

BS 6349-1-3:2021



BSI Standards Publication

Maritime works

Part 1-3: General — Code of practice for geotechnical design

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Foreword

Publishing information

This part of BS 6349 is published by BSI Standards Limited, under licence from The British Standards Institution, and came into effect on 30 April 2021. It was prepared by Technical Committee CB/502, *Maritime works*. A list of organizations represented on this committee can be obtained on request to the committee manager.

Supersession

This part of BS 6349 supersedes [BS 6349-1-3:2012](#), which is withdrawn.

Relationship with other publications

BS 6349 is published in the following parts:

- Part 1-1: *General – Code of practice for planning and design for operations*;
- Part 1-2: *General – Code of practice for assessment of actions*;
- Part 1-3: *General – Code of practice for geotechnical design*;
- Part 1-4: *General – Code of practice for materials*;
- Part 2: *Code of practice for the design of quay walls, jetties and dolphins*;
- Part 3: *Design of dry docks, locks, slipways and shipbuilding berths, shiplifts and dock and lock gates*;
- Part 4: *Code of practice for design of fendering and mooring systems*;
- Part 5: *Code of practice for dredging and land reclamation*;
- Part 6: *Design of inshore moorings and floating structures*;
- Part 7: *Guide to the design and construction of breakwaters*;
- Part 8: *Code of practice for the design of Ro-Ro ramps, linkspans and walkways*.

This part of BS 6349 is intended to be read in conjunction with BS EN 1997-1:2004 and BS EN 1997-2:2007.

Information about this document

This is a full revision of the standard, and introduces the following principal changes:

- general restructuring;
- inclusion of clause on bearing piles, previously in [BS 6349-1-4](#);
- enhanced reference to and alignment with BS EN 1997-1:2004 and BS EN 1997-2:2007;
- removal of general geotechnical guidance, which was more akin to a design manual.

This publication can be withdrawn, revised, partially superseded or superseded. Information regarding the status of this publication can be found in the Standards Catalogue on the BSI website at bsigroup.com/standards, or by contacting the Customer Services team.

Where websites and webpages have been cited, they are provided for ease of reference and are correct at the time of publication. The location of a webpage or website, or its contents, cannot be guaranteed.

Use of this document

As a code of practice, this British Standard takes the form of recommendations and guidance. It is not to be quoted as if it were a specification. Users are expected to ensure that claims of compliance are not misleading.

Users may substitute any of the recommendations in this British Standard with practices of equivalent or better outcome. Any user claiming compliance with this British Standard is expected to be able to justify any course of action that deviates from its recommendations.

Presentational conventions

The provisions in this standard are presented in roman (i.e. upright) type. Its recommendations are expressed in sentences in which the principal auxiliary verb is “should”.

Commentary, explanation and general informative material is presented in smaller italic type, and does not constitute a normative element.

Where words have alternative spellings, the preferred spelling of the Shorter Oxford English Dictionary is used (e.g. “organization” rather than “organisation”).

Contractual and legal considerations

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Section 1: General

1 Scope

This part of BS 6349 gives recommendations for geotechnical activities associated with the design and implementation of maritime works. It covers ground investigation and geotechnical design, and gives additional guidance on testing procedures.

2 Normative references

The following documents are referred to in the text in such a way that some or all of their content constitutes provisions of this document¹⁾. For dated references, only the edition cited applies. For undated references, the latest edition of the referenced document (including any amendments) applies.

[BS 6031](#), *Code of practice for earthworks*

[BS 6349-1-2](#), *Maritime works – Part 1-2: General – Code of practice for assessment of actions*

[BS 6349-1-4](#), *Maritime works – Part 1-4: General – Code of practice for materials*

[BS 6349-2](#), *Maritime works – Part 2: Code of practice for the design of quay walls, jetties and dolphins*

[BS 8006-1](#), *Code of practice for strengthened/reinforced soils and other fills*

[BS 8081](#), *Code of practice for ground anchorages*

BS EN 1536, *Execution of special geotechnical work – Bored piles*

BS EN 1538, *Execution of special geotechnical works – Diaphragm walls*

BS EN 1992 (all parts), *Eurocode 2 – Design of concrete structures*

[BS EN 1995](#), *Eurocode 5: Design of timber structures*

BS EN 1993-5:2007, *Eurocode 3 – Design of steel structures – Part 5: Piling*

BS EN 1997-1:2004, *Eurocode 7 – Geotechnical design – Part 1: General rules*

BS EN 1997-2:2007, *Eurocode 7 – Geotechnical design – Part 2: Ground investigation and testing*

BS EN 1998 (all parts), *Eurocode 8 – Design of structures for earthquake resistance*

BS EN 12063:1999, *Execution of special geotechnical work – Sheet pile walls*

BS EN 14731, *Execution of special geotechnical works – Ground treatment by deep vibration*

BS EN ISO 22475-1, *Geotechnical investigation and testing – Sampling methods and groundwater measurements – Part 1: Technical principles for execution*

NA to BS EN 1997-1: 2004, *UK National Annex to Eurocode 7 – Geotechnical design – Part 1: General rules*

¹⁾ Documents that are referred to solely in an informative manner are listed in the Bibliography.

3 Terms, definitions, symbols and abbreviations

3.1 Terms and definitions

For the purposes of this part of BS 6349, the following terms and definitions apply.

3.1.1 deadman anchorage

anchorage that relies on the mobilization of passive resistance

3.1.2 extreme high water (EHW)

highest level that can be predicted to occur as a combination of astronomical tides, positive or negative surges, seiches and freshwater flow

3.1.3 extreme low water (ELW)

lowest level that can be predicted to occur as a combination of astronomical tides, positive or negative surges, seiches and freshwater flow

3.1.4 geotechnical investigation

studies and investigation of the site, including ground investigations, the studies and appraisals of existing structures and the studies of the historical development of the site

3.1.5 ground investigation

direct and indirect investigation of the physical characteristics of the ground at the site

NOTE Ground investigations can include boreholes, penetration testing, trial pits, laboratory testing and geophysical profiling, amongst other things.

3.1.6 highest astronomical tide (HAT)

highest level that can be predicted to occur under average meteorological conditions and under any combination of astronomical conditions

3.1.7 lowest astronomical tide (LAT)

lowest level that can be predicted to occur under average meteorological conditions and under any combination of astronomical conditions

NOTE It is often the level selected as the datum for soundings on navigational charts.

3.1.8 mean high water springs (MHWS)

average, over a long period of time, of the heights of two successive high waters at springs

NOTE This is the average level that would exist in the absence of tides; a long period is typically 18.6 years (one cycle of the moon's nodes).

3.1.9 mean low water springs (MLWS)

average, over a long period of time, of the heights of two successive low waters at springs

NOTE This is the average level that would exist in the absence of tides; a long period is typically 18.6 years (one cycle of the moon's nodes).

3.1.10 neap tide

occasion in a lunar month when the average range of two successive tides is least

3.1.11 range

difference in height between one high water and the preceding or following low water

3.1.12 return period

period that, on average, separates two occurrences

3.1.13 spring tide

occasion in a lunar month when the average range of two successive tides is greatest

3.1.14 waterway

body of water in front of a structure

3.2 Symbols

For the purposes of this part of BS 6349, the following symbols apply.

B_e	breadth of earth-retaining structure
$c_{\min}$	minimum concrete cover
d_p	depth of pile toe from dredge level
H_R	retained height of structure
K_a	coefficient of active earth pressure
K_p	coefficient of passive earth resistance
z	depth at which a calculation is to be made
Δ_c	concrete cover tolerance for deviation
γ	density of soil
γ_w	weight density of groundwater

3.3 Abbreviations

For the purposes of this part of BS 6349, the following abbreviations apply.

CPT	cone penetration test
ELW	extreme low water
EHW	extreme high water
HAT	highest astronomical tide
LAT	lowest astronomical tide
MHWS	mean high water springs
MLWS	mean low water springs

Section 2: Geotechnical investigation

4 General

Geotechnical investigation of the surface and subsurface conditions at and near the site of proposed works should be carried out in a progressive manner as a key feature of the design of maritime structures. The investigation should be carried out in accordance with BS EN 1997-1:2004 and BS EN 1997-2:2007.

Preliminary studies should be undertaken to provide a basis for determining the extent of ground investigation and laboratory testing required. These studies should also include, where possible, the interpretation and evaluation of the information obtained.

The preliminary studies should include an assessment of the characteristics of soil or rock formations that can be retained by, or provide the foundation of, structures, or can be incorporated in or affected by earthworks in the form of dredging and reclamation. The preliminary studies should also include the collection of data on locally available materials for use in constructing the works, including the long-term durability of these materials in the particular location where the works are to be constructed.

NOTE 1 Ground investigation practice is described in BS EN 1997-2:2007.

NOTE 2 Information on geophysical surveying techniques is given in CIRIA Report C562 [1].

NOTE 3 Ground investigation prior to the planning, design and construction of dry docks is of greater importance than for many other structures of similar value or size. The subsoil conditions can greatly influence the choice of construction method.

NOTE 4 Appropriate methods of calculation, drawing attention to the interdependence and interaction of different types of structure and their surrounding soil masses, are described in general terms in [Section 3](#).

Maritime structures normally fall within geotechnical category 2 as defined in BS EN 1997-1:2004, but in situations where complex or unusual engineering is involved, structures or parts of structures should be assumed to be in geotechnical category 3.

NOTE 5 The ground investigation requirements are normally at least those indicated in BS EN 1997-2:2007, but additional investigations and more advanced tests might be required, dependent upon the circumstances that place the structure or structural element in geotechnical category 3.

5 Planning of geotechnical investigations

5.1 Existing data sources

The first stage of the geotechnical investigation should be a desk study of available published and unpublished information, including a thorough visual examination of the site where possible (see [5.2](#)).

NOTE Sources of information relevant to maritime structures include:

- Admiralty charts and handbooks (the Pilot series) [2];
- bathymetric charts and maps;
- Ordnance Survey maps and old maps;
- meteorological data;
- national and local government records;

- existing ground investigation reports and geological records;
- geological maps and memoirs;
- local and national government and Environment Agency reports and data concerning contamination and other anthropogenic material(s);
- aerial and satellite photographs; and
- information on existing works in the locality.

Admiralty charts and Ordnance Survey maps should be studied to identify evidence of changes in seabed levels and in the configuration of the foreshore that can indicate areas of erosion or accretion.

5.2 Site reconnaissance

COMMENTARY ON 5.2

Many maritime sites are areas of recent geomorphological development, and such processes are more active if the site is nearer to the shore. The timescale of these changes is often comparable with the lifespan of a project, and they can often be the most significant feature of the ground conditions, affecting many maritime works.

It is important to recognize characteristic features of coastal sediments. Those laid down in estuarine conditions are commonly flocculated silts and clays, although the flocs can also entrap coarser sediments brought into the estuary by coastal currents. Thus, estuarine deposits are often characterized by great depths of very fine soils. Deltaic deposits have been laid down seasonally and therefore usually contain alternating bands of coarse and fine sediments corresponding to the variation in transporting power of the river in winter and in summer. Beach deposits often result from coastal rather than river transport and are usually of medium to coarse size. They can arise from small embayments and are therefore very local, but they can occasionally arise from long lengths of foreshore.

It is also important to recognize the chrematistic features of river, lake and stream sediments. Depending on the velocity and size of the stream/river, alluvial/fluvial deposits can range from fine clays and silts, to coarse sands, gravels, cobbles and boulders. The dynamic nature and evolving geological sequencing and depositions at river deltas are of critical consideration for projects in these environments.

A thorough visual examination of the site should be made, where possible, as part of the desk study (see 5.1). Exposures of soil or rock on the foreshore or coastal cliffs should be examined to obtain preliminary information on the geology of the site and to obtain any evidence of erosion, accretion or instability. The appearance of existing structures and earthworks should be examined for signs of subsidence or ground heave.

The landforms of the foreshore should be studied in relation to seabed contours and information on littoral currents, in order to delineate areas of active erosion and accretion, and to provide a basis for predicting changes that might result from construction of the new works.

Depending on the size of the proposed project or construction activities, a bathymetric survey should be undertaken where a greater understanding of the erosion and/or accretion activities is required. The bathymetric survey should cover an area that provides sufficient understanding of the seafloor conditions for the project, and for any construction-related activities (e.g. dredging, seaborne transportation). The bathymetric survey should be accompanied by a detailed onshore topographic survey.

Particular attention should be paid to the possibility of leaching and the formation of caverns in organically formed and carbonate-rich deposits, especially where major structures such as breakwaters or dry docks are proposed.

NOTE Such deposits are mainly calcareous, of which coral and calcite (excluding algae that cement detrital material) are examples.

Sedimentary rocks formed by induration are also subject to cavernous formation, so a ground investigation programme arranged to locate such features should be adopted in these types of ground.

Similarly, attention should be paid to carbonaceous organic deposits such as peat or inorganic soils with a modest organic content, as these materials are compressible and crushable and can be difficult to work with.

An assessment of the likelihood of encountering anthropogenic material at the site should also be carried out. Attention should be paid to the presence and likelihood of potentially contaminated material, and a review of the previous site and near-site uses and users should be undertaken as these can provide useful data. Local government or reports by the government environmental agency should also be consulted. Finally, the likelihood of encountering unexploded ordnances should be taken into account via the commission of an appropriate survey.

5.3 Selection of investigation and sampling methods

The types of investigation methods to be carried out should be chosen on the basis of the size and complexity of both the underlying ground conditions and the proposed works. The selection of drilling and sampling methods for soil and rock, and measurement of groundwater, should be in accordance with BS EN ISO 22475-1.

NOTE 1 The types of investigation methods can be classified into two broad categories, which are:

- *non-intrusive: geophysical surveys such as seismic reflection and refraction; and*
- *intrusive: boreholes, cone penetration tests (CPTs), trial excavations.*

The advice of a suitably qualified and experienced geotechnical engineer should be sought when planning the investigation.

NOTE 2 The quality of data, and of soil, rock or groundwater samples, is influenced by the geological and hydrogeological conditions and by the choice and execution of the investigation, drilling and/or sampling method, including the handling, transport and storage of the samples.

5.4 Location and extent of geophysical surveys

A clear purpose should be established for a geophysical survey. The location and extent of geophysical surveys should then be planned such that the relevant information to be obtained on the surface and subsurface conditions to achieve that purpose can be determined. The survey lines should provide full longitudinal and lateral cover of the extent of the works. An orthogonal orientation of survey lines with longitudinal and lateral lines should be adopted in most investigations, with diagonal or offset lines carried out if deemed appropriate or necessary.

Geophysical survey lines should also be undertaken to focus on known or suspected subsurface features that could influence the proposed works, such as faults and dykes (predominantly in rock), paleochannels, remnant or active submarine landslides or any other similar subsurface feature. Geophysical survey lines that are planned to assess the detailed location of a known feature should be carried out orthogonal to the known alignment of the feature, in order to have the best chance of identifying its position and characteristics.

The advice of a specialist marine geophysical engineer, ideally with local knowledge and experience, should be sought at an early stage of the planning and preparation of the geophysical surveys.

5.5 Location of boreholes, CPTs and trial excavations

The layout of exploratory boreholes and CPTs should cover the full longitudinal and lateral extent of the works. Trial excavations, if practicable, should also be undertaken. The existing data (where available) and/or results of surveys (bathymetric, geophysical) should be used to inform the location and spacing of boreholes and CPTs.

For large and complex proposed works, the combination of a borehole and CPT at each investigation location should normally be adopted, unless it is considered that this would be of only marginal benefit.

NOTE 1 For smaller and less complex projects, boreholes without an adjacent CPT might be suitable.

The advice of a suitably qualified and experienced geotechnical engineer should be sought when scoping and planning intrusive investigations. The number and layout of boreholes should be determined, taking into account the expected ground conditions, the results of bathymetric and geophysical surveys, and the size of the structure. In general, unless the ground is very uniform, investigation locations should be not more than 50 m apart.

Intrusive investigations for wharves and quay walls should be spaced at regular intervals along the waterside frontage of the structure. In a transverse direction, locations should be chosen to assess the ground conditions over the width of the works, including any ground that could affect the wall and backfill. The intrusive investigation should also allow for any anchorages on the landward side. The investigation layout should be sufficient to assess possible risks for instability due to a rotational slip.

Investigations for jetties should be sited along the line of the jetty as a whole, including berthing heads, mooring structures and approach structures. At least one investigation location should be within the ground that will be influenced by the particular component of the structure, including mooring or fender structures.

For a simple ship building berth, there might be a need for a retaining wall at the lower end to provide deep water, so the ground investigation should take into account that a retaining wall might be needed at that location.

The remainder of the site should be investigated to ascertain whether the allowable ground pressure is sufficient to support shipyard hard standing areas by direct loading, or whether bearing piles will be required. In the latter case, the ground investigation should provide sufficient information to establish the probable required length of the bearing piles.

For a shiplift, the investigation locations should be positioned on the lines of the piers such that the size and length of the new piles, which might be heavily loaded, can be determined.

The layout of investigation locations for dredging and reclamation work should be based on the extent of the operations required and on the variability of the subsoil.

NOTE 2 If the depth of ground to be removed is limited to a few metres, a relatively simple method of ground investigation, such as vibrocoring, can be used.

If unexpected variations in level, thickness or the properties of various layers of subsoil are revealed during intrusive investigations, the adequacy of the investigation should be reviewed. This should be undertaken in consultation with a suitably qualified and experienced geotechnical engineer. The need to increase the number of the investigation locations should be determined, either as part of the current investigation or as part of a future investigation, to ensure a sufficient understanding of the subsoil conditions can be attained.

5.6 Depth of intrusive investigations

The depth of boreholes and CPTs should be in accordance with BS EN 1997-2:2007.

For all cases, intrusive investigations should extend a sufficient depth below any proposed foundations, dredging surfaces, excavations and likely slip failure surfaces to allow for design to be carried out.

In order to obtain soil parameters to form the basis of slope stability analyses, the depth of intrusive investigations should cover the likely maximum depth and lateral extent of slip surfaces (see [Figure 1](#)). The depth of investigations for piled foundations should extend to a sufficient depth to establish the bearing capacity and settlement characteristics of both individual piles and groups of piles.

NOTE 1 For individual piles, this is typically at least 3 m below base of pile, or five times the pile diameter, whichever is the greater. For pile groups, this is typically 1.5 times the width of the pile group.

In order to obtain information on the stability and deformation of the foundations of gravity-type quay walls, such as sheet pile cellular structures, or monoliths, the boreholes should be drilled to a depth below the base of the structure of 1.5 times the width of the structure or pile group supporting the structure (see [Figure 2](#)).

Boreholes drilled in rock formations should be taken to a depth sufficient to explore the thickness and characteristics of any rock that could affect the behaviour of slopes and foundations. Where heavily loaded structures depend for their stability on the strength of fresh unweathered rock, the boreholes should be drilled to a depth of 3 m or five times the diameter of foundations below the base of the foundation, whichever is the greater, into such material to establish and confirm its quality and continuity. Advice on the likely depth of weathering in rock should be sought from a suitably experienced and qualified geotechnical engineer or engineering geologist, but in any case, this should be established by the ground investigation.

Dredging below the seabed can involve removal of soil from below the designed dredge level, depending upon the excavation technique, and should be taken into account in planning the depth of investigations. The possibility of future deeper dredging should be reviewed. Boreholes in dredging areas should be extended below design dredge level until a stratum of known geological characteristics is encountered or to a depth of 5 m below design dredge level, whichever is the lesser. The investigation should be made within the planned areas of dredging. It is not sufficient or acceptable to rely upon other investigations outside the proposed dredging areas, although the results of such investigations should be examined and made available, where relevant.

The possibility of heave of the floor of the excavation due to swelling of clay soils should be taken into account. Boreholes should be taken to a sufficient depth to establish the thickness and characteristics of swelling soils and to enable the risk of floor heave to be assessed and evaluated.

NOTE 2 Deep excavations can involve a risk of uplift of the base, due to shear failure in soft to firm clays, or to the occurrence of groundwater under pressure in pervious layers underlying impervious soils or rocks at the base of the excavations.

Where groundwater lowering schemes for excavations, or installations to cut off inflow into excavations, are proposed, the boreholes should be drilled completely through the water-bearing formation to locate the underlying impervious stratum, and located far enough into the stratum to establish its continuity.

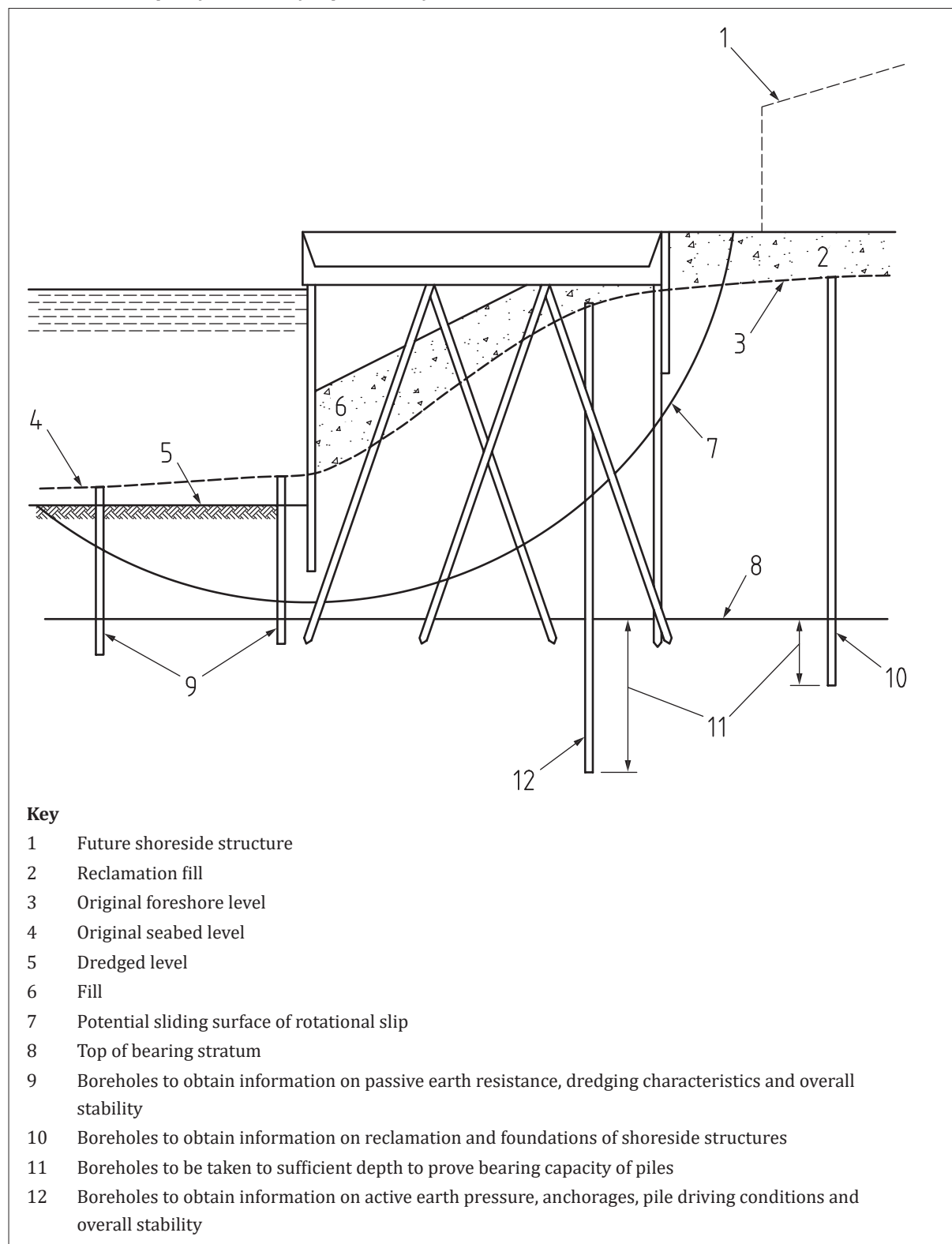
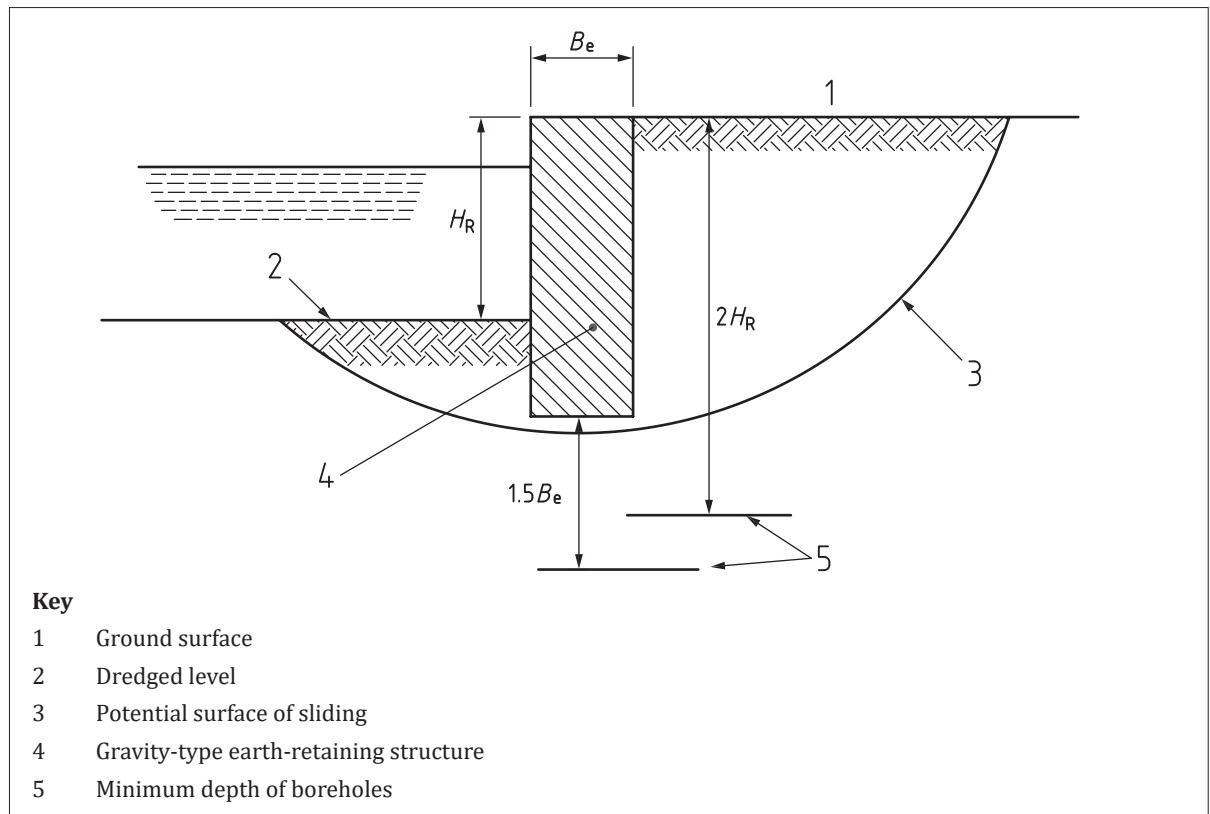
Figure 1 — Location and depth of boreholes for piled wharf

Figure 2 — Depth of boreholes in relation to retained height of soil and width of quay wall

5.7 Sealing of boreholes

All boreholes should be sealed upon completion in such a way as to prevent leakage into the excavation and contamination of or connections between aquifers. Sealing should be in accordance with BS EN ISO 22475-1, with a material of equal or lower permeability than the original ground.

NOTE 1 The use of grout is preferable.

NOTE 2 There have been cases of leakage into dock excavations from abandoned boreholes which have been extremely difficult to seal.

5.8 Ground investigations over water

COMMENTARY ON 5.8

The scope of the work, including the methods of boring, sampling and in-situ testing, requires careful consideration depending on the particular difficulties of the site. Attention is drawn to health and safety requirements, navigational warnings, and the regulations of governmental departments and other authorities that might be relevant when working over water.

General guidance on geotechnical investigation and testing is given in BS EN ISO 22475-1.

5.8.1 General

Ground investigations conducted over water are more difficult and time-consuming than comparable investigations conducted on land, and should be planned well in advance of the time identified to undertake the investigation so that the logistics and constraints of carrying out the investigation can be adequately addressed. Where a phased approach to an investigation is to be adopted, the likely full extent of the ground investigation should be identified at the outset such that adequate allowance is made in the overall project planning.

NOTE 1 Geophysical surveys are extensively used at the planning stage to provide additional geological information for the ground beneath the construction site and the positioning of the investigation boreholes.

NOTE 2 The sinking of boreholes and CPTs below water presents particular difficulties and requires a fixed, floating or heave-compensated working platform.

Suitable measures should be established to protect the investigation string from the effects of currents and waterborne objects.

When planning an overwater investigation, a realistic allowance should be made for the possibility of delays being caused by adverse weather conditions.

NOTE 3 For any given weather condition, the amount of delay depends on the type and size of the installation. In general, the larger the platform or floating craft, the smaller the risk of delay due to adverse weather conditions but, on the other hand, the greater the complexity.

NOTE 4 Sinking boreholes and CPTs between high and low tide levels may be achieved in a number of ways, including:

- *scaffold platforms by using flat-bottomed pontoons;*
- *shallow draft jack-up rigs; and*
- *moving boring rigs to the location when it is dry and exposed during periods permitted by the tides.*

5.8.2 Platforms and barges

The design of all barges and platforms should take into account the capability of the sea-bed strata to withstand the foundation actions. The design should also include the effects of the fluctuating water levels due to tides, waves and swell conditions. Such constructions should be sufficiently strong for the boring operations to resist waves, tidal flow, other currents and floating debris.

Onshore ground investigation equipment should be used only where stable working platforms are available or can be provided, such as oil drilling platforms and jetties or purpose-built scaffold platforms and drilling towers. Where such equipment is used, the current loads on the drill string should be taken into account. When working from existing structures, a cantilever platform on which to mount the boring rig should, if necessary, be constructed over the water. Advice should be sought from a geotechnical investigation engineer who specializes in both onshore and offshore investigations.

NOTE 1 When carrying out intrusive investigations close to the shore in relatively shallow water, the convenience of constructing a scaffold or other tower at the borehole location to avoid working in water can be advantageous.

Where free-standing independent towers are used, a means of transporting the boring equipment to the tower should be provided. The tower should be constructed such that it can be moved from one position to another.

NOTE 2 Platforms and other specialized craft fitted with spud legs are commonly used during overwater investigations. These can be self-propelled or might require a separate transport craft in order to be manoeuvred into position. These fulfil the requirement for a fixed working platform and provide manoeuvrability.

5.8.3 Floating craft

Where floating craft are to be used, the following factors should be taken into account in selecting and determining the suitability of the floating craft:

- a) the geotechnical properties of the seabed;
- b) the likely weather conditions;
- c) the depth of water;
- d) the strength of currents;
- e) whether the water is sheltered or open; and
- f) whether accommodation is required on board for personnel.