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THE ANALYSIS OF THE USEFULNESS OF WELDED MESHES TO EMBANKMENT REINFORCEMENT

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Abstract: The aim of this paper was to find an answer to the question about the possibility of using steel welded mesh in building the retaining walls of gabion baskets. In light of the currently used gabion structure solutions, among which double-woven mesh is much more popular, the focus was put on the possibility of using welded mesh. A numerical analysis was conducted to examine the behavior of welded and woven mesh subjected to various loads and the results obtained for both types of mesh were directly compared. The maximal displacement in mesh nodes was admitted as the measurement of the system behavior (in the case of both undamaged and damaged mesh).

Key words: *application of numerical techniques to analysis of problems involving foundations, underground structures, slopes and embankment*

1. INTRODUCTION

The intensive development of vehicle and rail infrastructure in Poland results in the necessity to build bridges, flyovers and embankments on their approach roads. Bridges are much more rigid than embankments, therefore it is important to avoid big distortions on their approach roads.

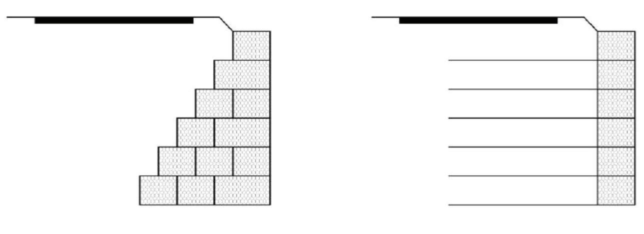


Fig. 1. Comparison of gabion structures: massive (on the left) and with reinforced fill (on the right) [4]

Recently retaining walls with the use of reinforced soil technology has been frequently used in building light retaining constructions [1]. Gabion structures are "ecological", mainly because of using lowly processed products which can be processed once again. This shows the trend of balanced development [2]. Light gabion constructions with the use of reinforced soil (in contrast to massive constructions) consist of gabion facing as well as reinforced soil. A comparison of massive structures and reinforced fill structures is depicted in Fig. 1. Geosynthetics or steel double woven mesh play the role of a reinforcement rod in this type of structures, [3], [4], [5].

A good alternative for steel double woven mesh is welded mesh, which is not prone to the change of mesh geometry during stretching in the main direction (alongside wires), which is characteristic of double woven mesh. The European standard [6] states that it is possible to use welded mesh in soil reinforcement, however, it does not provide any additional guidelines about its application and calculation. A sample gabion basket made of welded mesh is presented in Fig. 2.

An important aspect of the research about the usefulness of steel mesh in soil reinforcement is its anticorrosive resistance, achieved thanks to zinc-aluminium layers. As a result, with time gabion structures show a similar level of usage to other common types of retaining structures [7].

Taking into consideration the practical usage of welded mesh, the authors of this article decided to first compare the behaviour of welded and double-woven mesh assembled in retaining structures and uniformly loaded in the process of numerical analysis. The obtained results will be the basis for creating a model research setup in the laboratory and later in situ.

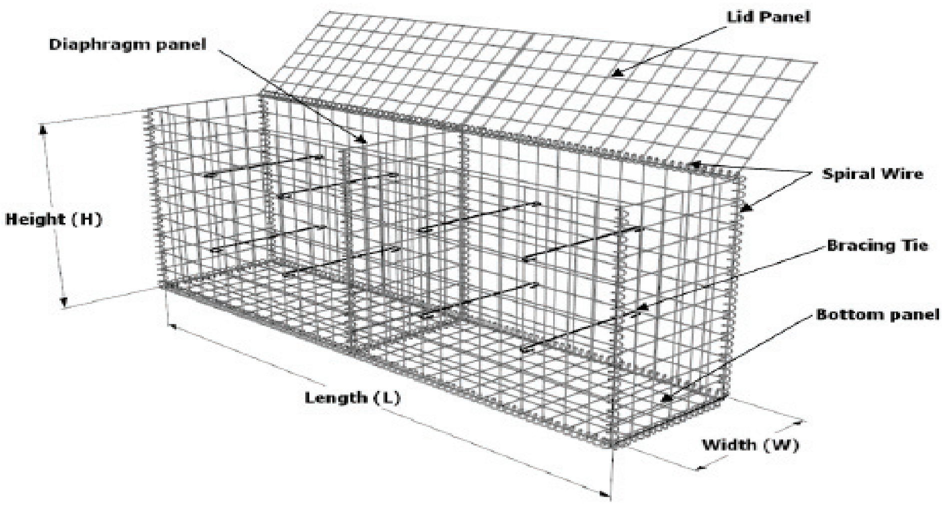


Fig. 2. Schematic image a welded mesh gabion basket [8]

2. NUMERICAL ANALYSIS OF MESH STRETCHING

Research concerning mesh stretching was conducted by means of a numerical analysis using the Autodesk Robot program. The stretching tests for each type of mesh were conducted in three ways, i.e. in the first method the load force was uniformly distributed over the breadth of the mesh, in the second single rods were additionally cut out to simulate the damage to the mesh during aggregate assembly, and in the third one a single rod was loaded with concentrated force.

2.1. MESH GEOMETRY

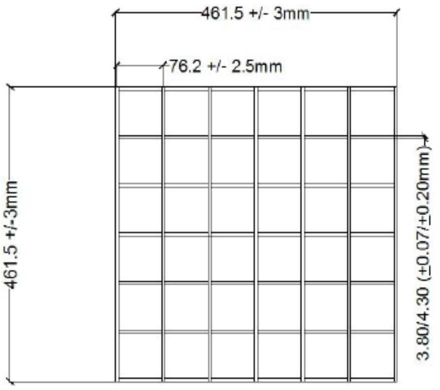
On the basis of the target research apparatus geometry it was assumed that the size of mesh used in the research should be about 1000 × 500 mm. The mesh was stretched in the log side direction. In the analysed mesh there were from 7 to 14 wires, depending on the type of mesh, in the direction of force impact.

The standard mesh size of the welded mesh in accordance with the manufacturer's specification [8], [9] is 76.2 × 76.2 +/– 2.5 mm (Fig. 3a). The mesh size in woven mesh is about 80 × 100 mm to 80 × 120 mm, and the angle of bending of the wires is approximately 135 degrees, which is depicted in Fig. 3b. A wire of 2.7 mm in diameter was used in both types of mesh.

2.2. LOADING

The characteristics of steel in the examined mesh are similar to 18G2 steel, which was adopted in the model. It has the following characteristics:

- tensile yield stress f_y = 305 MPa,
- modulus of elasticity E = 205 GPa,
- Poisson's ratio in elastic stage ν = 0.3,
- shear modulus G = 80 GPa.

a) 

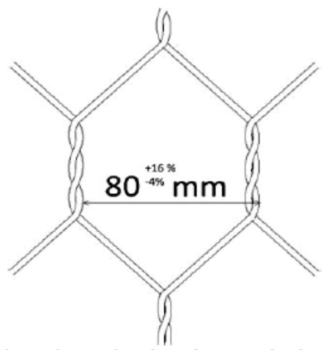
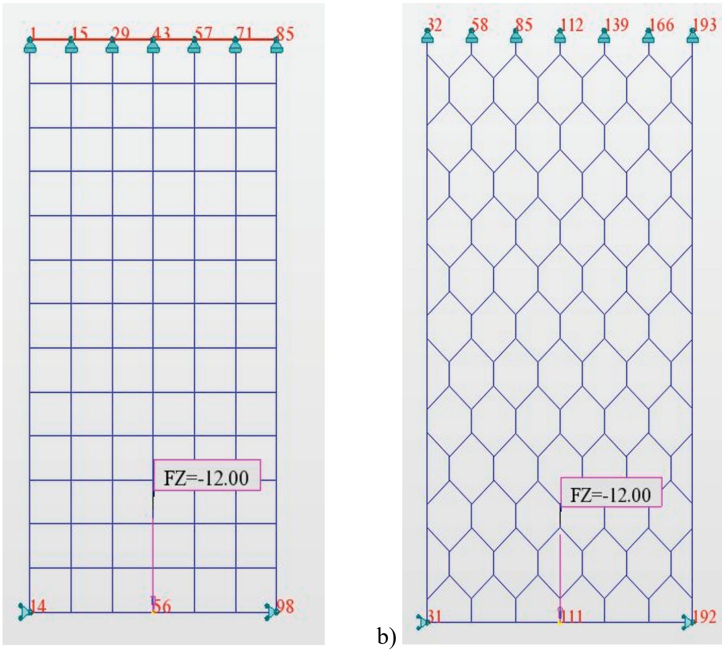
b) 

Fig. 3. Geometry of: a) welded mesh [9], b) woven mesh [4]



a) b)

Fig. 4. A scheme of : a) welded mesh load, b) woven mesh load

Because of the desire to limit the movements of the finished long-retaining structure it was assumed that the used power should not plasticise mesh, so that it operates in the elastic range. It is easy to notice that the sample of welded mesh has only 7 wires in the direction of load application, therefore the maximum load was assumed in accordance with this mesh. The elastic model of material behaviour was analysed analogically, which additionally simplified the numerical model and computation time.

A wire with a diameter of 2.7 mm can carry the load about $F_{\max} = \pi \cdot 2{,}7^2/4 \cdot 10^{-6} \cdot 305 \cdot 10^6 = 1.75$ kN, hence 7 wires carry about 12.25 kN before they are plasticised. It was assumed that the force that would be used in the calculation would have the value of 12 kN. The application scheme of the load depending on the type of mesh is shown in Fig. 4. In order to achieve uniform mesh stretching, the concentrated force was applied to the lower horizontal wire was characterised by very high stiffness. In the real laboratory research, this pattern will be mapped by attaching the mesh to steel jaws made with a set of two channel bars. However, in the case of loading mesh with concentrated force, it was decided to apply this force directly to the wire mesh.

2.3. DEFORMATION WITH REGULARLY DISTRIBUTED LOAD

After applying a load of 12 kN, which was regularly spread using the handles, it can be easily seen that the nature of mesh work is completely different. The welded mesh is stretched along the wires and, as a result, the elongation of the mesh is directly dependent on its cross-sectional area, whereas in the case of woven mesh the mesh geometry is changed because it is restricted in its middle part. With the applied power value the welded mesh elongated by 1.5 mm (Fig. 5a), while the woven mesh by 2.7 mm (Fig. 5b).

2.4. DEFORMATION WITH REGULARLY DISTRIBUTED LOAD AND DAMAGE OF INDIVIDUAL WIRES

Meshes constitute fill reinforcement behind a light retaining structure and can be locally damaged during aggregate assembly. The analysis of the behaviour of damaged meshes was begun with the removal of the central and extreme welded mesh wire. The behaviour of the welded mesh with a broken vertical wire is shown in Fig. 6. When the middle wire was removed, the others had to take a part of the load, so the mesh elongated a bit more than in the previous case (1.7 mm; Fig. 6a). When the damage resulted in uneven extreme wire elongation, the side from which the wire was removed was more distorted. In the direct vicinity of the damage the displacement amounted to 2.9 mm, and in the extreme mounting place 2.7 mm (Fig. 6b). The acting of the mesh was in accordance with expectations. The cut wire was excluded from operation.

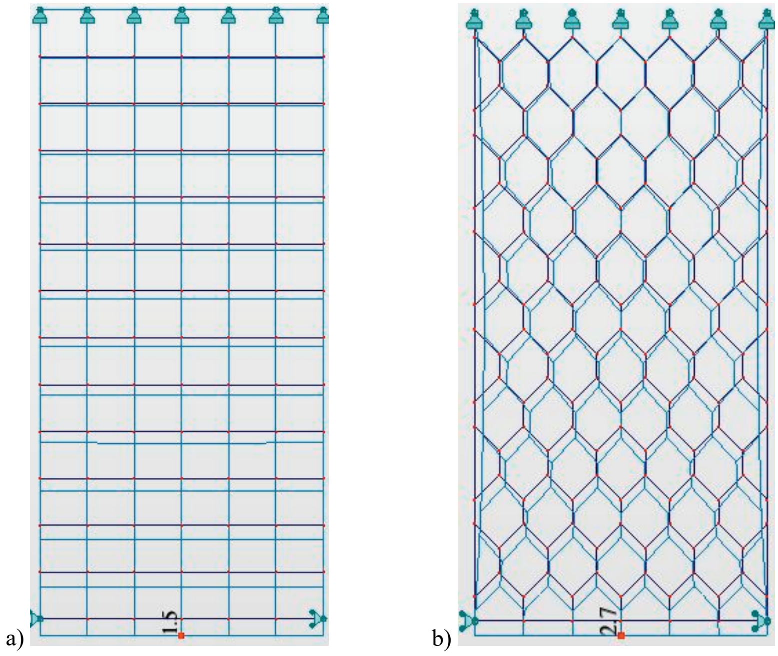


Fig. 5. Displacement of the load evenly distributed in: a) welded mesh, b) woven mesh

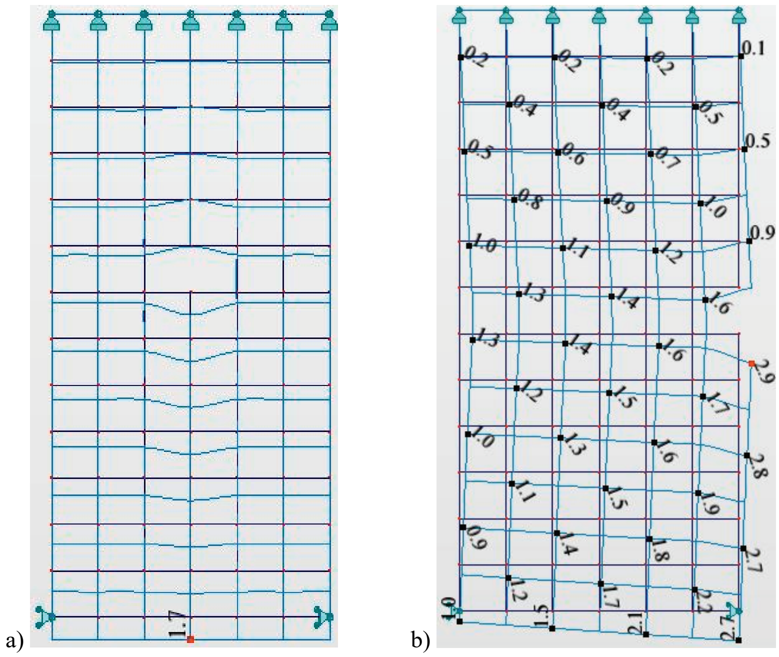


Fig. 6. Displacement of welded mesh nodes with a damaged: a) internal wire, b) boundary wire

In the case of woven mesh it was decided to cut the central vertical wire, i.e. two plaited wires (Fig. 7a), the single diagonal wire (Fig. 7b), and the thicker edge wire (Fig. 7c). Removing the wires from the middle of the mesh did not affect the increase in the deformation of the entire mesh. However, the woven mesh shows very high sensitivity to damage caused by the wire edge. In the case of such a damage, the mesh becomes highly deformable, and the maximal displacement in the examined case was even 39.4 mm.

2.5. DEFORMATION AND DISTRIBUTION OF FORCES AT A LOAD OF CONCENTRATED FORCE

Due to the assumption of the elastic model of material behaviour, it was decided to apply the same force as in the previous example, F = 12 kN, but to a single (central) wire of each mesh in order to check the distribution of stresses in the wires of the other

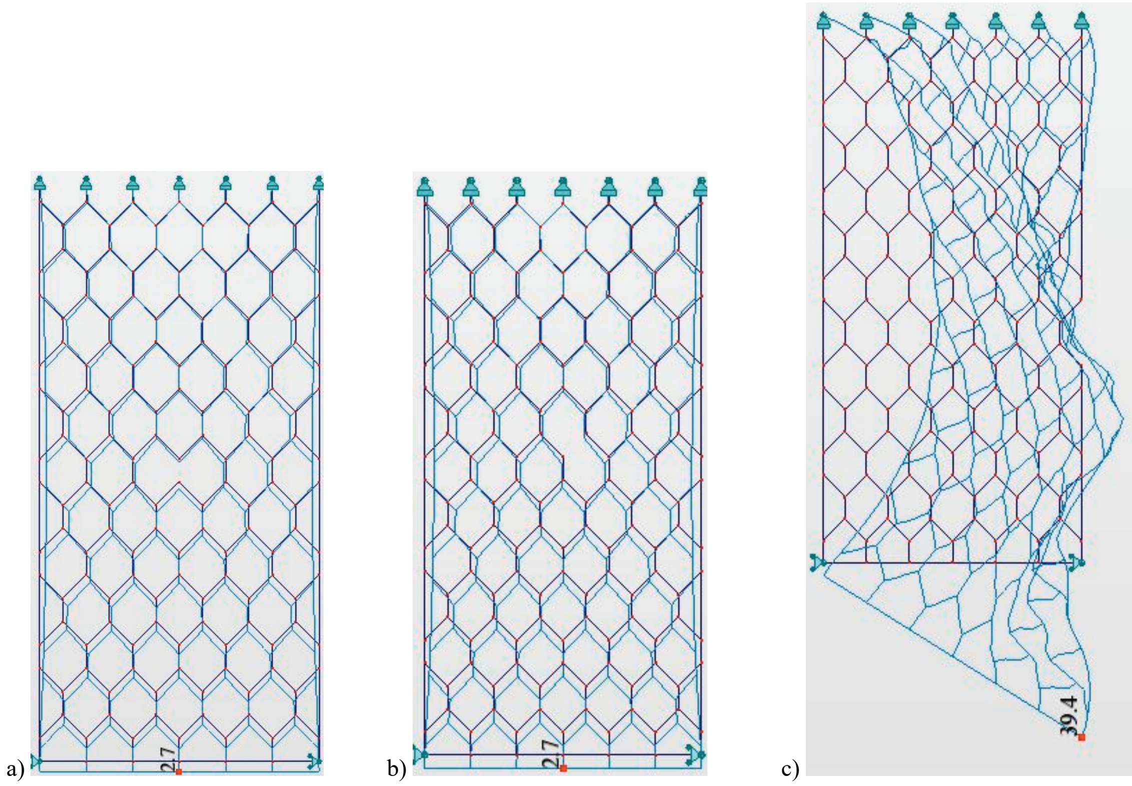


Fig. 7. Displacement of woven mesh nodes with damaged:
a) internal vertical wire, b) internal diagonal wire c) boundary wire

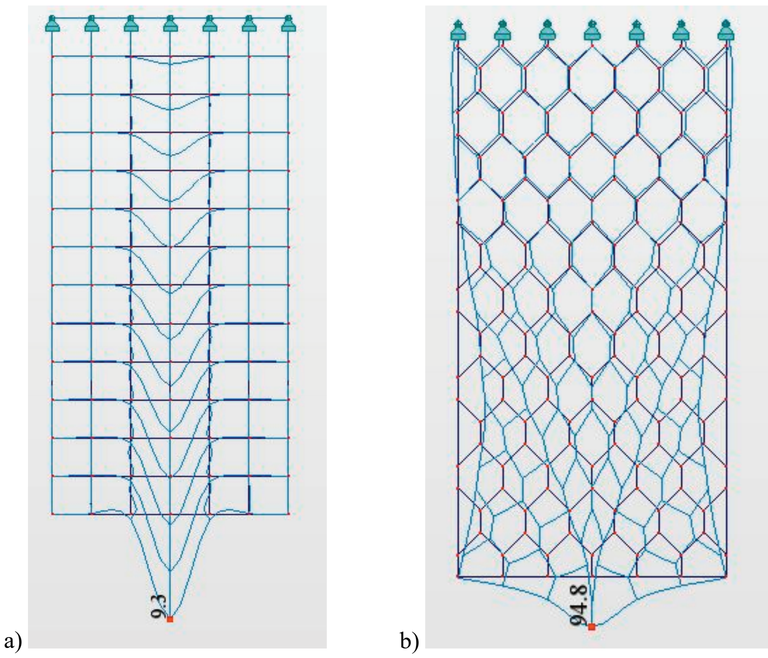


Fig. 8. Distortions while loading with the concentrated force of: a) welded mesh, b) woven mesh

mesh. The purpose of this task is only to compare mesh deformability, not to determine precise movements. A comparison of the behaviour of the welded mesh and woven one under the concentrated load is shown in Fig. 8.

In the case of welded mesh strength is acquired by one wire, and it is also extended by 9.7 mm (Fig. 8a). The strength of the neighbouring wires is transferred through transverse wires which act as suspension arms due to their low transversal stiffness.

The woven mesh heavily deforms when a force focused is applied. The maximal deformation is up to 94.8 mm (Fig. 8b).

In the woven mesh the highest stresses occur in edge wires, and the remaining wires are pressed, which means buckling in case of small rigidity of the wires and nodes. This excludes it from cooperation.

3. CONCLUSIONS

The results obtained from the analysis have been arranged and presented as maximal displacements in Table 1.

Table 1. A tabular summary of the maximal displacements in stretching woven and welded mesh

Research type	Maximal displacement [mm]	
	woven mesh	welded mesh
Uniformly distributed force stretching	2.7	1.5
Uniformly distributed force stretching – internal wire damaged	2.7	1.7
Uniformly distributed force stretching – boundary wire damaged	39.4	2.9
Concentrated force stretching	94.8	9.3

On the basis of the conducted analysis, the following conclusions have been drawn:

- welded mesh made of the same material and the same thickness of the wires show a smaller distortion in both the regular load the and the single wire load,
- woven mesh, made of wire whose diameter is the same as in the welded mesh, can transfer more power before the material starts to plasticise. This is due to a greater number of wires used in it. Test samples are made of approximately 14.0 running meter of wire for welded mesh and 18.1 running meter of wire for woven mesh (including 3.0 running meter of wire 3.5 mm in diameter). Less ability to transfer power by the welded mesh is, however, compensated by the possibility to use a thicker wire. The maximum thickness of the wire used for woven mesh is 3.0 mm (due to the fact that with the thicker one, PVC coating is destroyed in the process of wire bending [10]), whereas in the welded mesh there is not limit, and wires with thickness of 3.8 mm are commonly used.
- thanks to quite easy redistribution of loads, woven mesh shows greater tolerance to damage of single wires within a mesh,
- the key element of the woven mesh is the edge wire. Its rigidity heavily affects the deformation of the entire mesh. In case of damage, the whole system is deformed about 15× more than welded mesh with a damaged edge wire.
- the stress distribution in wires proposed in [6] is reflected in the welded meshes, whereas in the woven ones it is different. Perhaps after assembly in aggregate, mesh loses the ability to be deformed in a plane perpendicular to the load and is not submitted to narrowing, and thus it has smaller total deformations as well as different stress distribution in individual wires.

In further research it will be necessary to:

- check calculation in laboratory research and calibrate the model,
- create a setup for research on mesh assembled in soil,
- develop a calculation method which will allow to determine the force needed to pull or break mesh as well as to design retaining walls made of welded mesh.

On the basis of the conducted numerical analysis, it can be stated that welded meshes compared to the woven ones have comparable or higher stretching force bearing capacity (concerning the possibility to use a thicker wire), and above all, they have much smaller deformation, which leads to the conclusion that they can be recommended for using them to reinforce a fill behind a retaining structure. The aforementioned conclusion concerns only a narrow range of research connected with the use of welded mesh in the reinforced embankments and it needs to be expanded and checked in laboratory and field research.

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