Minimum requirements for geotechnical investigations

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University of Stellenbosch

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Our Proud Heritage:

Swartberg Pass
1881-1888, Thomas Bain

Preamble
Our Proud Heritage:
Andrew Geddes Bain
Thomas Bain

Preamble

Andrew Geddes Bain
(1797 – 1864)

Thomas Bain
(1830 – 1893)
Our Proud Heritage:
Andrew Geddes Bain
Thomas Bain
Jere Jennings
Tony Brink
Tony Williams
Ken Knight

Des Midgley and Jere Jennings

Tony Brink

Tony Williams

Preamble

Central Johannesburg
1967

Sandton, 2015
Our “Hall of Fame”:
Andrew Geddes Bain
Thomas Bain
Jere Jennings
Tony Brink
Tony Williams
Ken Knight
Ian Braatvedt
Ross Parry-Davies
John Everett

Why then do we still have problems like these?
Outline of Presentation

- Relevant legislation and standards
  - Mandatory or voluntary?
  - Specific requirements
- Professional obligations
- Common problems
- Solutions
Legislation

- Housing Consumers Protection Act – No. 95 of 1998.
National Building Regulations .. Act

Act – No. 103 of 1977

§ 17

Building Regulations

SANS 10400

Mandatory
no mention of geotechnical investigations

Mandatory
Defines a geotechnical investigation
Regulations F: Investigation SHALL be conducted
• contaminated land
• unstable land
• problem soils
References SANS 10400

Gives options for satisfying functional requirements
• deemed-to-satisfy rules (prescriptive)
• rational design / assessment (10400-B)
• Agrément certification

National Building Regulations .. Act

Regulation F3:
• Owner (applicant) SHALL appoint a competent person to do a geotechnical investigation if:
  • informed by local authority of problem soils
  • owner aware of problems
  • problems are evident (e.g. dolomite)
• Competent person SHALL:
  • conduct investigation in accordance with 10400-B for dolomite land or 10400-H
  • Report to owner and local authority
National Building Regulations .. Act

SANS 10400-B, section 4.4:
• Competent person (dolomite land) SHALL investigate in accordance with SANS 1936-2

SANS 10400-H, section 4.2:
• Geotechnical investigation by competent person SHALL:
  • classify the site (H1-H3, C1-C2, etc.) based on expected movement of single or double storey masonry structures

Legislation

• National Building Regulations and Building Standards Act – No. 103 of 1977.
• Housing Consumers Protection Act – No. 95 of 1998.
Occupational Health and Safety Act

Act – No. 85 of 1993

Mandatory
no mention of geotechnical investigations

§ 43 & 44

Construction Regulations

Mandatory
Regulation 6(1): The designer SHALL:
• provide the client with a report containing the "geotechnical-science" aspects where appropriate
• inform the client of any hazards related to the work and relevant information required for safe execution.

Regulation 13: Gives requirements for excavations to be met by the contractor.

Legislation

• National Building Regulations and Building Standards Act – No. 103 of 1977.
• Housing Consumers Protection Act – No. 95 of 1998.
Housing Consumers Protection Act

Mandatory
- Establishes NHBRC
- Act includes Home Building Manual

NHBRC

Mandatory for Housing
- Sets performance requirements
- Refers to other standards (10400, 1936, etc.)
- Requires appointment of competent persons
- Defines site class designations and requires classification of individual sites
- Modifies SANS 1936 requirements
- Defines permissible development on dolomite

Home Building Manual
2015
Standards

- Housing Standards
- Dolomite Standards
- Design Standards
- Site Investigation Standards

Standards are not mandatory unless:
- Referred to in applicable legislation
- Required to fulfill Local Authority or NHBRC requirements
- Specified by contract

Housing & Dolomite Standards

- SANS 1936-2: Development on dolomite land – Geotechnical investigations and determinations
- GFSH-2: Dept. of Housing – Geotechnical investigations for housing developments
- SANS 934: Geotechnical investigations for township development
Housing & Dolomite Standards

Common Factors:
• Specify methods of investigation
• Specify minimum no. of holes and tests
• Phased investigation approach

<table>
<thead>
<tr>
<th></th>
<th></th>
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<th></th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>During planning and site selection phase</td>
<td>Preliminary investigation</td>
<td>Preliminary geotechnical site investigation</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Prior to township development</td>
<td>Phase 1 detailed investigation</td>
<td>Phase 1 geotechnical site investigation</td>
<td>Feasibility level dolomite stability investigation</td>
<td></td>
</tr>
<tr>
<td>Before detailed design</td>
<td></td>
<td></td>
<td>Design level investigation including footprint investigation</td>
<td></td>
</tr>
<tr>
<td>During installation of township services</td>
<td>Phase 2 detailed investigation</td>
<td>Phase 2 geotechnical site investigation</td>
<td>Investigations during installation of services</td>
<td></td>
</tr>
</tbody>
</table>
### Standards

- Housing Standards
- Dolomite Standards
- **Design Standards**
- Site Investigation Standards

### Preliminary site investigation:

<table>
<thead>
<tr>
<th>Purpose</th>
<th>SANS634</th>
<th>GFSH-2</th>
<th>SANS1936-2</th>
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<tbody>
<tr>
<td>Minimum</td>
<td>4.2.1, 4.2.2</td>
<td>4.1</td>
<td>-</td>
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<tr>
<td>requirements</td>
<td>4.2.3 – 4.2.4</td>
<td>5.1 and 5.2.1</td>
<td>-</td>
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<tr>
<td>Reporting</td>
<td>4.2.5 – 4.2.7</td>
<td>5.2.2</td>
<td>-</td>
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</table>

### Phase 1 / Feasibility level investigation

<table>
<thead>
<tr>
<th>Purpose</th>
<th>SANS634</th>
<th>GFSH-2</th>
<th>SANS1936-2</th>
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<tr>
<td>Minimum</td>
<td>4.3.1</td>
<td>4.2</td>
<td>4.4.1</td>
</tr>
<tr>
<td>requirements</td>
<td>4.3.1 – 4.3.3</td>
<td>5.1 and 5.3.1, 5.3.2</td>
<td>4.2.1 – 4.2.5</td>
</tr>
<tr>
<td>Reporting</td>
<td>4.3.2.3, 4.3.2.4</td>
<td>5.3.1.4 and 5.3.2.7</td>
<td>4.2.6</td>
</tr>
</tbody>
</table>

### Design level and footprint investigations

<table>
<thead>
<tr>
<th>Purpose &amp; need for</th>
<th>SANS634</th>
<th>GFSH-2</th>
<th>SANS1936-2</th>
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</thead>
<tbody>
<tr>
<td>Minimum</td>
<td>-</td>
<td>-</td>
<td>4.3.1</td>
</tr>
<tr>
<td>requirements</td>
<td>-</td>
<td>-</td>
<td>4.3.2</td>
</tr>
<tr>
<td>Reporting</td>
<td>-</td>
<td>-</td>
<td>4.3.3</td>
</tr>
</tbody>
</table>

### Phase 2 investigation / Investigation during installation of services

<table>
<thead>
<tr>
<th>Purpose</th>
<th>SANS634</th>
<th>GFSH-2</th>
<th>SANS1936-3</th>
</tr>
</thead>
<tbody>
<tr>
<td>Minimum</td>
<td>4.4.2, 4.4.3</td>
<td>5.1 and 5.4.1.1, 5.4.2.1</td>
<td>4.4.2 and 4.8.3.1 of SANS 1936-3</td>
</tr>
<tr>
<td>requirements</td>
<td>4.4.2.2</td>
<td>5.4.1.2, 5.4.2.2</td>
<td>4.4.3 and 4.8.3.2 of SANS 1936-3</td>
</tr>
<tr>
<td>Reporting</td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>
### Design Standards

- **SANS 10160-5**: Basis of structural design and actions – Geotechnical design
- **SANS 10161**: Design of Foundations for buildings
- **SAICE lateral support code**: 1989

### SANS 10160-5

**Geotechnical Categories:**

Four categories defined ranging from straight-forward to highly complex.
SANS 10160-5

Geotechnical Category determines:

- Geotechnical investigation requirements
- Design level and responsibility
- Supervision and QC requirements
- Ongoing monitoring

Category 1 - Straightforward

- Negligible risk or limited consequence of instability or movement
- Inspection of soil profile, possibly some lab tests
- "Deemed to satisfy"-type design
- Routine inspections & QC
- Monitoring only reactive

e.g. House foundations
SANS 10160-5

Category 2 - Routine

- No abnormal risks
- Routine field and lab tests yielding design parameters
- Quantitative design by Structural Engineer
- Systematic inspections & documented QC
- Monitoring only if appropriate

E.g. Spread footings, piled foundations, retaining walls, etc.

SANS 10160-5

Category 3 - Complex

- No abnormal risks but complex design or site conditions
- Specialised field & lab tests yielding design parameters
- Specialised design assisted by geotechnical engineer.
- Detailed inspections & rigorous QC
- Planned Monitoring programme

E.g. Anchored retaining structures, tunnels, soil structure interaction problems.
SANS 10160-5
Category 4 – Highly complex

- Fall outside Categories 1 – 3
- Involve abnormal risks or complex / unstable ground conditions
- Additional or alternative rules required.

SANS 10161  Design of foundations

3.1.1 a): Designer’s responsibility to ensure that site is investigated in order to:
- assess suitability
- enable design
- foresee construction difficulties

3.1.1 c) b): Designer to determine extent of investigation
SANS 10161 Design of foundations

3.1.2: **Designer** to appoint person responsible for detailed investigation where required. Designer to submit report to local authority.

3.4.1: **Designer** to inspect site to ensure design compatible with site conditions

3.4.2: **Designer** to ensure suitably qualified person to inspect site conditions during construction

SAICE Lateral support code

- Chapter 2 – Site Investigation
  - Objectives and planning
  - Desk study & preliminary fieldwork
  - Detailed field and laboratory investigation
  - Existing structures and services
  - Reports
SAICE Lateral support code

Chapter 2 – Site Investigation ……continued

– Quantification of parameters required
– Must extend beyond the plan area of works
– Investigate to 2x depth or stable stratum
– Gives guidance of lab and field tests (App B)
– Verification and further investigation / monitoring during construction
– Advice on reporting
Standards

- Housing Standards
- Dolomite Standards
- Design Standards
- Site Investigation Standards

SAICE Site Investigation CoP

Took 6 years and three days to write!
SAICE Site Investigation CoP

Standards

SAICE Site Investigation CoP

Standards
SAICE Site Investigation CoP

• Purpose
  – Set down standards of good practice
  – Give guidance to geotechnical practitioners
  – Assist Clients in specifying and procuring investigation services.

SAICE Site Investigation CoP

• Contents
  – Planning
  – Procurement
  – Execution
  – Reporting
  – Verification during Construction
  – Bibliography
## Standards

<table>
<thead>
<tr>
<th>Stage</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>Project start-up</td>
<td>Identify initial site risks, geotechnical constraints &amp; estimate likely scope of work.</td>
</tr>
<tr>
<td>Pre-feasibility</td>
<td>Desk study and walkover survey, maximise use of existing data and local experience.</td>
</tr>
<tr>
<td>Feasibility</td>
<td>Create conceptual geotechnical model, Update scope of site investigation.</td>
</tr>
<tr>
<td>Safety</td>
<td>Evaluate risks and benefits at each site, value engineer around clients requirements.</td>
</tr>
<tr>
<td>Safety</td>
<td>Abandon project</td>
</tr>
<tr>
<td>Safety</td>
<td>Project feasible?</td>
</tr>
<tr>
<td>Safety</td>
<td>Yes</td>
</tr>
<tr>
<td>Safety</td>
<td>No</td>
</tr>
<tr>
<td>Safety</td>
<td>Feasibility Report</td>
</tr>
<tr>
<td>Safety</td>
<td>Comprehensive desk study, limited fieldwork and lab testing.</td>
</tr>
<tr>
<td>Safety</td>
<td>Brief from client: type of structures, performance, safety.</td>
</tr>
<tr>
<td>Safety</td>
<td>Propose a number of feasible sites and possible alternative founding solutions at each site.</td>
</tr>
</tbody>
</table>

*Flowchart* showing the process of project planning and evaluation.
Typical parameters from a geotechnical investigation will include the following:

**Classification: Soil**
- Grading properties (75mm to 2μm)
- Atterberg limits
- Maximum compacted density and optimum moisture content
- California bearing ratio
- Consistency
- Exudability

**Classification: Rock**
- Unconfined compressive strength
- Joint characteristics
- Rock mass classification

**Characterisation - State**
- Specific gravity
- In-situ density & moisture content (void ratio)
- Permeability
- Collapsibility, heave and swell potential

**Characterisation - Strength and Compressibility**
- Shear strength
- Compressibility
- Consolidation and creep properties

---

**Cost of Investigation**

<table>
<thead>
<tr>
<th>Type of Work</th>
<th>% of capital cost of works</th>
<th>% of earthworks and foundation costs</th>
</tr>
</thead>
<tbody>
<tr>
<td>Earth dams</td>
<td>0,9 - 3,3</td>
<td>1,1 - 5,2</td>
</tr>
<tr>
<td>Embankments</td>
<td>0,1 - 0,2</td>
<td>0,2</td>
</tr>
<tr>
<td>Docks</td>
<td>0,2 - 0,5</td>
<td>0,4 - 1,7</td>
</tr>
<tr>
<td>Bridges</td>
<td>0,1 - 0,5</td>
<td>0,3 - 1,3</td>
</tr>
<tr>
<td>Buildings</td>
<td>0,1 - 0,2</td>
<td>0,50 - 2,0</td>
</tr>
<tr>
<td>Roads</td>
<td>0,2 - 1,6</td>
<td>1,6 - 5,7</td>
</tr>
<tr>
<td>Railways</td>
<td>0,6 - 2,0</td>
<td>3,5</td>
</tr>
<tr>
<td><strong>Overall mean</strong></td>
<td><strong>0,7</strong></td>
<td><strong>1,5</strong></td>
</tr>
</tbody>
</table>
Cost of Inadequate Investigation

Figure 2: Cost overruns as a function of expenditure on site investigations for United Kingdom highway projects (Mott MacDonald and Soil Mechanics Ltd, 1994)

The Geotechnical Division of SAICE

Essential Reading!!

Site Investigation
Code of Practice
Standards

Download free from:


Professional obligations
Types of liability

- Criminal:
  - e.g. OHSA contravention, Dept of Labour
- Civil:
  - Contractual claim by client
  - Delictual claim by third party
- Professional:
  - ECSA / SACPCMP / SACNSP / SACAP code violation

Obligations

- FIDIC: exercise reasonable skill, care, diligence
- NEC: uses the skill and care normally used by professionals
- ECSA: adhere to the norms of the profession
- SACPCMP: discharge duties in a responsible and competent manner
Professional Obligations

Error?

Negligence?

Professional negligence

Norms of the profession

- Norms in the profession established by
  - Standard forms of agreement (if no formal contract)
  - Scope of services and schedules of tariffs
  - Codes and standards
  - Professional codes of conduct
  - Expert testimony

Increasing relevance
Common Problems

Professional negligence

Norms of the profession

• Norms in the profession established by
  – Standard forms of agreement (if no formal contract)
  – Scope of services and schedules of tariffs
  – Codes and standards
  – Professional codes of conduct
  – Expert testimony

Increasing relevance

Common Problems

Technical Problems

• Inadequate depth and coverage of investigation
  – Basements
  – Piles
  – Problem soils (heave, collapse)
• Insufficient holes – interpolation / extrapolation
• Use of auger holes and test pits where rotary core drilling required
• Absence of quantitative data where such data is required for responsible design.
Other Problems

• Failure to recognise value of adequate investigation and cost of not doing one.
• Failure by those who procure investigations to require adherence to established norms.
• Willingness of geotechnical professionals to undertake inadequate investigations.
• Willingness of contractors to bid on the basis of inadequate data
• He who pays the piper is calling the wrong tune.
Bains saw a solution! ...

Based on the sites shown in earlier slides:

- No investigation (3)
- Inadequate investigation (4)
- Problem not recognised (4)
- Inadequate design (2)
Solutions

Proposed solution:

Inform and Equip

Inform

• Engage with other professionals
  – Property developers, project managers, structural engineers, quantity surveyors
  – NHBRC, SALGA, IMESA, ECSA, CESA
• Publish case histories
• Increase awareness of norms set by standards and legislation
Equip

- Make it easy to do the right thing!

Geotechnical Division should compile minimum requirements and standard specifications for various types of development based on existing standards and legislation.

Solutions

Solutions

Good example of a paper that “makes things easy”
SABS 1200 Standardised specifications

SOUTH AFRICAN BUREAU OF STANDARDS
STANDARDIZED SPECIFICATION
for
CIVIL ENGINEERING CONSTRUCTION

M : ROADS (GENERAL)

1 Scope
This specification covers definitions, materials, tolerances and testing applicable to the construction of controlled layers and surfacing of urban and industrial roads.

NOTE — The publications referred to in the specification are listed in appendix A.

2 Interpretation
2.1 Supporting specifications

Standardised requirements

• For various types of structures:
  – Requirements to be Specified
    • Investigation methods
    • Extent of investigation
    • Lab and Field tests
    • Reporting
  – Guidance Notes
  – Site data to be provided
Summary

• Requirements and methods adequately spelt out

• Failure to adhere to norms is tantamount to negligence

• Geotechnical Division should facilitate specification of investigations

Thank you