Relevance of present urban geotechnical investigations for urban development in South Africa

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Abstract: The government of South Africa has set as one of its goals the provision of housing for the previously disadvantaged communities in South Africa. The economic advancement of a large part of the population has also created a middle class with the means to provide their own housing. This situation has sparked enormous urban residential and commercial development in areas adjacent to existing cities.

The local authorities and financial institutions require developers to provide a so-called geotechnical report on the foundation conditions underlying sites to be developed. The National Home Builders Registration Council regulates this, which requires competent persons to execute the investigations and foundation design for single storey residential masonry structures. In response to this regulation the relevant professions, including the structural, civil, geotechnical engineers and engineering geologists have come up with guidelines for investigation phases, requirements and a site class designation relating to the more common geological constraints around the city centres in South Africa.

A critical appraisal is given of the present situation regarding the investigation methods, phases, typical results and the design philosophy for urban residential development. New methods and ways to improve the present situation are suggested in the paper.

Résumé: Le gouvernement d'Afrique du sud a entrepris de faire un de ses buts déterminés la fourniture de logement aux communautés précédemment désavantagées dedans L'Afrique du sud.

L'avancement économique d'une grande partie de la population a également créé une bourgeoisie avec les moyens de fournir leurs propres logements. Cette situation a provoqué une énorme mise en valeur de lotissement résidentiel urbain et développement commercial dans les secteurs à côté des villes existantes.

Les autorités locales et les institutions financiers exigent des réalisateurs à fournissez un prétendu rapport géotechnique sur les conditions de base emplacements fondamentaux à développer.

Le Conseil d'enregistrement National de Constructeurs de Maison, règle ceci, au lequel exigez les personnes compétentes exécutez les investigations et la conception de base pour l'étage simple édifices résidentielles de maçonnerie.

En réponse à ce règlement professions appropriées, y compris les ingénieurs structural, civil, géotechniques et les géologues de technologie ont fourni des lignes directrices pour les phases de recherche, les conditions et un emplacement classent la relation en désignation aux contraintes géologiques plus communes autour des centres de la ville dedans L'Afrique du sud. Une évaluation critique est donnée de la situation actuelle concernant les méthodes de recherche, phases, résultats typiques et la philosophie de conception pour le développement résidentiel urbain. Nouvelles méthodes et manières d'améliorer la situation actuelle sont suggérées dans le papier.

Keywords: foundations, site investigation, urban geosciences.

INTRODUCTION

An essential part of meeting the basic needs of people is the provision of housing, drinking water and sanitation (ANC, 1994). The housing backlog is such that vast areas of land are needed for the construction of houses. Due to the rapid urbanisation of the recent past, most of the best land suitable for development in close proximity to urban centres has been exhausted. Future urban development land is required and must be identified and approved by the local authorities prior to any development taking place. The relevant investigations include the environmental impact assessment, bulk services supply plans and also a geotechnical urban investigation.

The three important documents regulating these investigations presently are the Code of Practice for Foundations and Superstructures for Single Storey Residential Buildings of Masonry Construction that was published through a joint effort of the South African Institution of Civil Engineers and the Institute of Structural Engineers (SAICE, 1995), the National Home Builders Registration Council's Standards and Guidelines document (NHBRC, 1999) and the Generic Specification GFSH-2 by the National Department of Housing (2002). These documents list the approach to site investigations, typical founding materials with expected soil movement for each material type and suggested foundation designs and building procedures for each class. These proposed foundation solutions are reflected as construction requirements.

INVESTIGATION APPROACH

The National Housing Code in Chapter 3 of Part 3 makes provision for the determination of the technical feasibility of the extent to which construction methods employed in the project are "effective, viable and practicable in relation to physical, climatological, geotechnical and topographical characteristics of the project site".

The two documents governing the approach to the actual site investigations are the 1997 "Guidelines for urban engineering geological investigations"(SAIEG/SAICE, 1997) and the generic specification GFSH-2 of the National Department of Housing (2002). Both these documents attempt to outline the process of these investigations with the SAIEG/SAICE (1997) guidelines stating that an investigation can pass through a number of stages with each stage beginning with the gathering of general information and becoming more detailed in successive steps. Each investigation type is unique and the extent and detail of work to be performed is clearly specified to minimise the likelihood of a misunderstanding occurring between consultant and client.

Geotechnical/engineering geological investigations are divided into three categories:

- **planning**, providing information for town and regional planners and decision-makers involved in urban development;
- **development**, providing information to developers of urban areas; and
- **specialised** investigations, which are detailed investigations of complex sites or the investigation of sites for which specific engineering design parameters need to be determined.

The National Department of Housing specification mentions two phases following on the **preliminary investigation** that comprises the gathering of all known information relating to the geotechnical conditions of the land as well as the interpretation of this information. The outcome of this initial stage is the determination of the suitability of the land for the proposed housing project.

The **Phase 1** investigation is executed at the stage when feasibility reports are needed and the **Phase 2** investigation is commissioned by the developer during the installation of services and basically only need to confirm the site class designations of the individual land parcels in accordance with the NHBRC (1999) requirements for enrolment. Special stability assessment is required for land underlain by dolomitic bedrock or undermined areas.

The end result of the Phase 1 and Phase 2 investigations are the so-called residential "site class designation" or the more specific dolomite area designations for individual land parcels. A summary of these designations is listed in Table 1.

Table 1. Summary of site class designations (GFSH-2, 2002)

Site Class Designation	Typical Founding Material	Character of Founding Material	Single storey masonry house construction type
R	Rocks	Stable	Normal
H	Clays,silty clays,clayey silts and sandy clays	Expansive soils	Normal
H1			Modified normal/soil raft
H2			Stiffened or cellular raft/piled or split construction/ soil raft
H3			Stiffened or cellular raft/piled construction/ soil raft
C	Silty sands, sands, sandy and gravelly soils	Compressible and potentially collapsible soils	Normal
C1			Modified normal/compaction of in-situ soils below individual footings/deep strip foundations/soil raft
C2			Stiffened strip footings, stiffened or cellular raft/deep strip foundations/ compaction of in-situ soils below individual footings/piled or pier foundations/ soil raft
P	Contaminated soils, controlled fill, dolomitic areas, landslip, landfill, marshy areas, mine waste fill, mining subsidence, etc.	Variable	Variable
S	Clayey silts, clayey sands of low plasticity, sands, sandy and gravely soils	Compressible soils	Normal
S1			Modified normal/compaction of in-situ soils below individual footings/deep strip foundations/soil raft
S2			Stiffened or cellular raft/piled or split construction/ soil raft

Site Class Designations for Land Underlain by Dolomite Bedrock

Area Designation	Description	Single storey masonry house construction type
D1	No site and service precautionary measures required	As for site class R,H-H3, C-C2 and S-S2
D2	General site and service precautionary measures required	As for site class R,H-H3, C-C2 and S-S2
D3	Precautionary measures in addition to D2 are required	Special foundations e.g. fill mattresses, rafts spanning near surface pinnacles
D4	Unsuitable for housing developments	-

The estimated ground movement to distinguish between the settlement classes, S to S2 and C to C2, and also the heaving subdivisions, H to H3, is at millimetre scale. To decide, for instance, whether a site is a C or C1 site one has to determine the expected collapse settlement and if it is less than 5 mm the site is classified as C and between 5 and 10 mm as a C1. The same holds for the other classes. This classification of the site is already done at the Phase 1 investigation stage, where most of the information is gained from soil profile descriptions in a number of test pits scattered across the site. Typically the site investigation will entail the excavation of test pits with a backactor (Figure 1) and the description of the soil profile (SAIEG, 1996). There are different approaches to the number of test pits needed. The SAIEG/SAICE (1997) guidelines distinguish between sites smaller than 10 hectares and sites larger than 10 hectares. For sites smaller than 10 hectares six to ten test pits are recommended and for the larger sites between one and six test pits per 10 hectares are suggested.

It is however emphasized that the variability in bedrock geology and variability of the terrain (i.e. landform, drainage, etc.) will influence the test pit sampling density.

The Generic Specification (Department of National Housing, 2002) gives a minimum frequency for exploratory holes and also distinguished between sites of not more than 10 hectares in size and sites greater than 10 hectares. It is stated that this gives a minimum requirement for input needed for realistic engineering judgements.

Figure 1. Backactor excavating test pit.

No mention is made of the possible influence of bedrock or terrain variability on the spacing of sample points. On a 10 hectare site a minimum of ten sampling points are required. If the entire site is situated on a concave slope with mudrock as bedrock geology without any drainage features, half this number of test pits will probably suffice. The professional judgement is to a large extent removed from these guidelines, which is fine for the inexperienced professional, but quite frustrating for an experienced person, with intimate knowledge of a specific area.

Another issue is the number of soil samples to be tested. After completion of the soil profile description the engineering geologist must decide on which soil horizons may be problematic on the site and sample these horizons. The general guideline (SAIEG/SAICE,1997) states that at least three samples per soil horizon identified as potentially problematic are necessary. In the Generic Specification (2002) it is required of the competent person (Geotechnics) to arrange for laboratory tests at an accredited soil mechanics laboratory. The tests should be on representative bulk, disturbed and/or undisturbed samples of **all significant ground profile variants**.

A list of tests is given, but generally grading and Atterberg Limits will be the more common tests requested. If settlement is perceived to be a major problem consolidation tests, double oedometer or collapse potential test will be performed. If heave is regarded as a possible problem free swell and swell pressure tests may be included. An important parameter that should also be determined is the road building potential of the upper site soils. Depending on the visual assessment of the grading, compaction and CBR testing may also be included.

GEOTECHNICAL EVALUATION OF SITES

Due to the present amount of site investigations being undertaken for urban development, and especially residential development, consultants are overworked and only do the necessary to get the process, through which land change from agricultural to urban, started as is legally required by the local authorities.

It is therefore logical that a conservative approach will be followed when in doubt about the suitability of a particular site or when the ground response to foundations, excavation and earthworks is estimated. This conservative approach will be followed with the initial Site Class Designation classification and the design engineer tends to also be conservative in the final design of the foundations. It will then follow that in most instances single-storey residential developments are over designed. With the pressing need for housing wasting of money on foundations cannot really be afforded.

In theory the Phase 2 investigation should follow on the Phase 1 investigation at the time when foundations are open for individual structures, or when subsurface services are installed. This appointment of a competent person should be by the developer of the land. A sound relationship is needed between the competent person and the services contractor to enable the engineering geologist to visit the site at the optimum time prior to backfilling of the trenches. This Phase 2 investigation is usually more expensive than the Phase 1 investigation given the amount of professional time involved in travelling to and from the site and time spent on site to check the initial site classes and compare it with the new exposed soil profiles. For this reason many developers do not bother to institute this Phase 2 investigation. This is another reason why the engineers may over design the foundations to compensate for the eventuality of weaker soil conditions on a site. Figure 2 shows an example of such a case where the backactor refused during the site investigation at shallow depth (<1,0m). The site was given a Site Class Designation of S, which translates to a suggested foundation design of normal strip footings or slab-on-the-ground foundations with good site drainage.

During the excavation for the foundations, that was done by pick and shovel, the labourers had difficulty opening the foundation trench in honeycomb to hardpan magnesite/calcrete. The design stipulated that a steel reinforced strip footing was needed and the contractor followed the design without any queries.

Developers of commercial property within the urban spread surrounding the historic central business districts, are required to apply for land-use change and are also required to submit a geotechnical report. It has become common use to apply the same NHBRC (1999) site class designation in the Phase 1 investigation for these developments as for residential development. When the site is eventually developed fill or deep excavation render the geological data obtained during the investigation worthless.

Figure 2. Reinforcement in shallow foundation.

PROPOSED CHANGES TO PRESENT INVESTIGATION PROBLEMS

A number of proposed changes are listed to assist with the present need to develop urban areas as well as commercial property in land adjacent to present cities. These changes also take into account that existing information is not always available at the Council for Geoscience or at the local authorities.

The phased approach should be abandoned and geotechnical site investigations should be named after the specific purpose of the investigation. The following terminology could be used:

- **Land-use change investigation**, which will typically be a preliminary and/or Phase 1 investigation to indicate to the local authority the suitability of the land for the intended or proposed use.
- **Residential foundation investigation**, which will be something between the present Phase 1 and Phase 2 investigations where shallow foundation conditions and material properties are investigated. This will have the present NHBRC site class designation as outcome.
- **Dolomite stability investigation**, which will follow the accepted scenario supposition approach to determine the surface stability in land underlain by dolomite bedrock.
- **Special foundation investigation**, which may be an investigation for any specific structure including dams, high rise buildings, road foundations, bridges, etc.
- **Construction material investigation**, where the properties of materials needed for specific purposes are determined.

The site class designation alphanumeric indicator may also be expanded to include the proposed three-tiered classification according to the twelve typical geological constraints as proposed by Partridge,et al (1993). The costs involved in determining the soil volume change at 5 mm sensitivity for housing projects are probably necessary. Laboratory testing to determine this parameter should therefore be part of every site investigation and if the local authorities start to keep a record of these determined soil volume changes a cost saving may eventually be passed on to the tax payer. This aspect is a totally different issue and will not be elaborated on further.

CONCLUSIONS

The approach to site investigations in South Africa has changed dramatically over the past 10 years from a situation where the professional engineering geologist or geotechnical engineer decided what was necessary to a situation where legislation has become quite prescriptive. This is obviously not a bad approach, but the legislation cannot be the overriding factor determining the outcome of geotechnical site investigations. As has been illustrated in the above paragraphs we have reached a situation where the bedrock geology and specific foundation conditions are no longer taken into account, but the foundation design that was based on a millimetre movement scale in a published table in a guideline document plays the main part.

The present situation is probably creating a comfort zone for the design engineer and financial institutions mortgaging the structure, but is also in a way a waste of money when foundations are over designed.

There are obviously also some shortcomings in the above approach, but for the present situation to be changed it will probably be necessary to move back to the basics and approach each site investigation with an open mind to the variables, such as bedrock geology, terrain characteristics and not least the competent person's past expertise and knowledge of a specific area.

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