digest

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Low-rise building foundations on soft ground

Digest 471

This Digest aims to be an authoritative source of general information about how best to provide foundations for low-rise buildings on soft ground. It describes how to identify and investigate soft ground, outlines the particular difficulties likely to be encountered and provides guidance about the different foundation options available. Most importantly, it emphasises that specialist advice from competent professionals who are experienced in the engineering of soft ground is essential to the delivery of successful development of soft ground sites.

Introduction

Increasing environmental and demographic pressures are forcing many new building developments in the UK into areas where the ground was historically considered to be marginal and best avoided. Soft, natural ground, such as alluvial clays and peat deposits, is one of these areas. Improved technology now allows economic building on this ground but its soft nature presents greater challenges than most other ground types. With proper planning and the employment of appropriate professionals who offer expertise in building on soft ground, good results can be achieved.

The problems with soft ground

Soft ground is characterised by low shear strength (and therefore low bearing capacity), high compressibility, low permeability and the probability of significant variability. Bearing failure, excessive foundation settlement and tilting and disruption between a building and its services are significant risks that must be minimised. To do this, the advice of professionals experienced in soft ground engineering should be sought at the earliest possible opportunity. It will be difficult, costly and involve long delays if expert opinion is required after problems have occurred on site or after completion of works. Planning authorities and a building control organisation responsible for ensuring compliance with the Building Regulations should be consulted. The building control service may be provided by the local authority building control office or by an approved inspector.

The level of difficulty involved when building on soft ground varies considerably depending on the type and size of structure, and the level of experience and expertise of those involved. For example, a local builder who is experienced in building on soft ground may proceed quite satisfactorily, relying on his own knowledge and guidance from the building control organisation that checks for compliance with the Building Regulations. Conversely, someone not experienced in building on soft ground may struggle and require specialist help.

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What is soft ground?

For the purposes of this Digest, soft ground is 'soft natural ground such as alluvial clay or silt, often including deposits of highly compressible organic matter such as peat'. BS 5930 describes simple field tests:

- for soft soil – 'finger pushed in up to 10 mm';
- for very soft soil – 'finger easily pushed in up to 25 mm'.

Soft ground has low shear strength, typically between 20 and 40 kPa, with very soft ground having a shear strength less than 20 kPa (or kN/m^2). Soft ground is highly compressible and can be extremely so if organic material (eg peat) is present. The low shear strength limits the pressure a foundation can impart to the ground without causing failure (the limiting pressure is known as the bearing capacity), while the compressibility can lead to large settlements – both initially, if foundation pressures are too high, and in the long term. Figure 1 shows a shear strength profile with depth for a soft soil and indicates a stronger surface layer. This stiffer 'crust' (typically 0.5 to 2 m thick) results from seasonal desiccation caused by evaporation and the removal of moisture by plant roots. The higher strength of the crust can play a positive role for shallow foundations if their construction leaves it largely undisturbed.

Soft ground is likely to be highly impermeable. This means that new building loads imposed through the foundations will raise water pressures in the soil that will take a considerable time to dissipate; in short, the building may settle over several years if foundation pressures are too high.

There is a high potential for differential movements to occur when soft ground is found in small pockets in otherwise competent ground.

Soft natural ground is typically found in lowland areas such as river estuaries, floodplains and other places where water abounds in the vicinity of springs, streams, lakes, the sea etc. Groundwater levels in soft ground are likely to be very close to the surface and to fluctuate seasonally. Tidal effects may also influence groundwater levels.

Soft ground deposits can vary considerably in extent, both laterally and with depth. It is common to find soft ground as:

- laterally-extensive layers at or near the ground surface (eg the floodplain deposits of the Thames, Severn and Forth rivers, the Fens in East Anglia and the Somerset Levels);
- discrete layers buried between other geological sequences. These vary in depth, thickness and plan area (eg peat lenses beneath layers of fill or natural ground);
- small, localised soft spots that can occur almost anywhere. They are usually formed by flooding, underground springs, leaking drains or water supplies, or by human activities that alter the natural drainage of the land.

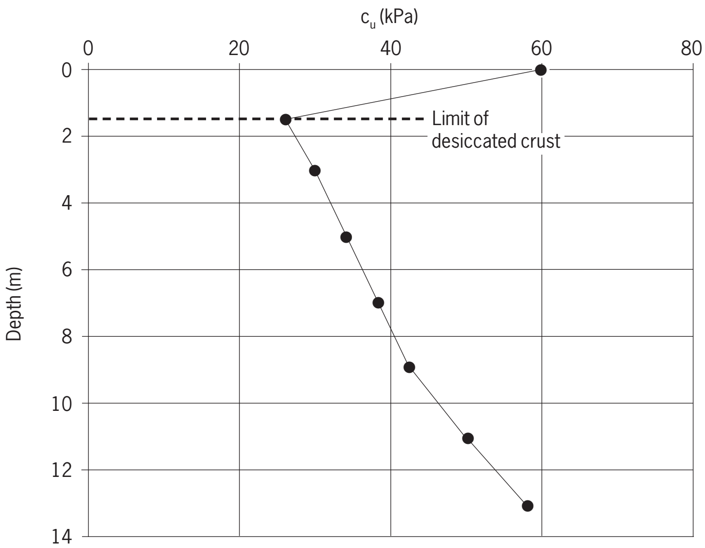

Figure 1 Soft ground shear strength (c_u) profile

Planning and regulatory matters

Planning authorities will require evidence that a proposed development has been planned and designed appropriately for its location and the ground conditions. As well as demonstrating that the foundations will be stable in the long term, it will be necessary to show that flood protection and the impact of changing surface water run-off characteristics on wildlife habitats have been considered. The planning authorities may also ask for measures to be taken to protect important habitats.

All new habitable building on soft ground must satisfy the requirements of the Building Regulations; if the development contains private housing, NHBC Standards (or other certification scheme requirements) must also be met. The Approved Documents (ADs) to the Building Regulations impose particular requirements for soft ground: Table 12 in AD A1, 1E – specifies minimum widths for strip foundations on soft and very soft ground; wall loading greater than 30 kN per metre run requires specialist advice to be obtained. The deemed-to-satisfy provisions of BS 8004 will apply.

Using local knowledge

Local knowledge in the possession of building control bodies, planning officers, local builders and engineers, and NHBC inspectors is an important and often overlooked resource. Accessing their expertise and experience speeds up the process of obtaining planning permission and Building Regulations approval.

The key requirements for building, including building in soft ground, are to provide assurance of:

- adequate bearing capacity;
- acceptable settlement in both the short and long term;
- during construction, stable excavations for foundations and for trenches to carry drainage and other services;
- adequate drainage of the property and surrounding ground;
- adequate provision to cater for any differential settlement between the building and drainage and services runs;
- minimal risk of flooding through scheme location or the provision of protection;
- adequate protection of the local environment.

Table 1 highlights some of the specific requirements of the Building Regulations and NHBC Standards that must be satisfied.

Table 1 Specific requirements for building in soft ground

Item	Requirement	
Bearing capacity	***Building Regulations***	***NHBC***
	Prescribed minimum foundation width: From Table 12 in Approved Document A	*Prescribed minimum foundation width:* From Table 12 in Approved Document A
	Simple calculation: Bearing pressure of foundation $<$ allowable bearing pressure on soil	Safe transfer of load from the structure to the ground without exceeding allowable bearing pressure of soil. Suggested Factor of Safety = 3 applied to bearing capacity. This can be increased for sensitive structures
Settlement	Foundation design must ensure that differential movement does not adversely affect the supported structure *Common local rule:* upper limit of 25 kPa on bearing pressure *Total Settlement:* maximum of 50 mm *Differential settlement:* maximum of 25 mm *Tilt:* maximum of 1/500	
Drainage and services	*Applied loads:* allowance must be made for loads from foundations, surface features and traffic. *Ground movement:* allowance must be made for ground movement; all pipes should have flexible joints; gradients should allow for anticipated movements. *Chemical attack:* special care is needed where groundwater may contain chemicals that are aggressive to plastics, concrete and ceramic pipework.	

The 1980s and 1990s were amongst the warmest years in the past millennium. There is growing evidence of increasing winter rainfall and storms. Precipitation patterns are changing, sea levels are rising, river flow extremes are on the increase and flooding is a frequent threat.

Flooding

The risk of flooding is frequently associated with the low lying regions where soft ground is likely to be encountered.

Five million people in two million homes in England and Wales are at risk of flooding. In addition, 185,000 businesses with property and land assets valued at more than £200bn are potentially affected. In autumn 2000, 10,000 buildings in England and Wales were flooded causing immense damage. The insurance bill, including storm damage, was around £1.3bn (£860m for homes and £440m for commercial property)[1]. A further 37,000 properties were protected by sandbags.

New planning guidelines for developments in flood risk areas, issued by the Government to local authorities, state that the susceptibility of land to flooding is a material planning matter, and requires a risk based, sequential approach starting with the safest sites[2].

Developments in flood risk areas will be subjected, in future, to stringent checks to ensure that adequate investigation of the risks and the need for protection measures have been made. A first step is to assess, from Environment Agency (EA) floodplain maps, the risk of flooding. Although only indicative, these maps offer a good starting point from which to develop a detailed analysis of the threat of flooding. A second step is to contact the local planning office, EA or the British Geological Survey for specialist advice. These checks could also give an early indication of the likelihood of having to found on soft ground.

Checks on the effectiveness of existing flood defences (flood embankments, balancing reservoirs, and surface water drainage schemes) will be required. If they are found to be inadequate they must be upgraded to cope with the demands of the new development. The provision and maintenance of flood defences have traditionally been carried out by Government, but it is likely that developers will be called upon to contribute to the cost of upgrading and maintaining existing and new flood defence systems for new developments. Soft ground can affect the performance of these flood defences in ways similar to those affecting building foundations. If flood defence embankments are raised to provide better protection, it is important to remember that the extra loading may cause settlement of soft ground which could impact, in turn, on any nearby buildings.

The Institution of Civil Engineers (ICE) also publishes useful information on flood risks[3].

Climate change and its impact on soft ground

Climate change predictions suggest that there will be more summer drought and more winter flooding of low lying, soft ground areas.

If these predictions prove correct, we could expect the following changes to soft ground:

- the thickness of desiccated crust slowly increases due to longer periods of drier, summer weather;
- longer periods of more intense flooding caused by wetter, windier winters leading to some surface softening of the ground. Tension cracks developing during drought will allow winter storm water to penetrate the ground quickly, leading to more rapid softening of the ground surface.

While climate change will have a relatively minor impact on the behaviour of existing buildings on soft ground, it will have an impact on the way planning applications are reviewed and dealt with. A wider range of criteria (eg the impact of surface water drainage schemes on the hydrology of the ground, and hence predictions of ground settlement induced by these changes) will have to be shown to be acceptable before planning applications are approved.

Changes in groundwater levels

Developments on low lying, soft ground will inevitably impact on groundwater levels. Changes in run-off patterns and rates – through landscaping and raised site levels to guard against flooding, physical changes in the drainage characteristics of the ground, and engineered modification such as ground improvement – will impact on original groundwater levels. These changes may cause both short and long term changes to levels. Short term changes are only likely to occur during construction, although they may have long term consequences. Any long term changes in groundwater levels must be anticipated and their consequences (engineering, environmental and hydrological) must be carefully considered.

The engineering issues

Foundation settlements should be the biggest concern when developing soft ground; they may be large and continue for many years. Settlements are very difficult to predict accurately. Local variability of the ground can lead to differential settlements that can be as damaging or, in some instances, more damaging or disruptive than overall settlement. If ground conditions are suitable, foundations utilising piles or ground improvement techniques will minimise settlements. Services and drains that are constructed in quite shallow trenches within soft ground so that they settle relative to the building, can be disrupted at connections with the building. This problem may be avoided with enhanced support to the drains and services; specialist advice should be sought in these circumstances.

Site investigation for soft ground

General site investigation for low-rise building is covered in a series of BRE Digests:

- desk studies (318);
- procurement (322);
- walk-over surveys (348);
- trial pits (381);
- soil descriptions (383);
- direct investigations (411);
- optimising ground investigation (472).

BS 5930 suggests that site investigation should proceed in a logical, sequential process, in the following manner:

- Stage 1 – desk study and site reconnaissance;
- Stage 2 – detailed investigation for design including ground investigation, topographic and hydrographic surveying, and any special studies;
- Stage 3 – construction review, including any follow up investigations during construction, and the appraisal of building performance.

Reference should also be made to the guidelines, *Site investigation in construction*, provided by the ICE Site Investigation Steering Group[4], Clayton *et al*[5] and *NHBC Standards*, Chapter 4.1[6], which give procedures for designing and carrying out a site investigation.

Site investigation for soft ground

'Without site investigation, ground is a hazard' (*Site investigation in construction*, ICE[4])

Site investigation (SI) is the collection and interpretation of site information to determine its probable influence on the design, construction and subsequent performance of a building. It is a process of continually questioning, exploring and interpreting information that will evolve and change as data are obtained.

It is important to determine the type, extent, variability and depth of soft ground, and the nature of the underlying soils. The investigation should be appropriate for the planned building and should be designed, supervised, carried out and interpreted by specialists experienced in dealing with soft ground. Construction should not commence until site investigation and foundation design have been carried out, and an appreciation of the magnitude and timescale of any potentially large, time-dependant settlements and other hazards has been acquired.

The desk study

The desk study for a soft ground site is essential for gathering preliminary information from which to identify the requirements of the foundations for the project. It offers the first insight into any potential problems through a review of historical and factual information about the site. The desk study should include a review of Geological and Ordnance Survey maps, old plans, photographs and records.

Topographical features which indicate soft ground include:

- lakes, lagoons, rivers, streams, and springs;
- floodplains, fenland, valley bottoms and other low lying areas.

A review of all the available information from the desk study, in conjunction with a walk-over survey, leads directly to planning the most appropriate ground investigation that can be afforded.

Walk-over survey

The first time that an engineer or surveyor conducts a walk-over survey of a site could be an important stage in the investigation process. It should be used to confirm the findings from the desk study, uncover new information and identify specific areas requiring further investigation. Although it is usually limited to the inspection of surface features it may be possible to do some shallow investigation using simple hand tools, augers or probing equipment to gain crude estimates of ground characteristics (see box below).

Checks should be made to see if there are any tell-tale signs on other buildings adjacent to the site (cracking, tilting etc), if there are any signs of flooding, and if a working platform of compacted, granular soil will be required during construction.

If it is possible, returning to the site at different times of the year might establish whether there are changes in ground conditions.

Direct ground investigation

Direct ground investigation usually includes trial pits and boreholes (Digests 381 and 411). Some simple in situ testing using a hand shear vane may be carried out in the sides of pits or on large excavated samples to obtain very approximate shear strength values, while further in situ tests (see box at right) may be conducted to interpolate between pits and holes or to extend the investigation to other parts of the site.

Features specific to soft ground

- Green vegetation, flourishing undergrowth and certain species of trees, such as willow can indicate localised wet, soft areas.
- Low lying ground that, with rivers, streams, lakes or ponds close by, may suffer from local flooding. This could seriously impact on site activities, construction techniques and foundation design.
- Signs of movement in existing buildings.
- Localised soft spots. Is the ground excessively soft for the time of year? Is there anything unusual? For example, is the grass especially green in certain areas? All of these things could be indicators of soft ground.

Extensive prodding of the ground with a probe (eg a simple road-pin) should enable areas of soft and firm ground to be identified – remembering to note where they are. Even probing the top few inches of ground can be a good indicator of areas requiring more detailed investigation.

It shouldn't be assumed that because the surface feels fairly stiff that there isn't soft ground beneath it. It is common for many soft ground areas to have a thin (typically 0.5 to 2.0 m) desiccated crust that can give the impression of competent ground. Below this the ground properties can be very different.

Foundation choices and design

Foundation choices

The various factors governing the choice of foundation are presented in Table 2. Figure 3 shows a general approach for selecting a foundation on soft ground.

Foundation design

Foundations on soft ground could suffer large, long term settlement. Therefore, except in the simplest cases, design should be carried out by suitably experienced and qualified personnel. Approved Document A of the Building Regulations requires specialist input when the ground is soft (or worse) and wall loadings exceed 30 kN/m.

Direct investigation of soft ground

Aims and techniques that could be used include:

- establishing the boundary and extent of the soft ground, and whether there are any isolated soft spots or hard spots;
- if undisturbed block samples cannot be easily taken from trial pits, considering taking U100 samples. If the highest quality samples are required piston samples may be an alternative. Otherwise it can be of much more value to replace extensive sampling and laboratory testing with field tests to establish important information about settlement and compressibility characteristics of the ground using simple pad loading tests or skip tests and precise levelling (Digest 386);
- using mechanical probes (eg dynamic probing) to determine the immediate sub-surface characteristics of the ground. On sites of varying geology they can be an efficient way of locating local soft spots or localised compressible peat lenses. They should be used with other techniques to clarify findings;
- establishing groundwater levels. These will almost certainly be near the ground surface and have a considerable bearing on construction activities. Near to river estuaries these levels may be affected by tidal fluctuations and an average level should be obtained;
- establishing organic content of the material to see if any special requirements are needed for buried structural concrete. Special Digest 1 provides guidance on how to deal with chemical attack, but it does not remove the need to seek specialist advice;
- importantly, establishing an undrained shear strength profile of the ground. This should be from ground level (or very near to it) to a depth slightly deeper than the predicted zone of influence of foundation loading.

If more detailed investigation of the ground is required, in situ testing (eg with the field vane or the piezocone, Digest 411) can be used to obtain engineering properties of the soil. The heavy plant often involved in piezocone testing may require a working platform to be installed.

Table 2 Options for selecting a foundation on soft ground

Factor	Ground issues	Foundation options
Ground properties	Strength; compressibility; depth to stronger layer; extent and properties of surface 'crust'	**1** Shallow foundation in stiffer crust **2** Remove soft ground and replace with competent material. May sometimes be appropriate for localised, shallow soft spots **3** Use piles to found through soft ground into competent stratum **4** Treat the ground
Groundwater	Location; drainage options	May influence choice where pumping of foundation and service trench excavations becomes difficult or expensive. May require local drainage measures beneath embankments installed for road access, landscaping and noise suppression
Required performance	Amount of settlement tolerable both in absolute and differential terms	If movement is to be tightly controlled for very sensitive structures, piling or other deep foundation becomes more appropriate. Careful consideration of the choice between, say, wide strips, where the ground is stressed to limited depth, and rafts where lower stresses are applied but to significantly greater depth (Figure 2). Requires specialist advice
Budget	Costs of different foundation options	Much depends on the location, size of project, local experience and the availability of specialist foundation companies
Site constraints	Access into and within site may affect choice of foundation equipment	With the advent of small, highly mobile piling and vibro rigs, access to the majority of sites has become much less of a problem; very difficult access can often be catered for with specialist equipment

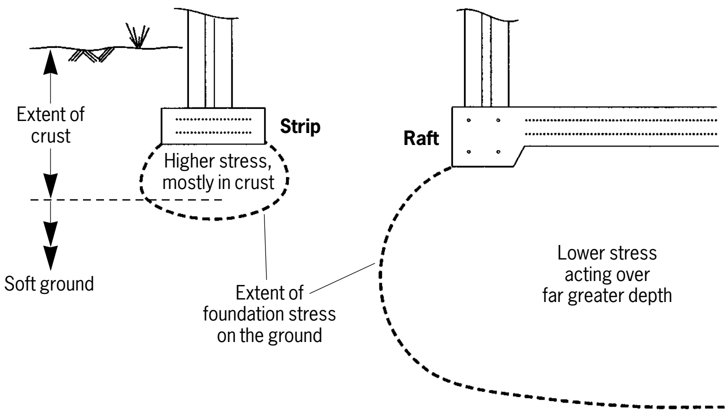

Figure 2 Ground stresses beneath strip and raft foundations

A satisfactory foundation design is one where the requirements of stability and acceptable deformation are met at minimum cost; acceptable deformation applies both to the structure being supported and to the interface between it and ancillary structures and services attached to it (eg drainage pipework).

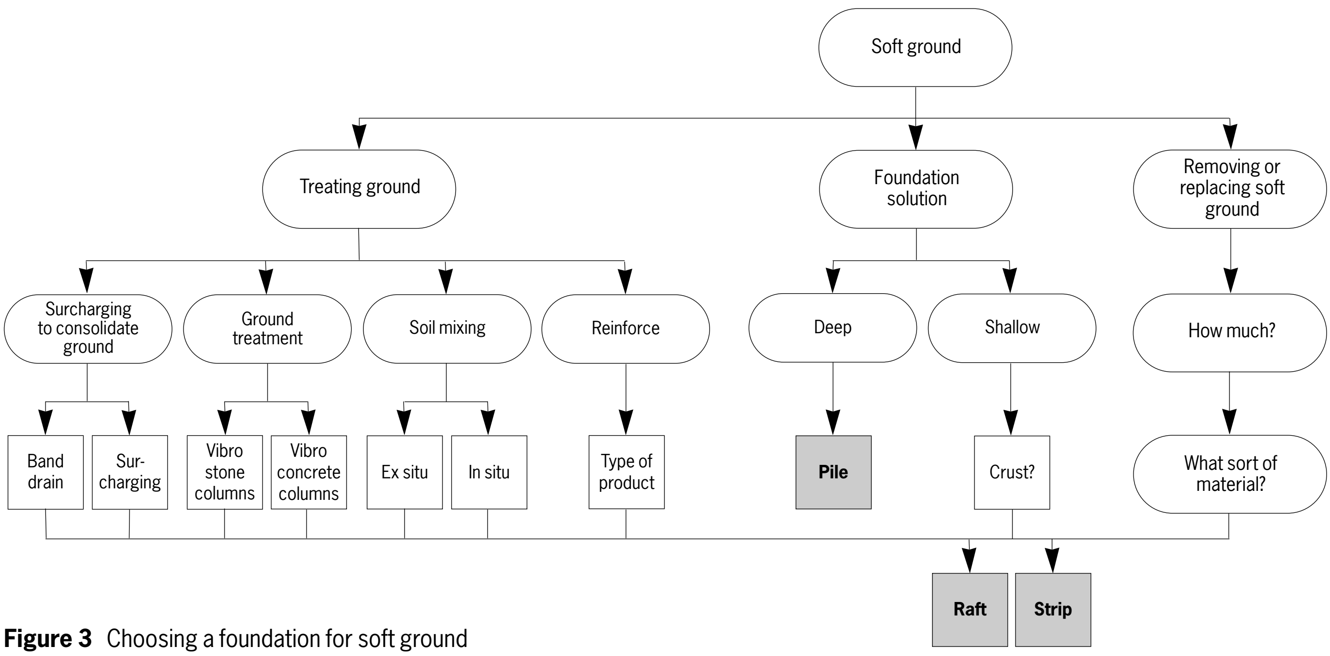

Figure 3 Choosing a foundation for soft ground

Shallow foundations

Using a shallow foundation has the advantage that differential movement between the building and its services, including access roads, is minimised. A disadvantage is the building may tilt, especially where the ground is laterally variable or where loading is highly non-uniform.

Rafts or wide reinforced strips have been extensively used in areas such as the Somerset Levels. The choice between strip and raft depends upon strength, compressibility, depths of material and external factors such as frost penetration and proximity of trees that might cause desiccation and shrinkage of clay. Some simple rules-of-thumb to limit settlements have been developed in some areas, such as an upper limit of 25 kN/m^2 bearing pressure.

Strip foundations

There are restrictions to the use of strip foundations on soft ground; for example, the NHBC will usually require an engineer's design before permitting the use of reinforced strips. The local building control body or NHBC regional engineer will advise if strip foundations are acceptable for the locality.

Raft foundations

Two types of raft are normally used: the plane raft (Figure 4) and the stiffer, edge-beam raft (Figure 5). Both rafts have been shown to perform adequately at a deep, very soft soil site[7]. The stiffer raft may be more appropriate for very soft ground but much depends on any contribution made by the crust.

The design of plane rafts requires only basic calculations to check the structural adequacy of the reinforced concrete section. Typical raft thickness is between 150 mm and 300 mm, depending on loading and ground properties, with steel mesh reinforcement in the top and bottom. Wall loads are considered to act only on the localised strip beneath them, with no account taken of load distribution across the area of the raft.

The design of edge-beam rafts is a little more involved; several methods are available. The procedure proposed by Atkinson[8] is relatively straightforward and allows the designer scope to minimise the beam cross-sectional area by spreading the building loads across the area of the raft. Typical dimensions are shown in Table 3.

A less common application of rafts on soft soil is for them to be used in combination with some form of surface stiffening to further reduce pressures on the soft ground and to reduce the structural response to any differential settlement. Surface stiffening usually involves the application of a compacted, granular platform. For embankment and road construction on soft ground, the platform may be reinforced with layers of 'geogrid' (proprietary plastics membrane). Not surprisingly, this application requires specialised design advice.

Table 3 Typical edge-beam dimensions

Depth of edge-beam	450 – 600 mm
Width of edge-beam	600 – 900 mm
Depth of slab	150 – 300 mm

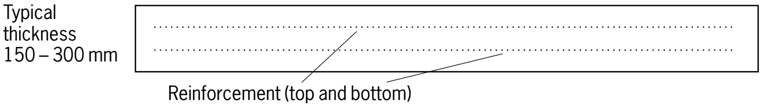

Figure 4 Section through a typical plane raft

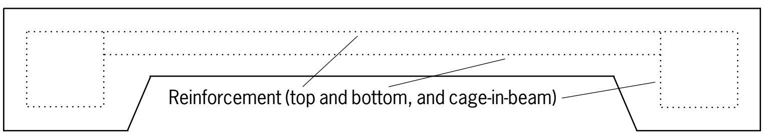

Figure 5 Section through a typical edge-beam raft

Deep foundations

Piles that extend through soft ground to a firm base have a very low risk of suffering settlement. This option is frequently feasible in areas such as the Thames floodplain where soft ground is typically 5–15 m deep overlying dense gravel. Piles will usually be of the driven type (eg precast, mini-shell or steel tube – Digest 315). A number of proprietary foundation systems involving precast beam elements (sometimes with post-tensioning) supported on square-section, precast piles are coming onto the market.

Specialist design is required to ensure that factors such as additional loading from any general settlement of the ground around the pile (down-drag) are catered for.

The use of piles to found only the building can introduce problems: differential settlement between buildings and drainage/service runs, and garages and driveways, has been quite common on some major developments on soft ground. Damaged pipework and ducting at the entry points to buildings and raised manhole covers are typical symptoms of this differential movement; the latter are potentially dangerous and can be difficult to repair.

The increasing availability of small piling rigs, often developed by the underpinning industry, makes piling a more feasible option for small projects, provided that ground conditions allow the use of these piles and the normal criteria for pile depth are adhered to; specialist advice should be sought.

When opting for a piled foundation, some consideration should be given to future additions to buildings; for example, a piled foundation to the main structure may require a similar foundation type for any future extension if it is not to settle relative to the main structure. Good Building Guide 53 gives guidance on foundations for extensions.

Ground treatment

In circumstances where providing deep, stable foundations is prohibitively expensive (for example because the soft ground extends to some depth) or where overall settlement of a shallow foundation is estimated to be unacceptably large, some form of ground treatment may be appropriate. Treatment such as installing vibro stone columns (BRE's *Specifying vibro stone columns*) may be appropriate in combination with rafts or strips.

Pre-treatment in the form of surcharging the ground (with and without the provision of vertical drainage to accelerate consolidation settlement, depending on soil permeability) may be applied for roads, car parking areas and embankments, to limit future settlements.

The design of compatible movement for a development on a variety of foundations is a matter for specialist geotechnical engineers.

Further specialist options may be available including chemical treatment where materials (eg lime, cement and ash waste products) are injected and mixed with the soil by special equipment to produce columns of a stiffer and stronger material. To date, this technology has been only applied to the foundations of embankments for roads and railways, but may have future application for industrial and commercial buildings.

Drainage blankets and de-watering systems

By definition, soft ground has a high moisture content with groundwater levels that will be at or close to the ground surface. This can seriously affect on-site activities and may require the installation of temporary de-watering systems or the provision of permanent drainage blankets. De-watering of a site before and during the construction phase can have unwelcome side effects such as the settlement of existing structures in the vicinity. The provision of drainage and de-watering systems requires specialist advice.

Constructing foundations in soft ground

The key operations, and their impacts, when installing foundations in soft ground, are summarised in Table 4.

Table 4 Foundation construction: hazards and impacts

Feature	Operations	Impacts
General site practices and workmanship	**1** Excavating in the crust	Over-digging can have serious consequences since the foundation may rely on the support of the stiffer crust. Not only must excess material not be removed, any disturbance must be avoided by carefully controlling construction plant and other vehicle movements and, if necessary, by providing a temporary working platform, with or without geotextile reinforcement, on haul roads, to minimise surface disturbance and to prevent vehicles becoming bogged down
	2 Excavating deeper into soft ground	Deep excavations within soft ground should be avoided as they may be potentially unstable and a threat to safety. They can be eliminated by using other foundation types (eg piles). Extra care is required to support open excavations, trenches and cut slopes. Excavations also need protection from loads which could cause instability (eg from vehicles passing or stacked materials placed close-by). The Health & Safety Executive publishes guidance on these and other related safety matters
	3 Pouring concrete into excavations	The chances of standing water or untrimmed excavation bottoms having surplus, loose and soft material are far greater in the crust of a soft soil. Failure to bail out and clean excavation bases may result in excessive settlement
	4 Encountering soft spots in otherwise competent ground	If these are overlooked and not excavated and replaced with stiffer soil (eg a granular fill), there is a high risk of differential settlement
	5 Stockpiling materials on site	Long term loading of ground prior to foundation construction creates hard spots that can lead to differential settlement and subsidence of existing nearby structures
	6 Replacing soft soil with heavier fill	Care must be taken to ensure that any compression of deeper soil from the additional loading is taken into account. A soils engineer should be consulted
Groundwater	De-watering to permit excavation and concreting of foundations	Lowering the groundwater table causes local consolidation settlements. Some heave can occur as groundwater levels rise after de-watering has ceased. In peat, however, the settlements arising from de-watering are likely to be permanent. A soils engineer should be consulted
Haulage roads	Providing fill above ground level	Additional loading from fill may induce settlements locally. A soils engineer should be consulted

Services in soft ground

Services in soft ground can, and often do, suffer from the same problems as foundations on soft ground; that is time-dependant, total and differential settlements, and construction difficulties (eg trench collapse).

Overburden pressures from trench backfill material, and surface loads from landscaping and traffic (most services run under roadways and pavements), can often lead to settlements that distort and fracture services.

Best practice involves using flexible pipe joints and service connections. Where services enter building, sliding couplers should be used that allow sufficient differential movement to occur between the structure and the service. Using sliding couplers means that drainage must be installed deeper than normal, which can lead to further settlement.

Table 5 summarises the more common problems and solutions for services in soft ground.

Table 5 Common problems and solutions for services in soft ground

Requirement	Problems	Solutions
Compatibility of settlement between structures and services	● Differential settlement ● Leaking drains ● Localised damage	● Integrated design approach using complementary systems ● Using flexible connections and sliding couplers ● Supporting services by hanging them from suspended floors
Maintaining falls of foul and surface water drainage pipes	● Excessive and differential settlement of service pipes causing excessive falls and reversals of falls ● Blocked drains ● Installation difficulties	● Running services through areas of least loading ● Using lightweight backfill material ● Using flexible couplings ● Minimising distance between manholes ● Considering pipe jacking ● Placing manholes and catchpits on firm strata if possible, or on deep foundations
Minimising backfilling materials	● Loss of backfill material into soft soil leading to excessive cost, increased loading and further settlement	● Using a geotextile to retain material
Stable excavations for services	● Collapse of trench sides and heave of base with high watertable	● Providing excavation support with trench boxes, braced sheet piles etc

References and further reading

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British Standards Institution
BS 5930:1999 Code of practice for site investigations
BS 8004:1986 Code of practice for foundations

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