Reconstruction of Bearing Roof Trusses an Industrial Building without Interrupting the Production Process

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Abstract. The main stages of the reconstruction of the supporting metal truss at the operating industrial enterprise are considered. Reconstruction is due to the need of changing the process. An original solution was proposed to change the design scheme of the truss due to the rearrangement of the lower belt. Main features of this reconstruction are the difficulties caused by limited working space and the implementation of all types of work without stopping the process. The stress-strain state of the farm is investigated at various stages of work: the actual state at the time of the technical survey, during the work period and after all types of reconstruction work have been completed. The article provides technological solutions for the preparation of the working platform, the organization of assemblies, and the installation of structures. Each stage of the reconstruction was controlled by performing various types of calibration calculations. The distribution of internal efforts in the elements of the farm is shown before and after its installation in the working position. Additionally, the behavior of the design of the farm on various possible operational impacts is investigated.

1. Introduction
In the process of long-term operation of facilities, there is a need to change technological processes that require the reconstruction of individual bearing elements. Reconstruction of industrial buildings and structures is most often associated with the expansion of production, changes in technological processes, the installation of new equipment, etc. To perform such work requires strengthening, modifying or replacing structures in a short time and preferably without stopping production. This task is also complicated by the fact that in the development of documentation for the reconstruction it is necessary to consider the constrained conditions of its implementation, the saturation of the existing technological equipment, engineering networks and communications [1,2].

The main requirement for the reconstruction is the maximum use of existing structures that are suitable for their strength and deformation characteristics to the new operating conditions [3-5].

Considering all this, each stage of reconstruction must be carefully thought out and planned considering measures that ensure the strength and stability of the reconstructed structures.

2. Main part
The work presented in this article was performed at one of the industrial enterprises of the Volgograd region. The building in which the reconstruction was carried out, was commissioned in 1975 and was used for the production of film. During the operation of the housing process regulations have changed repeatedly. The change in process regulations was not accompanied by changes in the design schemes...
and the actual loads on the main supporting structures of the building. At the same time, the technological equipment occupied the interfermen space and was located on the newly erected two-level working site.

The need to perform this work is due to a change in the technological process that required the movement of transport trucks on the working platform at the level of the lower belts of roof trusses. In Figure 1, the existing structures are shown in black, the working platform in red, erected in connection with the change in the technological process. se follow these instructions as carefully as possible so all articles within a conference have the same style to the title page. This paragraph follows a section title so it should not be indented.

To ensure the smooth transportation of goods, it was necessary to change the design scheme of roof trusses with the removal of the lower belt rod. For this, a detailed study of the stress-strain state of the elements of the trusses was carried out, working drawings were developed at the CMD stage to perform the reconstruction of the trusses and recommendations were given on the production of works.

After considering all external factors, a truss design scheme with a trapezoidal outline of the lower belt with a triangular stand was adopted, due to the presence of carrying I-beams of the working platform under the truss nodes (Figure 2). Sprengel puffs are often used to increase the bearing capacity of various building structures [6-11]. Figure 2 shows in red a trussed tie with a modified lower farm belt.

In the study of the stress-strain state of structures, analytical calculations were first carried out: the first, static calculation of the original farm for the design load with and without snow with the definition of effort in the elements and movements of nodes (Figure 3).
Figure 3. Bearing truss after reconstruction.

The second, static calculation of the farm after reconstruction on the actual load from the coating with and without snow (Figure 4) with the determination of the forces in the elements and movements of the nodes.

Obviously, the simplest solution to the task at assembly of the lower belt corresponds to the installation of a sprengel without prestressing and then removing the rod 2 of the lower belt (Figure 3). However, research has shown that this will lead to a significant redistribution of effort and additional vertical movement of nodes.

Figure 4. The design scheme of the farm after reconstruction.

The most rational option turned out to be that the zero force in the removed rod was ensured during mounting of the sprengel. Such a state can be created if vertical compensating loads are applied in nodes 2 and 3 of the existing truss (Figure 2).

It was established that in the absence of snow on the coating, the control parameters will be: the value of the compensating load \( F = 162,945 \) kN at each node; vertical movement of nodes \( \delta = 17,84 \) mm; the relative deformation of the rod being removed is \( \varepsilon = 6,82 \cdot 10^{-4} \).

The implementation of the adopted scheme required additional studies of the stress-strain state of the truss from the effect of actual and compensating loads.

The third, static calculation of unit forces applied at nodes 2 and 3, with the determination of the forces in the elements. This calculation to determine the compensating load was carried out by the method of forces [12-14]. Considered additional loading farm single forces. After determining the unit effort in the rod 2 (Figure 3), the canonical equation of the force method was compiled from which the value of the compensating load was found.

The forth, static calculation of the truss loaded with the calculated actual load from the coating and two forces applied in non-supporting nodes of the lower belt of the truss, directed upwards, providing
zero effort in the rod 2, with determination of the forces in the elements and movements of the nodes. The results are shown in table 1.

| № art. | Effort actual loading, kN | Effort considering pre-existing loading, kN |
|--------|---------------------------|--------------------------------------------|
|        | snow+overlap | overlap | snow+overlap | overlap |
| 1      | -112,19      | -89,96  | -85,01       | -68,09  |
| 2      | 0            | 0       | 0            | 0       |
| 3      | -112,19      | -89,96  | -85,01       | -68,09  |
| 4      | 0            | 0       | 0            | 0       |
| 5      | -298,06      | -238,72 | -244,66      | -195,95 |
| 6      | -324,76      | -260,11 | -298,06      | -238,72 |
| 7      | -298,06      | -238,72 | -244,66      | -195,95 |
| 8      | 0            | 0       | 0            | 0       |
| 9      | -45,21       | -36,21  | -45,21       | -36,21  |
| 10     | -90,42       | -72,42  | -90,42       | -72,42  |
| 11     | -268,01      | -214,66 | -303,36      | -242,97 |
| 12     | 119,61       | 95,80   | 14,81        | 11,86   |
| 13     | -62,41       | -49,99  | -132,90      | -101,44 |
| 14     | 322,92       | 258,63  | 322,92       | 258,63  |
| 15     | 345,30       | 276,56  | 345,30       | 276,56  |
| 16     | -61,00       | -48,86  | -61,00       | -48,86  |

Comparing the efforts, it is easy to establish that the rod 17 will be stretched after the removal of the compensating load, therefore, the rod will be compressed only during the lifting of the truss. In the rod 18, the force after the reconstruction will be -132,90 kN, which is -36,26 kN more than in a typical farm and the calculation of the rod for stability is necessary.

Considering the found value of the compensating load, a calibration analytical calculation of the supporting truss was carried out.

The resulting internal efforts, deformations and movements became the control in the development of the project of production of works.

The bearing structures of the coating in a reconstructed form were investigated for various possible operational impacts. The most probable was considered a horizontal shock at node 2 by a trolley weighing 200 kg, moving at a speed of 0,5 m/s. Comparison of the received efforts and displacements with the results of the calculation for stationary impacts showed that the stress-strain state of the trusses and connections was ensured for all rods with a sufficient safety factor and trouble-free operation of the building after reconstruction was guaranteed [15,16]. Then, the strength and stability of the rods of the reconstructed truss were checked and the welds were calculated [17,18].

The calculation of the stability of the rods 1 and 3 of the lower belt and the diagonals 17, 21, 33, 36 showed that the stability of the rods is ensured. However, taking into account the possibility of exceeding the calculated parameters when lifting the truss, it was decided to reduce the calculated rod length by an additional node device in the middle of the panel and, in addition, additional pads should be installed to ensure joint work of the corners. Spatial rigidity in the lower zones of the trusses was provided by additional cruciate bonds. Work on the reconstruction was carried out in several stages.

Stage 1. Preparatory work. At this stage, work was carried out on the preparation of components and elements of the farm for reconstruction. To this end, the intersections of the intermediate nodes of the lower belt were cut off, additional gussets were welded to the girders of existing farms and stiffening ribs along the rack axis of the main truss to the bottom of the gusset. The axles were marked...
and the boundary between the butt and the feather was marked. Installed additional gaskets. Holes are cut in the flooring of the working platform to skip the corners of the triangular stand of the bolt pull.

Hydraulic jacks with a capacity of at least 15t.s. are installed on both sides of each node, and they were supported by a gear set under the truss node.

Strictly under the reconstructed truss nodes, racks were placed from pipe $\varnothing 159$ and instrumentation installed on the lower belt of the truss.

The instrumentation must record three parameters: the vertical force $F_1$ of lifting the truss at each node using hydraulic dynamometers; the magnitude of the vertical displacement $\delta$, which can be easily obtained using the deflection meter of any structure, in particular, the deflection of the design N.N. Aistova PAO-5; the value of the relative deformation $\varepsilon$ of the core 2 of the main truss, which can be controlled either by lever strain gauges with a base of 20–250mm, or electric strain gauges [19].

Also, control parameters were calculated that ensure zero effort in element 2.

Depending on the season, that is, in the presence or absence of snow on the coating, the control parameters have a different meaning: in the absence of snow cover, $F_1 = 162,945$ kN, $\delta = 17,84$ mm, $\varepsilon = 6,82 \times 10^{-4}$; in the presence of snow cover, $F_1 = 203,445$ kN, $\delta = 22,28$ mm, $\varepsilon = 8.52 \times 10^{-4}$.

Stage 2 Raise the farm. The following guidelines were developed for jacking up the truss. Farm loading should be symmetrical. The amount of force in each jack must be the same. The increase in load is stepwise; the load step should not exceed $F_1/10$ [20]. After each step of increasing the load do 20 minutes exposure. After reaching any of the three parameters of the reference value, the load increase ceases. Check that the two remaining parameters match the control values. It should be borne in mind that the main parameter is $\varepsilon$ - the relative deformation of the rod 2 of the lower belt. The achievement of the reference value by the parameter $\varepsilon$ corresponds to the end of the loading process. Hold the farm under load after the end of the lift for 30 minutes.

Stage 3 Installation of the lower trapezoidal belt farm.

Stage 4. Dismantling the element of the lower belt of the original farm.

The disassembly of the rod 2 lower farm belt was carried out in stages. Initially, the feather and pickup of the corner were cut to 70 mm (Figure 5), and then the remaining metal was uniformly heated to a temperature of approximately 600. This provided a static redistribution of forces and a gradual horizontal displacement of nodes 2 and 3. The unloading process was controlled by a strain gauge mounted on the rod 2. After the deformations stopped, the lower belt was completely dismantled.

![Figure 5. Dismantling the farm lower belt.](image)

Stage 5 Farm unloading.

Reducing the load in the same way as when lifting stepped, the load should not exceed $F_1/10$. It is necessary to monitor the state of the rods. In the event of an emergency situation, the unloading process had to be stopped, the system was fixed and the project developers were called.
3. Conclusions
The proposed version of the trapezoid bottom belt device was carried out without stopping the technological process and did not affect its parameters.

Currently, all structures of the industrial workshop are in working condition. The planned surveys did not reveal the operational characteristics of deviations from the given.

References
[1] Ignatyev A V 2015 Vestnik MGSU 1 16
[2] Klochkov Yu V, Nikolaev A P and Kiselyev A P 2011 Structural Mechanics of Engineering Constructions and Buildings 3 49
[3] Shestakov S A, Popov A V and Dushko O V 2007 Welded metal structures. Calculation and design (Volgograd: VolgGASU)
[4] Khudayarov B and Bandurin N G 2007 Journal of Applied Mechanics and Technical Physics 48(2) 279
[5] Raizer V 2009 Reliability of Structures Analysis and Applications Backbone Publishing Company (New York)
[6] Mandrik-Kotov B B and Ovchinnikov I G 2018 Technical regulation in transport construction 1(27) 73
[7] Ovchinnikov I I, Ovchinnikov I G, Valiev Sh N and Zhadjonova S V 2013 Internet-magazine Naukovedenie 5(18) 56
[8] Kupchikova N V 2014 Structural Mechanics and Analysis of Constructions 3(254) 17
[9] Tikhvinskaya A Yu 2006 Vestnik VolgGASU 6 186
[10] Dzhinchvelashvili G A 2016 Civil Engineering: science and education 2 5
[11] Makarov A V, Kalinovskii S A and Sinitsyn A V 2018 Vestnik VolgGASU 52(71) 117
[12] Jazyev B M, Litvinov S V and Kozel'skij Ju F 2013 Engineering journal of Don 2
[13] Evdokimov E E, Arzamaskova L M, Klimenko V I and Konovalov O V 2019 Engineering journal of Don 1
[14] Bogomolov A N and Ushakov A N 2017 Vestnik MGSU 2(101) 184
[15] Burlachenko O V, Elfimov K A and Bunin D V 2018 Vestnik VolgGASU 54(73) 217
[16] Pshenichkina V A, Glukhov A V and Glukhova S G 2019 Vestnik VolgGASU 1(74) 23
[17] Pshenichkina V A, Politov S I and Chirkov A A 2016 Soil Mechanics and Foundation Engineering 52 6 311
[18] Golikov A V and Sitnikov I R 2018 Structural Mechanics of Engineering Constructions and Buildings 14 4 278
[19] Bandurin N G, Kalashnikov S Yu, Golikov A V and Churakov A A 2016 Construction and reconstruction 2 12
[20] Pshenichkina V A, Sukhina K N, Drozdov V V, Babalich V S, Suhin K A and Zhukov A N 2016 International Review of Civil Engineering 7 6 158