

Maritime works –

Part 3: Code of practice for the design of shipyards and sea locks

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Published by BSI Standards Limited 2013

ISBN 978 0 580 78084 4

ICS 47.020.99; 93.140

The following BSI references relate to the work on this document:

Committee reference CB/502

Draft for comment 13/30259247 DC

Publication history

First published August 1988

Second (present) edition, December 2013

Amendments issued since publication

Date	Text affected
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Summary of pages

This document comprises a front cover, an inside front cover, pages i to iv, pages 1 to 126, an inside back cover and a back cover.

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 31 December 2013. It was prepared by Technical Committee CB/502, *Maritime works*. A list of organizations represented on this committee can be obtained on request to its secretary.

Supersession

This part of BS 6349 supersedes BS 6349-3:1988, which is withdrawn.

Relationship with other publications

BS 6349 is published in the following parts ¹⁾:

- Part 1-1: *General – Code of practice for planning and design for operations*;
- Part 1-2: *General – Code of practice for assessment of actions*; ²⁾
- 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: *Code of practice for the design of shipyards and sea locks*;
- 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*; ³⁾
- 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*.

The recommendations in this part of BS 6349 are intended for use in all global locations, but taking into account local conditions. As a British Standard, this part of BS 6349 makes reference to other British Standards and to other publications commonly used in the UK, but it is recognized that in some locations there will be alternative local or international publications that are equally applicable. It is the responsibility of the designer to take steps to be fully cognisant of the prevailing codes and standards in any particular location.

Information about this document

This is a full revision of the standard. The principal change is to broaden the scope to include all principal maritime waterfront structures designed for shipyards and their interrelationship in the design of the whole shipyard. The general criteria for maritime works have been removed in this revision, as they are now collected together in the four subparts of BS 6349-1 ⁴⁾, which includes general planning and design for operations, actions, geotechnical conditions and materials. BS 6349-3 covers the criteria which are specific to works in shipyards and sea locks.

¹⁾ A new part 9, covering port surfacing, is in preparation.

²⁾ In preparation.

³⁾ Some of the recommendations in BS 6349-6:1989 have now been incorporated into Clause 9 of the present part of BS 6349, and brought up to date. It is anticipated that these recommendations will be removed from BS 6349-6.

⁴⁾ At the time of publication of BS 6349-3, BS 6349-1-2 is still at drafting stage.

Shipyards incorporate industrial processes which determine the operational requirements of the facilities and hence their design. To assist the designer in the use of BS 6349-3, a common format has been adopted for each clause from Clause 4 onwards. This common format is as follows.

- a) **Operational parameters.** The operational parameter is defined as the requirement of a system or element necessary to be incorporated or designed in, to undertake a defined function or facilitate operations either alone or in conjunction with other elements or systems, i.e. what is the facility for and why is it necessary?
- b) **Siting.** The siting is defined as the location, routing and/or position of the respective element or system with respect to its requirements and other structures, services or elements necessary to be provided as part of the facility, i.e. where should the facility be located?
- c) **Elements.** The element is defined as the important minimum individual items, components or elements that are necessary for a system, structure or unit serving the facility that need to be considered in the design, i.e. what are the key factors or items that need to be included and what are their specific design parameters?
- d) **Equipment.** The equipment is defined as the individual key items of plant or equipment that are critical in that system, structure or service which it is necessary to incorporate, i.e. what equipment is needed to make the facility work?

Use of this document

As a code of practice, this part of BS 6349 takes the form of guidance and recommendations. It should not be quoted as if it were a specification and particular care should be taken to ensure that claims of compliance are not misleading.

Any user claiming compliance with this British Standard is expected to be able to justify any course of action that deviates from its recommendations.

It has been assumed in the preparation of this British Standard that the execution of its provisions will be entrusted to appropriately qualified and experienced people, for whose use it has been produced.

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.

Contractual and legal considerations

This publication does not purport to include all the necessary provisions of a contract. Users are responsible for its correct application.

Compliance with a British Standard cannot confer immunity from legal obligations.

1 Scope

This part of BS 6349 gives recommendations and guidance on the design of shipyard waterfront layouts, dry docks, piers, quays, slipways, shipbuilding berths, shiplifts, floating docks, sea locks, hydrolifts, dock and lock gates, mechanical and electrical services distribution and control systems.

It focuses on shipyard-specific design considerations. It does not apply to general maritime works design or to the detailed planning and design of sea locks, as well as their hydraulic design, which are covered by other parts of BS 6349 and PIANC publications.

This part of BS 6349 is applicable to the design of both commercial and naval base facilities.

2 Normative references

The following documents, in whole or in part, are normatively referenced in this document and are indispensable for its application. For dated references, only the edition cited applies. For undated references, the latest edition of the referenced document (including any amendments) applies.

BS 6349-1-3, *Maritime works – Part 1-3: General – Code of practice for geotechnical design*

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

BS 6349-4, *Maritime structures – Part 4: Code of practice for design of fendering and mooring systems*

BS EN 1991-1-4, *Eurocode 1 – Actions on structures – Part 4: General actions – Wind actions*

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

BS EN 1993 (all parts), *Eurocode 3 – Design of steel structures*

BS EN 1997 (all parts), *Eurocode 7 – Geotechnical design*

BS EN 13001 (all parts), *Cranes – General design*

3 Terms, definitions and abbreviations

3.1 Terms and definitions

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

3.1.1 bilge block

ship support unit under the hull sides of a ship when it is drydocked

3.1.2 declivity

longitudinal inclination

3.1.3 dry berth

area of dry land to which ships can be moved for repairs

3.1.4 dry dock

fixed and gated structure with a floor below water level into which ships can be floated and subsequently be made dry

NOTE Dry docks are sometimes referred to as “graving docks”.

- 3.1.5 drydocking**
putting a ship in a dry condition for repair
- 3.1.6 floating dock**
structure with variable buoyancy than can be submerged for a ship to enter and then be raised to lift the ship into a dry condition
NOTE Floating docks are called "dry docks" in some countries.
- 3.1.7 hydrolift**
fixed and gated structure which uses water to lift or lower ships to or from the level of dry land
- 3.1.8 keel block**
ship support unit along the line of a ship's keel when it is drydocked
- 3.1.9 operation**
activity required to undertake ship repair or shipbuilding
- 3.1.10 pumphouse**
location of pumping equipment
- 3.1.11 shipbuilding**
industrial process of building a new ship
- 3.1.12 shipbuilding berth**
berth dedicated to shipbuilding
- 3.1.13 shiplift system**
method of lifting or lowering ships to/from the level of dry land
- 3.1.14 ship repair**
industrial process of repairing a ship
- 3.1.15 sill**
fixed structure forming the bottom of a gated entrance through which ships pass
NOTE This is sometimes spelled "cill".
- 3.1.16 slipping**
inclined retrieval or launching of ships
- 3.1.17 slipway**
inclined system for retrieval and launching of ships extending from dry land to below water level
- 3.1.18 sue point**
ship contact with a support unit at one location along its length before the full keel length is in contact
NOTE This is sometimes spelled "sew".
- 3.1.19 under-drained floor**
floor which has the natural ground water pressure beneath it reduced

3.2 Abbreviations

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

DCS	distributed control systems
EHWL	extreme high water level
HAT	highest astronomical tide
HAZID	hazard identification
HAZOP	hazard and operability
LAT	lowest astronomical tide
LBP	length between perpendiculars
MDL	maximum distributed load
MHWN	mean high water neaps
MHWS	mean high water springs
MLWS	mean low water springs
PLC	programmable logic controllers
SCADA	supervisory control and data acquisition

4 Shipyard layout

4.1 Operational parameters of shipyards

4.1.1 Shipyard life cycle

The life cycle of a shipyard starts at the early concept stage and follows through to the decommissioning stage, and includes each and every stage in between. The design of the shipyard should be developed with a holistic approach, such that the consequences of decisions made at a particular stage are taken into account for all subsequent stages of the life cycle.

4.1.2 Consultation

Throughout the life cycle of a shipyard, timely coordination should take place with all identified stakeholders. The stakeholders should include, but are not limited to, the following:

- shipyard owner;
- shipyard operator (management, procurement, engineering and maintenance);
- port authority;
- fire authority (authority having jurisdiction);
- host country governing departments;
- local business, people and representative bodies;
- country utility providers (power supply, water supply, phone, sewage disposal and data services);
- insurance companies.

4.1.3 Input to shipyard layout design

The shipyard layout should be able to achieve a set of facilities which provides an operationally efficient shipyard. In order to achieve this, the input to the design should include the following principal parameters and constraints:

- intended shipyard types of business (see 4.1.4);
- throughput mix of ships, including offshore work where applicable, which the shipyard is intended to accommodate (see 4.1.4);
- potential shipyard physical site data;
- local construction capability constraints;
- stakeholder constraints and opportunities.

The final layout should be the result of a progressive iterative optimization of all of the input information and applied to each of the individual facilities. The designer should have a good understanding of the operational purpose of each facility and of the following constraints:

- a) operational parameters of the facility;
- b) siting of the facility;
- c) structural elements of the facility;
- d) equipment of the facility.

4.1.4 Target throughput

The basis of design for the shipyard should be defined clearly in terms of the type of business it is intended to undertake, such as shipbuilding, ship repair, ship conversion, ship recycling or a mix of these, together with the target throughput mix of ships to be accommodated subdivided into ship size, ship types and numbers.

For commercial shipyards, the target throughput should be derived from a market study which has identified the potential revenue, which should be taken into account as a budgetary parameter for the scale and affordability of the shipyard facilities.

For naval bases, the current and planned fleets usually provide the target throughput parameters with an associated support facilities budget.

4.1.5 Landside and waterfront

The shipyard layout should be planned to optimize the overall capacity of both the landside and waterfront facilities, taking into account the combined operations and construction. The designer of the waterfront marine works should be aware of and contribute to the operational layout planning.

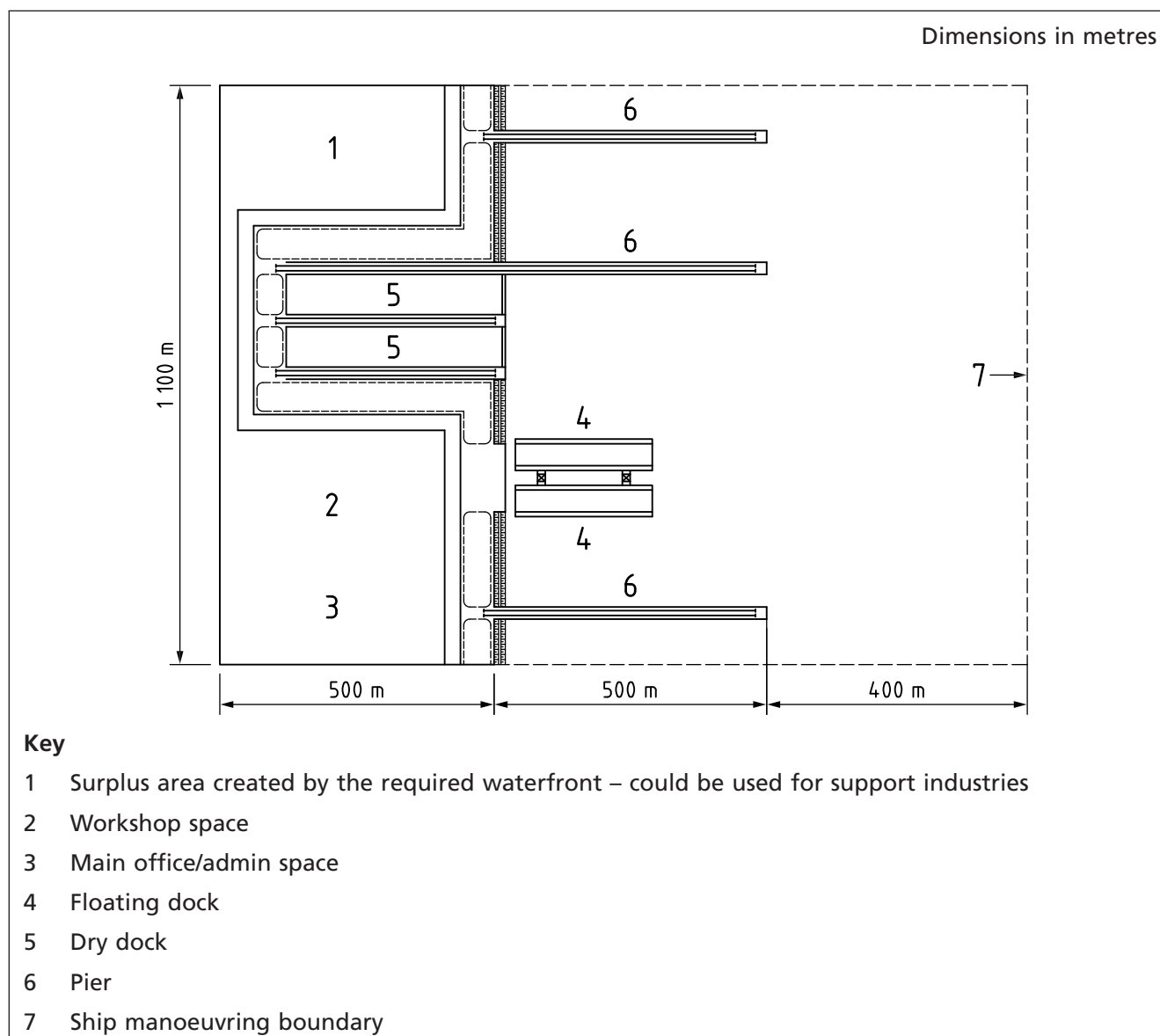
4.2 Siting of shipyards

4.2.1 Site selection

For the design of a new greenfield site shipyard, the site selection process should take account of the full range of parameters which encompass both the physical site constraints and operational needs. There should be an informed balance for the physical site needs of landside and waterfront facilities. A simplified shipyard footprint area of the waterfront and land requirements should be derived from the target throughput mix of ships (see 4.1.4), as a basis for the scale of the site needed (an example is given in Figure 1).

For the upgrading of existing shipyards or for predefined locations, the optimum layout should be determined from the combined opportunities and constraints for both the landside and waterfront facilities.

Figure 1 Example of a shipyard footprint



The physical site data should be collated for all sites under consideration, and should be sufficient to make a preliminary assessment of the scale of resources required to develop each site. The principal data headings should be:

- topography and bathymetry;
- geology and ground conditions;
- wave climate and currents;
- climatic conditions;
- environmental constraints;
- hinterland infrastructure;
- existing facilities.

As much data as possible should be collected through a desk study to inform the decision on whether or not new survey data is required and to what level of detail it should be specified. A risk assessment should be used to determine the value of having sufficient information to provide high confidence in a selected site versus using resources on detailed survey work which might only be used at the detailed design stage.

Survey data, particularly for the ground conditions, should therefore be acquired in two stages, firstly sufficient for the site selection to determine the shipyard layout and secondly, after the shipyard layout has been agreed in detail, for the specific structural elements anticipated.

The environmental constraints should include the results and recommendations from environmental impact assessments where present.

4.2.2 Conceptual layouts

To derive the optimum layout of a selected site, a minimum of two concept layouts should be derived which can accommodate the target throughput. Through a comparative principal quantities estimation exercise, the preferred layout should be derived through optimization.

On completion of the site selection, the actual site opportunities and constraints adjust the actual throughput capacity and this should be fed back to the target throughput mix of ships. In turn the conceptual layout should be reviewed to accommodate significant changes in throughput, as part of an iterative optimization process. The preferred layout should maximize the opportunity for phased development to enable early start-up of some operations. Flexibility to alter the throughput mix of ships in line with changing markets during the design life of the shipyard facilities should also be incorporated in the layout.

4.2.3 Preferred layout principal quantities estimate

A preliminary design for the principal facility items in the preferred concept layout should be prepared to enable a reliable principal quantities estimate to be made for the development evaluation. This principal quantities estimate should be provided for input to the financial model for the shipyard to help to determine the overall feasibility. The phasing of the development should reflect the financial model.

The principal quantities estimate should be used to identify areas for construction optimization arising from the interaction of the individual facility structures, and the preferred layout should be adjusted accordingly.

4.2.4 Designing for risk

The identification of hazards should be undertaken at the concept layout stage, as the earlier they are identified, the more efficient is their mitigation.

NOTE The primary consideration is the identification of potential hazards which could lead to personnel injury or death, including outside the shipyard site boundary. Unidentified hazards have the potential to become major obstacles later in the detailed design phase of the shipyard and equipment. Identifying and subsequently risk ranking the hazards early in the project provides a focus for the design so that early mitigation can be implemented. The risk assessment process yields a level of risk (probability of occurrence of harm and the severity of that harm).

A method should be adopted of systematically identifying hazards, such as through a hazard identification (HAZID) study.

Safety and asset-loss scenarios should be assessed with the considered input of all discipline designers (mechanical, electrical, control, civil), the operations designer and maintenance departments of the operator of the shipyard. The result of the HAZID study should be a schedule of identified risks for each system, structure or item of plant and the associated mitigation measures which should subsequently be integrated into the design and equipment specifications.

4.2.5 Hierarchy of hazard control

The application of protective measures should be appropriate to the desired degree of risk reduction. Protective measures should be applied in a hierarchical order as follows:

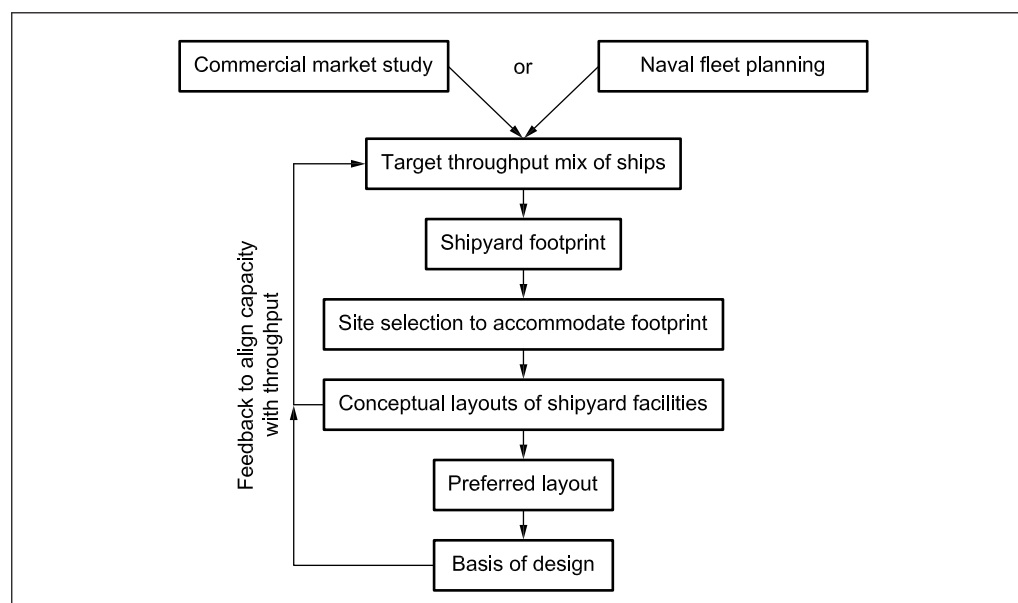
- a) elimination of the hazard source;
- b) substitution by a lower risk hazard source;
- c) engineering controls;
- d) administrative controls;
- e) collective protective equipment;
- f) personal protective equipment.

4.3 Elements of shipyards

4.3.1 Basis of design

The basis of design and site-wide parameters for the shipyard should be documented and agreed by all parties. Each facility within the preferred layout should be clearly indicated in the documentation, and the physical area of that facility should be defined. Within the basis of design documentation, each facility should have the facility-specific design parameters recorded as discrete sections for clarity. The process which should be followed to achieve the basis of design is summarized in Figure 2.

Figure 2 Process to achieve basis of design



4.3.2 Structure specific surveys

From the preliminary design work on the preferred layout, the types of structural elements should be identified, and a set of structure-specific site data surveys and studies should be defined, targeted at providing good quality design information. These surveys, including testing, should be carried out in accordance with BS 6349-1-3.

4.4 Equipment of shipyards

4.4.1 Equipment and structure optimization

When the preferred shipyard layout is established, a list of principal shipyard waterfront equipment, such as cranes, should be prepared. A review should be carried out of the effects and actions associated with the principal equipment on the preliminary structure designs, and an exercise carried out to optimize the equipment specified and the associated structure principal quantities.

For clarity, within the basis of design documentation, the integral waterfront structure and ship handling related equipment, such as winches, pumps and capstans, should be distinguished from the landside shipyard production process equipment, such as cranes.

4.4.2 Standardization

The equipment should be standardized where practicable across the shipyard facilities, for ease of maintenance and spares planning. Where an existing shipyard is being upgraded, due account should be taken of the specifications, performance and condition of existing equipment which is to be retained, whilst ensuring that up-to-date equipment is specified.

4.4.3 Equipment within each facility

The equipment and the mechanical and electrical services within each facility should be treated as an integral part of the facility design. This is to ensure that sufficient space for and actions arising from installation, operation and maintenance are incorporated in the design of the structures.

4.4.4 Piped services and electrical systems

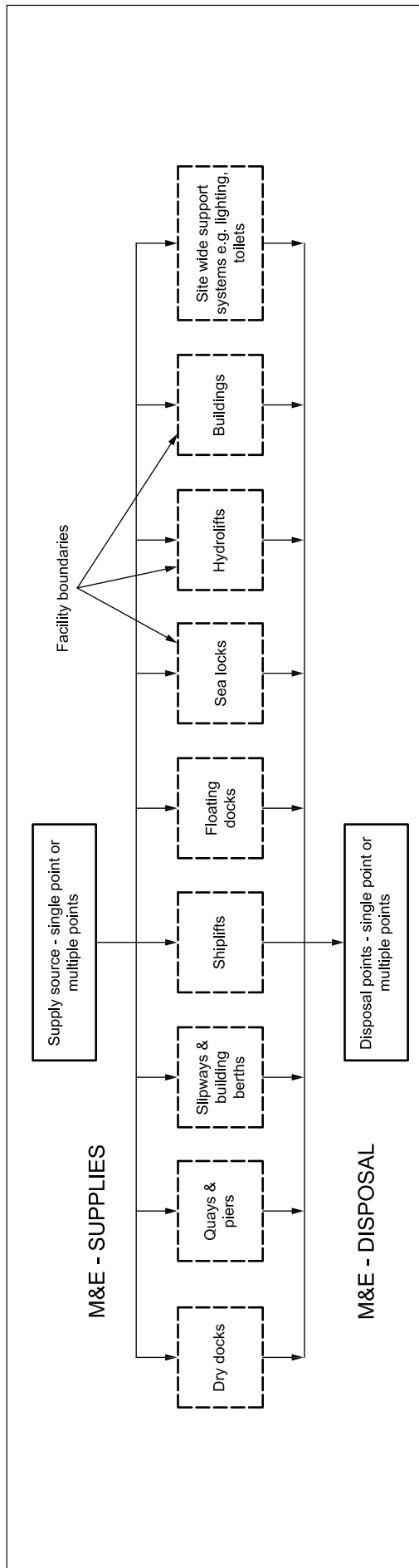
The waterfront and landside facilities should be assessed together in the design of the mechanical piped services and electrical distribution system. For clarity, the distribution system should be taken as the shipyard-wide provision of each service from the source or disposal point to the interface boundary of the facility as defined for the basis of design.

NOTE Figure 3 shows the definition of the distribution system interface boundaries.

4.4.5 Control systems

A control system should be provided for all equipment. The overall shipyard control system design should be in accordance with Clause 14.

Figure 3 Distribution system definition



5 Dry docks

COMMENTARY ON CLAUSE 5

Dry docks within this clause refer to fixed structures, usually of concrete construction with mobile dock gates at the seaward end. The gates are closed and the water removed from the dock to form the dry dock. The nomenclature for this type of dock varies, both geographically and historically. Dry docks have often been referred to as graving or basin docks. For the purpose of this part of BS 6349 they are referred to as dry docks.

5.1 Operational parameters of dry docks

5.1.1 Shipbuilding versus ship repair

The operational purpose of the dry dock should be determined at the outset as there are fundamental differences between shipbuilding and ship repair dry dock requirements. The principal parameters which should be defined include flooding, speed of handling ships, pumping times, access to dock floor, services and crange.

5.1.2 Capacity

The capacity of the dry dock should be described in terms of:

- length, breadth and depth, together with working space at the sides and ends, the heights of keel blocks and the tidal conditions;
- ship docking displacement.

The use of deadweight tonnage (dwt) when defining dock capacity should be avoided as it does not define the size with any precision and can, on occasions, be misleading.

5.1.3 Entrance depth and floor level

The sill level should be calculated from the required depth of water for a ship to enter the dry dock in conjunction with the height of the dock blocks. The calculation should allow for the declivity of the dock floor and the dock block height, which is typically in the range 1.6 m to 2.2 m.

The under keel clearance of the ship during drydocking should be assessed according to the site water level parameters and drydocking duration, but should be not less than 0.5 m.

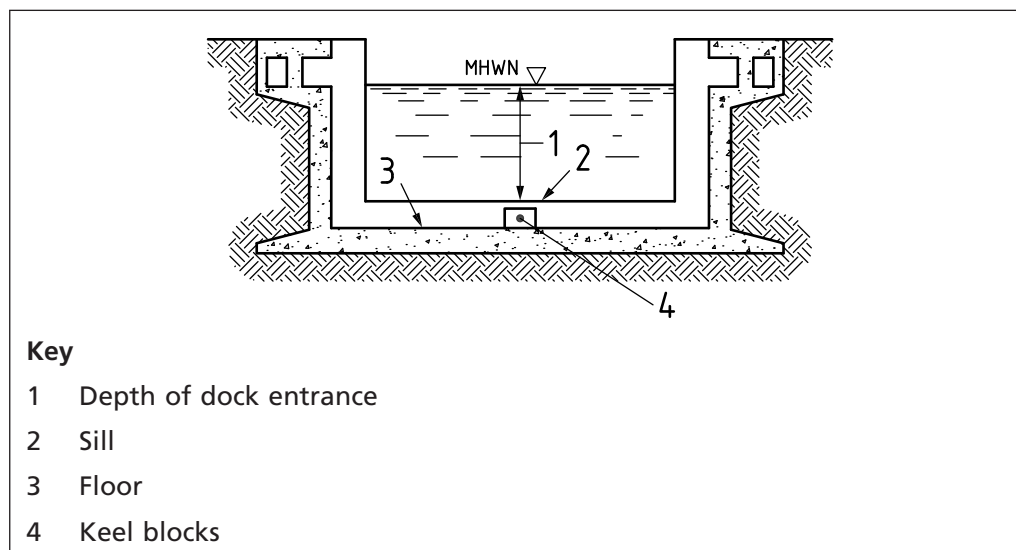
The maximum entrance docking draught should be measured from mean high water neaps (MHWN) to the top of the sill or top of the keel blocks adjacent to the sill, whichever is the higher. The keel block declivity should be stated.

NOTE Figure 4 shows the dimension which defines the depth of the dock entrance in conjunction with entrance docking draught.

The potential for accommodating damaged ships, which might require a depth of water over the sill greater than that which would be required under normal docking conditions, should be defined in the dry dock requirements.

An optimization of the principal quantities should be undertaken to finalize the dock floor level according to the actual site conditions, as in some locations increased depth of the dry dock can result in disproportionate increases in principal quantities, whereas in other locations there is only a minimal associated increase in principal quantities.

Figure 4 Cross-section of dry dock: depth of entrance



5.1.4 Entrance width

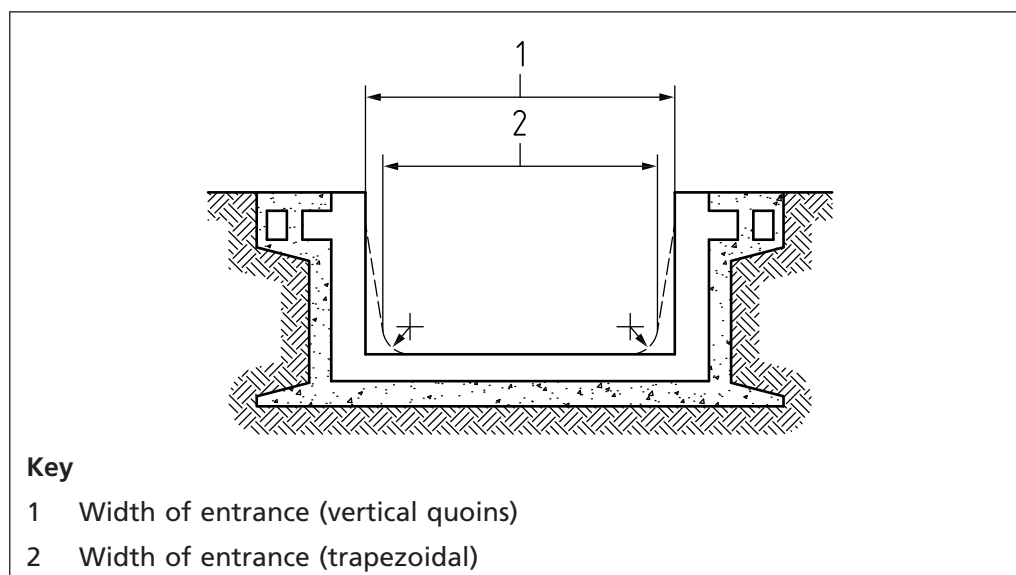
The width at the dock entrance normally controls the maximum beam of ship able to enter the dock. Due allowance should be made for clearances, which can vary according to wind and tidal conditions, the ship handling facilities available and the type of ship to be docked. The clear width should normally be not less than 0.6 m greater than the beam of the largest ship to be docked.

Some dock entrances are trapezoidal in shape and are often curved at the bottom corners. In this case, the width should be measured between the bottoms of the battered sides at the tangent points of the curves.

The width of the entrance should be calculated as the clear distance between the permanent fenders or structure at the dock entrance (subject to the variation for battered sides).

NOTE Figure 5 shows the dimension which defines the width of the entrance.

Figure 5 Cross-section of dry dock: width of entrance

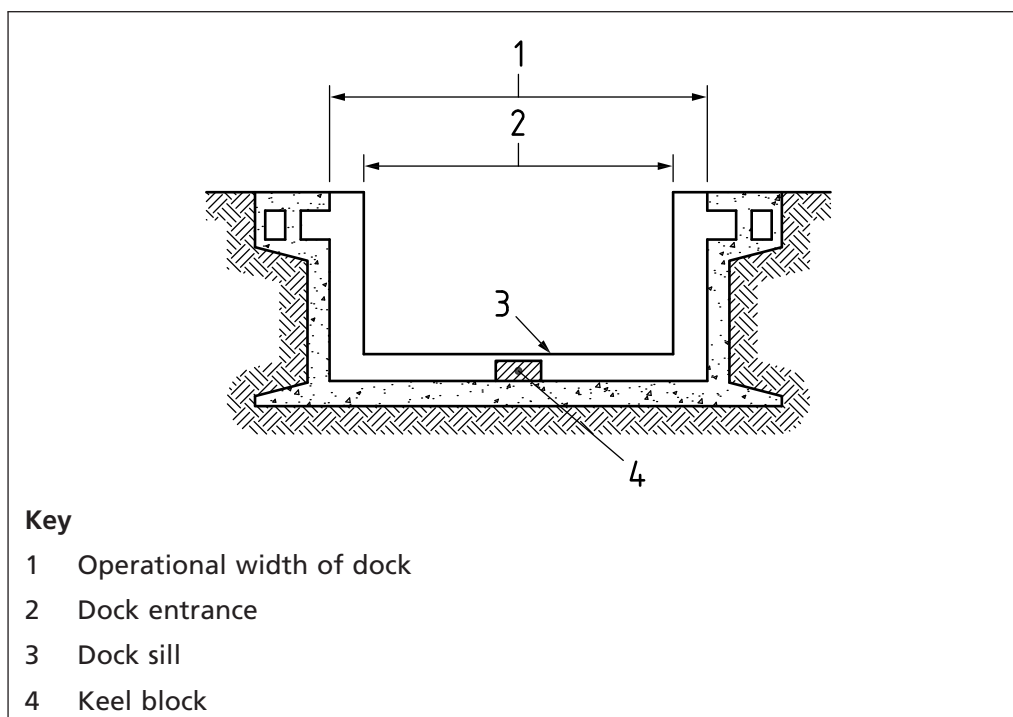


5.1.5 Internal width

The width between dry dock walls, often termed the dry dock barrel, should be not less than the width of the dry dock entrance. The internal width should allow for working space at the side of the ship and for operation of equipment, such as dock arms, travelling along the face of the dock walls. The dry dock width should be calculated as the minimum clear distance between the faces of the dock wall (or projecting altars) above keel block level.

NOTE Figure 6 shows the dimension which defines the operational width of the dock.

Figure 6 Cross-section of dry dock: operational width of dock

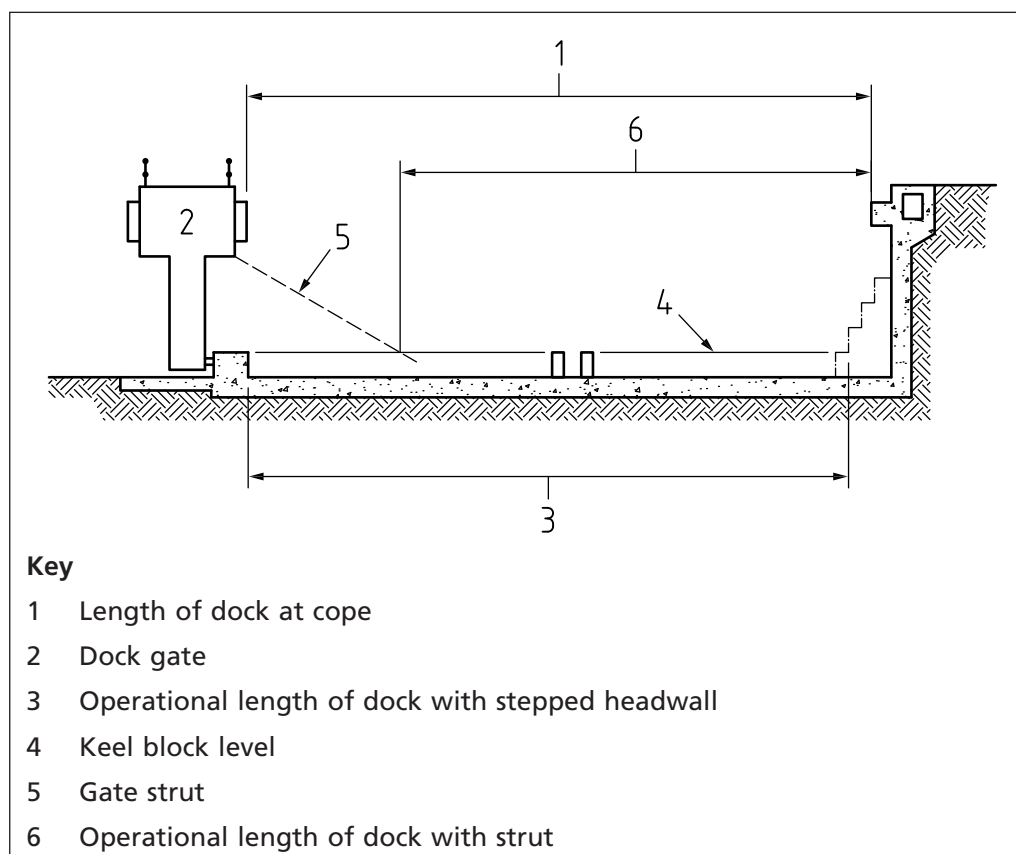


5.1.6 Internal length

The length of a dry dock should be measured on the centre line of the dock. It should be the minimum horizontal distance between the internal face of the head wall, or the furthest projecting fender thereon, and the furthest internally projecting part or fender of the dock gate. In cases where the head wall is stepped, the length should be measured to the vertical face of the step at keel block level. Some dock gates are supported by internal inclined struts, which can restrict the effective length of the dock; therefore, measurement should be taken to the appropriate point on the strutting system at keel block level.

NOTE Figure 7 shows the dimension which defines the operational length of the dock.

Figure 7 Operational length of dry dock



5.1.7 Working space between ship and dry dock

At the sides of the dock, the working space clearance between the side of a ship and the face of the wall should normally be not less than 1.5 m. The use of dock arms should be taken into account according to their actual size. Working space should also be allowed for special equipment removal or fittings such as stabilizers at the side of ships which might require recesses to be formed in the dock walls.

At the ends of the dock, the removal of tail shafts can require an extra length of dock and due allowance should be made for this process.

Working space should be provided by high keel blocks or pits in the dock floor for sonar domes and other protuberances below the keel of ships of sufficient dimensions to facilitate their removal and refitting. Keel blocks should be not less than 1.8 m high for the use of mechanical equipment on wheeled vehicles to clean and paint the underside of ships.

The expected shipbuilding strategy should be used to define the block heights for shipbuilding docks. The height of blocks in building docks should normally be smaller than in repair docks due to a lesser working space requirement.

5.1.8 Height of dry dock cope

When selecting the height of the cope above dock floor level, the following should be taken into account:

- the highest water level likely to be attained outside the dry dock entrance, allowing for fluvial flooding, wave swell and surge;
- the highest water level likely to be attained in the dock;
- the need to provide services near the dock cope and the necessity or otherwise for them to remain in the dry when the dock is filled;

- the general level of the ground surrounding the dock and the advantage of maintaining the cope level similar to that level;
- the provision of rails for dock arms or ship leading equipment below dock cope level, which normally should remain in the dry.

5.1.9 Dewatering of dry dock

The dewatering time for a dry dock should be specified as the time taken to empty the dock from MHWN without a ship in dock. Before undertaking the design or specification of the pumping system, the dewatering time should be defined by the dry dock owner and user.

For a ship-repairing dry dock, the specified time should be between 2 h and 4 h. The specified time adopted should take account of several factors including the range of the tide at the site and the influence of the tide on ship movement operations.

At locations with a large tidal range, the dewatering rate should be designed in conjunction with the ability of the gate design selected, to withstand a reverse head if the dock water level lags behind the falling tide level.

For a shipbuilding dry dock, the specified dewatering times should be in the range of 4 h to 12 h.

The design dewatering time adopted should be determined from an analysis incorporating at least the following factors:

- frequency of annual dockings;
- tidal range;
- increase of equipment needed to reduce dewatering time;
- multiple uses of the dock;
- floor profile;
- working hours in shipyard.

5.1.10 Filling of dry dock

Filling times should be limited to reduce the amount of time during which the dry dock is unusable for hull repair work between dockings. The rate of filling and resultant water velocities should be limited so as not to induce scouring or disturbance of the dock blocks. This can be achieved by providing inlets or cross-dock culverts with sufficiently large cross-sectional areas.

The filling time for a ship-repairing dry dock should be between 1 h and 2 h, and is normally expressed as the time taken to fill the dock with the outside water level at MHWN without a ship in dock.

The filling time for a shipbuilding dry dock, should be between 4 h and 12 h, with the adopted time determined from an analysis in a similar manner to the dewatering time in 5.1.9.

5.1.11 Floor profile

The floor profile should be adopted to suit the particular functions and usage of the dry dock.

Ship repair docks should generally be provided with a longitudinal slope of between 1:200 and 1:400.

NOTE 1 The slope is normally arranged as being down towards the dock entrance, which coincides with the normally stern-down trim of a ship entering the dock bow first and so tends to reduce sue loads when the ship settles.

Shipbuilding docks should generally be provided with a flat floor profile, as shipbuilders normally prefer the keel of a ship to be horizontal when under construction and the keel blocks to be of constant height.

NOTE 2 To increase the rate of floor drainage where the keel line is flat or has very small gradients, transverse falls of the order of 1:100 can be incorporated in conjunction with longitudinal channels connected to the dock sump.

In dry docks fitted with an intermediate gate, provision should be made for drainage of surface water from the head end of the dock when the gate end is flooded. A separate sump and pump should always be provided.

5.1.12 Floor waste collection and contaminants

The use of shot blasting and high pressure water methods of cleaning ships in dry dock produce a large quantity of debris/contaminants to be removed from the dock floor. Provision should be made for the collection of debris before it is washed into the pumphouse sump, where it can cause damage to the pumps. The use of mechanical dozer equipment on the floor should be taken into account and upstanding steelwork gratings, holdfasts, etc. should be avoided. Joint sealants in the floor should not project above floor level for the same reason.

A system to divert contaminated water to a holding tank or treatment plant should be incorporated into the design.

5.1.13 Services at dock floor level

Provision should be made, commensurate with the dock use, for services at dock floor level, both near the walls and across the dock floor. Services should be located in transverse ducts with flush covers or dual-use transverse drain channels able to accommodate the service pipes.

For both shipbuilding and ship repair dry docks, holdfasts should be provided on the dock floor and lower parts of the walls to assist work on the ships. They should be flush-fitted or recessed.

5.1.14 Access to dock floor

The dry dock design should incorporate provision of adequate access for personnel and materials to the dock floor to support the operations for which the dry dock is built.

A vehicular ramp should be provided where rapid mobilization of vehicles, personnel and materials to the dock floor is necessary, in particular for ship repair operations. The ramp slope should not exceed 1:10 for wheeled vehicles travelling to and from the dock floor. However, where space is a constraint the slope should not exceed 1:8. The design should include vertical transition curves where vehicles with lower ground clearance will be used.

Stairs should normally be provided at the head and entrance of the dock with additional intermediate stairs for long walls. Where possible, stairs should be in the open for ease of construction and maintenance. If stairs have to be placed behind the dock wall, as much ventilation as possible should be provided, since the enclosed space can trap floating and other debris after the dock is pumped out.

Emergency escape from the dock floor should be provided at a maximum spacing of 60 m. Emergency ladders from dock floor to cope should be provided along both side walls and the head of the dry dock in addition to stairs or ramps to achieve this maximum spacing. They should preferably be set in recesses to avoid damage and to protect personnel. Access to and from the top of the emergency ladders should be open at all times. Manhole or access hatch covers should not be provided on openings.

5.1.15 Arrangement at dry dock copes

The arrangement of various installations and details at the cope of a dock is a major design task involving sometimes conflicting requirements. Account should be taken of the following items which influence the optimized design, with due regard to the use of the dock for ship repair or shipbuilding:

- ducts and subways for electrical and piped services;
- connections of services to the ship and dock floor;
- track for shiphauling trolleys;
- upper track for dock arms;
- personnel access to dock arm platforms;
- electrical pick-up or trailing cable groove for dock arms;
- safety handrails;
- dockside crane tracks including storm anchors, jacking points and cable turnover pits;
- bollards;
- capstans;
- fairleads;
- staircase to dock floor;
- ladders to dock floor;
- access towers to ships' decks;
- fendering;
- piped services take-off pits and isolation valve pits;
- electrical services take-off points;
- propeller winches and sheaves;
- substations;
- lighting;
- drainage.

5.1.16 Surrounding area

The area surrounding the dock should be of adequate dimensions to provide for shipbuilding or ship repair operations, as appropriate.

Modern shipbuilding methods require considerable layout space for prefabricated parts of ships, depending upon the particular techniques used. Layout space should be determined by the ship production process designer. Part of the area is likely to be covered by a goliath crane which also straddles the dock and/or by heavy dockside cranes, and this should be taken into account in the layout. The whole area should be well drained, and should be suitable for the passage of heavy trailers and for the high concentrated loads arising from the temporary storage of prefabricated ship parts on trestles.

Ship repairing also requires an area surrounding the dock for the storage of equipment removed from the ship to enable repairs to be carried out, or for new equipment to be installed on the ship, as well as for temporary mobile machinery. The area provided should be sufficient for these purposes and should be suitable for wheeled vehicles to travel freely. In addition, an adequate space should be provided for the dockside cranes to operate.

The area surrounding a dry dock should be designed for a minimum uniformly distributed load of 25 kN/m², as well as for concentrated loads, which should be determined from the type of wheeled vehicles and trestle foot loadings, etc. likely to be used.

5.1.17 Equipment housing requirements

Large items of equipment such as pumps, compressors and substation electrical equipment can have significant housing requirements, especially if they are to be located underground in order to maximize working space at cope level. Such requirements and locations should be determined at an early stage in the design, as they can impact on the choice of structural form and many of the design elements.

Equipment rooms should be provided with sufficient space to allow good access into the room and any lower levels. They should also be provided with ventilation to suit the housed equipment so as to maintain a suitable working environment. Access should be suitable to allow personnel to carry tools and spare parts. Sufficient space should be provided inside the rooms for maintenance personnel to work.

A typical model or size of equipment should be assumed at the early design stage. During subsequent procurement and installation, alternative models of differing dimensions might be introduced. A generous space should therefore be made available for plant and equipment in the early design stages, allowing additional equipment, modifications and expansions to be incorporated at a later date if necessary.

5.1.18 Covered dry docks

Dry docks should be covered under the following circumstances:

- where protection is required against adverse environmental conditions;
- where security is a critical factor, e.g. in naval ship repair or shipbuilding dock facilities;
- where there is a particular need to support overhead travelling cranes.

The width of deck at cope level to be provided under cover should accommodate the width required for the shipbuilding or ship repair technique to be adopted.

In addition to the usual shipbuilding or ship repair services, appropriate lighting, heating, ventilation and fire precautions should be provided in covered dry docks to suit the operational requirements.

End doors provided at the dock entrance should have sufficient width and height to provide clearance to the superstructure and top of any ship likely to be built in the dock. The dock gate should be designed to provide support and/or guides for such doors. Doorways of sufficient size to accept prefabricated units of ships carried on transporters should be provided at the landward end.

5.2 Siting of dry dock

5.2.1 General

The siting of the dock can significantly affect future shipyard expansion options and hence should be planned as part of any long-term layout.

5.2.2 Navigational approach

A repair shipyard should be provided with an easy navigational approach, if possible, as some vessels might be under tow.

Where the navigational approach is more difficult, lead-in jetties or dolphins should be provided.

5.2.3 Anchorages and quays

A sheltered anchorage and/or a mooring facility should be provided, to allow for a delay before the ship is accepted in the dry dock. The design should allow for repair work to be carried out afloat before or after docking, to minimize dock occupation. A minimum of two repair/fitting out quays should be provided in conjunction with each dry dock for normal shipyard operations. The depth of water should be sufficient at all states of the tide at quays and anchorages.

5.2.4 Position with respect to subsoil conditions

The position of a dry dock should be determined in conjunction with subsoil conditions, as they can greatly influence the scale and extent of the construction required to create the dry dock.

Where possible, positioning should be arranged to take advantage of rock formations.

NOTE Rock at floor level can produce a very efficient floor construction and, whilst excavation in rock material might be difficult, no temporary works to support the sides of the excavation are generally required. The dock walls, in this case, can be simple or even eliminated.

As a drained dry dock floor is generally more structurally efficient than gravity or tied down floors, a site should be researched with the benefit of suitable impervious substrata, in close proximity to dock floor level, such that an economic ground water cut-off can be formed.

The location should be identified with adequate depth of water at the completed dock entrance and associated piers and/or quays, but due account should be taken of the scale of temporary cofferdams, which are easier to construct in shallow water. The removal of bundled cofferdams and the entrance dredging should be combined for efficiency. Dredging in rock is relatively difficult and can extend the construction programme significantly, and therefore should be minimized, wherever possible, by suitable positioning of the dock and other structures.

The final position of the dock should be selected by optimizing the many competing factors. The final dry dock location suitability should be verified by accurate subsoil investigation together with land and bathymetric surveys.

The level of detail in the surveys should be sufficient to provide the structure-specific data needed for the detailed design.

5.2.5 Prevailing wind

In order to allow for frequent ship movements, dry docks used for ship repair should be oriented with the centre line as close as possible to the direction of the prevailing wind.

Where ship movements are infrequent, such as for shipbuilding, priority should be given to the shipyard layout efficiency if this conflicts with prevailing winds, as launches can usually be delayed to await suitable weather conditions.

5.2.6 Tidal flow and currents

Account should be taken of currents and tidal streams, if the dock is to be located on an unprotected coast or on a tidal river. Docking and undocking is generally carried out around high water, but the tidal streams before and after high water should be checked to confirm that there is sufficient time for the operations to be carried out before an unacceptable velocity develops.

5.2.7 Geotechnical investigation planning

5.2.7.1 General

Site investigation prior to the planning, design and construction of dry docks should be thorough, with special attention given to the control of ground water flows.

NOTE 1 The subsoil conditions can greatly influence the choice of design which, in turn, controls the final scale of the construction required.

NOTE 2 General recommendations on geotechnical investigation are given in BS 6349-1-3 and BS EN 1997.

5.2.7.2 Desk study

Prior to designing the site investigation and carrying out site reconnaissance, a desk study should be undertaken in accordance with BS EN 1997-2. The desk study should be used to help design any intrusive investigations and inform a project risk register.

5.2.7.3 Site reconnaissance

Site reconnaissance should be conducted in accordance with BS 6349-1-3 and BS EN 1997, and is of great importance particularly with respect to the early recognition of cavernous/karstic features, which can make conventional dry dock construction very difficult if the cavernous/karstic features are connected to the sea. Where cavernous/karstic features are suspected, additional investigation through non-intrusive methods (e.g. geophysical investigations) should be undertaken.

5.2.7.4 Design of ground investigations

The design of a ground investigation should ensure that sufficient investigation will be carried out to provide all relevant ground information required to design and construct the proposed dry dock. All methods of investigation should be assessed at this stage, and an appropriate method chosen to obtain this comprehensive design and construction information.

NOTE The investigation might require two or more phases, depending on the findings of the desk study, site reconnaissance, findings on site during the intrusive investigation, the stage of the project, and changes made to final dock design and construction requirements as the project proceeds.

The geotechnical investigation should obtain soil/rock samples, and should include relevant in situ and laboratory testing as well as describing the soil/rock. From the results of the investigation, post-investigation interpretation should be carried out to produce a working ground model and all necessary soil/rock properties for design purposes.

The ground investigation should involve several investigation points, the total number and type of which should be determined by the size and type of structures to be designed and constructed. The level of investigation should be not less than that specified in BS EN 1997, and the number of points significantly increased where the ground is thought to be highly variable.

Due to the nature of dry dock design and construction, the design of the ground investigation should also include the installation of water level monitoring standpipes (or similar) to allow ground water levels to be assessed. If necessary, the water levels should be monitored over an extended period to obtain the relevant data required. Field trials involving full scale pumping tests and borehole permeability tests should also be carried out if necessary to establish ground permeability and information for ground water control measures.

5.2.7.5 Depth of boreholes

The depth of boreholes should be sufficient for all types of dock design and should be much deeper than the depth of the dock in order, for instance, to investigate ground which might be used to anchor the dock floor to prevent uplift or construct a ground water cut off wall for drained dock floor design. Boreholes are typically required to a depth of at least 30 m below the anticipated dock floor level, but the depth should be determined according to the specific site.

5.2.8 Location of pumphouse

Pumphouses for dry docks are usually located near the dock entrance to achieve a short discharge distance to the sea, but other locations should be assessed for suitability before a final decision is made.

- For dry docks that have a declivity down towards the dock entrance, the pumphouse should be located at the entrance resulting in a simpler culvert system.
- For dry docks with longitudinally horizontal floors, the location of the pumphouse should be midway along the dock so as to halve the maximum length of dock floor to the sump. This arrangement should only be used if the length of discharge culvert is short.

The discharge system should be as short as possible, for both pumping and construction efficiency.

5.2.9 Multiple use of pumphouse

If two docks are to be built in close proximity, a design featuring multiple use of the pumps and common dewatering culverts and sumps in the form of a combined pumphouse should be evaluated against that of dedicated pumphouses for each dock. The factors that should be evaluated and compared include:

- scale of construction;
- whole life maintenance;
- space requirements;
- complexity of pumping and dewatering culverts and control system including interlocking;
- hydraulic conditions;
- safety and isolation.

If a multiple use/combined pumphouse is to be adopted, the design of the sump, culvert and isolation system should be capable of allowing one dock to be flooded and dewatered when the other is dry. At the same time it should be possible for the seepage drainage system to be maintained in operation for the dock that remains dry.

In the case of under-floor drainage systems for each dock, these should each be independent and not connected to another dock.

NOTE It might be feasible to utilize a combined pumphouse for more than two docks, but this can result in the culvert system and means to isolate each dock becoming more complex.

5.2.10 Dry docks with intermediate gates

Some dry docks feature intermediate gates which allow filling of part of the dock whilst allowing the other part to remain dry. This can be advantageous when smaller ships are being constructed or repaired.

The dewatering (and other water removal systems) should operate satisfactorily when these gates are in position.

5.2.11 Locating equipment underground

Pumps require a minimum suction head to operate efficiently. The suction head is determined by the design of the pump and the operating conditions under which it is being used. As dry docks are usually deep structures, the pumps should be sited well below the cope level.

Other equipment should be located underground where the benefits outweigh the drawbacks. Siting of equipment underground should be adopted where clear space is required above ground, or to protect equipment from hazards such as vehicle impacts.

Where equipment is located below ground, it should be protected from detrimental effects including:

- flooding;
- overheating;
- fire;
- accidental impacts from falling loads from cranes.

5.2.12 Availability of services

The availability of electric power, fresh water and other services should be established in relation to the siting of the dry dock.

5.2.13 Position of buildings, workshops etc.

The position of buildings, workshops etc. should normally be arranged to suit the best position of a dry dock in a new or existing shipyard, and it might be advisable to relocate existing buildings based on the overall efficiency of both dry dock and the buildings.

5.3 Elements of dry docks

5.3.1 Design of dry dock floors

5.3.1.1 Loading sources

Dry dock floors should be designed in reinforced or unreinforced concrete to carry safely all loads and worst combination of loads to which they are subjected, including:

- uplift from ground water, including the possible presence of artesian conditions;
- concentrated loadings from ships when docked;
- uniform water loading when the dock is full;
- horizontal loading from earth and water pressure on walls;
- seismic loading.

NOTE 1 Depending on the ground conditions, the following types of floor can be used to resist uplift from ground water:

- *under-drained (see 5.3.1.8.1);*
- *gravity (see 5.3.1.8.2);*
- *tied (see 5.3.1.8.3).*

NOTE 2 Depending on the ground conditions, concentrated loading from ships may be carried by the following means:

- *by floors bearing directly on the ground (see 5.3.1.8.4);*
- *by floors supported on piling (see 5.3.1.8.5);*
- *by ground improvement (see 5.3.1.12).*

A minimum partial factor of 1.5 should be applied for all ship-derived dock floor loads.

5.3.1.2 Loading distribution on ship-repairing dock floors

The loading to which the dock floor will be subjected through its design life will not be known with precision, and in the absence of data provided by the dock operator, the design load values derived in 5.3.1.4 and 5.3.1.5 should be used for preliminary studies.

The average loadings follow directly from the docking displacement of the design vessel (see 5.3.1.3), but the magnitude and application of local concentrated loads depends upon the relative stiffness of the ship structure and the dock floor, as well as the ballasting and positioning practice of the dock operator.

The loadings described in 5.3.1.4 and 5.3.1.5 are those which can occur when the dock has been dewatered and the ship is supported by the blocks. The design should incorporate those loads which occur only as a ship sues or settles on to the blocks.

Ships are normally docked on a line of keel blocks plus two or more symmetrically disposed lines of bilge blocks arranged on each side of the keel blocks. In large dry docks, the design should allow for ships not necessarily positioned centrally on the dock floor.

5.3.1.3 Docking displacement

The docking displacement, D_d , should be estimated from:

$$D_d = 0.7 \times (\text{LBP}) \times B \times (\text{MDD})$$

where:

- B is the ship's beam;
- LBP is the length between perpendiculars;
- MDD is the mean docking draught.

Until accurate information is available, preliminary approximate mean docking draughts should be taken as:

- for container ships: light ship draught plus 3 m;
- for passenger vessels: three-quarters of the summer draught;
- for tankers and bulk carriers: 5 m.

5.3.1.4 Keel and bilge block load distribution

Design loadings should be chosen after consultation with the dock operator but, for the purpose of preliminary design, ships can be divided into two categories:

- those which are stiff transversely, i.e. most of their weight rests upon a central line of keel blocks;
- those larger vessels in which the weight is more evenly spread transversely over all the blocks.

The boundary between the two categories should be taken as ships with a docking displacement of 30 000 t.

For ships larger than 30 000 t docking displacement, the design should assume 60% of the docking displacement on the keel blocks, and 50% of the displacement should be assumed to be distributed between bilge blocks placed at distances from the keel blocks of between one-twelfth and two-fifths of the ship's beam.

For ships of 30 000 t or less docking displacement, 95% of the docking displacement should be assumed to be carried on the keel blocks and 15% distributed between the lines of bilge blocks. The bilge block loading should be positioned at distances from the keel blocks of between one-sixth and one-third of the ship's beam.

The design should apply the ship load as a line load equal to the average keel and bilge block loading intensities together with local concentrated loads, representing the effects of:

- unequal block loadings;
- local increases in distributed load associated with concentrations of mass within the ship.

NOTE 1 Load concentrations typically occur beneath the engine room and the tanks used for ballasting.

Much greater load concentrations than those occurring in keel blocks have been observed in bilge blocks. Keel blocks should be assumed to extend for 100% of the length between perpendiculars (LBP).

Bilge blocks should be assumed to extend for about 90% of LBP in the case of larger vessels and for between 50% and 70% of LBP for smaller vessels, depending upon the fineness of the hull shape.

NOTE 2 The keel and bilge block loadings on which the recommendations given in 5.3.1.4 and 5.3.1.5 are based were derived from measurements taken in a dock with a floor founded on rock, which is a very stiff foundation. The large load intensities observed were probably accentuated by the stiffness of the floor foundation. In other circumstances, the loads represented by those intensities might be spread over a greater area.

In the design of any dock floor, provision should be made for the support of similar total loads to those given in 5.3.1.4 and 5.3.1.5, spread in a manner appropriate for the particular design.

Semi-submersible platforms, FPSO type vessels and other anomalous structures have different load application arrangements to those for standard vessels. The requirement to allow for any such loading should be identified and defined in the basis of design documentation.

The dock floor should have sufficient capacity in local shear to be able to support individual block loads located anywhere beneath the ship, based upon an extreme contact pressure over the area of the block cap of up to 3 000 kN/m² (300 t/m²). This extreme block load should be treated as an accidental load.

5.3.1.5 Keel block load design values

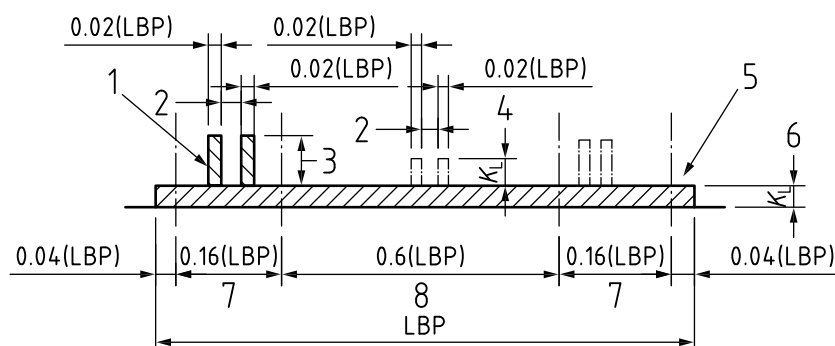
The keel block loading, which in every case assumes that reverse docking might take place, should be taken as a uniformly distributed line load operating over the full length of the keel (i.e. LBP), plus two local concentrated loads each of finite length placed anywhere along the length of the keel. The distance between the two local concentrated loads should be varied to produce the maximum sagging and hogging bending moments and shear at each point in the floor.

The intensities of the uniformly distributed load and the local loads should be calculated from the formulae given in Figure 8.

NOTE The intensity of the local loads is higher when they are located in the end sections of the keel for vessels larger than 30 000 t docking displacement.

No local loads should be applied nearer than 0.04(LBP) to the ends of the keel.

Figure 8 Keel block loading on dock floor

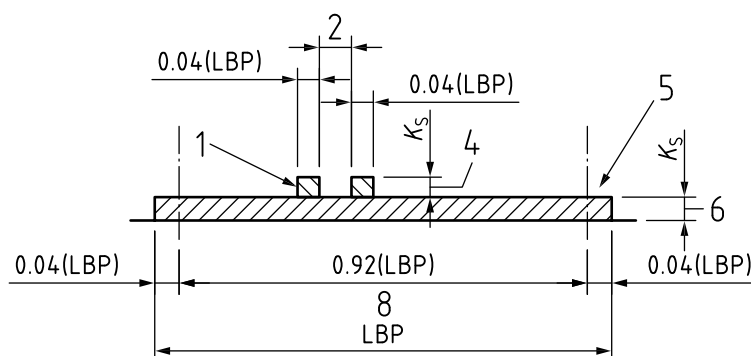


$$K_L = \frac{0.6D_d}{(\text{LBP})}$$

where:

K_L is the intensity of uniformly distributed load in a large vessel;
 D_d is the docking displacement of the vessel.

a) For ships larger than 30 000 t docking displacement



$$K_S = \frac{0.95D_d}{(\text{LBP})}$$

where:

K_S is the intensity of uniformly distributed load in a small vessel;
 D_d is the docking displacement of the vessel.

b) For ships of 30 000 t or less docking displacement

Key

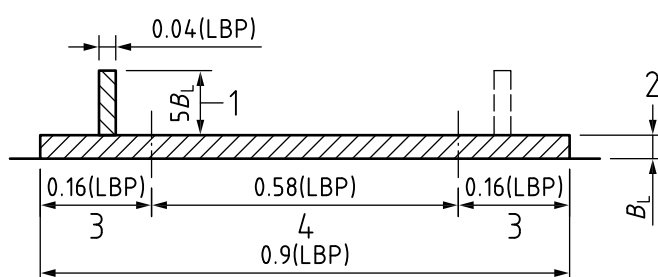
- | | |
|--|--------------------------------|
| 1 Local concentrated loads | 6 Intensity of uniform loading |
| 2 Variable length | 7 End section |
| 3 Local load increase in end sections $2K_L$ | 8 Centre section |
| 4 Local load increase in centre | |
| 5 No local load in this or corresponding section at opposite end | |

5.3.1.6 Bilge block load design values

The bilge block loading, which in every case assumes that reverse docking might take place, should be taken as a uniformly distributed line load operating on a fraction of the length of the keel plus, in the case of vessels over 30 000 t docking displacement, a single local concentrated load of finite length operating at any location in the end sections (see Figure 9).

The bilge block loading in Figure 9 should be applied to each side of the dock. Where more than two lines of bilge blocks are used, the loading for each side of the dock should be divided equally between the bilge blocks on that side of the dock.

Figure 9 Bilge block loading on dock floor

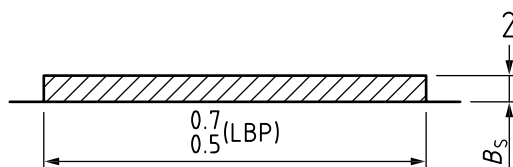


$$B_L = \frac{0.25D_d}{0.9 \text{ (LBP)}}$$

where:

B_L is the intensity of uniformly distributed load in a large vessel;
 D_d is the docking displacement of the vessel.

a) For ships larger than 30 000 t docking displacement



$$B_S = \frac{0.075D_d}{0.5 \text{ to } 0.7 \text{ (LBP)}}$$

where:

B_S is the intensity of uniformly distributed load in a small vessel;
 D_d is the docking displacement of the vessel.

b) For ships of 30 000 t or less docking displacement

Key

- 1 Local load increase in end sections only
- 2 Local load increase of uniform loading
- 3 End section
- 4 Centre section

5.3.1.7 Loading on shipbuilding dock floors

The design loading applied to shipbuilding dock floors should be determined to accommodate the block loading during the construction process for the types and sizes of ships for which the dry dock is planned.

The designer should develop the design loading as a set of line loads and point loads each of which can occur at any position on the floor. The development of the set of loads should take into account the following factors.

- a) The arrangement of blocks for shipbuilding is related to the size of prefabricated units of the new ship's hull. The blocks are normally more evenly spread under the hull than the blocks required for ships docked for repair.
- b) A ship can be constructed on one side of the dock floor, or two or more ships might be built simultaneously side by side in a large dock. The designer should not assume that the major loading will occur on the centre line of the dock or that the loading will be symmetrical about the centre line of the dock.
- c) Drilling rigs under construction produce different loading conditions from those produced by ships, and the conditions vary greatly from rig to rig.
- d) It is possible that a newly constructed ship might have to return to the shipbuilding dock after fitting out afloat, when normal ship repair docking supports would be used but docking might not be on the centre line of the dock.

To facilitate future dry dock operational flexibility, the design should include an assessment of whether the ship repair loading described in 5.3.1.2 can be efficiently accommodated within the shipbuilding design capacity.

5.3.1.8 Types of dock floors

5.3.1.8.1 Under-drained floors

An under-drained dock floor should be adopted where the ground water below the floor can be controlled such that it can be collected to be pumped away, so that no net uplift of the floor is allowed to develop.

The underfloor drainage system should include a layer of gravel or no-fines concrete, combined with a series of porous pipes and culverts which are led to a sump in the pumphouse. The pumping from the sump should be continuous throughout the life of the dock, so that the ground water regime surrounding the dock can remain as constant as possible whether the dock is full or empty.

The design should allow for the possibility of the dock being full of water for an extended period and the underfloor pumping being stopped, leading to a rise in ground water levels immediately surrounding the dry dock. The basis of design documentation should clearly state the minimum duration that the underfloor pumping has to be operating prior to commencing the dewatering of the dry dock.

NOTE 1 This is to prevent excessive uplift pressures on the floor outside the safe design values.

Where docks are founded on hard formations, or where on piled dock floors the requirement for a constant ground water regime might not be deemed necessary, a separate enclosed sump for underfloor drainage should be omitted from the design.

Where the dock is founded on rock of low permeability, the underfloor water pressure should be relieved by allowing it to discharge directly into the dock. Non-return valves should be installed on the inlets into the dock to prevent water from the filled dock flowing back into the ground. These valves can be subjected to damage from shipbuilding or ship repairing operations and should be regularly inspected and maintained.

A simple pressure relief system should be introduced into all under-drained floor installations. The system should be such that, if for any reason (such as pump failure) an unacceptable underfloor pressure develops, it is dissipated by direct discharge over the dock floor.

For fully pumped schemes, manhole covers should be provided over the underfloor drainage culvert, to lift off if unacceptable pressure develops and to allow maintenance of subfloor drainage collection pipes.

The system should be capable of being vented to the atmosphere at its upper extremity by a vent pipe rising above maximum sea level, to avoid high air pressures developing during filling of the dock.

Dry docks with underfloor drainage fitted with intermediate gates should be arranged so that the underfloor pumping is maintained for the whole floor at all times.

Account should be taken of the need to ensure that, where intermediate gates are present, inadvertent flooding does not occur due to downward leakage from an intentionally flooded part.

NOTE 2 Simple vented floors are not usually possible for docks with intermediate gates, unless the underfloor stratum has very low permeability and a cut-off seal is formed on the line of the intermediate gate.

5.3.1.8.2 Gravity floors

Gravity floors should either have sufficient mass themselves, or be able to call upon sufficient mass, to overcome the upward pressure of the ground water.

Where equilibrium is provided by taking into account the mass of the dock walls and backfill, it should be ensured that the floor can span across the width of the dock, thereby providing a uniform resistance to the uplift pressure.

Where the soil is highly permeable and the continuous pumping of large volumes of ground water would be required throughout the life of the dock, a gravity design should be adopted if appropriate.

NOTE Narrow docks can more easily be designed as gravity structures than wide ones, since the walls form a greater proportion of the whole dock self-weight.

5.3.1.8.3 Tied floors

A tied dock floor should be used where there is insufficient weight to withstand the hydrostatic uplift of the ground water and the floor has to be tied to the soil below the dock for equilibrium.

Tension piles, which also act as compression piles when supporting ship loads, should only be used with caution, since the reversal of load can tend to break down the adhesion between the soil and the pile. Failures of dock floors designed on this principle have been recorded, and fatigue issues should be taken into account before adopting this method of support.

The designer should assess the potential severity of the consequences to dock operations and also to a ship in the dock of an upward failure of a tied floor.

The prestressing of piles can avoid reversal of stresses. However, the use of steel at high stress for prestressing should be adopted with caution as all types of prestressing tendon are susceptible to stress corrosion cracking.

NOTE Only small quantities of water need to be present to provide a source of hydrogen, so the exclusion of all moisture is important. Anchorages and tendons are not normally subjected to large water pressure heads along their length as occurs when a dock is empty. Therefore, the exclusion, displacement and sealing of tenders has to be to a very high specification and proven by testing.

The present state of knowledge of stress corrosion cracking and hydrogen embrittlement of highly stressed steel in concrete is such that the risk of failure from these causes cannot be evaluated with high confidence, and therefore the use in dock floors of highly stressed anchors should be avoided.

5.3.1.8.4 Floors bearing directly on the ground

Where adequate bearing capacity exists, the ground immediately under the dock floor should be used to support the concentrated loads from ships and the distributed load from the water in the filled dock.

If the dock has been designed as a gravity structure, it is likely that it will be sufficiently stiff to spread the concentrated load from ships adequately without reinforcement, but this should be checked in relation to the soil conditions and floor thickness.

If the floor is relatively thin, it should be designed as a reinforced concreted plate to accommodate the imposed loads moments and shear forces.

5.3.1.8.5 Floors supported on piling

COMMENTARY ON 5.3.1.8.5

Piles can be used in conjunction with an under-drained floor, in which case they can be designed solely as compression piles supporting only the downward vertical loads.

The use of piles tends to limit flexibility in the layout of ship supporting blocks, unless there is a considerable excess of piling used.

Where weak soil is present at the subfloor level, piling should be provided to resist vertical loads and control settlement.

The floor and piles should be able to carry the maximum moments and loads indicated by the design loading.

5.3.1.8.6 Floors constructed under water

Where dewatering of the site is impossible or where inordinate temporary works are required, the dock floor should be designed to be constructed under water, by methods including bottom-opening skips, tremie pipes and grout intrusion of pre-placed aggregate.

Dock floors constructed under water should normally be a gravity design and therefore thick, but are difficult to make watertight.

The design should include an impervious layer of concrete on top of the mass concrete, placed after dewatering. The impervious layer may either be tied to the mass concrete below, or be laid on top of a thin porous concrete layer from which the seepage has to be continuously pumped. The finishing layer of concrete should be used to provide the required accuracy of profile of the dock floor.

5.3.1.9 Joints

The design should allow for initial shrinkage in the concrete of the dock floor by incorporating dowels, joggled joints or other methods together with water bars and seals at joints to give structural continuity. The order of casting bays should be defined by the designer, e.g. by casting from the dock head towards the entrance in an arrowhead formation, rather than chequerboard.

NOTE This facilitates both drainage and cleaning of the bays about to be cast whilst accommodating the necessary time lapse between casting adjacent bays.

The design should include an assessment of the need for expansion joints in dry dock floors. The average temperature of a dock floor is controlled, to some extent, by its mass and the proximity of ground water and tends not to vary appreciably. Expansion joints should, therefore, be used only in exceptional circumstances as the design has to ensure the transfer of loads across the joints and to maintain watertightness.

5.3.1.10 Structural analysis

The structural analysis of a dry dock floor should include the stability of the structure generally, as well as the incidental bending moments and shear forces from ship loading in accordance with 5.3.1.1 to 5.3.1.7 inclusive. The design should incorporate the elasticity of the subsoil or piles, as appropriate, including the potential variation of the elasticity across the dock floor area.

The floors of gravity docks should also be analysed for transverse bending moments generated by net upward water pressure and resulting in the dock floor spanning between the dock walls. The moments should be capable of being resisted by the dock floor acting as an inverted arch or by the introduction of reinforcing steel. The effect of ship loading on gravity docks should be analysed to check that the thickness of such a floor is sufficient to spread the load to the subsoil without reinforcement.

5.3.1.11 Factor of safety of dry dock against flotation

Dry docks designed as gravity structures and those tied down with piles or ground anchors should have an adequate factor of safety against flotation. The limiting condition generally arises with the dry dock empty and sea and/or ground water levels at their highest. The following parameters and their potential variation should be assessed in the selection of the factors of safety:

- a) ground water level causing flotation;
- b) density of ground water;
- c) density of concrete or other materials forming structure;
- d) density of soil which can be used to resist uplift;
- e) construction tolerances and, therefore, variation in the mass of the structure subject to uplift.

Due to the potentially severe consequences of floor uplift, conservative figures should be adopted for the parameters listed in a) to e), to calculate the total mass resisting uplift and to compare that with the total uplift force. The factor of safety calculated in this way should be not less than 1.2.

Semi-probabilistic limit state methods should not be used to assess the factor of safety.

During the detailed design and then later during construction, checks should be made that the parameters used in the initial calculations, including the densities of concrete, ground water and soil, remain valid in order to verify that the factor of safety is achieved.

The contribution made by prestressed ground anchors in calculating the factor of safety should be conservatively assessed. The contribution should be limited to 0.75 times the load in stranded cable anchorages and 0.85 times the load in solid rod anchorages. Normal allowances for corrosion and creep, etc. should also be included.

5.3.1.12 Ground improvement

The bearing capacity of poor ground at subfloor level can, in some cases, be improved by ground improvement methods, and hence the appropriateness of carrying out ground improvement for docks should be assessed where underfloor drainage is envisaged.

NOTE This is because such a permanent drainage scheme can itself cause shrinkage of some soils with the consequent risk of long-term settlement of the floor. Under those conditions, ground improvement is unlikely to prove appropriate.

The viability of the removal of the soft material and replacement with a suitable granular material should be assessed where the soft layer is of limited depth overlying a stronger soil.

In areas where timber is readily available, the viability of driving of timber piles at close centres to stiffen the ground should be assessed. Timber in saturated ground is normally expected to remain in good condition, but care should be taken to prevent the tops of the piles drying out.

Vibration methods or dynamic methods of ground improvement are theoretically possible, but acceptability of the impact on the project delivery programme for these processes should be assessed, since the work has to be carried out in a deep, open excavation before adjacent permanent work is carried out.

5.3.2 Design of dry dock walls

5.3.2.1 General

Dry dock walls should be able to carry safely all loads to which they are subjected, and should be so shaped as to suit the services and equipment which might be carried on the walls.

Concrete and steel structures should be analysed and designed as described in BS EN 1992 and BS EN 1993, respectively.

The walls form part of the overall structure of the dock and their design should therefore not be undertaken in isolation, except during the temporary construction stage when the dock floor might not yet be constructed.

The range of types of dock wall should be assessed to select the most appropriate for the full range of design parameters.

Walls should be designed in accordance with BS 6349-2.

5.3.2.2 Horizontal loads on walls

Dry dock walls should be able to withstand the worst combination of loading that can apply at any given time.

The loadings that should be taken into account include, but are not limited to, the following:

- earth pressure, including surcharge effects;
- ground water pressure;
- ship hauling gear loading;
- dock arm loading;

- dockside bollard loading;
- crane surge loading;
- access tower loading;
- seismic loading.

5.3.2.3 Vertical loads on walls

Dry dock walls should be capable of withstanding the worst combination of loading that can apply at any given time.

The loadings that should be taken into account include, but are not limited to, the following:

- surcharge loading;
- crane loading;
- dock arm loading;
- access tower loading;
- soil;
- ground water;
- water in the dock;
- seismic loading.

5.3.2.4 Types of dock wall

5.3.2.4.1 Gravity dry dock walls

COMMENTARY ON 5.3.2.4.1

Gravity dock walls rely on their own weight to overcome all loading to which they are subjected. The majority of gravity dock walls of modern design are constructed with in situ mass, or partially reinforced, concrete.

The dry dock construction sequence should be planned to obviate, where practicable, critical design cases for gravity dock walls.

NOTE For example, the dock floor might not be constructed and resistance to sliding might not be sufficient temporarily when the ground is excavated for the floor construction.

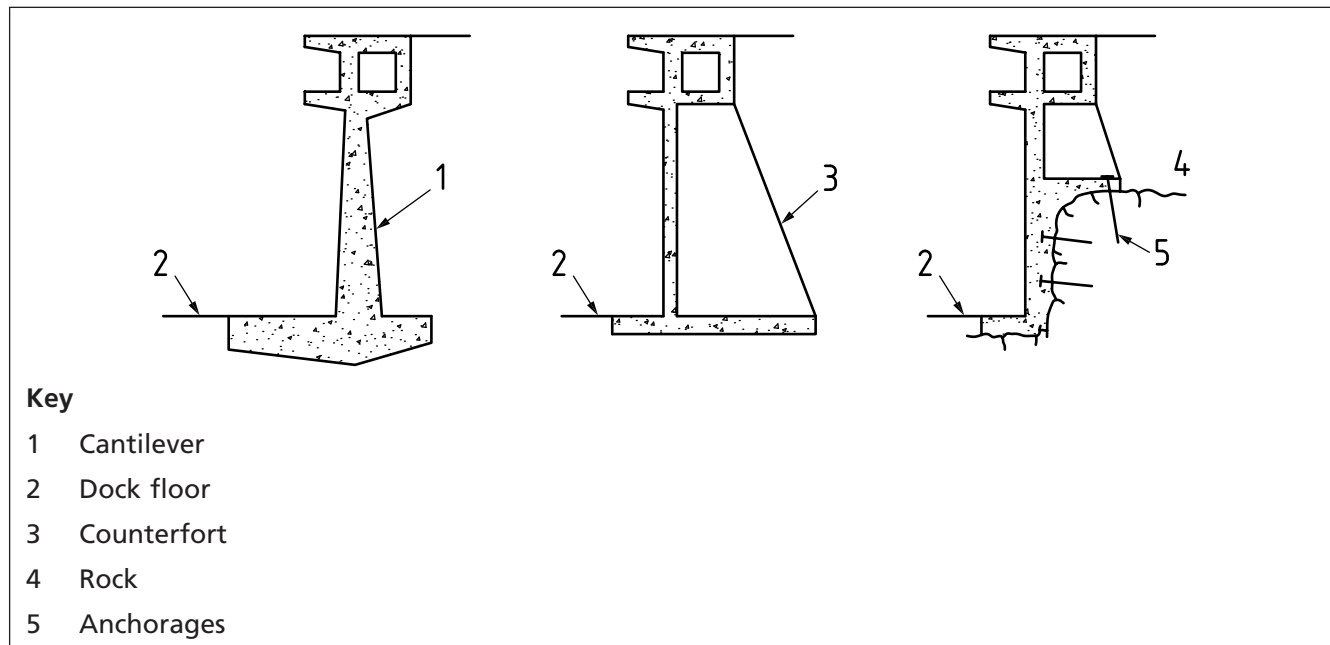
5.3.2.4.2 Reinforced concrete walls

The full range of reinforced concrete options for dock walls should be assessed, from simple cantilever construction to relatively thin walls spanning between counterforts with base slabs utilizing the mass of backfill for stability (see Figure 10). In suitable conditions, the wall might be tied to a rock formation.

The integration of the wall with part of the dock floor should be assessed, forming a toe to the wall. The possibility of this design producing high bearing pressure under the toe of the wall should be taken into account and appropriate measures, such as piling, introduced.

Account should be taken of the alternate wet and dry states of the dry dock, which produce severe conditions for the reinforced concrete of the dock wall, especially where sea water is usually present. The quality of the concrete and the cover to reinforcement should be carefully controlled to provide high performance resistance to corrosion of the reinforcement.

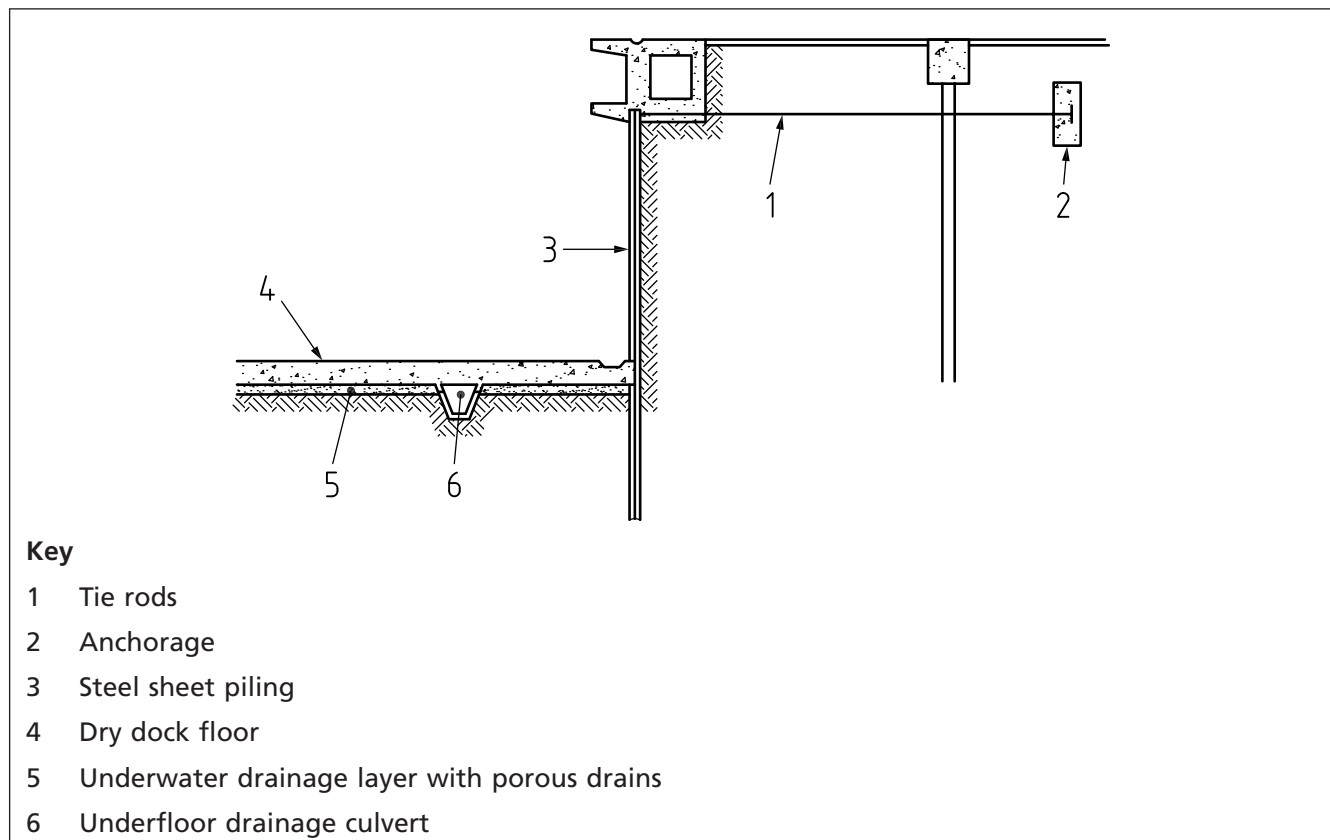
Figure 10 Types of dry dock wall construction in reinforced concrete



5.3.2.4.3 Sheet-piled walls

Steel sheet piling can be used successfully for dry dock walls (see Figure 11), but the use of concrete sheet piling for this purpose is not common, and should not normally be used owing to the difficulty of making watertight joints between concrete sheet piles. The resulting relatively flexible structure should be taken into account in the torsional design of the dock cope.

Figure 11 Sheet-piled dry dock wall with drained dock floor



Where space behind the walls during the construction stage is limited or where ground conditions do not favour an open-cut excavation, the use of steel sheet piles should be adopted if appropriate, as they effectively form part of the temporary works.

NOTE 1 In suitable conditions, steel sheet piling has the advantage that it might be able to terminate in an impervious layer below dock floor level and thus act as a ground water cut-off, permitting an under-drained floor to be provided.

Where ground water is present behind the wall, the sealing of pile clutches can be difficult, and solutions should be developed to solve this problem before pile driving is started.

NOTE 2 A relieving platform to limit the effects of high surcharge loading surrounding the dock and high soil pressures when the dock is empty can be viable in the design of deep docks. Another form of steel sheet-piled wall consists of straight web piling in the form of cells, normally filled with granular material. Various patterns of cells are possible, but the curved face of the piling on the dock face can present difficulties with some details such as dock arm beams and staircases.

Account should be taken of the horizontal deflection associated with sheet-piled or cellular structures when they resist horizontal earth and water loading. The cope superstructure and sensitive components, such as crane tracks, which might possibly be supported by the wall, should not be constructed until the initial horizontal deflection has taken place.

The construction programming implications should be incorporated into the design, as the external ground water pressure might not be present until all the piling for the dock has been completed and a complete water barrier formed.

The design of the joint between the sheet piling and the dock floor should address potential leakage from the dock into the under-drainage system, which has been experienced in some docks when the dock has been filled and the piling has deflected outwards under the reverse pressure of the water in the dock.

The potential corrosion of sheet piling should be incorporated in the design through a combination of:

- regular painting of the exposed face undertaken;
- added thickness of steel as a corrosion sacrificial allowance;
- cathodic protection.

Where necessary there should be a corrosion allowance on the concealed unmaintainable faces of the piling.

A suitable section for the sheet piling should be chosen for driving to a depth of penetration capable of achieving the design requirements.

5.3.2.4.4 Diaphragm walls

Diaphragm walling for dock wall construction should be adopted where a combination of the following features are of particular advantage and where ground conditions permit:

- a) the installation can take place from ground level negating open excavation;
- b) the construction process provides a continuous record of the actual soils along the line of the wall verifying the ground conditions adopted for the design;
- c) the depth of the wall can be extended to terminate in impervious layers below dock floor level and hence form the ground water cut-off for an under-drained dock floor;

- d) the need for anchorages or ties might be eliminated by the use of a stiff plan section such as a T-shape.

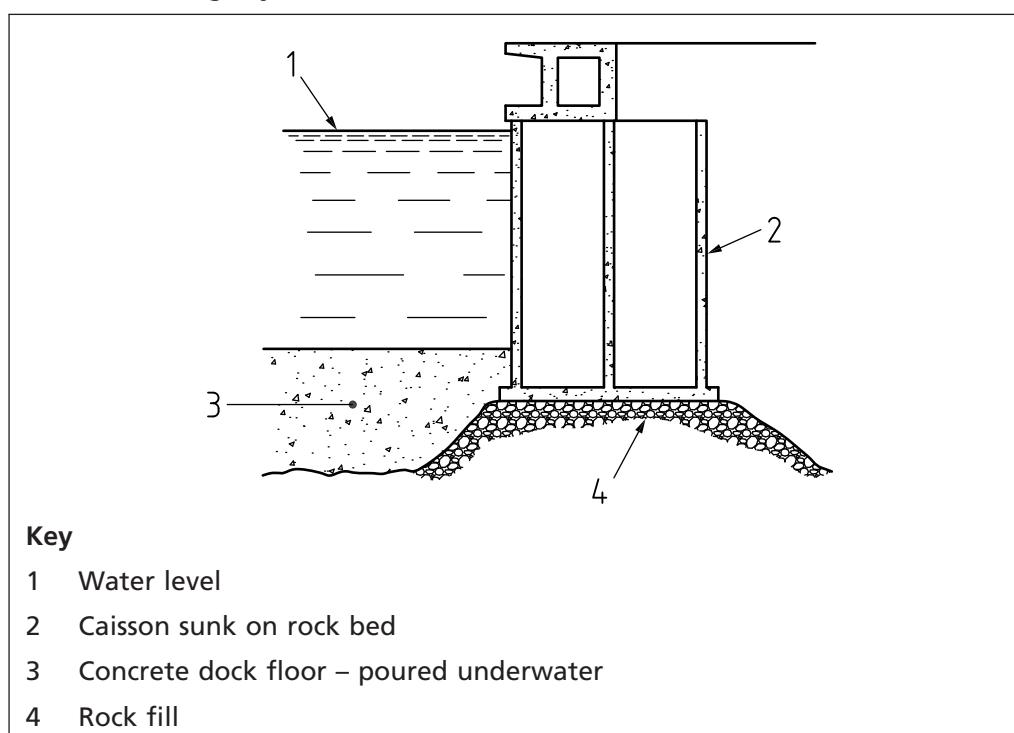
Where the constructed rough face of the diaphragm wall exposed within the dry dock is unacceptable for aesthetic or operational reasons, a high quality in situ finish should be designed and an adequate space allowed for in the initial design. A water-bar should be provided between diaphragm wall panels to reduce ground water leakage into the dock.

5.3.2.4.5 Caissons forming dry dock walls

Reinforced concrete caissons should be designed as a form of construction for dry dock walls where the initial dewatering of the site is difficult or impossible.

NOTE The caissons can be constructed in a nearby dry dock, floating dock, shiplift, or slipway, and then floated to site and sunk on to prepared foundations which consist, usually, of a levelled stone bed. (See Figure 12.)

Figure 12 Caissons forming dry dock walls



Provision should be made in the design for inaccuracies in the placing of the caissons.

All super-structure work above sea level should be formed after the caissons have been bedded and subjected to the majority of the horizontal pressures which can cause movement.

The design should incorporate the construction stages required to maintain stability until the dock floor has been constructed and the final permanent design case achieved.

Caissons should be used where the dock is to be constructed in deep water and where the foundation material is hard and relatively impervious and an under-drained floor can be provided. The caissons, in this case, form a cofferdam that encloses the site, and great care should be taken to form the seal under the caissons. Precision dredging or grouting of the bedding of the caisson should, if necessary, be undertaken before dewatering. In general, the use of temporary cofferdams with all permanent dock structures being built in the dry should be fully investigated before resorting to the use of floating caissons for dock walls.