

# Статичний аналіз фермових конструкцій

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У цій статті представлена інформація щодо навчальних розробок для предмету «Технічна механіка». Викладання цього предмету входить до навчальної програми студентів-першокурсників. Класична форма викладання не є цікава сьгоднішнім студентам і не мотивує їх. Метою викладачів, які забезпечують викладання предмету «Інженерна механіка» на факультеті виробничих технологій у Пряшеві, є покращення якості викладання за допомогою нових сучасних методів навчання з використанням комп'ютерних технологій і відповідного програмного забезпечення для статичного та динамічного аналізу систем твердих тіл.

У завданні зі статичного аналізу вибраної реальної фермової конструкції пояснюються процедура та принципи розрахунків плоских ферм за допомогою класичного методу та за допомогою ПК. Шукаючи відповідну програму, яка б найкраще підходила для вирішення завдань у цій галузі, було опрацьовано кілька програм САПР. Головним критерієм вибору була доступність програми для студентського користування, а також можливість швидкого та легкого розрахунку рівноваги плоских ферм. Була вибрана програма Autodesk Robot Structural Analysis Professional 2011. На цей вибір, головним чином, вплинув той факт, що у 2010/2011 навчальному році на кафедрі розробки технологічних пристроїв (Технічного університету Кошице) факультету виробничих технологій у Пряшеві була створена спеціальна аудиторія для викладання комп'ютерного моделювання з програмним забезпеченням Autodesk Inventor, до якого можна додати і вже раніше згадану програму того ж виробника.

Для розв'язання зазначеного типу задач за допомогою програми Autodesk Robot Structural Analysis Professional був розроблений підручник. Він подається у формі інструкції для користувача та навчального відео, щоб студенти могли розв'язати прості задачі з розрахунку рівноваги плоских ферм лише за допомогою цієї програми. Студенти також повинні опанувати основи роботи з програмним забезпеченням Autodesk Robot Structural Analysis. Ця робота написана завдяки підтримці проекту KEGA номер 270-014TUKE-4/2010 та VEGA 1/0884/10.

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# Static analysis of truss structures

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*In the article is introducing the information about creation of the study aids for teaching Engineering mechanics. In a task about a static analysis of selected real truss structure are explained the procedures and principles for solving of the plane trusses by the classical method and solving with the support of PC. Part of this study aid is manual for solution of defined type of tasks in the program Autodesk Robot Structural Analysis Professional. The paper was written thanks to support provided by the project KEGA num. 270-014TUKE-4/2010 and VEGA 1/0884/10.*

**Keywords** - plane truss, axial force, CAD system.

## I. Introduction

Engineers work in every area of technical practice is now unthinkable without the use of computer technology. CA - literacy is now required from each technical university graduate. The role of universities is to prepare students for practice in order to be able to solve various technical problems on the basis of understanding of the theoretical knowledge with the support of appropriate CA-technologies.

Teaching of engineering mechanics puts high demands on students to understand the issues which is taught. Condition for successful mastering of the subject by students are a basic knowledge of physics and mathematics and especially the ability of logical thinking and spatial imagination. From the side of teachers it is important to arouse interest of students in the content of this article. Classical form of education is for today's students little incentive and uninteresting. The objective of teachers teaching the subject of Engineering mechanics at the Faculty of Manufacturing Technologies in Prešov is to contribute to improving the quality of teaching by finding new modern teaching methods with the use of computer technology and suitable software for static and dynamic analysis of systems of solids. To cooperate on solution and processing of individual tasks were also invited students. Depending on the extensivity and intensity of partial tasks they were assigned to students and they were solved and processed in the form of bachelor's or diploma works.

## II. Static analysis of truss structures

One of the solved tasks was design and creation of teaching aids to support the illustration of theoretical interpretation, to simplify understanding of the issue of the static analysis of truss structures and part of the solution of set tasks was to facilitate and accelerate their own mathematical solution. To achieve that objective were set the following tasks:

- Select a real truss structure suitable for processing of a model example of the static analysis.
- Create an analysis model (plane truss) of the selected truss structure.
- Implementation of the "hand" calculation of the axial forces of plane truss.
- Proposal a suitable analysis system for solving the balance of plane trusses.
- Preparation of instructions for the static analysis of truss structure in a selected CAD program.

### III. Selection of the truss structure

Subject Technical Mechanics I. is included in the curriculum for students of the first year. The content of one from the awards whose solution is a necessary condition for successful management of this course is the calculation of axial forces in plane trusses. It was also subordinated to choice of the real truss structure for creation of a model solution.



Fig. 1. The railway bridge over the river Danube at Komárno [1]



Fig. 2. Proposal of the computational model-plane truss [1]

For choosing a suitable object were criticized more objects located near the school building and also the structures found on the Internet. It was selected a railway bridge over the river Danube in Komárno (Fig. 1). The bridge has a simple standardized construction which allows the creation of the computational model for students in a transparent and comprehensible manner. An important factor in the selection was the availability of all necessary data about dimensions and loading of the bridge. Model solution was prepared for the selected model situation: Static analysis of one segment of the railway bridge on 60 m length loaded with a standing train.

Prepared was a complete solution of the task by several methods of determining axial forces in truss members from the creation of computational model - plane truss to the calculation of size of the wanted axial forces. Objective of the defined task was to explain to students the principle and methods of solving this type of problems in statics and inform them about the possibility of static analysis with support for PC.

### IV. Selection of CAD program

When searching for a suitable program that best meets the needs for solving tasks in given area, it was made an exploration of these CAD programs: Creo Elements /Pro 5, Autodesk Inventor Professional 2011, Autodesk Robot Structural Analysis Professional 2011. On the ground of following facts was selected program Autodesk Robot Structural Analysis Professional 2011:

- The program Autodesk Robot Structural Analysis Professional is designed especially for the design, creation of models and analysis of loading at various types of constructions.
- In school year 2010/2011 was in the Department of Technological Devices Design (KNTZ) FVT in Prešov created a special classroom for teaching computer modeling equipped with Autodesk Inventor software, which can be append with the above program from the same provider.
- In the case of tasks solved in the course Technical Mechanics I. program provides quick and easy solution.

### V. Autodesk Robot Structural Analysis Professional 2011

The program Autodesk Robot Structural Analysis Professional is a computational system which with its versatility and progressive principles enable to keep in step with competing companies in designing of the engineering structures [2].

„Software uses the "BIM" (Building Information Model) technology, which now belongs to the most progressive and fastest evolving methods of complex model of the structures "[2].

The program allows to create a 3D model of engineering construction and then convert it to the static or dynamic analysis.

"Next allows you to make the nonlinear analysis of constructions and also contains a large number of national standards, including the Eurocodes, which allows to obtain the final assessment of the elements very fast in a very short time" [2].

„Autodesk Robot Structural Analysis Professional allows to retrieve data in various formats, e.g. \*. dwg, \*. dxf, \*. stp, \*. ifc, \*. sat, etc.. It also enables two-way data exchange with the program Revit Structure.

The big advantage is the creation of custom applications. Autodesk Robot Structural Analysis Professional 2011 allows to perform a complex analysis of different types of constructions from buildings across the bridges to unconventional objects "[2].

### VI. Creating a 3D model of plane truss

The basis for the realization of static, respectively dynamic analysis of constructions is to create a 3D model (for plane trusses 2D model) of system of the truss members. The system allows to create models of different types of constructions. [3]

For plane trusses modeling is designed a tool "Truss 2D design" (Fig.3). Scheme of the truss members system

can be model specially for each case particularly. This procedure must be used in case if the shape of the construction is nonstandard. In the case of chosen truss structure there is a simple standardized shape of the construction. Model of the plane truss was therefore created using a library of the standardized forms of the truss constructions (Fig.4). This procedure considerably reduces the time required to create it. Number of fields, dimensions, type and cross sections of the assigned profiles are defined through dialog boxes (Fig.5).

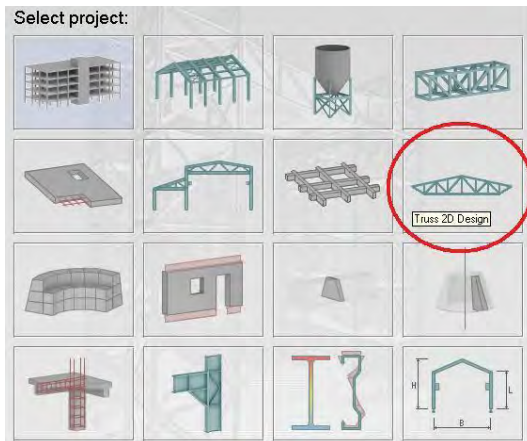


Fig. 3. The choice of the work-bench "Truss 2D Design" [4]

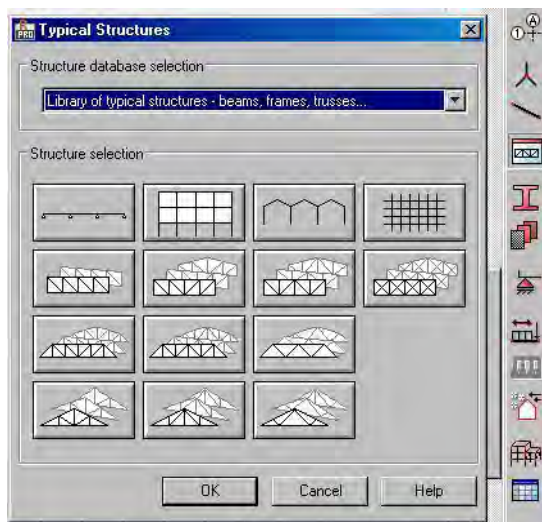


Fig. 4. Load of the shape of the construction from the library[4]

External links are defined by using the tool "Supports". It is possible to use directly built-in links, respectively it is possible to edit these links as necessary. Autodesk Robot Structural Analysis Professional 2011 enables creation of more types and ways of loading. The system works with them as with the independent files. This means that it allows independent analysis of the construction which are loaded by its own weight, or which are loaded by permanently or temporarily acting force or by a continuous load, e.g. snow. Individual loaded forces are added using the "Load definition". This tool allows to design loads at junctions.

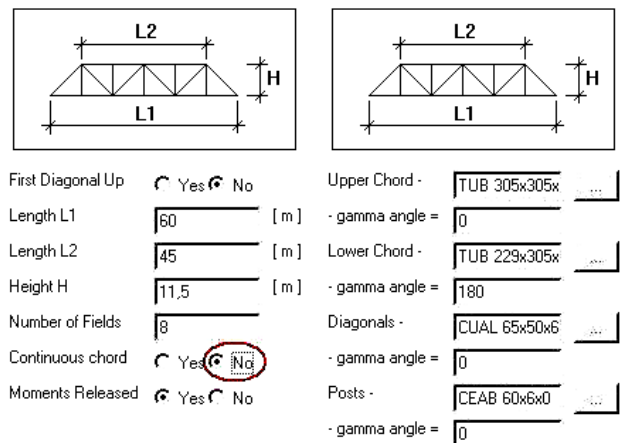


Fig. 5. The choice of the size of the construction and the cross sections of the beams [4]

Plane truss which is solved is loaded just by lonely forces which are acting in junctions. Use the button "Nodal force" to set the size of the forces which are acting on the junction component of force after component of force (Fig.7). Loaded forces which are acting in a direction other than the direction of axes of coordinate system must be separated into their components acting in the direction of the chosen coordinate axes.

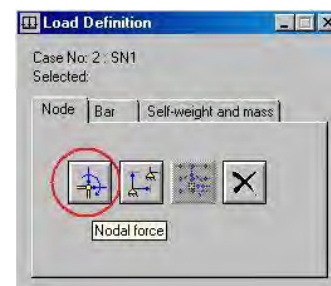


Fig. 6. Addition of the acting force [4]

In Fig. 7 is the final shape of the model of considered segment of the construction of the bridge loaded by train.

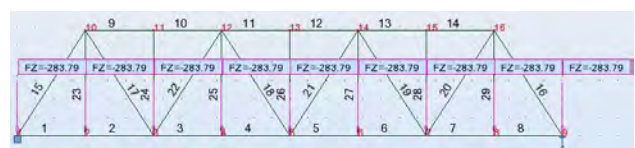


Fig. 7. The final model of the plane truss [4]

After create a complete model of the plane truss can be choose the type of the analysis and run an analysis by selection of "Calculations" in the popup menu "Analysis".

Analysis results can be viewed in tabular or by graphical form. The solution of the assigned task are the results of the reactions in the external links (Fig. 8) and size of the axial forces in bars (Fig. 9).

Analysis results can be displayed in graphical form too. Graphical representation is suitable for obtaining the illustrative idea about loaded of specific bars. Viewing the sizes of numerical values of the axial forces over their graphs may be replaced by their tabular view.



Node/Case	FX (kN)	FZ (kN)
1/ 2	0,00	1277,07
9/ 2	0,00	1277,07
Case 2		
SM1		
Sum of val.	0,00	2554,14
Sum of reac.	0,00	2554,14
Sum of forc.	-0,00	-2554,14
Check val.	0,00	0,0
Precision	2,91706e-015	1,59055e-033

Fig. 8. The table of resultant reactions in external links [4]

Bar/Node/Case	FX (kN)	Bar/Node/Case	FX (kN)
1/ 1/ 2	-647,79	16/ 9/ 2	1185,84
1/ 2/ 2	-647,79	16/ 16/ 2	1185,84
2/ 2/ 2	-647,79	17/ 3/ 2	-847,03
2/ 3/ 2	-647,79	17/ 10/ 2	-847,03
3/ 3/ 2	-1388,12	18/ 5/ 2	-169,41
3/ 4/ 2	-1388,12	18/ 12/ 2	-169,41
4/ 4/ 2	-1388,12	19/ 7/ 2	508,22
4/ 5/ 2	-1388,12	19/ 14/ 2	508,22
5/ 5/ 2	-1388,12	20/ 7/ 2	-847,03
5/ 6/ 2	-1388,12	20/ 16/ 2	-847,03
6/ 6/ 2	-1388,12	21/ 5/ 2	-169,41
6/ 7/ 2	-1388,12	21/ 14/ 2	-169,41
7/ 7/ 2	-647,79	22/ 3/ 2	508,22
7/ 8/ 2	-647,79	22/ 12/ 2	508,22
8/ 8/ 2	-647,79	23/ 2/ 2	-283,79
8/ 9/ 2	-647,79	23/ 10/ 2	-283,79
9/ 10/ 2	1110,49	24/ 3/ 2	0,0
9/ 11/ 2	1110,49	24/ 11/ 2	0,0
10/ 11/ 2	1110,49	25/ 4/ 2	-283,79
10/ 12/ 2	1110,49	25/ 12/ 2	-283,79
11/ 12/ 2	1480,66	26/ 5/ 2	0,0
11/ 13/ 2	1480,66	26/ 13/ 2	0,0
12/ 13/ 2	1480,66	27/ 6/ 2	-283,79
12/ 14/ 2	1480,66	27/ 14/ 2	-283,79
13/ 14/ 2	1110,49	28/ 7/ 2	0,0
13/ 15/ 2	1110,49	28/ 15/ 2	0,0
14/ 15/ 2	1110,49	29/ 8/ 2	-283,79
14/ 16/ 2	1110,49	29/ 16/ 2	-283,79
15/ 1/ 2	1185,84		
15/ 10/ 2	1185,84		

Fig. 9. The table of resultant axial forces in the bars [4]

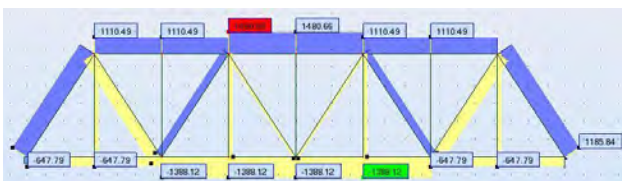


Fig. 10. Graphical view of the sizes of axial forces in bars of the plane truss [4]

To activate the graphic representation is used the tool "Diagrams for bars ..." in the roller blind "Results" of the main menu. After its start it is opened a window with several tabs which include:

- **NTM** - By the help of this tab are shown the individual components of forces which acting in the bars. In the case of the plane trusses is available only component of the force "Fx" which represents the resultant axial forces in the bars of the analyzed plane truss.
- **Parameters** - This tab enables adjust the appearance of the display diagram to make it understandable and readable. The card consists from three parts. In the first part called "Diagram description" can be

adjusts display characteristics of the resulting value beside the diagram which represents it.

In the second part called "Positive and negative values" can be adjusted a color severance of the diagrams which representing the values with the different orientation. This view in difference to the basic settings also provides clear informations about the bars loaded by pressure, or by tension.

For a graphical representation of results is also a tool "Maps on bars ...". It enables a color severance of the forces divided into the adjusted intervals according to their size.

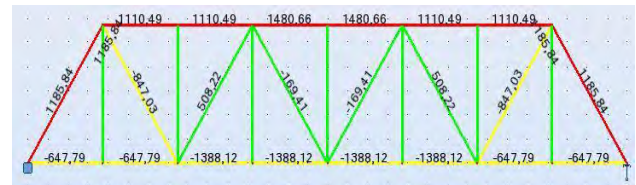


Fig.11. Graphical view by tool "Diagrams for bars ..." [4]

## Conclusion

The main objective of the solution above the described task was to create a study aid that will help students to understand issues of the static solving of the plane trusses. Important part of this work are the instructions for static solution of the plane trusses by help of the computer system Autodesk Robot Structural Analysis Professional 2011. With the basis of the work in this program, students will be informed within teaching a subject Computer modeling. Instructions for solution of the balance of the simple plane trusses is processed in manual form and also as an instructional video.

Our ambition was to arouse students interest not only about this issue but about the study of Engineering mechanics in general. Correct acquirement of the basic laws of mechanics and their application to solving technical problems in practice and development of the technical thinking is a great asset of students in their further studies and their application in engineering practice.

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