INFLUENCE OF THE EFFICIENCY OF DIFFERENT CONNECTION DETAILS ON THE CALCULATION OF A REINFORCED SOIL SYSTEM

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ABSTRACT: In the last few years a growing acceptance has been recognized in the use of geosynthetics for the reinforcement of soil structures. The one advantage of the construction are numerous different facings available for geogrid reinforced soil retaining structures. One type of the facing is the concrete – precast block and there are different types for the connection between the block and reinforcement.

This report describes the result of the trials following the ASTM D 6638-01 / NCMA SRWU-1 with different modes of the connection between facing blocks and geogrids in a geogrid reinforced soil retaining wall-system. The trials are made for three different modes of connection. In the second part of the report a typical project is described where a system using the tested facing blocks and connections has been installed.

1 INTRODUCTION

The reasons why reinforced soil is chosen more and more to construct many geotechnical and civil engineering structures are the efficient use of natural materials, maximisation of the inclusion of marginal fills, the use of environmentally sympathetic aesthetic features and last but not least the quick and easy to install construction. All those benefits lead to cost-effective solutions.

On the market, there are numerous different facings available for geogrid reinforced soil retaining walls. Basically, all those systems consist of the following elements: geogrid – connection – facing. For the calculation, the quality and durability of the facing units as well as the geogrid soil reinforcement must be assessed. Of very high importance is the connection strength between these two components because the reinforcement strength used in the design of reinforced soil walls with modular block facings is limited by the strength of the connection between the reinforcement and the face. Different solutions from the producers of geogrids have been developed to optimize the system geogrid – connection – facing. One of them is the system “Tensar Wall” which consists of prefabricated, unreinforced incremental concrete units, uniaxial stiff geogrids and special polymeric connectors. In the following paragraph this system is described in detail.

2 DESCRIPTION OF THE TESTED SYSTEM

The tested system comprises modular concrete block facing units, stiff, uniaxial geogrids an special polymeric connectors. The concrete block units have the dimensions 40 cm (width), 15 cm (height), 20 cm (depth). A rebate on their topside allows the downstand on the bottom of the following upper block to be arranged in this rebate. Before this upper block is positioned, the geogrid is fixed with the moulded grid connector on the back side of the rebate. For each concrete block element, two connectors, each with a length of 19.5 cm, are necessary for the connection with the retaining geogrids.

The vertical position of the geogrids is determined individually by the design of each wall (figure 1).

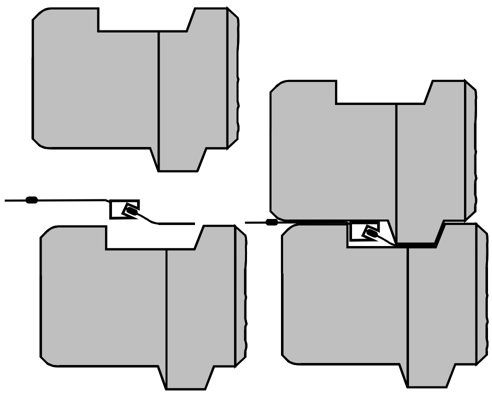

Figure 1: System drawing: Detail of the connection grid – modular concrete block (cross section)

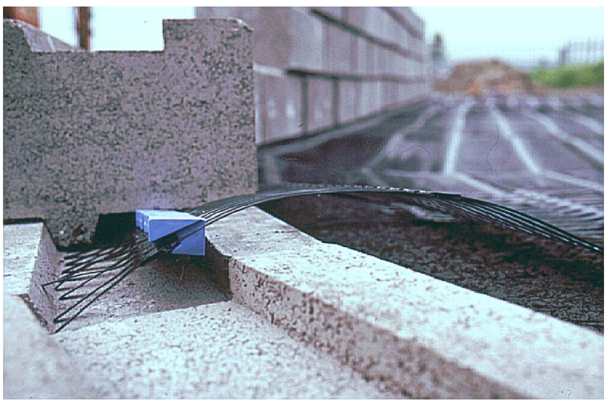

Figure 2: Photograph of the connection grid – modular concrete block

The connector can tolerate small differences in the transverse pitch of the geogrid ribs by the use of flexible links every third aperture. The shape of the blocks and the flexibility of the connectors allow the construction of convex or concave curves down to a minimum radius of 3 m in plan.

3 TESTING AND APPROVAL

3.1 *General*

Design standards of many countries require that a high proportion of the grid design strength is available at the connection for permanent reinforced soil retaining walls, i.e. between the reinforcement and the facing. The British Code of Practice for reinforced soil, BS 8006, 1995, requires that the available connection strength is 70-100% of the design strength of the reinforcement, depending on the vertical position of the reinforcement in the structure. That means that a connection system which provides a high connection design strength is desirable.

Laboratory tests for connection strength are generally short-term test. However, whilst it is the long-term strength available at the connection which is important for design, BS 8006 gives no guidance how long-term connection strength should be calculated. The approach to this problem is to determine a short-term connection efficiency relative to the short-term tensile strength of the reinforcement and apply this connection efficiency to the creep limited strength of the geogrid. To calculate this correctly requires wide-width tensile tests to be undertaken on control samples of the reinforcing grid using the same sample size, equipment and strain rate as for the connection tests. Once a short-term connection efficiency has been established, this can be applied to the long-term creep limited strength of the geogrid to calculate the long-term connection strength.

The German recommendations EBGEO reduces the base strength of the reinforcement by a number of partial factors of safety (A1-A4) to derive the design strength. In this code practice the reduction factor for connection is A3.

In EBGEO the design strength for the connection is giving with the following ratio $C_F = F_{BA,d} / F_{B,d}$, where $F_{BA,d}$ is design strength of the connection and $F_{B,d}$ is the design strength of geogrid. If no exact proof can be given, the ratio can be assumed with 0,8 by walls with concrete facing.

The following tests for geogrid to facing unit connection have been carried out using the industry standard method NCMA SRWU, 1997. This method is divided into two parts. The method SRWU-1 is for the “Determination of Connection Strength between Geosynthetics and Segmental Concrete Units”, while the “Determination of Shear Strength between Segmental Concrete Units” is determined with method SRWU-2. Because the system described uses a connector for the transfer of the strength, this system is tested using method SRWU-1 after the NCMA test method.

3.2 *Connection testing*

The connection strength between geosynthetic reinforcement and segmental concrete block units is used in design of reinforced soil retaining walls.

The connection strength test is meant to be a performance test, therefore, it should be conducted using full-scale system components. The conditions for the test are selected by the user and are not for routine testing.

The tests are carried out according ASTM D6638-01 – Determining Connection Strength Between Geosynthetic Reinforcement and Segmental Concrete Unit -.

Figure 3: Photograph of the application of geogrid with connector (by tBU)

Figure 4: Photograph of the test device for SRW tests (by tBU)

The test principle is that one end of a wide geosynthetic reinforcement test specimen (normally 1m wide), here a monoaxial stretched extruded HDPE geogrid, is attached to dry laid segmental concrete block units assembled as specified by the user. The other end of the test specimen is attached to a clamp (see figure 3 and 4), which is part of a tensile loading machine which produces a constant rate of extension. The top course of the segmental concrete block units is then loaded vertically to a constant normal load and the geosynthetic is then tensioned under constant rate of displacement (20mm/min).The peak connection and the tensile capacity after a user prescribed displacement criteria (20 mm) is measured. A typical curve of the connection capacity versus displacement is given in figure 5.

The tests are conducted at a minimum of three unique normal loads within the range of loads typical of wall design. Additionally, at least two more tests at one normal load are necessary to verify repeatability.

For the tests a system was used as shown in figure 1 with a monoaxial stretched extruded HDPE geogrid. The tensile strength of the material measured according EN ISO 10319 (ULS) is 55 kN/m.

The normal loads, the different versions of the tests and the results F_{ult} (peak load) and F_{20} (service state connection at 20mm displacement) of the tests are given in table 1 and figure 6.

Table 1: Test Program and results of SRW-tests

Test-No.	Wall height in m	Normal load in kN/m	Connection capacity at 20 mm displacement in kN/m	peak connection capacity % of the geogridstrength	Peak connection capacity in kN/m	remarks
1	2	10.0	43.5	90.2	49.6	with two connectors for each block element
2	5	21.4	43.7	80.9	44.5	with two connectors for each block element
3	8	34.4	43.1	83.1	45.7	with two connectors for each block element
4	8	34.4	43.5	84.7	46.6	with two connectors for each block element
5	8	34.4	42.5	79.3	43.6	with two connectors for each block element
6	10	41.7	42.2	82.9	45.6	with two connectors for each block element
7	8	34.4	-	54.0	29.7	with one connector for each block element
8	8	34.4	-	56.0	30.8	with one connector for each block element
9	8	34.4	12.4	37.8	20.8	without connector
10	8	34.4	13.8	31.8	17.5	without connector

Additionally to the tests with the “normal system”, some tests with a reduced number of connectors and without any connectors were carried out. These results are also given in table 1.

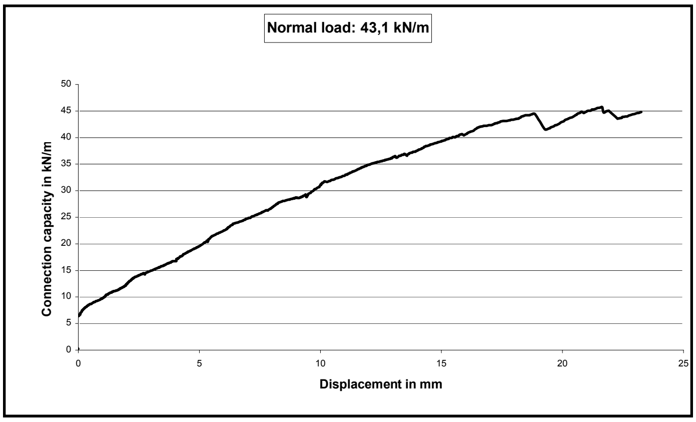

Figure 5: Typical curve of the connection capacity versus displacement

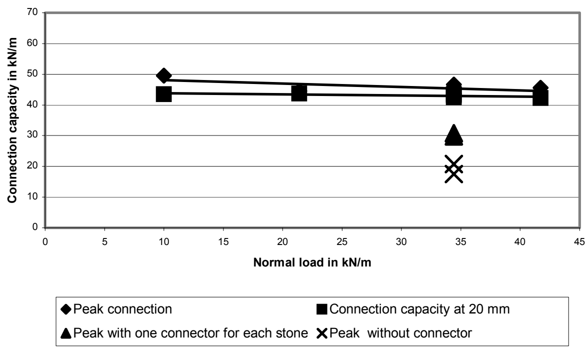

Figure 6: Results of the tests carried out with the monoaxial stretched geosynthetic

The results show clearly that no difference could be observed in the results of F_{ult} and F_{20} independent of the normal load regime. A reduction in F_{ult} and F_{20} can be seen in the tests with the reduced number of connectors and without a connector.

4 EXAMPLE - BRIDGE IN UK -

In Newcastle-upon-Tyne, UK, a new bridge had to be constructed around an existing bridge which had to remain open during construction. For the new structure, concrete spandrels were used to span a small tributary of the River Tyne. The retaining wall construction with the block system was selected for its ease of construction and cost benefits. The maximum wall height for the structure is 12m. The technique lent itself particularly well to working in the tidal zone at the base of the structure; though progress was a little slower than normal, it negated the need for any expensive and time consuming dewatering temporary works.

Figure 7: Picture of the bridge in Newcaste-upon-Tyne

The project shows how a completely dry-laid construction process can conform to the arches of the structure and the construction could proceed without the expense and complications of temporary protection from the tidal movements. With a modular system and no metallic components the rise and fall of the tide could be accommodated without having the complications of the temporary protection works that would have been required if a traditional wet concrete solution had been adopted. The reinforcement strength used in the design of reinforced soil walls with modular block facings is limited by the strength of the connection between the reinforcement and the face. The more efficient the connection is, the greater the proportion of the available reinforcement strength can be used. Independent certification of systems including the facing blocks, connectors and the reinforcement is gained through recognised approval bodies such as the British Board of Agrément (BBA) or Building Research Establishment (BRE).

Figure 8: Photograph of the construction of the bridge in U.K.

5 CONCLUSION

This report describes the result of the trials following the ASTM D 6638-01 / NCMA SRWU-1 with different modes of the connection between facing blocks and geogrids in a geogrid reinforced soil retaining wall-system. The trials are made for three different modes of connection.

The connection strength between modular concrete facing blocks and soil reinforcement is an important factor in the design methods of some countries. Efficient use of the reinforcement can only be achieved if the connection strength is assured.

For sections of a structure where the full design strength of the reinforcement is not required, an efficient construction could include a reduced design strength using a modified connector layout with reduced numbers. For this case the efficiency of the reduced connector configuration had to be tested to confirm that no consequent problems are apparent.

The flexibility of construction that can be achieved with modular concrete block systems with reinforcement / block connection details allows the development of economic solutions to complicated wall geometry construction.

In the second part of the report a project erected with the investigated concrete modular blocks has been described.

6 REFERENCE

ASTM D6638-01: Standard Test Method for Determining Connection Strength Between Geosynthetic Reinforcement and Segmental Concrete Units (Modular Concrete Blocks).

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