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# INTRODUCTORY GUIDE TO FOUNDATIONS

Text by

G.W. DONALDSON

and

P.A. BILLINGHAM

Drawings by

C.J. LE ROUX

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## **CONTENTS**

<b>What is a foundation?</b>	<b>5</b>
<b>What can go wrong with foundations?</b>	<b>7</b>
<b>What can one do to avoid cracks?</b>	<b>14</b>
<b>How can one build on a poor site?</b>	<b>19</b>
<b>Designing a foundation.</b>	<b>21</b>

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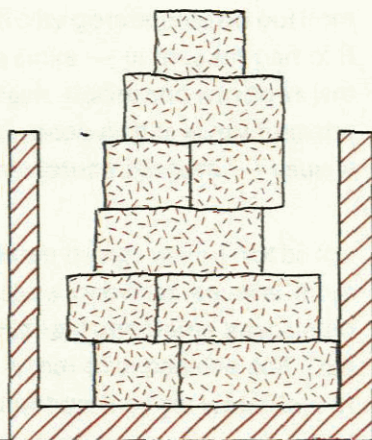
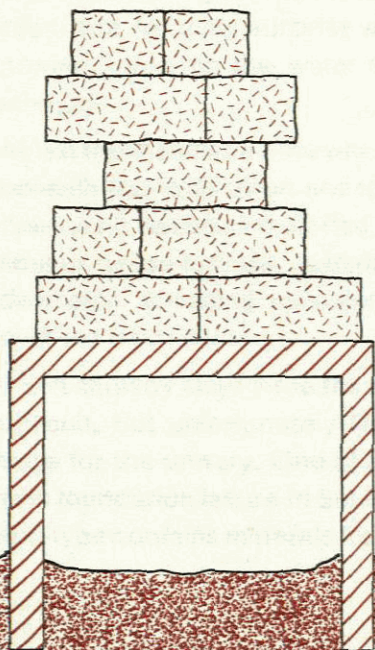
# WHAT IS A

# FOUNDATION ?

# ?

The words 'built on a firm foundation' have become part of the language and most people would unhesitatingly agree that a house 'has to have a foundation' without perhaps understanding exactly why.

If one were to place an open wooden box upside down on a patch of soft soil and load it with bricks it would not be long before the edges sank into the ground. On the other hand if the box were the right way up it would probably hardly sink at all.



Same box; same load of bricks. The only difference is that in the first case the full weight of the load is on the narrow edge of the box while in the second it is spread over the entire area.

A house is a heavy structure — it can weigh more than 150 tons — and it is in effect resting on the edge of the walls which represents only a tiny fraction of the area of the house. Solid rock will have little trouble supporting a load like this but in soft ground the whole edifice could sink like the wooden box.

The ideal solution is of course to 'turn the box over' by building the house on a massive raft of concrete but this would make the structure very expensive.

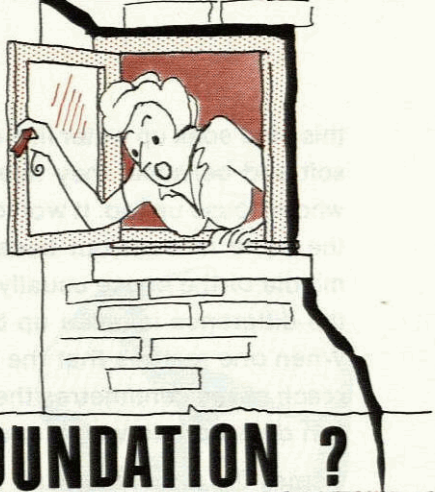
The most usually adopted solution is to cast wide concrete strips on which to build, thus spreading the load sufficiently for the ground to support the building.

The secret of successful foundations is knowing just how much the subsoil can support.

As one goes deeper, the ability of the ground to support a load becomes greater so that the foundation engineer can choose between deep foundations and the expense of larger masses of concrete.



# WHAT CAN GO WRONG WITH A



# FOUNDATION ?

It is not enough simply to find out that the ground where you want to build your house will support such and such a weight. The character of some subsoils changes depending on whether it is wet or dry and this process of change is what leads to foundation failure and many of the builder's foundation problems.

For example you will already be aware that a rugby pitch on which you can crack your ribs in the dry season will just about swallow you whole after a good rain.

The fellow who guesses the strength of a clay subsoil during a dry spell is in for a big surprise when the drought breaks. The thirsty ground soaks up the water and the clay rapidly begins to lose strength.

At last there comes a time when the soft clay gets squeezed out from beneath the foundation and the house sinks — or at least part of it does. As it becomes distorted, walls crack, doors and windows jam shut or refuse to close, guttering comes loose or tilts away from the downpipe, shedding its water like a miniature Niagara — usually over the front door.

If soft squishy clays were the only problem things would not be too difficult, but unfortunately Mother Nature provides several more traps for the unwary. One of the commonest problems associated with foundation failure in South Africa is that of expansive soil. This soil-type contains minerals that swell up when they get wet. Clays of

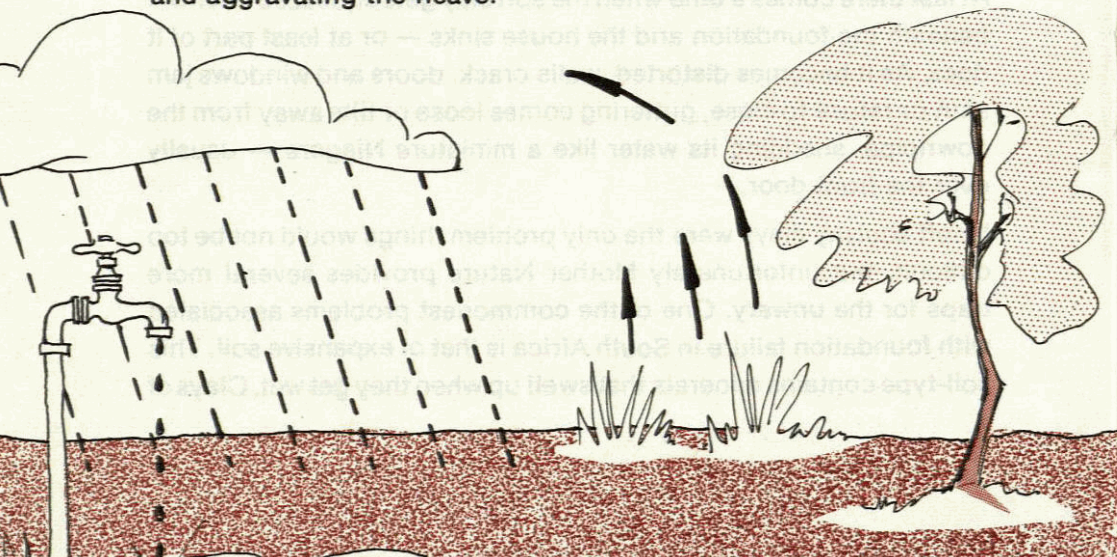


this kind soak up water like dehydrated vegetables — they don't get soft and collapse, they rise up like a cake in the oven and lift the whole house up too. It wouldn't be so bad if every part were lifted by the same amount but because of uneven wetting and drying the middle of the house usually gets raised more than the corners and the difference is taken up by the production of enormous cracks. When one realises that the heave on an ordinary house can easily reach seven centimetres then it is no longer surprising that a crack can develop into which one can put one's whole hand.

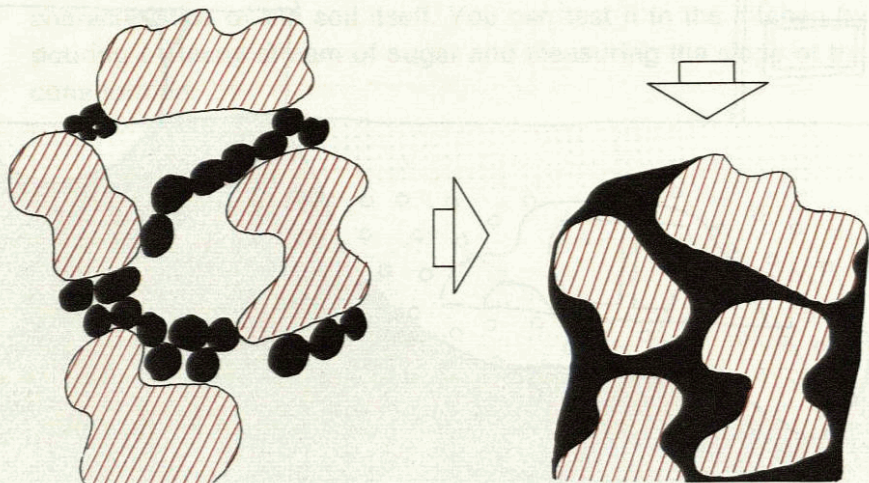
Comes the dry season and the soil will shrink — in some cases the building may even subside. If in the meantime the cracks have been filled the subsidence will create new ones and then when the rains come again the situation gets rapidly out of hand.

In the open veld the natural vegetation transpires or 'breathes' away the water that fails to run off and it is soon returned to the atmosphere. This keeps the clays relatively dry. However, when building begins the natural cover is first removed and from that moment the water content of the underlying clay begins to increase. When the house is completed it shelters the ground from sun and wind and the moisture content increases even more rapidly.

Leaking pipes and sewers increase the volume of water fed to the clay while ornamental trees planted around the house dry it out faster, thus increasing the contrast between the wet and dry areas and aggravating the heave.







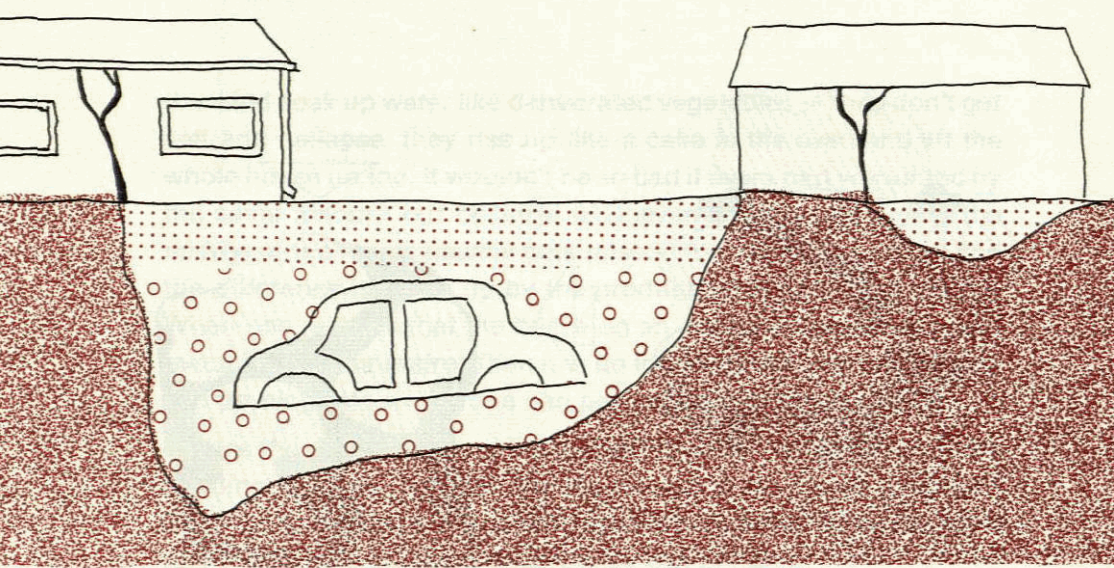
A completely different problem is caused by what are known as collapsing sands. These are usually fine-grained sands that have particles of dry clay included along with the grains of quartz. The presence of the clay particles prevents the sand from packing down tightly. However, though it is full of air spaces it still gives the appearance of an acceptable foundation material.

The trouble comes when landscaping, new vegetation, intensive gardening, leaky sewers and surplus surface water from rainwater pipes begin to raise the moisture content of the clay particles. Slowly they soften and eventually they no longer have the strength to hold the grains apart with the result that the sand shrinks in volume and the foundations collapse.

Fortunately deposits of these sands are not usually very deep and once the first movement has taken place subsequent collapse is unlikely to be so severe.

A similar effect can be caused by certain man-made deposits — what we might call the 'tin-can-conglomerates'. They get covered over with a few feet of loose topsoil and are then sometimes sold as building land. Thereafter it steadily settles as the old motor-car bodies and discarded beer tins quietly rust away underneath.





The same kind of situation occurs when a site has been levelled with a bulldozer and where pockets of soft fill have been left behind. In the course of time the weight of the building, aided by seeping water, will work the sand grains into a more compact position and settling will occur. Cracks springing from this kind of situation are rarely serious, and do not often recur.

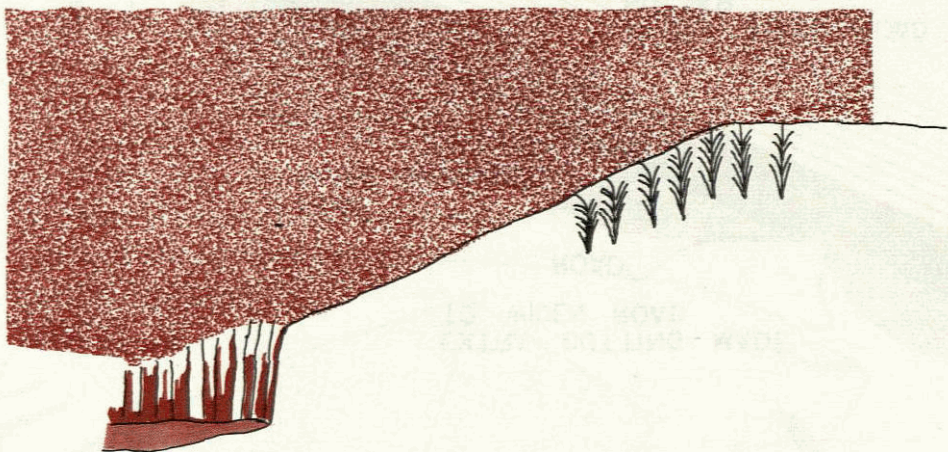
The last cause of unstable foundations that needs to be discussed arises from building on slopes that are themselves unstable.

The soil cover that is found over most of the world is caused by the action of wind and rain, frost and plants, which breaks down the surface of the rocks. At the foot of hills the soil will collect to a depth that makes it certain that a foundation will not reach to bedrock, but as we go up the hillside the soil cover will get less until the slope becomes too steep for soil to collect. Above this point only bare rock remains. The dangerous zone is mid-way, because the soil is fairly close to sliding down the hillside, if not actually doing so.

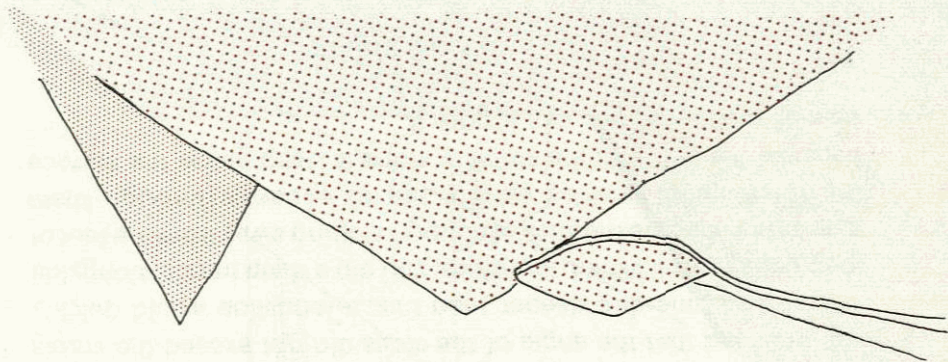
You may often have noticed some land where dump-trucks have been tipping their loads, and may have observed that the heaps have sides that all slope up at the same angle. Gravel and soil particles always tend to settle at an angle which is fixed by the natural



you must suspect that the slope is at or near its limit of stability.



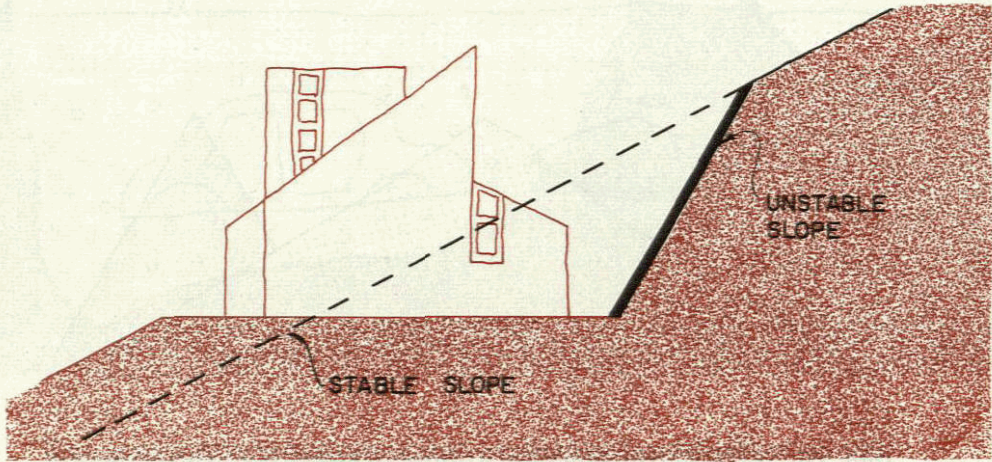
Salt, you will discover, settles at a different angle. If you take a spoon and excavate a spoonful of sugar from the side of the heap, the grains above this point will slide down to fill the space. This is because you momentarily created a slope that was unstable. Where you see a natural hillside sloping downwards, especially one like this:



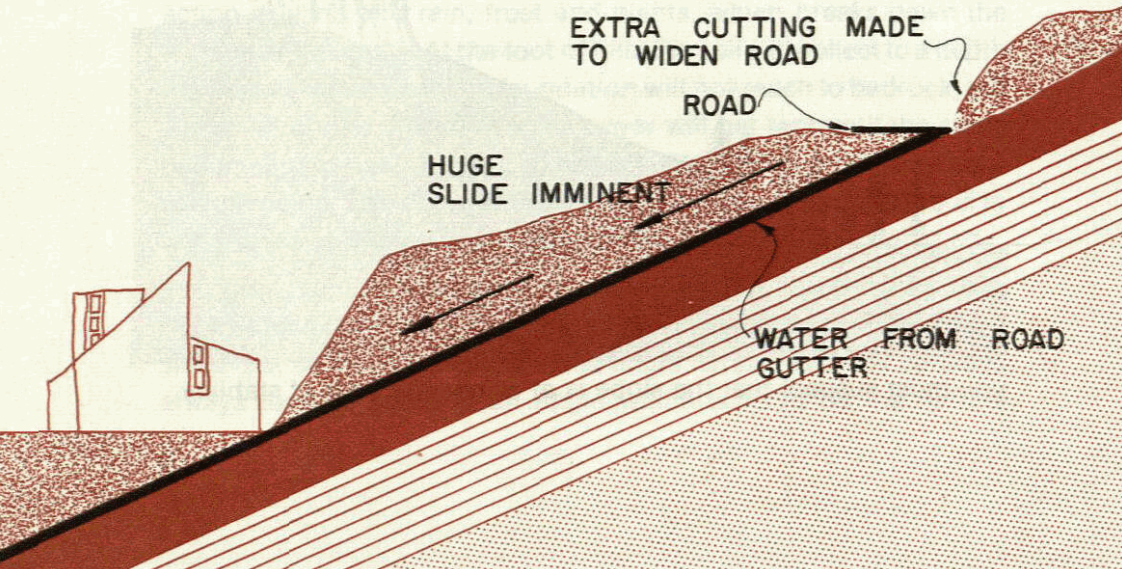
characteristics of the soil itself. You can test it in the kitchen by pouring a steady stream of sugar and measuring the slope of the cone formed.



Cutting out a site for a house in such a slope will take the angle into the zone of instability and may well create landslip problems.

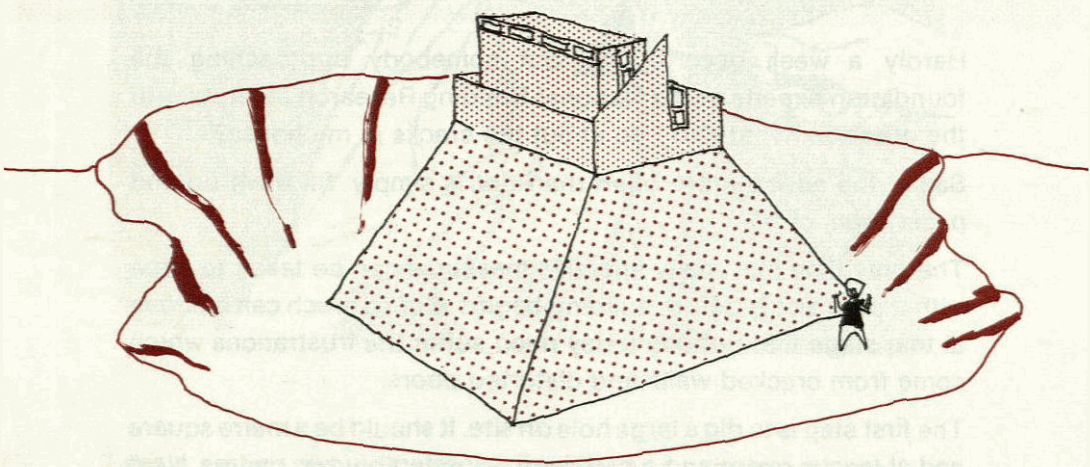


Where the slope of the bedrock is in the same direction as the slope of the hillside, cutting into the hill may allow water to penetrate to the bedrock and precipitate a massive slide.

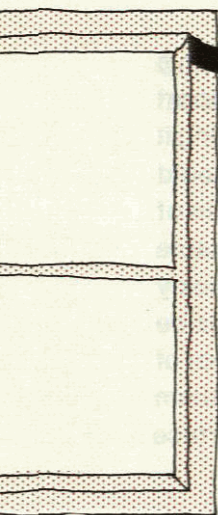




It is not necessary to live on a hillside to experience the effects of this kind of slide. Even though there is no stable slope visible to support the foundations of a house on level ground, the soil that is holding it up is nevertheless concentrated into a cone. Theoretically one could dig the garden away and leave the house perched on a pyramid of soil provided that the angle of the sides did not exceed the stable slope. Once one dug deeper than this, a landslide would quickly topple the house. When, therefore, you dig a deep trench alongside a building, imagine the lines of support sloping away from the foot of the foundations and be careful not to excavate through them because the fact that the stability slope is deep below the surface doesn't mean that you can ignore it.







**WHAT CAN  
ONE DO  
TO**

**AVOID  
CRACKS**

Hardly a week goes by without somebody approaching the foundation experts at the National Building Research Institute with the question 'What can I do about the cracks in my house?'

Sadly, the advice more often than not is simply 'fill them up and paper them over'.

The only time that really effective measures can be taken to cope with a poor site is before building begins. But so much can be done at that stage that nobody today need suffer the frustrations which come from cracked walls and distorted doors.

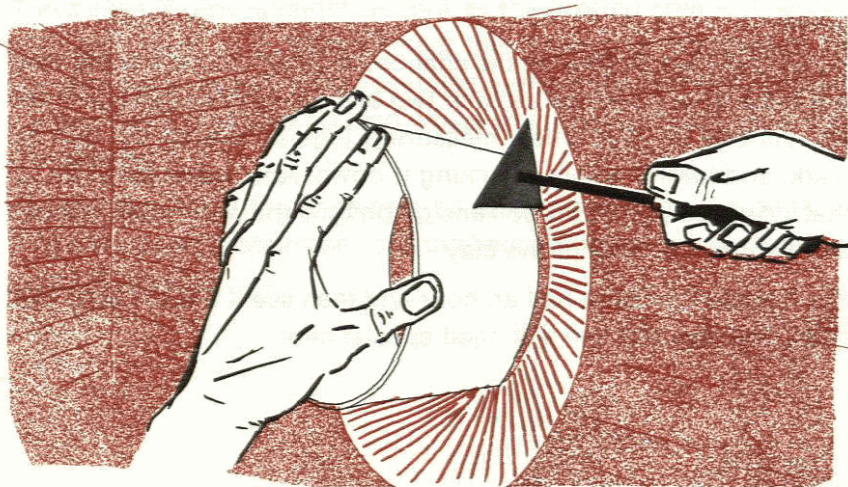
The first step is to dig a large hole on site. It should be a metre square and at least a metre and a half deep — preferably two metres. Next you should climb into the hole and examine the rocks and soil that have been revealed in the sides. They will normally be either sand or clay or perhaps both in alternating layers like a sponge cake. Take a tiny piece of soil and press it between the backs of your thumbnails, moving them about. If it is a clay, you will feel its smooth, almost soapy, texture.

A sand, on the other hand, will scratch the nail and you will have no

difficulty detecting the hard grains that are present. Sometimes a clay has quite a high percentage of sand. Try biting a small piece between your teeth — the sand grains are easily felt while the clay will soften to the point where you can taste it.

### *Sands*

Where firm, these form sound foundation materials, except in the south-western Transvaal and the north-western Free State. See map on pages 16 and 17. It is not possible to tell them by their colour because they occur in many hues. However, they are often red, and sands of this colour should be treated with suspicion.



Take a tin can about 80 mm in diameter and cut out both the top and the bottom. Take it down into your pit and push it by hand as far as you can into a layer of good undisturbed sand.

Now, with a knife or scraper remove the sand from around the outside of the tin until you can push it in another 5 mm or so. Continue this process of 'scrape and push' until the tin is completely full of sand. The idea is that the sand should be just as it was in the ground — quite undisturbed.

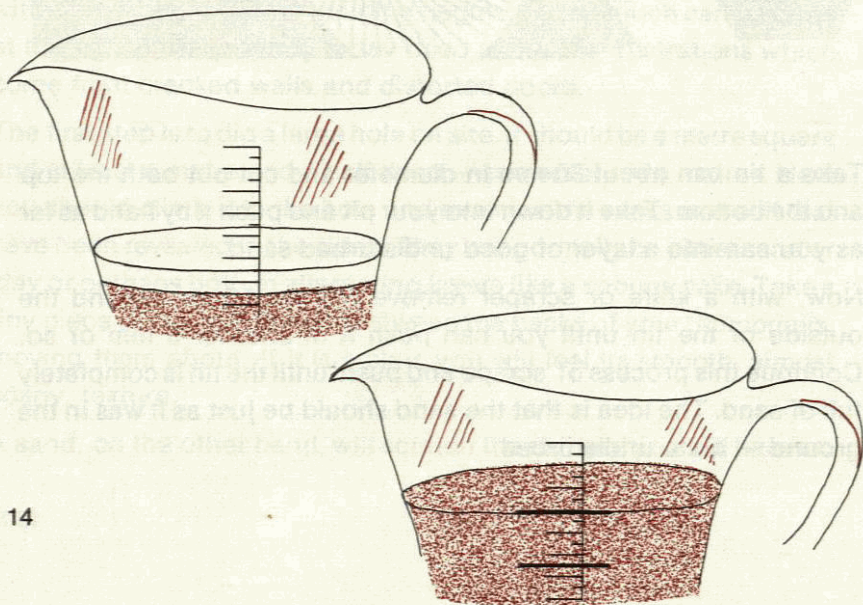


Now put the tin upright in a bowl and pour water through it gradually until the sand is well moistened. Then take a tamper such as a 15 cm nail or an old bolt and try to compact the sand with the head end. If you find you can squeeze it into the can you are certainly dealing with a collapsing sand. If you cannot compress it, push the whole sand plug out of the tin into the bowl, add a little water and break the sand down into small pieces. Crush it up into a moist paste and try to get it all back into the tin. If it all goes in you have troubles because with a normal sand you will not be able to do so. Be sure that the sand is well saturated with water or surface tension effects may mask the reduction in volume.

### Clays

If you find clays in your pit the chances in South Africa are that they are expansive. Crush up a kilo or two of dry clay to a coarse powder and fill one of your wife's measuring jugs to exactly the 500 cc mark, and level it without packing it down. Add water carefully so that it runs down into the soil and go on until the water level is about 3 cm above the level of the clay.

Put it aside for about half an hour and then see if the soil level has risen. If it has, the site will need special care.





One can get a good idea of the character of the site in advance by looking for cracks in the soil surface. A glance at nearby houses will often show if a neighbourhood is prone to cracks.

If you have any difficulty in deciding whether your site material will require special treatment, write to the National Building Research Institute, P.O. Box 395, Pretoria.

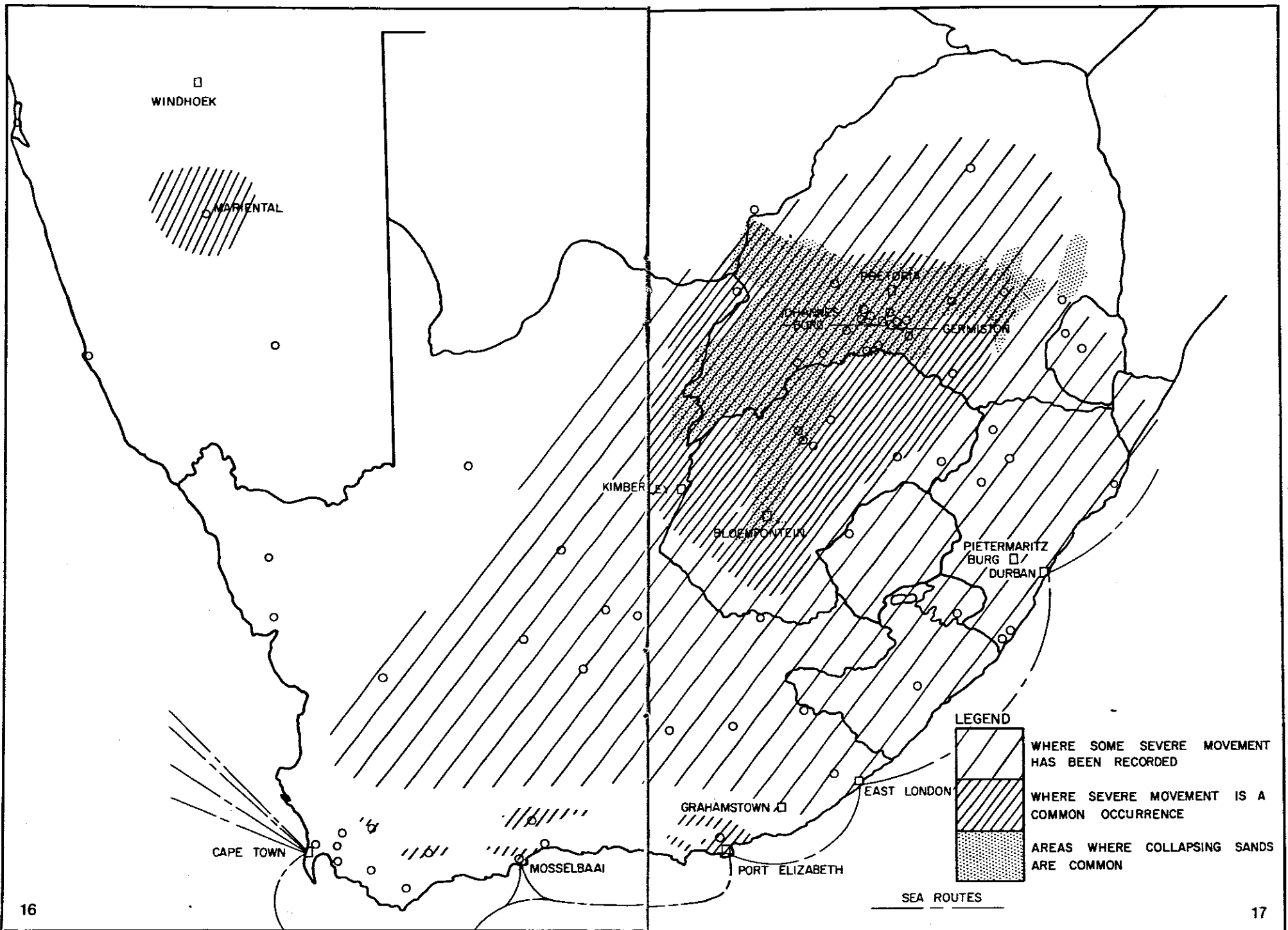
### *Unstable slopes*

A person who plans to build on a hillside should satisfy himself that it is safe to do so. This is really a job for a trained geological consultant but here are a few pointers that can serve to arouse your suspicions.

*Trees* always grow straight up, but as the ground creeps downhill they get tipped over. They correct this tipping for themselves by bending back up but the landslip is permanently recorded in their trunks. Beware of sloping land where the tree trunks all curve into the hillside.

*Humpy ground.* If the base of a slope displays humpy ground or looks like a giant's staircase, look out because these are the classical signs of landslip.





□  
WINDHOEK

○  
MARIENTAL

○  
KIMBERLEY

○  
BLOEMFONTEIN

○  
PRETORIA

○  
GERMISTON

□  
PIETERMARITZBURG

□  
DURBAN

○  
CAPE TOWN

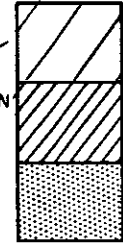
○  
MOSELBAAI

□  
GRAHAMSTOWN

○  
PORT ELIZABETH

○  
EAST LONDON

**LEGEND**



WHERE SOME SEVERE MOVEMENT HAS BEEN RECORDED

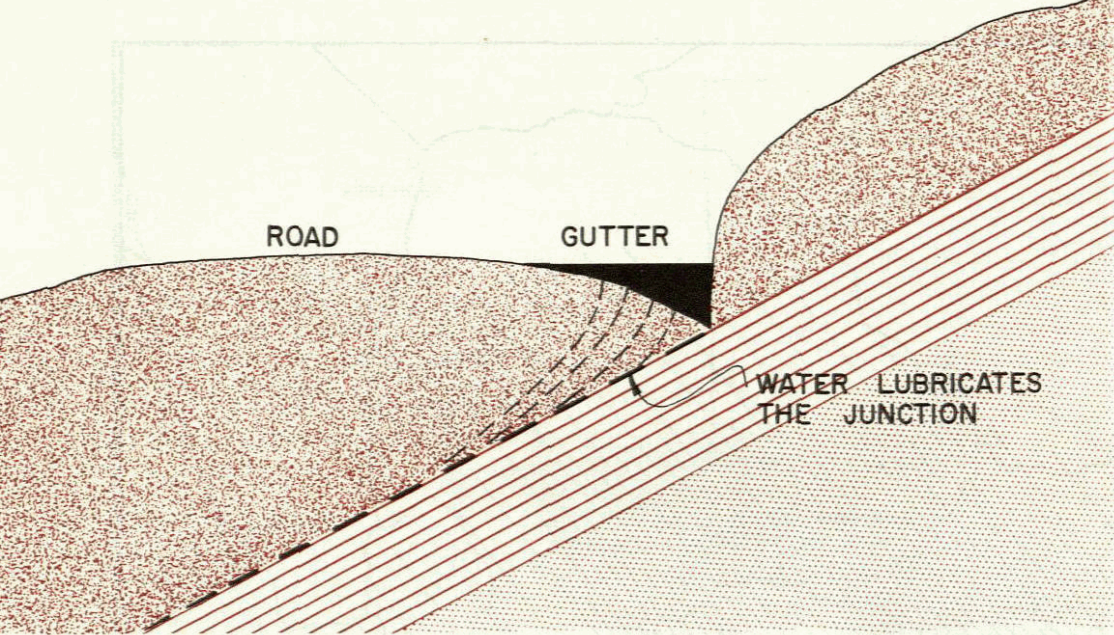
WHERE SEVERE MOVEMENT IS A COMMON OCCURRENCE

AREAS WHERE COLLAPSING SANDS ARE COMMON

SEA ROUTES

BM 3 26





*Steep slopes* are more often than not devoid of topsoil. If the slope is bare rock it should be fairly safe for building, but a steep slope (30 - 50 degrees) that has a metre or more of topsoil on it is only waiting for a road to be cut or a building site to be levelled. Once rainwater can run down the junction between soil and rock it is unlikely to be long before the conditions are right for a slide.

The greater the slope the more likely it is that a building will straddle the junction between two different kinds of material. This kind of situation is a frequent cause of trouble.

*Cut and fill.* It is almost impossible to pack soil back as tightly and effectively as nature does it, so that where the natural soil has been disturbed, it will always sink a little with time. If your pit shows loose material for its whole depth you will be well advised to dig deeper.

Driving a metal rod, such as a crowbar, into the ground is a good test. if you can drive it 1 metre or more in 45 seconds with a household hammer, then the ground cannot be considered to be firm enough to use as it is.



# HOW CAN ONE BUILD ON A POOR SITE?

Some of you may now be left looking at your plans and wondering how you are ever going to be able to build. Don't get too despondent. We said earlier that nobody need suffer the frustrations of cracked walls and this is strictly true. It could cost you a little more at the foundation stage but against the value of a house that remains free of flaws, it should not be excessive.

There are two lines of attack. The first is to treat the ground, the second is to treat the house. Different types of ground require different methods.

## *Collapsing sands*

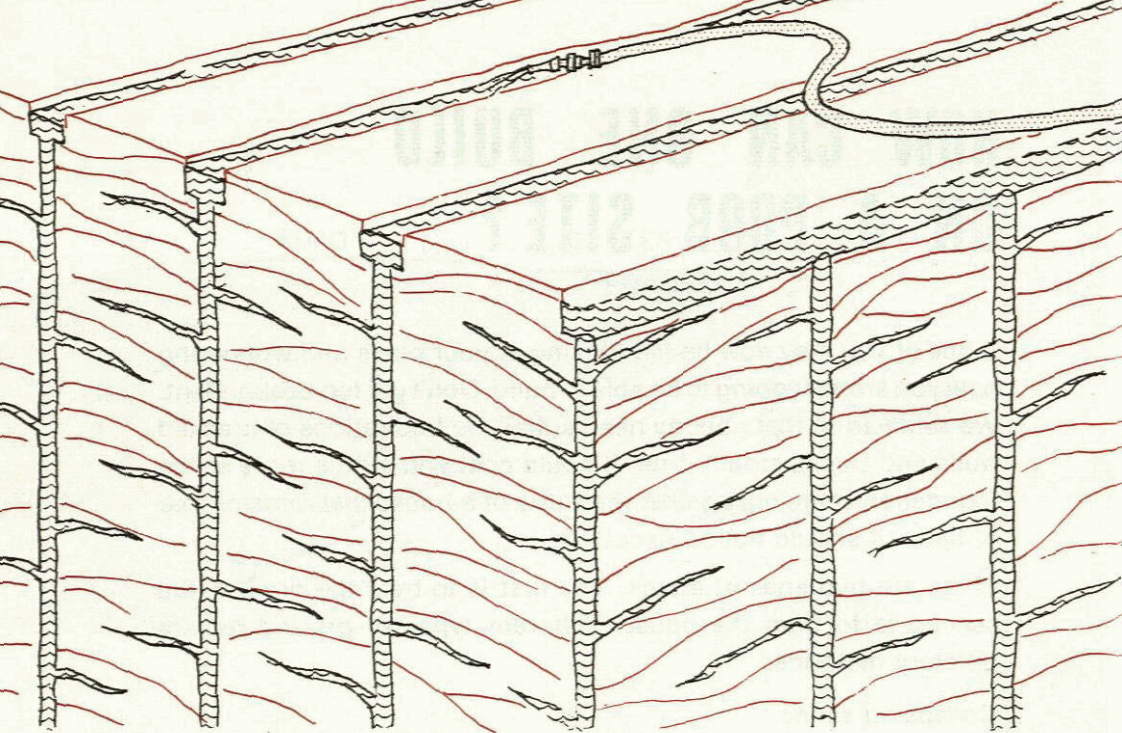
Because these sands are often not too deep it is sometimes a practical proposition to excavate down to firm rock and either to add a cellar to the house or to fill the hole with a better material. Once it has been dug out the same material can be improved by soaking it and then putting it back with the aid of a compactor or 'frog rammer'.

Another method is to stabilize the sand by mixing it with cement.

One can also use brute force in the shape of a heavy compacting roller which will hasten the sand's collapse to the point that one can build on it in reasonable confidence that it will not sink again.

*Ordinary clays* of the type that weaken when they get wet can be strengthened by ploughing in *lime*, which reacts with the clay and stabilizes it. Around 5 per cent of lime is usually enough.

*Expansive clays*, which are the commonest cause of trouble in South Africa, are best dealt with by ensuring that they get all their expansion over and done with before building begins. The best method is to dig trenches about 30 cm deep right across the foundation area and 2-3 metres apart. In the bottom of the trenches



auger holes are drilled every 2-3 metres with each one 2-3 metres deep.

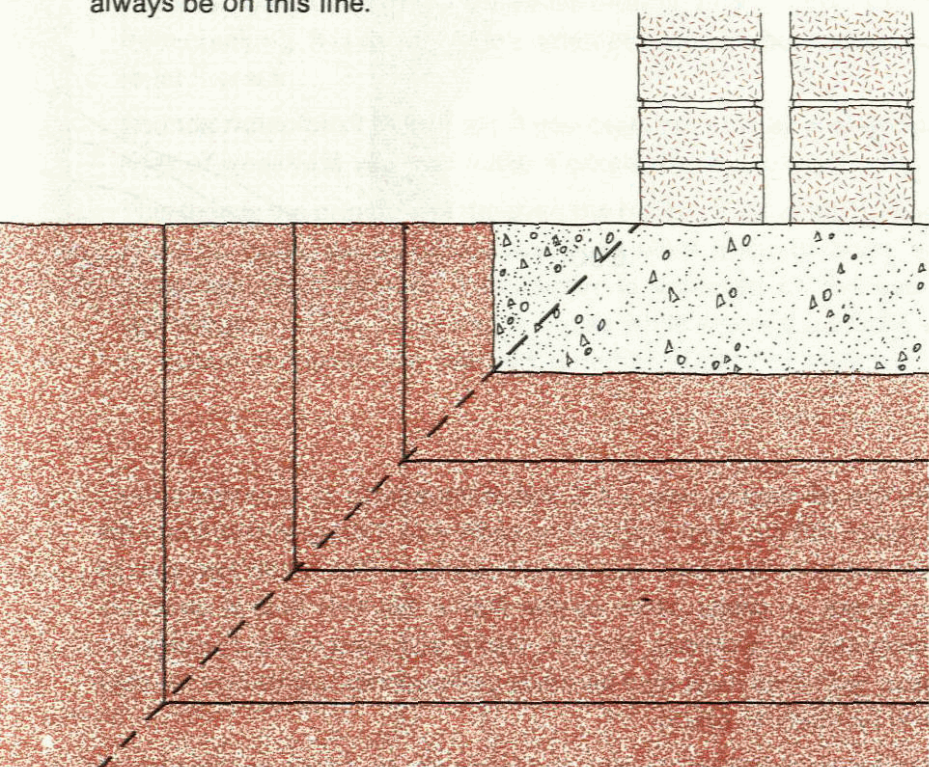
These trenches, and with them the auger holes, are now filled with water and kept full for 2-3 months. During this time water will seep deep into the ground and most of the expansion will be complete before construction begins.



# DESIGNING A FOUNDATION

We said on page 13 that the ground could, in theory, be excavated away from around a house until it was standing on a pyramid. In normal rock the sides would slope at 30 degrees to the vertical, but it is not hard to understand that in concrete a different angle would be called for.

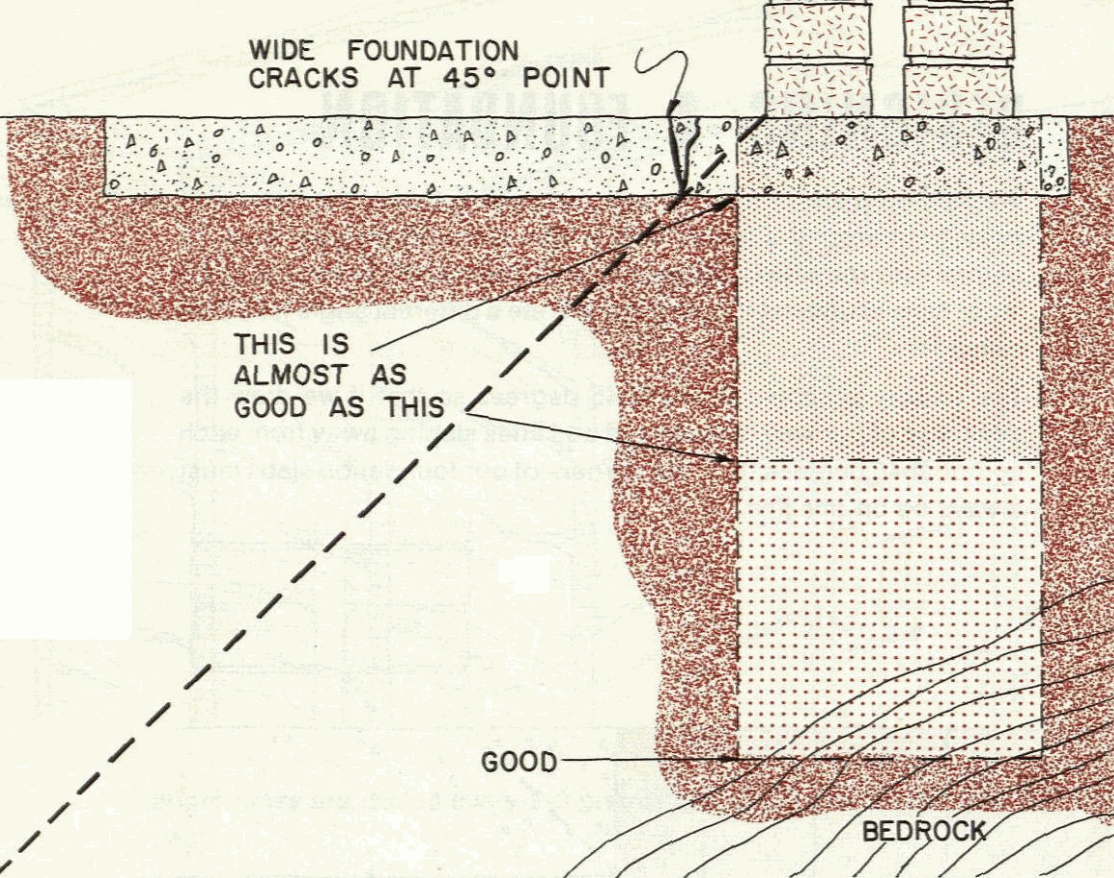
The usually accepted figure is 45 degrees so that if we draw the thickness of our wall to scale and add lines sloping away from each corner at 45 degrees then the corners of our foundation slabs must always be on this line.



Years of experience have produced a number of rules of thumb for normal foundations and it is interesting to see how closely they conform to the theoretical ideal.



WIDE FOUNDATION  
CRACKS AT 45° POINT



By the 45-degree rule a 230 mm-thick length of concrete should project 230 mm from the wall on each side. Taking into account the thickness of the wall, this would call for a 700 x 230 mm slab of concrete — pretty close to the 600 x 230 mm that is generally accepted. This means, though, that if you want wider footings for your wall they must also be made correspondingly thicker, or they will be likely to crack.

By the same token, deeper and narrower foundations will give no better support than shallow ones unless there is a marked improvement in the bearing quality of the subsoil at the greater depth.



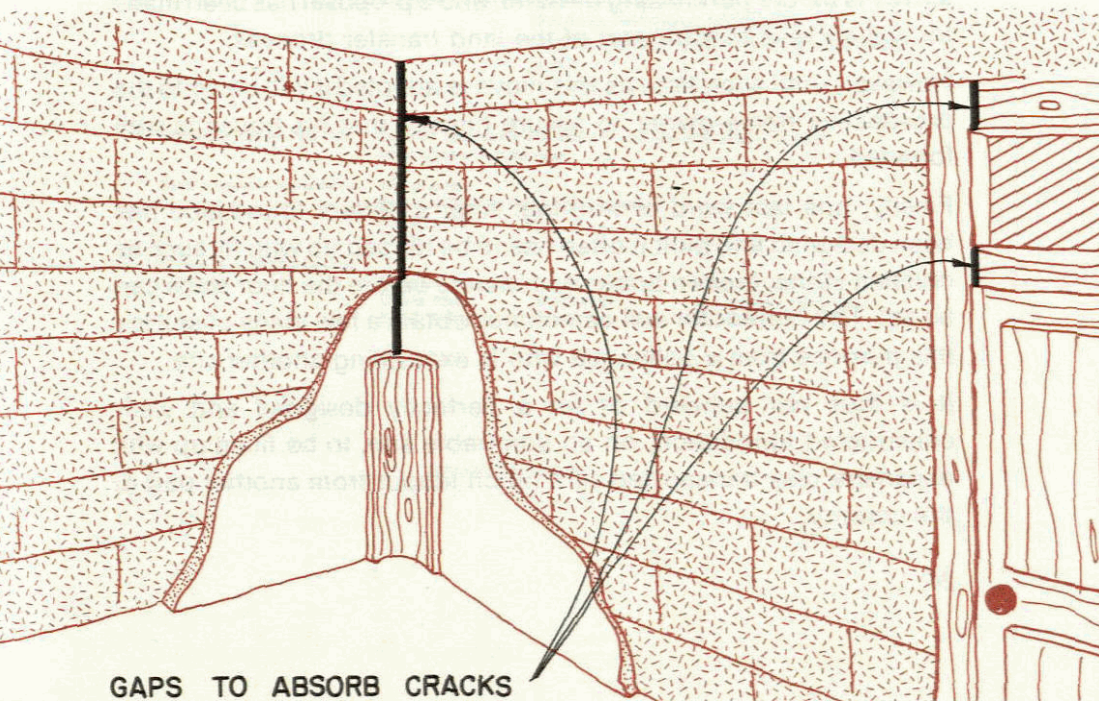
The rule of thumb sizes as accepted by most municipalities in South Africa are more than adequate for normal houses on a normal subsoil. But a poor site is not the only reason for strengthening foundations. This should also be done for a two-storey house or for one that is to have a suspended concrete floor.

Steel reinforcement in the concrete is usually only needed when the strength of the subsoil is very variable. From all this it will be clear that there is no such thing as a 'general purpose foundation'. Each foundation should be designed to carry its particular house on the site where it is intended to be built.

However, before designing a massive foundation to prevent a home from cracking, it is as well to ask whether it would not be easier just to let it crack.

Sounds ridiculous? Not at all. *If you build your house with special lines of weakness you can make it crack where you want it to.*

This then is the principle of 'treating the house'. First of all, the walls must be strengthened where we don't want them to crack and weakened where we do. The former is achieved by the use of reinforcing material between the bricks while where the cracks are to appear the walls are not tied together at all. For instance, an



GAPS TO ABSORB CRACKS



internal wall can go right up to an outside wall but not actually touch it. The gap is easily hidden behind an ornamental wooden moulding and any normal movement will not even flake the plaster.

Doorways can also be used to absorb movement by not bricking over the tops of them. Any damage that a wooden panel or window light above the door will suffer is easily repairable.

Further details on designing buildings for expansive sites are contained in Research Report RD 14 obtainable from the Director, National Building Research Institute, P.O. Box 395, Pretoria.

This booklet has concerned itself solely with foundations for houses and thus has not touched on any of the more expensive kinds of foundations; it is as well, however, for readers to bear in mind that there is a whole new world of solutions available where money is only a secondary consideration.

*Solutions that are applied after construction are, however, invariably more expensive, so the time for investigation is before building begins.*

Following this line of reasoning even further the best time for a soil survey is before purchasing the land, and a proposal has been made for soil surveys to form part of the land transfer process.

However, until such time as this move is adopted it will be up to the prospective home-owner to assure himself that his house is well founded.

Finally, one last word of warning. After a perfect foundation has been designed and built it often has to be topped up with fill such as crushed stone, broken bricks or concrete before the floor slabs can be set. The contractor will sometimes obtain a few loads of soil for this purpose from a colleague who is excavating another site.

*It is thus not unheard of for a perfectly designed and well-constructed foundation, on an admirable site, to be filled up with expansive clay transported with much labour from another part of the country.*