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THE RATIONAL SCHEME DEFINITION OF THE CROSSTRUSSWEB ALONG THE BOTTOM CHORD OF INDUSTRIAL BUILDINGTRUSSES

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Abstract. In the industrial buildings with the support of trussed rafters on the columns at the level of the bottom chord, the main system of horizontal nodes, which the horizontal load rests and provides the rigidity of the building, is located on the bottom chords of trussed rafters. These nodes are usually constructed in the form of trusses (so-called wind trusses). The issue of designing cross trusses with the rational design solutions is relevant. One of the ways to choose the rational design solution for a cross truss is to determine a rational scheme of the web for steel consumption. The method for determining the web rational scheme of typical cross trusses on the truss bottom chords in terms of material consumption has been developed. This example shows that the cross nodes are 37% more economical than triangular ones with additional posts.

Keywords: industrial building, frame, covering, trussed rafters, nodes, cross truss

Introduction. One of the important tasks in the field of improving steel structures is to reduce their material consumption, which can be achieved through further studying of the actual operation of the structures, the improvement of design schemes, the development of structural form, the use of high strength steel, the use of the effective types of cross sections. The design standards of steel structures [1] recommend “to choose the optimal structural schemes of structures according to technical and economic indicators; to apply progressive constructions…; to provide manufacturability and the least complexity of structure manufacturing; to use the designs providing manufacturability and the least complexity of installation”.

The designing issue of nodes to cover the frame of the industrial building with the rational design solutions is relevant. One of the ways to choose the rational design solution for a cross truss is to determine the rational scheme of the web for steel consumption.

Analysis of recent research and publications. The nodes of industrial buildings create the rigidity of the building frame, provide the spatial operation of cross frames with redistribution of local loads applied to one of the frames, adjacent frames with reduced horizontal deformations at the level of crane beams. The nodes carry a number of horizontal loads such as wind, seismic, provide the stability of compressed elements of the covering and the set geometry of the framework during the installation. Within the covering in the General case, there are the following systems of the nodes: cross and longitudinal horizontal nodes in the plane of the top and bottom chords of trussed rafters; vertical nodes between the trussed rafters, nodes on the lanterns (if there are). Cross horizontal nodes are installed in each span of the building and placed at the ends of the temperature and seismic blocks. If the length of the temperature block is more than 144 *м* in the buildings there are the additional cross horizontal nodes inside the block [1]. In the buildings with the estimated seismicity rate 7, 8 and 9 grades, the number of the additional cross nodes is determined by calculating the effect of horizontal seismic loads. Longitudinal horizontal nodes are provided in the buildings equipped with bridge supported cranes, which require the passage galleries along the crane tracks, with the presence of trussed rafters, with the estimated seismicity rate more than 7 grades and in other technically validated cases [1, 5]. These nodes in the buildings with a span number up to three should be placed only along the last rows of the columns, and in the buildings with a span number more than three also be placed along the middle rows of the columns, so that they are located after 1-2 spans. Vertical nodes are installed in the place of cross horizontal nodes. The layout of the node scheme depends on the type of covering, the design features of the building frame and its operating conditions.

In the buildings with the support of trussed rafters on the columns at the level of the bottom chord, the main system of horizontal nodes, which carries horizontal loads and ensures the structural rigidity, is located on the bottom chord of the trussed rafters. These nodes are usually in the form of trusses (so-called wind trusses). In this case, the nodes on the top chords of the trussed rafters are installed to ensure the stability of the top chords during operation and installation. Also, if there is a rigid disk, the horizontal cross nodes are placed only at the level of the bottom truss chords, but there are demountable temporary nodes at the level of the top chords to verify the structures and ensure their stability during installation [2, 3]. The estimation of the stress-strain state of trusses of single-story industrial buildings in the end node blocks taking into account the wind pressure at the end of the building was considered in the research work [4].

The issue of designing cross trusses with the rational design solutions is relevant. One of the ways to choose a rational design solution for cross truss is to determine a rational web scheme for steel consumption.

The aim of the work is to develop the method for determining the rational scheme of the web of typical cross trusses along the bottom chords as for material consumption.

Research results. The nodes on the bottom chords of trussed rafters in the end node blocks of industrial buildings carry the wind load to the gable facade (Fig. 1).

Traditionally, to carry the wind pressure to the gable facade, at the level of the bottom chords of the trusses, the horizontal trusses are arranged with the help of plate hinges on the frame columns. Then the support reactions of the horizontal trusses from the wind load, through the nodes in the plane of the columns, are transmitted to the foundation.

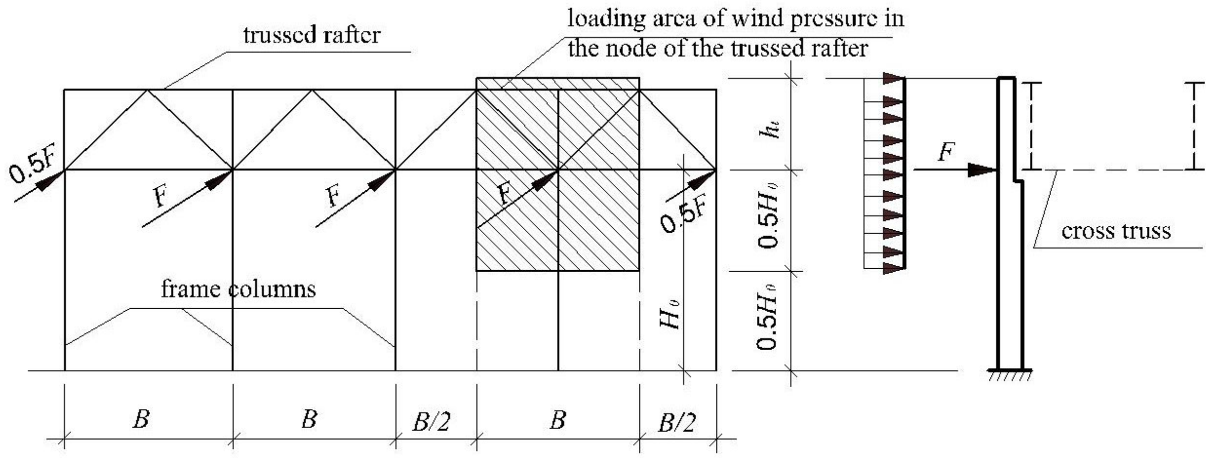

Fig. 1. Scheme of nodal load to the trusses along the bottom chords of trussed rafters in the end node blocks from wind pressure

The wind load to the gable facade through the enclosing wall structures is transmitted to the frame columns at the end of the building, as uniform distributed. The two horizontal reactions of the column arising from the wind load are distributed in such a way that one of them is transmitted to the foundation and the other one to the level of the truss bottom chords by means of plate hinges to the nodes of horizontal trusses (Fig. 1, 2).

These node horizontal trusses can be made with a cross web (Fig. 3, *a*), or with a triangular web and additional members (Fig. 3, *b*). In both cases, the bottom chords of the vertical nodes between the trusses are the web posts, and the bottom chords of the trusses are the chords of the node trusses.

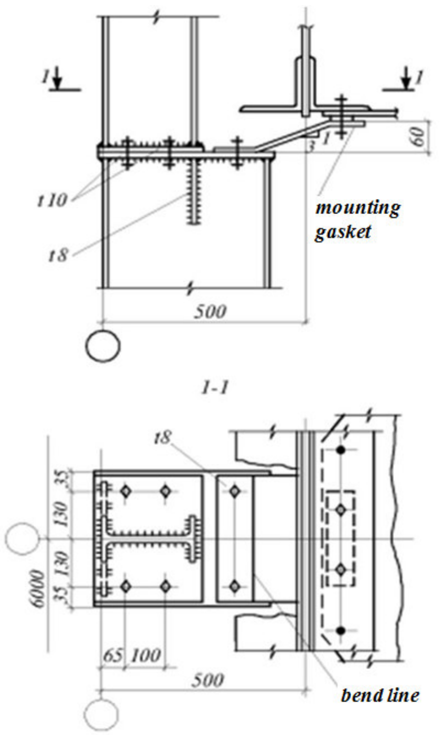

Fig. 2. The node connection of support column through the plate hinge to the horizontal node truss on the bottom chords of the lead trussed rafters

In Fig. 5 there are the geometric diagrams of node trusses on the bottom chords of typical trussed rafters of industrial buildings with the spans 18, 24, 30 and 36 *m* and the step 6 *m*. The forces in the node trusses from the single concentrated forces of wind pressure at the end of the industrial building, applied in the nodes of the bottom chords of the trussed rafters (at the level of plate hinges on the frame columns at the ends of the building) will be determined.

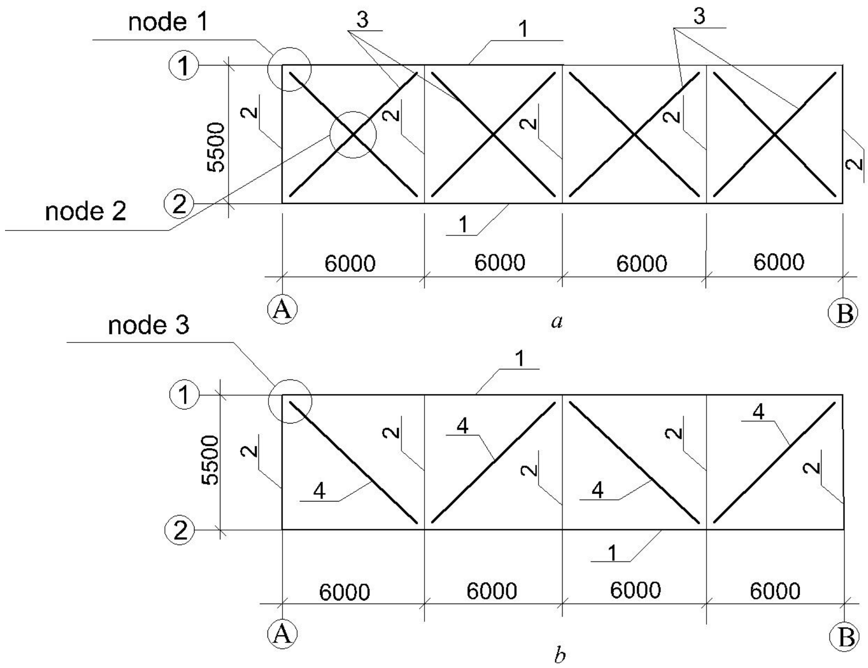

Fig. 3. Schemes of node trusses along the bottom chords of trussed rafters in the end node blocks of single-storey industrial buildings with the span 24 *m*

a – with a cross web; *b* – with a triangular web and additional posts

1 – bottom chord of the trussed rafter; *2* – bottom chord of the vertical node between the trusses; *3* – cross web of node truss; *4* – diagonal web element of node truss with a triangular web and additional posts

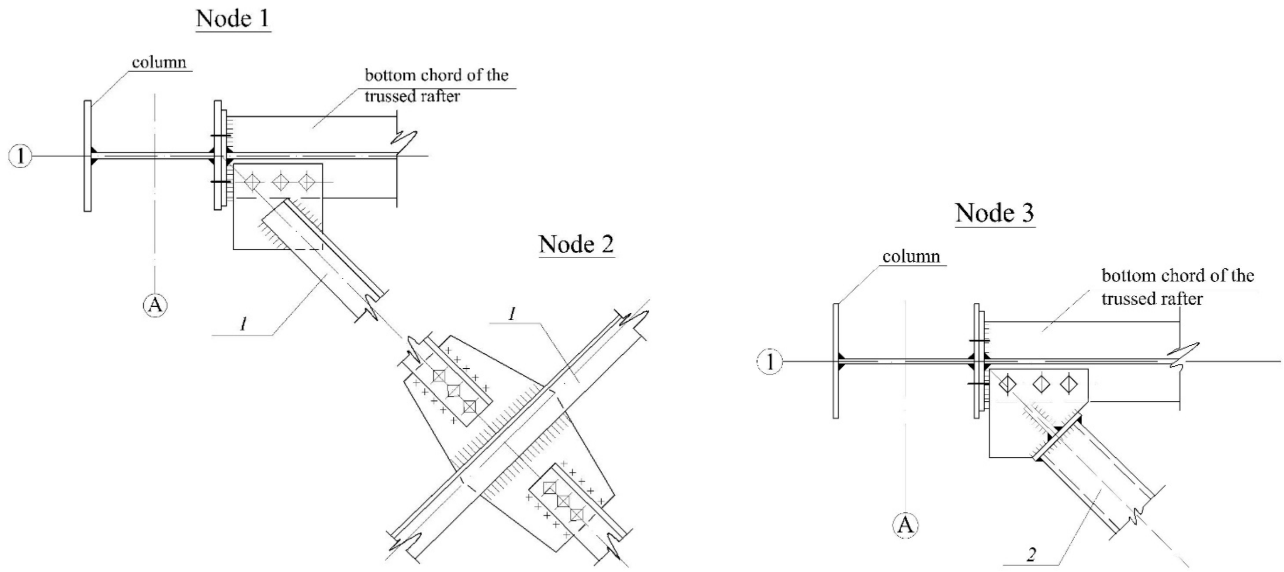

Fig. 4. Nodes 1, 2, 3

1 – cross web of the node truss; *2* – diagonal web element of node truss with a triangular web and additional posts

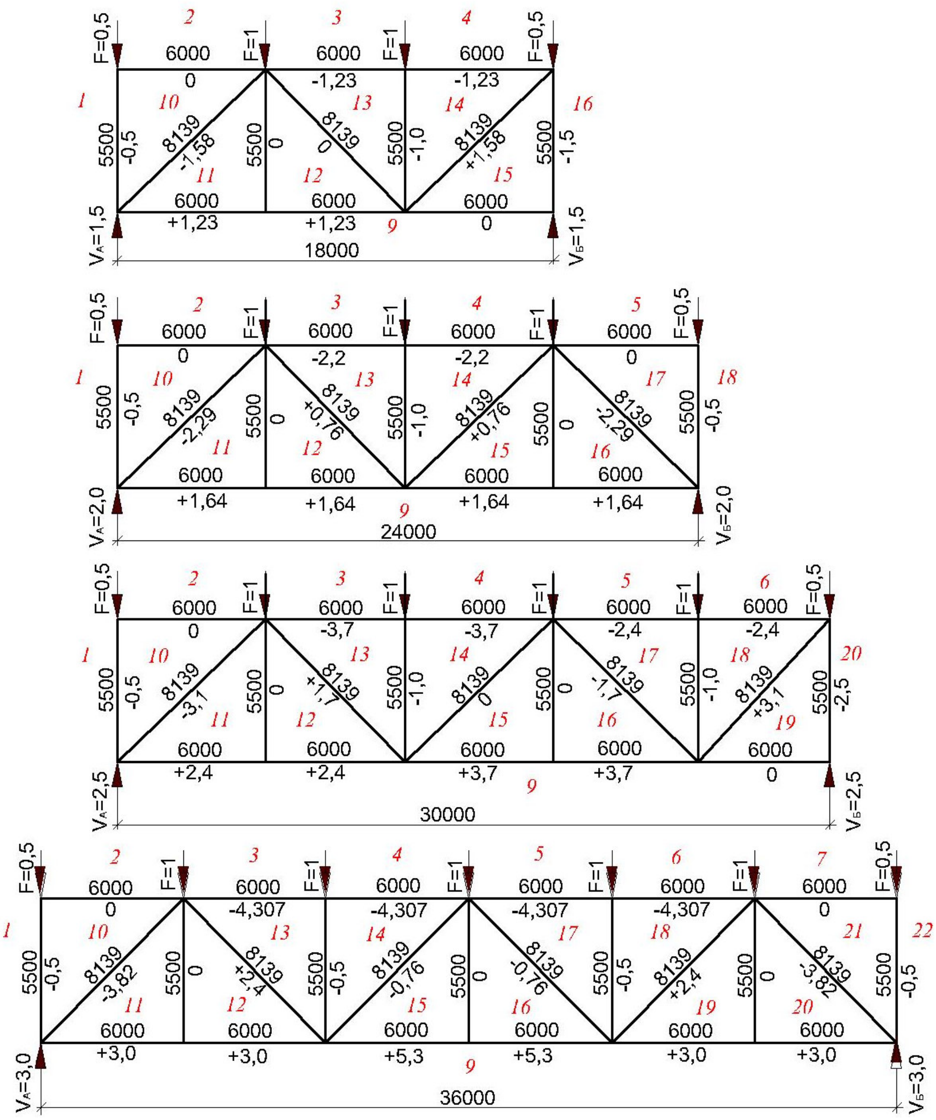

Fig. 5. Strength and length of node truss elements along the bottom chords of trussed rafters with a triangular web in node end blocks (length – *mm*, strength – *kN*)

Note: For node trusses with a cross web, its elements will have a positive value.

In these schemes (Fig. 5) there are the numbers of all the elements of node trusses, and each element in the numerator has its length *mm*, in the denominator – its strength *kN* from a single nodal load to the node trusses.

Thus, determining the nodal wind load for a specific area and multiplying it by the unit load effort, it is possible to determine the rational scheme (by steel consumption) of the nodes along the bottom chords of trusses in the end node blocks of single-storey industrial buildings.

There is the determination of the rational scheme of the web of cross node truss on steel consumptionas illustrated by the building with the following initial data: the building span $L = 24\ m$; calculated limit value of wind pressure $W = 0.45\ kN/m^2$ [6]; the shop height $H_0 = 7.0\ m$; the construction material – steel, grade C245; the step of frame columns $B = 6\ m$; $\gamma_{fm}= 1.035$ – the load reliability factor; $\gamma_n = 0.95$ – the safety factor for the responsibility; N_0 – the strength in the node truss element from the unit nodal forces of wind pressure (Fig. 4).

There are the actual nodal forces of wind pressure (Fig. 1, 6):

$$F = W \cdot \gamma_{fm} \cdot \gamma_n \cdot B \cdot (H_0 \cdot 0.5 + h_{truss}) = 0.45 \cdot 1.035 \cdot 0.95 \cdot 6 \cdot (7 \cdot 0.5 + 3.5) = 18.58 \qquad (\kappa H),$$

where: W – estimated maximum wind load, kN/m^2; γ_{fm}, γ_n – reliability coefficients; $B = 6\ m$ – step of frame columns; $h_{truss} = 3.5\ m$ – truss height, taking into account the size of the parapet ($h_{parapet} =$ $= 0.35\ m$).

<u>Node truss according to the scheme "*a*" (Fig. 2)</u>

Maximum force N_s in the support strut: $N_s = N_0 \cdot F = 2.29 \cdot 18.58 = 42.55 \qquad (\kappa H)$,

where: $N_0 = + 2.29$ – the forces in the element *10-11* (support strut) of the node truss from the single nodal forces of wind pressure for the step of the trussed rafters $B = 6\ m$ and the cross web (Fig. 5); $F = 18.58\ kN$ – the actual nodal force of wind pressure (Fig. 1, 6).

There is required diagonal member cross-sectional area:

$$A_{s.req.} = \frac{N_s}{R_y \cdot \gamma_c} = \frac{42.55}{24 \cdot 1.0} = 1.78 \qquad (cm^2).$$

Given the ultimate flexibility of the stretched element of the node truss ($\lambda_u = 400$), the minimum required gyration radius is:

$$i_{x,\min} = \frac{l_{ef,x}}{\lambda_u} = \frac{814}{400} = 2.04 \qquad (cm),$$

where: $l_{ef,x}$ – the effective length of the diagonal member for the web of node trusses coincides with the geometric one (Fig. 5).

We accept ∟ 70×5, $i_x = 2.16\ cm$, $A = 6.86\ cm^2$, $g = 5.38\ kg/m$ (Standard 2251-93).

Strength test:

$$\frac{N_s}{A \cdot R_y \cdot \gamma_c} = \frac{42.55}{6.86 \cdot 24 \cdot 1.0} = 0.26 < 1,$$

the strength condition is met.

Theoretical consumption of steel (per 1 mesh): $G = g \cdot l \cdot n = 5.38 \cdot 8.14 \cdot 2 = 87.6\ kg$,

where: $g = 5.38\ kg/m$ – weight of one running meter ∟ 70×5; l – geometric length (Fig. 5); n – number of elements per 1 mesh.

<u>Node truss according to the scheme "*b*" (Fig. 3)</u>

The diagonal member of the node truss according to the scheme "*b*" (Fig. 3, *b*) work in compression.

From the condition of ultimate flexibility ($\lambda_u = 180 - 60 \cdot \alpha = 180 - 60 \cdot 0.5 = 150$, [1]) the minimum required gyration radius is:

$$i_{x,\min} = \frac{l_{ef,x}}{\lambda_u} = \frac{814}{150} = 5.43 \qquad (cm),$$

where: $\alpha = N/(\varphi \cdot A \cdot R_y \cdot \gamma_c)$ – the ratio between strength and bearing capacity of the compressed rod; since we need the greatest flexibility, we take the smallest coefficient α (0.5).

We accept fl. □ 140×140×4 for which $i_x = i_y = 5.52$ *cm*, $A = 21.6$ *cm*^{2}, mass 1 *r.m.* $g = 17.0$ *kg/m* (Standard Б.В.2.6-8-95).

To perform the sustainability test, we find the value of the sustainability coefficient [1]:

$$\lambda_x = \frac{l_{ef,x}}{i_x} = \frac{814}{5.52} = 148; \quad \rightarrow \quad \bar{\lambda}_x = \lambda_x \cdot \sqrt{\frac{R_y}{E}} = 148 \cdot \sqrt{\frac{24}{20600}} = 5.05 \quad \rightarrow \quad \varphi = 0.299.$$

Sustainability test:
$$\frac{N_s}{\varphi \cdot A \cdot R_y \cdot \gamma_c} = \frac{42.55}{0.299 \cdot 21.6 \cdot 0.299 \cdot 1.0} = 0.27 < 1,$$

the condition of sustainability is fulfilled.

Theoretical steel consumption on the nodes according to the scheme "*b*": $G = g \cdot l = 17.0 \cdot 8.14 = 138.4$ *kg*.

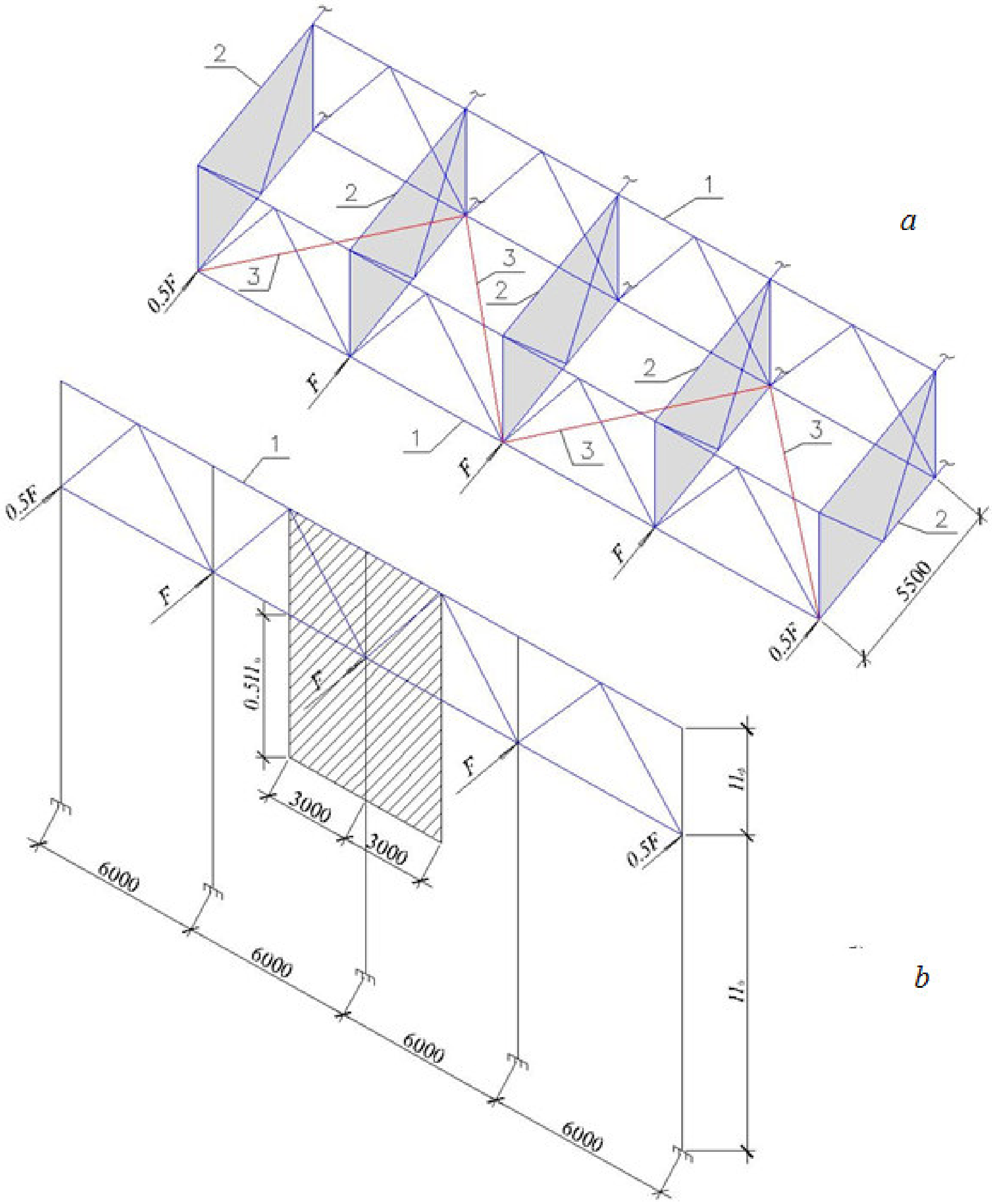

Fig. 6. Distribution scheme of wind pressure at the end of industrial building along the frame structures

a – scheme of the end node block; *b* – share of wind pressure at the end of the industrial building, which is at the level of the horizontal node truss along the bottom chords of the trussed rafters

1 – trussed rafters; *2* – vertical nodes between the trusses; *3* – diagonal members of the horizontal node truss along the bottom chords of the trussed rafters

Conclusion: With the help of the developed and presented method of determining the rational scheme of the web of typical node trusses along the bottom chords of the trussed rafters, the material consumption in this example is 37% more economical than triangular ones with additional poles.

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ВИЗНАЧЕННЯ РАЦІОНАЛЬНОЇ СХЕМИ РЕШІТКИ ПОПЕРЕЧНОЇ В’ЯЗЕВОЇ ФЕРМИ ПО НИЖНІМ ПОЯСАМ ФЕРМ ПОКРИТТЯ ПРОМИСЛОВИХ БУДІВЕЛЬ

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Анотація. В'язі покриття промислових будівель створюють загальну жорсткість каркаса будівлі, забезпечують просторову роботу поперечних рам. В'язі сприймають ряд горизонтальних навантажень таких, як вітрові, сейсмічні, забезпечують стійкість стиснутих елементів покриття і задану геометрію каркаса при монтажі. В межах покриття в загальному випадку призначаються наступні системи в'язів: поперечні і подовжні горизонтальні в'язі в плоскості верхніх і нижніх поясів кроквяних ферм; вертикальні в'язі між кроквяними фермами, в'язі по ліхтарях (за наявності ліхтарів). Компоновка схеми в'язів залежить від типа покриття, конструктивних особливостей каркаса будівлі і умов його експлуатації.

В будівлях з обпиранням кроквяних ферм на колони в рівні нижнього поясу основну систему горизонтальних в'язів, що сприймає горизонтальні навантаження і забезпечує жорсткість будівлі, розташовують по нижніх поясах кроквяних ферм. Ці в'язі зазвичай вирішують у вигляді ферм (так званих вітрових ферм). В цьому випадку в'язі по верхніх поясах кроквяних ферм встановлюють для забезпечення стійкості верхніх поясів при експлуатації і монтажі. Також при наявності жорсткого диска покриття горизонтальні поперечні в’язі розміщують тільки в рівні нижніх поясів ферм, але при цьому передбачають інвентарні тимчасові в’язі в рівні верхніх поясів для вивіряння конструкцій і забезпечення їхньої стійкості під час монтажу [2].

Актуальним є питання проектування поперечних в’язевих ферм з раціональними конструктивними рішеннями. Одним із шляхів вибору раціонального конструктивного рішення поперечної в’язевої ферми є визначення раціональної схеми решітки за витратою сталі.