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USING OF SPATIAL STEEL TRUSSES IN THE ROOF

TELPISKO TĒRAUDA KOPŅU IZMANTOŠANA PĀRSEGUMĀ

V. Goremikins, J. Grabis and D.Serdjuks

Keywords: large span roof, rational geometrical parameters, grades of steel

1. Introduction

Large span roofs structures are widely used for the public and industrial buildings such as theaters, exhibition halls, covered stadiums, hangars, machine building enterprises. Large span roof structures can be divided into the following main groups depending on the static scheme:
- beam structures;
- frame structures;
- arch structures;
- shell structures;
- suspended structures;
- spatial structures.

The most significant advantages of large span beam structures are small width of supporting columns, simplicity of design procedure, producing, assembling and joints constructions, decreased sensitivity to temperature actions and displacements of foundations. The increased dead weight is the most significant disadvantage of these structures [1-5].

The truss is the main load bearing element of large span beam structures. The trusses are divided into the plane and spatial depending on the main load bearing elements placement. The spacious trusses (Fig.1.) are characterizes by the decreased dimensions of the elements cross-sections and decreased dead weight in some cases [3].

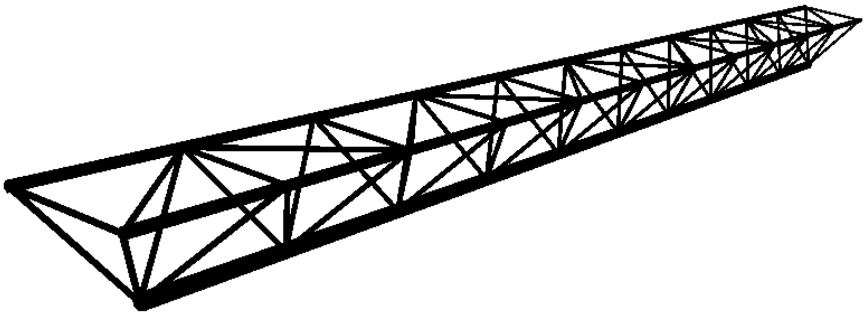

Fig.1. Spatial steel truss

The values and distribution of internal forces, acting in the elements under design load, depend on the main geometrical parameters of the truss. The main geometrical parameters of the spatial steel truss are angles between the grains and elements of lattice and height.

So, the aim of the paper is to consider using of spatial steel truss as the main load bearing element of large span roof. The main geometrical parameters of the spatial steel truss which enables to decrease the material consumption also should be evaluated.

2. Solution of the problem

The spatial steel truss is considered as the main load bearing element of the roof with the span which is equal to 60 m. The truss is with the parallel chords and height equal to 3 m.

The truss is loaded by the design vertical loads combination in 2.17 kPa, which includes dead weight of the roof and snow. The design value of snow load is 1.28 kPa. The structure of the roof contains purlins. So, design vertical load is applied as the concentrated forces to the nodes of top chords of the spatial truss. All elements of the spatial truss are with the welded round pipe cross-sections.

Steel grades C245, C285 and C375 with the design strength in 240, 280 and 365 MPa correspondingly, were considered as materials of the truss.

Rational from the point of view of materials consumption angles between the grains and elements of lattice (Fig.2.) were evaluated by the response surface method [6].

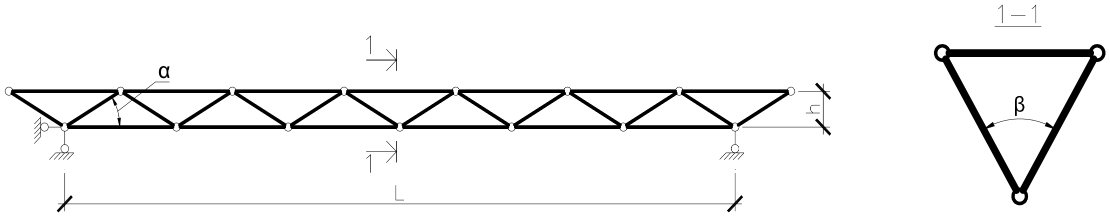

Fig.2. Scheme of the spatial truss: L – span of the truss; h – height of the truss; α - angle between the elements of lattice; β - angle between grains of the spatial truss

The dependences of the materials consumption on the angles between the grains and elements of lattice was evaluated in the form of second order polynomial equations for three mentioned grades of steel [7,8]:

$$P = b_0 + b_1\alpha + b_2\beta + b_{12}\alpha\beta + b_{11}\alpha^2 + b_{22}\beta^2 . \qquad (1)$$

The coefficients of equation (1) were determined on the base of numerical experiment. The experiment was joined with the determination of internal forces, which acts in the elements of the truss when the vertical design load is applied. All elements of the truss were axially compressed or tensioned. Areas of cross sections for tensioned elements were determined by the equation:

$$A = \frac{N}{R_y \gamma_c}, \qquad (2)$$

where: N – axial force acting in the element; R_y – design strength of steel; γ_c – material safety factor.

Then tensioned elements were checked by slenderness, which should not exceed 400. The value of safety factor was equal to 0.95. Areas of cross sections for compressed elements were determined by the equation:

$$A = \frac{N}{\varphi R_y \gamma_c}, \qquad (3)$$

where: φ – buckling coefficient.

The value of the buckling coefficient was taken as 0.8 in the first approximation. Then it was corrected basing on the equation (3). The value of safety factor was equal to 1.00 for compressed elements.
Rational values of angles α and β were determined by the system of equations (4) and then corrected to satisfy by the constructional requirements [3-5].

$$\begin{cases} \dfrac{\partial P}{\partial \alpha} = b_1 + b_{12}\beta + 2\mathrm{b}_{11}\alpha = 0, \\ \dfrac{\partial P}{\partial \beta} = b_2 + b_{12}\alpha + 2\mathrm{b}_{22}\beta = 0\,, \end{cases} \tag{4}$$

Second limit state also was taken into account. The maximum allowable vertical displacement of the spatial truss was equal to $\frac{1}{300}$ of the span.

3. Numerical results

Nine variants of spatial truss were analyzed by the computer program LIRA 9.4 for each considered grade of steel. The variants were differed by the values of angles between the grains and elements of lattice. The angle between grains of the spatial truss changes within the limits from 30 to 90 degrees. The angle between the elements of lattice changes within the limits from 30 to 60 degrees.
The values of coefficients of second order polynomial equations, which describe the dependences of material consumption on the angles α and β, are given in the table 1 for three grades of steel. The deviation of the results, obtained by the equations does not exceed 2.4%.

Table 1.

Coefficients of the equation (1)

Grade of steel	**Values of coefficients**					
	b_0	b_1	b_2	b_{12}	b_{11}	b_{22}
C245	16.702	-0.128	1.078	0.433	1.652	0.302
C285	14.927	-0.427	1.000	0.715	1.260	0.400
C375	12.610	-1.088	0.963	0.578	1.585	0.260

The materials consumption of the spatial truss changes within the limits from 16.24 to 20.32 t, from 14.33 to 17.88 t and from 11.91 to 15.93 t for grades of steel C245, C285 and C375, correspondingly.
Character of the dependences between material consumption and angles α and β can be illustrated by the Figure 3, where are shown the results, obtained for the grade of steel C 285.
In the case of steel grade C375 the growing of the angle β between grains of the spatial truss from 30 to 90 degrees causes the increase of materials consumption by 6.53, 12.38 and 28.14 % for the angles between the elements of lattice α equal to 30, 45 and 60 degrees, correspondingly.
Growing of the angles between the elements of lattice α from 30 to 60 degrees causes the decrease of materials consumption by 28.31, 16.86 and 6.68% for the angles between grains of the spatial truss β equal to 30, 60 and 90 degrees, correspondingly.

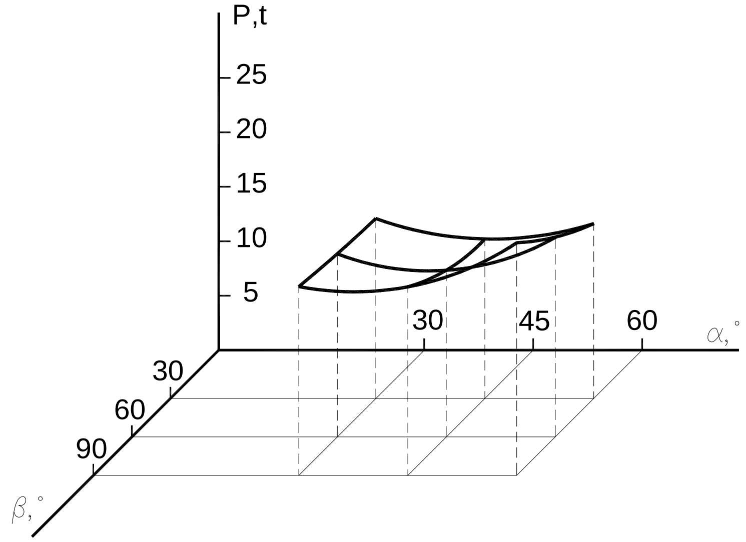

Fig. 3. The dependence of material consumption P on the angle between the elements of lattice α and the angle between grains of the spatial truss β (steel grade C285)

The dependences of the maximum vertical displacements of spatial truss on the angle between the elements of lattice α and the angle between grains of the spatial truss β also were obtained.
The maximum vertical displacement of the rational variants of spatial truss changes within the limits from 0.150 to 0.199 m. Character of the dependences between maximum vertical displacements and angles α and β can be illustrated by the Figure 4, where are shown the results, obtained for the grade of steel C 285.

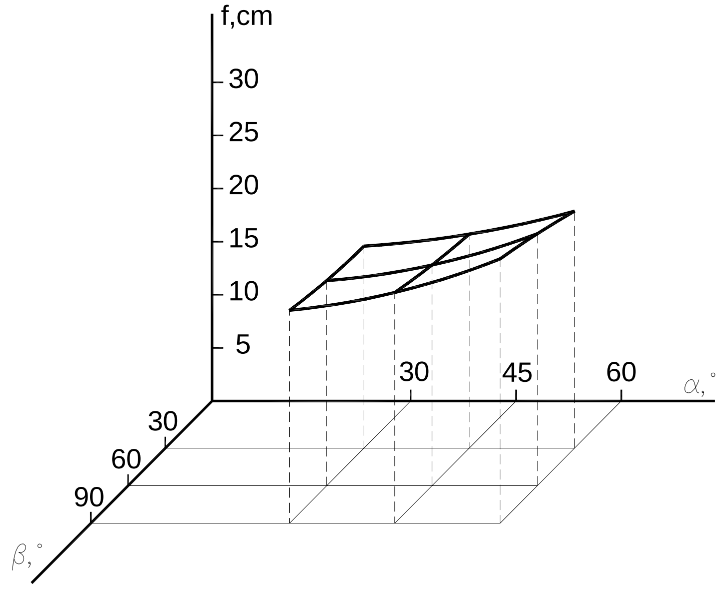

Fig. 4. The dependence of maximum vertical displacements f on the angle between the elements of lattice α and the angle between grains of the spatial truss β (steel grade C285)

The obtained dependences were used for the determination of the rational geometrical parameters of spatial truss, which are shown in table 2. The maximum vertical displacements of the rational variants of spatial truss changes within the limits from 0.179 to 0.199 m.

Table 2.

Rational geometrical parameters of spatial truss

Grade of steel	Angle between the elements of lattice α, degrees	Angle between grains of the spatial truss β, degrees	Material consumption P, t	Maximum vertical displacements, m
C245	48°	30°	16.11	0.179
C285	45°	30°	14.65	0.199
C375	45°	30°	14.44	0.199

The second limit state has significant influence on the obtained rational geometrical parameters of spatial truss. The materials consumption for spatial truss can be decreased till 13.99 and 11.46 t for grades of steel C285 and C375, correspondingly. Rational angle between the elements of lattice α is equal to 52.43° in the case. But the maximum vertical displacements will be equal to 0.209 and 0.261 m. The diagram, which illustrates the dependence of materials consumption on the grade of steel for spatial trusses with the rational geometrical parameters, is shown in Figure 5.

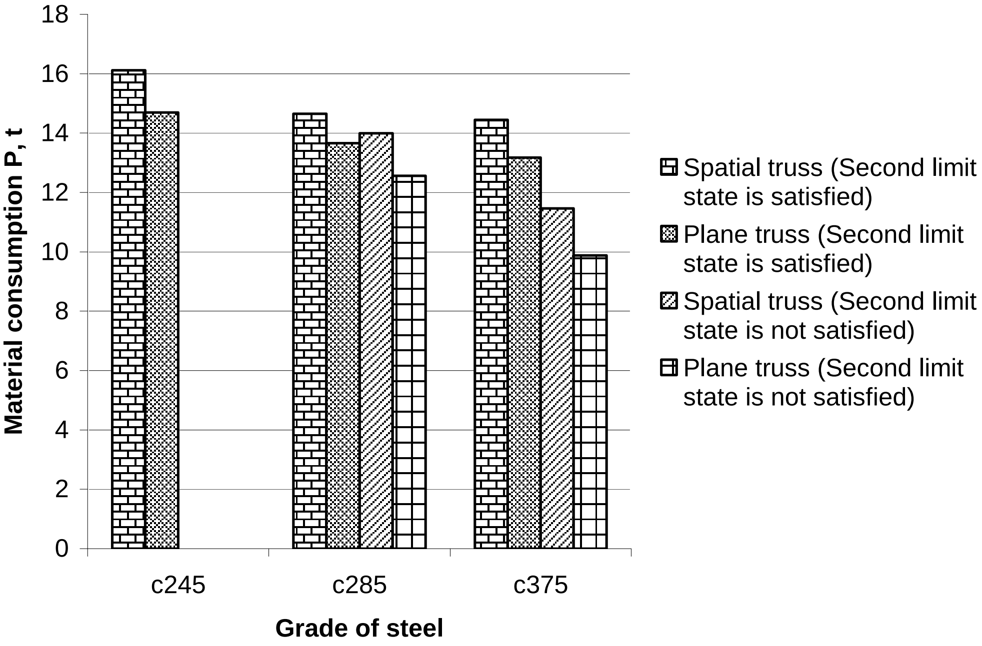

Fig. 5. The dependence of materials consumption on the grade of steel for spatial trusses with the rational geometrical parameters

The variants of the plane truss with the angle between the elements of lattice changing within the limits from 30 to 60 degrees also were analyzed. The comparison of rational from the point of view of materials consumption variants of plane and spatial trusses for grades of steel C245, C285 and C375 allows us to conclude that the plain trusses are at 10-15% more rational, than the spatial ones in considered case.

4. Conclusions

Large span spatial truss was considered as the main load bearing element of the roof.

The dependences of material consumption on the angles between the elements of lattice and angle between grains of the spatial truss were obtained for grades of steel C245, C285 and C375.

In the case of steel grade C375 the growing of the angle β between grains of the spatial truss from 30 to 90 degrees causes the increase of materials consumption by 6.53, 12.38 and 28.14 % for the angles between the elements of lattice α equal to 30, 45 and 60 degrees, correspondingly.

It was shown, that the rational from the point of view of materials consumption values of angle between the elements of lattice and angle between grains of the spatial truss are equal to 45 and 30 degrees, correspondingly, for grades of steel C285 and 375.

The dependences of the maximum vertical displacements of spatial truss on the angle between the elements of lattice and the angle between grains of the spatial truss also were obtained. It was shown, that the maximum vertical displacements of the rational variants of spatial truss changes within the limits from 0.179 to 0.199 m.

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Goremikins V., Grabis J. un Serdjuks D. Tērauda telpisko kopņu izmantošana liellaiduma pārsegumos

Darbā ir izpētīta trejskaldņu liellaiduma telpiska kopne. Kopnes veids – trapecveida paralēljoslu kopne ar trīsstūrveida režģa sistēmu. Ir pieņemts minimālais ieteicamais kopnes augstums – 3 m. Kopnes elementi ir veidoti no metinātām caurulēm.

Darbā ir atrastas sakarības starp kopnes režģa elementu slīpuma leņķi un kopnes masu, sakarības starp leņķi starp skaldnēm un kopnes masu, sakarības starp pielietoto tērauda klasi un kopnes masu. Ir atrastas optimālas režģa elementu slīpuma leņķa vērtības un leņķa starp skaldnēm vērtības. Darbā ir izvērtēta kopņu izliece atkarībā no pielietotas tērauda klases, leņķa starp skaldnēm trējskaldņu kopnei un režģa elementu slīpuma leņķa. Ir salīdzinātas trejskaldņu un plakanas kopnes no materiāla patēriņa viedokļa. Slodžu aprēķina kombinācija iekļauj sevī pašsvara slodzes, slodzes no jumta seguma, sniega slodzes. Kopnes aprēķins veikts pēc pirmā un otrā robežstāvokļiem.

Darbā ir secināts, ka plakanas kopnes ir izdevīgākas par trejskaldņu kopnēm, optimālākais kopnes režģa elementu slīpuma leņķis ir 45°, optimālākais leņķis starp skaldnēm ir 30°. Augststiprības tēraudu pielietojums kopņu elementu konstruēšanā nav racionāls. Kopnes izliece ir lielāka kopnēm no augststiprības tēraudiem, ar lielāku leņķi starp skaldnēm un lielāku režģa elementu slīpuma leņķi.

Goremikins V., Grabis J. and Serdjuks D. Using of Spatial Steel Trusses in the Roof

Spatial steel truss with the span equal to 60 m was investigated. The truss is with the parallel chords and triangular lattice. The minimum recommended height of the truss equal to 3m was adopted. The elements of the truss is the round welded pipes.

The dependences of material consumption on the angles between the elements of lattice and angle between grains of the spatial truss were obtained for three grades of steel. The dependences of the maximum vertical displacements of spatial truss on the angle between the elements of lattice and the angle between grains of the spatial truss also were obtained. The dependences were obtained for the case, when the structure is loaded by the design vertical load, which includes snow and structural dead weight. Two limit states were taked in to account.

It was shown, that the rational from the point of view of materials consumption angle between the elements of lattice and the angle between grains of the spatial truss are equal to 45 and 30 degrees, correspondingly. The usage of high-strength steel is not rational for such kind of trusses. Vertical displacements of spatial truss is greater for high-strength steel trusses with greater angle between the elements of lattice and greater angle between grains.

Горемыкин В., Грабис Я. и Сердюк Д. Использование пространственных ферм в большепролётных перекрытиях

В работе исследована трёхгранная большепролётная пространственная ферма. Вид фермы – трапециевидная с параллельными гранями и треугольной системой решётки. Принята минимальная рекомендуемая высота фермы – 3м. Элементы фермы сконструированы из электросварных круглых труб.

В работе найдены зависимости между углами наклона элементов решётки фермы и массой фермы, зависимости между углом между гранями и массой фермы, зависимости между использованным классом стали и массой фермы. Найдены оптимальные значения угла наклона элементов решётки и угла между гранями. В работе оценен прогиб фермы в зависимости от угла наклона элементов решётки, угла между гранями и использованным классом стали. Сравнены трёхгранные и плоские фермы с точки зрения материалоёмкости. Расчетная комбинация включает нагрузки от собственного веса, веса покрытия и снега. Расчет производился по двум предельным состояниям.

В работе доказано, что плоские фермы выгоднее трехгранных ферм. Оптимальный угол наклона элементов решётки равен 45°, оптимальный угол между гранями равен 30°. Использование высокопрочных сталей для элементов фермы не рационально. Прогиб фермы увеличивается при увеличении расчетного сопротивления, увеличении угла между гранями и увеличении угла наклона элементов решётки фермы.