water supply and water disposal, industrial and civil construction, etc.);
- IT-skills:
- working in CAD systems, design using information modeling technologies;
- organization of working interaction in a consolidated information environment;
- storage of information and sharing information with regard to information security;
- soft-skills, which determine the ability to cross-disciplinary communication, ensuring effective interaction of different specialists in the framework of working on a single CCP.

Currently, engineering training at Russian higher education institutions is mostly based on the principle of training within the framework of specialization: students receive professional knowledge in their field of activity, practically without interacting with students specializing in other areas. For example, a bachelor in construction engineering studies issues related to the construction industry, and in the course of education there is no need for him/her to work on a joint project with a bachelor in electrical engineering or heat power engineering. This method of learning can be described as "monodisciplinary".

The method is justified by the fact that the actual design of a CCP includes sections of the design of individual engineering systems and building structures, and the student needs to get specialized skills so that he could prepare a relevant section of the design. However, in real-life the design of a single engineering system strongly depends on the design of other systems. The effectiveness of design depends on the effectiveness of collective decision-making and on how well an engineer of a particular field of specialization participates in teamwork [1]. Therefore, the "monodisciplinary" format does not enable to fully master hard and soft skills that are required for real-life joint design.

Real design is (as opposed to student learning) "multidisciplinary". Students can only see examples of a "multidisciplinary" design process during their work placement internship. However, after completing their internship, they return to the traditional educational process and prepare their individual final qualification thesis. Therefore, they do not have the skills of "multidisciplinary" team design of CCP trained or tested.

The discrepancy between the formats of training and professional activity leads, at least, to an extended period of adaptation of a young specialist, and in some cases results in a loss of quality of the results of design work. What is needed is methodological unification of

formats, that is, introduction of learning the skills of team design of CCP to the educational process. For the organization of advanced training of students, it is advisable to teach design using the information modeling technology.

3 Base for unification of training formats and professional activities of a design engineer

The formation of a competence profile on the part of an educational institution is generally carried out in a classic way using such formats as lectures, practical classes, and so on. Examination of the level of development of competencies is implemented in the form of preparation of the final qualification thesis.

In order to develop the ability to design CCP in a team and apply a unified information environment, it is necessary to use appropriate training methods: project-based, practice-oriented training in "multidisciplinary" teams, which are currently being introduced and started theirs implementation in the educational process.

In Russia, two-stage design is adopted [2], namely: the "Design Documentation" and "Detailed Design Documentation" stages. Throughout the design stages, sections of design documentation and sets of detailed design documentation are developed in a parallel-serial order (figure 1).

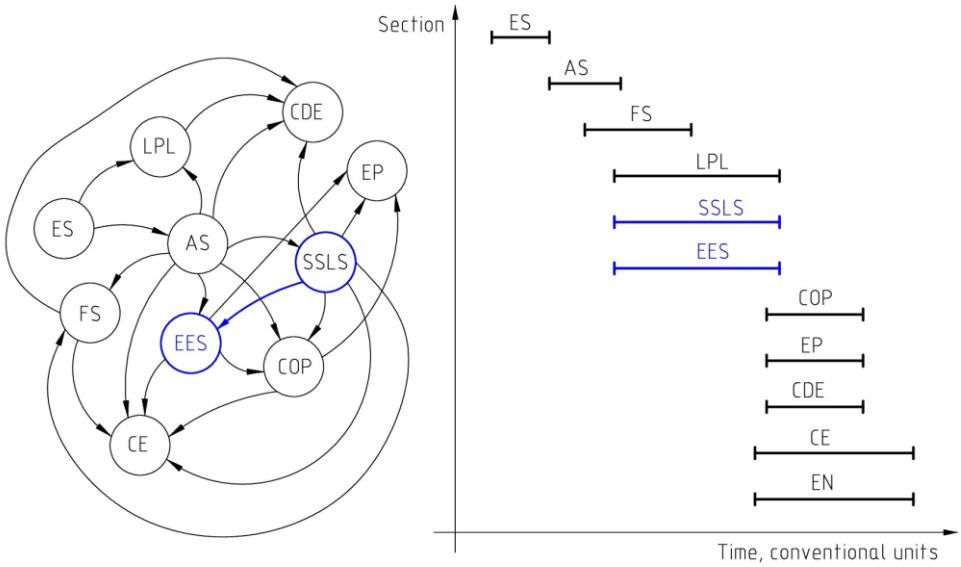

Fig. 1. Sections of CCP design at the stage of Design Documentation, designations: ES – Engineering surveys, AS – Architectural solutions, FS – Fire safety measures, LPL – Land plot layout, SSLS – Structural and spatial layout solutions, EES – Data on engineering equipment, on engineering and technical support networks, list of engineering and technical measures, contents of technological solutions, COP – Construction organization plan, EP – List of environment protection measures, CDE – List of measures for civil defence, measures for preventing natural and man-made emergencies, measures for counteracting terrorism, CE – Cost estimate for construction of capital construction projects, EN – Explanatory note. (according to Resolution No. 87 of the Russian Federation Government dated February 16, 2008 (revised on April 28, 2020) "On the composition of sections of design documentation and requirements to their content" and GOST R 21.1101-2013 System of design documentation for construction (SPDS). Basic requirements for design and detailed design documentation).

From the entire set of design documentation, we will distinguish two sections:

- SSLS – structural and spatial-layout solutions;
- EES – information on engineering equipment, engineering support networks, list of engineering activities, content of technological solutions (subsections "Power supply system", "Water supply system", "Water disposal system", "Heating, ventilation and air conditioning, heat networks", "Communication networks", "Gas supply system", "Process solutions").

Without diminishing the importance of the other sections and without arranging their ranking relative to each other, note the specifics of the selected section: it is in the course of their fulfilment that a construction project is filled with infrastructure, utilities, and the digital model of the project is filled with data defining the basic functionality of the CCP and responsible for life support of the project users. Besides, the SSLS and EES sections run simultaneously, and design engineers with overlapping tasks and goals would share data in the information environment during their implementation in order to prepare their respective parts. These two factors determine the methodological feasibility of modelling and assessing the implementation of these sections in the framework of student training.

4 Example of modelling the work and assessing the qualifications of engineers using the methodology of the WorldSkills International

Competence R94 "Engineering Design" of the WorldSkills Russia "Young Professionals" national championship was initiated in 2017 by Rosatom State Corporation. This is a competence in which team members demonstrate and improve their skills in designing buildings and structures for various purposes, including networks and engineering support systems, using information modelling technology.

Team members:

- participant 1 - structural engineer;
- participant 2 - engineer for design of electrical installations;
- participant 3 - engineer for design of pipeline systems (process pipelines, heating and air conditioning systems, heating networks, process solutions for boiler houses, central heating points and minor thermal power plants, water supply and water disposal systems);
- participant 4 - information modelling specialist.

The team is given a competitive assignment for the design of CCP, during which participants must apply hard-skills, soft-skills (cross-disciplinary communication, understanding their mutual dependence in the production process) and IT-skills (working with CAD and a digital model). The team is working together on a single CCP. The OpenBIM concept is used in the organization of work [3].

The key tasks of the team are:

- performing engineering calculations according to their respective fields of specialization;
- making collective design decisions on the basis of calculations and source data;
- creating an consolidated digital model;
- obtaining drawings from the model.

Due to the limitations imposed by the competitive process (the competition period is 24 hours, it is impossible to consult with colleagues, search for proven solutions in the archive, or use ready-made templates or pre-prepared data), a special approach is used to set tasks for contestants, which is conventionally referred to as “in-contest working”.

This approach is in partial joint implementation of the stages of preparation of design and detailed design documentation. Some of the documents that need to be executed within the design documentation are excluded, and the remaining part is set for more detailed

calculations, selection of equipment, materials, etc. Most of the stage of preparation of detailed design documentation is also excluded, but the essence of the design process is preserved. At the same time, the requirements in terms of current norms and rules are preserved, the technical decisions made take into account the requirements of industrial, fire and radiation safety, environmental protection and human life safety, and the problem of determining the estimated cost of construction is solved.

Having carried out the above scope of work, the design participants can form a minimum sufficient level of data to create a digital model of the CCP.

The "in-contest" task at the championship has a related structure (figure 2), which is worked out in such a way that the tasks for the participants' fields of specializations would have a complete list of source data and requirements for the formation of output documentation.

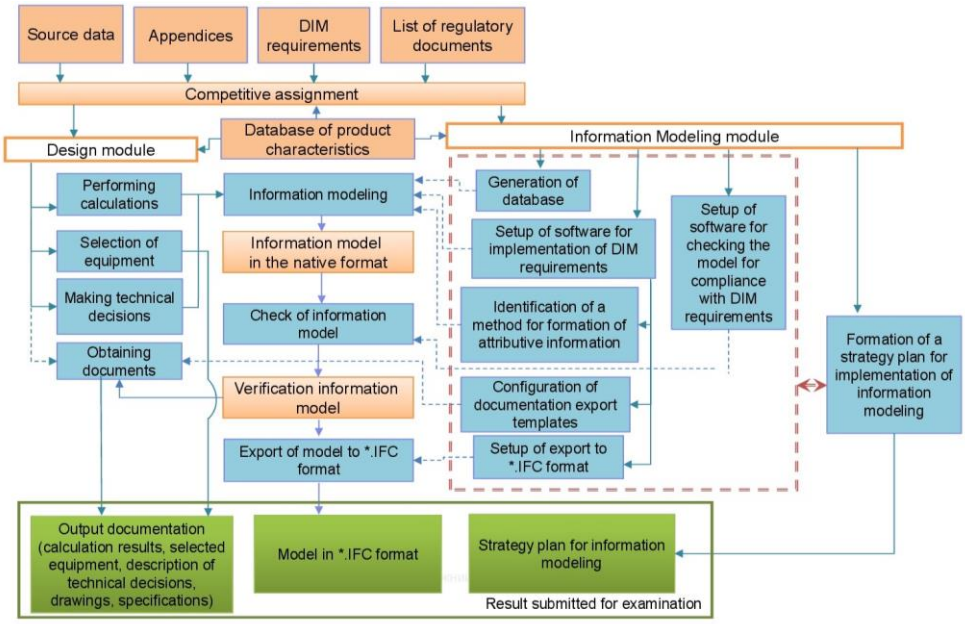

Fig. 2. Structure of "in-contest" task.

The "in-contest" task consists of two interrelated principal modules: a) design and b) information modelling.

Design module. In the course of working in the design module, the participants jointly form the minimum sufficient level of data for creating a digital model.

The "in-contest" task for the participating process engineer includes a description of the technological process for implementation of which the CCP being designed is intended, and that of the required equipment. Depending on the type of technology, seasonal operating modes or other special conditions can be set. In the course of performing the assignment, the participating process engineer must make calculations, select equipment, draw up process flow charts and issue tasks for the participating electrical engineer to connect the process equipment to the power grid, and for the participating construction engineer to provide information on the weight and dimensions of the equipment and on routing of process pipelines.

The "in-contest" task for the participating construction engineer involves the design of building structures of the CCP. In the course of performing the assignment, he is to design and execute drawings, perform the necessary calculations, both in an expanded form and via

using a computational system. The construction engineer would receive information about the weight and layout of the process equipment as an assignment from the process engineer.

The “in-contest” task for the electrical engineer on the design of electrical installations is developed for two systems: those of power supply and indoor electric lighting of the CCP. The electrical engineer would receive a task from the process engineer with characteristics of the process equipment to be connected to the power supply system. Together with the construction engineer and the process engineer, they choose the places of installation of electric switchboards, lighting fixtures, the locations of networks and cabling routes.

Information modelling module. During the work within the information modelling module on the basis of the “in-contest” task data, the results of calculations performed in the design module, specifications, selected equipment, products and materials, model requirements, a consolidated digital model of CCP is generated.

For the digital model (DM) to be generated and filled, the teams participating in the competition would include an information modelling specialist (“IM Specialist”). In the course of the competition, he will create a strategy plan for the implementation of information modelling technology, which would contain a list of actions to be taken to fulfil the DM and meet the requirements to the model. The consolidated digital model is formed in the native format and in the “IFC” format according to [4]. The resulting model is the consolidation of engineering decisions made by the team.

It is also worth noting the interaction between the construction engineer, the process engineer and the electrical engineer with the DM specialist as regards meeting the requirements to the digital model in terms of the level of its elaboration. While performing the task, the DM specialist requests the necessary data on the level of DM elaboration from the other team members and controls the level of its elaboration. In its turn, the level of DM elaboration is determined by the team's strategy; for example, the team can set the minimum level of graphic elaboration (LOD200) and the maximum level of information content elaboration (LOI400). When forming the database, the DM specialist and the electrical engineer work in the special information and reference system “iPRO” [5], which allows participants to quickly share the necessary data and improve the quality of data entered in the DM.

The team's performance is evaluated based on criteria collected in key groups of the WSOS – WorldSkills Occupational Standard, with their respective specific weights indicated. The criteria and their specific weights are determined and reviewed annually by the expert community consisting of representatives of various industries (petrochemical industry, metallurgy, nuclear industry). The list and significance of the WSOS sections is an "average" characteristic, an employee's competence profile formed by experts.

5 Conclusion

Today's system of training design engineers does not fully reflect the specifics of teamwork and the need for "cross-discipline" interaction in the course of design. To solve this problem, it is advisable to use the methods of project-based training of students in "multidisciplinary" teams in the educational process.

Competence R94 "Engineering Design" of the WorldSkills Russia "Young Professionals" national championship makes it possible to assess knowledge and skills as well as the teamwork of participants at the design of CCP. The content-related and methodical approach to the development of competitive assignments and assessment criteria, which is developed within the competence, can be used as a basis for the formation of educational content for project-based training of students, future design engineers. The level of students' team design skills can be controlled in the form of competence championships or in the form of an examination with use of WorldSkills approach.

The WorldSkills movement provides universities with modern and convenient tools for unifying the content and formats of learning and professional training of engineering specialists. Here, the key point is the active participation of the expert community, which enables to maintain the current level of requirements for the knowledge, skills and abilities of a design engineer, creates a basis for the development of the design engineer profession and training of personnel for construction engineering.

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