CI/SfB (11)

Simple foundations for low-rise housing

GBG 39

Part 3

Groundworks: getting it right

good building guide

Part 3 of this Good Building Guide gives advice on many matters of detail that site supervisors and groundworkers should follow wherever possible. It sets out guidance so that commonly arising faults can be recognised and avoided, and the quality of site work controlled to a good standard. The focus is on strip footings and trench-fill foundations but the guidance given is applicable to the vast majority of foundations for low-rise housing described in Part 2.

Other parts to this Guide

For site investigation – see Part 1
For 'rule of thumb' design – see Part 2

Foundations are crucial to the continuing satisfactory state of the building they support. The careful consideration given to the initial site surveys and to the design of the foundations (see *Parts 1* and *2*) deserves to be matched by equally careful site work. *Part 3* sets out guidance to groundworkers and supervisors so that commonly arising faults can be recognised and avoided and the quality of site work controlled to a good standard.

Part 3 deals with work on strip footings and trench-fill foundations. It does not deal with foundation work for ground-supported slabs or for rafts, nor does it deal with groundwork associated with specialist foundations such as those involving piling or ground-improvement techniques. Its content is none the less applicable to the vast majority of foundations for low-rise housing as described in *Part 2*.

This Guide offers specific advice, on many matters of detail, that groundworkers should follow wherever possible, but two issues of over-riding importance that should be kept firmly in mind follow on page 2.

Concrete footings

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Box 1 Storing materials on site

- Keep different sizes or types of aggregate completely separated from each other. Each should be on a clean, hard, free-draining base.
- Keep aggregate heaps well away from site traffic and make sure that they do not get contaminated by mud, leaves or site rubbish.
- Cover aggregate heaps in freezing conditions or in very hot weather. Don't use aggregates that are frozen. Spray water on them if they get hot.
- Keep cement dry and use cement bags in sequence. After a few weeks even well-stored cement can lose a fifth of its strength.
- Keep reinforcement bars or mesh protected from the weather. If reinforcement is left lying around on site it will almost certainly get contaminated by mud and rubbish and may also go rusty and be physically damaged.

- *The requirements set out in the specification for the foundation work must take precedence over generalised advice given here or elsewhere.*

And, most importantly:

- *Anything encountered in the course of the foundation work that may not have been foreseen should be drawn to the attention of whoever is responsible for deciding what action should be taken. If in doubt about whether to carry on or whether to stop and report, err on the side of caution.*

Foundation work

Storing materials on site

It is important to look after materials stored on site and protect them from extremes of weather. Some important points to remember are listed in Box 1.

Setting out

Setting out distances

- Use a tape that is in good condition with clear calibrations.
- Use the tape so that it is fully supported and on a reasonably flat surface.
- If taping on a slope, make a correction to the reading (read the correction off Figure 1).
- Check where the zero is at the tape end (eg does it include the ring or not?)
- Don't try to estimate the reading if the tape cannot be in contact with the measured point (project the point up vertically to meet the tape, so avoiding parallax, see Figure 2).

Setting out angles

When using a tape to set out a 90° angle using the 3:4:5 triangle, take the same precautions as those listed above. The method is not reliable if setting out on uneven ground. A tripod-mounted optical square can be used whether or not the ground is uneven, and can also be used in trenches. The precision obtainable with a theodolite is superior if in the hands of a skilled user, particularly if it incorporates an optical plummet. However, it does not find much use on smaller building projects.

Setting out straight lines

A theodolite greatly simplifies the process of establishing straight lines. On projects where only tapes and levels are available, lines are established by

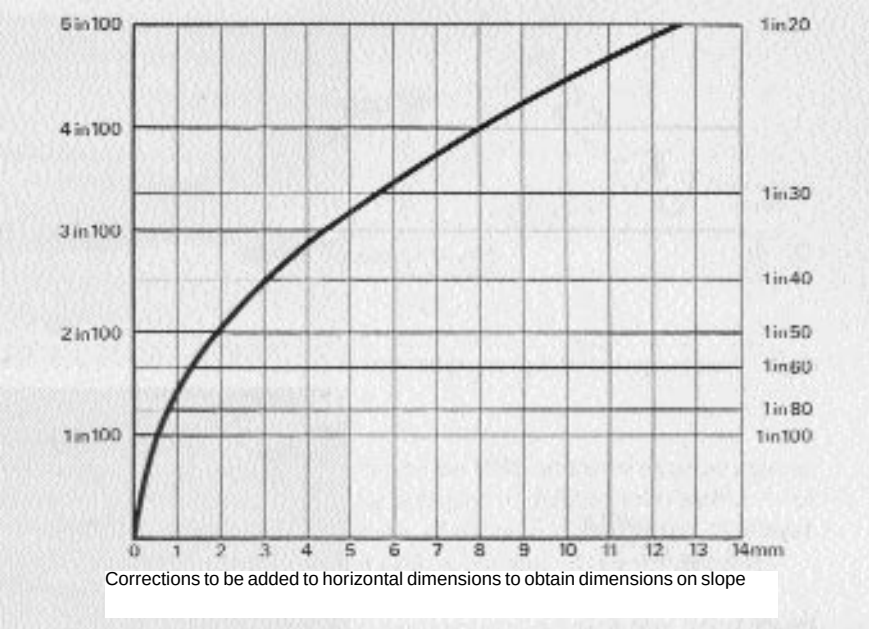

Figure 1 When setting out a specified horizontal dimension add these corrections to every 10 metres to get the corresponding tape reading if working on sloping ground

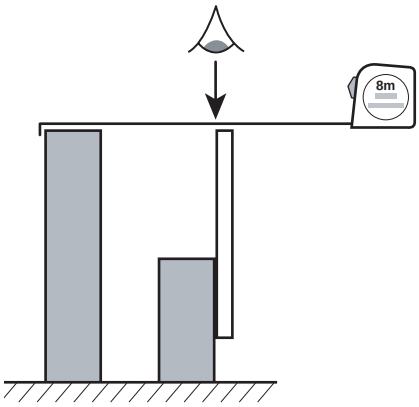

Figure 2 Avoiding parallax

Safety!

Do not enter a trench more than 1.2 m deep unless it is adequately shored.

stretching twine between established points marked for example by nails. Even a light wind can produce a marked sideways bow in the twine. The stronger the material of which the line is made, the thinner it can be and yet still able to stand greater tension. Both the smaller wind resistance of the thinner line and the greater tension in it, help to reduce the amount of bow and so reduce errors in positioning items with reference to a line.

Trenches

It is important to check before starting work that there have been no changes in requirements. In particular, check the required *depth* of trenches by reference to the drawings, specification and the requirements of the Building Control body. The depths of foundation trenches, when dug, should be checked by reference to a reliable level datum.

Setting out on plan should be by reference to reliable reference lines, checking that no major positional errors occur. Check where appropriate for equal diagonals, to ensure squareness.

Foundation trenches should be dug only after all surface growth and organic material has been removed to a depth of *at least* 150 mm.

All setting out, including the positioning of all profile boards in the work area, should be completed before any excavation begins. Information about the soil, obtained from the initial site surveys, may already have led to a decision about whether trench sides are likely to be self-supporting. However, the final decision should be based on an examination of the trench sides as excavation proceeds, since the soil type may well vary across the site.

This is an important issue, primarily because the safety of site workers may be at risk if trench sides are unstable, but also because concrete (whether for strip footings or trench-fill) can be seriously contaminated by soil falling from the trench sides while pouring is in progress. Take account also of the stability of trench sides in relation to the proximity of site traffic.

If roots are found, or if the soil in the trench bottom proves to have areas that are softer or harder than the remainder, make sure that those responsible for the work know about it. Tell them, too, if any kind of existing construction is found, for example old footings, cellars, drains or other services, or former paved areas or hardstandings. If nothing untoward is found, the trench sides are stable and the trench bottom is uniform, level, clean and dry, the foundation work is ready for the next stage.

Reinforcement

If reinforcement is specified it should be prepared and where necessary assembled so that it is ready to be installed *as soon as the excavation work is complete*. Trenches deteriorate if they stand open as a result of unforeseen delay in starting the next stage of the work.

Reinforcement must be *clean* if a good bond between steel and concrete is to be obtained. Slight rusty discoloration is acceptable but it is very important to remove loose rust or scale, which would prevent the concrete from bonding with the steel beneath the rust layer, and to remove anything that would act as a slippery layer, such as mud, paint, grease or ice.

Before any reinforcement is installed in the trench make sure that you are clear about where it is to be located - both in terms of its position on plan and its location at the top or bottom of the foundation.

The reinforcement should be checked to see that it is *still* in a clean condition immediately before pouring the concrete.

Steel mesh

Reinforcement in the form of steel mesh should be:

- cropped to fit well within the trench width, so that it will have at least 75 mm clearance at each side.

If specified to be in the bottom of the foundation concrete, the steel mesh should be:

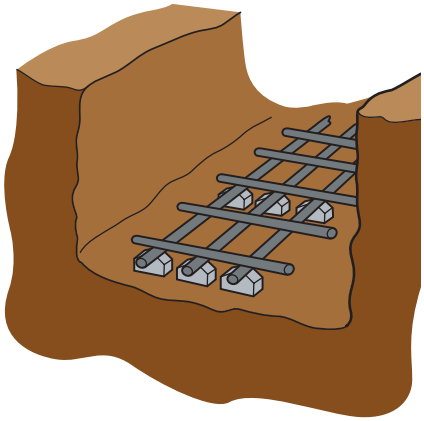

Figure 3 Long bars underneath when steel mesh is laid at the bottom of foundation concrete

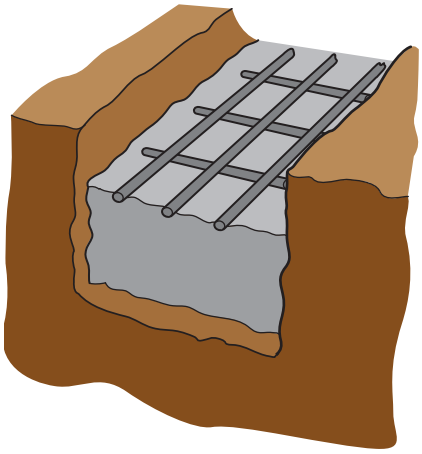

Figure 4 Long bars on top when steel mesh is laid in the upper part of foundation concrete

Safety!

When mixing concrete wear suitable protective clothing to prevent dry cement from entering the eyes, nose and mouth. Fresh concrete will cause cement burns which may not be felt immediately so take care to ensure that it does not come into contact with your skin or eyes.

- supported off the trench bottom on purpose-made non-corrodible spacers; do not use anything else as supports,
- supported at least 75 mm above the trench bottom,
- laid so that the long bars are on the underside of the mesh (Figure 3),
- supported at sufficiently close spacing to ensure that the reinforcement will not be displaced when the concrete is poured.

If specified to be in the upper part of the foundation concrete, the steel mesh should be:

- laid so that there will be 75 mm or more of concrete above it,
- laid with the long bars uppermost (Figure 4).

Steel mesh, whether in the top or the bottom of the trench, should be laid with overlaps between successive sections. Check whether the lap required is specified, otherwise place with an overlap of not less than 300 mm.

Pre-assembled reinforcement 'cages'

Where reinforcement is in this form the drawings or specification should be carefully checked for requirements for its location on plan and its positioning within the depth of the trench.

- Check that bars are securely tied together and that supports are firmly fixed in place.
- Check that there are enough spacers to support the cage so that it will not be displaced when the concrete is poured.

Concrete work

Before starting, check what mix proportions and what cement type are specified. Some site conditions, such as those where there is a high sulfate content in the soil, may make it necessary to use different mixes from those normally used, perhaps with a higher cement content than usual or with sulfate-resisting cement rather than ordinary Portland cement. In such cases, the concrete must be delivered to site ready-mixed.

Site-mixed foundation concrete

Site-mixed 'standardised prescribed' concrete (BS 8500) is suitable for strip footings and trench fill foundations, providing the ground is not chemically aggressive. It is not appropriate for reinforced foundations.

Batching of materials for site-mixed concrete should be by mass (ie 'by weight') unless volume batching is permitted. If volume batching is permitted it should be based on purpose-made gauge boxes or, at the very least, buckets should be used. Batching 'by the shovelful' should never be regarded as good enough (Figure 5).

Mixes should if possible be based on a whole 25 kg bag of cement. Unless otherwise specified (as may be the case if reinforcement is present) and provided that the soil is non-aggressive, mixes made on site can be an ST2 mix for strip footings and trench fill, with an adjustment to the mix proportions for the latter to give greater slump: the recommended slump for concrete for strip footings is 100–150 mm, whereas for trench fill it is 160–210 mm. The ratios of cement:sand:aggregate are given in Box 2.

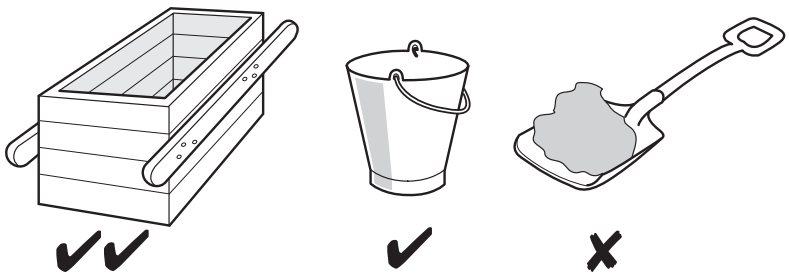

Figure 5 When volume batching, gauge boxes are best, buckets are second best and shovels are not good enough

Box 2 Standard concrete mixes

ST2 mix for strip footings*

An ST2 mix to give 1 m^3 of concrete having 100–150 mm slump:

- 285 kg Portland cement:
  735 kg concreting sand:
  1105 kg coarse aggregate.

ST2 mix for trench fill foundations*

An ST2 mix to give 1 m^3 of concrete having 160–210 mm slump:

- 300 kg Portland cement:
  725 kg concreting sand:
  1080 kg of coarse aggregate.

*Recommendations for 20 mm maximum aggregate size (assumes cement of standard strength class 32.5).

Safety!

This *Good Building Guide* does not deal with all health and safety issues that arise in the course of work on site. Readers will find useful guidance on relevant health and safety matters in *CIRIA Special Publication 130 'Site safety handbook'*.

It is generally best to put the coarse aggregate into the mixer first. This practice helps to reduce the amount of cement and sand 'caking' on the drum and the blades and so becoming lost to the mix. Even if this is done, the first mix out of the drum may be short of cement and sand. With skill and experience it is possible to reduce the quantity of coarse aggregate in the first mix to compensate for the cement and sand retained in the drum.

A mixing time of one-and-a-half to two minutes is usually enough and mixing times greater than this should generally be avoided. The machine should not be allowed to continue mixing simply because no-one on site is ready to deal with it. Check that the mix looks uniform before discharging it and mix a little longer if it does not.

Discharge the whole of the mix each time before putting in the next batch. *Don't add anything to the mix that has not been specified.* Don't use water for mixing that may have been contaminated. Remember that contamination may not be visually obvious, and quite small amounts of some contaminants could seriously weaken the concrete. Often the mix water will be specified to be 'of potable quality'. The best way to be sure that the water is indeed safe to use is to take it from the mains supply using an anti-siphon device.

Ready-mixed concrete

Where the ground is not chemically aggressive (eg negligible sulfates present), the concrete mix for strip footings and trench fill foundations can be Designated Concrete GEN1 of BS 8500. Where the ground has been assessed as aggressive, engineering advice should be sought on concrete specification. The use of an appropriate Designed Concrete (DC Class) or Designated Concrete (FND Class) will be necessary. Fully buried reinforced foundations will generally require RC30 of BS 8500, but follow any specific engineering advice which accompanies the reinforced concrete design.

Check that the delivery note matches the specification. Ensure that trenches are ready to receive the mix and that any temporary shuttering needed is in place and firmly secured. Check that the mix lorry has safe access.

Important points when working with site-mixed and delivered ready-mixed concrete

- Don't put concrete into frozen ground or trenches with ice or snow on the surfaces.
- Don't place concrete during heavy rainfall or into water-filled trenches.
- Don't mix or place concrete if the air temperature is 5 °C or less and likely to fall further.
- Check that any steps in the bottom of the trench are correctly formed (see *Part 2* of this Guide).
- Make sure that any reinforcement specified is in place.
- Make sure that any compressible boards (for clay soils) are in place, positioned on the specified trench face, and secure.
- Make sure that reinforcement or compressible boards are not displaced when concete is poured.
- Take particular care to work concrete fully around reinforcement so that no voids are created.
- Make sure that the top is brought to a reasonably smooth level surface so that there is a good base for brick and block laying.
- Take particular care that the top surface of trench fill is correct to level datum (there are likely to be too few courses between the concrete and dpc level to correct errors in level).
- In hot weather cover completed foundations immediately with polythene sheet so that the concrete will not dry out too rapidly.
- In very cold weather, or if there is a risk of overnight frost, cover newly-placed concrete with insulating material.
- Store test cubes under damp hessian.

Important points when laying brickwork and blockwork below the dpc

- Take particular care to set out blockwork accurately on the foundation concrete if the ground floor is to be of pre-cast beam and block (there is otherwise a risk that floor beams will oversail the inner leaf and project into the cavity, leading to accumulation of mortar droppings and later to rain penetration).
- Make sure that the bricks and blocks selected are as specified or known to be suitable for use below dpc level.
- Wall cavities below dpc should be solidly filled with mortar to a level not closer to the dpc than 150 mm. (This is intended to ensure that mortar droppings in the cavity will not bridge the dpc and is therefore particularly important if the wall is not to be fully filled with insulation batts.)
- Take care when brushing grout onto a beam and block ground floor not to brush grout into the external wall cavity.
- If ground floor level will be 1 metre or more above finished external ground level fix straps at 2 metre spacing to retain the top of the inner leaf at ground floor level wherever walls are not restrained by the ground floor itself.
- As soon as practicable cover open cavities at ground floor thresholds so that they do not become filled with rubbish (this is a particular risk at the time when structural floors are being cleaned of rubbish and mortar droppings).
- If a block is left out of a beam and block ground floor, eg to provide a space for services to run through, don't use this as a convenient hole into which to sweep all the rubbish (this is particularly important on clay soils because the void below the floor is intended to permit any subsequent expansion of the clay without disrupting the floor).

BRE Good Building Guides

Good Building Guides have been developed to provide practitioners with concise guidance on the principles and practicalities for achieving good quality building. The guides are designed to encourage and improve mutual awareness of the roles of different trades and professions.

The guides draw on BRE site experience and research, and on other reliable sources, to provide clear technical advice and solutions. Every effort is made to ensure that the guidance given is the most authoritative at the date of issue.

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Further information

BRE
BRE Building Elements: *Foundations, basements and external works — performance, diagnosis, maintenance, repair and the avoidance of defects.* H W Harrison & P M Trotman. BR 440. 2002

Digest
298 The influence of trees on house foundations in clay soils

Special Digest
1 Concrete in aggressive ground (4 Parts)

Good Building Guide
34 Building in winter

The Stationery Office
Building Regulations (England and Wales) 1991, Approved Document A

British Standards Institution
BS 8500: 2002: Concrete – Complementary British Standard to BS EN 206-1
Part 1: Method of specifying and guidance for the specifier
Part 2: Specification for constituent materials and concrete
BS 8103:– Structural design of low-rise buildings
Part 1: 1995 Code of practice for stability, site investigation, foundations and ground floor slabs for housing

NHBC
NHBC Standards. Part 2: Materials (2.1 Concrete and its reinforcement); Part 4: Foundations (4.1 Land quality — managing ground conditions, 4.2 Building near trees, 4.4 Strip and trench fill foundations). January 2000

CIRIA
Site safety handbook. Special Publication 130. 1997

Addendum to Part 2

Load category A is now included in Table 4 below.

Table 4 Minimum foundation widths in relation to soil type and load category

Soil	Minimum foundation widths (mm) for load category								
	A	B	C	D	E	F	G	H	J
Compact: gravel, sand[1]	250	300	400	500	600	650	800	900	1000
Stiff: clay, sandy clay[2]	250	300	400	500	600	650	800	900	1000
Firm: clay, sandy clay[3]	300	350	450	600	750	850	950		
Loose: sand, silty sand, clayey sand[4]	400	400	600						
Soft: silt, clay, sandy clay, silty clay[5]	450	450	650						
Very soft: silt, clay, sandy clay, silty clay[6]	600	600	850						
Hard rock	Width of wall	Width of wall							

Note: In no case should width of foundations be less than the width of the wall.

1 Requires pick for excavation
2 Requires pick or pneumatic spade, not mouldable in fingers
3 Excavated with spade, mouldable with difficulty in fingers
4 Easily dug with spade, little cohesion when moulded
5 Easily dug, easily moulded in fingers
6 Exudes between fingers when squeezed

Adapted from BS 8103.

Correction to Part 2

Page 4

Minimum foundation depth

The second bullet point should read:

- In clay soils, the foundation should be at such depth as will not be significantly affected by seasonal moisture content changes (in practice, not less than 1.0 m, but deeper if local experience dictates).

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