

CAD in interdisciplinary integration as a tool to increase specialist training quality in “Construction” education

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Abstract. Subject: subject of research is characterized by the requirement to master and efficiently apply CAD tools in the teaching process for analyzing reinforced concrete structures and engineering of facilities to be built under current construction standards and regulations.

Objectives: consideration and analysis of updated software applications for simulation enabling to reduce academic load and improve process of education for less period of time. Methods of teaching such subjects as “Reinforced concrete and masonry structures” and “Construction engineering” are improving together with updating of simulation software, meaning consideration of the process for problem solving in calculations, engineering and mounting of reinforced frame elements to one-storey industrial facilities.

Materials and methods: scientific papers by authors of this work were used as reference literature, the article methodology is based on standards of objectivity and development, statistical level of methodological analysis was applied.

Results: comprehensive description for getting modern IT learning skills in using software simulation facilities was prepared under analysis of the below mentioned materials. Problems in making 3D simulation model of a frame of a building considering facilitation for the students in their appreciation and maximum approach to actual behavior of structures were reviewed either. In the course of analysis a number of assumptions was proposed for engineering of connection between bearing elements of the frame and statistical estimation in linear statement.

Conclusions: bases for calculation, engineering and mounting of reinforced concrete structures were considered therewith in accordance with present norms and regulations. Currently a problem in making simulation algorithm for 3D calculation scheme of standard frame to one-storey industrial facilities is still very important.

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1 Introduction

Construction branch is one of the key fund-creating industries that is greatly influencing on the Russia economy [1, 2]. Further development of the construction industry stimulating new modern innovation technologies and materials results in complication of engineering solutions, with commissioning thereof being prevented from by insufficient qualification of design engineers. One of the reasons is non-compliance of teaching bachelors, masters and specialists with current requirements. To meet the demands of current economy and to comply with changing requirements of the society by each student, the RF program “Development of Education” for 2013-2020 (<http://government.ru/programs/202/events/>) puts forward an objective to upgrade both contents and technologies of the vocational education. Therefore it is necessary to develop technologies for interdisciplinary integration in all steps of training highly-skilled specialists in “Construction” education.

Nowadays, opportunities of modern software applications are not fully disclosed in the education process of construction institutions of Russia. This issue is especially important due to elaboration and continuous updating of current software applications for modernization of construction branch. Application of IT technologies in CAD enables to greatly increase level and quality of the work to be done, to reduce construction period and costs. Application of IT design tools is also able to provide for wider opportunities for building facilities under the data obtained.

Transition to layered system of higher education provides for realization of different events, with updating of the educational materials being the most important one therewith.

Current training manuals for students in “Reinforced concrete and masonry structures” course over dozens of years still use standard engineering approach in calculations. Less attention is paid to using of modern software applications in education process which is of vital importance due to development of wide spectrum of programs and continuous updating and expansion of opportunities thereof [3, 4]. Appearing training manuals and books [5, 6] devoted to CAD are very popular with students and not always may satisfy the demands if used in educational process.

These provisions make students learn methods for reinforced concrete structures calculation under current norms and rules with efficient use of modern software engineering applications. In spite of the problems being clearly set, the process is quite complicated and contradictory [7, 8]. On the one hand, reduction of teaching process in Bachelor’s education results in reduction of hours in almost all subjects being taught. Here, application of IT and communication technologies is successful by learning more for less period of time. On the other hand, theoretical learning of compulsory minimum in combination with the skills of software application user leads to intensification of the teaching process [9, 10]. All kinds of teaching aids and recommendations aimed at efficient combination of both in the national educational standard are considered by the authors as useful in solving problems set above [11, 12].

2 Materials and methods

Mechanism of teaching subject “Reinforced concrete and masonry structures” in Institute of Architecture and Civil Engineering at Ufa State Petroleum University is based on the principle of well-balanced sequential process for considering problems of engineering reinforced concrete frame to one-storey industrial facility [13, 14], being an object of both term papers and graduation design engineering in engineering training of builders for the last several dozens of years.

Programs providing automated solutions procedure (documentation) for the construction technology and construction management both in the site, on the whole, and

for separate process complicated operations, in particular, reinforced concrete frame making technology (Fig.1) [13, 14], are supposed to be used in the first step of making flow diagrams within “Construction technology” subject. These programs are the database for methodology in making the working plan in the construction site.

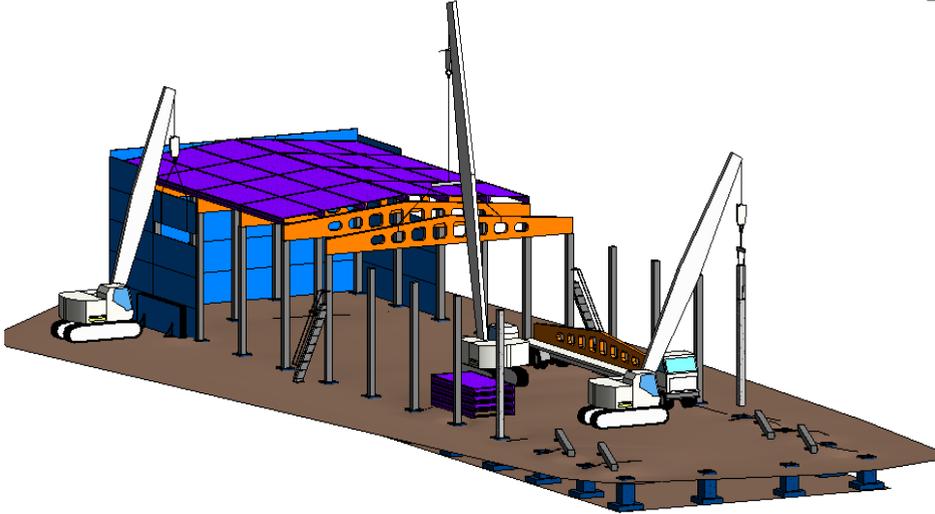


Fig.1. 3D model of flow diagram

Structural engineering of transverse bents for the frame to one-storey industrial facility should be considered further.

The problem is divided into four consequently interrelated steps:

1. Static analysis and design engineering of structural elements of the frame by traditional method (version 1 – “manual” calculation of plane bent). Calculation model is given in Fig.2.
2. SCAD software application [15, 16, 17] to solve problems of the 1st step (version 2 – automated static analysis and engineering of flat transverse bent of the frame). Finite-element model is given in Fig.3.
3. Making 3D model of the frame in SCAD and analysis of stress and strain behavior of bearing elements (version 3 – automated analysis and engineering of 3D problem).
4. Comparative analysis of the results obtained.

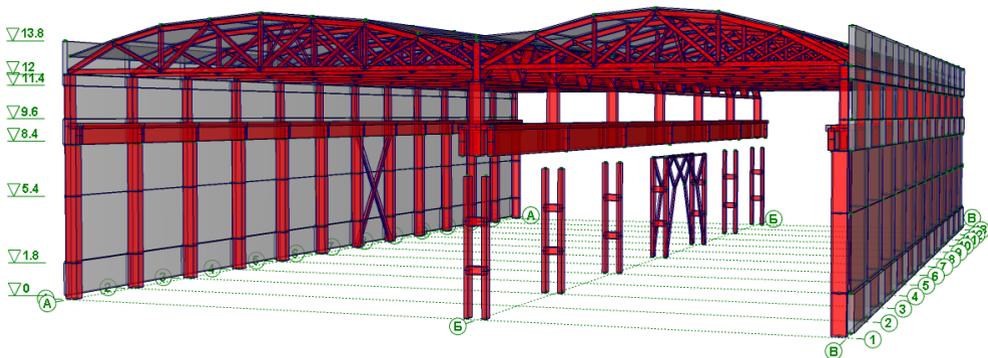


Fig.2. Calculation model

3 Research data

The first step (version 1) is paid special attention to in manuals [18, 19, 20] as the most important one. The future structural engineer is unable to work with software engineering tools without learning of “engineering” principles of calculation and design of elements in accordance with local building requirements.

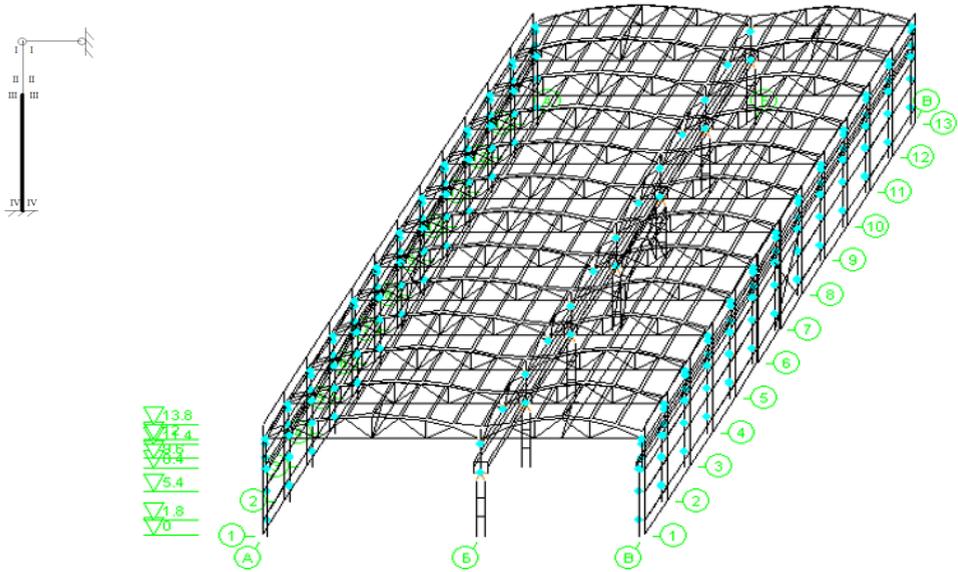


Fig.3. 3D calculation model of the frame

When making 3D calculation model of the frame [21, 22] (version 3) to be well understood by the students and with maximum approach to actual behavior of structures the following assumptions are accepted (Fig.2):

1. Bearing elements of 3D frame (columns, roof and eaves beams, crane runway beams, and bracing) are taken as axial elements (type 5);
2. Enclosing structures (curtain wall panels, glass fixing, roof slabs) are taken as plate (shell) elements (type 44);
3. Simulation of connection between bearing elements of the frame [23, 24] is made by solid bodies (type 100);
4. Method for combining relocations is applied to provide for mutual operation of frame elements;
5. Static analysis is made by standard method;
6. Elongated elements affected by external load are conditionally indicated as elements with stiffness properties of reinforced concrete unstressed elements [25];
7. Crane runway beams are accepted as split with vertical load transmissions from crane through the wall, while horizontal load – to columns through top flange;
8. Pivotaly connected reinforced concrete roof planks lie on panel points and get into operation together with rafter parts of a roof;
9. Bracing along the frame is made as simple frame metal constructions;
10. Conditionally there are no non-bearing cross walls because a temperature module of specified length (72m) is analyzed.

4 Conclusion and discussion

Static analysis results of three analytical model versions of the frame to one-storey industrial facility consisting of two unequal spans with different column space along external and internal axes have revealed that stress and strain behavior of basic bearing structures by version 1 and 2 (plane model) and version 3 (3D model) has distinctions both in kind and degree (table 1). Such distinctions are explained by approaches assumed and assumptions in defining the rules for making analytical model to each version.

An attempt to make an algorithm for simulation of 3D calculation model of standard frame to one-storey industrial facility gave absolutely no answers but raised many interesting problems to be thoroughly studied in special courses by MA programs “Industrial and Civil Engineering”, “Engineering and Construction of Buildings & Facilities for Petroleum Industry”, “Technology of Construction Procedure, Efficient Application of Materials and Structures” in “Construction” education.

Table 1. Applied load in edge column section along A axis

Load	Analytical model	Loading No.	Sections and applied load (kN, kN*m)						
			II-II		III-III		IV-IV		
			N	M	N	M	N	M	Q
1	2	3	4	5	6	7	8	9	10
Dead load	manual	–	303,37	6,11	380,28	-33,68	455,18	16	-5,95
	plane bent	1	303,37	5,73	455,18	-34,06	455,18	14,79	-5,85
	block	11+5	324,83	-0,64	418,98	-39,24	518,55	15,1	-4,16
Snow, vers.1 uniform loading	manual	–	218,88	9,85	218,88	-25,18	218,88	3,68	-3,46
	plane bent	2	218,88	9,57	218,88	-25,45	218,88	2,81	-3,38
	block	3	220,2	2,15	220,2	-33,92	220,2	-19,54	-1,73
Crane Dmax A	manual	–	0	-	245,43	64,22	245,43	-10,39	8,94
	plane bent	5	0	-	245,43	64,47	245,43	-9,59	8,87
	block	6	0,71	-	341,83	86,66	341,83	-18,20	12,59
T, A	manual	–	0	±9,57	0	±9,57	0	±24,63	±8,19
	plane bent	6	0	±8,98	0	±8,98	0	±26,49	±4,25
	block	8	1,25	±7,28	1,25	±15,13	1,25	±35,33	±6,06
Wind loading, left	manual	–	0	3,07	0	3,07	0	67,66	-12,5
	plane bent	3	0	4,76	0	4,76	0	73,08	-
	block	1	0,06	0,26	0,06	0,76	0,06	55,61	-9,80
Wind loading, right	manual	–	0	-6,68	0	-6,68	0	-57,51	9,06
	plane bent	4	0	-8,28	0	-8,28	0	-62,65	9,49
	block	2	0,03	0,26	0,03	-4,21	0,03	-46,35	7,06

Actual questions are:

Analysis of framing scheme affecting 3D operation under crane loading;

Analysis of stress and strain behavior of roof framework with roof slabs to be included thereto;

Numerical analysis of actual load transfer from unequally deformed roof slabs upon roof framework parts;

Analysis of stress and strain behavior of roof framework with roof slabs to be included thereto in the construction phase and subsequent operation thereof (“MOUNTING” mode);

Alternate engineering of frames under the given plan with application of different structures (sub-schemes);

Behavior of two-element columns in 3D model is still to be studied.

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