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The Influence of Beams` Axes Shifting on the Level of Stress and Displacements

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Abstract

In the case of metallic structures consisting of beams, there are situations where, technically, many beams can not or should not get fixed in their nodes, so that their axes intersect. In many cases, for these structures there are adopted computational models having beams with intersected axes, which no longer meet the real situation. In the present paper, the authors will present, on concrete examples, the results of the resistance calculus for structures of which the beams have intersected axes, versus the results of the resistance calculus for structures of which the beams have non-intersected axes.

Key words: *resistance calculus, beams, concurrent axes.*

General Considerations

Generally, the metallic structures are plane or spatial complex systems, multiple statically undetermined, consisting of beams with different cross-sectional shapes. The intersection of two or more beams is defined by the term "node”. Fixing the beams at nodes is usually done by welding or by rivets, so that a plane or a spatial structure with rigid nodes is built. The „rigid node”, in this paper, means that node which does not allow relative rotations of the beams that intersect the node.

In almost cases, the resistance calculus for these structures is made considering that the beams` axes intersect the nodes. In many situations, the calculus model having beams that intersect the nodes does not correspond with the real construction of these structures.

Figure 1 shows a spatial structure made of beams with circular or annular cross-sections. From the technical point of view, it is possible to weld them so that the beams` axes intersect the nodes.The model calculus of this structure, shown in figure 2, is consistent with the real structure and, in this case, the results obtained from a static or a dynamic calculation are correct. There are also situations where, technically, the beams can not or should not get fixed in the nodes, so that the axes intersect them.

Figure 3 presents a structure made of angle section profile beams and rectangular cross-section beams. From technical and technological reasons, the beams are welded at nodes, as it can be seen in figure 3, which means that their axes are not intersected. Adopting a calculus model with beams having intersected axes, as it is shown in figure 4, no longer meets the real situation. It is obvious that, in this case, the values of stress and displacements, resulting from a static model calculus, is incorrect. In practice, however, for structures similar to those shown in figure 3, in most cases, there are adopted calculus models with beams intersecting the nodes.

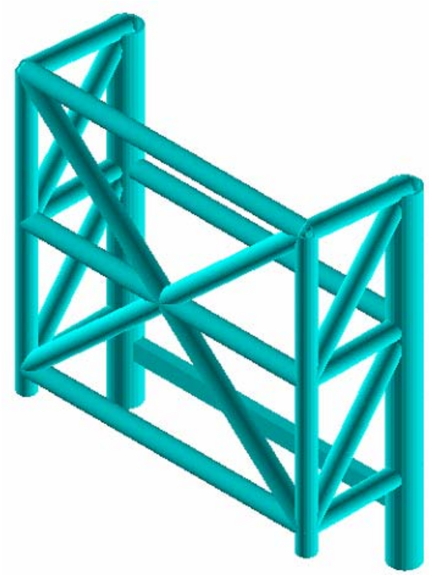

Fig. 1. Spatial structure (circular/annular cross-sections)

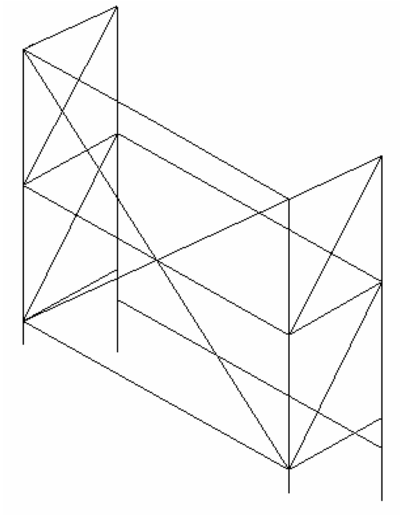

Fig. 2. Calculus model

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In the following chapter, there will be presented, using concrete examples, the results of the resistance calculus made for structures of which beams have intersected axes, in comparison with the results of the resistance calculus done for structures made of beams of which axes do not intersect.

There will be considered the structure shown in figure 5 (perspective view) and figure 6 (side view), which beams have an angle section profile. It is noted that the beams` axes do not intersect the nodes. The structure is embedded in nodes 2 and 4 and is submitted to a force in node 3, contained in its plan (see figure 7). For the static calculus of such structures there have been conceived specialized computer programs that allow the beams` shifting, so that they can meet the real situation, as it is shown in figure 5. Using such a program, after the static calculus which takes into account the fact that beams do not intersect the nodes, one gets the distorted form in figure 8 (plan view) or the one in figure 9 (side view). The structure no longer remains flat, having an overall maximum displacement along the Z axis (see figure 7) of 2.33 mm.

As it is shown in the stress map from figure 8, the maximum bending stress is $\sigma_{max} = 191{,}79 MPa$ and the minimum one is $\sigma_{min} = -200{,}61 MPa$. Calculation was repeated for the same structure, but with the beams having concurrent axes at nodes, as it is shown in figure 10. In this case, the distorted form shown in figure 11 shows that there is a lower lack of flatting of the structure and the maximum displacement along the Z axis is 0.46 mm.

Very important is that the level of the stress declined significantly, compared to the previously analyzed situation. The maximum bending stress has the value $\sigma_{max} = 63{,}36\text{MPa}$ and the minimum one is $\sigma_{min} = -93{,}5\text{MPa}$. By adopting a computational model with concurrent axes for a structure which beams have non-concurrent axes, it results significant calculation errors of 80.2% (when calculating the overall maximum displacement along the Z axis), of 67% (when calculating the values for maximum stress), and of 53.3% (when calculating the minimum stress).

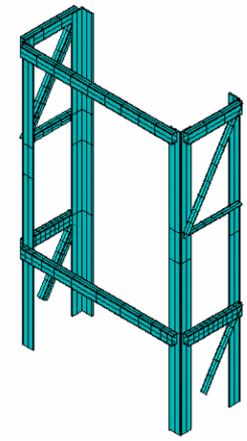

Fig. 3. Structure made of angle section profile beams and rectangular cross-section beams

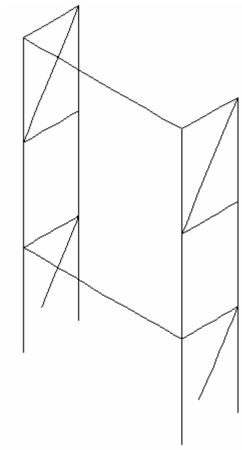

Fig. 4. Calculus model

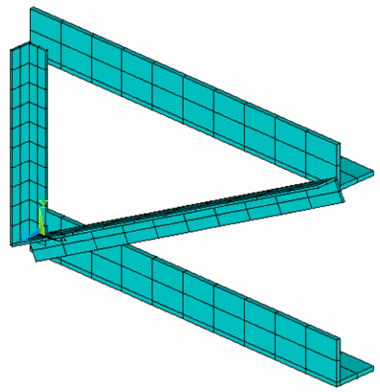

Fig. 5. Perspective view

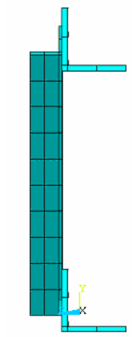

Fig. 6. Side view

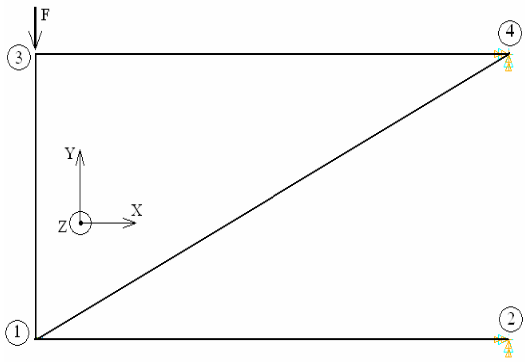

Fig. 7. Structure's loadings

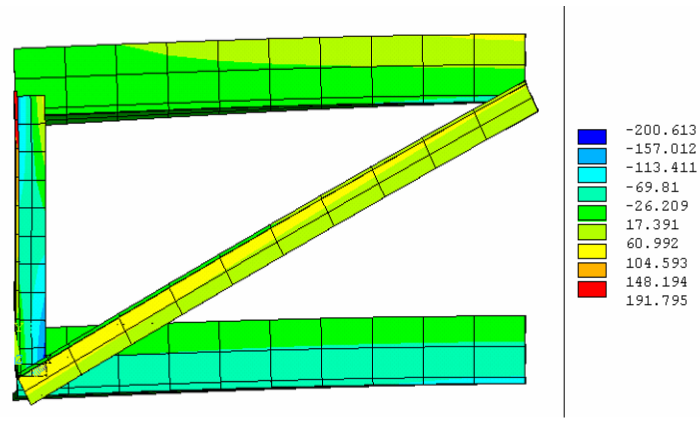

Fig. 8. Stress map (distorted form in plan view)

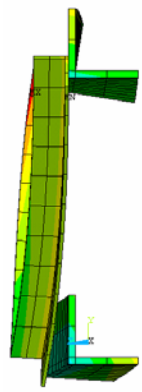

Fig. 9. Distorted form in side view

One considered the same structure, submitted to forces perpendicular to the structure's plan (along the Z axis) in the points 1 and 3, $F_3 = -F_1 = 10\text{kN}$. After calculation, the following values for the maximum and minimum bending stress were obtained:

- for the structure in which beams have non-concurrent axes at nodes: $\sigma_{max} = 176{,}6\text{MPa}$, $\sigma_{min} = -193{,}8\text{MPa}$.

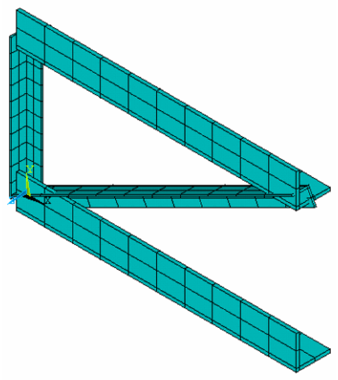

Fig. 10. Distorted form (plan view)

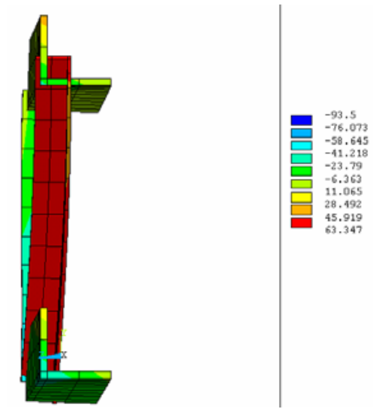

Fig. 11. Distorted form (side view) and stress map

- for the structure in which beams have concurrent axes at nodes: $\sigma_{max} = 190{,}1\text{MPa}$, $\sigma_{min} = -188{,}1\text{MPa}$.

The difference between the stress values, in this case is explained by the fact that the direction of forces acting on structure is the same with the axes\` shifting.

Conclusions

For the static or dynamic calculus of a given structure, one must take into account the real configuration of all beams. By adopting a calculus model with beams having concurrent axes, regardless of their real situation, the calculation can lead to significant errors. As result of the foregoing, the calculus errors exceed 50% when determining the stress and reach values like 80% when determining the displacements.

References

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Influența dezaxării barelor asupra nivelului de tensiuni şi deplasări

Rezumat

În cazul structurilor alcătuite din bare, există situații în care barele nu se pot sau nu trebuie să se prindă la noduri, astfel încât să rezulte concurența axelor acestora. Daca se adoptă modele de calcul cu axele barelor concurente, fapt care nu mai respectă situația reală, apar semnificative erori de calcul. În articolul de față se vor prezenta, pe exemple concrete, rezultatele calculelor de rezistență pentru structuri având bare cu axele concurente în noduri, comparativ cu rezultatele în cazul structurilor din bare cu axele neconcurente în noduri, precum şi erorile ce apar.