Outdoor carports for automobile transport

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Abstract. Carports for transport parking as well as for unloading and loading are highly-demanded engineering structures. Open metal carports of medium spans have been considered. The influence of some structural solutions of carports on the consumption of material has been evaluated. The calculation of the carports frames has been carried out using the LIRA software package. Recommendations for choosing options for carports frames with lower material consumption have been given.

1. Introduction

Carports for the transport parking as well as for unloading and loading are popular engineering structures. Out of competition, the use of metal canopies as supporting structures [1-5]. Often, typical farms are used (Figure 1). The problem of the construction material effective use arises with the sufficiently large spans of such structures, and each specific situation usually requires its own solution [6-20].

Figure 1. Typical farms.

The results of designing and calculating an outdoor carports for unloading medium spans (from 12 to 24 m) are presented. The load-bearing structure of the carports is a steel frame (Figure 2a; the structure is symmetrical, accordingly half frame is shown in the figure).
a) - The "Molodechno" profile 60x40x4
- The "Molodechno" profile 100x60x4
- The "Molodechno" profile 100x60x6

b) - The "Molodechno" profile 60x40x4
- The "Molodechno" profile 100x60x4
- The "Molodechno" profile 100x60x6
Figure 2. The results of designing and calculating an outdoor carports for unloading medium spans (from 12 to 24 m).

When designing, alternative design models of the frames were considered (Figure 2). The goal was to obtain the lowest weight sound construction; apart from that the construction implicitly had to satisfy the rigidness requirements.

2. Methods
Determination of the stress and the frames deformations has been carried out using the specialized LIRA software package (PC); this structural analysis programme, based on the finite element method, is widely used in the construction design and allows to efficiently calculate the stresses in the frame elements and displacement of nodal points.

By comparison, the following alternative design models of a carport have been considered:
- a frame with rigid node points (Figure 2b);
- a frame with an articulated connection of a girder and pillars, the other node points are rigid (Figure 2c);
- a frame with an articulated connection of the girder and racks, the other node points are rigid, the girder is of different design (Figure 2d);
- some other frame options with rigid node points, 2a.
The frame section is the "Molodechno" profile [21].
Frame loading - design snow load (the third snow region) and the structure dead weight.

3. Results and Discussion
At the first stage of the analysis, using the LIRA PC, the stresses in the frame elements have been calculated. The design diagrams have been formed using the library truss web (where possible). The dimensions of the elements sections of the redundant frames that satisfy the static requirements have been determined according to these forces. In Figure 2 elements of different section sizes are shown in different colors (Figure 2a).

Then the maximum frames deflections have been estimated. It turned out that the frame in Figure 2a the maximum deflection is much smaller than that of the frames in Figure 2b - d (Figure 2). Moreover, with the above dimensions of the frame elements cross-sections Figure 2b - d do not even satisfy the rigidity requirements [22] (the maximum deflections of these frames exceed the permissible values - Figure 3).

![Diagram of the frames deflections](image)

**Figure 3.** Diagram of the frames deflections (№ 1 - the designed frame of Figure 2a; № 2 - the frame of Figure 2b; № 3 - the frame of Figure 2c; № 4 - the frame of Figure 2d).

At the next stage the frames (Figure 2b – d) have been calculated for larger than in Figure 2a, sizes of the elements cross sections; as a result, the dimensions of the cross sections, where these frames satisfy the rigidity requirements, have been determined [22]. An increase in the size of the elements cross-sections of these frames has led to an increase in the weight of the frames. The volume of the material for the frames and the runover of the material volumes for the frames (in Figure 2b – d) over the material volume of the frame (Figure 2a) at a span of 18 m have been shown in the table.

| Frame № (according to Figure 3) | The volume of material per product-, m³ | The excess of the volume of material per article over the material volume of a frame № 1% |
|-------------------------------|--------------------------------------|-----------------------------------------------------------------|
| 1                             | 0.12                                 | 0                                                               |
| 2                             | 0.18                                 | 50                                                              |
| 3                             | 0.17                                 | 42                                                              |
| 4                             | 0.19                                 | 58                                                              |

4. Conclusions
Consequently,
1. the developed carport for unloading (Figure 2a) has advantages over constructions with typical trusses Figure 2b – d (with medium spans (from 12 to 24 m));
2. it is the most effective in terms of material consumption;
3. with a sufficiently large span of carports, the material savings obtained by using the proposed design are significant.

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