

# Monotonic triaxial tests on reinforced unbound base courses

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## 1 Introduction

In railway construction, an unbound base course is installed between the existing ground and the ballast layer. This base course has various functions, such as distributing stresses caused by traffic loads, protecting the track from the negative effects of frost and draining or allowing surface water to seep away. Geogrids could be used to improve load bearing and system behaviour. Geogrids provide reinforcement and stabilisation. The behaviour of geogrid-reinforced base courses can be investigated in various ways, e.g. in drive-over tests, in model tests or by triaxial tests. This study will present the results of monotonic triaxial tests.

## 2 Experimental Studies

### 2.1 Used materials

Monotonic triaxial tests were performed to investigate the behaviour of the geogrid in the base course material. A 0/16 base course material made of crushed gneiss was used. This material is a wide-graded gravel with an average grain size diameter of  $d_{50} = 4.2$  mm, a non-uniformity coefficient of  $C_U = 19.6$  and a curvature number of  $C_C = 1.45$ .

To ensure an effective connection between the geogrid and the base course material, the opening width of the geogrid must be adjusted to the maximum grain size of the used material. Therefore, a geometrically scaled geogrid was produced from a standard polypropylene geogrid. This scaled geogrid has an average bar width of  $\bar{b} = 2.4$  mm, an average opening width of  $\bar{l}_w = 12.2$  mm and a bar thickness of  $d = 0.8$  mm.

## 2.2 Experimental procedure

In monotonic triaxial tests, the specimen size was  $d \times h = 100 \times 200$  mm. The geogrid was located in the centre of the reinforced specimens. The specimens were consolidated under drained conditions and afterwards axially loaded until failure. The effective radial stresses in the tests were  $\sigma'_3 = 20 / 40 / 60$  kPa. In all tests, the loading rate was  $v = 0.25$  mm/min. During the shear phase, the drainage remained open on both sides of the specimen. The tested material had a compaction degree of 100 % Proctor density ( $\rho_{pr} = 2.01$  g/cm<sup>3</sup>).

## 2.3 Experimental results

In this study six triaxial tests were performed in which three different effective stresses  $\sigma'_3$  were applied to reinforced and unreinforced specimens, respectively.

Fig. 1 a) shows the stress-strain behaviour during the monotonic triaxial tests. The deviator stress  $q$  increases with increasing effective stress  $\sigma'_3$  for both reinforced and unreinforced specimens. It can be seen that the deviatoric stress  $q$  is higher for the reinforced specimens at the same axial strain  $\epsilon_1$ . An increase in the load-bearing capacity due to the inserted geogrid is therefore clearly recognizable. Looking at the volumetric behaviour, as shown in Fig. 1 b), it can be observed that dilatancy is reduced with increasing effective stresses  $\sigma'_3$ . Initially, the behaviour of the unreinforced and reinforced specimens is similar, with contractancy occurring at a low axial strain  $\epsilon_1$ . With increasing axial strain  $\epsilon_1$  and the transition to dilatancy, i.e. an increase in volume with increasing shear stress, there is a lower dilatancy of the reinforced specimens compared to the unreinforced specimens. Thus, the lateral deformation  $\epsilon_3$  is reduced by the inserted geogrid.

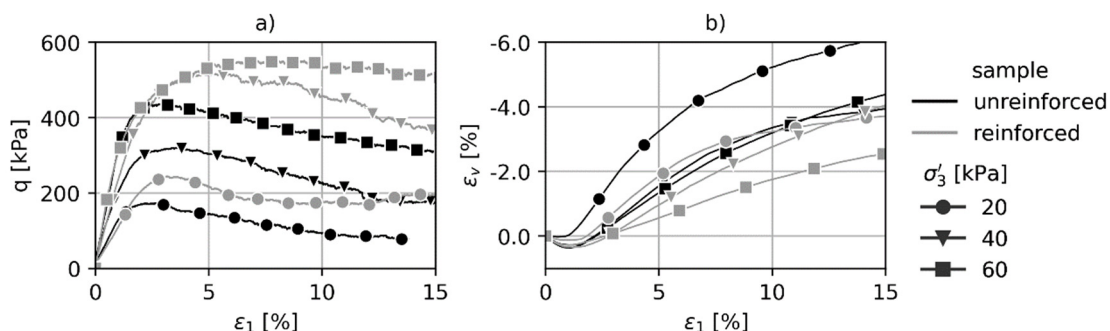


Fig. 1: a) Stress-strain curves, b) volumetric strain - axial strain curves

This effect can also be seen in Fig. 2, which shows the deformation of the specimen after shearing. On the left-hand side the unreinforced specimen is presented, where a clear shear zone is recognizable in combination with a large shear displacement. In comparison, on the right hand side the reinforced

specimen is displayed, where the geogrid is placed in its middle part. There is an obvious interruption of the shear zone, and the lateral deformation of the upper part is noticeably greater than of the lower part, which apparently remained undeformed. This clearly shows the positive influence of the inserted geogrid on the failure behaviour by limiting lateral deformation.



Fig. 2: Specimens after shearing, left: unreinforced, right: reinforced

Finally the Mohr-Coulomb failure criterion was evaluated for the unreinforced and reinforced specimens in their peak states, as shown in Fig. 3.

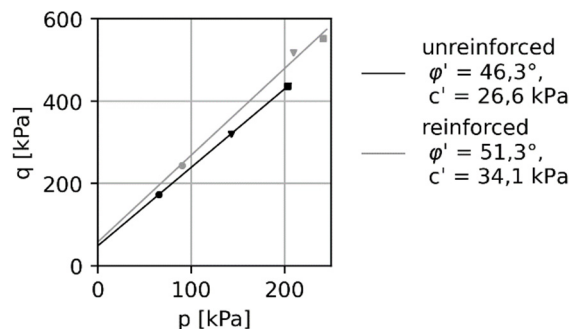


Fig. 3: Shear strength diagram

For the unreinforced specimens, the shear strength parameters were determined to  $\varphi' = 46.3^\circ$  and  $c' = 26.6$  kPa, whereas for the reinforced specimens to  $\varphi' = 51.3^\circ$  and  $c' = 34.1$  kPa. Thus, in the peak state, the cohesion increased by  $\Delta c' = 7.5$  kPa and the friction angle by  $\Delta\varphi' = 5^\circ$  due to the geogrid. These values confirm the results by (Kawamura, et al., 2000) and (Yasufuku, et al., 2002).

The role of the reinforcement can be understood as a 'tensile' and a 'confining' effect. The 'tensile' effect arises to the tensile strength of the geogrid, resulting in an increase in cohesion and friction at the shear plane. The 'confining' effect results from the interlocking of soil particles within the geogrid openings and is reflected in an increase in the friction angle.

### 3 Conclusion

The results of the monotonic drained triaxial tests show a positive influence of the geogrid on the shear resistance. This could be quantified in terms of an increased load-bearing capacity. By reducing the lateral expansion, a higher deviatoric stress  $q$  could be observed for the specimens with geogrids at the same amount of axial strain  $\varepsilon_1$ .

### 4 References

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