

Code of practice for

Maritime structures —

**Part 3: Design of dry docks, locks,
slipways and shipbuilding berths,
shiplifts and dock and lock gates**

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- British Steel Industry
- Concrete Society
- Department of the Environment (Property Services Agency)
- Department of Transport (Marine Directorate)
- Federation of Civil Engineering Contractors
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- Institution of Civil Engineers
- Institution of Structural Engineers
- Oil Companies International Marine Forum

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Foreword

This Part of BS 6349 has been prepared under the direction of the Civil Engineering and Building Structures Standards Committee.

This code of practice contains material which is both for the information and guidance of engineers and material which forms recommendations on good practice. As such, conformity with its recommendations is not obligatory and variations from its recommendations may well be justified in special circumstances and engineering judgement should be applied to determine when the recommendations of the code should be followed and when they should not.

A code of practice is intended for the use of engineers having some knowledge of the subject. It embodies the experience of engineers successfully engaged on the design and construction of the particular class of works so that other reasonably qualified engineers may use it as a basis for the design of similar works.

It is not intended that it should be used by engineers who have no knowledge of the subject nor that it should be used by non-engineers.

A code of practice represents good practice at the time it is written and inevitably, technical developments may render parts of it obsolescent in time. It is the responsibility of engineers concerned with the design and construction of works to remain conversant with developments in good practice, which have taken place since publication of the code.

Following suggestions from the Maritime and Waterways Board of the Institution of Civil Engineers, the Standards Committee for Civil Engineering Codes of Practice set up an ad hoc panel to make further studies. The panel's report, presented in 1975, concluded that existing British codes were inadequate for the special aspects of maritime structures and that there was a need for such a code.

It has been assumed in the drafting of this British Standard that the execution of its provisions is entrusted to appropriately qualified and experienced people.

The standard will be issued in seven Parts as follows:

- *Part 1: General criteria;*
- *Part 2: 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: Design of fendering and mooring systems;*
- *Part 5: Recommendations for the dredging of waterways and for land reclamation¹⁾;*
- *Part 6: Design of buoy moorings, floating and buoyant structures and anchorage systems¹⁾;*
- *Part 7: Design of breakwaters and training walls²⁾.*

In BS 6349-1 recommendations are given to assist clients and engineers to obtain the basic data relevant to the design of any maritime structure.

¹⁾ In preparation.

²⁾ To be issued initially as a Draft for Development.

The full list of the organizations which have taken part in the work of the Technical Committee responsible for BS 6349-3 is given on the back cover. The Chairman of the Committee is Mr. J. T. Williams OBE, CEng, FICE, FIStructE and the following were members of the Technical Committee.

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Summary of pages

This document comprises a front cover, an inside front cover, pages i to x, pages 1 to 74, an inside back cover and a back cover.

This standard has been updated (see copyright date) and may have had amendments incorporated. This will be indicated in the amendment table on the inside front cover.

³⁾ Past member.

Section 1. General

1.1 Scope

This Part of BS 6349 gives recommendations and guidance on the planning, design, construction and maintenance of maritime structures related to the support and movement of ships and other floating structures during their construction and repair. This Part of BS 6349 is applicable to structures located at or close to the shore, it is not applicable to locks or other structures located in inland waters, although many of the principles dealt with will apply to such structures.

This code is not applicable to floating docks (see note 2 to 1.2.3.1).

The following sections each discuss the features and design of separate structures or types of structure and should be considered as an aide-memoire by those required to plan or design such a structure.

Section 2 deals with dry docks which are used both for the building and repair of ships and discusses the special features required for each purpose.

Section 3 deals with locks, but recognises that their construction may be similar to dry docks and that they may be used as dry docks in some locations.

Section 4 deals with slipways and shipbuilding berths and the methods of moving ships on dry land including haulage systems, winches and ropes.

Section 5 deals with shiplifts, their mechanisms and the supporting structure.

Section 6 deals with dock and lock gates, their structure, operating mechanism, seals and other features.

NOTE The titles of the publications referred to in this standard are listed on the inside back cover.

1.2 Definitions

For the purposes of this Part of BS 6349 the following definitions apply.

1.2.1 Tides

1.2.1.1

range

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

1.2.1.2

spring tides

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

1.2.1.3

neap tides

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

1.2.1.4

mean high/low water springs (MHWS/MLWS)

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

1.2.1.5

mean high/low water neaps (MHWN/MLWN)

the average, over a long period, of the heights of two successive high/low waters at neaps

1.2.1.6

mean sea level (MSL)

the average level of the sea surface over a long period, preferably 18.6 years (one cycle of the moon's nodes) or the average level which would exist in the absence of tides

1.2.1.7

highest/lowest astronomical tide (HAT/LAT)

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

1.2.2 Ship tonnages

1.2.2.1

gross registered tonnage (grt)

the gross internal volumetric capacity of the vessel as defined by the rules of the registering authority and measured in units of 2.83 m³ (100 ft³)

1.2.2.2

deadweight tonnage (dwt)

the total mass of cargo, stores, fuels, crew and reserves with which a vessel is laden when submerged to the summer loading line

1.2.2.3

displacement

the total mass of the vessel and its contents

1.2.3 Structures

1.2.3.1

dry dock

a dock from which water may be pumped out leaving it dry to enable a vessel to be built or repaired

NOTE 1 Dry docks were originally referred to as "graving docks", a term associated with ship repair, deriving from the practice of smearing "graves" or dregs of tallow on to the hulls of timber ships to provide watertightness. This term has largely been superseded by the term dry docks, which can refer to structures used both for the repair and building of ships.

NOTE 2 In some parts of the world, notably North America, the term dry dock is also applied to floating docks. Such usage is to be avoided as it can lead to confusion.

1.2.3.2

lock

an enclosure on a river, canal or at the entrance to a non-tidal dock, with movable watertight gates through which vessels pass and proceed from one water level to another

**1.2.3.3
slipway**

an inclined structure built partly on land and partly under water and usually fitted with a rail track and carriages on which vessels are hauled out of water for repair and launched after repair or on which new vessels may be built and then launched using the mechanism of the slipway

**1.2.3.4
marine railway**

an inclined structure built partly on land and partly under water and similar to a slipway, except that the carriage is arranged so that the vessel is raised on an even keel and can be transferred ashore on a secondary carriage running on a level track

NOTE Marine railways are used mainly in North America.

**1.2.3.5
shipbuilding berth**

an inclined structure built partly on land and partly below high water on which vessels are built at an inclination and launched at high tide by sliding down the berth under the action of gravity

**1.2.3.6
launchway**

the track on which the ship on a shipbuilding berth is launched. The launchway usually consists of a fixed (or standing) way attached to the berth and a sliding way attached to the ship

**1.2.3.7
gated shipbuilding berth (half-dock)**

an inclined structure usually built partly below water level in locations having a small tidal range and fitted with a gate to exclude the water when the ship is under construction. When the gate is opened the function is the same as a simple shipbuilding berth

**1.2.3.8
impounded dock**

a dry dock or wet dock that has the facility to retain water above that of the adjacent waterway to which it is connected. The impounding may be achieved by pumping or result from the lowering of the tide

1.2.4 Shiplifts

**1.2.4.1
shiplift (mechanical lift dock)**

a platform structure capable of being lowered under water and lifting a vessel out of the water by means of winches or jacks. The vessel is raised on an even keel and can be transferred ashore on a carriage running on a level track

**1.2.4.2
maximum distributed load (MDL)**

the load, in tonnes per metre, that can be distributed along the centre line of the platform for which the structure of the platform has been designed, including the mass of cradles and blocks used to support the ship

**1.2.4.3
nominal lifting capacity (NLC)**

the maximum displacement, in tonnes, of a ship of normal form that can be lifted without exceeding the maximum distributed load for which the platform is designed

Section 2. Dry docks

2.1 Capacity and dimensions of dry docks

2.1.1 Capacity

Dry docks are often described or advertised by reference to the size of the largest ship that can be docked under the most favourable tidal conditions and by the deadweight tonnage (dwt) of such a ship. Whilst this system is understandable, it does not define the size with any precision and may, on occasions, be misleading. On the other hand, simple dimensions of length, breadth and depth can be equally misleading. Therefore, working space at the sides and ends, the heights of keel blocks, and the tidal conditions should also be included in descriptions of dry dock capacity.

2.1.2 Depth

2.1.2.1 General. The depth of water over the sill will, in most cases, control the draught of the ship able to enter. In addition, due account has to be taken of the longitudinal inclination of the dock floor and/or keel blocks, as this could, in some cases, be limiting.

The level of the dock sill is normally arranged at the design stage to be at, or slightly above, the top of the keel blocks. The height of blocks may range from 1.6 m to 2.2 m.

The depth of the dock should be measured from MHWN to the sill or keel block at the entrance, whichever is the higher. The keel block declivity should be stated where appropriate. (See Figure 1.)

2.1.2.2 Additional depth for damaged ships. It should be recognized that damaged ships may require a depth of water over the sill greater than that which would be required under normal docking conditions. The additional depth required is a matter of commercial judgment on the part of the dock owner, as an extra depth for some designs of docks may be very expensive, whereas, for other designs, there may only be a nominal increase in cost.

2.1.3 Width of entrance

The width at the dock entrance will normally control the maximum beam of ship able to enter the dock. Due allowance should be made for clearances, which will vary according to wind and tidal conditions, the ship handling facilities available and the type of ship to be docked.

The clear width should not normally be 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 defined as the clear distance between the permanent fenders or structure at the dock entrance (subject to the variation for battered sides). (See Figure 2.)

2.1.4 Width of dry dock barrel

The width between dry dock walls (often termed the dry dock barrel) is normally greater than the width of the dry dock entrance. The extra width is required 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 barrel width should be defined as the minimum clear distance between the faces of the dock wall (or projecting altars) above keel block level. (See Figure 3.)

2.1.5 Length

The length of a dry dock should be measured on the centre line of the dock and should be the minimum horizontal distance between the 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 may restrict the effective length of the dock, therefore, measurement should be taken to the appropriate point on the strutting system. (See Figure 4.)

2.1.6 Clearances between ship and dry dock

The working space clearance between the side of a ship and the face of the dock wall should not normally be less than 1.5 m and may be greater if dock arms are used.

As well as the minimum clearances required for repair at the sides and the bottom of ships, additional clearances should be allowed for special features of ships and for equipment.

Asdic domes and other protuberances below the keel of ships often require pits in the dock floor of sufficient dimensions to facilitate removal.

The removal of stabilizers at the side of ships has, in the past, required recesses to be formed in the dock walls but many stabilizers are now being designed to be removed internally.

The removal of tail shafts often requires an extra length of dock and due allowance should be made for this process.

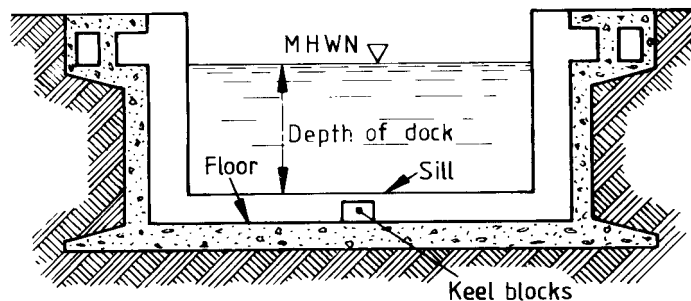


Figure 1 — Cross section of dry dock: depth

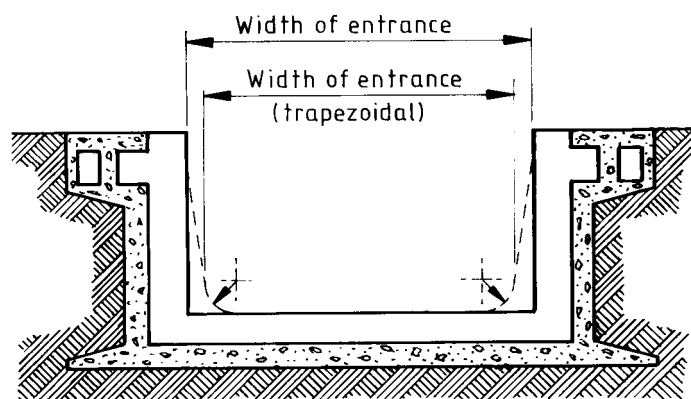


Figure 2 — Cross section of dry dock: width of entrance

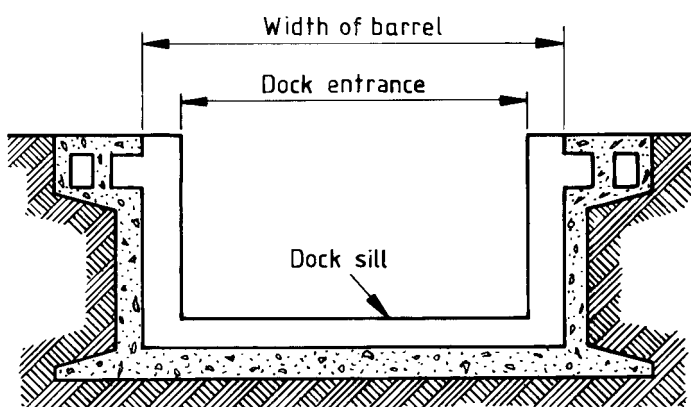


Figure 3 — Cross section of dry dock: width of barrel

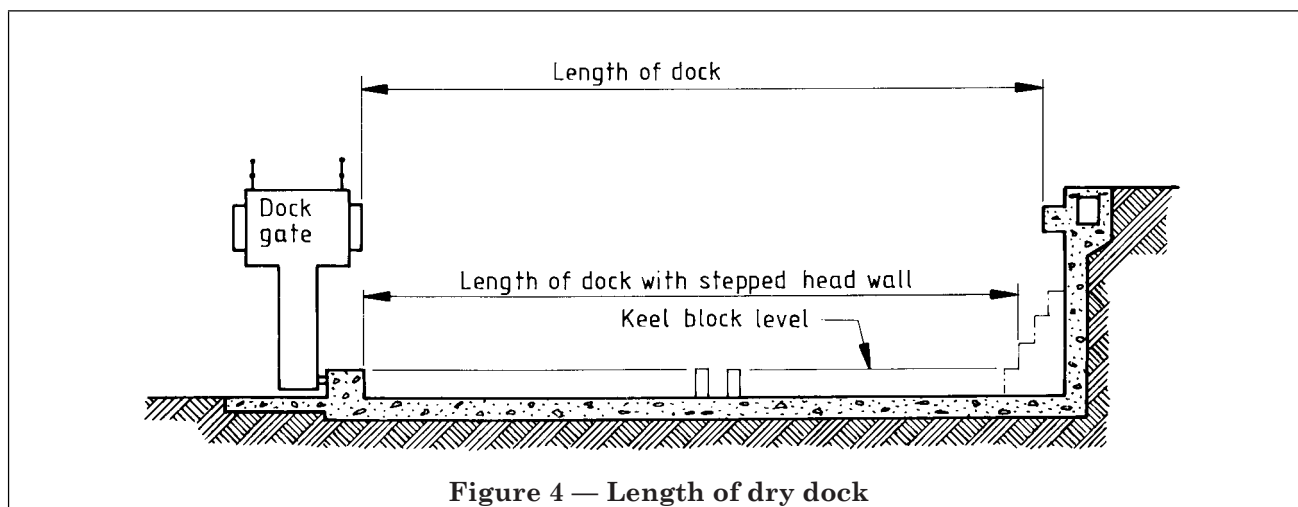


Figure 4 — Length of dry dock

The use of mechanical equipment on wheeled vehicles to clean and paint the underside of ships has required higher keel blocks to be introduced and a minimum height of 1.8 m is recommended if this equipment is adopted.

In general, the height of blocks in building docks can normally be smaller than in repair docks but this is a matter for the individual yard and the techniques used for construction.

2.1.7 Height of dry dock cope

When choosing the height of the cope the following should be taken into account:

- a) the highest water level likely to be attained outside the dry dock entrance, allowing for wave swell and surge;
- b) the highest water level likely to be attained in the dock;
- c) the provision of external services near the dock cope and the necessity or otherwise for them to remain in the dry when the dock is filled;
- d) the general level of the ground surrounding the dock and the advantage of maintaining the cope level similar to that level;
- e) the provision of rails for dock arms or ship leading equipment below dock cope level, which normally should remain in the dry.

2.2 Siting of dry docks

2.2.1 General

The siting of a new dry dock is often dictated by the location and arrangement of the existing shipyard in which it is to be built and the choice may thus be limited.

If, however, the whole shipyard is new, the siting of the dry dock may well govern the future arrangement of the yard and, indeed, its general location.

2.2.2 Navigational approach

A repair shipyard should be provided with an easy navigational approach, if possible, as some vessels may be under tow. Lead-in jetties or dolphins may be required in some locations.

2.2.3 Anchorages and quays

A sheltered anchorage and/or a mooring facility should be provided, since there may be a delay before the ship can be accepted in the dry dock. Repair work may also have to be carried out afloat before or after docking. It is normally accepted that at least two repair/fitting out quays should be provided to be used in conjunction with one dry dock. The depth of water has to be sufficient at all states of the tide at quays and anchorages.

2.2.4 Availability of services

The availability of electric power, fresh water and other services is an essential factor for the siting of the shipyard and their easy provision is of prime importance.

2.2.5 Position with respect to subsoil conditions

The position of a dry dock with respect to subsoil conditions can, in some cases, greatly influence the cost of the dock.

The level or contours of rock formations below the surface can affect the choice of dock structure, which, in turn, will influence the method and time of construction as well as the material cost. Rock at floor level can produce a cheap and excellent floor construction and, whilst excavation in rock for the dock barrel may have a high unit cost, no temporary works to support the sides of the excavation are required. The dock walls, in this case, are often simple or may be eliminated and the overall cost of a dock in rock may be cheaper than one in soft ground.

The presence of suitable impervious substrata at dock floor level or at a level into which a cut-off can be formed may enable a drained floor to be kept dry without excessive pumping. This is normally cheaper than the provision of a gravity or tied down structure.

An adequate depth of water at the completed dock entrance and associated quays is clearly essential but due consideration should be given to the cost of forming temporary cofferdams, which are cheaper to construct in shallow water. Dredging will normally be required to remove bundled cofferdams and the dredging can then be extended to form the necessary depths for the dock entrance and quays without great extra expense. However, dredging in rock is extremely expensive in both time and money and should be minimized, wherever possible, by suitable positioning of the dock and other structures.

The final position of the dock is normally a matter of compromise and judgment and the necessity of an accurate subsoil investigation together with land and bathymetric surveys cannot be over emphasized.

2.2.6 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.

The orientation of dry docks used mainly for shipbuilding is not normally as critical, since ship movements are not so frequent and can usually be delayed to await suitable weather conditions. Ships entering dock require more favourable conditions than on leaving, and, in general, ships do not often enter shipbuilding docks.

2.2.7 Tidal flow, currents and waves

It is essential that consideration be given to 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.

Currents resulting from river flow do not normally affect the operation of a dry dock, except to modify the effect of tidal conditions. Currents in the sea are unlikely to have a great direct effect on a dry dock, which is normally within the protection of a harbour, but consideration should be given to anchorages associated with the dry dock installation. The effect of waves on the dry dock structure is not normally of great importance, except with respect to the gate and mooring conditions of associated quays and ship anchorages.

2.2.8 Position of buildings, workshops, etc.

The position of buildings and workshops can normally be arranged to suit the best position of a dry dock in a new or existing shipyard and it may be advisable to move existing buildings if, for example, the ground conditions favour a particular location of the dock, which is occupied by those buildings.

2.3 Site investigation for dry docks

2.3.1 General

Site 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 design which, in turn, will control the final cost. For general recommendations on site investigation, reference should be made to clause 48 and 49 of BS 6349-1:1984 and to BS 5930.

2.3.2 Site reconnaissance

Site reconnaissance should be conducted in accordance with 49.3 of BS 6349-1:1984, and is of great importance particularly with respect to the early recognition of cavernous formations, which can make conventional dry dock construction very difficult if the caverns are connected to the sea.

2.3.3 Exploratory drilling

The assumption should be made initially that the construction of the dry dock will be undertaken in the dry. All possible investigation should, therefore, be made to determine the permeability of the soil in situ in accordance with 49.4 to 49.7 of BS 6349-1:1984.

2.3.4 Layout of boreholes

The number and layout of boreholes cannot be defined with certainty before the investigation work is started but, 10 equally spaced along the walls of the dock would normally be the minimum. If variations in level, in thickness or in the properties of various layers of subsoil are revealed, the number of the boreholes should be increased until a sufficient understanding of the subsoil conditions can be attained. Further boreholes should be made to determine the condition related to any temporary coffer-dam that may be necessary. A similar borehole pattern may be required if alternative locations are available for the dock within a larger site and, in this case, it may be prudent, initially, to put down boreholes at wide centres embracing the whole site in order to establish if one location has a potential advantage over another.

2.3.5 Depth of boreholes

The depth of boreholes should be sufficient for all types of dock design and may 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.

2.3.6 Sealing of boreholes

It is essential that boreholes formed within the area of the future dock excavation be properly sealed, preferably with concrete, before being abandoned. There have been cases of leakage into dock excavations from abandoned boreholes which have been extremely difficult to seal.

2.3.7 Ground water conditions

Ground water levels, including any possible artesian conditions, should be established. It is essential that great care be taken to maintain water equilibrium in the boreholes during the drilling process in order to obtain satisfactory samples and standard penetration tests (SPT). If artesian conditions are present it will be necessary to maintain the top of the borehole tube at a level at least equal to the artesian head.

Field trials involving pumping tests should be made to establish permeability and ground water control measures. This information is necessary to establish the extent of temporary pumping required during construction and may also be needed in the design of a permanent under floor drainage system.

2.4 Planning of dry dock

2.4.1 General

The arrangement and planning of the various features and equipment of the dry dock will depend greatly on the special requirements of the dry dock owner and user. In particular, there will be great differences between shipbuilding and ship repairing dry docks with respect to the frequency of flooding, speed of handling ships, pumping times, access to dock floor, services, cramage, etc.

2.4.2 Arrangement at dry dock copes

The planning and arrangement of various installations and details at the cope of a dock is a major design task involving sometimes conflicting requirements. Consideration should be given to the following items which may influence design:

- a) ducts and subways for electrical and piped services;
- b) connections of services to the ship and dock floor;
- c) track for shiphauling trolleys;
- d) upper track for dock arms;
- e) electrical pick-up or trailing cable groove for dock arm;
- f) safety handrails;
- g) dockside crane tracks;
- h) bollards;
- i) capstans;
- j) fairleads;
- k) staircase to dock floor;
- l) ladders to dock floor;
- m) access towers to ships' decks;
- n) fendering.

The final arrangement is normally a compromise in order to incorporate some or all of the above, consistent with an acceptable structural design of the dock wall.

The equipment required for shipbuilding dry docks may not include all the items mentioned in a) to n). In particular, it is unusual for dock arms to be provided for shipbuilding, therefore, the services distribution, ladders and staircases and other items are less difficult to incorporate. (See Figure 5.)

2.4.3 Access to floor

An important factor in the planning of a dock is the provision of access for personnel and materials to the dock floor. Access can be provided in a number of ways.

Lifts have been installed in a number of docks but the maintenance problem is acute and some have become disused for this reason.

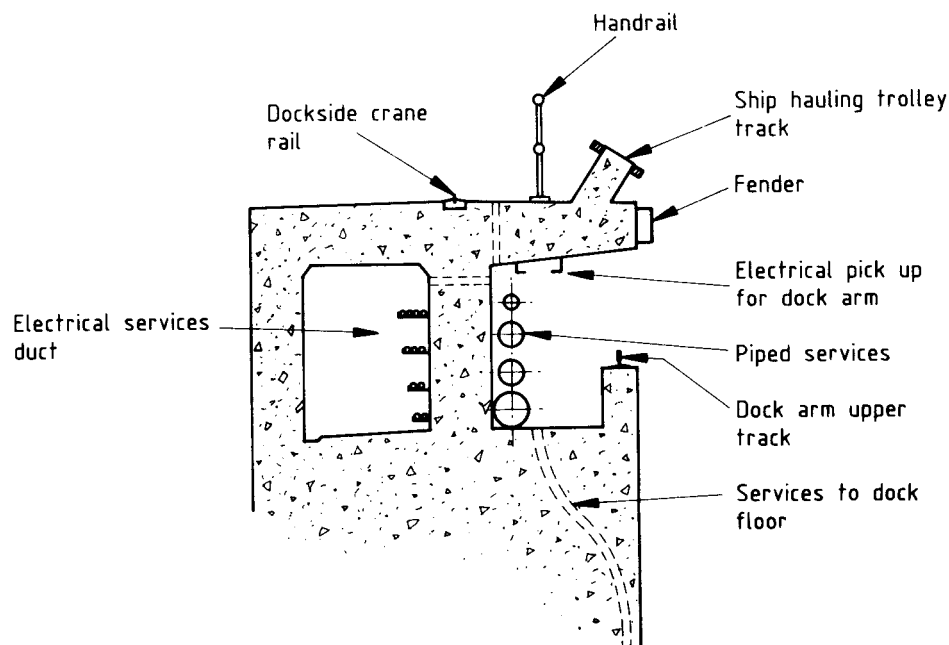


Figure 5 — Typical arrangement of dry dock cope

A vehicular ramp is favoured by many modern dock owners and some have been added to existing docks. Economies can be achieved by providing a ramp at the outset, as it can be used by the civil contractor during construction. A ramp slope of 1 : 10 is normally considered acceptable for wheeled vehicles travelling to and from the dock floor but a slope of 1 : 8 has been used where space is at a premium. With some vehicles, vertical transition curves may be required.

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 tends to trap floating and other debris after the dock is pumped out.

Emergency ladders from dock floor to cope should be provided at a spacing not exceeding 30 m along both side walls of the dock and should preferably be set in recesses to avoid damage.

2.4.4 Surrounding area

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

Modern shipbuilding methods require very considerable layout space for prefabricated parts of ships, depending upon the particular techniques used. Layout space should be fully discussed with the yard owners. Part of the area is likely to be covered by a goliath crane which also straddles the dock and/or by heavy dockside cranes. The whole area should be well drained and 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. The area provided should be sufficient for these purposes and should be suitable for wheeled vehicles to travel freely. In addition, the dockside cranes require an adequate space in which 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 have to be determined from the type of wheeled vehicles and trestle foot loadings, etc. likely to be used.

2.4.5 Intermediate gates

Dry docks may be fitted with intermediate gates to permit the head-end of the dock to remain dry whilst the gate-end of the dock is flooded and the gate opened. This arrangement is suitable for shipbuilding docks which are used for constructing a number of ships simultaneously, and has the considerable advantage of enabling some ships to be launched without flooding other parts of the dock.

The intermediate gates usually have to be erected and removed in the dry and may be of prefabricated lengths handled by the dock crane.

Some repair docks are fitted with intermediate gates so that a long-term repair job can be carried out at the head of a dock and the gate-end can continue to be used for short term dockings of restricted size. This arrangement is now common in modern repair docks.

2.4.6 Typical crane arrangements

Many modern shipbuilding docks are fitted with goliath cranes. The spans of the goliath cranes are normally arranged to be considerably greater than the width of the dock to enable them to pick up prefabricated units of ships, which are delivered to the dockside by multi-wheeled road transporters. The units are formed in fabrication sheds, often well clear of the dock area. Delivery to the dockside should be made to the required longitudinal position on the ships under construction in order to keep to a minimum the relatively slow longitudinal movement of the goliath crane carrying the unit.

Due to the three-pinned arch design of the structure of most large goliath cranes, the loadings on the two crane legs are often not similar and provision for shear is taken only on one side.

Shipbuilding docks may also be equipped with jib cranes which are usually arranged to operate independently of the goliath cranes and thus require separate tracks with adequate clearances to permit the cranes to pass each other. The maximum lift of the jib cranes is normally arranged to be at a radius extending at least to the dock centre line with an ancillary lift considerably in excess of that radius.

No detailed indication of crane loading can be given since the capacities vary greatly depending on the size of shipyard and the type and size of the ships to be built. Goliath cranes may, for instance, range between 80 t and 1 000 t capacity with heights of lift above cope up to 90 m. Jib crane capacities may range between 5 t and 120 t and they are usually of the level luffing type, but hammer head cranes are also used.

Most ship repair dry docks are equipped with level luffing jib cranes, the capacities of which may range between 5 t and 100 t depending upon the size of the dock and the type of work undertaken by the shipyard. The maximum lift of a jib crane is normally arranged to extend at least to the dock centre line with auxiliary lifts at greater radii. In general, one crane which is able to plumb the dock centre line and to lift the largest unit in the vessels that can use the dock will be provided. The unit may be a propeller, rudder or prefabricated element of structure and lifts of 80 t or more have been required. The installation of dock arms can effectively reduce the work requirements of light dockside cranes by the elimination of staging, etc.

2.4.7 Covered dry docks

A cover over a dry dock may be required for protection against adverse environmental conditions. The supporting structure of the cover can also be used to support overhead travelling cranes, which may well be more efficient and cheaper than goliath cranes.

Shipbuilding processes can therefore take great advantage of covered dry docks and of the precision lifting and fast longitudinal travel of overhead travelling cranes.

The width of deck at cope level to be provided under cover should be carefully considered with respect to the width required for the shipbuilding technique to be adopted and the resulting additional span of the cover and the overhead travelling cranes.

It may be advantageous to have a wide area on only one side of the dock, in which case, the possible effect of stanchion loads on one or both dock walls should be considered. In addition to the usual shipbuilding services, the provision of lighting, heating, ventilation and additional fire precautions should be considered.

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

Dry docks used only for ship repair do not usually have to be covered, except in some modern naval dockyards.

2.5 Design of dry dock floors

2.5.1 General

2.5.1.1 Loadings. Dry dock floors should be designed in reinforced or unreinforced concrete to carry safely all loads to which they are subjected, including the following:

- a) uplift from groundwater, including the possible presence of artesian conditions;
- b) concentrated loadings from ships when docked;
- c) uniform water loading when the dock is full;
- d) horizontal loading from earth and water pressure on walls.

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

- 1) gravity (see 2.5.2);
- 2) under-drained (see 2.5.3);
- 3) tied (see 2.5.4).

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

- i) by floors bearing directly on the ground (see 2.5.5);
- ii) by floors supported on piling (see 2.5.6);
- iii) by ground improvement (see 2.5.7).

Analysis of reinforced and prestressed concrete should be carried out either by limit state methods, in accordance with BS 8110, or by working stress methods (see note). For limit state analysis, normal loading conditions should be multiplied by a partial load factor of not less than 1.5 to obtain ultimate stress conditions. Crack widths may be calculated either for the serviceability state or for the working stress state. Cover to reinforcement should preferably be 75 mm but in no case less than 50 mm. Unreinforced concrete should be analysed by working stress methods; compressive stresses should not exceed one-quarter of the characteristic cube strength f_{cu} and the principal tensile stress should not exceed $0.24 \sqrt{f_{cu}}$.

NOTE Working stress methods for the analysis of reinforced and unreinforced concrete and for the calculation of crack widths were previously given in CP 114, which is withdrawn.

2.5.1.2 Floor profile. The floor profile should be adapted to suit the particular functions and usage of the dock. The following features should be taken into consideration:

- a) longitudinal slope (see 2.5.9);
- b) transverse slope (see 2.5.10);
- c) ducts and recesses for drainage and services (see 2.5.10).

2.5.2 Gravity dry dock floors

Gravity floors are those which have sufficient mass themselves, or are able to call upon sufficient mass, to overcome the upward pressure of the ground water. In the second case, equilibrium may be obtained by taking into account the mass of the dock walls and backfill where appropriate, and by spanning the floor across the width of the dock, thereby providing a uniform resistance to the uplift pressure.

Thick, and therefore heavy, floors may be necessary when the concentrated ship loads have to be spread over a large area due to weak soil conditions.

Advantage may be taken of this to produce a gravity design. If the soil is of high permeability and the continuous pumping of ground water would be an uneconomic proposition for the life of the dock, a gravity design may also be appropriate. Narrow docks can more easily be designed as gravity structures than wide ones, since the walls form a greater proportion of the whole.

2.5.3 Under-drained floors

Under-drained dock floors are those which provide for the ground water below the floor to be pumped away so that no net uplift pressure is allowed to develop.

It is normal to provide an underfloor drainage layer of gravel or no-fines concrete combined with a series of porous pipes and culverts, which are led to a separate and enclosed sump in the pumphouse. It is recommended that the pumping from the sump 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.

If the dock remains full for an extended period and the underfloor pumping is stopped, the ground water levels immediately surrounding the dock may rise. When, subsequently, the dock is to be emptied, it is essential to start the underfloor drainage pumping beforehand and in due time to reduce the ground water pressure to a safe value to avoid uplift conditions.

In some cases, notably when the dock is on rock of low permeability, it may be possible to relieve the underfloor water pressure by allowing it to discharge directly into the dock. Non-return valves may be placed on the inlets into the dock to prevent water from the filled dock back flowing into the ground. These valves may be subjected to damage from shipbuilding or ship repairing operations and should be regularly inspected and maintained.

It is recommended that a simple pressure relief system 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. Such a system can be provided for fully pumped schemes by introducing manhole covers over the underfloor drainage culvert which will lift off as the unacceptable pressure develops.

It is also recommended that the system be vented to the atmosphere at its upper extremity by a vent pipe rising above maximum sea level. This avoids high air pressures developing during filling of the dock.

Some leakage from the filled dock into the underfloor drainage system is inevitable but should be kept to the minimum to avoid excessive pumping.

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. Extra pumping may be necessary when one part of the floor is inadvertently flooded due to downward leakage from an intentionally flooded part. 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.

2.5.4 Tied floors

Tied dock floors are those which do not have sufficient weight to withstand the hydrostatic uplift of the ground water and have to be tied to the soil below the dock for equilibrium. Reference should be made to clause 53 of BS 6349-1:1984 for methods of anchorage.

Tension piles, which also act as compression piles when supporting ship loads, should be very carefully studied before use, since the reversal of load may tend to break down the adhesion between the soil and the pile. Failures of dock floors designed on this principle have been recorded. It should be noted that the maximum total downward load to which the dock floor will be subjected occurs when the dock is flooded and that a full reversal of load can occur at each docking.

The prestressing of piles may avoid reversal of stress and thus overcome to some extent this particular problem. However, the use of steel at high stress for prestressing should receive most careful consideration before adoption. The difficulty of excluding or displacing all water from prestressing tendons makes this type of anchorage subject to brittle failure. The cause of failure has been attributed to both stress corrosion cracking and to hydrogen embrittlement but there is evidence that the latter is the most usual cause in the case of steel stressed to a large proportion of its yield strength. Atomic hydrogen, which causes embrittlement when it diffuses into steel, may arise either as a result of low pH (acidic) conditions or as a result of local electrolytic action. Only small quantities of water need to be present to provide the source of such hydrogen so that the exclusion of all moisture is most important. All types of prestressing tendon are susceptible to stress corrosion cracking and should be adequately protected. 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.

2.5.5 Floors bearing directly on ground

The ground immediately under the dock floor may, in suitable conditions, be used to support the concentrated load 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 thin, reinforcement may well be necessary and the thickness of the floor can be varied to suit the imposed loads and moments.

2.5.6 Floors supported on piling

Piling may be required to support the floor when weak soil is present at the subfloor level. Piles may be used in conjunction with an under-drained floor, in which case, they may be designed solely as compression piles supporting only the downward vertical loads.

The floor and piles should be designed to carry the maximum moments and loads indicated by the design loading. It is pointed out that the use of piles tends to limit flexibility in the layout of ship supporting blocks, unless there is a considerable excess of piling used.

2.5.7 Ground improvement

The bearing capacity of poor ground at subfloor level can, in some cases, be improved by ground improvement methods.

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

The driving of timber piles at close centres to stiffen the ground has successfully been used in areas where cheap timber is readily available. Timber in saturated ground will normally 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 consideration should be given to the time taken for these processes, since the work has to be carried out in a deep, open excavation before adjacent permanent work is carried out. These methods are sometimes rejected for this reason.

Ground improvement would normally be considered for docks where underfloor drainage is envisaged. Such a permanent drainage scheme can itself cause shrinkage of certain soils with the consequent risk of long-term settlement of the floor. Under those conditions ground improvement is unlikely to be appropriate.

2.5.8 Floors constructed under water

Where dewatering of the site is impossible or prohibitively expensive, it may be necessary to construct the dock floor under water. Various concreting methods have been successfully used for this purpose, including bottom-opening skips, tremie pipes and grout intrusion of pre-placed aggregate. Dock floors, constructed under water are normally of gravity design and therefore thick, but are difficult to make watertight in these conditions. Reference should be made to BS 6349-1 with respect to under-water concrete.

Provision may have to be made for seepage by casting an impervious layer of concrete on top of the mass concrete 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. In any case, a finishing layer of concrete would normally be required to produce the required accuracy of profile of the dock floor.

2.5.9 Longitudinal slope of floors

Dry docks may either be provided with a longitudinal fall on the centre keel line of between 1 : 200 and 1 : 400 or may be laid level.

The inclination is normally arranged as being down towards the dock entrance, which coincides with the normally stern-down trim of a ship entering dock bow first and so tends to reduce seaward loads when the ship settles. Thus, docks with longitudinal inclinations tend to be suitable for ship repairing.

As shipbuilders normally prefer the keel of a ship to be horizontal when under construction and the keel blocks to be of constant height, docks with horizontal floors tend to be suitable for shipbuilding.

2.5.10 Drainage

Transverse falls of the order of 1 : 100 from the line of the keel blocks to the dock walls may be introduced and will usually be associated with longitudinal channels formed to carry the water to the pumphouse sump.

A transverse channel or duct may be required to connect the remote longitudinal channel to the sump. Such an arrangement, combined with a longitudinal fall, will dry out the floor quickly and will ensure that the minimum time is lost while awaiting access to the floor. It is, therefore, suitable for ship repair docks, which are normally flooded at frequent intervals. This arrangement is not always suitable to shipbuilders, particularly in very wide docks, where the difference in level between the floor at the keel and at the walls will be considerable. In such cases, transverse channels at close intervals are sometimes introduced with the floor falling fore and aft into the ducts.

In dry docks fitted with an intermediate gate, provision should be made for drainage of the head end of the dock when the gate end is flooded. It is essential that a separate sump and pump be provided.

2.5.11 Cleaning

The use of shot blasting and, to a lesser extent, high pressure water methods of cleaning ships in dry dock produces a large quantity of debris to be removed. Various methods are used but consideration should be given to providing suitable containers, possibly in recesses in the floor, which can collect the 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 considered and upstanding steelwork gratings, holdfasts, etc. should be avoided. Joint sealants in the floor should not project above floor level for the same reason. (See Figure 6.)

2.5.12 Services

Provision for services at dock floor level, both near the walls and in the body of the dock, may sometimes be required. Transverse ducts with flush covers may be required and consideration may be given to the dual use of transverse drain channels to accommodate the service pipes.

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

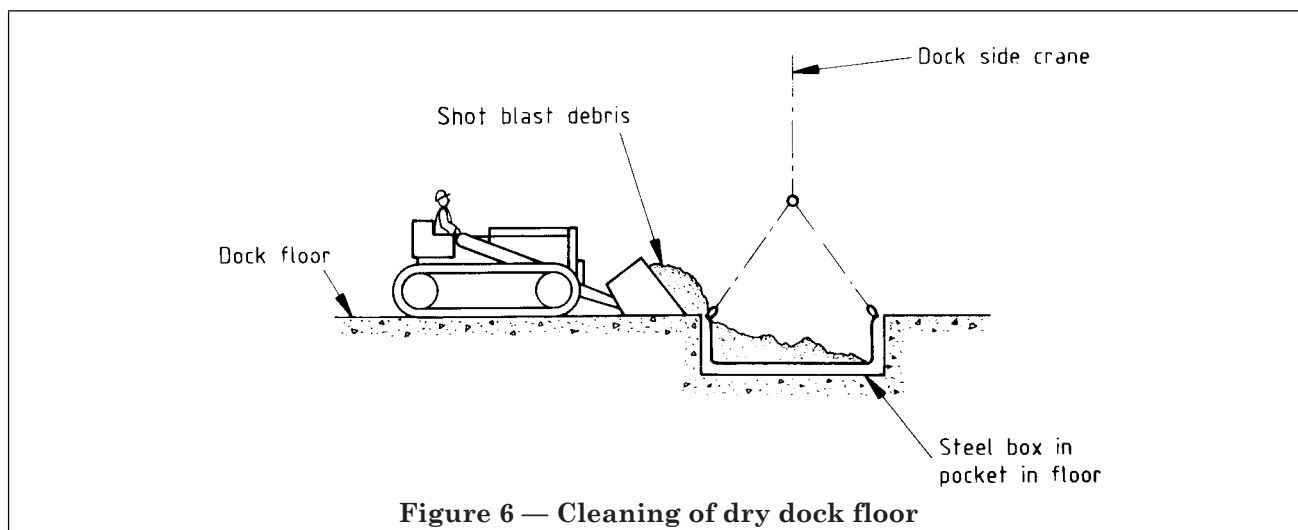


Figure 6 — Cleaning of dry dock floor

2.5.13 Joints

Consideration should be given to initial shrinkage in the concrete of the dock floor by providing 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 carefully arranged.

The provision of expansion joints in dry dock floors should be very carefully considered. 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. It is also difficult to transfer loads across the joints and to maintain their watertightness. Expansion joints should, therefore, be used only in exceptional circumstances.

2.5.14 Loading on dry dock floors

Dry dock floors should be designed to withstand the worst combination of loads from the ships or structures likely to use the dock.

2.5.15 Loading on ship repairing dock floors

The loading to which the dock floor will be subjected will not be known with precision but the loadings given in 2.5.17 and 2.5.18 may be used for preliminary studies.

Average loadings follow directly from the docking displacement of the design vessel (see 2.5.16) but the magnitude 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 2.5.17 and 2.5.18 are those which may occur once the dock has been dewatered and the ship is supported by the blocks. Account should also be taken of those loads which occur only as a ship sews or settles on to the blocks. Depending upon the differences in trim between the ship's keel and the blocks, sewing loads can reach significant magnitudes.

Ships will normally be docked on a line of keel blocks and two or more symmetrically disposed lines of bilge blocks arranged parallel to the keel blocks. In large dry docks, ships may not necessarily be positioned centrally and the dock operator's practice in positioning both vessels and blocks should be accommodated in the design. In some cases, it may be necessary to design for the occurrence of line loads over a very large part of the dock floor.

Design loadings should be chosen after consultation with the dock operator but, for the purpose of preliminary design, ships may be considered as being divided into two categories, namely, those which are stiff transversely, i.e. most of their weight rests upon a central line of keel blocks, and those larger vessels in which the weight is more evenly spread over all the blocks. The boundary between the two categories may be taken as about 100 000 dwt.

For the smaller vessels, 95 % of the docking displacement may be assumed to be carried on the keel blocks and 15 % distributed between two lines of bilge blocks. Bilge blocks may be positioned at distances from the keel blocks of between one-sixth and one-third of the ship's beam.

Keel blocks for larger vessels should be designed for 60 % of the docking displacement and 50 % of the displacement should be assumed to be distributed between bilge blocks placed at distances between one-twelfth and two-fifths of the ship's beam from the keel blocks. The narrowest separation of bilge blocks is likely to occur only under a ship's bow or stern.

Dock floor loadings may be represented by a line load equal to the average keel and bilge block loading intensities together with local concentrated loads to represent the effects of unequal block loadings and of local increases in distributed load associated with concentrations of mass within the ship. Such concentrations typically occur beneath the engine room and the tanks used for ballasting. Much greater concentrations than those occurring in keel blocks have been observed in bilge blocks. Keel blocks may be assumed to extend for 100 % of the length between perpendiculars (LBP). Bilge blocks may 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.

The keel and bilge block loadings on which the recommendations given in **2.5.17** and **2.5.18** are based were measured in a dock with a floor founded on rock which is, in consequence, very stiff. The large load intensities observed were probably accentuated by the stiffness of the floor and, in other circumstances, the loads represented by those intensities might be spread over a greater length. It is important in the design of any dock floor to make provision for the support of similar total loads to those given in **2.5.17** and **2.5.18**, spread in a manner appropriate for the particular design.

2.5.16 Docking displacement

Docking displacement may be estimated from the product of

$$0.7 \times \text{LBP} \times \text{beam} \times \text{mean docking draught}$$

An approximate mean docking draught may be taken as:

for cargo liners: two-thirds of the loaded draught

for passenger vessels: three-quarters of the summer draught

for tankers and bulk carriers: 5 m.

2.5.17 Keel block loading

The keel block loading, which in every case assumes that reverse docking may take place, consists of 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 keel, as shown in Figure 7. 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 7 and it should be noted that the intensity of the local loads is higher when they are located in the end sections of the keel for vessels larger than 100 000 dwt. No local loads are to be applied nearer than 0.04 (LBP) to the ends of the keel.

2.5.18 Bilge block loading

The bilge block loading, which in every case assumes that reverse docking may take place, consists of a uniformly distributed line load operating on a fraction of the length of the keel plus, in the case of vessels over 100 000 dwt, a single local concentrated load of finite length operating at any location in the end sections (see Figure 8). No concentrated load is required for ships up to 100 000 dwt.

NOTE The above loading applies to each side of the dock. Where more than two lines of bilge blocks are used the loading for each side of the dock may be divided equally between the bilge blocks on that side of the dock.

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).

2.5.19 Loading on shipbuilding dock floors

For shipbuilding dry docks, the determination of block loading for design purposes is even less precise than for ship repairing docks for a number of reasons, including the following.

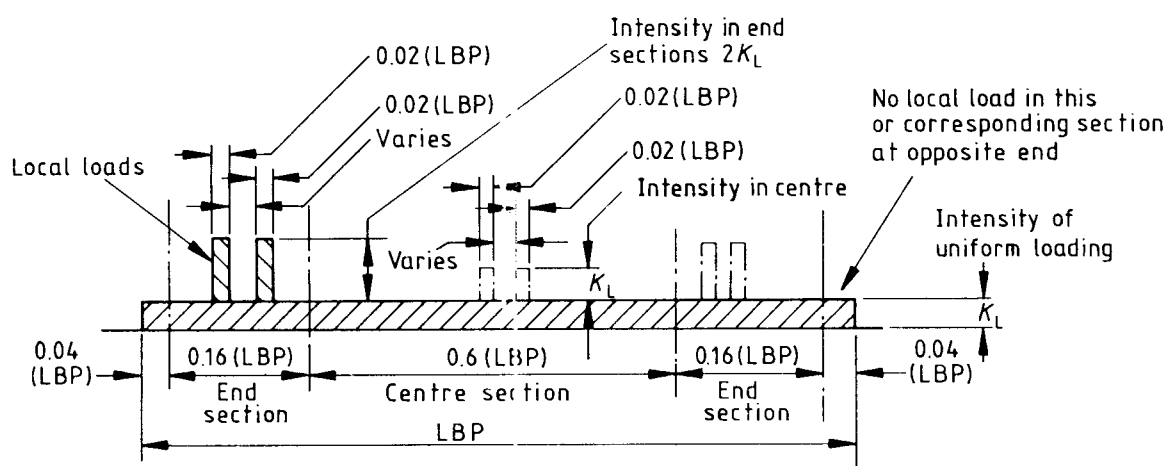
- a) The arrangement of blocks for shipbuilding is related to the size of prefabricated units of the new ship's hull and the blocks are normally more evenly spread under the hull than the blocks required for ships docked for repair.

b) It is not unusual for a ship to be constructed on one side of the dock floor or for two or more ships to be built simultaneously side by side in a large dock. It cannot, therefore, be assumed 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 may produce very 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 may have to return to the shipbuilding dock after fitting out afloat, when normal ship repair docking supports would be used. However, docking may not be on the centre line of the dock.

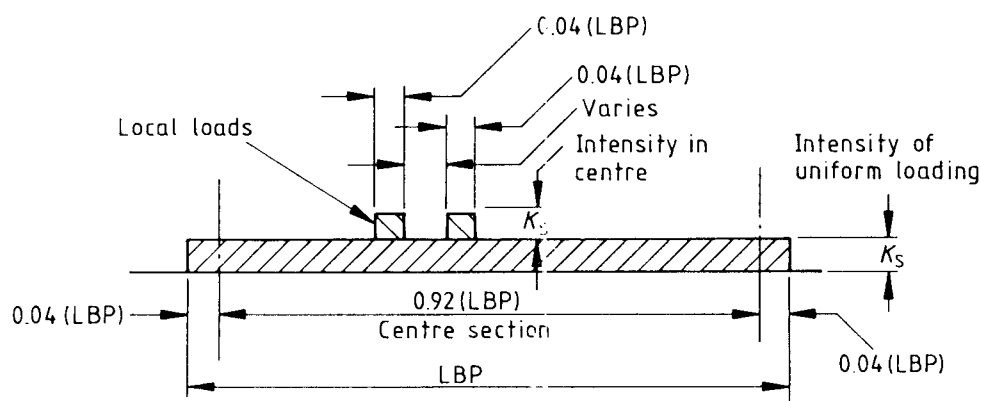
For the reasons given in a) to d) it may be preferable to assume that a set of arbitrary line loads and point loads are applied to the floor and that this loading may occur at any position on the floor.



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

K_L is the intensity of uniformly distributed load in a large vessel.

(a) For ships larger than 100 000 dwt



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

K_S is the intensity of uniformly distributed load in a small vessel.

(b) For ships up to 100 000 dwt

Figure 7 — Keel block loading