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The connection strength of masonry block faced retaining walls

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ABSTRACT
Segmental masonry blocks are widely used as a facing to reinforced soil retaining walls and bridge abutments. Due to the safety critical nature of structures constructed using such systems, concerns are often expressed regarding the connection strength between the soil reinforcing grid and the block facing. With segmental block facings, the blocks are laid without mortar, the reinforcement trapped between the blocks. In the event of a fire in front of a block faced reinforced soil structure, there is therefore potential for loss of structural integrity of the connection, leading to collapse of the facing system. The paper describes the development of a block system which enables the full grid strength to be mobilised between the grid and the blocks, whilst offering protection to the geogrid reinforcement in the event of fire. The resulting wall system was subjected to a half hour fire test and the grid connection strength re-evaluated.

1 INTRODUCTION

The use of polymeric reinforcing materials in conjunction with segmental masonry blocks for reinforced soil retaining walls is commonplace. The ease and speed of construction of this type of facing leads to considerable cost savings over conventional retaining wall designs whilst allowing a variety of surface finishes to be achieved. A key feature of the structural integrity of such retaining walls is the connection strength between the reinforcement and the facing blocks. Many block facing systems exist, most of which rely on friction to provide the required connection strength. With such systems, as the blocks are laid dry without mortar and the grid reinforcement lies in the bed joints of the blocks, the end of the grid reinforcement can be partially exposed at the face. In the event of a fire in front of a block faced reinforced soil structure there is potential for loss of structural integrity of the connection system, leading to collapse of the facing system.

The authors have recently worked on the development and testing of a facing system which achieves high connection strength by the use of a mechanical connector which fully interlocks with geogrid reinforcement. The system developed enables the full grid strength to be mobilised at the grid to block connection, whilst offering full fire protection to the geogrid reinforcement.

As part of an independent assessment of the resulting wall system, by the British Board of Agrément, the system was required to pass a fire exposure test to simulate a fire occurring in front of a completed structure. A sample panel of wall was constructed in front of a laboratory furnace and subjected to a half hour fire test during which, the wall face reached a temperature of 871°C. Following the fire exposure test, the grids were examined for physical damage and the grid to block connection strength determined.

2 CONNECTOR DEVELOPMENT

The Geolock retaining wall system comprises segmental concrete blocks, concrete connector units and **Tensar** SR geogrids. Three versions of the block are used, an upstand block with integral shear key, a connector block with a recessed upper surface and a capping block. The connector unit is sized to enable the connector

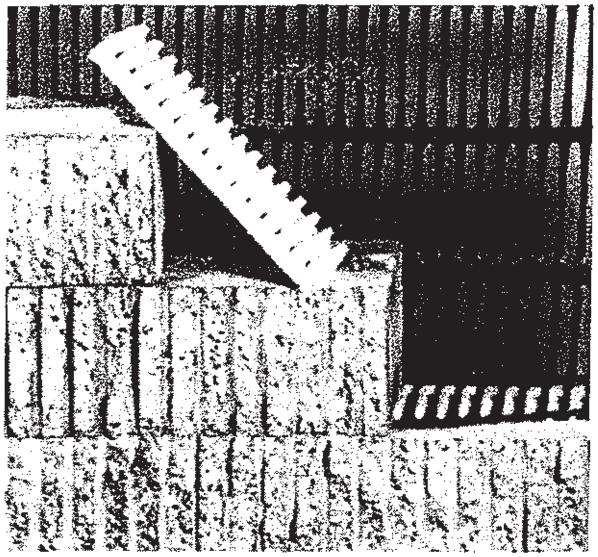

Figure 1 System components

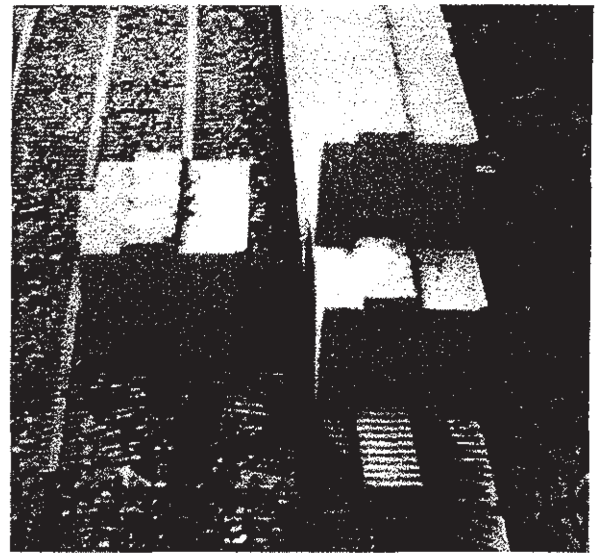

Figure 2 Wall during construction.

upstands to interlock with the apertures of the geogrid reinforcement, Figure 1 and 2. To establish the correct geometry for the connector, a survey of the maximum and minimum width tolerances on the finished geogrid was undertaken. This determined the geometry of the upstand fingers and the maximum number of fingers per connector. In addition to providing a connection between the grid and the blocks the connector also acts as a shear key between blocks. To meet durability and 120 year design life requirements for major highway structures in the UK the blocks and connectors are made from $30N/mm^2$ concrete.

3 CONNECTION TESTING

Short-term grid connection strength tests were undertaken by trapping the connector units in a purpose made jaw that accurately replicated the dimensions of the insitu condition and pulling the grid from the connector, at a strain rate of 10% per minute, in a tensile testing machine. These tests with 1.0m wide grid specimens, showed the ability of the connector to transfer the full short-term strength of the geogrid. Additional tests are currently underway to prove the connection strength further, by pulling the geogrid from between the actual facing blocks to simulate the in-situ condition.

In addition to proving the short-term connection strength of the system a load hold test was undertaken. The load hold test was carried out using SR110 geogrid. In this test a 1.0m wide by 3 ribs long specimen of grid was loaded at strain rate of 10mm per minute at 20°C. When a load of 60kN in the grid was achieved, the load was maintained at that level, until tensile creep failure of the grid occurred. Figure 3 shows the load - time relationship during the test and Figure 4 the load-extension curve.

During the load hold period the extension of the grid increased by 17 % over a period of 2.6 hours at which point failure of the grid occurred. Isochronous creep data for Tensar SR110 at 20°C, shows that for a duration of 2.6 hours, 10% strain in the grid would occur under a load of approximately 54 kN/m. Whilst the grid would continue to support a 54 kN/m load beyond 2.6 hours it would achieve a higher strain. When calculating the long-term creep limited strength of geogrid reinforcement a performance limit strain of 10% is normally used. Hence during the load hold test the grid /connector system withstood a load greater than is achieved by the grid alone, at it's 10% performance strain limit.

In a retaining wall the in-service load in the grid will be substantially lower than the long-term creep limited strength of the geogrid. For SR110 a typical factored design load would be 30 kN/m. The testing carried out demonstrates the ability of the connection system to withstand considerably higher loads than required in service. The connection between the grid and the connector unit can therefore be regarded as a full strength connection.

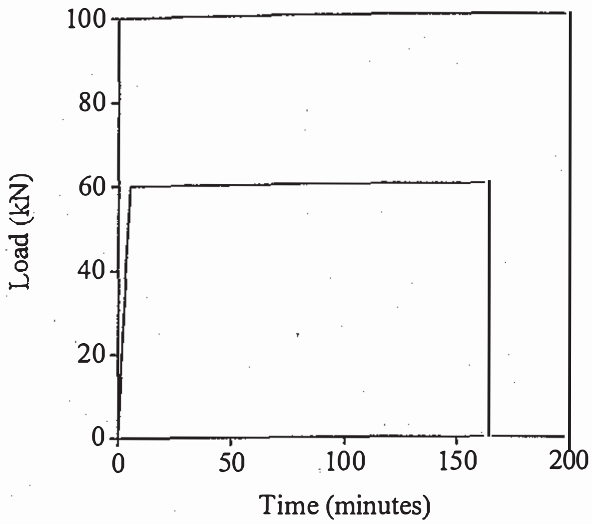

Figure 3 Load-time curve for load hold test

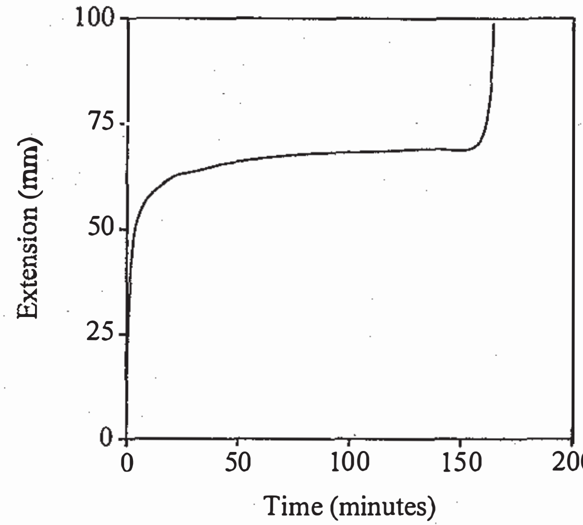

Figure 4 Extension-time curve for load hold test

4 FIRE TESTING

4.1 Fire exposure

To address concerns regarding the effects of fire exposure on the system a fire test was undertaken. In this test two different wall configurations were tested:

1) Standard connector block only
2) Standard connector block with 35mm cavity and a half brick wall facing.

The brick faced structure was anticipated to provide greater protection to the geogrid from the fire. The fire exposure test was a ½ hour test to BS 476 Part 20 (1), where the furnace temperature is raised from ambient to 871°C in 30 minutes.

The test panel was constructed inside a $1m^2$ frame. The entire $1m^2$ aperture was filled with connector blocks, surrounding gaps being filled with ceramic fibre installation. Each of the 5 horizontal joints between the blocks housed a connector unit and a sample of geogrid. Half of the face of the blocks (about the vertical centre line), was faced with standard clay bricks. The bricks were laid dry jointed, with simulated mortar at the horizontal bed joints where stainless steel ties coupled the blocks to the bricks using a stainless steel tie. A cavity of 35mm, as typically used, was maintained between the rear of the bricks of the blocks. The cavity was sealed down the centre line edge of the frame with insulation. Thermocouples were bonded on the rear of the blocks and at the joints and on to geogrids where they emerged from the rear of the blocks. Thermocouples were placed in the void above the inserts, midway behind the block wall and one midway behind the brick faced wall.

The concrete frame housing the test wall was clamped to the face of the gas fired furnace with grids extending from the area of the test panel into the laboratory. At the start of the test the ambient temperature was 14°C. The furnace was lit and the temperature curve of BS 476 Part 20, Figure 5, was followed for 30 minutes at which point the furnace was extinguished. Maximum face temperature after 30 minutes was 871°C.

Figure 6 shows the temperature recorded at the connector locations during the test. It is interesting to note that the maximum temperature recorded in the cavity over the connector insert behind the block wall, was 66° at the end of the half hour test and only 17° behind the brick faced half of the test panel. On dismantling each layer of grid was inspected and labelled prior to being removed for testing.

Two samples of Tensar SR55 and SR80 and one sample of Tensar SR110 were returned from the fire test. Each sample was approximately 900mm wide. Half the width of each sample had been used in the standard wall configuration and half in the brick faced wall configuration. Each sample of grid therefore yielded one tensile test specimen of each type (block faced and brick faced wall). On examination of the grid samples only the grid which had been in the exposed block wall showed any visual sign of damage. This was limited to softening and slight distortion of the transverse bar which had been nearest to the front face of the wall and the tips of ribs close to the exposed face of the block.

During wall construction some of the grid samples

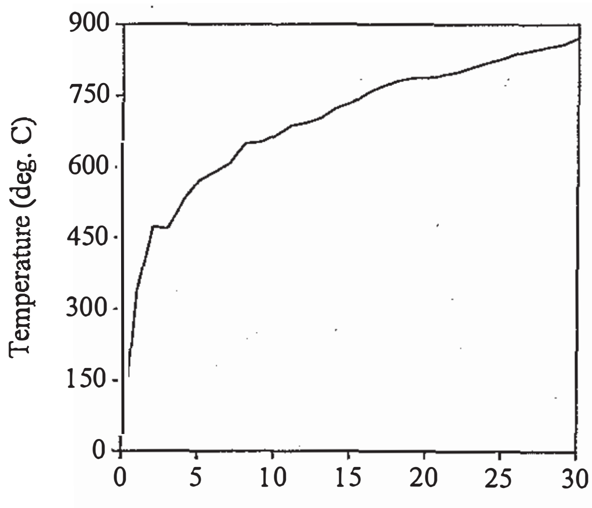

Figure 5 Furnace temperature during fire test

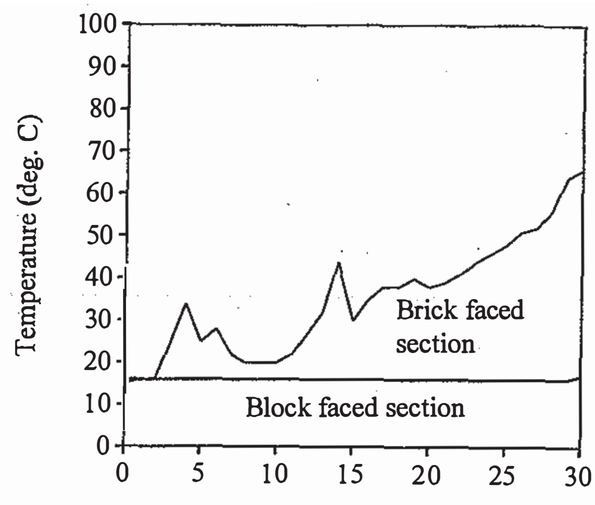

Figure 6 Connector temperature during fire test

Table 1 - Summary of Tensile Test Results

	Control Test	Block faced wall		Brick faced wall	
Grid Type	Mean Tensile Strength kN/m	Mean Tensile Strength kN/m	Retained Strength %	Mean Tensile Strength kN/m	Retained Strength %
SR55	51.56	49.77	96.53	51.43	99.7
SR80	74.88	72.56	96.9	73.21	97.8
SR110	113.44	109.26	96.3	111.10	97.9

had been cut with up to 60mm of LD rib left protruding on the transverse bar which bears on the connector unit. These ribs were therefore located closer to the exposed face than the first transverse bar of the grid. No damage to such ribs was noticed on the grid from the brick faced section of wall. On the block faced section, these ribs showed signs of minor softening and melting to within 28mm of the front face of the first transverse bar.

4.2 Tensile Testing

The exposed specimens of grid were tested over a width of 12 ribs. 3 control specimens of each grid type were used to establish a mean strength. The width of specimen was chosen to test the widest sample of grid which will have been fully exposed to the furnace whilst working within the width of the jaws available to grip the grid. A single new concrete connector unit, which had not been used in the fire test, was used for each tensile test. The connector unit was placed in the purpose made jaw and the grid placed centrally over the connector. The top half of the jaw was fitted and the jaw installed in the Instron.

The results of the tensile testing, carried out at a strain rate of 10% per minute are given below in Table 1.

4.3 Discussion on fire test results

The controlled heating of the furnace followed very closely that of BS 476 Part 20 temperature gradient and during the test a zero pressure was maintained within the furnace to simulate a fire on an exposed wall. The heating regime of BS 476 Part 20 is intended to represent a fire in an enclosed environment and consequently the rate of heat transfer into the test panel was more rapid than would be expected outdoors.

The fire tested samples were subjected to surface damage due to handling, wall construction and dismantling in addition to the effects of elevated temperature, each of which would affect the strength of the connection compared to control specimens.

There was no significant temperature rise at the rear of the wall or on the geogrid above ambient. Temperature rise within the cavity over the insert was not significant in terms of the softening temperature of the geogrid material. From the visual and test results comparing exposed and non exposed samples of geogrid the test proved there was no detrimental effect on the strength of the geogrid or connection between the geogrid and the block wall system.

The added protection given by the brick facing was apparent in that the samples of geogrid behind that half of the panel were indistinguishable from the original there being no evidence whatsoever of softening of the geogrid ribs near to the face of the blocks. Inspection of the blocks revealed that there was no evidence whatsoever of any spalling or cracking due to exposure to the fire.

5 CONCLUSIONS

From the short-term tensile and load hold tests carried out, the connection between the grid and the concrete connector can be regarded as a full strength connection.

Based on the tests reported above, exposure to elevated face temperatures up to 871°C for short periods of time, has no effect on the short-term connection strength of the Geolock wall system.

REFERENCES

BS 476 Part 20:1987 Method of determination of the fire resistance of elements of construction, (general principles). British Standards Institution, London.