RESEARCH OF THE BEHAVIOR OF ROOF SINGLE WELDED LAP JOINTS

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Abstract: *New tendency of design of steel roofs of cylindrical tanks is to put cover plates under steel structure. This type of roof has only radial girders. Joints between cover plates are made with overlapping and filled welds. Usually these joints are single-welded.*

The author made research about real work of the thin roof cover plates and filled welds. Comparison between traditional methods of design and nonlinear solution with ANSYS is made.

Key words: *steel roof, radial girders, roof cover plates, single-welded lap joint, nonlinear solution*

During design of roofs for cylindrical tanks or silos, use of those one type in which the roof structure is positioned upon the roof plates, is more and more often. The advantages of this type of constructive solution are:

- smooth internal surface which will not retain microorganisms and it is easy to put protective painting;
- facilitate the production and erection works;
- facilitate the maintenance works of the protective cover lays put upon the roof structure.

As disadvantages can be mentioned:

- roof plates are two-side supported which means bigger thickness;
- the radial roof girders are not supported by the roof plates against the loss of stability in the plane of the cover.

1. The conditions and purpose of the research

The roof construction is external (upon the plates). It is made through the radially positioned girders. The sheets in roof cover plates are overlapped on width $5.t_r$ (fig.1). The joint between them has been done with single weld that is done in bottom position. The cathetus of these joints is equal to the thickness of the sheets.

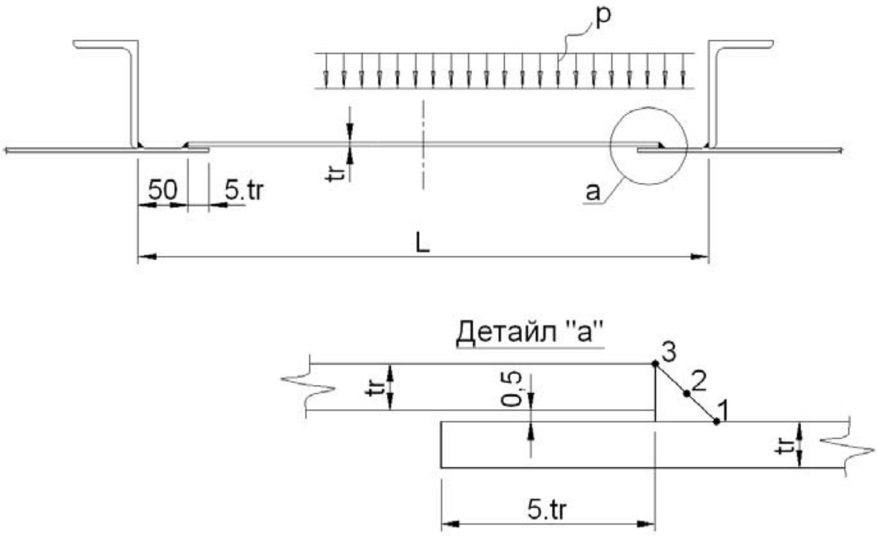


fig. 1 Roof construction and joints

The purpose of the current research is to be analyzed:

- real work of the roof plates when supporting structure is above;
- up to what level the weld joint between the two sheets may cause their equal rotations;
- concentration of stress in field near to welding joints.

2. Variants of the research

Behavior of roof plates is analyzed according to two independent methods in order to compare the calculated results:

- manual, traditional solution, with geometrical linear solution;
- numerical, FEA analysis, with use of ANSYS. The system has geometrically nonlinear behavior which has been considered.

Pressure upon the roof' sheets depend on the area where the facility is erected and on conditions of exploitation of the facility. During this research it is accepted that the pressure is equally distributed with intensity $p = 2$ kN/m^2.

a) checking of efforts and deflections when the condition of the problem is linear

The roof sheets are accepted as a single span girder which is moment resisting in its two ends (fig.2) because the supporting sections do not rotate. It is accepted that the weld joint between sheets assures their equal rotation – there are not pins in the girder.

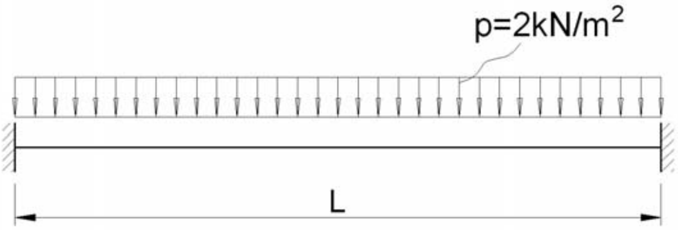


fig. 2 Scheme of the roof's cover plate

The distance between supports is equal to the maximum distance between radial girders. The construction's geometrical nonlinear behavior is not reported as it is the usual practice in the traditional calculations and design.

Stress in various points in the girders, in the middle of the field $\boldsymbol{\sigma_m}$ and above the support $\boldsymbol{\sigma_{supp}}$, as well as the deflection $\boldsymbol{f}$ in the middle , by pressure $p = 2$kN/m^2, depending on the thickness of the joint $\boldsymbol{t_r}$ and span $\boldsymbol{L}$ are shown in the Table 1.

This research cannot determine the real stress in field near to welding joint (p.1, p.2 and p.3 of fig. 1), joining two sheets.

TABLE 1

t_r, mm	L = 1000 mm			L = 1500 mm			L = 2000 mm		
	σ_m, MPa	σ_{supp}, MPa	f, mm	σ_m, MPa	σ_{supp}, MPa	f, mm	σ_m, MPa	σ_{supp}, MPa	f, mm
4,0	31,24	62,48	4,65	70,31	140,62	23,54	125	249,99	74,41
5,0	20	40	2,38	45	90	12,05	80	160	38,09
6,0	13,88	27,76	1,38	31,25	62,5	6,98	55,55	111,11	22,04

б) checking of the efforts and deflections during the geometrical nonlinear solution of the problem

Using the opportunities given by a ANSYS the three dimensioned models of the roof plates have been created (fig.3). During the FEA calculation the geometrically nonlinear behavior of the construction and the influence of lap weld joints have been considered.

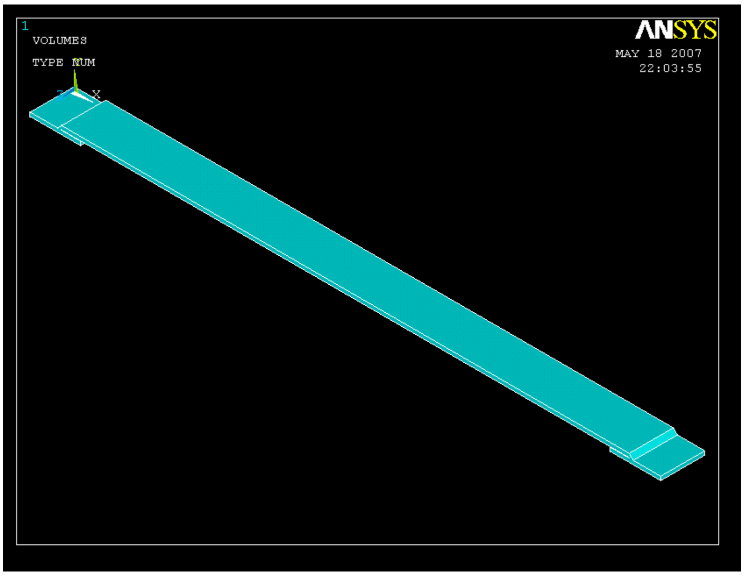
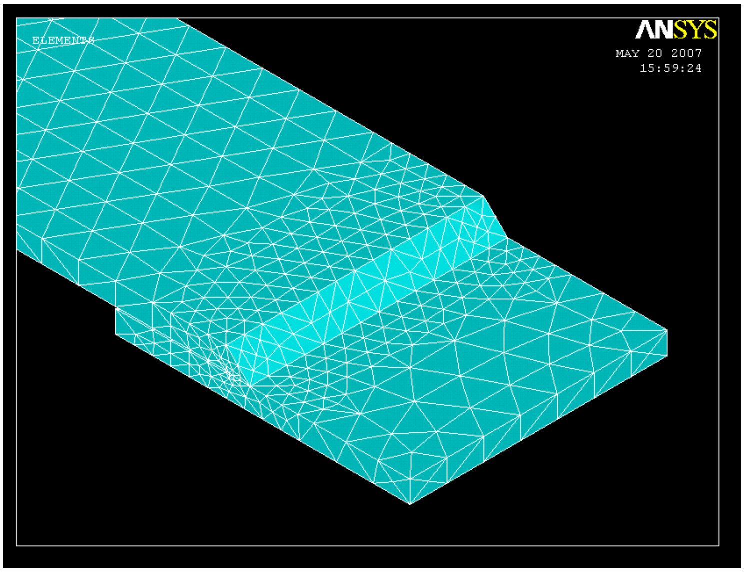


fig. 3 Spatial model of the roof plates and overlap

The model of overlap of the roof sheets and single weld lap joints has been created (fig.4).



фиг. 4 Overlap of the roof sheets

The research has been done under the following conditions:
Roof plates are steel and have characteristics as follow:
- yield strength **R_{yn} = 235 MPa;**
- modulus of elasticity **E = 2,1.10^8 KPa**;
- coefficient of Poisson **ν = 0,3**.

The area of overlap of sheets has width 5.t_r and is changed depending on the thickness of plates $\boldsymbol{t_r}$.
The thickness of the sheets is $\boldsymbol{t_r}$ = 4 ÷ 6 mm;
The distance between the sheets is Δ = 0,5 mm.
During creating of the models the elements SOLID 186 have been used. Everyone has 20 nodes. The maximal dimension of every one finite element is 10 mm. In the area of the weld joints the net of elements is denser in order that the calculated results will be more precise.

The deviations and rotation in the two ends of the model are impeded.
The pressure upon the sheets is equally distributed with intensity p = 2 kN/m^2.

The calculated stress in the plates, determined according to *von Mises*, in the middle of the field $\boldsymbol{\sigma_m}$, above the support $\boldsymbol{\sigma_{supp}}$, in the welding joint in the point 1, point 2 and point 3 from the fig. 1 - $\boldsymbol{\sigma_1}$, $\boldsymbol{\sigma_2}$, $\boldsymbol{\sigma_3}$, as well as deflection $\boldsymbol{f}$ in the middle, depending on the thickness of the roof plates $\boldsymbol{t_r}$ and the span $\boldsymbol{L}$ are shown on the Table 2, 3 and 4.

- distance between radial girders $\boldsymbol{L}$ = 1000 mm

TABLE 2

t_r, mm	deflection in middle f, mm	Stresses by *von Mises* , MPa				
		σ_m	σ_{supp}	σ_1	σ_2	σ_3
4,0	4,6	31,314	47,286	40,277	73,085	30,083
5,0	2,37	23,607	22,618	15,163	41,779	21,645
6,0	1,26	15,825	10,893	8,225	28,313	12,911

- distance between radial girders $\boldsymbol{L}$ = 1500 mm

TABLE 3

t_r, mm	deflection in middle f, mm	Stresses by *von Mises* , MPa				
		σ_m	σ_{supp}	σ_1	σ_2	σ_3
4,0	10	14,92	88,96	95,12	95,59	38,06
5,0	8,33	22,97	77,59	72,57	90,23	36,04
6,0	6,39	26,24	46,63	52,33	76,91	31,9

- distance between radial girders $\boldsymbol{L}$ = 2000 mm

TABLE 4

t_r, mm	deflection in middle f, mm	Stresses by *von Mises* , MPa				
		σ_m	σ_{supp}	σ_1	σ_2	σ_3
4,0	14,54	2,44	128,75	134,94	112,65	40,36
5,0	13	10,3	112,27	111,74	106,43	41,15
6,0	11,46	16,82	79,51	94,97	102,41	37,94

3. Conclusions of the research

a) in case of small distance between supports $\boldsymbol{L}$ the difference between the results calculated in the two above shown ways are small. When the distances between supports become bigger the differences also become considerable;

b) the deflection of the roof's plates influences considerably its stress and deformations. When the distance between the supports $\boldsymbol{L}$ is big the problem for its thickness must be solved according to the deformed scheme;

c) for determination of necessary thickness of the roof plates $\boldsymbol{t_r}$ the most important is the check for deformations;

d) the most important tensions in the plates are shown in the weld joints which is due to the concentration of the stress due to the change in the geometry;

e) single weld lap joints, executed with cathetus equal to the sheets' thickness assures equal rotation of the joined with overlap roof sheets, that is to say they can be considered as an girder on many spans.