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ENGINEERING COUNCIL OF SOUTH AFRICA

ECSA

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PRACTICE NOTE ARISING FROM THE CONTRAVENTION OF THE ECSA RULES OF CONDUCT FOR REGISTERED PERSONS

Practice Note No. 2017/01

THE FAILURE OF CONRETE RETAINING BLOCK (CRB) WALLS IN SOUTH AFRICA

1. INTRODUCTION

1.1 In recent years, there has been an increase in the number of failures of concrete block retaining walls to the extent that ECSA's Investigating Committee has identified these walls as problem structures.

1.2 ECSA supported an investigation by the University of Stellenbosch into the causes of failure of these structures.

1.3 Eighteen case studies of failed gravity and reinforced CRB walls in three provinces of South Africa were extensively reviewed to identify common trends and aspects that typically cause problems with these types of retaining walls. The case studies, which included both gravity structures and fabric-reinforced walls, were drawn from ECSA's case records and from project files of various consulting engineering companies.

1.4 This Practice Note summarises the main causes of the failures and provides guidance on the factors to be considered in order to reduce the number of failures in future.

2. COMMON FEATURES

2.1 The walls included in this study were typically 4-8m high, with wall inclinations between 60^0 and 90^0 and a slope on the retained fill of less than 4^0. The failures usually occurred less than one year after completion of construction.

In many instances, the backfill consisted of moisture sensitive soils such as Berea Red sand and residual granite, often poorly compacted.

2.2 Six of the walls excessively deformed while the remaining 12 collapsed.

2.3 In roughly one quarter of the cases (4 out of 18), the failure of the wall was attributed to construction deficiencies. The failure of the remaining 75% was attributed to design deficiencies as the walls would have failed even if correctly constructed.

3. NATURE OF PROBLEMS ENCOUNTERED

3.1 Many of the failures of gravity walls were the result of water ingress from external and internal sources, leading to the formation of a slip plane behind, through or beneath the walls. In some cases, the walls were extended beyond their original design height or subjected to surcharge loading for which they were not designed.

3.2 Internal instability problems were common among reinforced CRB walls due to inadequate reinforcement design and installation. Again, water ingress was a factor, especially in the tension cracks which develop at the end of the reinforcement due to settlement and lateral wall movements. In at least two instances, the potential for wall movement resulting from creep of the geosynthetic reinforcement was not recognised.

3.3 Deformation of the wall and breakage of blocks often preceded failure.

3.4 The quality and compaction of the backfill was another recurring problem. All too often, any material available on site is used as backfill without due regard to its drainage characteristics, strength, compaction requirements and sensitivity to water ingress.

3.5 Typical design related issues include the incorrectly assumed soil properties, inadequate provision for surface and subsoil drainage, and incompatibility of the design with the actual conditions on site. Other issues attributable to the designer include inadequate construction monitoring and poor standard of the construction drawings.

4. MAJOR DESIGN AND CONSTRUCTION ISSUES

Eleven main design and construction-related issues were identified:

4.1 The use of fine grained (not free-draining) or moisture sensitive soils (soils that soften or swell on wetting) in the backfill / reinforced soil zone;

4.2 Poor placement and compaction of backfill coupled with lack of inspection;

4.3 Poor control of ground water coupled with the absence or inadequacy of sub-soil drainage behind the wall;

4.4 Poor control of surface water and incorrect positioning of surface drains and wet services behind the wall;

4. 5 Incorrectly assessed and/or misunderstood design details;

4.6 Inadequate performance monitoring;

4.7 Incomplete construction drawings and specifications;

4.8 Changes to the retaining wall system not foreseen at design stage;

4.9 Incorrect selection or inadequate strength of facing units;

4.1.0 Inadequate incorporation of reinforcement or soil stabilization; and

4.11 Inadequate design which includes:

4.11.1 Incorrectly assessed site conditions;

4.11.2 Incorrect selection or design of reinforcement;

4.11.3 Incorrect foundation design; and

4.11.4 Failure to check overall stability.

5. BREACH OF PROFESSIONAL DUTIES

5.1 In many instances, the designer had not exercised the necessary skill and care in all three phases of the assignment – Investigation, Design and Construction Monitoring.

5.2 Design parameters for in situ soils and the backfill are often assumed without any testing and without the necessary inspections and site control during construction. In some cases, it was found that designers lacked a basic understanding of soil mechanics principles and the manner in which CRB walls act. Some designers make use of empirical methods without understanding their limitations while others used computer programmes (often unlicensed versions) without knowledge of how the programme operates or the input parameters required.

5.3 In so doing, these designers breached the ECSA Rules of Conduct for Registered Persons; the relevant rules are quoted below in part:

"*3(1)(a) - must discharge their duties to their employers, clients, associates and the public with due skill, care and diligence,*

3(1)(b) - may only undertake work which their education, training and experience have rendered them competent to perform and is within the category of their registration,

3(1)(c) - must, when carrying out work, adhere to the norms of the profession."

6. WHAT LESSONS CAN BE LEARNED?

6.1 Competence – before accepting an appointment for the design of a CRB wall, make certain that you understand how these walls operate and the basic soil mechanics principles involved.

6.2 Selection of Wall Type – CRB walls are seen as economical, easy to construct and flexible in their application, however, they are not suitable in all applications. Alternative wall types should be considered where there is inadequate space for construction of a CRB wall (particularly reinforced walls), high surcharge loads are expected or there are limitations on the long term movement of the wall. In the case of high CBR walls, the use of reinforcement or stabilised fill should be considered. Where a CRB wall is used as cladding to protect an excavated slope face, it is essential that the face itself is stable and that the cladding is adequately tied to the existing face using soil nails or similar.

6.3 Site conditions – ensure that the site conditions are adequately investigated prior to design and are verified by inspections during construction. These conditions include the properties of the founding soils and the retained material, available fill material, the groundwater regime including seasonal changes, the required geometry of the wall and the geometry of the slope above and below the wall and any surcharges that will act on the wall. Adequate account should be taken of the future use of the areas above and below the wall, including the possibility of future excavations or service trenches below the toe of the wall.

6.4 Materials – ensure that the correct materials are selected and that the properties of the materials are correctly incorporated in the design. In particular, the appropriate strength reduction factors for degradation, installation damage and creep should be used in assessing the design strength of geosynthetic reinforcement. Adequate account must be taken of the load-extension characteristics of the reinforcement and, in the case of anisotropic materials; the direction in which the fabric is to be laid must be clearly specified. Avoid the use of fabrics that are designed for separation and drainage as reinforcing, non-woven fabrics in particular.

6.5 Design of Wall – use recognised design methods. Where standard designs or empirical rules are used, ensure that the limitations of these methods are clearly understood. Where computer programmes are used, ensure that the input parameters are correctly assessed. Check the results using simple hand calculations. Consider all potential modes of failure including bearing, sliding, internal stability and overall stability. Checks on overall stability are particularly important for tiered walls or walls on sloping sites.

6.6 Design of Drainage – adequate provision must be made to prevent the development of water pressures within, below or behind the backfill. In areas where seepage is possible or where the fill material is not free draining, this will require the provision of drains behind and below the backfilled/reinforced zone. Surface drainage should preferably be away from the top of the wall and should have sufficient fall to ensure efficient removal of surface water thereby minimising water ingress into the retained material. Water bearing services should preferably not be placed behind the wall. Any surface drains or water bearing services behind the wall should be capable of withstanding the expected wall movements.

6.7 Design Coordination – where various parties are responsible for different aspects of the work, ensure that all design requirements are correctly assessed and that all aspects of the design are covered. Limitations on the positioning of services and surcharges, design surcharge loading, expected movements of the wall and surface drainage requirements must be adequately communicated between designers and shown on the drawings.

6.8 Design Review – for high walls, walls carrying large surcharge loads, walls on difficult soil conditions or walls with limited deflection tolerances, consider having the design of the wall independently reviewed by a specialist geotechnical engineer.

6.9 Drawings and Specifications – ensure that drawings contain all the necessary detail and that all materials and construction processes are clearly specified. With regard to fill materials, use standard material specifications (e.g. G5, G6, etc.) coupled with standardised earthworks specifications (e.g. the SABS 1200 or SANS 2001 series specifications). Compaction requirements should be specified in terms of the required percentage of the Mod AASHTO maximum dry density (typically 93% or 95% Mod AASHTO MDD) and the moisture content at which compaction should take place (typically within 2% of the optimum moisture content). Limitations on compaction directly behind the blocks should be specified.

6.10 Construction Monitoring – the designer should carry out sufficient inspections during construction to ensure that the design assumptions are met and that the completed structure fulfils the design intent. These are essential requirements for the issue of Completion Certificate for the wall. Do not issue a Completion Certificate before the work is complete and a final inspection has been undertaken. Do not issue a Completion Certificate simply on the assurance from the contractor that the work has been correctly undertaken.

6.11 Quality Control – the designer / project manager should ensure that testing is carried out as required by the particular specification or the standardised specifications. This applies especially to the properties of the backfill and compaction achieved. If the fill material comes from different sources or is variable, additional Mod AASHTO maximum dry density determinations should be carried out.

6.12 Maintenance and Monitoring – it is essential for the long term stability of the wall that the wall is maintained and monitored. This applies particularly to the maintenance of surface drainage and monitoring of any activities that could affect the stability of the wall such as excavations in front of the wall or surcharges behind the wall. The adequate functioning of subsoil drains and functioning of weep holes or other drainage outlets should be checked periodically.

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This practice note was prepared on behalf of ECSA, by Loren Agostini and Peter Day on completion of a research programme into the failure of CRB walls at Stellenbosch University.

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