

THE ENGINEERING COUNCIL OF SOUTH AFRICA

**PRACTICE NOTES ARISING FROM CONTRAVENTION OF ECSA's RULES OF
CONDUCT FOR REGISTERED PERSONS.**

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Practice Note No. 2015/2:

The results of a failed Concrete Raft foundation

THE PROJECT

A residential dwelling in a housing estate development, which evidenced severe cracking to its walls. The estate was situated in a coastal region and was located on the site of a former borrow pit which had been excavated for road building materials. The dwelling was founded on a "concrete raft" which failed. The dwelling owner filed a complaint with ECSA against the designer, a registered professional engineer.

BACKGROUND

The site, situated in a coastal region on the lower slopes of a mountain range, was acquired by a Developer for the purpose of establishing an upmarket housing estate with individually designed homes, each on its own stand. The estate site had formerly been a farm and the estate was located over what had been a borrow pit, excavated for road construction into thick scree at one end of the mountain range, being mainly a source of natural gravel. The estate site was sloping, with its elevation ranging from 60 to 37m above sea level. In 2001 a geotechnical investigation was carried out for the overall area of the estate.

The borrow pit had been backfilled, in an apparently uncontrolled manner, with waste rock, demolition and builder's rubble, miscellaneous fill and soil mixed with organic material, tree logs and rotting vegetable matter. These materials lay beneath the proposed dwelling which is the subject of this Practice Note. Much of the surface area was occupied by dumped rubble, grass, weeds and shrubs. In 2005 a site investigation was undertaken by a firm of geotechnical engineers to determine the nature, aerial extent and variation in thickness of fill covering the site. The investigation was preceded by a geophysical survey to determine areas of maximum fill thickness, and to facilitate the strategic location of test pits. Twenty seven test pits were subsequently excavated.

From the geophysical survey a plan was prepared showing the expected fill thickness in 3 zones: less than 1m, 1 – 2m, and more than 2m. The test pits revealed that most

of the coarse colluvium had been removed and replaced with fill. In most of the test pits the fill was underlain by reworked residual sandstone or bedrock; in some pits fine and coarse colluvium, which could not be penetrated, was encountered. DCP tests were unsuccessful since boulders and rubble in the fill prevented meaningful results from being obtained to assess consistencies of the materials exposed in the test pits.

Regarding foundations, the fill was unsuitable to support any structure sensitive to differential settlement. It was recommended that the full thickness of fill beneath the footprints of buildings be excavated and replaced with “engineered fill” to provide a “Soil Raft”. Alternatively deep pad and pier foundations could be taken through the fill to underlying on site horizons.

The engineer elected to follow the soil raft approach but instead of replacing the full depth of fill with a compacted soil backfill, a “stiffened concrete” raft was adopted.

DETAILS OF THE PROBLEM

Construction of houses and infrastructure on the estate began approximately seven years after the 2005 investigation. Both the foundation solutions proposed were costly and the engineer appointed for the design of the house in question sought a cheaper solution at the request of the Developer, and decided instead to provide a stiffened reinforced concrete raft. Several such rafts had been used successfully by the engineer previously for houses in the same estate. In terms of the “deemed to satisfy” rules of SANS 10400:2011 – Part H Foundations, a stiffened raft foundation is an alternative foundation design solution that will enable a building structure to accommodate differential movement without significant damage occurring.

The problem manifested itself in the form of serious cracking to brick walls of the house, emanating from door and window openings. Based on the crack width in an external brick wall, the differential movement between two corners of the raft was estimated to be about 50 – 75mm. In other words, the raft had tilted. The cast depth of the reinforced concrete raft foundation was increased by the engineer to suit the sloping site. The raft was not very stiff, given the beam (450 – 600 x 600 mm) and slab (150mm thick) but was of uniform rectangular dimensions, incorporating integral edge and internal beams. A very stiff raft with say deflection limit less than span/3500 would have prevented flexural failure of the solid unarticulated brickwork, (span/1000 for articulated brickwork) but would not have prevented rotation of the building structure above the fill platform. It was concluded that the non-uniform and variable nature of the fill beneath the platform across the width of the raft, being softer in one area than in the other, allowed the raft to tilt. This was aggravated by the presence of a stormwater pipe outlet in the vicinity of the softer fill. The sand and gravel fill in the fill platform had relatively high permeability and ingress of water could heighten the progressive collapse potential of loose, voided soil.

The engineer concluded the raft had developed a diagonal crack, roughly in the position where the supporting strata changed from in situ to filled material. This could be regarded as a construction joint which could allow a certain amount of movement, and it should be managed as such. A groove was proposed to be cut along the joint and sealed with suitable joint filler. The same treatment was proposed for the cracked walls.

This would not detract from the integrity of the building. To prevent further settlement at the corner of the dwelling it was further proposed that this corner and the opposite corner of the raft should be underpinned by excavating through the underlying

material to a founding stratum and constructing a reinforced concrete column to underside of the raft. The engineer maintained the choice of a reinforced concrete raft foundation was logical, given the disadvantages and high costs of the alternatives of an engineered soil raft and/or piers through the fill from founding stratum to underside of building. This solution had moreover been used effectively elsewhere on the estate.

The NHBRC issued a notice of non-compliance, believing the damage was not structural but from adjustment. The engineer had indicated a “C” classification of soil on the site on the NHBRC enrolment form, but a “P” classification (Fill) would have been more appropriate. However the soil type and nature of the founding material in terms of SANS 10400:2011 – Part H Foundations Table 1 requirements, was correctly indicated. The engineer signed off the certificates in respect of the structural system (Foundations, brickwork to wall plate height, A19 roof) in terms of the National Building Regulations

The engineer accepted responsibility for the failure of the alternative raft design solution and referred the matter of introducing additional support measures to his Professional Indemnity insurers. The owner of the house grew frustrated at the lack of prompt implementation of the remedial measures and submitted an Affidavit to ECSA, with a complaint alleging incompetence on the part of the engineer, citing clauses 3(1)(a) - 3(2)(b), - (compromise professional ability), (3(2)(j) – (correctness of certification), and 4(j) – (respond to correspondence).

ECSA referred the complaint to an expert to determine the existence of prima facie evidence of improper conduct by the engineer, judged in terms of ECSA’s Rules of Conduct for Registered Persons. It was concluded the matter did not constitute improper conduct, but rather the failure of an alternative design solution that could be rectified, and the engineer had acted in a reasonable manner. The application of the remedial measures was the subject of a P.I. claim to his insurers by the engineer.

WHAT LESSONS CAN BE LEARNED?

There are essentially two fundamental lessons to be learned:

1. Firstly, while raft foundations offer a logical solution to the founding of buildings in materials of poor bearing capacity, the concrete raft, even if it is made very stiff, will not be able to resist tilting if the bearing capacity of the variable subsurface materials under the footprint of the building is such that differential settlement between one side of the raft and the other becomes possible. This can occur even if the subsurface materials are excavated to a modest depth and replaced with compacted granular material

In comparison, a soil raft involves excavating all the suspect fill materials over the full footprint down to competent stratum and replacing them with material suited to being compacted in layers to a specified density, i.e. in a controlled manner, to provide an “engineered fill” with a uniform bearing capacity across the full footprint. This can eliminate the risk of differential settlement and consequent tilting of the building.

2. Secondly, where the engineer has unknowingly allowed a fault or error in his design to develop, resulting in a deficiency in the article produced, but which can be rectified, it would be difficult to show the engineer had transgressed one or more of ECSA’s Rules of Conduct – the key rules in this case being

3(1)(a) (lack of due care skill and diligence), and 3(1)(b) - (not competent to perform). A mistake or error in design can arise even though the engineer has exercised due skill, care and diligence, but has adopted an inappropriate approach or made an incorrect design decision. A complaint affidavit to ECSA by the person impacted by the engineer's actions is not likely to resolve the problem.

The correct approach would be for the engineer to bring the matter before his professional indemnity insurers. Failure to do so could then justify a complaint to ECSA alleging unprofessional behaviour by the engineer.

Disclaimer

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