

Load Bearing Behaviour of Geotextile Containers Using Velcro Strips

Comportement à l'appui des conteneurs géotextiles avec de bande velcro

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ABSTRACT

Geotextile containers are made of soil as a filling material and a casing of woven or non woven geotextile, which exercises the function of a packaging. The field of use is an alternative to the hard construction methods of concrete or stones in the coastal construction and hydraulic engineering. Advantages of the geotextile containers are the high cost efficiency and the protection of natural resources, because the filling material is available already on site, without a need for long routes of transport. Furthermore, they integrate better in the landscape and are easy to remove. Due to the extremely smooth surface of the geotextile packaging, the containers have only a low internal stability of the structure and the construction height is limited. With the help of velcro strips fastened on the surface of the geotextile containers, the friction between the layers of geotextile containers can be improved substantially. Due to the increase of the internal stability of the structure there are new applications possible, for example using the geotextile containers as a supporting structure for slope stability. The efficiencies of the velcro strips were examined using a shear box apparatus under different boundary conditions (arrangement of the velcro strips, pollutions of the surface, humidity, load steps). The tests show a clear increase of load bearing behaviour. The effectiveness of the faster depends mainly on the type of velcro strips and on the amount of soil particles present on the surface of the velcro strips. In order to estimate the increase in bond analytically, parameters (adhesion factors and wall friction angles) were derived from tests and the behaviour of a geotextile container construction as a supporting structure was investigated in general by experimental and numerical investigations. The use of geotextile containers can therefore lead to an economical and ecological construction method.

RÉSUMÉ

Les conteneurs géotextiles se composent d'une matière terreuse comme fond et une enveloppe en textile non-tissé ou en tissu, qui ont la fonction d'un emballage. Leur domaine d'application est une alternative aux méthodes de construction dures, actuellement répandues de béton et des pierres dans la construction de côtes et l'aménagement des voies navigables. Des avantages des conteneurs géotextiles se trouvent dans la haute rentabilité et le ménagement des ressources naturelles, puisqu'en général le remboursement est déjà disponible sur place sans longs trajets de transport. En outre ils s'intègrent mieux à l'image de paysage et sont plus faciles à démontés. En raison de la surface très lisse de l'emballage géotextile, les conteneurs ont seulement un bas accrochage et une basse adhérence de frottement. Il en résulte que les constructions n'ont pas assez de stabilité intérieure. Pour cela, la hauteur de construction est limitée. À l'aide de bande velcro disposée à la surface, la capacité de charge est augmentée. À l'aide d'essai de cisaillement, une bande velcro convenable était testée sous les conditions variées (l'ordre des bandes velcro, pollutions de la surface, humidité, des charges différentes) et était aussi étudiée dans des essais de système ainsi que l'efficacité était prouvée. L'accrochage et adhérence de frottement peuvent distinctement être augmentée par l'application de bande velcro entre les conteneurs géotextiles. Des paramètres étaient déduits dans des essais et de calculs numériques pour prendre cette augmentation en considération par des calculs. Ainsi l'application de conteneurs géotextiles empilés en sécurité peut servir à une méthode de construction plus économique et écologique.

Keywords: geotextile container, supporting structure, velcro strips, geotechnical engineering, slope stability

1 INTRODUCTION

In the last decades geotextiles have proved themselves in coastal and geotechnical engineering very well. Started as with sealing functions at waste dumps or reinforcement at slope stabilisations, geotextiles were soon used as packaging material for geotechnical purposes. The forerunner role was, besides, the synthetic sandbags for the protection of dikes at river and coastal areas in case of storm flood and high water. Nowadays geotextile containers are produceable in most forms and dimensions. They are produced of non woven geotextile predominantly (Heibaum 2002). The geotextile containers are an alternative to the hard construction methods in the coastal engineering and are furthermore easy to remove. Normally the filling material is already on site and because of this the costs for transportation to the construction site are reduced and natural resources are spared. The range of application is extremely

varied. In the last years the geotextile containers were used successfully as scour protection (Saathoff & Witte 1994), erosion protection at beaches and dunes (Heerten et al. 2000), groyne (Restall et al. 2002) or synthetic reefs and breakwater walls (Jackson & Hornsey 2003). In addition an application as a supporting structure for slopes is conceivable. Volumes from small sandbags to several cubic metres and even up to 1000 m³ including geotubes are possible (Pilarczyk 1997).

There is no general calculation formula available for the design of geotextile containers. The stability of a geotextile containers construction depends on the deformation behaviour of each container, the stress distribution and the movement of the sand grains inside the containers, porosity of load effects by water, the filling degree of a container and as a main point the friction between the containers (Recio & Oumeraci 2005).

Because of a determining influence of friction on the load bearing behaviour, different model tests and numerical calcula-

tions were carried out to investigate the effect of velcro strips between each container layers.

2 STATE OF THE ART

Because of the different field of applications it is not possible to develop a general calculation formula. In fact the design must occur project-specific.

The filling degree is of great importance for an optimum adaptation of the container to the neighbouring elements. After Oumeraci et al. (2002) the optimal filling degree is about 80 % to the theoretical filling volume. A lower filling rate abets movements of the container and a rearrangement of the sand grains is possible. A higher filling rate reduces the contact area to the neighbouring elements. In analogy to masonry constructions an overlapping of each container raises the stability of the whole construction.

In the known projects a sand with the density in a range between 1,4 to 2,0 kg/dm³ was used as a filling material (Bezuijen et al. 2004). However, the filling material must be adjusted with the permeability of the geotextiles due to tidal variations. So the geotextile should be designed as a filter or should have a minimum permeability from 10 times higher than the filling material (Restall et al. 2004).

After Heibaum (2002) the mass per unit area should be more than 500 g/m² and the tensile strength more than 25 kN/m. A high elongation of the geotextile is of great importance. The danger of damage during installation is reduced and the container can adapt itself to the other container better. After Restall et. al. (2004) an ultimate elongation of greater than 50 % is recommended.

The UV resistance is in regions with high UV-radiation (> 180 Kilo Langley) a main design point for long term survivability of the container. It is tested by a MBTF Lamp and a minimum of 80 % strength retention is recommended after an 672 h illumination, which correspond to a lifetime of 10 years (Restall et al. 2004).

Furthermore there should be a resistance against abrasion and damage by vandalism. For the determination of the abrasion resistance the German rotating drum test method is recommended (Restall et al. 2004). After 80.000 rotations of the geotextile in a water/gravel mixture there should be a 75 % strength retention.

More information about application range and design advices can be found in Heibaum et al. (2008).

Anything about a systematic investigation of using velcro strips for getting a better connection between the geotextile containers is not known.

3 SHEAR TESTS

For the investigation of the friction between each container layers shear tests (element tests) were conducted out. The examined area in the shear test apparatus amount to 100 cm². Different microplast velcro strips (type 1 and type 2) and different types of geotextiles (a staple fibres soft needle punched non woven (500 g/m²) and a staple fibres strong needle punched non woven (600 g/m²) geotextile) under several load levels were examined. Furthermore the influence of pollution and humidity on the load bearing behaviour was studied. The pollution was simulated by a sand strewed test specimen with a total mass of 7,5 g. With it the effectiveness of polluted velcro strips (e.g. at the installation process) should be checked. The velcro stripe was installed in the middle of the test specimen and was sewn up with the geotextile. Two different microplast velcro strips with a width of 8 mm were tested.

Figure 1 and figure 2 shows some chosen results.

From the results of the tests the parameter in equation 1 could be derived. They are shown in figure 3 and table 1.

$$\tau = a + \sigma \cdot \tan \delta \quad (1)$$

where τ is the shear stress, σ is the vertical stress, a is the adhesion factor and δ is the wall friction angle. In case of pollution the adhesion factor decrease significantly and the wall friction angle increase slightly.

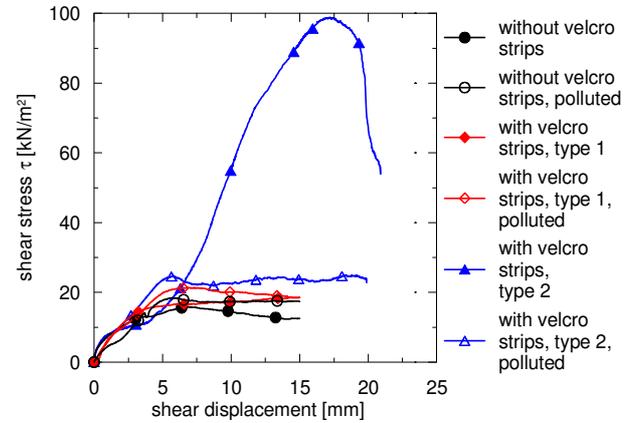


Figure 1. Chosen results of the shear tests

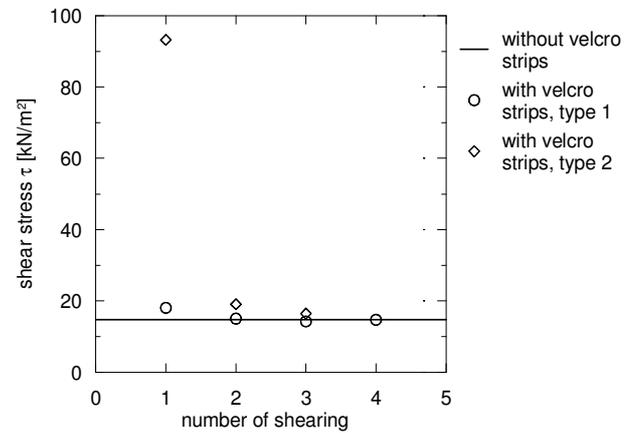


Figure 2. Decreasing of shear stress against increasing number of shearings

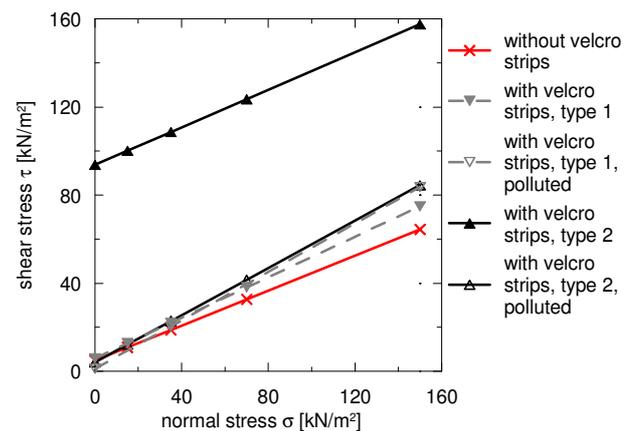


Figure 3. Deriving of an adhesion factor (best-fit line)

The results of the shear tests can be summarised as followed. An increase in the load bearing behaviour can be achieved by the use of velcro stripes. The increase depends mainly on the type of the velcro stripes. With type 2 is a clear increase visible. In comparison with that shows type 1 only a low increase. In a case of pollution the effectiveness of the velcro stripes decrease

clearly, see figure 1. The humidity reduces the bearing behaviour about approx. 10 to 20 %.

Table 1. Summary of the derived adhesion factors and wall friction angles for the different shear tests

	Adhesion factor a [kN/m ²]	Wall friction angle δ [°]
Without velcro strips	4,9	21,6
With velcro strips, type 1	5,9	24,7
With velcro strips, type 1, polluted	1,2	28,8
With velcro strips, type 2	93,8	23
With velcro strips, type 2, polluted	4,1	28,2

A repeated shearing means a high reduction in effectiveness. After the third shearing the load bearing behaviour is comparable to the model tests without velcro strips, see figure 2.

To the full mobilisation of the maximum shear stress a movement of approx. 1.5 cm is necessary.

A stable fibre strong needle punched non woven geotextile is better suitable than a soft needle punched one, because the fibres do not pull out so easy.

It is important to the fact, that the container should not have contact with each other until the end state of positioning during the installation process on the construction site. If the containers are parted from each other repeatedly, that would mean a clearly reducing of the effectiveness of the velcro strips, because they clogged with stripped fibres.

4 SIMULATION OF A SUPPORTING STRUCTURE

This model test is conducted out for checking the increase in bearing behaviour as shown in the element tests.

A supporting structure was reconstructed as shown in figure 4 and 5 in a scale of 1:3. Two model tests were carried out. Containers with and without velcro strips were used. The dimensions of the container were 0,55 m x 0,4 m x 0,1 m (length x width x height). They were filled with 26 kg sand (filling degree 80 %). The velcro strips were arranged in a distance of 15 cm. The inclination of the construction against the horizontal was 80°. The load was increasing in different load steps until the construction collapsed. The movement of each container were determined by a tachometric deformation measurement.

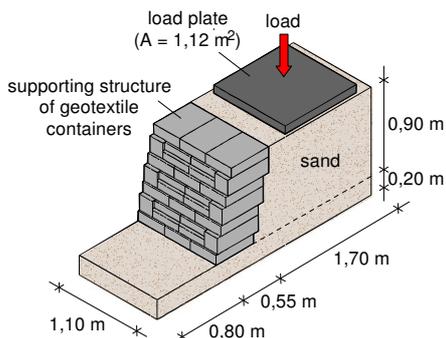


Figure 4. Schematic view of the model test

The results of the deformation measurement are shown in figure 7 and 8 in comparison to the numerical calculations.

At a loading rate of 66,7 kN/m² the structure without velcro strips sheared off between the first, second and the third layer (seen from below). Furthermore a high relative deformation between each container layers was noticeable. The construction collapsed in each splices.

The second model test with using the velcro strips shows a different result. At a loading rate of 107 kN/m² a slope failure takes place. Moreover a lateral buckling were found out. No damage at the supporting structure was visible. It reacted like a monolithic block. Only a low relative deformation between each containers was detectable.



Figure 5. Front view of the supporting structure

The velcro strips have proved their effectiveness. The failure appeared in the soil body and different deformation behaviour of the structure was visible. Unfortunately only velcro strip type 1 was available at the time of this model test.

5 NUMERICAL CALCULATION

The purpose of the numerical calculations was the back calculation of the experimental tests and the suitability of the program for this issue. The numerical calculations were conducted out with the finite-elemente program system PLAXIS 8.2. A two dimensional numerical model was generated as shown in figure 6.

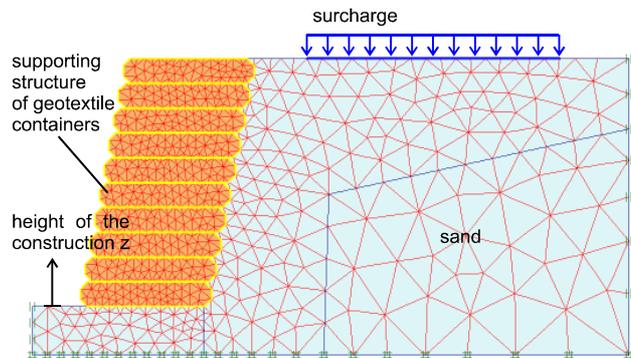


Figure 6. Generated model for the numerical calculations

The filling material and the geotextiles of the containers were simulated by a linear-elastic material model. The sand was emulated by Mohr-Coulomb.

The modelling of the splice between the containers is a decisive factor for realistic results. However there had to be done some simplifications, because the simulation of the behaviour of the containers between each other by the FE-program is problematic. For simulating the contact between the container layers a 2 mm high continuum element was arranged.

Figure 7 and 8 show the results of the numerical calculation in comparison to the experimental tests.

The calculated deformations were smaller then the measured one. So by applying the factor 4 to the FE-results the deforma-

tion using FEM can provide a qualified representation of the model test results. The reasons for this divergence are seen in the simplification of the numerical model, particular in the modelling of the geotextile containers.

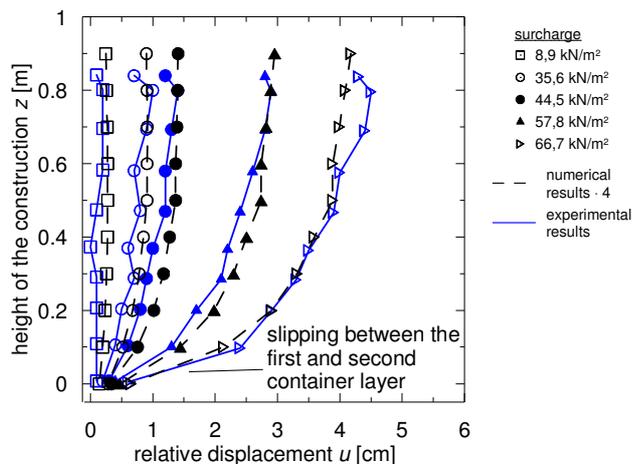


Figure 7. Results of the experimental tests and the numerical calculations (without velcro strips)

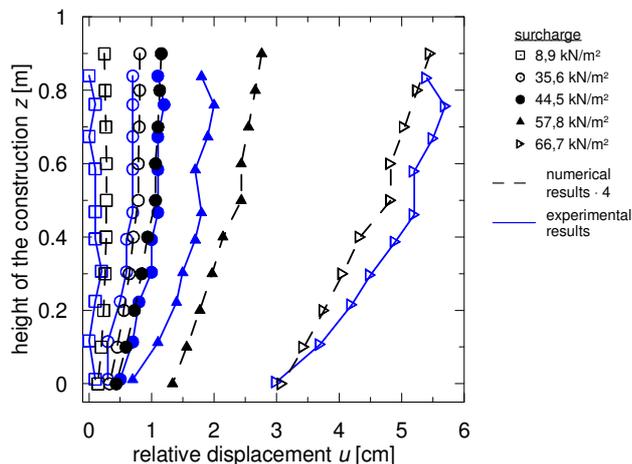


Figure 8. Results of the experimental tests and the numerical calculations (with velcro strips)

6 CONCLUSIONS

This paper examined the increase in bearing behaviour of geotextile containers using velcro strips. A clear increase of load bearing behaviour could be observed. The shear tests show that this increase depends mainly on the type of the used velcro strips. Because of this it is recommended to carry out some shearing tests before using the velcro strips. Furthermore an adhesion factor could be derived.

Pollution reduces the effectiveness of the velcro strips significantly. During installation it is important to mind a not polluted surface of the geotextiles. Moreover the humidity reduces the bearing behaviour in a low way. After a repeated shearing no increase in bearing behaviour was determinable.

The effectiveness of the velcro strips could be demonstrated in a replica of a supporting structure in a scale 1:3. With no use of velcro strips the containers sheered of between the first and the second layer. With the use of the velcro strips the containers acted like a monolithic and a slope failure could be observed.

It is possible to calculate a container construction by FE-programs, which are used in practice. Nevertheless, the applica-

tion should occur with caution, because the numerical results had to verified by a factor. This must be examined by further studies.

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