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Research paper

A Variation Study of the Bearing Designs of a Covering of the Designed Building of the II Level of Responsibility Span of 24 m.

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Abstract

In this work were considered the sequence of calculation of a metal-wooden farm of a segment outline, according to the set of rules "Wooden glued and whole wooden designs" Construction Norms and Regulations II - 25 - 80 (the joint venture 64.13330 - 2011) [1], "Steel structures" Construction Norms and Regulations of II - 23 - 81 (the joint venture 64.13330 - 2011) and Construction Norms and Regulations 2.01.07-85 "Loadings and influences" [2] for calculation of a metal farm with a trapezoid outline.
The comparative analysis of calculations of loading of a body weight of farms, calculation of evenly distributed constant of the loading located on all flight, calculation of distributive snow loading is carried out. Settlement efforts in elements of farms are determined by method of cutting knots, longitudinal forces of N and the selections and check of sections of farms bending M. Derived moments are calculated in panels of the top belt. Owing to, the above-stated calculations a positive assessment of a possibility of design of the building with flight of 24 m is given, when calculating of the bearing designs on the greatest possible loadings where as a covering are offered metal-wooden segment and metal a trapezoid outline of a farm. According to the carried-out calculations, sections are picked up truly and undergo testing on all groups of limit conditions of building constructions, but after calculation of a consumption of material on designs of farms, it turned out that it is economically effective for design of the bearing designs of coverings to use a metal-wooden farm.

Keywords: *segment farm, building constructions, simple truss designs, distributive snow loading, trapezoid farm.*

1. Introduction

Public buildings and constructions are objects of long use and in use very often are exposed to all external influences, including climatic loadings (wind, snow). All this not only influences a general architecture, but also causes additional efforts from new operational loadings, and also influences work of structural elements of the building. Important criterion in selection of structural elements is decrease in prime cost of structures of buildings and constructions at observance of the main indicators of the bearing ability of designs, and also criterion of safety of buildings and constructions at various external influences. A particular interest in modern construction is represented by farms with curved belts so-called segment metal wooden [3]. If to compare traditional types of farms segment have a number of advantages. One of main is that, the effort on belts is almost identical on all flight [4,9]. And also differs in relative simplicity of production and assembly that reduces labor input and reduces production terms that in turn is economic.
In the real work we will carry out the comparative analysis, for further rational design of an object, with metal farms of a trapezoid outline, even more popular in construction. As well as segment, possess a number of positive characteristics, namely relative simplicity and convenience of installation, high speed of performance of work.
In recent years in Russia dozens of various buildings and constructions with application of farms of big flights, segment and metal with parallel belts, are built, these are sports constructions, shopping centers, showrooms, etc. all of them favorably differ from the point of view of an architectural esthetics.
In this work, the basis for the choice of the bearing covering design, the designed building of the sporting venue with big flight of 24 m served. The interest is of both from the scientific and practical point of view, and from the architectural and esthetic party.

2. Methods

As research object for the subsequent design structural elements served: a metal farm of a trapezoid outline and a segment wooden farm with the lower metal belt. To pick up the settlement scheme of metal wooden or metal farms optimum in all respects taking into account all requirements and norms, it is necessary to make calculation of wind, snow loadings according to normative documents.
As basic data for calculations the designed building of the sporting venue of the II level of responsibility, reliability coefficient served to destination $\gamma_n = 0{,}95, \gamma_n = 0{,}95,$ heated. The area of construction is chosen as the V snow (Naberezhnye Chelny) with a calculated value of snow load of the horizontal Earth's surface of 3,2 kPa. A step of the bearing designs of 6 m.
Materials of a segment metal wooden farm: a covering plate on the plan 5980kh1490mm: wood of edges - a pine 2 grades in accordance with GOST 8486-86*E; coverings from plywood of the FSF brand of a grade II/III»« GOST 3916-89; glue the FRF-50 brands; heater - heat-insulating plates of Rockwoolruf BATTS, mineral wool on synthetic binding. Vapor barrier - a polyethylene

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film 0,2 mm thick. Metal wooden farm: the top belt and brace strut we carry out from a pine 2 grades in accordance with GOST 8486-86*E; the lower belt - corners steel hot-rolled equal-flange L90x6*4 in accordance with GOST 8509-93.

3. Results and discussion

In order that, in use the building did not occur the collapses of a roof of the building, it is necessary to consider snow and wind loadings which correspond to this climatic area at design and calculations.

After selection of the scheme of a segment farm, according to design requirements, decided on the general sizes of a farm:

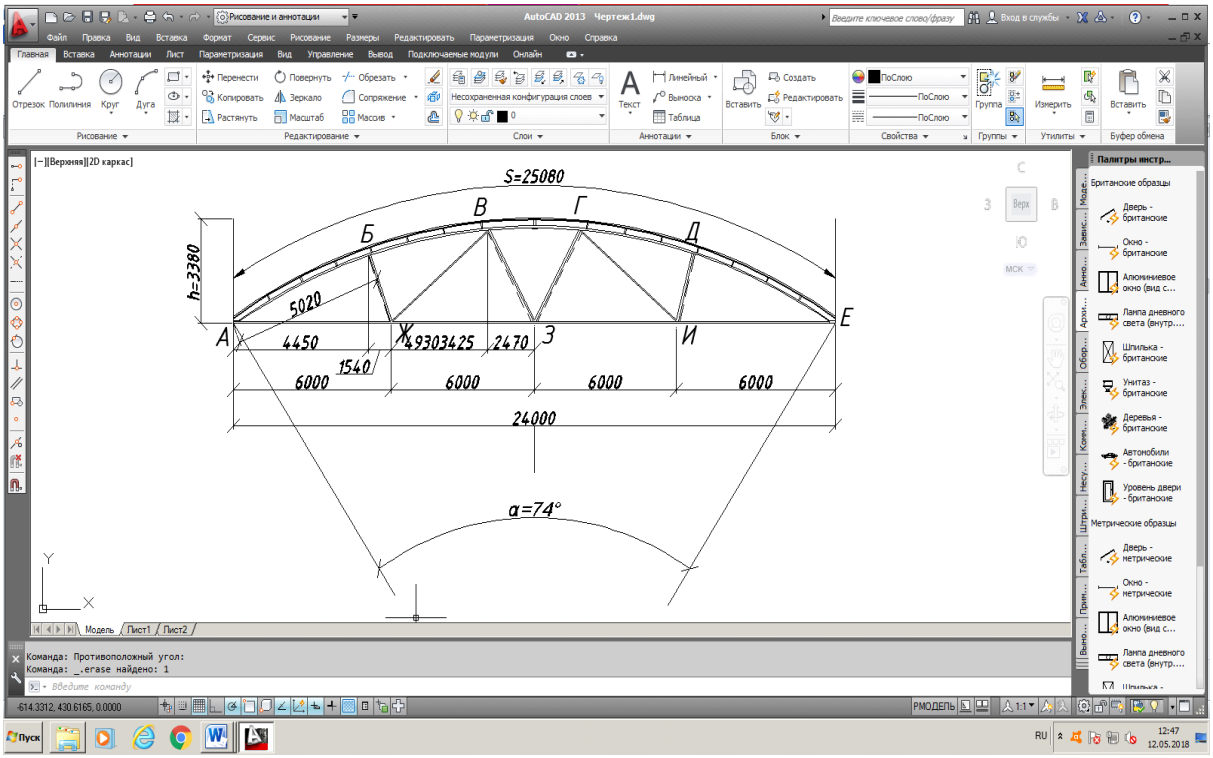

Fig.1: Geometric layout of the farm.

Settlement flight of a farm *of l=24,0 of m.* We accept a segment farm with a triangular lattice flight in axes 23,7 and height 3,38m.

The picked-up scheme of a farm, gives the chance to design minimum, in comparison with other types of lattices, cross sections of elements that gives the chance to reduce costs of production of a design, and it is already economic effect [5].

The top belt of a segment farm not cutting therefore we will accept the settlement scheme shown in the figure 1. At the same time the curvilinear top belt is replaced rectilinear - we connect knots of the top and lower belt straight lines - chords.

Static calculation of farms is conducted by the general rules of construction mechanics:

a constant and temporary (snow) loading on all flight;

constant loading on all flight and temporary (snow) on a half of flight;

the constant which is evenly distributed on all flight and under the law

triangles temporary;

the constant which is evenly distributed on all flight and temporary distributed under the law of a triangle on a half of flight;

calculation of efforts by method of cutting knots.

For definition of loading from a body weight of a roof calculation of flooring according to the joint venture 20.13330.2011 from which it was revealed was executed that, the snow evenly

distributed loading $s^{I} = 13{,}34 кН/м s^{I} = 13{,}34 кН/м$,

snow evenly distributed $s^{II} = 27\ кН/м s^{II} = 27\ кН/м$.

Settlement data are provided in table 1.

Table 1: Outer force on the truss.

Type of loading	Standard loading, kN/m	Coefficient reliability on loading	Settlement loading, kN/m
1. Body weight of a plate плиты	2,94	-	4,04
2. Body weight of a farm	1,02	1,1	1,122
Constant	3,96	-	5,162
Снеговая равномерно распределенная s^{I}	-	-	13.34
Снеговая равномерно распределенная s^{II}	-	-	27

In compliance of the joint venture 20.13330.2011 "Loadings and influences" the staticized editorial office Construction Norms and Regulations 2.01.07-85 * for the building with folding coverings two options of a load were considered.

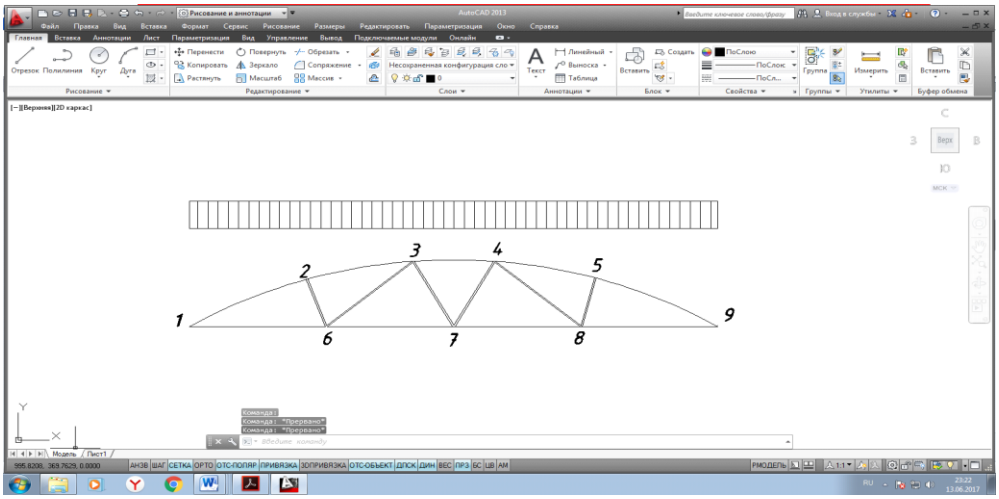

Fig.2: The first variant of snow load scheme

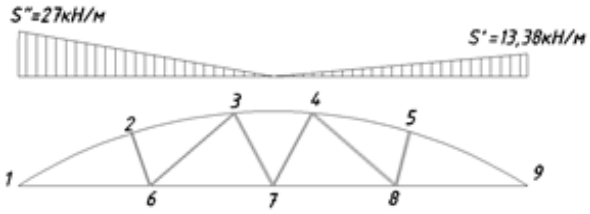

Fig. 3: The second variant of snow load scheme

Considering bulkiness of calculations and also the fact that authors already carried out certain calculations and results [6] which are necessary for use in this work are received, it became expedient to be limited only to the results of calculations presented in table 2.

Table 2: Rated force in the elements of the truss in kN

№ core No. No.	Designation of efforts	Efforts from constant loading of g=5.162 of kN/m of K=0,343	Efforts from snow loading		Settlement combinations of efforts	
			Uniform $s^I = 13.34 \frac{кН}{м}$	Triangular	gr.3+gr.4	gr.3+gr.5
1-2	N_1 $M_{s^{II},g.s^I}$ M_N $\sum M$	-101,96 11,32 -13,87 -2,55	-297,27 33,021 -40,43 -7,409	-218,2 54,56 -29,72 24,844	-399,23 -9,959	-320,16 22,294
2-3	N_2 $M_{s^{II},g.s^I}$ M_N $\sum M$	-95,4 14 -13 1	-278,08 402 -37,82 2,7	-184,72 34,035 -25,2 8,913	-373,48 3,3	-280,12 9,913
3-4	N_3 $M_{s^{II},g.s^I}$ M_N $\sum M$	-89,043 13,86 -12,11 1,75	-259,6 40,7 -35,31 5,39	-145,14 -19,74 	-348,64 7,14	-234,83
4-5	N_4 $M_{s^{II},g.s^I}$ M_N $\sum M$	-95,4 14 -13 1	-278,08 40,52 -37,82 2,7	-141,14 17,0175 -19,2 -2,1825	-373,48 3,7	-236,54 -1,1825
5-9	N_5 $M_{s^{II},g.s^I}$ M_N $\sum M$	-101,96 11,32 -13,87 -2,55	-297,27 33,021 -40,43 -7,409	-155 27,28 -21,08 6,2	-398,53 -9,959	-256,96 3,65
1-6 6-7 7-8 8-9	H_1 H_2 H_3 H_4	92 93 93 92	268,14 271 271 268,14	196,8 155 135,4 154,8	360,14 364 364 360,14	288,8 248 227,6 246,8
2-6 3-6 3-7	D_1 D_2 D_3	3,56 -4,3 1,55	10,38 -12,456 4,525	-28,96 24,75 -16,2	13,94 16,756 6,075	-25,4 30,45 -14,65
4-7 4-8 5-9	D_4 D_5 D_6	1,55 -4,3 3,56	4,525 -12,456 10,38	16,2 4,05 3,375	6,075 16,456 13,94	14,65 -0,25 6,935

Reliability of the received results compared to the set of rules Construction Norms and Regulations of II - 25 - 80 (the joint venture 64.13330 - 2011) "Wooden designs".
After stay in each knot of a farm of efforts from distributive snow loading, longitudinal forces and the bending moments, selection and check of section of a farm are made.
Section of the top belt and elements of a lattice appointed 2 grades from wood and picked up that quantity of layers in a glued element 12 the general height $h = 39{,}6$ см. $h = 39{,}6$ см., at the section of boards 3,3x18. The chosen section of the top belt undergoes testing for durability

$\sigma = 0{,}989$ кН/см^2 $= 9{,}9$МПа $< Rc = 15$N

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Having considered D1 compressed brace strut with $N = -25{,}4$кН $N = -25{,}4$кН, accepted section height under the terms of designing equal $h = 13{,}2$см.$h = 13{,}2$см. the section of the compressed brace strut Received by calculation is minimum necessary for ensuring durability of farms. Having calculated D2 stretched brace strut: $N = 30{,}45$ кН, $N = 30{,}45$ кН, defined that fastening in knot bolts $d = 12$мм$d = 12$мм. Tension in the stretched brace strut does not exceed settlement resistance

$\sigma_p = \frac{0.16\text{кН}}{\text{см}^2} < R_p = 0.9 * 0.8 = 0.72 \frac{\text{кН}}{\text{см}^2}$

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The lower belt is accepted from 2 steel corners 90x90x6 90x90x6. The top belt is fixed in knot by one constructive d=16mm bolts. Having calculated the support plate, accepted the cm A=20x25 sizes, $\delta = 12$мм.$\delta = 12$мм.
Taking into account all requirements and norms the optimum section of a metal wooden farm meeting all conditions of designing necessary for ensuring durability of a design was developed. According to it calculation of prime cost and weight of a design was made. Results are given in table 3.

Table 3: Wood expense on the roof consumption in Naberezhnye Chelny city

Item number	Constructive group	Element length	Element section	Weight	Price
		m	mm	kg	rur.
F1	Top belt	25,08	Glued board Timber of coniferous breeds in accordance with GOST 18288-97 L180x396	39*24=936	55200 (2300 – 1 board)
D1	Brace struts	2.59	Timber of coniferous breeds in accordance with GOST 18288-97 L180x108*2	87	7301
D2	Brace struts	4.73	Timber of coniferous breeds in accordance with GOST 18288-97 L180x132*2	193,5	16295,8
D3	Brace struts	4.07	Timber of coniferous breeds in accordance with GOST 18288-97 L180x132*2	166,5	14022
M1	Lower belt	24	Corners are steel hot-rolled equal-flange. Range. GOST 8509-93 L90x6*4	8,33	11961,12
H1	Flooring	3	Plywood covering Timber of coniferous breeds in accordance with GOST 18288-97 L1490x9*4	121,52	1068
H1	Flooring	6	Longitudinal edge Timber of coniferous breeds in accordance with GOST 18288-97 L170x40*4	13,832	972
H1	Flooring	0,44	Cross edge Timber of coniferous breeds in accordance with GOST 18288-97 L170x40*15	38,04	267
H1	Flooring	3	Plywood covering Timber of coniferous breeds in accordance with GOST 18288-97 L1490x9*4	121,52	1068
Nails		0,1	D=4 mm, 5984 pc	56,85	10215
Corner		6	Corners steel hot-rolled equal-flange Range. GOST 8509-93 90x90*2	6	46331
M20 bolt		0,71	179 pieces	45,3	3555,2
Total				1794	152824,32 rur

As basic data for calculation of a metal farm with parallel belts flight of 24 m it is given:
-step of farms of 6 m;
-section of elements of a lattice of a farm is executed from square steel profiles;
-warm covering;
-the climatic area on a snow cover - V.
Farm material - C245 brand steel in accordance with GOST P 54157-2010, connections of cores in farm knots welded, reliability coefficient to destination buildings $\gamma_n = \mathbf{1{,}1}$. Farm height on the center of 3150 mm.
Calculation and designing of knots of a farm is made according to requirements, shown Construction Norms and Regulations ll-23-81 (91) *. Calculation of a metal farm is executed by means of the program SCAD complex realized as the integrated system of the strength analysis and design of structures on the basis of a finite element method. The maximum efforts in elements of the settlement scheme are presented in table 4.
After finding of efforts, calculation on finding of movements of knots of a metal farm was made. Results of calculation are presented in table 5 according to which it is possible to draw a conclusion that the picked-up rigidity elements, namely square pipes according to GOST P 54157-20100 undergo testing for a design deflection.
According to the joint venture 16.13330.2017 taking into account all requirements and norms the optimum section of a metal farm of a trapezoid outline meeting all conditions of designing necessary for ensuring stability of a design was developed. According to it calculation of prime cost and weight of a design was made. Results are given in table 6.

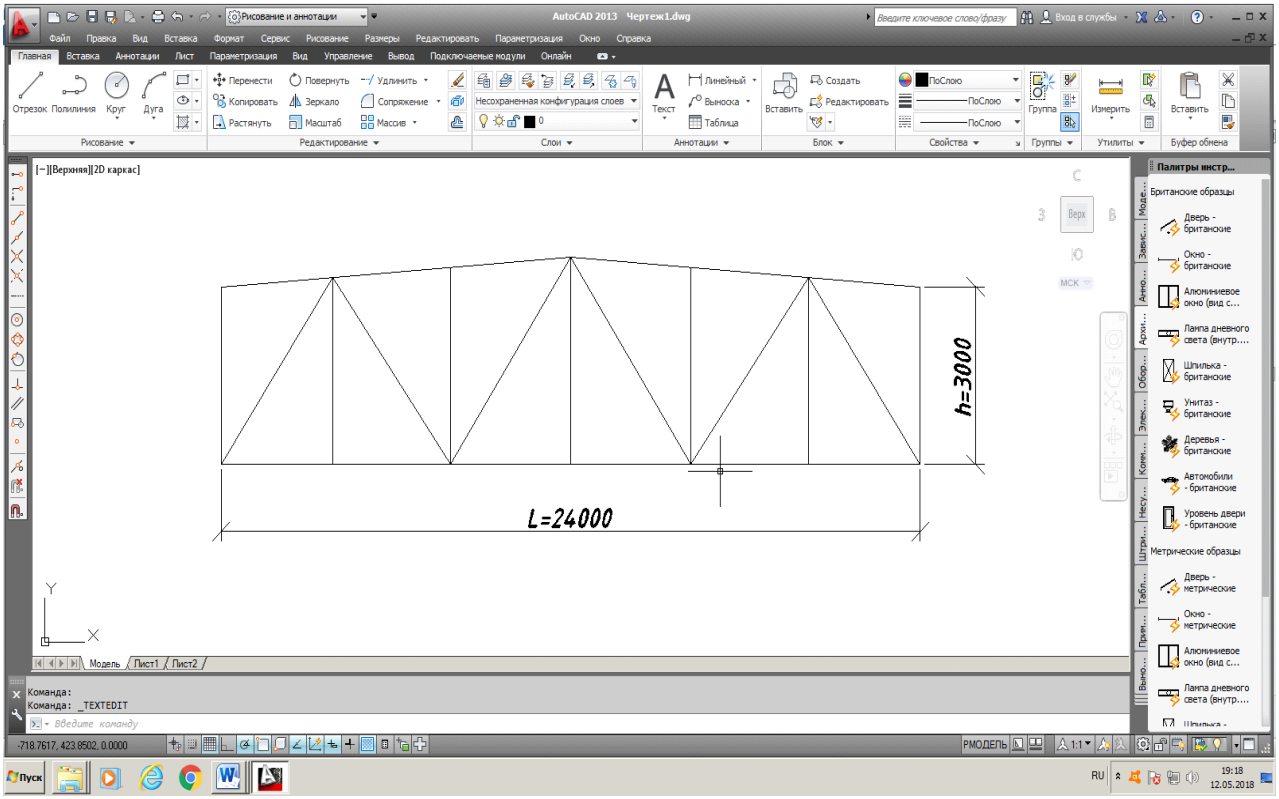

Fig.4: Scheme of the trussed rafters

Table 4: Maximum efforts in farm elements.

Name	max +				max -			
	Size	Element	Section	Ht.	Size	Element	Section	Ht.
N	17.9919	20	1	2	-40.977	15	1	2
My	1.94598	18	2	2	-3.594	13	3	2
Qz	4.72982	18	1	2	-4.7298	13	3	2

Table 5: Maximum movements of knots of a farm.

Name	max -			max -		
	Size	Knot	Ht.	Size	Knot	Ht.
X	2.0131621	15	2	-2.013162	18	2
Z	0.60541	16	4	-10.85149	7	2
UY	4.4421393	14	2	-4.442139	3	2

Table 6: Metal expense on the roof consumption in Naberezhnye Chelny city

Item number	Constructive group	Element length	Element section	Weight	Price
		m	mm	kg	rur.
14-15	Upper belt	4	Pipes are steel profile square section in accordance with GOST P 54157-2010 L180x12	128,2	13570
15-16	Upper belt	4	Pipes are steel profile square section in accordance with GOST P 54157-2010 L180x12	128,2	13570
16-13	Upper belt	4	Pipes are steel profile square section in accordance with GOST P 54157-2010 L180x12	128,2	13570
13-17	Upper belt	4	Pipes are steel profile square section in accordance with GOST P 54157-2010 L180x12	128,2	13570
18-3	Upper belt	4	Pipes are steel profile square section in accordance with GOST P 54157-2010 L180x12	128,2	13570
1-5	Lower belt	4	Pipes are steel profile square section in accordance with GOST P 54157-2010 L120x8	57	6429
5-6	Lower belt	4	Pipes are steel profile square section in accordance with GOST P 54157-2010 L120x8	57	6429
6-7	Lower belt	4	Pipes are steel profile square section in accordance with GOST P 54157-2010 L120x8	128,2	13570

7-8	Lower belt	4	Pipes are steel profile square section in accordance with GOST P 54157-2010 L180x12	128,2	13570
8-9	Lower belt	4	Pipes are steel profile square section in accordance with GOST P 54157-2010 L120x8	57	6429
9-2	Lower belt	4	Pipes are steel profile square section in accordance with GOST P 54157-2010 L120x8	57	6429
1-15	Brace struts	5,03	Pipes are steel profile square section in accordance with GOST P 54157-2010 L180x12	128,2	13570
15-6	Brace struts	5,03	Pipes are steel profile square section in accordance with GOST P 54157-2010 L180x12	128,2	13570
6-13	Brace struts	5,09	Pipes are steel profile square section in accordance with GOST P 54157-2010 L120x8	57	6429
13-8	Brace struts	5,09	Pipes are steel profile square section in accordance with GOST P 54157-2010 L120x8	57	6429
8-18	Brace struts	5,03	Pipes are steel profile square section in accordance with GOST P 54157-2010 L180x12	128,2	13570
18-2	Brace struts	5,03	Pipes are steel profile square section in accordance with GOST P 54157-2010 L180x12	128,2	13570
15-5	Brace struts	3,05	Pipes are steel profile square section in accordance with GOST P 54157-2010 L120x8	65,2	3943
16-6	Brace struts	3,1	Pipes are steel profile square section in accordance with GOST P 54157-2010 L120x8	66,3	4007
13-7	Brace struts	3,15	Pipes are steel profile square section in accordance with GOST P 54157-2010 L120x8	67,4	4077
17-8	Brace struts	3,1	Pipes are steel profile square section in accordance with GOST P 54157-2010 L120x8	66,3	4007
18-9	Brace struts	3,05	Pipes are steel profile square section in accordance with GOST P 54157-2010 L120x8	65,2	3,943
3-2	Brace struts	3	Pipes are steel profile square section in accordance with GOST P 54157-2010 L120x8	64,2	3878
14-1	Brace struts	3	Pipes are steel profile square section in accordance with GOST P 54157-2010 L120x8	65,2	3,943
Total				2213 kg	215707 rur

4. Summary

By results of the done work it is possible to draw a conclusion those settlement schemes of metal wooden and metal farms optimum in all respects taking into account all requirements and norms were developed. On the basis of all calculations the conclusion is drawn that all sections of farms are picked up truly and undergo testing on all groups of limit conditions of building constructions.

According to the executed calculations of a consumption of material of designs, it is revealed that the picked-up segment metal wooden farm is less on the weight and prime cost of a design, than metal that once again favorably distinguishes segment metal wooden farms from traditional building constructions of a covering [7].

5. Conclusions

In work the comparative analysis of calculations of loading of a body weight of farms, check on durability at the set climatic loadings was carried out. The conclusion that the chosen design, namely the metal wooden segment farm, can be chosen as a covering for the building with flight of 24 m, around construction - the V snow (Naberezhnye Chelny) with a calculated value of snow load of the horizontal Earth's surface of 3,2 kPa was by results drawn. At design of a metal wooden farm as a covering, it is possible to reduce considerably amount of the used material and to make construction of a roof much cheaper. Having applied the correct technique to finding of settlement data, the optimum ratio between the price of construction of a design, and its operational characteristics is reached.

In the offered work remained not mentioned questions on ensuring durability of wooden designs and on protection against ignition [8,9].

Acknowledgements

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