Module 7: The Foundations (sub-structure)

Module Objectives:

By the end of this session, participants will understand:

1. The important concepts to be aware of when setting out foundations
2. Rules for excavating foundations
3. Compacting fill
4. Types of foundations

Module at a glance:

<table>
<thead>
<tr>
<th>Topic</th>
<th>You will learn</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Importance terms</strong></td>
<td>- What is bearing capacity?</td>
</tr>
<tr>
<td></td>
<td>- The rules regarding the use of fill</td>
</tr>
<tr>
<td></td>
<td>- Who is a &quot;competent person&quot; and when are the services of a competent person required</td>
</tr>
<tr>
<td><strong>Excavating foundations</strong></td>
<td>- The rules governing the excavation of foundations</td>
</tr>
<tr>
<td></td>
<td>- Clearing and shaping of the site</td>
</tr>
<tr>
<td></td>
<td>- Dimensions and nature of the foundation excavations.</td>
</tr>
<tr>
<td></td>
<td>- Soil poisoning</td>
</tr>
<tr>
<td><strong>Compaction of fill</strong></td>
<td>- The rules regarding the compaction of fill</td>
</tr>
<tr>
<td><strong>Under-floor membranes</strong></td>
<td>- The rules concerning under-floor membranes</td>
</tr>
</tbody>
</table>
Type of foundations

- Shallow foundations - including pads, strip footings and raft foundations.
- Deep foundations – including piles and piers.

Foundation problems

- Which common foundation defects the home inspector should look out for.

The sub-structure (foundations)

Important terms

An understanding of the following terms is important as regards foundations:

Bearing capacity of substrate

“Bearing capacity” is the capacity of a surface to carry a required load. As regards foundations, the bearing capacity of the ground substrate (the underlying material) beneath the concrete foundations is important. This substrate should be stable and if prone to movement, then the concrete foundation must be suitably strengthened to cope with the anticipated movement.

In this regard the nature of the bearing is important.

- Is it bedrock?
- Is it virgin ground?
- Is the soil expansive or collapsible?
- Is the fill suitable and has the fill been adequately compacted?
Fill

This is material placed in an excavation after foundations have been cast, or material used to raise the levels in construction of slab-on-the-ground foundations or floor slabs. Fill shall (NHBRC 2.3.1):

- Contain little or no organic material (either plant or animal);
- Exclude stones larger than 75mm;
- Not contain more than 10% of rock or hard fragments larger than 50mm;
- Not be predominantly clay, nor contain large clay lumps which do not break up under compaction;
- Be such that the fill can be placed without significant gaps/voids

Controlled fill

This is material in shallow fills (which do not require "engineered fill" - see below), but which provides adequate bearing capacity for slabs.

Engineered fill

This is material in fills which has been placed and compacted in layers under the direction of a Competent Person (see below). Engineered fill must be compacted in layers, within defined moisture ranges and to defined density requirements in order to provide adequate bearing capacity for foundations and slabs.

Remember...
Any fill on which edge, beams of slab-in-the-ground foundations and strip footings are to be founded, must be engineered fill, placed under the direction of a Competent Person.
**Competent person**

A Competent Person is required to approve fill beneath slab if fill height exceeds 400 mm, and also to approve foundations if fill height exceeds 1000 mm. (NHBRC Part 3.Figure CF7 – Page 16).

A “Competent Person” is defined (NHBRC Part 1.1.1) as a registered person in terms of the Engineering Professions of South Africa Act (Act 114 of 1990) or a person registered in terms of Section 11 of the Natural Scientific Professions Acts (Act 106 of 1993) and holding indemnity insurance in respect of the appropriateness and design of homes.

**Strip footing**

This is a rectangular unreinforced, or lightly reinforced concrete foundation, cast in trenches to support masonry walls.

**Slab-on-the-ground foundations**

This is a concrete slab incorporating a lightly-reinforced edge beams and possibly internal beams also. This is also known as a "raft foundation".

**Setting out and excavating**

(NHBRC Part 3.2.4)

The "setting out" of the foundations for a house is done in accordance with the plans. The accuracy of the setting out of the house should be checked by measurement from site boundaries and adjacent structures. These checks should include checks on trench widths and lengths and trench corners.
General regulations

The NHBRC prescribes (Part 3.2.Table 1) the following as regards the location of the foundations, free-standing masonry walls and drains and other underground services:

- All refuse and vegetation including bushes, shrubs and trees within 1.5m of the perimeter of the house must be cleared and tree roots must be removed and these areas must be properly compacted.
- The site must be shaped to fall at least 30mm over the first 1000mm to ensure that no water will pond within 1500mm of the house.
- The site must be examined for active termites and if found, the building area must be treated with a soil insecticide/poison. In terms of the National Building Regulations (F5) the local authority will determine whether soil poisoning is required. In areas of termite infestation such as KwaZulu Natal and Mpumalanga, soil poisoning is normally required, prior to the slab being thrown.
- Top soil containing grass roots must be removed from the areas to be covered by concrete slabs and all loose and disturbed ground must be compacted.
- Trench sides and steps must be kept near vertical and trench bottoms must be horizontal or sloped at a maximum gradient not exceeding 1:10.
- Sites to receive slab-on-the-ground foundations must be leveled and the necessary fill properly compacted.

Depth of trenches

Except when founded on rock, the minimum founding depth below ground level shall be 400mm (for strip footings) and 300mm for slab-on-the-ground foundations (NHBRC Part 3.2.5.12). Where a foundation is placed on solid rock, the rock must be cleaned and stepped or dowelled (a dowel is a solid cylindrical steel rod, used in foundations, as structural reinforcements) to prevent the possibility of lateral movement of the foundations.
• Trenches must be excavated to reach virgin ground and may be deepened to remove soft spots. Boulders must be removed wherever practical. Where soft spots/isolated boulders do not exceed 1.5m in diameter, unreinforced strip footings should be reinforced with two Y12 bars extending at least 1.5m beyond the soft spots or boulders.
• The bottoms of trenches must be kept free of surface water; where bottoms of trenches have dried out excessively or softened due to rain or ground water, and then the trench must be re-bottomed prior to concreting. Excessive foundation excavations should be avoided.
• On sloping ground, foundation trenches for strip footings can be stepped, but not within 1m of the corners of the trenches.

**Width of trenches**

The width of trenches for strip footings for single story structures depends on the founding and also on the roof structure (NHBRC Part 3.2.Table 2).

<table>
<thead>
<tr>
<th>Founding</th>
<th>Tiled or sheeted roof</th>
<th>Reinforced concrete roof</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Int. bearing wall</td>
<td>Ext. bearing wall</td>
</tr>
<tr>
<td>Rock</td>
<td>400mm</td>
<td>400mm</td>
</tr>
<tr>
<td>Soil</td>
<td>400mm</td>
<td>500mm</td>
</tr>
</tbody>
</table>

Sites to receive slab-on-the-ground foundations must be leveled and the necessary fill properly compacted.

**Compaction**

(NHBRC Part 3.2.6)

• The maximum height of fill beneath floor slabs or slab-on-the-ground foundations must not exceed 400mm unless the fill is certified by a Competent Person.
• Fill must be slightly moistened prior to compaction so that a squeezed handful is firm, but not wet. Fill must be placed in un-compacted layers not exceeding 100mm
(hand compaction) and 150mm (mechanical compaction). Each un-compacted layer must be properly compacted before the following layer is added.

- Compaction is tested by means of a dynamic cone penetrometer. In excess of three blows from the device must be needed to penetrate 100mm of the fill. Note that misleading readings can be obtained in gravels or when the cone strikes a boulder.

**Under floor membranes**

(NHBRC Part 3.2.7)

- Under floor membranes must have a thickness of at least 0.25mm and overlaps must be at least 200mm.
- Membranes beneath floor slabs must be turned up around the perimeter of the slab by at least the thickness of the slab.
- Penetration of the membrane by pipes, plumbing fittings and punctures must be taped with adhesive tape.

**Types of foundation**

**Shallow foundations**

Shallows foundations are used when surface soils are sufficiently strong and stiff enough to support the imposed loads. Shallow foundations are unsuitable in weak or highly compressible soils, including, poorly-compacted fill, drained wetlands or alluvial deposits (silt deposited by a river).

Shallow foundations are sometimes called “spread footings" and include pads (“isolated footings"), strip footings and rafts. Shallow foundations are those founded near to the finished ground surface; generally where the founding depth is less than the width of the footing, and less than 3m.
Pad foundations

Pad foundations are used to support an individual point load, such as that due to a structural column. They may be circular, square or rectangular. They usually consist of a block or slab of uniform thickness, but they may be stepped if they are required to spread the load from a heavy column. Pad foundations are usually shallow, but deep pad foundations can also be used.

Strip foundations

Strip foundations are used to support a line of loads, either due to a load-bearing wall, or if a line of columns need supporting where column positions are so close, that individual pad foundations would be inappropriate.

Did you know...

*Strip foundations are the most common footings used for building houses in South Africa.*
Raft foundations

Raft foundations (also called slab-on-the-ground foundations or floating slabs).

Typical raft foundation – slab on the ground with thickened edge beam

Raft foundations are used to spread the load from a structure over a large area, normally the entire area of the structure. They are used when column loads or other structural loads are close together and individual pad foundations would interact.

A raft foundation is essential a slab foundation with thickened edges or in situ beams within the slab. The purpose of a raft foundation is to support a structure on a site with low soil bearing conditions. A raft foundation is used to distribute the building pressure over a large area so the soil can bear the stress. Raft foundations are often used on soft or loose soils with low bearing capacity, as they can spread the loads over a larger area.

Deep foundations

Deep foundations include piles and piers (see below). Deep foundations are used to transfer the loading to a deeper, more stable stratum at depth, if unsuitable soils are present near the surface - this is usually at depths greater than 3 m below finished ground level.
Piles

Piles are long, slender concrete members which transmit foundation loads through low bearing capacity soil, to deeper soil or rock strata which has a high bearing capacity. Piles are used to transmit loads to strata beyond the practical reach of shallow foundations. Piles are also used to anchor structures against uplift forces, and to assist structures in resisting lateral and overturning forces.

It is important to understand that piles get support from both end-bearing, and skin friction. The proportion of carrying capacity generated by either end bearing or skin friction depends on the soil conditions.

End bearing piles:  
End bearing piles are those which terminate in hard material, such as rock or very dense sand and gravel.

Friction piles:  
Friction piles obtain most of their carrying capacity by skin friction or adhesion. This is when piles are not able practically to reach an impenetrable stratum but are driven for some distance into a penetrable soil. Their carrying capacity is derived partly from end bearing and partly from skin friction between the embedded surface of the soil and the surrounding soil.

Types of pile construction

Displacement piles:  
The soil is displaced as the pile shaft is driven or jacked into the ground. The dropping weight or drop hammer is the most commonly used method of insertion of displacement piles. A weight is raised a suitable distance in a guide and released to strike the pile head.

Jacked piles are most commonly used in underpinning existing structures where the foundations have sagged. By excavating underneather a structure short lengths of pile can be inserted and jacked into the ground using the underside of the existing structure as a reaction.
Jacked piles are often used, in preference to pads, to underpin house foundations which have localised subsidence – for example caused by rotting roots after a tree has been removed close to a house. **The sagging foundations are literally jacked back into position and are then supported by the pile.**

**Non-displacement piles:**
With non-displacement piles, a hole is bored, and soil is removed by means of a borehole type drill or auger. The resulting hole is filled with concrete, or sometimes a precast concrete pile is dropped into the hole and grouted in. Clays are especially suitable for this type of pile. This is because in clays the borehole walls only require support close to the ground surface.

**Piers**

Piers are foundations (pillars) for carrying a heavy structural load, which have been constructed in situ in a deep excavation. Typically formwork of metal, wood or brick will be used to contain the reinforced concrete which gives the pier its strength.

**Common defects found in foundations**

Here follows is a brief list of some of the most common defects which the South African home inspector may encounter when inspecting the foundations of a house. Depending on how level the building plot is, all or part of the foundation walls may be below ground level and therefore cannot be inspected without invasive excavation (which the home inspector does not do).

In this case the inspector needs to look at the walls of the house for clues regarding the condition of the foundations. Wall cracks are often the result of foundation movement. However other possible causes of wall cracks are damp (water damage) and stresses resulting from roof load or roof movement. This illustrates how the components of a house (in this case foundations, walls, roof and storm water management) can impact on each other, and why it is important that the inspector looks at a house in its entirety before drawing conclusions as to the probable cause of the defects observed.
Cracked or sagging foundation as a result of problem soils

Problem: If the foundation is below ground level, then the indication of a defective foundation is usually cracks in the walls above. Expansive or collapsible soils can result in differential slip (where a portion of the foundation footing cracks away and either “settles” or “heaves”). Incorrect backfill material in the foundation trenches and the inclusion of large rocks in the backfill, can also result in foundation cracks. Cracks in the wall above the foundation are the clearest indicator of foundation problems.

Foundation failure in problem soils is usually the result of inadequately designed footings. Steel reinforcement, a strong concrete mix, or deeper (or wider) foundations should be designed by a professional engineer to counter the anticipated impact of problem soils.

Possible remedy: The input of an expert builder or engineer is recommended. Common repairs would involve some type of foundation "under-pinning" where new concrete is inserted under portion of the foundation in the form of "pads" or a widened footing. Sometimes it is possible to "jack-up" the foundation using a hydraulic jack and then insert a new footing or a foundation pile.

Tree root damage

Problem: Tree roots growing too close to a house wall can cause stress and cracking to the foundation footing. If the tree is chopped down, sometimes this can make the problem worse, because when the dead tree roots under the footings eventually rot, a cavity can form beneath the foundation resulting in sagging foundations.

Possible remedy: Same as for cracked or sagging foundations above.
Horizontal cracks running at weep hole level in cavity walls

Problem: If the bottom of the weep holes are proud of (higher than) the bottom of the wall cavity, then water may pond within the wall cavity, on top of the damp proof plastic. Ponding water within the cavity will eventually damage the masonry, and will often result in horizontal cracks running at slab level, observable on the exterior of the wall. Sometimes the water enters through the weep holes, because the finished ground level is too high, thereby enabling water run-off to enter the cavity.

Possible remedies: Lower the ground levels; open up the weep holes to the level of the DPC; or close up the weep holes in the problem area, to prevent water ingress.

Water damage to foundations

Problem: Storm water seeping under the foundations can cause serious long-term damage and sagging of the foundations. This is typically caused by a down pipe discharging at the base of the house walls, or from uncontrolled storm water run-off, ponding against the walls. Over a long period, water seeping through the soil may tend to carry off the “fine soil”, leaving behind the coarser soil particles (sand) and resulting in eventual soil collapse and foundation settlement.

Possible remedies: Divert all storm water from down pipes, and surface run-off, away from the house. Install a 1000mm wide impervious apron (paving or concrete) around the house walls, suitably sloped away from the house. Assess and repair already compromised foundations as per the remedies described for cracked or sagging foundations.

Foundation walls below suspended wooden flooring

Problem: Foundation walls built on concrete footings with a suspended wooden floor above, can be problematic if the ventilation grids (air bricks) in the wall have been closed up. Inadequate sub-floor cross ventilation can lead to damp conditions and rotting floors.

Possible remedies: Rectify inadequate sub-floor cross ventilation by opening up existing or installing new ventilation grids in the foundation walls.
Before you take the online test, please.....
Make sure that you are thoroughly familiar with the material in this module before completing the online test. The more familiar you make yourself with the information presented in this Module the better you will be as a professional home inspector. Review thoroughly all areas of this module before and during the open book online test.