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HIGH-STRENGTH GIRDERS FOR THE CONSTRUCTION INDUSTRY

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Abstract: *The main objective of the project was to develop lightweight and affordable girders to be used primarily in building industry as mobile platforms. These platforms must be competitive with commercially produced toe boards, mainly from aluminium alloys. The variant included expanded metal which is made from ordinary steels and has significantly lower density when compared to solid sheet metal. The second one involved high-strength materials combined with expanded metal. Designs and simulations of girders were prepared using DEFORM 3D software. The designs yielding best results were subsequently used for production and testing. Thanks to the numerical simulation it was possible to design more complex girders.*

Key words: *expanded metal, girders, high-strength material*

1. INTRODUCTION

The key goal of development of new types of girders used as platforms is to reduce their weight while maintaining their required strength. This trend offers an opportunity to utilize high-strength materials or those materials with lower weight than conventional metal stock.

An example of a material which had been made lighter is expanded metal. Expanded metal is produced by shearing and expanding sheet metal with the thickness between 0.4 and 6 mm. Final rolling of the expanded metal, if applied, provides uniform thickness and smooth surface without burrs. Its major advantage over sheet metal of identical thickness is its lower weight and the fact that it is manufactured by a wasteless technology.

This paper deals with applications of expanded metal made from ordinary structural DC01 steel, grade St37-3 metal sheet and high-strength material DOCOL 1200M. Welding was intentionally omitted from the assembly process. This process is widely used in all branches of industry. However, it has a great weakness in the presence of the heat-affected zone where the material is degraded and its mechanical properties are significantly poorer.

1.1. Expanded metal

The process of selection of the type of expanded metal included basic mechanical tests, such as tensile, compression and three-point bending tests. Results of measurement and simulations showed that the most suitable type of expanded metal for the specified purpose is the one with rhombus-shaped openings sized 22x12 mm made from 2 mm thick sheet (Nový Et al., 2007). This type showed the best strength-mass ratio. The tested expanded metal was made from DC01 (Voldřich, 2007).

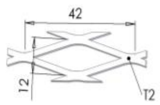


Fig. 1. Basic geometric parameters of the expanded metal

1.2. Grade St37-3 Sheet

This grade of steel was selected on the basis of its availability and cost. It is mild structural steel which is used in the form of 2 mm sheet metal.

1.3. High-Strength DOCOL 1200M Sheet

High-strength steel DOCOL 1200M made by the company SSAB has been selected on the basis of previous tests. Metal sheet with the thickness of 1 mm was used.

2 EXPERIMENTAL

Several design variants have been proposed in order to identify the optimum section for the girder in question. The design variants were analyzed by means of FEM prior to their production. The purpose was to find critical points of the structure (marked with circles in images showing the sections). As the first approximation, the numerical model was considered a shell-like structure with perfect joints. This method of calculation guaranteed short computing times and relatively good results of comparison between individual variants. Real joints were later considered in order to increase the precision of computation (e.g. high-strength rivets).

Girders were loaded in three-point bending under identical boundary conditions. In the numerical model, the girder was supported at the ends and a single, linearly increasing force of 14 kN acted on the centre of the girder. To ensure comparability between the simulation and real-world testing of girder specimens, quasi-static simulation conditions were kept identical to those in a testing rig in a mechanical testing shop.

Parameters of girders were based on standard section dimensions for these types of girders (300x70x1000 mm). Numerical simulations were used to find the optimum distribution of stress in the girder under three-point bending conditions. The design variants with best results were used for manufacturing actual girders to be tested in three-point bending.

2.1. Variant A

The first simplest section was manufactured entirely from expanded metal. It was made from a single blank in a press brake.

Fig. 2. The cross-section of the variant A

2.2. Variant B

Based on the results of the variant A, it was decided to reinforce the section. The brace (2) was also made from expanded metal. No joining elements were used for assembling the girders. The girder and the brace have made a perfect fit but the assembly was more complicated and difficult.

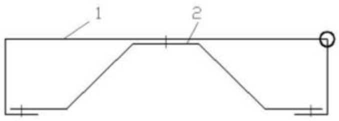


Fig. 3. The cross-section of the variant B

2.3. Variant C

The exclusive use of expanded metal does not guarantee required strength of the girder structure. For this reason, further development was focused on variants combining sheet metal and expanded metal sections. The girder was reinforced with sheet metal side plates (1) from the material grade St37-3. The joining and walkable element (2) was made from expanded metal and the joint (3) was made with rivets.

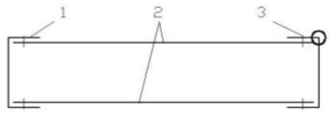


Fig. 4. The cross-section of the variant C

2.4. Variant D

This is based on the C variant. The side plates (1) were bent to a greater angle on the bottom side. The walkable part (2) and the brace (4) were made from expanded metal. The brace supports the walkable part along the entire girder length.

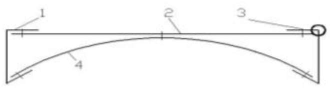


Fig. 5. The cross-section of the variant D

2.5. Variant E

For higher load bearing capacity, a pressed section (5) was inserted under the walkable element (2) and attached with metal strips to the side plates (1). The width of the strips was 40 mm and their spacing 250 mm. All parts were made from the material ST37-3, except section 2, which was made from expanded metal.

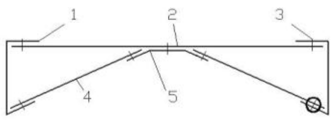
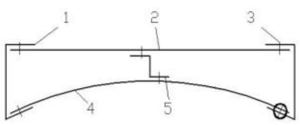


Fig. 6. The cross-section of the variant E

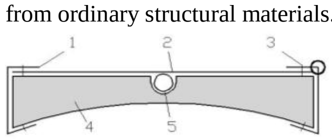
2.6. Variant F

Another modified variant had Z-shaped pressed sheet metal braces positioned along the longitudinal axis of the girder. On the bottom side it was supported with 40 mm wide sheet metal strips with 250 mm spacing in between. In this case too the material ST37-3 was used primarily.



2.7. Variant G

The load bearing capacity of this variant was provided by a tube sized 20x2 mm. The tube was positioned along the entire girder length in the longitudinal axis under the walkable element. The tube was kept in place by sheet components with the thickness of 2 mm (4) mounted in pairs at a distance of 15 mm. These pairs were spaced at 250 mm. This entire variant was made from ordinary structural materials.



2.8. Variant H

This type of girder was almost identical to the previous variant. Only the material of the side plates was changed to high-strength DOCOL 1200M with the thickness of 1 mm.

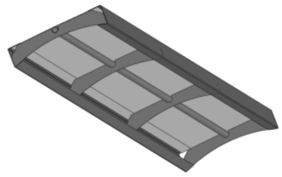


Fig. 4. The cross-section of the variant G

3. RESULTS OF MEASUREMENT

The three-point bending test was carried out up to the plastic deformation region. The girder spacing was 600 mm. One commercial girder was tested as well to obtain comparison with commercial products.

Girder type	**Mass [kg]**	**F [kN]**	**Main material**
Variant A	3,9	2,8	expanded metal
Variant B	5,4	5,6	expanded metal
Variant C	8.2	13.2	St37-3
Variant D	8.3	14.3	St37-3
Variant E	8.1	17.1	St37-3
Variant F	7.9	18.2	St37-3
Variant G	9.2	24.7	St37-3
Variant H	5.4	17.6	DOCOL
commercial girder	7	15.4	-

tab. 1. Results of three-point bend measurement

4. CONCLUSION

Numerical simulation was successfully used to obtain comparison between a number of variants of sections. Sections with best results were subsequently optimized and subjected to real-world load.

Results have shown that all-expanded metal girders did not have the required strength. For this reason, the variants with sheet sections began to be tested.

The G variant of the 2 mm sheet girder made from the material St37-3 was the one which sustained the highest load which was about 7.1 kN higher than that of the commercial girder. In comparison with a batch fabricated girder, the current one sustained a load higher by 4 kN in three-point bending. Its drawback lay in the higher weight. It has been eliminated by using 1 mm thick high strength sheet metal DOCOL 1200 M. At the same stiffness as the commercially produced girder, its weight was lower by more than 1.5 kg/m.

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