Finite Element Type and the Features of the I-Beam Simulation Influence on the Calculation Results

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INTRODUCTION

CAx applications field is unlimited and can help structural engineers and designers in any production industry to develop products better and faster. But using these systems is a very time-consuming process, requiring special knowledge and high qualification of employees in various fields of engineering. In case, when CAE is used to perform engineering calculations at the design of the product, it is necessary not only to have data about its parameters of the product, the loads acting on it, but also to understand how it is better to represent this object as a model for obtaining a result of a high level of accuracy.

A large separate class of calculated physical models is reinforced shells, which are used to model frames: ships, aerospace, railroad and automotive technologies. However, this models class representation from the point of view of FEM is possible in completely different ways: beams, beam and shells, only shells or solid models (e.g. Fig.1). Obviously, the results of calculating the stress-strain state of all these models will not be identical. Accordingly, there a problem of analyzing of used model type influence on the calculation results arises.

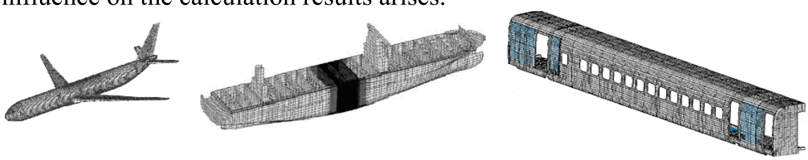


Fig.1 Typical Finite Element Models of Structures Constrictions

In this analysis, various approaches to the stress-strain state of I-beam with the help of FEM are considered. The variants of a typical for engineering analysis submission bending beam in the form of beam, shell, beam and shell finite elements are addressed. To assess influence of model's finites elements type choice on final calculations accuracy, simulation results are compared.

ANALYTICAL APPROACH BY THE BEAM THEORY

To calculate the normal and shear stresses, dependencies obtained in beam theory in the elastic approach are used.

Normal stresses at arbitrary point of the cross section are directly proportional to the values of the internal bending moment and the distance from the neutral axis and inversely proportional to the moment of inertia of the cross section about the neutral axis:

$$\sigma = \frac{M \cdot z}{J} = \frac{P \cdot x \cdot z}{J} \tag{1}$$

where M − internal bending moment;
P − external force;
x − distance from beam edge to a point of interest;
z − distance from the neutral axis to a point of interest;
J − moment of inertia about the neutral axis.
Shear stresses for I-beam cross section are calculated by:

$$\tau = \frac{Q}{8b_c}\left[b_p h^2\left(1-\frac{h_p^2}{h^2}\right)+b_c h_p^2\left(1-\frac{4z_p^2}{h_p^2}\right)\right] \tag{2}$$

where Q − internal force;
z_p− distance from the neutral axis to a point of interest;
b_c, b_p, h, h_p – parameters of the cross section presented in Fig.2;

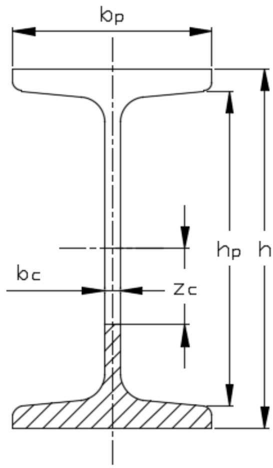
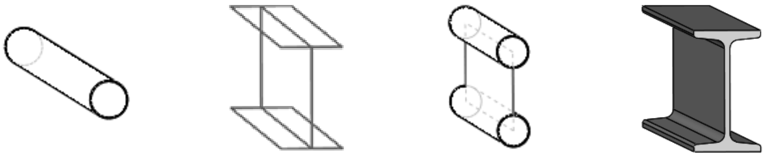


Fig. 2 I-beam cross section

ANALYSIS STRESS-STRAIN STATE OF THE BEAM

The calculation was made in CAE ANSYS in the module Static Structural. An analysis of a number of simulations in which the beam is presented in the form of finite elements such as beam (Fig.3a), shell(Fig.3b), beam and shell(Fig.3c), solid(Fig.3d).



a) b) c) d)

Fig. 3 Schematic representation of FE models

Obtained distributions of nominal stresses are shown in Fig.4 and Fig.5:

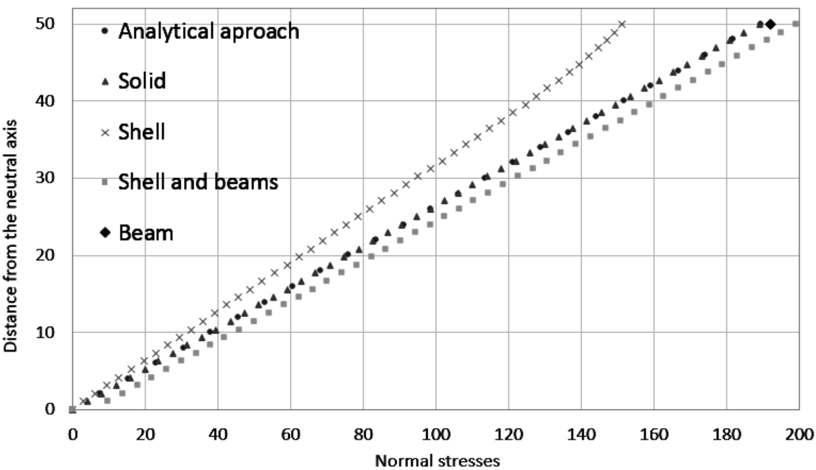


Fig. 4 Example distributions of normal stresses in height

Obtained results show, that normal stresses difference between analytical approach and simulation are next: beam is 1.4%; shell - 20%; shell and beams - 5%; solid - 0.2%. Shear stresses difference respectively for shells is 9.7%; shell and beams -27%; solid - 2%.

Obviously, the results analytical approach and solid presentation almost coincide, because in both solution methods for objects of such form and dimensions are similar. Significant differences with shell model are explained by bigger moment of inertia. The reason is that typical simulation maximum detail height becomes distance between caps centers of gravity. Differences of shear stresses are explained by features of simulation in the performance combination of FE various types in the same model.

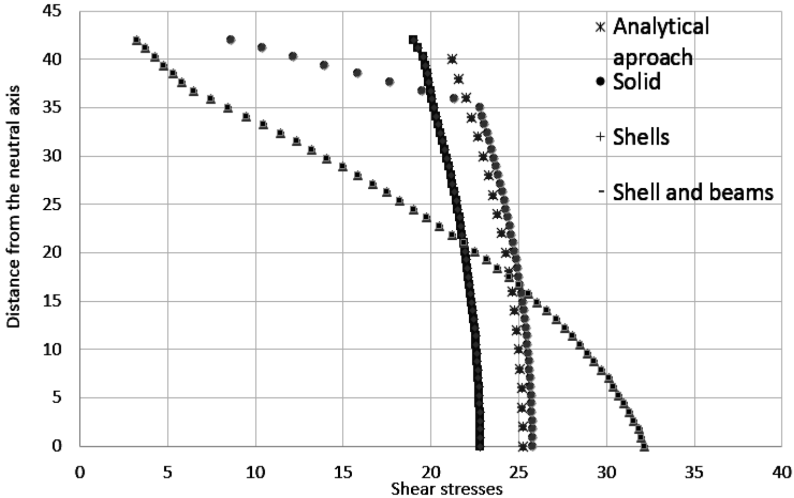


Fig. 5 Example distributions of shear stresses in height

CONCLUSIONS

It should be noted, that FE type choice is defined mainly by solving problem nature. In the design and verification calculations different finite elements types are usually applied. As can be seen from results, analytical approach and simulation, are different. Depending on selected finite element to represent the model difference and how it is applied in simulation systematically differences in greater or lesser side appear. Therefore it is required to apply special features in simulating such problems.

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