BS 6349-8:2007

BRITISH STANDARD

Maritime structures –

Part 8: Code of practice for the design of Ro-Ro ramps, linkspans and walkways

ICS 47.020.99; 93.140

British Standards

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Summary of pages

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Foreword

Publishing information

This part of BS 6349 is published by BSI and came into effect on 30 April 2007. It was prepared by Subcommittee B/525/11, *Maritime structures*, under the authority of Technical Committee B/525, *Building and civil engineering structures*. A list of organizations represented on this committee can be obtained on request to its secretary.

BSI Committee B/525 takes collective responsibility for the preparation of this part of BS 6349. The Committee wishes to acknowledge the personal contribution of Paul Lacey C Eng, FICE, FI Struct E., FIHT, FRSA, Chairman of B/525 from 1986 to 2005.

Relationship with other publications

This is a new part of the BS 6349 series. The other parts in the series are:

- Part 1: *Code of practice for 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: *Code of practice for design of fendering and mooring systems*;
- Part 5: *Code of practice for dredging and land reclamation*;
- Part 6: *Design of inshore moorings and floating structures*;
- Part 7: *Guide to the design and construction of breakwaters*.

This part of BS 6349 should be read in conjunction with BS 5400. When using BS 5400 the word "bridge" should generally be read as "structure". The various loads and load factors to be used when considering the ultimate limit state and serviceability limit state should be as given in Clause **8** of this part of BS 6349.

An alternative approach to the design of Ro-Ro ramps, linkspans and walkways is given in the Lloyd's Register *Rules and regulations for the classification of linkspans* (hereinafter referred to as *Lloyd's Rules*). BS 5400 is an ultimate limit state code and *Lloyd's Rules* is a working stress design code, and the treatment of load factors and vehicle impact factors is very different between the two codes. It is permissible to use both *Lloyd's Rules* and BS 5400 in the design of the same structure, provided that the designer takes the full implications of each code into account.

Both *Lloyd's Rules* and BS 5400 can be used as the basis of structural design of linkspans, but only *Lloyd's Rules* gives guidance on the structural design of floating structures.

CIRIA report C518 [1] gives an extensive discussion on the coverage and limitations of *Lloyd's Rules*.

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Information about this document

Assessed capability. Users of this part of BS 6349 are advised to consider the desirability of quality system assessment and registration against the appropriate standard in the BS EN ISO 9000 series by an accredited third-party certification body.

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 part of BS 6349 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 part of BS 6349 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.

Attention is drawn to the regulations listed in the Note to **4.4**.

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0 Introduction

0.1 Design traditions

The design of Ro-Ro linkspans and walkways has historically been carried out by two types of designers: highway bridge designers and naval architects. These two types of designers have historically used different types of design rules. Bridge designers have referred to bridge design codes, such as BS 5400. Naval architects have referred to *Lloyd's Rules*.

This part of BS 6349 includes recommendations for a number of issues that are not covered by either BS 5400 or *Lloyd's Rules*. In particular:

a) BS 5400 does not cover:
   - pontoons or floating structures;
   - overall hydrostatic stability;
   - wave, current and ship-induced loadings;
   - aluminium structures;

b) *Lloyd's Rules* does not cover:
   - specific rules for upstanding plate girders with U-frame action;
   - specific rules for dealing clearly with members in which lateral torsional buckling is likely;
   - overall hydrostatic stability;
   - concrete structures.

In addition to these differences, BS 5400 assumes a design life or return period of 120 years, whereas this part of BS 6349 deals with structures that have an anticipated design life of 30 years.

0.2 Limit states

Ultimate Limit State (ULS) and Serviceability Limit State (SLS) are terms defined by BS 5400 and are not used in *Lloyd's Rules*. If it is necessary to use these terms in conjunction with *Lloyd's Rules*, the following interpretations can be made:

- the ULS is the load or effect combination causing the largest stresses for comparison with the allowable stresses permitted by the *Rules*;
- the SLS is the load or effect combination causing the largest deflections or movements for comparison with the deflections or movements permitted by the *Rules*.

The Ultimate Limit State (ULS) usually covers:

- overall failure by rupture or yielding;
- overall instability by overturning or sinking;
- collapse, loss or removal of support to elements, including linkspans, ship ramps, adjustable flaps, flaps, fingers and bearings;
- failure or malfunction of operating machinery;
- failure by fatigue.

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The Serviceability Limit State (SLS) usually covers:

- excessive deflection, slip within components, cracking of concrete, yielding, damage to finishes or protective coatings, all as defined by the various parts of BS 5400;
- grounding of vehicles causing damage or gross discomfort to users;
- excessive gaps, gradients, obstructions and other impediments to the safety of users of the facility;
- loss of reliability or performance of operating machinery due to excessive wear, impact or other effect;
- traps/pinch points.

0.3 Design conditions

0.3.1 Operating condition

This is when traffic is permitted on the facility and when traffic might travel between successive surfaces over joints where relative articulation or movement can occur. The maximum range of water levels, sea state and wind effects appropriate to the operating condition of the facility will not necessarily encompass the maximum movement of loads for which the facility is to be designed. At both ultimate and serviceability limit state all traffic and pedestrian areas need to be loaded such as to cause the maximum detrimental effect.

Additional SLS checks for clearances, movements, etc., need to be made with the associated live loading as appropriate. This is particularly the case with pontoon-supported linkspans because the linkspan's freeboard could vary as traffic traverses the pontoon or floating body.

0.3.2 Extreme tidal condition

This is when the facility is subjected to loads and/or movements arising from the most severe tidal and sea state conditions expected during its design life. Depending on operational requirements, traffic and pedestrian loading might be excluded in these circumstances, except for emergency vehicle loading. The risk assessment in **4.2** is expected to identify whether the circumstances are such that only the ultimate limit state need be considered.

0.3.3 Methods of adjustment

In Method I, the linkspan is supported by a system distinct from the lifting system. This support system ensures that the mass of the ramp and live loads are fully supported during boarding operations; and maintenance vehicles are fully supported during lifting system repair and replacement periods. Therefore the lifting system only supports permanent and environmental loads.

In Method II, the lifting system supports the linkspan during boarding operations whether being adjusted or not.

The systems of support include a floating pontoon or semi-submersible buoyant tank as well as mechanical lifting systems.

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0.3.4 Prevention of collapse

The ramp supporting system needs to be designed to prevent sudden or catastrophic failure of the ramp, taking into account both the ultimate limit state and the serviceability state.

The risk assessment undertaken for the linkspan is expected to identify the conditions and loadings to which the linkspan and any machinery is likely to be subjected throughout its life.

Appropriate measures need to be taken to ensure that these risks are mitigated. A linkspan with a suspension system requires particular consideration (see **8.8**).

0.3.5 Maintenance condition

This occurs during the time when the facility is not in use by vehicles or pedestrians, and is relevant to the design of spragging or parking facilities for the facility whilst being maintained, or stored out of use. Allowance needs to be made for specified maintenance vehicles and materials. The maximum range of water levels and sea state is appropriate to the extreme tidal and sea state condition.

0.3.6 Design criteria

The criteria for the operational conditions need to be agreed with the end user.

1 Scope

This part of BS 6349 gives recommendations for the design of roll-on/roll-off (Ro-Ro) ramps, linkspans and walkways, used for the transfer of passengers and vehicles between shore and ship.

It applies to the structural elements only and does not cover the design of any operational equipment, traffic control, mechanical or electrical equipment, heating, lighting, life saving or rescue equipment other than as the structures forming a facility need to incorporate and/or support any of these features. Most geometrical aspects of fixed shore ramps are covered in this part of BS 6349, but recommendations for all other aspects are given in BS 6349-2.

This part of BS 6349 does not apply to Ro-Ro facilities used by rail vehicles in that it does not give recommendations for railway loading and associated ramp gradients. However, many of its recommendations are applicable to rail Ro-Ro facilities and can be used in the absence of other guidance.

NOTE This part of BS 6349 is generally intended to cover facilities constructed in the British Isles. Although the majority of the contents are directly applicable elsewhere, local conditions might necessitate modifications, e.g. environmental effects and traffic loading.

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2 Normative references

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

Standards publications

BS 5400 (all parts), *Steel, concrete and composite bridges*

BS 6349-1:2000, *Maritime structures – Part 1: Code of practice for general criteria*

BS 6349-2:1988, *Maritime structures – Part 2: Design of quay walls, jetties and dolphins*

BS 6349-4:1994, *Maritime structures – Part 4: Design of fendering and mooring systems*

BS 6349-6:1989, *Maritime structures – Part 6: Design of inshore moorings and floating structures*

BS 6399-2:1997, *Loading for buildings – Part 2: Code of practice for wind loads*

BS 6399-3, *Loading for buildings – Part 3: Code of practice for imposed roof loads*

BS 6779-1:1998, *Highway parapets for bridges and other structures – Part 1: Specification for vehicle containment parapets of metal construction*

BS 7818:1995, *Specification for pedestrian restraint systems in metal*

BS 8004, *Code of practice for foundations*

BS EN 1997, *Eurocode 7 – Geotechnical design*

BS EN ISO 14122 (all parts), *Safety of machinery – Permanent means of access to machinery*

ISO 7061, *Shipbuilding – Aluminium shore gangways for seagoing vessels*

Other publications

LLOYD'S REGISTER. *Rules and regulations for the classification of linkspans*. London: Lloyd's Register, 2003.

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3 Terms, definitions and symbols

3.1 Terms and definitions

For the purposes of this part of BS 6349, the definitions given in BS 6349-1 and the following apply.

3.1.1 abutment
structure onto which the shore bearings of a linkspan, shore ramp or link bridge are seated

NOTE 1 An abutment can provide resistance against anchorage forces. It can be placed at the edge of the quay, jetty approach bridge or on the edge of a reveted reclamation slope.

NOTE 2 An abutment is sometimes referred to as a "bankseat".

3.1.2 approach ramp
fixed ramp or bridge structure at the shore end of a linkspan to allow access between the linkspan roadway level and the normal quay or paving level

3.1.3 approach span
bridge structure at the shore end of a linkspan, which is normally fixed in place

3.1.4 belting
projecting continuous-protective strip along the side of a Ro-Ro ship or ferry

NOTE Belting is usually at the level of the main vehicle deck, although at the bow or stern it might be at more than one level.

3.1.5 berthing line
front face of fenders alongside a quay or other type of berth

3.1.6 blunt-ended ramp
ramp that is not equipped with flaps

3.1.7 boarding pod
platform that is mechanically or buoyantly lifted, which allows pedestrian access to a ship via a brow or gangway and is connected to the hinged link

3.1.8 brow
bridge that is hinged onto a boarding pod or telescopic end and either rests on the coaming or other means of support at the ship's passenger access door or opening, or is supported by cantilever action from the boarding pod or the telescopic end

3.1.9 coaming
upstand from the deck plate at the passenger entrance in the hull of a ship or raised edge along an open deck on a ship

3.1.10 designer
person or organization that carries out the design of the structures which form a facility or part of a facility

3.1.11 design water level variation
variation of the water level that is used to establish gradients and dimensions for a facility

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3.1.12 drawbridge
liftable bridge section hinged at the shore end and supported by a mechanical strut or tie or rope system at the seaward end

3.1.13 extreme water level
highest or lowest water level that is predicted to exist at a facility

3.1.14 facility
part of a port that deals with Ro-Ro ships

3.1.15 finger flap
narrow bridging element generally hinged to the end of a linkspan or ship ramp, which allows for varied amounts of articulation across the road or walkway width

3.1.16 fixed shore ramp
fixed inclined structure between the normal quay level and a level upon which the shore end of a ship ramp can rest

3.1.17 fixed walkway
walkway structure that has no moving parts

3.1.18 flap
extension, normally hinged to a ship or to the shore end of a linkspan, that provides a transition with an adjacent road or walkway where relative articulation or movement could occur

3.1.19 gangway
bridge that is hooked onto the coaming and supported on the telescopic end, boarding pod or drawbridge

3.1.20 guide pile
vertical pile that is used as a guide structure to restrain a pontoon/link bridge or semi-submersible or integral tank type linkspan from floating away, but allows it to move up and down with the rise and fall of the tide

3.1.21 hinged link
bridge between a ship or a boarding pod that is capable of rotating to take up level differences between the terminal building and the ship

NOTE A hinged link always rotates in the vertical plane, but can also rotate in the horizontal plane.

3.1.22 hoist tower
structure mounted on the shore or on a dolphin for supporting the lifting equipment of a mechanically lifted type of linkspan

3.1.23 interface
boundary between a ship ramp, ship vehicle access opening or ship passenger access opening and a linkspan or passenger walkway

3.1.24 interface limit line
seaward end of a ship ramp landing area

3.1.25 lifting frame
fixed or carriage-mounted frame that supports the lifting equipment

3.1.26 link bridge
bridge connecting a pontoon to the shore

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3.1.27 linkspan
articulating structure, which can be a floating or a lifted bridge structure, that links a Ro-Ro ship either directly to the shore, to a fixed structure or to a pontoon, or that links a pontoon with the shore

NOTE The term "linkspan" can also refer to facilities comprising a pontoon and link bridge combined.

3.1.28 motorized carriage
rail-mounted or rubber tyre-mounted bogey and carriage system that is motorized

3.1.29 operating water level
high or low water level at which operations are allowed to be carried out, i.e. traffic or passengers can be transferred across a facility

3.1.30 operator
person or organization responsible for operating a facility

3.1.31 passenger walkway
ship-to-shore facility for the transfer of pedestrians, capable of vertical and/or horizontal adjustment at the ship end and incorporating any fixed walkway

3.1.32 pontoon
floating structure of large plan area relative to its draught used as a buoyant support for a link bridge to the shore and sometimes as a manoeuvring area for vehicle movement

NOTE The ship ramp rests on the ship end of the pontoon.

3.1.33 project adviser
person who helps the purchaser to identify the options for procurement and who assists in preparing the project brief

3.1.34 restraint systems

3.1.34.1 pedestrian restraint system
device to restrain pedestrians from falling off the edge of a structure or part thereof, or to guide pedestrians to keep them from unsafe terminal or vehicle movement activities

NOTE Examples of pedestrian restraint systems include pedestrian parapets, guardrails and handrails.

3.1.34.2 vehicle restraint system
device to keep vehicles in designated traffic lanes, to protect vulnerable features or to prevent vehicles from driving off the edge of a structure.

NOTE 1 Examples of vehicle restraint systems include vehicle parapets and safety barriers.

NOTE 2 Vehicle restraint systems are also known as road restraint systems.

3.1.35 Ro-Ro ramp
fixed ramp or bridging structure that enables vehicles to pass between a Ro-Ro ship's vehicle decks and the shore

NOTE Either the ship ramp lands on the end of the fixed ramp, or the fixed ramp is between the linkspan and the shore. Ro-Ro ramps include approach ramps, approach spans and fixed shore ramps.

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3.1.36 semi-submersible linkspan
linkspan that derives its seaward support from a fully submerged underwater tank, usually with narrow legs between tank and bridge desk, but which is additionally supported by the ship or other means during operation

3.1.37 service walkway
designated route for use by service operational personnel only

3.1.38 ship ramp
adjustable structure fitted to a ship that when lowered to and resting on the approach structure, quayside, or linkspan, forms the connecting roadway between the ship and approach structure, quayside, or linkspan

3.1.39 slave carriage
rail-mounted or rubber tyre-mounted carriage that is not motorized but moves when pulled by a motorized carriage

3.1.40 slave pod
platform supported on a slave carriage

3.1.41 sprag
short pin or bar used to support a lifted platform or structure at a particular height on a spragging frame or beam so that the lifting equipment can be taken out of operation

3.1.42 systems engineer
person appointed by a contractor or supplier to carry out the co-ordination of the electrical and mechanical aspects of linkspan or walkway works, including design, manufacture, commissioning and handover

3.1.43 telescopic end
section at the end of a hinged link or drawbridge that is co-linear with the hinged link or drawbridge and capable of being extended telescopically

3.1.44 traversing drawbridge
drawbridge that is able to traverse laterally in a boarding pod and hinge vertically

3.1.45 threshold height
height of a vehicle or passenger deck above the water level at the vessel's door opening

3.1.46 well deck
platform on the ship end of a linkspan or pontoon, set at a lower level than the roadway, onto which a blunt ended ramp can rest

3.1.47 whole life cost
cost of construction, maintenance and removal of a structure

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3.2 Symbols

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

A_2	solid area in normal projected elevation, viewed longitudinally, of a structure, in square metres (m^2)
a_1, a_2, etc.	surface areas of individual windward face, leeward face, roof and floor, in square metres (m^2)
C_D	drag coefficient relating to frontal area
C_F	frictional drag coefficient depending on the surface roughness
c	speed of wave propagation in a material, in metres per second (m/s)
E	Young's modulus of a material, in newtons per square metre (N/m^2)
H_{max}	maximum design wave height, in metres (m)
j	maximum ordinate on influence line, in newtons (N)
L_b	base length of influence line, in metres (m)
N	whole number of lanes greater than 3
n	number of effective longitudinal members in a parapet
P_{LL}	total longitudinal wind load from live load, in newtons per square metre (N/m^2)
P_{LS}	total longitudinal wind load from structure, in newtons per square metre (N/m^2)
P_T	transverse wind force, in newtons per square metre (N/m^2)
q	dynamic pressure head as defined in BS 5400-2:2006, **5.3.3**, in newtons per square metre (N/m^2)
T	magnitude of proof test load, in newtons (N)
V	velocity of impact, in metres per second (m/s)
V_b	basic hourly mean wind speed, in metres per second (m/s)
V_d	maximum wind gust speed, in metres per second (m/s)
V_s	site hourly mean wind speed, in metres per second (m/s)
W	applied design load, in tonnes (t)
γ_{fL}	partial load factor
γ_{f3}	factor that takes account of the inaccurate assessment of the effects of loading, unforeseen stress distribution in the structure, and variations in dimensional accuracy achieved in construction.
γ_m	reduction factor specified in the relevant parts of BS 5400
ρ	density of a material, in kilograms per cubic metre (kg/m^3)

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4 General recommendations

4.1 Planning

The purpose of a Ro-Ro ramp, linkspan or walkway is to enable the safe transfer of traffic between the shore and the designated ships, taking account of relevant environmental considerations, for the design working life of a facility. When planning a Ro-Ro facility, account should be taken of current traffic requirements, the number and type of ships, and also the possibility of future developments which could economically be met by modification or relocation of part of all of the facility. Fixed ramps should be designed in accordance with BS 6349-2:1988, Section **8**.

Assessed capability. *Users of this British Standard are advised to consider the desirability of quality system assessment and registration against the appropriate standard in the BS EN ISO 9000 series by an accredited third-party certification body.*

NOTE The Introduction gives information on the historic background to the methods recommended in this part of BS 6349 and the design philosophy behind the recommendations.

4.2 Risk assessment

It is essential to undertake a fundamental risk assessment prior to establishing the exact type of facility to be provided. This should take into account the hazards, risks and consequences of all credible uses and failure modes of the facility. The form of the facility should be selected such that the structural integrity and control systems are not compromised.

Further risk assessments should be carried out, as part of the design process, for each element of the facility.

The effects of extreme environmental conditions should be included in the assessment.

4.3 Operation and maintenance manual

Each facility needs to have an operation and maintenance manual, which is usually written by the supplier of the facility. The author of the manual is expected to be experienced in the writing of such manuals for machinery but is often not in possession of the overall design specification for the facility. It is the designer's responsibility to supply the author of the manual with all information that the author needs concerning the overall capability and limitations of the facility.

4.4 Design parameters

NOTE Attention is drawn to the following regulations:

- *Supply of Machinery (Safety) Regulations 1992 [2];*
- *Management of Health and Safety at Work Regulations 1992 [3];*
- *Lifting Operations and Lifting Equipment Regulations 1998 [4];*
- *Provision and Use of Work Equipment Regulations 1998 [5];*
- *Construction (Design and Management) Regulations 1994 [6].*

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4.4.1 General

Design parameters that are likely to affect the overall concept of the facility should be established to form a project brief.

4.4.2 Layout of facility

The overall layout of the facility should be established early on in the procurement process and before detailed design of the facility is commenced. It should include the required numbers and relative location of linkspans and walkways, taking account of the anticipated traffic flows, type of ships, and location of loading and discharge points onto the ships.

In the design of the facility, account should be taken of the need to provide an adequate means of escape in the event of emergency, including fire escape arrangements.

4.4.3 Ships

The type and characteristics of ships that are expected to use the facility should be determined. Information that should be obtained for each ship includes:

- draught;
- beam;
- length;
- displacement;
- threshold height dimensions;
- dimensions and positions of openings and deck accesses;
- height of ship belting;
- propulsion system forces;
- ship ramp details (e.g. dimensions, flaps, permitted gradients and mass);
- variation of ship trim and roll during the unloading and loading cycle;
- passenger and ship access door positions;
- swept geometry of bow visors or clamshell doors;
- the geometry of bulbous bows;
- whether multi-deck access is required.

Depending upon the type of ship, it should be determined whether loading and discharge is at bow, stern, side or any combination of these.

Where the Ro-Ro ship does not have a ship ramp, full details of the ship openings should be obtained, including the vertical profile within the ship, so that the requirements for any finger flaps forming part of the facility can be determined. Other details of ships should be obtained that might affect the facility, such as protrusions below water line and location of propellers.

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4.4.4 Usage and design life

The frequency of ship berthing and required speed of turn-around should be established, together with any demands for continuity of use and seasonal use. The intended maintenance regime, including availability of competent personnel, should be investigated and agreed with the maintenance organization. The intended design life should be determined. A design life for structural elements within the facility is typically taken as 30 years for the purposes of verifying fatigue endurance.

4.4.5 Method of ship control

The method of control of ship movements, including berthing and mooring procedures, should be established for all ships that might use or could affect the facility. This can affect a decision as to whether the facility is required to perform any function in the berthing and mooring of ships. Wherever practicable the arrangements for berthing and mooring of ships should use independent elements such as berthing fenders or mooring dolphins that do not involve the transfer of loads through linkspans or walkways. Fixed ramps should be designed in accordance with BS 6349-2:1988, Section **8** and design criteria should be determined in accordance with BS 6349-4.

The facility should be designed to take into account the possibility of accidental or residual impact and to minimize any adverse effects from such an impact.

4.4.6 Degree of automation in operation of facility

The degree of automation of the linkspan or passenger walkway should be determined taking account of the envisaged usage (see **4.4.4**). This can affect the method of height or other adjustment to be used and the form of traffic control, e.g. whether vehicles are likely to be present on the facility during adjustment.

4.4.7 Adjustment of facility

Where the design water level variation is too great for a fixed shore ramp used in conjunction with the ramp of a ship (normally a maximum of 1.5 m), a device for height adjustment of the facility at the ship end should be provided. The amount of height adjustment should be established for each deck level where access is to be provided. In certain cases transverse adjustment might be necessary in order to cater for different locations of ship openings. This applies especially in the case of passenger walkways.

Longitudinal adjustment might also be necessary to cater for different ships, especially where access is required to more than one deck level. The need for longitudinal adjustment, and the required amount thereof should be established and taken into account.

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4.4.8 Types of vehicles

The types of vehicles that are likely to use the facility should be established. These might include all or any of the following:

- cars with restricted height (e.g. 1.8 m);
- cars with extra height;
- cars with caravans;
- vans;
- coaches;
- HGVs;
- port vehicles, e.g. tractors, roll-trailers, cranes, fork-lift trucks;
- military vehicles, e.g. tanks;
- vehicles with abnormal mass;
- vehicles with abnormal height, width or length;
- vehicles required for the maintenance of the facility.

The numbers of each vehicle type for each ship berthing should be estimated, taking account of the type of ships (see **4.4.3**) and the envisaged usage (see **4.4.4**).

4.4.9 Passenger traffic

The number of passengers who are likely to be using a passenger walkway at a given time should be determined, together with the method by which passengers will be transferred from the terminal building onto the ship, as this will affect the extent and widths of walkways. Where there is to be specific provision for disabled access, allowance might have to be made for more gradual gradients and extra landings. Details of typical gradients are given in **6.3.3**.

NOTE Attention is drawn to the Disability Discrimination Act 1995 [7].

4.4.10 Parking of vehicles or storage

Any requirement to park vehicles or store cargo or materials on the facility during any of the design conditions given by **0.3** should be identified.

4.4.11 Services

The requirements for services on the facility, e.g. water, fuel, sewage, electrical supply, telecommunications, stores, refuse/waste disposal, baggage facilities, etc., should be established and quantified as these can affect the overall dimensions of the facility and loadings carried.

4.4.12 Operational equipment

The required forms of operational equipment should be determined, including:

a) method of sensing for automatic operations;

b) degree of redundancy in controls;

c) extent and forms of traffic control to regulate the use of traffic on the facility.

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4.4.13 Water levels

Water levels at the location of the facility should be determined for at least:

- highest recorded tide (HRT);
- mean high water springs (MHWS);
- mean low water springs (MLWS);
- highest astronomical tide (HAT);
- lowest astronomical tide (LAT);
- lowest recorded tide (LRT);
- highest impounded level for an enclosed basin (HIL);
- lowest impounded level for an enclosed basin (LIL).

The design water level variation should be based on the MHWS and MLWS, or HIL and LIL for an enclosed basin, unless otherwise required for the operation of the facility.

The operating water level should be agreed with the operator of the facility.

The facility should also be designed for an extreme condition based on the HAT and LAT plus an allowance to cover for atmospheric pressure and storm surge due to wind (see BS 6349-1). Alternatively, if reliable values of HRT and LRT are available, these can be used instead.

Any predicted long-term or short-term rise or fall in general water level should also be taken into account for both the design and the extreme conditions.

4.4.14 Wave data

Wave data should be established for the location of the facility; if necessary hydraulic modelling should be carried out. Guidance is given in BS 6349-1.

4.4.15 Effect of passing ships

The effect of wash and other displacement effects on the facility and the berthed ship should be taken into account in the design of the facility.

4.5 Environmental conditions

4.5.1 Environmental impact

The potential impact of the construction, operation, maintenance and decommissioning of the facility upon the marine and terrestrial environment should be taken into account (see BS 6349-1:2000, **5.2**).

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4.5.2 Meteorology and climatology

Meteorological and climatological data should be taken into account (see BS 6349-1:2000, Clause **7**). For wind speeds and air temperatures at coastal and inland locations, guidance can be obtained from BS 5400-2, but data should be collected where possible for the location of the facility.

NOTE Attention is drawn to the effects of temperature on the selection of appropriate steel grades (see BS 5400-3 and Lloyd's Rules).

4.5.3 Bathymetry

Bathymetric information should be obtained, including any updating to allow for changes in water depth due to siltation, dredging, etc. (see BS 6349-1).

NOTE Floating or semi-submersible linkspans might need additional depths to those required by the ships.

4.5.4 Geotechnical considerations

Geotechnical studies and site investigations should be undertaken to ascertain whether ground conditions are suitable for support of the facility or whether they might be affected by any earthworks envisaged. This should include any adjacent dredging or reclamation (see BS 6349-5).

4.5.5 Water quality

Information should be obtained where possible to assist with the overall design and operating performance [i.e. corrosion protection, materials selection (including for machinery), cathodic protection, etc.], including:

a) a water sample to determine at least the following:
   - maximum and minimum water temperatures;
   - PH;
   - conductivity;
   - Langelier Index;
   - sulfate content;
   - chloride content;

b) a mud sample if appropriate to determine the same parameters as for the water sample;

c) historical information with regard to suspended solids, sediment transportation rates, water velocities, marine growth, marine fauna, etc.;

d) any history of microbiological-induced corrosion.

*NOTE For information regarding water quality and sediment transport, refer to BS 6349-1:2000, Clause **13** and Clause **14**.*

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Although much of this data is important to allow the robust design of the fixed elements of the structure and to assess the environmental impact of the facility, it is equally important to allow the selection of suitable materials for machinery, such as ballast pumps, anti-fouling screens, pipework and the like. This data will ensure that the whole life cost approach can be readily adopted.

4.6 Load testing

Each linkspan or walkway should be proof tested in its working position by applying appropriate test loads after installation, and following any major repair, renewal or modification. This helps determine the capability of the structure and its support arrangement. Testing should be carried out throughout high and low tide conditions to allow for the dynamic effects of tidal movement.

NOTE Testing has limitations for verifying structural integrity and will not verify fatigue strength.

The magnitude of the proof test load, T, should be based on the applied design load, W, in tonnes (t), of the linkspan, ramp or walkway section derived from the design loads. In the case of linkspans and ramps, the maximum vehicle load or safe working load is as follows:

$$T = 1.25W \text{ where } W \leqslant 20$$

$$T = W + 5.0 \text{ where } 20 < W \leqslant 50$$

$$T = 1.1W \text{ where } W > 50$$

The purpose of the load test is to test the lifting machinery and bearing elements and their associated linkages rather than to test the integrity of the structures themselves. Therefore, in most cases, it is sufficient to apply loads that will induce the maximum loads to lifting machinery or bearings only. Loads should also be applied to measure the flotation performance of the facility.

If the facility is identified as being of unusual construction either in whole or in part, consideration should be given to carrying out a load test to determine the integrity of the structure or appropriate part of the structure as well as the machinery.

5 Types of structure

5.1 General

The types and forms of structures making up the facility should take account of the design parameters and environmental conditions given in **4.4** and **4.5**.

Whatever type of structure is adopted, the design should take account of the relative movements that are likely to occur between the stationary shore end of the facility and the ship, which will be subjected to vertical, translational and rotational movements. The type of structure is mainly dependent upon the water level variation and upon the range of ship deck heights to be accommodated and the ramp or linkspan gradients to be achieved.

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5.2 Ro-Ro linkspans

A variety of structures is possible for Ro-Ro ramps and linkspans. Where the design water level variation is small (typically 1.5 m), fixed shore ramps might be suitable. For larger design water level variations, a combination of fixed approach ramps and linkspans, or only linkspans, is likely to be more appropriate. Generally vehicles are loaded at the bow or stern of ships at lower deck levels, but multi-deck access or access from the quarter or side of the ship is also possible. For all ramps and linkspans, a primary design consideration is the transition areas (between gradients) to avoid grounding of the vehicles.

Generally two elements are provided.

a) The first is an articulated structure that connects the shore with a point close to the ship, the seaward end of which moves up and down to take account of the range of water levels and/or of different ship deck heights. This structure may consist of:

   1) a mechanically lifted linkspan;

   2) an integral tank or semi-submersible linkspan; or

   3) a link bridge supported by a pontoon.

b) The second, often shorter, element provides the connection onto the ship and mainly caters for movements of the ship, particularly rolling or pitching. It may be formed by the ship ramp itself that rests on the linkspan, either on the designated ship ramp landing area (see **6.2.3.1**) or within a well deck. Alternatively, where the ship has no ship ramp then fingers are provided as part of the facility and these rest on the ship's deck. This arrangement is commonly used for the upper decks of two deck facilities and should allow for the variations in the relative longitudinal position of the edge of ship upper decks relative to the lower deck.

Typical types of structure for Ro-Ro linkspans for different water level variations and ship ramp heights are given in Figure 1.

The type of structure might depend upon other factors, such as:

- the wave climate at the site, which could prevent the use of floating facilities;
- a terminal layout that is favourable to the use of a pontoon type linkspan. For instance, the surface area of a pontoon may conveniently be used for turning vehicles prior to entry to the vessel. Equally, if one pontoon can serve two Ro-Ro berths, a pontoon might be favoured;
- a terminal layout that favours the use of a lifted type of linkspan. Lifted linkspans are generally more compact and can be fitted into constrained site areas more easily;
- whether the facility is required to provide multi-deck access.

Pontoon structures might be appropriate where relocation of the facility to another site is planned, although the cost of providing new shore abutments and restraints at the new positions for such a facility are significant and should be assessed before concluding that there is a benefit.

Sometimes it is necessary to provide facilities that receive quarter ramps or side-loading ramps from ships.

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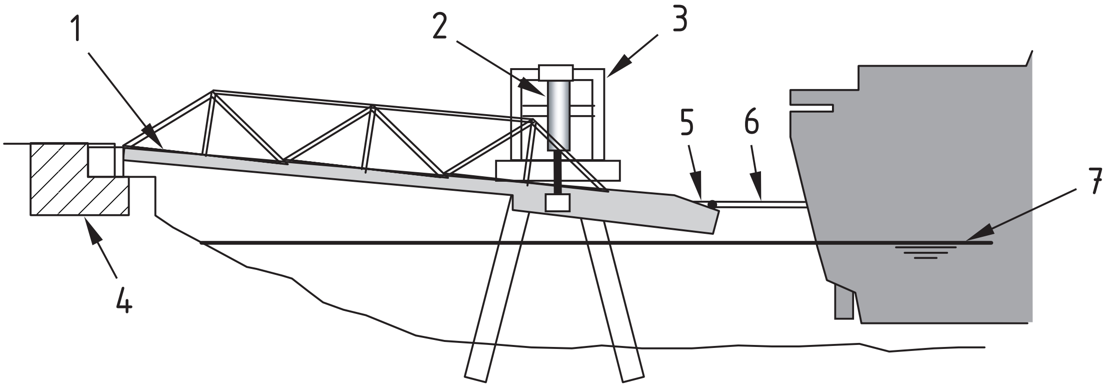
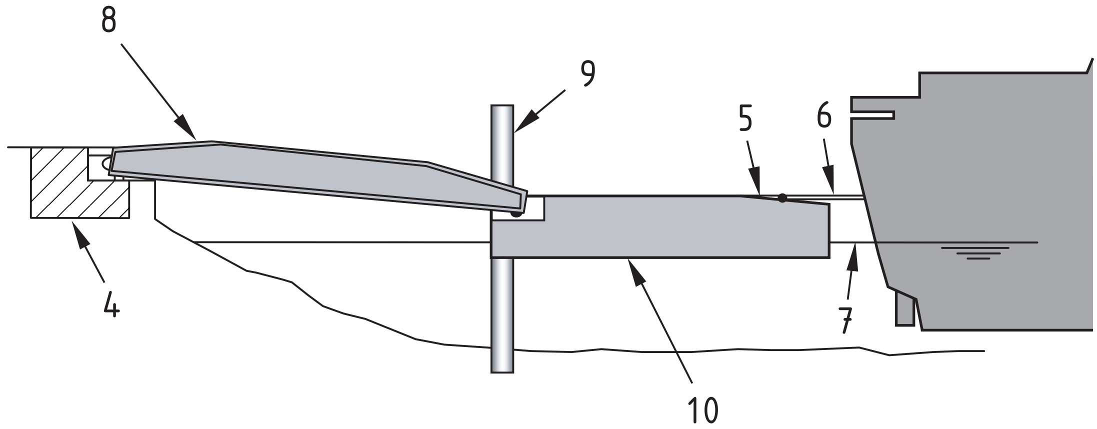
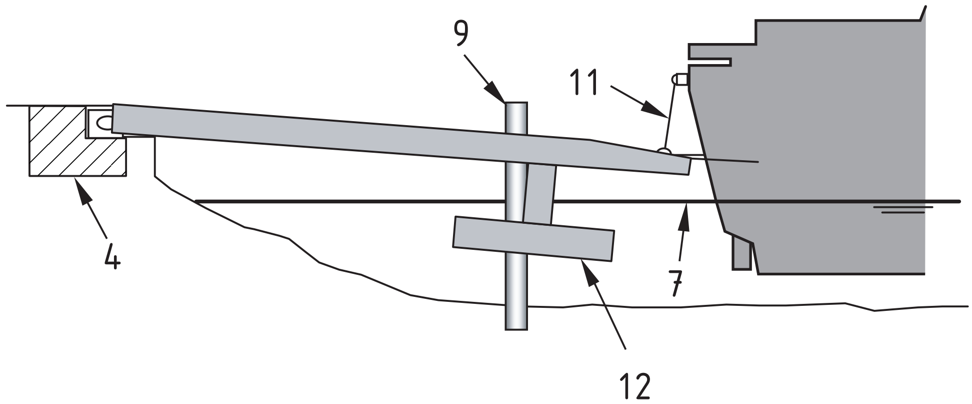
Figure 1 **Linkspan types**



a) Lifted type



b) Pontoon type



c) Semi-submersible type

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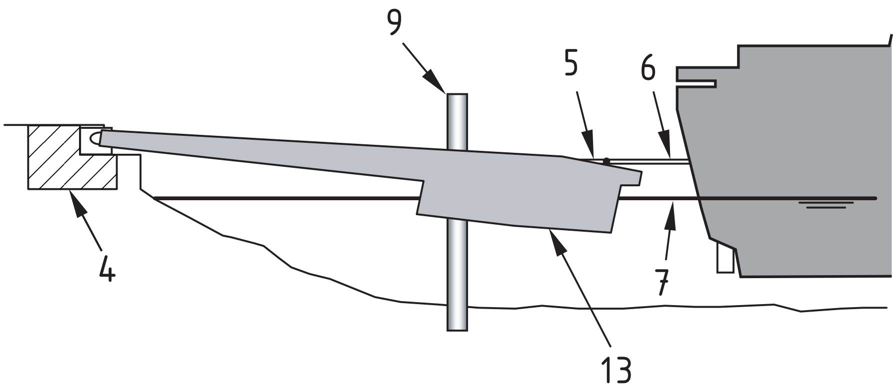
Figure 1 **Linkspan types** (*continued*)



d) Integral tank type

Key

1	Linkspan	8	Link bridge
2	Lifting equipment	9	Guide pile or restraint system
3	Hoist tower	10	Pontoon
4	Abutment or bankseat	11	Pennant ropes [A)]
5	Finger flap	12	Float
6	Ship ramp	13	Tank
7	Water level		

A) The linkspan sometimes rests on the vessel's transom.

5.3 Fixed shore elements

It is likely that a majority of Ro-Ro facilities will include a fixed shore element, even if it is only a short ramp of low height, e.g. an approach embankment behind an abutment, providing a transition between the quay and the spanning structure.

A fixed approach ramp or bridge structure might be needed to transfer loads from the articulating linkspan back to other supports or foundations.

For low design water level variations it is possible that the ship ramp will need to be supported by the end of the fixed shore ramp.

For multi-decked facilities where design water levels are large, a longer fixed ramp will be needed to raise the carriageway (or walkway) to the level from which the linkspan articulates. Depending on land use requirements and ground conditions, the ramp could be formed as a ground-supported retained structure. Alternatively, fixed bridge structures spanning between piers, which might allow use of the land below, and span over other traffic lanes, could be used.

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5.4 Walkways

Walkways should be designed to suit the numbers of passengers that are expected to use the facility and to take account of the likely weather conditions at the site. It is also important to remember that these structures often access the ship at a high level, so the consequences of a fall by a passenger or passengers from a walkway can be life-threatening. For this reason it is essential to take careful account of the movements of the ship relative to the walkway and to design facilities to maintain the final connection to cater for as much movement as is reasonably practicable. Furthermore, safety handrail systems need to be very robust with a suitable infill to prevent falling of items from the walkway to any occupied deck or paving area below. In temperate and cold climates it will also usually be necessary to protect passengers against wind and rain.

Simple gangways can be used for sites where the tidal range is very small, for access from a pontoon or where it is acceptable for access to be available for a limited time period only. Aluminium gangways should conform to ISO 7061.

Passenger walkways can be either end-loading onto the stern or bow of the ship, where the walkway is normally combined with the linkspan, or side-loading into a door or onto an open deck on the side of the ship. Side-loading walkways are frequently at higher levels where the structures are more vulnerable to movement of the ship. For passenger walkways, brows are often used which overhang or rest on the coaming of the ship opening. The exact arrangement for the connection of the final link to the vessel should be decided as a result of the risk assessment (see **4.2**). If the facility is to be used by different ships then there are likely to be significant variations in the number of passenger access points and the location of the doors or open deck along the side, all of which should be accommodated in the design.

Stern-loading or bow-loading passenger walkways can be supported by the vehicle linkspan, in which case a small adjustment might be needed to alter the difference in height between the lower deck and upper deck of different ships. The brow is lowered onto the ship; it normally overlaps the ship's coaming and has a safety hook to prevent it falling away.

It is also essential to consider provision for escape in the event of fire. The layout of fire escape and fire control facilities will often need to be agreed with the relevant local authorities. In many cases it might be necessary to provide escape routes in the middle of the facility in order to reduce escape distances.

Side-loading passenger walkways, if they are to access a reasonably wide range of vessels, can be very complex facilities. There are four main types of walkway, as indicated in Figures 2 to 5 (based on CIRIA Report C518 [1]).

a) Type A (Figure 2) has a motorized carriage at the ship entry and a hinged link that pivots at a fixed building or platform.

b) Type B (Figure 3) has a motorized carriage at the ship entry plus a slave carriage and pod of fixed height that communicates with a fixed platform.

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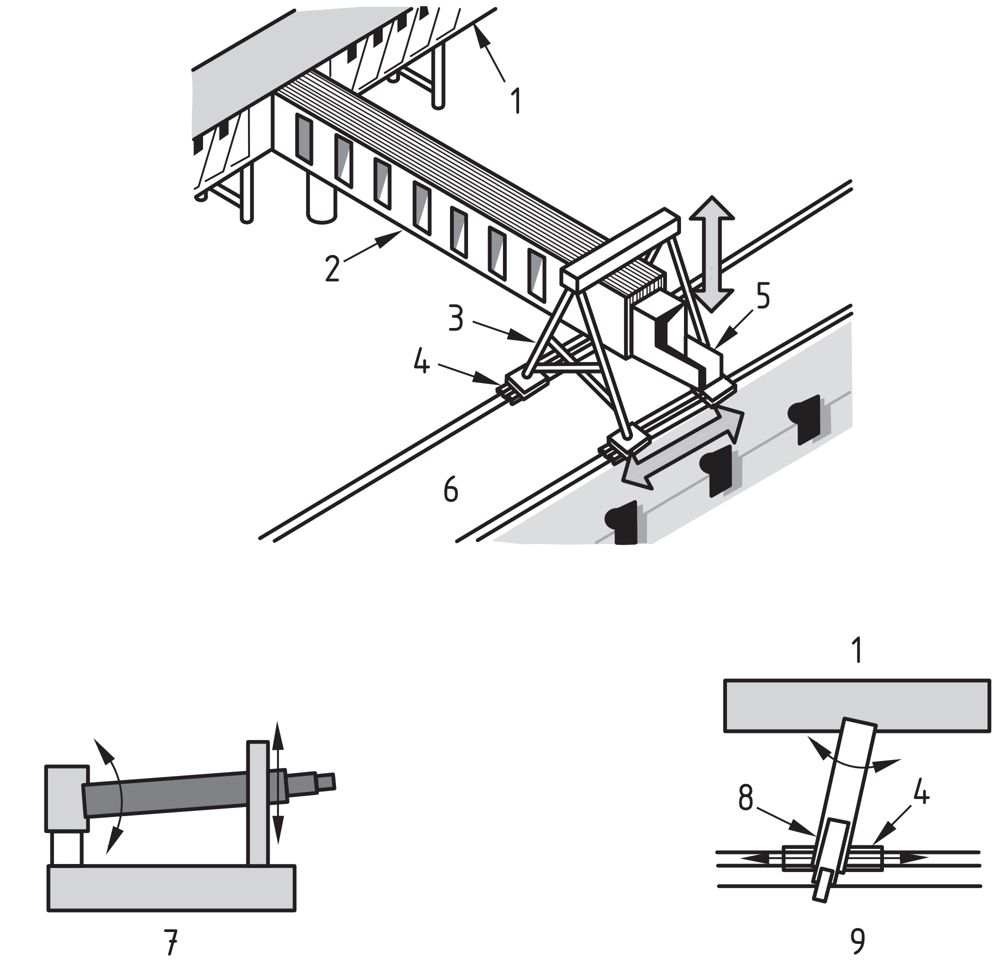
c) Type C (Figure 4) has a traversing drawbridge on a long boarding pod that communicates with a hinged link to a fixed platform.

d) Type D (Figure 5) is similar to Type A, but with the ship and the shore end on a motorized gangway (or the whole inside a motorized gantry frame).

Figure 2 **Passenger walkways – Type A – Motorized carriage at ship entry, swivel at building**



Key

1	Fixed building	6	Quayside
2	Hinged link	7	Elevation view
3	Lifting frame	8	Telescopic end
4	Rail-mounted carriage	9	Plan view
5	Gangway		

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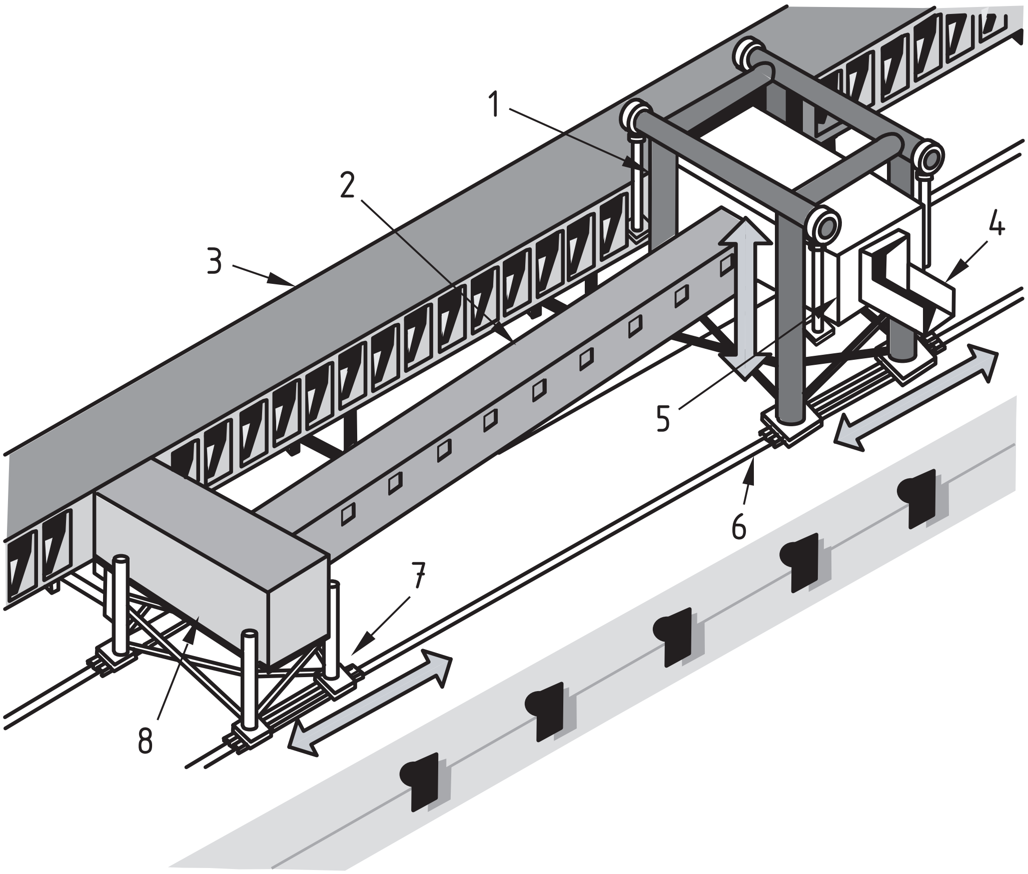
Figure 3 **Passenger walkways – Type B – Motorized carriage at ship entry plus slave carriage and pod**



Key

1 Lifting frame	5 Passenger boarding pod
2 Hinged link	6 Rail-mounted carriage
3 Fixed building	7 Slave carriage
4 Gangway	8 Slave pod

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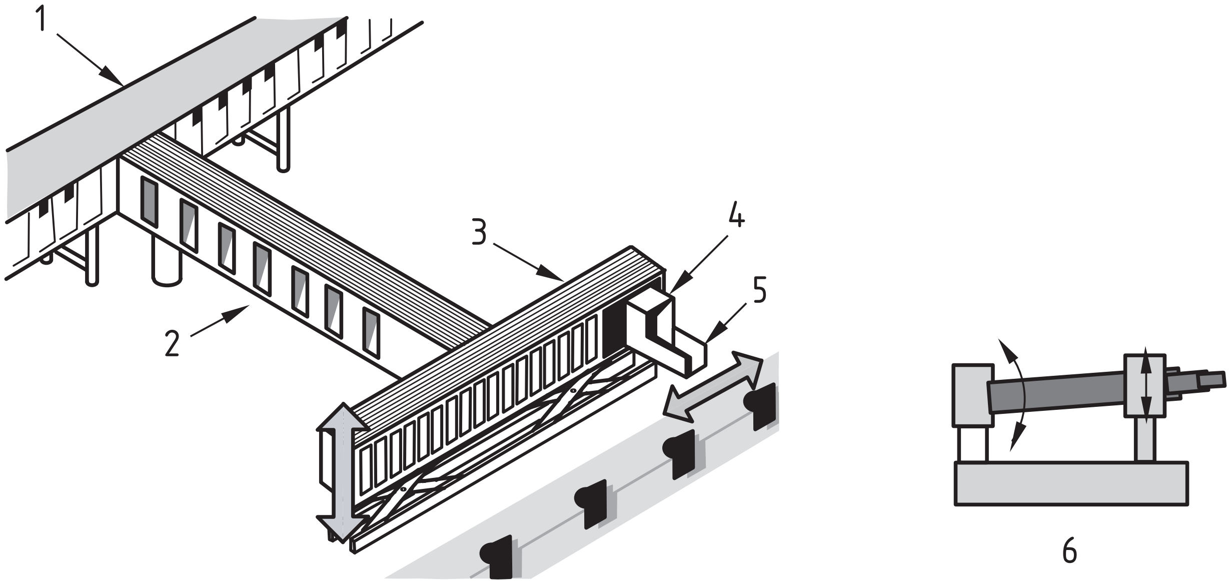
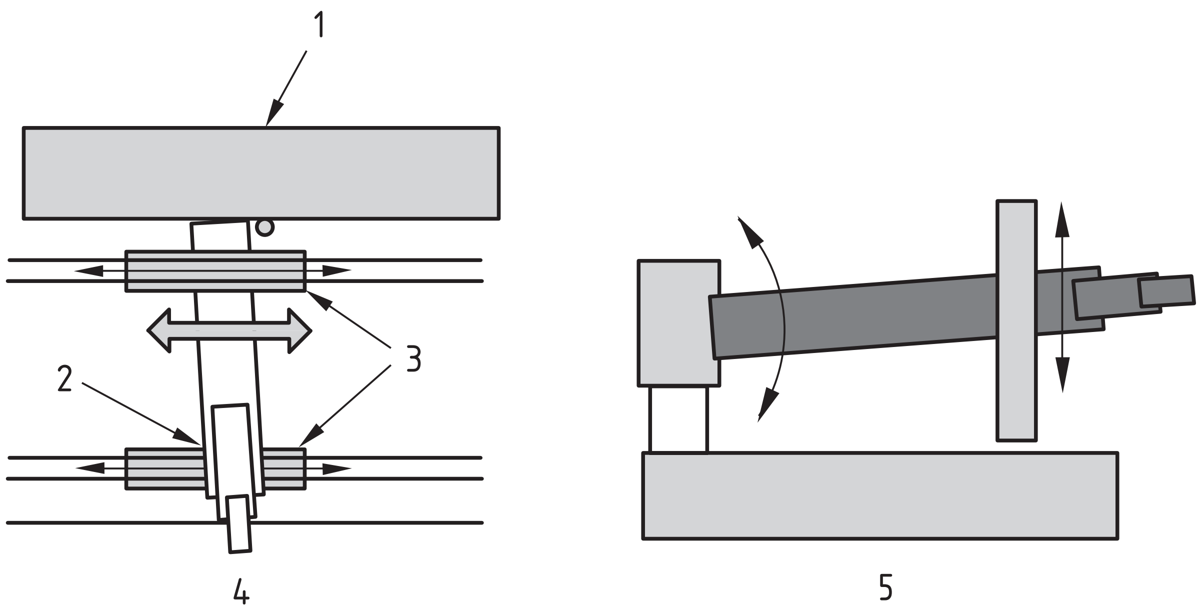
Figure 4 **Passenger walkways – Type C – Traversing drawbridge on boarding pod**



Key

1 Fixed building
2 Hinged link
3 Traversing drawbridge
4 Passenger boarding pod
5 Gangway
6 Elevation view

Figure 5 **Passenger walkways – Type D – Single tunnel supported on rail mounted gantry**



Key

1 Fixed building
2 Telescopic end
3 Rail-mounted carriages
4 Plan view
5 Elevation view

NOTE Tunnels can follow zig-zag line in plan to keep gradients to acceptable levels.

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6 Geometry

6.1 General

The overall layout and dimensions of the facility should take account of existing features such as port buildings, quay walls, dolphins, ship operations and future planned developments. Allowance should be made for predicted and relative movements of the facility due to water level variation, sea state, deformation of fendering, etc. Allowance should also be made, as required, for non-traffic areas on the facility for the purposes of storage of materials or plant including control cabins and traffic control equipment, safety barriers, safety fences, lighting and other services.

The overall geometry should ensure that, during operating conditions, vehicles and pedestrians can be safely transferred between shore and ship taking account of the changes in level in threshold heights, tidal variation and sea state. This should achieved by:

- using linkspans or fixed shore ramps of sufficient length so that maximum permitted gradients are not exceeded;
- providing transitions, where necessary, at changes of gradient and at locations where relative articulation and movement can occur to ensure against vehicle grounding or gross discomfort.

Plan geometry should take account of the turning requirements of vehicles along the length of the facility and where vehicles manoeuvre on and off the ship. There should be a landing area of sufficient width to accommodate the biggest ship ramp that will use the facility.

6.2 Plan geometry

6.2.1 Roadway width

A roadway width of not less than the value shown in Table 1 for the appropriate number of traffic lanes should be provided between vehicle barriers. Where raised kerbs are provided, a minimum lateral clearance of 300 mm should be provided to the vehicle barriers as shown in Figure 6.

Table 1 **Minimum roadway widths**

Number of traffic lanes	Roadway width m	Roadway width for cars only m
1	4.5	3.5
2	8.0	7.0
3	12.0	10.5
4	16.0	14.0

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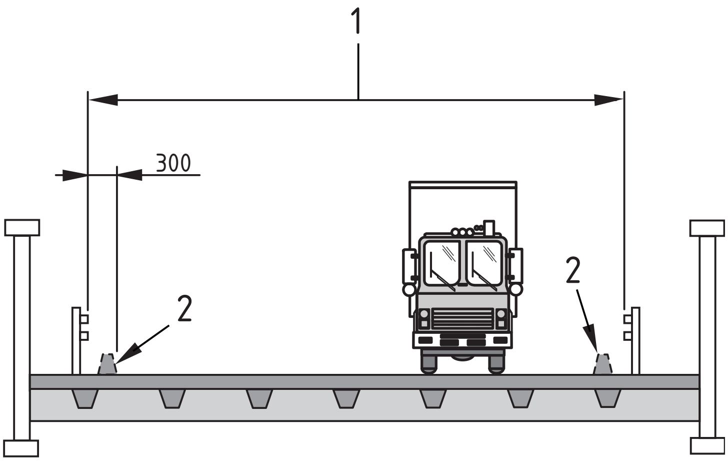
Figure 6 **Roadway width and recommended edge clearance at raised kerbs**

Dimensions in millimetres



Key

1 Roadway width

2 Possible raised kerbs

At the seaward end of the facility, the structure should be wide enough to accommodate the widest ship ramp determined for the facility, taking account of the position of the ship relative to the facility, and with an allowance for transverse movements of the ship. A nominal allowance of at least ±500 mm should be allowed for ship movement and tolerance on position, taking account of the geometric limitations of the berthing face. The exact amount of allowance should be set after the appropriate risk assessment has been completed. If the roadway width on a linkspan is not wide enough to accommodate the ship ramp then a splayed end to the linkspan should be provided.

The minimum roadway widths should be increased, especially at changes in plan direction and at splayed ends, to allow for the turning requirements of vehicles, especially long vehicles. As a general rule, deviation ratios at splayed ends should be no more acute than 2.5 (longitudinally) to 1 (transversely), or 4 to 1 for roll trailers to allow for reversing manoeuvres, as shown in Figure 7.

Clear lane markings should be provided along the main span of the bridge. It is not necessary to carry these markings through to the seaward end of the bridge where there is a splayed end.

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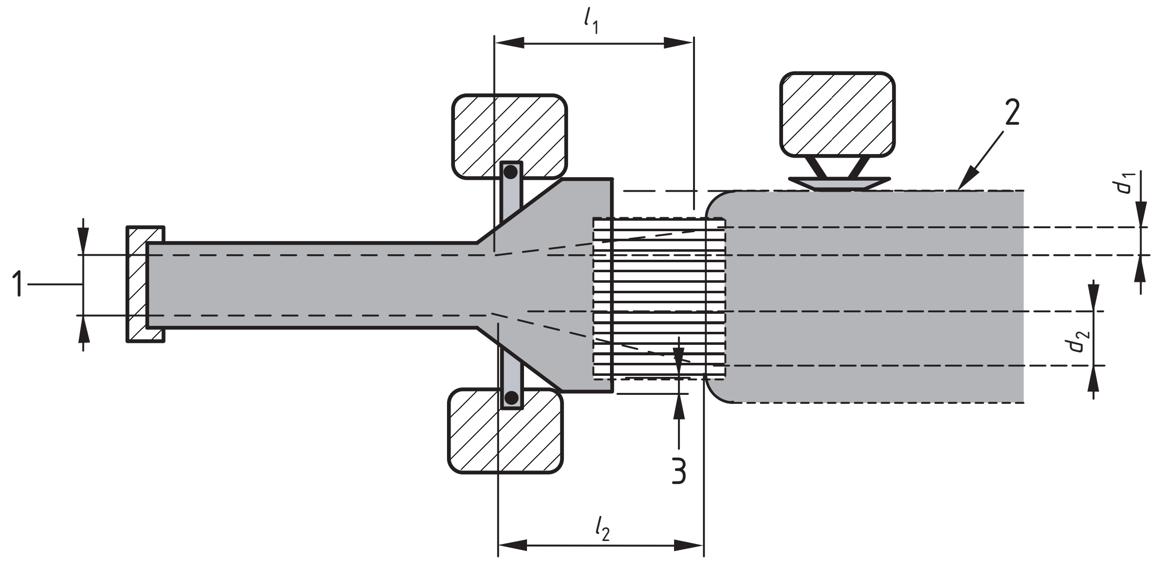
Figure 7 **Plan geometry of linkspans**



Key

1 Greater than or equal to roadway width (see Table 1)

2 Berthing line

3 Greater than 500 mm to allow for ship movement and tolerances

For normal traffic movements, l_1/d_1 and l_2/d_2 should be greater than 2.5.

For ship approached by reversing manoeuvre, l_1/d_1 and l_2/d_2 should be greater than 4.0.

Passenger walkways adjacent to a roadway should be provided with a clear width of at least 1.2 m, which should be increased to 2.0 m where the walkway is to be used by unaided disabled persons. Passenger walkways on separate structures should have a clear width of at least 2.0 m. Where high passenger flows are anticipated, greater widths might be necessary.

Service walkways should have a width of at least 1.0 m and preferably 1.5 m, and should conform to BS EN ISO 14122 where appropriate.

6.2.2 Interface and ship ramp landing area

NOTE 1 This subclause is equally applicable for situations where ship ramps land onto linkspans or fixed shore ramps, and where finger flaps from linkspans land inside a ship.

Ship ramps and fingers on linkspans are usually equipped with finger flaps and are intended to be lowered onto a shaped surface. The difference between the roadway level on the ship ramp and the surface onto which it lands is taken up by the finger flaps, which are usually hinged onto the end of the ship ramp.

In the case of blunt-ended ramps, the seaward end of the linkspan or the entry door of the ship should be detailed to provide a well deck so that the roadway levels on the ramp and the roadway are identical.

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A blunt-ended ramp is sometimes intended to butt up against the end of the well deck. In these cases there are implications for the design of fendering and restraining arrangements because the impact of the end of the blunt ramps on the linkspan arising from ship movements needs to be resisted and should not cause overload to the bridge structure or bearings. In these circumstances, the linkspan should be effectively designed as though it were part of the mooring or restraining system for the ship at the berth, and should be able to resist the resulting forces.

NOTE 2 Since this part of BS 6349 does not cover the design of ships, it can only give guidance for the situation where linkspans or finger flaps land on the ship.

*NOTE 3 See **7.7.6**, **7.7.7** and **7.7.8**, BS 6349-1 and BS 6349-4.*

6.2.3 Interface limit line, clearances and design approach

6.2.3.1 Linkspans onto which a ship ramp is lowered

For linkspans onto which a ship ramp is lowered, the interface limit line is the line that defines the safe minimum distance between the seaward end of the ship ramp landing area and the outer face of a linkspan or fixed shore ramp or the finger flap landing area [see Figure 8a) and Figure 8b)]. This excludes the depths of any fendering attached to the outer face. The main part of the ship ramp, not including any finger flaps, should bear securely on an area to the landward side of the interface limit line.

6.2.3.2 Linkspans with finger flaps or ramps that lower onto the deck of a ship

For linkspans with finger flaps or ramps that lower onto the deck of a ship [see Figure 8c)], the interface limit line is the line that defines the safe minimum distance between the landward end of the finger flap landing area and the threshold of the ship.

Any face fenders should be deemed to be beyond the end of the ramp and their width should not be included in the measurement to the interface limit line. There should be no permanent obstacles within the ship ramp landing area, which allows for the largest ship ramp expected, or seawards of the interface limit line.

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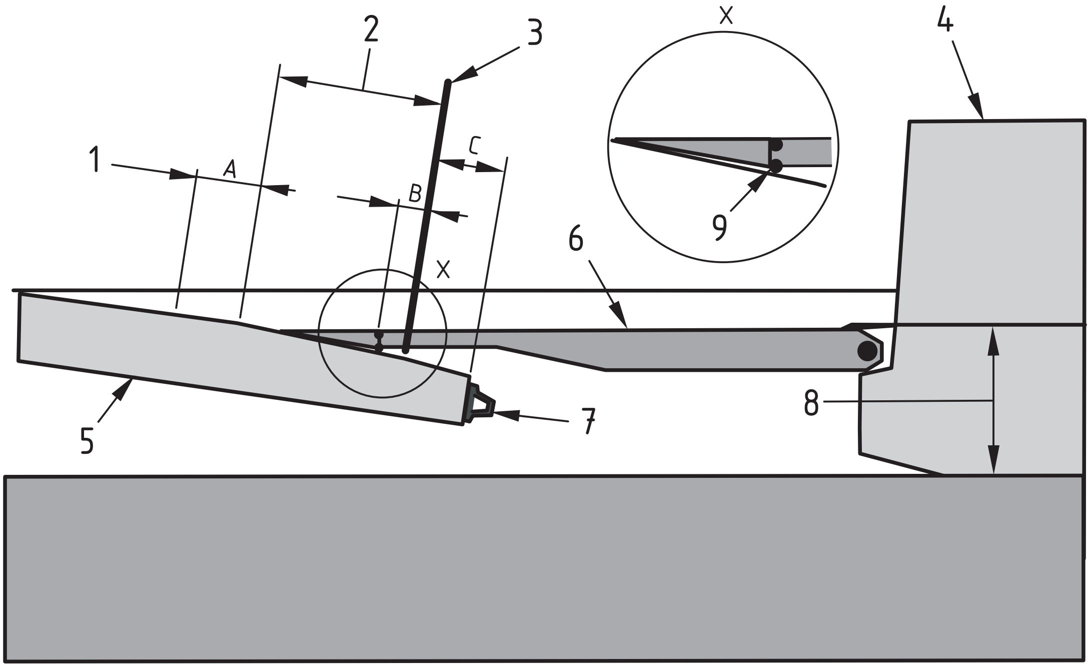
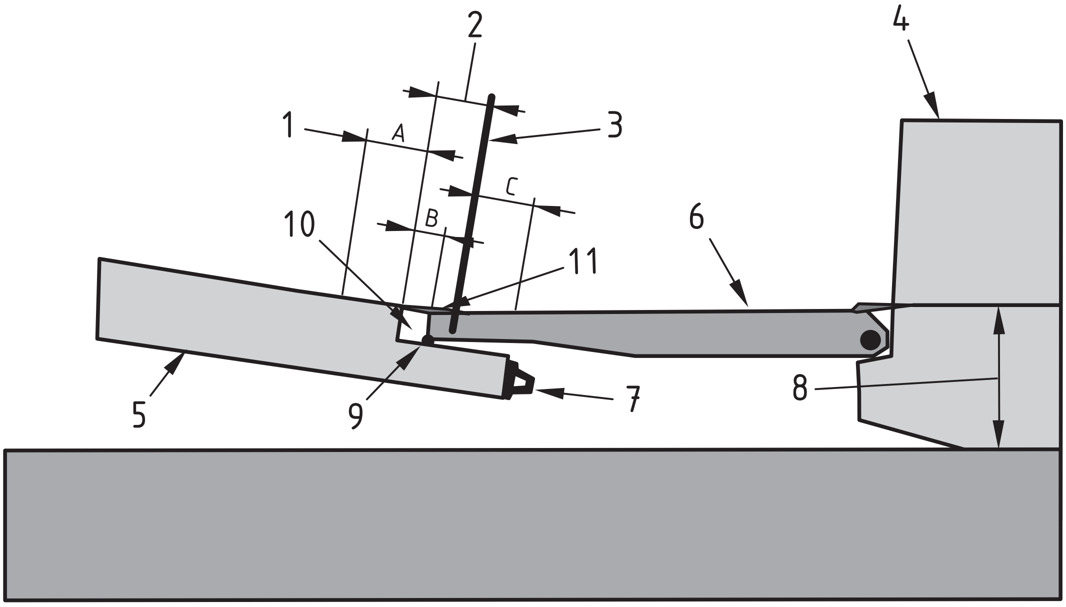
Figure 8 **Interface diagrams**



a) Ship ramp with finger



b) Blunt-ended ship ramp A)

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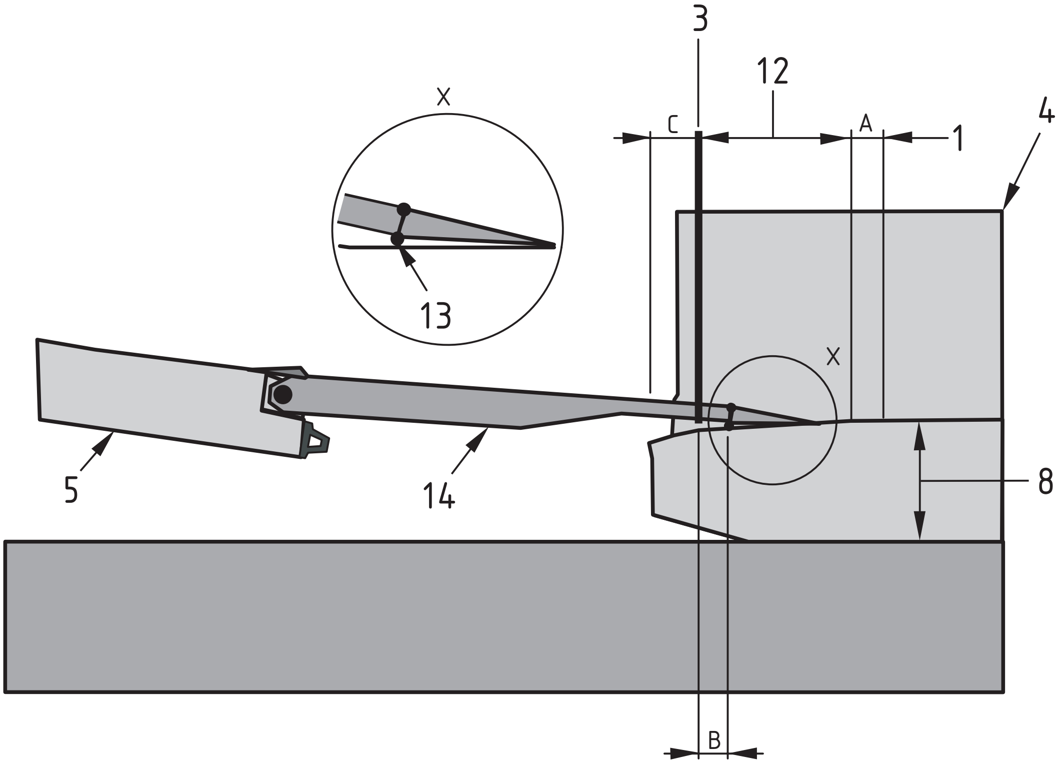
Figure 8 **Interface diagrams** (*continued*)



c) No ship ramp

Key

1	Additional clear area	8	Threshold height
2	Ship ramp landing area	9	Nominal ramp landing point bearing detail at end of ship ramp
3	Interface limit line	10	Ramp end clearance space, >0.5 m
4	Ship	11	Finger flap overlap by at least 0.6 m
5	Linkspan	12	Finger flap landing area
6	Ship ramp	13	Nominal ramp landing point bearing detail at end of fingers
7	Fender	14	Fingers

A ⩾ 1.0 m
B = 0.5 m
C ⩾ 0.5 m

A) If there is no ramp end clearance space, provide a fender and design the linkspan for mooring forces.

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6.2.3.3 Other clearances

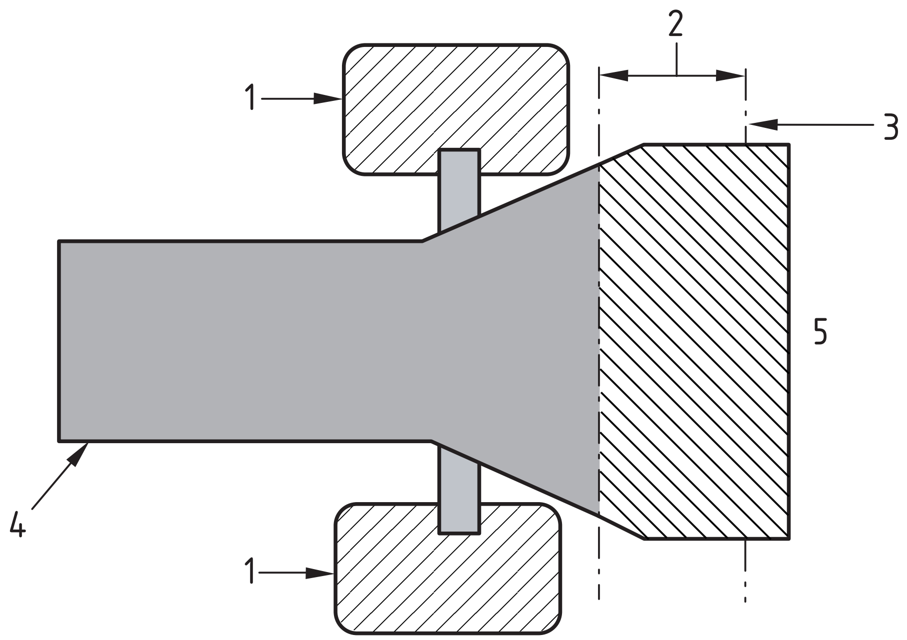
A risk assessment should be performed to identify any possible locations where fouling between the ramp and the linkspan might occur during the berthing approach, connection or operation of the linkspan. This risk assessment should take into account extremes of movement, including those due to extreme environmental conditions.

NOTE 1 The risk assessment might lead to a need for a modification of any of the dimensions recommended below.

If the safety clearances for blunt-ended ramps are less than those recommended in **6.2.3.1** and if obstacles exist within the ship ramp landing area shown in Figure 9, the design of the linkspan should take into account the ship approach berthing energy and mooring forces as though it were part of the berthing and mooring facilities. See also **6.2.4**. This normally occurs as part of a manoeuvre where the ship is brought under control away from the linkspan and slowly warped towards it. In these circumstances, the energy absorption calculated for the linkspan should generally be in accordance with the recommendations for end fenders in BS 6349-4 with an approach velocity of 0.1 m/s.

*NOTE 2 This is not the same as the berthing energies required to cope with mode c) berthing as described in BS 6349-4:1994, **4.7.6** and Figure 3, which would normally be absorbed by parts of the structure other than the ramp/linkspan interface or even completely independent structures.*

Figure 9 **Plan clearances for design**



Key

1 Obstacles clear of shaded area, e.g. dolphins as shown, do not have to be designed for direct ship-induced forces

2 Ship ramp landing area to seaward (hatched) should be kept clear of obstacles

3 Interface limit line (see Figure 8)

4 Linkspan

5 Obstacles in this shaded area to be designed for direct ship-induced forces

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The ship ramp landing area or the landing area on a ship should be as small as possible consistent with these constraints. It is expected that:

a) in the case shown in Figure 8a), the length of the ship ramp landing area will normally be 3.0 m;

b) in the case shown in Figure 8b), the length of the ship ramp landing area will normally be 1.0 m.

These dimensions should be carefully checked against all ships that might use the facility, and adjusted if necessary.

There should be no permanent obstacles within the ship ramp landing area or seawards of the interface limit line. In additional to the areas identified, there should be a further distance of at least 1.0 m shorewards of the ship ramp landing area that should kept clear of obstacles [see dimension A in Figure 8a) and Figure 8b)].

Since any linkspan might be expected to serve any Ro-Ro ship that can visit the berth and since there remains a continuing trend towards development of Ro-Ro ship design, it is not possible to be prescriptive about the width of the seaward end of a linkspan. Therefore, the width should be decided on the basis of a study of all the ships that are expected to visit the berth. The dimension of the ship end should be based on the outcome of that study, which should make an allowance for potential movements of the ship on the berth.

6.2.4 Plan movements

There are two approaches to plan movements.

Normally, allowances should be made in the design of the facility for predicted plan movements of ships and of the facility itself to ensure safety, especially at points of articulation. In particular, the range of movement of bearings, joints and flaps should be sufficient to cater for horizontal movements that might include:

a) ship movements at deck level whilst berthed, longitudinally and/or laterally due to rolling, ranging, yawing, swaying, heaving and pitching as relevant, allowing for deflection of fenders and dolphins and the stretch of mooring lines;

NOTE 1 Table 2 gives some suggested values based on the PIANC Working Group No. 24 report [8], although at exposed berths the allowances might need to be revised in the light of the predicted performance of ships when at the berth.

b) movements within vertical guides to pontoons or arising from sea state. This should include an allowance for tolerance in verticality of piles. Any allowance should be not less than ±75 mm in any direction;

c) thermal expansion and contraction of the facility;

d) the horizontal components of vertical movements, e.g. during raising or lowering of one end of a linkspan (arcing), arising from changes in water level or height adjustment, or due to pitching of a pontoon or submergence of a floating linkspan as it is traversed by traffic.

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Table 2 **Suggested motions of moored Ro-Ro vessels in harbour**

Motion	Movement A)	Velocity B)	Movement		Velocity	
			Operational	Extreme	Operational	Extreme
Range/surge	0.6 m	0.3 m/s	±0.3 m	±1.0 m	0.12 m/s	0.3 m/s
Sway	0.6 m	0.3 m/s	+0.6 m −0.3 m	+1.0 m −0.5 m	0.38 m/s	0.42 m/s
Heave	0.6 m	—	±0.05 m	±0.15 m	0.03 m/s	0.06 m/s
Roll/heel C)	2°	1.0°/s	±2.0°	±5.0°	0.30 °/s	0.50 °/s
Yaw D)	1°	1.0°/s	±0.25°	±0.50°	0.15 °/s	0.20 °/s
Pitch/trim E)	1°	—	±0.50°	±1.0°	0.08 °/s	0.10 °/s

A) Based on Table 1.2 of the PIANC Working Group No. 24 report [8], for ships of 8 000 DWT side ramps fitted with rollers.
B) Based on Table 1.3 of the PIANC Working Group No. 24 report [8].
C) Not combined with swaying.
D) Proportional to ship length (values indicated are for a ship length of 80 m).
E) Not combined with heaving.

An alternative approach is to deliberately restrain the ship ramp so that it cannot move outside certain defined limits. If this approach is taken, a careful assessment should be made of the forces that can be generated by the ship as it experiences environmental and other forces, additional structural features should be provided to constrain the ramp, and facilities for suitably articulating the linkspan should be devised.

If the clearances indicated in Figure 9 are provided, then no forces other than friction need be considered in the design of the linkspan and support structure system. If these are not provided, then places where the ship or ship ramp could come into contact with obstructing features on the linkspan or the support structures should be designed to resist the lesser of:

1) the failure strength of the obstruction;
2) the failure strength of the ship ramp or other ship-mounted feature that might foul with such obstructions; or
3) the calculated load derived from an assessment of the wind, current or other loads that the ship might exert on the structure. This approach might not be advisable if these loads cannot be reliably calculated.

NOTE 2 For fingers or ramps, the same design approach applies to fingers or flaps that are hinged from the linkspan and are supported on the ship.

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6.3 Vertical geometry

6.3.1 Ship ramps

Figure 8 indicates two different types of ship ramp and a situation where the ship has no ramp. It is apparent that the different types of ramps are not compatible with all types of linkspan unless special adaptations are incorporated into the design.

For each linkspan design, the range of ship ramps with which the linkspan is compatible should be identified, and the information should be made available to the author of the operation and maintenance manual (see **4.3**).

Although most ship ramps are capable of varying in gradient between 1 in 10 upwards and 1 in 10 downwards, there are sometimes operational controls that limit the gradients for other reasons. If possible, these controls should be identified and the limits made available to the author of the operation and maintenance manual (see **4.3**). If there is any doubt about such limits, it should be assumed that the ship ramp will be within $\pm 1°$ of a horizontal position and that its normal position is horizontal.

6.3.2 Linkspans and fixed shore ramps

Whether or not a linkspan or a fixed shore ramp is needed depends entirely on the vertical geometry of the system. Linkspans (i.e. vertically adjustable ramps) should normally be provided where the total height variation due to design water level variation and ship deck height range variation exceeds 1.5 m. Linkspans might also be needed where the variation is less than 1.5 m and where the allowable vertical movement of the ship ramp is constrained for operational reasons (see **6.3.1**).

The vertical profile of the ramp landing areas, whether for fixed Ro-Ro ramps or linkspans, should be designed on the basis of the geometry of the expected ship ramps, the slope limitations in **6.3.3**, any operational limits on the ship ramp and an analysis of the transitions as described in **6.3.4**. In view of the considerable range of ship ramp and tidal conditions, it is not possible to be prescriptive about the linkspan end profile, and a specific study should be undertaken in each case. The geometry indicated in Figure 10 is a suitable starting point for an analysis of the ramp geometry.

Such transition studies should take account of the additional movements caused by sinkage of floating elements as the load traverses the facility.

Where no ship ramp exists, fingers are used and it might be necessary to increase the ramp height range, in particular the height above the high design water level, in order to ensure that fingers bear correctly on the ship deck and that grounding of vehicles does not occur.

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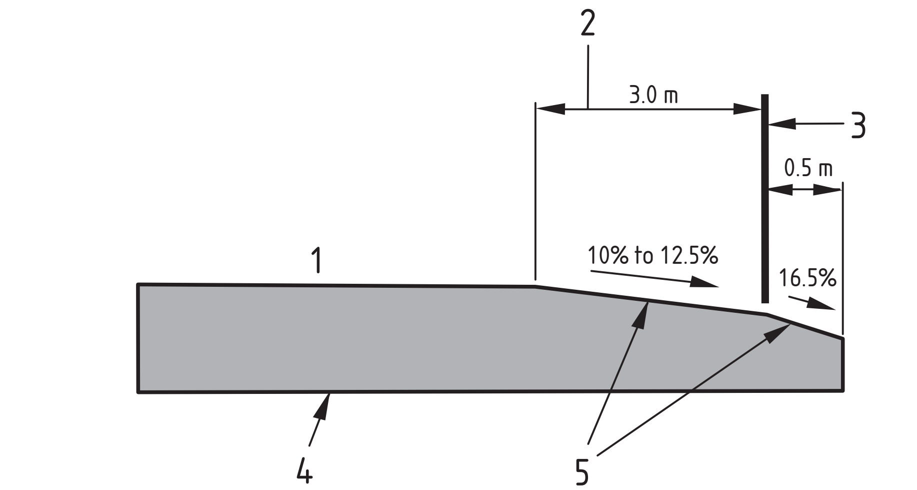
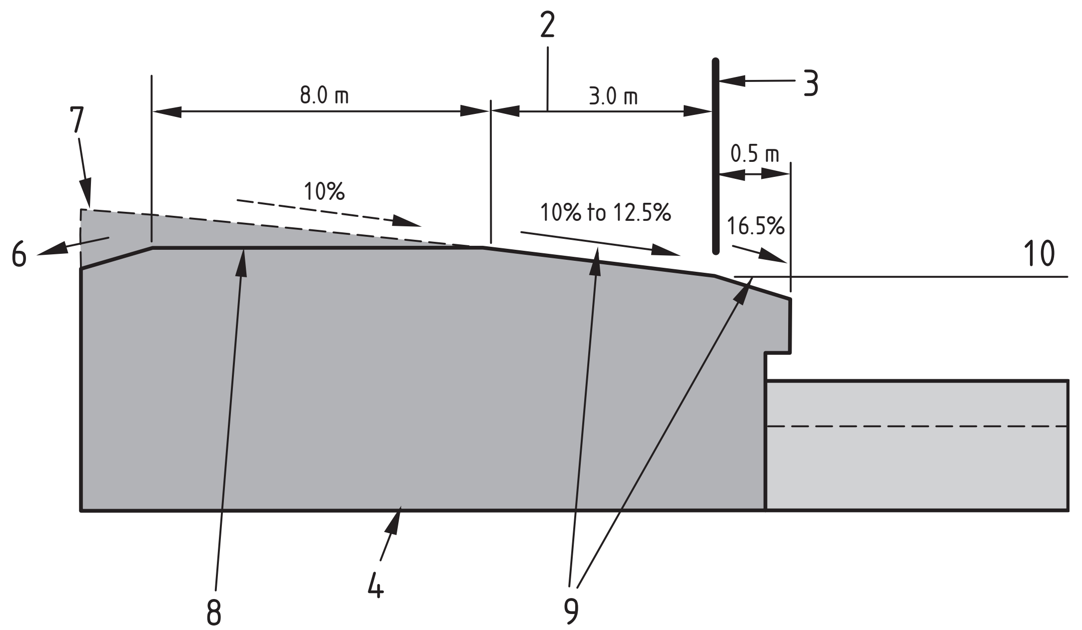
Figure 10 **Vertical geometry guidelines for normal circumstances**



a) Indicative vertical geometry of end of variable slope linkspan for ship ramps with finger flaps



b) Indicative vertical geometry of fixed shore ramps (for ship ramp with finger flaps) or stable pontoon frontage

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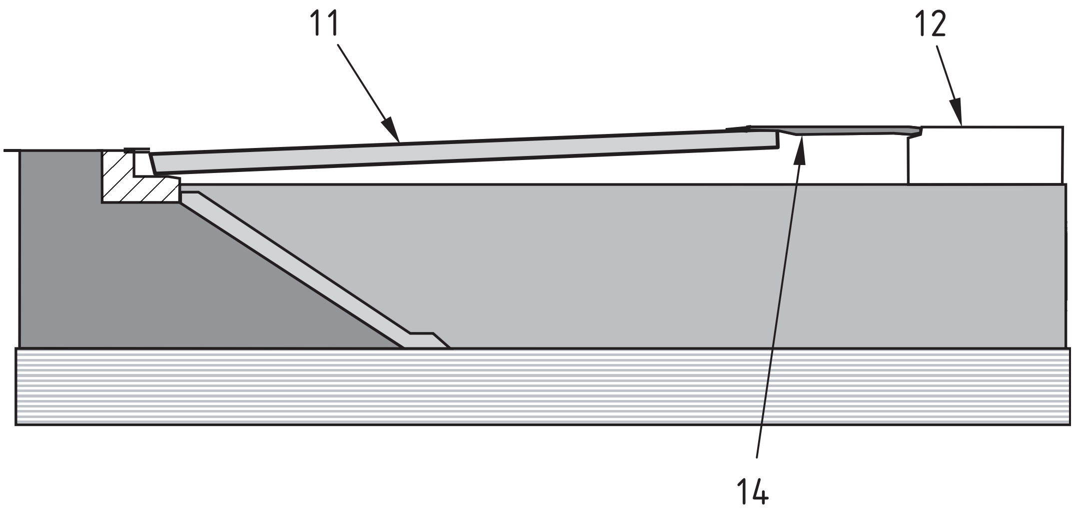
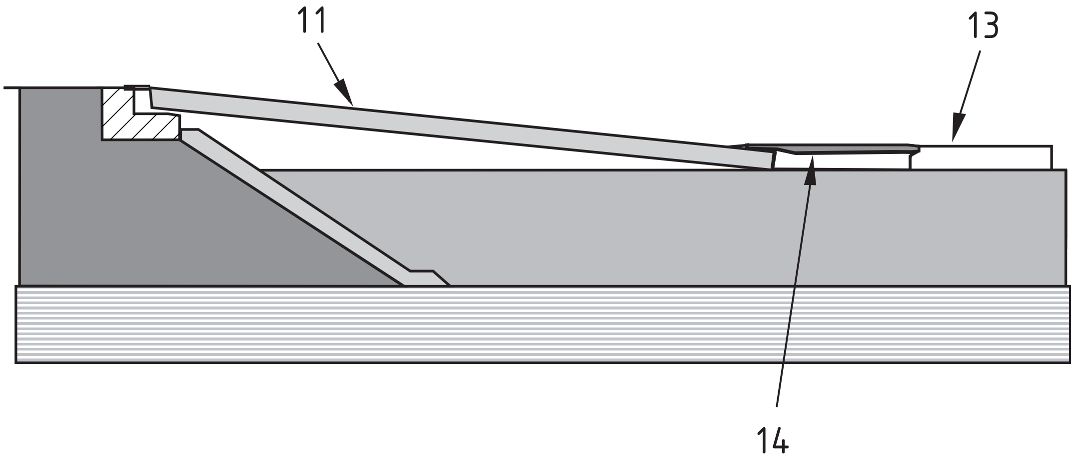
Figure 10 **Vertical geometry guidelines for normal circumstances** (*continued*)



c) Indicative vertical geometry of variable height linkspans or link bridges within design water range – high tide



d) Indicative vertical geometry of variable height linkspans or link bridges within design water range – low tide

Key

1 Normal running surface
2 Ship ramp landing area 3.0 m
3 Interface limit line
4 Linkspan
5 Slope changes relative to normal running surface
6 Refer to Figure 11 or Figure 12 as appropriate for transitions
7 Profile for transition to continuously rising gradient
8 Profile for transition to horizontal or reverse gradient
9 Gradients relative to horizontal surface
10 Level of average car deck height, taking account of tidal and threshold height variations
11 Downwards and upwards gradients not greater than 10%
12 Level based on highest design water level and highest predicted threshold height
13 Level based on lowest design water level and lowest predicted threshold height
14 In the absence of agreed data, design should assume the ship ramp is within ±1° from horizontal

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6.3.3 Maximum longitudinal gradient

The maximum gradients in the direction of traffic given in Table 3 should not be exceeded under the relevant design conditions, unless it can be demonstrated that the safety of both passengers and vehicles, including adequate slip resistance under all operating weather conditions, can be achieved.

Table 3 **Maximum operational longitudinal gradients for articulated elements (not including local slopes at ship ramp interface ends)**

Traffic	Between design low and high water levels	Extreme tidal and sea state condition and for use in emergency
Roadway	1 in 10	1 in 8
Passenger walkway	1 in 12	1 in 10
Service walkway	1 in 4	No additional limits

It is usual for disabled persons to be accommodated by the use of lifts or other transportation rather than by articulated ramps.

6.3.4 Transition areas

Transitions, or intermediate gradients, should be provided at changes of gradient and at all locations where relative articulation and movements can occur, to minimize the possibility of vehicle grounding or gross discomfort. A study should be undertaken of the movements of the vehicles that are expected on the facility at locations of change of gradient and articulation, and the results of the study should be taken into account when designing the transition areas. The study should include:

a) the need for adequate ground clearance, taking into account wheel base and the projection of vehicles and handling equipment;

   NOTE Long wheel base vehicles with limited ground clearance, such as roll trailers, or coaches with large overhangs, are likely to be most critical.

b) the full range between low and high design water levels, i.e. the design operating condition under the critical combination of loading;

c) movements due to relative deformations, including:

   - rotational twist of structures from eccentric loading;
   - relative translation and rotation between ship and facility;
   - relative translation and rotation between different elements of the facility, including the movements of pontoons;

d) the possibility of loose elements such as flaps projecting above roadway level under rotational movements.

The vertical geometry should generally be in accordance with Figure 11 and Figure 12, but may be adjusted for specific circumstances, e.g. steeper slopes than those shown in Figure 11 and Figure 12 can be permitted for shorter length slopes in certain circumstances.

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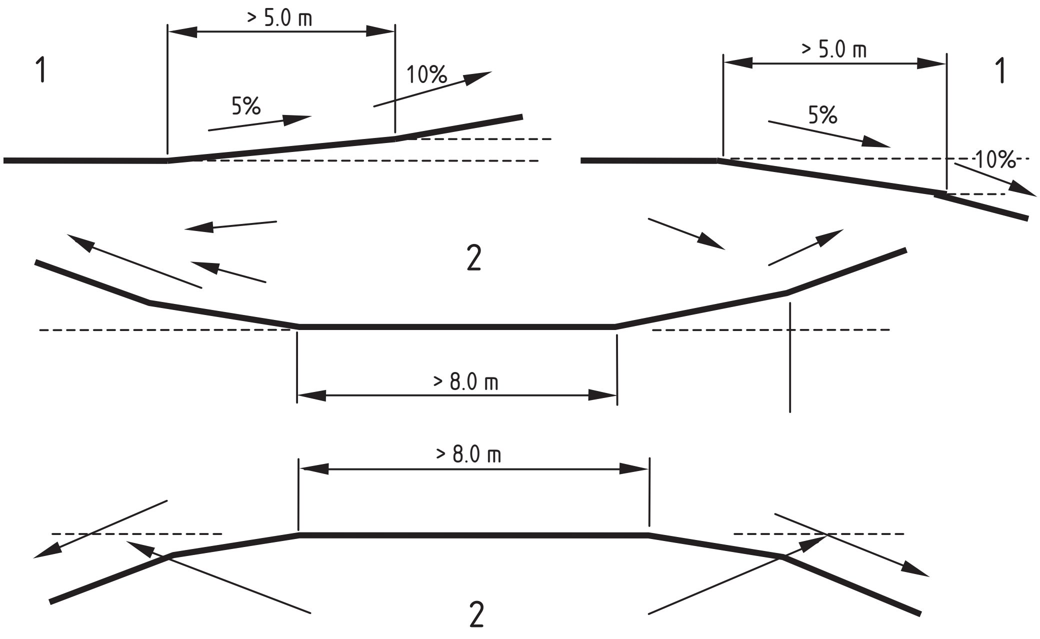
Figure 11 **Preferred transition geometry**

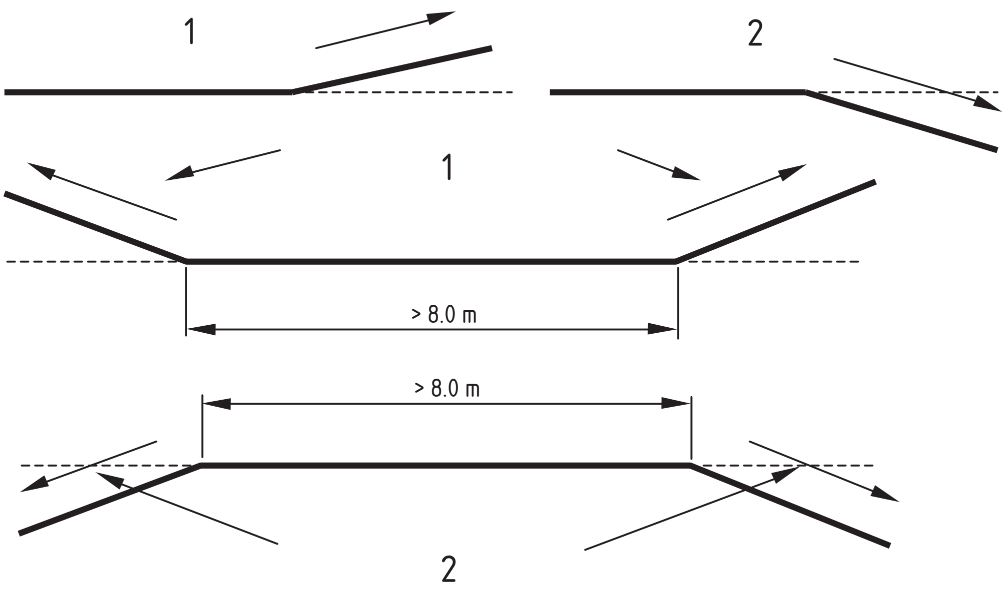


Key

1 Total slope change 10%

2 Overall slope change 10% comprising two changes of 5% each spaced 5 m apart

Figure 12 **Extreme transition changes**



Key

1 Slope change 12.5%

2 Slope change 10%

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6.3.5 Vertical clearances (headroom)

Where overhead structures or obstructions occur, the clearances for the unobstructed travel of traffic that will use the facility should be not less than the minimum values shown in Table 4.

Table 4 **Vertical clearances**

Type of traffic	Minimum clearance
Road traffic	6.0 m desirable 5.3 m absolute minimum
Pedestrian traffic	2.3 m over length of walkway up to and including 23 m 2.6 m over length exceeding 23 m

NOTE In the special circumstance where the linkspan is to carry light vehicles only, it is possible that this minimum value could be reduced.

The minimum clearance should be increased, as necessary, in the vicinity of both sag and hog vertical transitions to cater for the longest expected vehicles.

Allowance should also be made for live load deflection of overhead structures such as upper ramps.

Clearances might need to be increased for multi-purpose facilities, e.g. where vehicles carrying two high containers are to be accommodated or where maintenance crane access is required.

Where no ship ramp exists, fingers are used and it might be necessary to increase the ramp height range, in particular the height above the high design water level, in order to ensure that fingers bear correctly on the ship deck and that grounding of vehicles does not occur.

7 Loads, movements and factors

7.1 General

The design loads are applicable to conditions prevailing in the United Kingdom and the Republic of Ireland. Where different loading regulations or environmental conditions exist, project-specific modifications might be necessary.

The design loads can be used in conjunction with either the limit state design philosophy or with *Lloyd's Rules*. This part of BS 6349-8 uses BS 5400 as the basis for design, but *Lloyd's Rules* may be used as an alternative basis. Where *Lloyd's Rules* are used as the basis of design, the partial load factors given in this part of BS 6349 should not be used and instead the stresses calculated from the load combinations should be compared with the allowable stresses permitted by the *Rules*. When BS 5400 is used as the basis, the recommendations given in this part of BS 6349 should be followed in full. For whichever approach is used, it is essential for the designer to ensure that there is a margin of safety that is fully consistent with the appropriate code (BS 5400 or *Lloyd's Rules*).

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Where BS 5400 is used as the basis for design:

a) the nominal loads as specified in BS 5400-2 or as varied by this part of BS 6349 should be multiplied by partial load factors γ_{fL} to derive the design load effects for each of the limit states under consideration;

b) the values of γ_{fL} for each combination of load can be taken from Annex A;

c) the load combinations for use in selecting load factors should be as set out in BS 5400-2, as follows:

- combination 1 – general loads;
- combination 2 – loads with wind, current and wave effects;
- combination 3 – temperature effects;
- combination 4 – exceptional loads including seismic loads.

7.2 Dead loads

7.2.1 General

Dead loads should be determined in accordance with BS 5400-2.

Attention is drawn to the requirement in BS 5400-2 to increase the value of γ_{fL} at ULS to 1.1 for steel and 1.2 for concrete where the loads cannot be accurately assessed at the time of design.

Where concrete floating structures are used, an allowance should be made for a reduction in freeboard to allow for the effective increase in density of submerged concrete or inaccuracies in concrete construction.

7.2.2 Superimposed dead loads

Appropriate allowances should be made for the mass of operational equipment, machinery, control cabins, plant areas, traffic control equipment, services, and furniture such as lighting columns and signs. When checking buoyancy, stability and freeboard levels of pontoons, then upper and lower values of superimposed dead loads should be assumed where these are not evaluated with accuracy at the time of design, in particular, the weights of operating machinery.

For design loads the factor γ_{fL} should be in accordance with Table 5.

Table 5 **Values of factor γ_{fL} for superimposed dead loads**

Load	**Factor γ_{fL}**	
	At ULS	**At SLS**
Where superimposed dead loads cannot be evaluated accurately at the time of design	1.75	1.2
Where superimposed dead load cannot be determined accurately at the time of design but an upper bound can be set on the load	1.2	1.0
Other cases	1.2	1.0

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In the design of pontoons, the shape of the pontoon hull should be such as to permit an allowance for an amount of permanent ballasting to be installed to compensate for inaccuracies and variations in superimposed dead load (SDL).

7.2.3 Dead loads from ship ramps and finger flaps

The ship ramp landing area, and the facility as a whole, should be designed for the vertical loads arising from the dead weight of the ship ramp as supported on the facility. Ship ramps are normally designed so that the loading therefrom is applied as a line load to the ship ramp landing area.

NOTE The line loading will not be exactly uniform along the contact length between ship ramp and the ship ramp landing area. This is because there will be a finite torsional stiffness on the ramp that will lead to an uneven load as the ship rolls.

Where the risk assessment (see **4.2**) identifies disproportionate risks and consequences arising from this effect, e.g. a risk that part of the ramp landing might be on a piece of structure that is of inherently lower strength than the majority of the structure (such as might be the case with bolted in flaps or the like), consideration should be given to applying the entire ship ramp dead load (but not the finger flap load) to one end of the line as a point load or carrying out calculations based on a full structural analysis of the actual ship ramps' structures.

In addition, account should be taken of the effects that might arise from the use of ship ramps which are deployed by hydraulic cylinders. The extent to which these cylinders are free to move, and the forces that might be generated. These are usually intended to be fully free to move without generating forces when the ramp is deployed, but consideration should be given to the possibility that there might be friction effects that generate some additional forces. This information should usually be obtained from the ship owner or ship ramp designer.

For design loads the factor γ_{fL} should be in accordance with Table 6.

Table 6 **Values of factor γ_{fL} for dead loads from ship ramps and finger flaps**

Load	**Factor γ_{fL}**	
	At ULS	**At SLS**
Steelwork to ship ramp	1.1	1.0
Furniture on ramp, parapets, etc.	1.2	1.0
Surfacing	1.75	1.2

It might be necessary to increase the loads to account for the ship's acceleration.

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7.3 Wind loading

7.3.1 General

Wind loading for linkspans in both coastal and inland waters should be in accordance with BS 5400-2 except where recommended otherwise in the present subclause (**7.3**).

Where structures are located or are to be transported beyond coastal water then wind speed information should be obtained in accordance with BS 6349-1.

7.3.2 Maximum wind gust speed

The maximum wind gust speed V_d should be based on the site hourly mean wind speed V_s determined for a return period of 50 years, which is appropriate for the design life of the facility up to 50 years in the United Kingdom. The basic hourly mean wind speed V_b may be obtained from BS 6399-2:1997, Figure 6, but should be checked against local meteorological records.

The range of operating criteria (see **0.3**) should be agreed with the operator. For example, the facility might be in a parked position during extreme winds, and therefore not experience the maximum wind load when deployed for operation.

7.3.3 Wind on enclosed passenger walkways or service walkways

The design of the enclosure cladding and fixings should be in accordance with BS 6399-2.

Pressures on the floor of a suspended enclosed walkway should be taken to be the same as those for a flat roof.

The overall transverse load on suspended enclosed walkways should be in accordance with BS 5400-2.

NOTE 1 The maximum wind gust speed need not be limited to the operational condition unless this is also associated with the operational wave conditions.

Where structures for enclosed walkways are similar to buildings or freestanding canopy roofs etc., then the wind loading should be derived in accordance with BS 6399-2.

Where the distribution of transverse loading around the section is required, the difference between the transverse wind force P_T from BS 5400-2 and the external pressures on the windward and leeward faces from BS 6399-2 should be deemed to act as friction forces on the roof and floor of the section.

The longitudinal wind load should be applied in accordance with BS 5400-2, taking P_{LS} as follows, where C_D is 2.0:

$$P_{LS} = q\{\sum[(a_1 \times C_{F1} + a_2 \times C_{F2} + \dots a_n \times C_{Fn}) + (A_2 \times C_D)]\}$$

NOTE 2 Values of C_F may be taken from Table 7.

When considering structures without live load the external and internal surfaces should be included. When considering structures with live load then P_{LS} should include the external surfaces only added to P_{LL}.

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Table 7 **Wind on enclosed walkways**

Type of surface	Frictional drag coefficient, C_F
Smooth surface without corrugations or ribs across the wind direction	0.01
Surfaces with corrugations across the wind direction, e.g. profiled cladding	0.02
Surfaces with ribs across the wind direction, e.g. roof, wall or floor members	0.04

7.4 Temperature

The range of temperatures that occur over a period of time tend to cause movements within and between different parts of the structure. This can cause loads to be induced due to restraint by rigid construction, by friction at bearings, or by change in inclination of supports such as hydraulic cylinders or winches.

Temperature effects should be in accordance with BS 5400-2. The effective bridge temperature should be appropriate for a return period of 50 years.

Temperature difference within the structure causes two effects:

a) it induces loads in supports in indeterminate structures; and

b) it creates self-equilibrating stresses in the section.

Most linkspans are simply supported and the first effects may be ignored. The second effects are generally only important in pre-stressed concrete structures and where SLS checks are required in steel work.

7.5 Effects of shrinkage and creep, residual stresses, etc.

The effects of shrinkage and creep should be determined in accordance with BS 5400-2.

NOTE These effects are unlikely to be significant in a simply supported linkspan.

7.6 Differential settlement

The effects of differential settlement should be determined in accordance with BS 5400-2. This should include the effects arising from the differential movements of mechanical supports or changes in pitch or roll of a pontoon.

7.7 Other loads

NOTE This subclause deals with loads that are classified as "exceptional loads" in highway bridge design but many of which are quite normal for the maritime environment.

7.7.1 Snow load

Snow loading on the linkspan should be derived in accordance with BS 6399-3. The snow loading should be taken as that on the ground or on a flat roof as appropriate for the configuration of the linkspan.

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Snow loading need not be considered to act in combination with operational loads as it may be assumed that the snow has been cleared from the linkspan before it is put into operation. Snow need not be considered to act in combination with extreme wind loading.

Snow loading should be considered in combination with maintenance live loads and berthing loads in combination 1 and 3.

For design loads the factor γ_{fL} should be in accordance with Table 8.

Table 8 **Values of factor γ_{fL} for snow loads**

Load combination	**Factor γ_{fL}**	
	At ULS	**At SLS**
Combination 1	1.4	1.0
Combination 3	1.2	1.0

7.7.2 Hydrostatic loads

The design of elements subject to hydrostatic pressure, such as pontoons, buoyancy tanks and buoyancy spaces, should be based on a static pressure equivalent to the depth of the element, or where the element is submerged, upon the maximum depth of water above the underside of the element.

Where the risk assessment (see **4.2**) indicates that ballast water can be pumped into a chamber under pressure, vent pipes of a size commensurate with the rate of flow of ballast water should be provided to limit the internal water pressures, and the design of the walls of the ballast chamber should be based on the pressures that would be generated if water is forced to a hydrostatic head at least as great as that induced by the vent pipe system.

Hydrostatic loads should be considered in all combinations. For design loads the factor γ_{fL} should be taken as follows:

- ULS 1.1;
- SLS 1.0.

Where an absolute maximum water level can be defined, the value of γ_{fL} at ULS may be taken as 1.0, e.g. when the water rises to the level of the top of a vent pipe.

7.7.3 Water current loading

Where pontoons or other elements are partially or wholly submerged in flowing water then the effects of water current loading on the facility should be determined in accordance with BS 6349-6.

The maximum operational water current should be agreed with the facility owner and operator, and the loads from this water current should be combined with the vehicle or pedestrian live loads.

Water current loading should be used with wind and wave loading in combination 2. For design loads the factor γ_{fL} should be in accordance with Table 9.

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Table 9 **Values of factor γ_{fL} for water current loading**

Load	Factor γ_{fL}	
	At ULS	At SLS
Erection	1.1	1.0
Dead load plus superimposed dead load only, and for members primarily resisting water current loads	1.4	1.0
Appropriate combination 2 loads for the maximum operational conditions	1.4	1.0

7.7.4 Wave loading

The effect of wave action on structures, including floating or submerged structures, can be significant and should be taken into account for all locations, even in apparently sheltered locations, and including in the design of mooring or tethering systems of pontoons.

The maximum operational wave should be agreed with the facility owner and operator and the loads from these waves combined with vehicle or pedestrian live loads.

The effects of wave loading on the facility should be determined in accordance with BS 6349-6. In addition the effect of possible wave slam or additional buoyancy caused by waves should be taken into account.

Wave loading should be considered in combination with wind and water current loading in combination 2. For design loads the factor γ_{fL} should be in accordance with Table 10.

Table 10 **Values of factor γ_{fL} for wave loading**

Load	Factor γ_{fL}	
	At ULS	At SLS
Erection	1.1	1.0
Dead load plus superimposed dead load only, and for members primarily resisting wave loads	1.4	1.0
Appropriate combination 2 loads for the maximum operational conditions	1.1	1.0
Relieving effects of wind	1.0	1.0
Movements due to wave action applied to H_{max}	1.1	1.0

7.7.5 Berthing loads

Loads arising from berthing of ships should be applied where any part of the facility is used for this purpose. In addition, due account should be taken of the likelihood of accidental impact.

Clearances should be provided where practicable so as to avoid residual impact on the facility, e.g. arising from deflection of fendering or dolphins.

When the risk assessment (see **4.2**) indicates that it is possible for any part of a ship, or other floating vessel, to come into contact with a facility then an appropriate minimum accidental load should be determined that could be applied to the facility.

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Berthing forces should be derived in accordance with BS 6349-4:1994, Section **2**. Normal and abnormal energy should be evaluated. The reaction load imparted to the structure by the fender should be obtained from the manufacturer's published performance curves for the particular fender required. This reaction load should be increased by 10%, or as otherwise suggested by the manufacturer, to allow for possible variations in the nominal values obtained from performance curves.

For elements where berthing contact is made, the impact stress should be determined for local effects at SLS. The impact stress, σ, can be derived from:

$$\sigma = EV/c$$

$$c = \sqrt{(E/\rho)}$$

Berthing loads should be combined with other combination 2 loads but need not be combined with vehicle or pedestrian loads on the linkspan.

Berthing loads should be determined in combination 1 for normal berthing and combination 4 for all cases.

For design loads the factor γ_{fL} should be in accordance with Table 11.

Table 11 **Values of factor γ_{fL} for berthing loads**

Load	**Factor γ_{fL}**	
	At ULS	**At SLS**
Normal berthing, combination 1	1.1	1.0
Normal berthing, combination 4	1.4	1.1
Abnormal berthing	1.2	1.0
Accidental berthing	1.0	1.0
Movements due to berthing	1.1	1.0

7.7.6 Mooring loads

Mooring forces should be derived in accordance with BS 6349-4:1994, Section **4**.

Mooring forces should be determined for operational and maximum conditions of wind and waves.

Mooring loads should be determined in combination with wave and wind loading in combination 2.

For design loads the factor γ_{fL} should be in accordance with Table 12.

Table 12 **Values of factor γ_{fL} for mooring loads**

Load	**Factor γ_{fL}**	
	At ULS	**At SLS**
Erection	1.1	1.0
Dead load plus superimposed dead load only, and for members primarily resisting mooring loads	1.4	1.0
Appropriate combination 2 loads for the maximum operational conditions	1.1	1.0
Relieving effects	0.9	1.0

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7.7.7 Other ship-induced loadings

7.7.7.1 General

The ship-induced loadings described in **7.7.7.2** to **7.7.7.5** should be determined at both ULS and SLS (see **0.2**).

7.7.7.2 Secondary loads from ship interface

Horizontal loads arising from ship motion should be taken into account. A horizontal load, due to friction between the ship ramp and the ship ramp landing area or the linkspan fingers and the ship, should be considered to act in any direction. The coefficient of friction may be taken as 0.3.

Secondary loads from the ship interface should be considered in combinations 1, 2 and 3.

7.7.7.3 Inertial loads

Inertial loads resulting from the movement of the linkspan due to movements of the vessel or wave action on floating and semi-submersible linkspans should be considered. These can act on the ship ramp, fingers or the whole linkspan depending on the arrangement of the facility.

Inertial loads due to movement of the vessel should be considered in combination 2.

7.7.7.4 Forces from ship propulsion

The forces from thrusters, water jets or other propulsion units that could impinge on the submerged parts of the facility should be considered. These can include dynamic movement effects of water flows passing round semi-submersible tanks, although such movements are usually less than other motion effects.

These forces can induce scour that should be taken into account when designing restraint or other support structures.

Ship propulsion loads should be considered in combination with mooring loads in combination 2 or in combination with berthing loads or separately in combination 4.

7.7.7.5 Mooring of or impact from small vessels

Where it is possible for small vessels to moor or pass adjacent to a facility then provision should be made for the possibility of horizontal forces to be applied to the facility.

Unless otherwise determined, a nominal force of 50 kN should be applied in any direction acting between 0.5 m below water level and 2.0 m above water level on any affected element of the facility.

Mooring and impact loads from small vessels should be considered in combination 4.

For design loads the factor γ_{fL} should be in accordance with Table 13.

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Table 13 **Values of factor γ_{fL} for other ship-induced loads**

Load combination	**Factor γ_{fL}**	
	At ULS	**At SLS**
Combination 1	1.5	1.0
Combination 2 and 3	1.25	1.0
Combination 4	1.5	1.0

7.7.8 Live loads on ship ramps

For live loading the ship ramp should be taken as an extension of the loaded lanes on the linkspan and the loads from the ship ramp applied to the linkspan as a line load in the ship ramp landing area.

*NOTE The effects of possible torsional stiffness on ship ramps are discussed in **7.2.3**.*

Load factors and combinations should be the same as those for the live load on the linkspan.

7.7.9 Accidental damage to suspension system

For a linkspan using Method II (see **0.3.3**), the alternative load paths needed for prevention of collapse in accordance with **8.8** should be loaded with permanent loads, primary live loads and operational wind, water current and wave loads. The loads should be considered in combination 4 at ULS only.

Where duplicate suspension systems are used, the loading is applied to the system with any single element removed.

For design loads the factor γ_{fL} should be in accordance with Table 14.

Table 14 **Values of γ_{fL} for use with accidental damage to suspension system**

Factor γ_{fL}	**Load at ULS**
HRo loads, port vehicles or 3 t vehicle loads	1.25
HB loads	1.1
Wind, water current and wave loading	1.0

7.8 Erection loads

Loads that are applied during the construction or installation stage should be determined as erection loads in accordance with BS 5400-2.

Where it is intended to tow an element of the facility from its construction site to the port of operation, the structure should be assessed for the appropriate loadings associated with the passage, which might be in addition to hydrostatic and other loads previously determined. Elements of the structure supporting towage points should be designed to be 10% stronger than the ultimate strength of the towage point, with factor γ_m taken as 1.0.

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7.9 Highway loading

7.9.1 General

The structure and its elements should be designed to resist the most severe effects of the following types of loading:

- design HRo loading;

  NOTE 1 Type HRo loading is introduced into this part of BS 6349 to replace HA loading (as defined in BS 5400-2 and later standards) because Ro-Ro loading has been found to be different in its characteristics to normal highway loading. This represents the normal design loading for the United Kingdom. It covers the effects of all permitted normal vehicles licensed under the Road Vehicles (Construction and Use) Regulations 1986 [9].

  NOTE 2 The loading has been adapted from the standard highway loading in BS 5400-2 to take account of the particular circumstances of linkspan traffic. Adaptations and deviations from the standard loading are given in Annex B.

- design 3 t loading where appropriate;
- design HB loading;
- design HRo loading combined with design HB loading if there is a multi-deck linkspan (with HB loading applied to one nominated deck only and HRo on the others);
- design port vehicle loading;
- design abnormal indivisible loads.

Highway loadings for linkspans should be in accordance with BS 5400-2 except where otherwise recommended in **7.9** in the present part of BS 6349.

Additional requirements including use of port vehicles, any loading restrictions, the number of units of HB loading, any known abnormal vehicles, and any local vehicle loading should be agreed with the owner or operator of the facility. Type HB loading is derived from the nature of exceptional industrial loads likely to use the roads in the area and should not normally be less than 30 units of HB.

Where a linkspan roadway is to be used for cars and vans restricted to 3 t gross vehicle weight then use of the type 3 t loading should be agreed with the owner or operator. Account should be taken of possible use of the structure by emergency or maintenance vehicles of more than 3 t.

Alternative weight restrictions may be agreed with the owner or operator to suit local operating arrangements.

7.9.2 Lanes

Loading should be applied to marked lanes where they exist.

Where there are no marked lanes, for instance at the splayed end, then it should be assumed that the policy defined by the marked lanes is to be continued, i.e. if there were two lanes on the main body of the bridge, then it should be assumed that there are two lanes on the splayed end also, but the position of the lanes should be such as to follow any credible traffic route between the marked lanes and the entry to the ship vehicle deck.

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If there is no defined lane policy or marked lanes, then notional lanes should be applied as required by BS 5400-2. The deck should be divided into notional lanes between the raised kerbs or, in the absence of raised kerbs, between the parapets' faces. The notional lane width should be measured at right angles to the centre of the linkspan. Notional lanes should be taken to be not less than 2.50 m wide. Where the carriageway width is less than 5.00 m then the carriageway should be taken to have one notional lane with a width of 2.50 m at the location giving the most severe loading on the deck for the element being considered. Where the number of notional lanes exceeds two their individual widths should be not more than 3.65 m. The carriageway should be divided into an integral number of notional lanes as shown in Table 15.

Table 15 **Notional lanes**

Carriageway width m	**Number of notional lanes**
2.50 up to and including 5.00	1
5.00 up to and including 7.50	2
7.50 up to and including 10.95	3
$3.65 \times (N - 1)$ up to and including $3.65N$	N

7.9.3 Type HRo loading

7.9.3.1 General

Type HRo loading should consist of convoys of vehicles from Table 16, reference no. 1 or 2, arranged in each lane in accordance with **7.9.4**. Axle weight spacings are shown in Figure 13.

NOTE HRo loading normally comprises either of the loads for vehicle reference 1 or 2 in Table 16 with the load arising from both types being used to design the structure. Other types can be used if, by agreement between the designer and the operator, they are regarded as appropriate. Some types, for instance vehicle reference 8 in Table 16, have a greater load intensity, but represent vehicles such as quarry trucks that are unlikely to cross a Ro-Ro facility in a fully loaded convoy. More than one type can be used.

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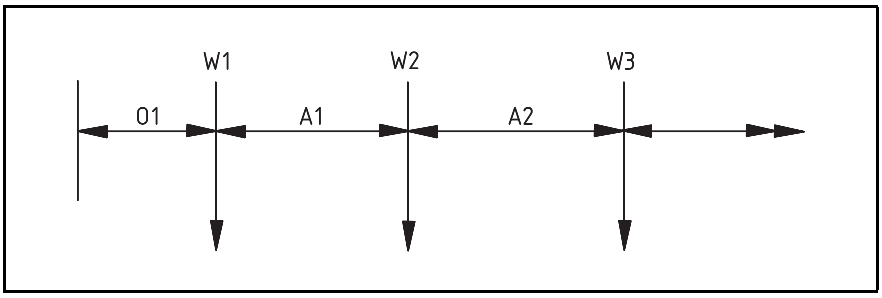
Table 16 **Standard vehicles**

Ref no.	**Vehicle gross weight** t	**No. of axles**	**Axle weights and spacing**												
			O1 m	**W1** t	**A1** m	**W2** t	**A2** m	**W3** t	**A3** m	**W4** t	**A4** m	**W5** t	**A5** m	**W6** t	**O2** m
1	44	5	1.0	7.00	2.80	11.50+	1.30	7.50+	7.60	9.00	1.35	9.00	—	—	1.0
2	44	6	1.0	6.00	2.80	10.50+	1.30	5.00+	4.70	7.50	1.35	7.50	1.35	7.50	1.0
3	41	6	1.0	5.00	2.80	10.50+	1.30	5.00+	4.18	6.83	1.35	6.83	1.35	6.83	1.0
4	40	5	1.0	5.00	2.80	10.50+	1.30	4.50+	4.80	10.00	1.80	10.00	—	—	1.0
5	40	5	1.0	6.00	2.80	11.50+	1.30	6.50+	5.28	8.00	1.02	8.00	—	—	1.0
6	40	5	1.0	6.00	3.00	11.50	4.20	7.50	1.35	7.50	1.35	7.50	—	—	1.0
7	38	4	1.0	6.50	3.00	11.50	5.10	10.00	1.80	10.00	—	—	—	—	1.0
8	32	4	1.0	6.50	1.20	6.50	3.90	11.50	1.30	7.50	—	—	—	—	1.0
9	26	3	1.0	7.00	3.42	9.50	1.30	9.50	—	—	—	—	—	—	1.0
10	26	3	1.0	7.00	3.42	11.50+	1.30	7.50+	—	—	—	—	—	—	1.0
11	26	3	1.0	6.50	3.00	11.50+	5.30	8.00+	—	—	—	—	—	—	1.0
12	20.32	3	1.0	4.32	2.67	8.00	1.02	8.00	—	—	—	—	—	—	1.0
13	18	2	1.0	6.50	3.00	11.50	—	—	—	—	—	—	—	—	1.0
14	7.5	2	1.0	6.00	2.00	1.50	—	—	—	—	—	—	—	—	1.0
15	3	2	0.75	2.10	2.00	0.90	—	—	—	—	—	—	—	—	1.0

NOTE This table is based on data published in UK Highways Agency document BD 21/02 [10].

+ The loadings in the axles marked thus are interchangeable.

Figure 13 **Axle weight spacings**

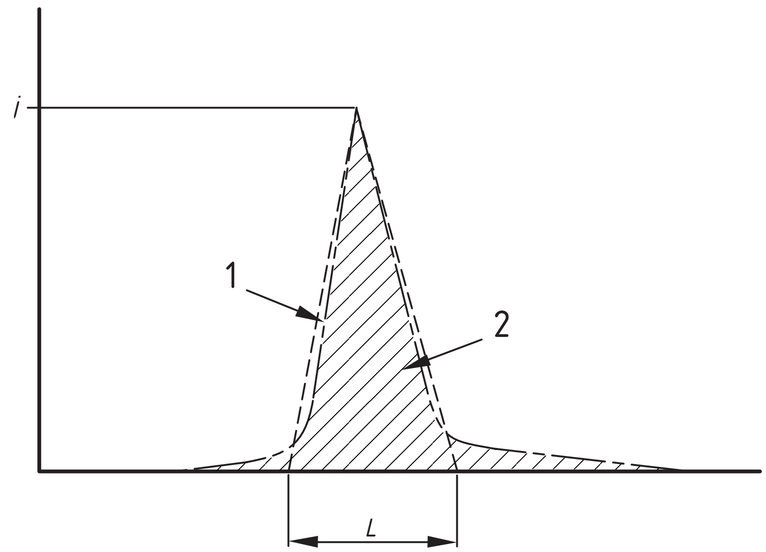


7.9.3.2 Loaded length

The loaded length for the member under consideration should be the full base length of the adverse area of the influence line. Where there is more than one adverse area, the maximum effect should be determined by consideration of the adverse area or combination of adverse areas using the loading appropriate to the full base length or the sum of the full base lengths of any combination of adverse areas selected.

Where the influence line has a cusped profile and lies wholly within the triangle joining the extremities of its base to its maximum ordinate, the base length (L_b) should be taken as twice the area under the influence line divided by the maximum ordinate (j), as shown in Figure 14.

Figure 14 **Loading influence line**



Key
1 Influence line
2 Area A

$$L = \frac{2A}{j}$$

7.9.3.3 Single nominal wheel load to design for local effects

The nominal wheel load for HRo loading should be based on either:

a) one 100 kN wheel, placed on the carriageway and uniformly distributed over a circular area with an effective pressure of 1.1 N/mm^2 (i.e. 340 mm diameter); or

b) a square contact area, using the same effective pressure (i.e. 300 mm side).

7.9.4 Single vehicles, convoys and impact factors

NOTE This subclause applies to convoys of standard vehicles making up the type HRo loading, convoys of 3 t vehicles for the type 3 t loading and also to emergency, maintenance and port vehicles where applicable.

The vehicles should be positioned within the lanes to cause the most onerous load effect but there should be at least 0.7 m lateral spacing between wheel centres of adjacent vehicles. The wheel loads should be applied at 1.8 m transverse spacing over a circular or square contact area assuming an effective pressure of 1.1 N/mm^2. Where convoys of vehicles are considered, the minimum distance between vehicles should be 1.0 m. For port vehicles and 3 t vehicles, alternative contact areas might be appropriate.

An impact factor of 1.25 should be applied to the most critical axle of the vehicles positioned for the most onerous part of the influence line diagram. These increased loads should be taken as the nominal loads.

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At discontinuities an alternative enhanced impact factor should be applied to the most critical axle of the vehicle positioned at the most onerous part of the influence line diagram. This factor should be taken as:

- 1.8 at the discontinuity decreasing linearly to 1.25 m at a distance of 5 m from the discontinuity, when using BS 5400;
- 1.3 at the discontinuity decreasing linearly to 1 m at a distance of 5 m from the discontinuity, when using *Lloyd's Rules*.

The factored axle and the remaining unfactored axles should be taken as the nominal loads.

7.9.5 Type HB loading

HB loading should be adopted in accordance with BS 5400-2.

7.9.6 Type 3 t loading

7.9.6.1 General

Type 3 t loading should consist of convoys of 3 t vehicles (vehicle reference 15 in Table 16), arranged in accordance with **7.9.4**.

7.9.6.2 Distribution

The loading should be taken to occupy one lane, applied as recommended in **7.9.4** and **7.9.9**.

7.9.6.3 Dispersal

No allowance should be made for dispersal of the loading.

7.9.6.4 Single nominal wheel load for design of local effects

The nominal wheel load for HRo loading should be based on either:

a) one 25 kN wheel, placed on the carriageway and uniformly distributed over a circular area with an effective pressure of 1.1 N/mm^2 (i.e. 240 mm diameter); or

b) a square contact area, using the same effective pressure (i.e. 215 mm side).

7.9.7 Emergency and maintenance vehicles

Emergency vehicle loading should be taken into account for the extreme water level and sea state. The emergency vehicle should normally be taken to be a single 18 t vehicle (vehicle reference 13 in Table 16), positioned in accordance with **7.9.4**.

This is equivalent to a vehicle restricted to 18 t gross vehicle weight. Other vehicles might be appropriate and should be agreed with the owner or operator of the facility.

Account should be taken of any mobile crane loads that will be required for maintenance of mechanical plant.

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7.9.8 Port vehicles

Where the facility is to be designed for port vehicles such as forklift trucks and roll trailers, information on the vehicles that are expected to be used should be assembled and wheel and axle loadings obtained. The payload capacity of the port vehicles, and the limits on the numbers of these vehicles permitted on the facility at any one time, should be agreed with the operator to suit the operating conditions for the facility.

Port vehicles should be positioned in accordance with **7.9.4**.

7.9.9 Application of types HRo, HB and 3 t loading

7.9.9.1 Type HRo loading and type 3 t loading

Type HRo loading should be applied to each lane in the appropriate parts of the influence line for the element or member under consideration. A lane or lanes may be left unloaded if this causes the most severe effect on the member or element under consideration.

Where the point under consideration has a different influence line for the loading in each lane, the appropriate loaded length for each lane will vary and the lane loadings should be determined individually.

7.9.9.2 Types HRo and HB loading combined

Type HB loading should be assumed to act within 500 mm of the centre of the linkspan with no other loading unless otherwise agreed with the owner or operator of the facility.

On multi-level structures, type HRo loading should be assumed to act on the other level to the type HB loading.

7.9.10 Accidental wheel loading

For linkspans designed for type HRo and type HB loading, the nominal accidental wheel load should be in accordance with BS 5400-2:2006, **6.6**.

For linkspans designed for type 3 t loading the accidental wheel loading should be one axle with 25 kN wheel loads.

7.9.11 Design loads

For design loads γ_{fL} should be in accordance with Table 17.

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Table 17 **Values of factor γ_{fL} for design loads**

Load and combination	Factor γ_{fL}	
	At ULS	**At SLS**
HRo considered alone		
Combination 1	1.50	1.20
Combination 2 and 3	1.25	1.00
HB, and HRo in combination with HB		
Combination 1	1.30	1.10
Combination 2 and 3	1.10	1.00
Type 3 t loading		
Combination 1	1.50	1.20
Combination 2 and 3	1.25	1.00
Emergency and maintenance vehicles		
At extreme water levels	1.10	—
Combination 1	1.30	1.10
Combination 2 and 3	1.10	1.00
Port vehicles		
Combination 1	1.50	1.20
Combination 2 and 3	1.25	1.00

7.10 Walkway live loads

Walkway loading should be in accordance with BS 5400-2 except where the appropriate authority agrees that exceptional crowd loading cannot occur. Generally passenger walkways experience peak loading such that a reduced loading is not justified.

7.11 Loads due to vehicle collision with parapets

The local effects of vehicle collision with parapets should be taken into account in the design of elements supporting parapets as specified in BS 5400-2.

7.12 Vehicle collision loads

7.12.1 General

Vehicle collision loads should be in accordance with BS 5400-2 except where it is assumed that vehicle speeds for road traffic will be strictly limited. Where speeds higher than 25 kph are likely, the provisions of BS 5400-2 should be applied in full.

7.12.2 Loads on superstructures

Where superstructures occur above a roadway or railway, e.g. in double deck structures or where an elevated passenger access or approach span crosses a roadway, with a headroom of less than 6.0 m in any design condition, a single point load of 50 kN should be deemed to act on the soffit of the superstructure parallel to the roadway below within its width between parapets, acting in any direction between horizontal and vertically upwards.

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The soffit load should be applied in combination with no other loads in combination 4. The load need only be determined at ULS with $\gamma_{fL} = 1.5$.

7.13 Fatigue loading

Roadway fatigue traffic loading should be applied in accordance with BS 5400-10. The load spectrum should reflect the amount and nature of traffic that is likely to use the facility over its intended design life. The factors γ_{fL} and γ_{f3} should be taken as 1.0 for fatigue loading.

The design life of the structure is 30 years so the simplified procedures given in BS 5400-10:1980, **7.2** are not applicable. Where general road traffic is to use the linkspan then the procedure given in BS 5400-10:1980, **7.3** may be used. This assumes the standard loading spectrum which is applicable with traffic comprising up to 30% HGVs. Where there are more than 30% HGVs or the linkspan is to be used with restricted vehicles or by port vehicles, the method given in BS 5400-10:1980, **7.4** should be used. This will necessitate the determination of load effects for the full range of vehicles expected to use the structure.

Where the structure is designed to carry restricted vehicles with a 3 t weight restriction then a standard car fatigue vehicle should be taken as representing the effects of the load spectrum. This consists of a two-axle vehicle with a weight of 20 kN, a track of 1.8 m and axle spacing of 3 m. Each of the four tyres contributes a load of 5 kN taken over a contact area of 150 mm × 150 mm.

Wherever possible the annual flow of commercial vehicles should be determined from estimates of vehicle flows at the facility. Table 18 gives guidelines on traffic that would be expected at various classes of facility. BS 5400-10:1980, Table 10 should be used where annual flows cannot be established easily.

Table 18 **Annual flow of road vehicles (valid for up to 30% HGVs only)**

Traffic type			**Annual flow of vehicles per lane** (× 10³)	**Annual flow of fatigue vehicles** A) (× 10³)
Usage	**Sailings per day**	**Traffic type**		
Light	1	Commercial and private	40	12
		Private cars and vans only B)	120	120
Medium	4	Commercial and private	200	60
		Private cars and vans only B)	600	600
Heavy	12	Commercial and private	1 000	300
		Private cars and vans only B)	3 000	3 000

A) Annual flow of fatigue vehicles is the annual flow of commercial vehicles compatible with BS 5400-10:1980, Table 1, and the number of 3 t fatigue vehicles for the restricted weight linkspans.
B) Private cars and light vans only applies to linkspans restricted to a 3 t weight limit.

Fatigue loading should be taken into account for every traffic lane or vehicular area to be used regularly by moving traffic. All lanes should be taken to be interchangeable. The use of multiple paths, as given in BS 5400-10:1980, **C.1.4**, should be considered for elements that directly carry wheel loads.

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7.14 Loads from operational equipment

Loads from operational equipment should be taken into account wherever such equipment is attached, supported on or by the structure, and is being used, for example, to alter the height of a linkspan under the adjustment condition. Account should be taken of the direction of loading about all axes and of any eccentricity of loading that can be applied to the structure, taking account of its range of articulation or adjustment. For example, where linkspans are supported and adjusted by hydraulic cylinders or winch ropes, the angle of inclination of the applied loads with respect to the linkspan will vary continuously throughout the height range, and can also vary with respect to the supporting structure depending upon the mode of articulation and means of thermal or other movements.

Allowance for inertia forces should be made wherever operational equipment is being used to adjust the structure and will vary depending on the type of equipment and its mode of operation. In the absence of other information, the following inertia factors may be applied:

- hydraulic cylinders or jacks, 1.10;
- winches, 1.05;
- screwjacks, 1.10;
- rack and pinion, 1.10.

The inertia factor should be applied to the calculated static loads from the equipment to overcome any weight supported, friction and other effects resisting movement of the operational equipment.

An inertia factor should be applied to the design of a support where a structure is lowered onto such a support using operational equipment, e.g. where a linkspan is lowered onto a maintenance sprag. The inertia factor should also be applied to any rapid changes of loading in accidental conditions. The inertia factor should usually be taken as 1.8.

NOTE Inertia factors are applied in addition to γ_{fL}.

In the calculation of static loads, allowance should be made for tolerance in the synchronization between different items of operational equipment due to additional forces being induced in the structure. For example, where a linkspan is being supported during adjustment by hydraulic cylinders or winches on each side then any departure from synchronization at the two supports will induce torsion within the linkspan structure, causing the load to be increased in one support and reduced in the other.

7.15 Loads on vehicle and pedestrian restraint systems and kerbs

Vehicle restraint systems should be designed for the loads given in Table 19. Low containment parapets should be used only when the roadway is straight in plan without splayed ends, or where it is to be used by cars or vans only.

The local effects of vehicle collision with parapets should be taken into account in the design of the elements of the structure supporting parapets, as specified in BS 5400-2:2006, **6.7**.

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Loads on vehicle restraint systems should be combined with the effects of the nominal accidental wheel loads given in BS 5400-2:2006, **6.6** under combination 4 only, but need not be taken as coexistent with other live loads.

Loads on pedestrian restraint systems should be deemed to act with the walkway loading given in **7.10**.

Table 19 **Loads on vehicle and pedestrian restraint systems**

Type and containment level		**Design load to effective longitudinal members of parapet** kN/m	**Design load per post** kN
Pedestrian parapet only		1.4 to all longitudinal members	1.4 × post spacing applied to top rail
Service walkway parapets		0.7 to all longitudinal members [A)]	0.7 × post spacing applied to top rail
Guardrails		1.0	1.0
Vehicle	Low containment, parapet or safety barriers	25/*n*	25
	Normal containment parapet	50/*n*	50

n = number of effective longitudinal members

Where a restraint system is surmounted on a continuous plinth (being a kerb or other structure connected to the deck of not less than 350 mm height) the plinth may be considered to be an effective longitudinal member and counted in the number "*n*".

A) Refer to BS 7818:1995.

Kerbs should be designed to resist the lateral force of 25 kN or 50 kN dependant on the containment level of the parapet or safety barrier. This need not be combined with the accidental road vehicle loading for verges or footways.

8 Structural analysis and design

8.1 Design approach

The design of pontoons and other floating structures, where these form part of the structure of linkspans and walkways, should be generally in accordance with either BS 6349-6 or *Lloyd's Rules*.

Structural analysis and design for supported linkspans should generally be in accordance with either BS 5400 or *Lloyd's Rules*.

Whichever code is used, it is essential for the designer to apply it consistently; the two codes should not be mixed as this can lead to flawed calculations and potentially unsafe structures. The recommendations given in **8.2** to **8.11** should always be followed whichever code is used.

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8.2 Foundations

Foundations that support or form part of a facility should be designed in accordance with BS 8004 or BS EN 1997.

BS 8004 is not based on limit state principles. If BS 8004 is to be used as the basis for designing foundations, the nominal loads recommended in the present part of BS 6349 should be adopted as the design loads, taking γ_{fL} as the values given in the "Operational equipment and geotechnical" columns of Table A.1, and γ_{F3} as 1.0. BS 6349-2 should be used in the design of quay walls, jetties and dolphins that form part of a facility.

BS EN 1997 is based on limit state principles. If BS EN 1997 is to be used at the basis for designing foundations, the designer should use the partial safety factors recommended in BS EN 1997 rather than those included in this part of BS 6349.

8.3 Articulation and structural movements

Linkspans accommodate changes in level and position of vessels, within operating limits as defined in **4.4**. They are subject to deflections resulting from motions of berthed vessels and pontoons and from changes in draft of vessels and pontoons as live loads pass over the linkspan. The response of the structure to these deflections is dependent on the disposition of supports and the structural form of the linkspan and, where such deflections can occur, they should be allowed for in the structural analysis. Torsional moments and reactions should be calculated for torsionally stiff structural systems and combined with other load effects as appropriate. Where torsionally weak systems are used so as to avoid torsional moments and reactions due to differential deflections within the structure, the analysis should demonstrate maintenance of equilibrium by other means.

For enclosed passenger or service walkways, the stiffness offered by the claddings and floor should be taken into account in assessing the effect of torsional rigidity upon four-point support reactions.

If a walkway is supported by a floating body, it is important to take account of the forces that can be induced by movements of the said floating body that might result from totally unrelated loadings such as waves or vehicles traversing a lower deck. This can be mitigated by attention to the articulation of the structure in the six degrees of freedom.

8.4 Stability

The linkspan and its components should be checked for overall stability at the ultimate limit state at appropriate load combinations as defined in **7.1** and at the design conditions defined in **0.3**. Loading should include the weight of water where this can act on parts of the structure with adverse effects. Resistance or restoring effects should exceed disturbing or overturning effects: to calculate this, the least restoring moment from minimum nominal loads divided by the greatest overturning moment from factored loads in accordance with BS 5400 should be greater than 1.

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In addition, supports should be designed to maintain their full resistance under all water levels and sea state conditions.

Particular attention should be given to the stability of semi-submersible linkspans where the position of the centres of gravity is high and that of the centre of buoyancy is very low. Such structures are often unstable unless they are torsionally restrained in a robust way, and can become unstable and capsize if the shore bearings lose their restrain. For instance, such a loss of restraint can occur during certain maintenance operations.

It is essential that the linkspan design ensures stability of the structure under both the operations, maintenance and most severe environmental conditions.

8.5 Sinking of floating structures

Pontoons and other floating structures should be designed to withstand the effects of puncturing of a flotation chamber by impact from ships or debris, either by means of subdivision of the pontoon into chambers or by filling them with a suitable buoyant foam with long-term durability of function.

NOTE Lloyd's Rules *includes minimum requirements for the numbers of subdivision in a pontoon.*

The subdivided flotation chambers, as well as catering for any ballasting facilities to alter trim and heel, should be so arranged as to allow any two chambers to become punctured and flooded (or relieved of ballast water depending on the circumstances) without the pontoon becoming unsafe or sinking.

8.6 Bearings

Linkspan bearings should be designed to accommodate the full range of movements and rotations occurring at the bearing as defined in Clause **7**.

Structural design of linkspan bearings should be generally in accordance with BS 5400-3 and BS 5400-9, but taking due account of rates of movement and potential dynamic loading effects associated with articulated linkspans and not usually found in bearings for fixed bridges. The bearings should be designed for appropriate factored loads at the ultimate and serviceability limit states.

Notwithstanding the above, bearings should be robust and as simple as is consistent with meeting the articulation requirements in a marine environment. It can be acceptable to use bearings with higher levels of wear if this results in a simpler and more robust structure. In such cases, sacrificial wear strips and easily replaceable parts are required.

Bearings should be accessible for inspection and maintenance, and pins and other components, which can be subject to wear in service, should be easily removable.

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All bearings, guides and restraints should be designed so that they can be inspected without removal. Jacking or other suitable means should be provided such that bearings can be removed and replaced if necessary. Enclosed pin type bearings should permit pin removal without dismantling the remainder of the bearing and whilst the load is supported. Pin bearings should be designed such that pins are subject to double not single shear. Pins should be retained in position by robust keep plates, double locking nuts or other measures which ensure pin retention under all conditions, but which permit removal. It is recommended that pins are provided with a central through hole so that they can be inspected for straightness whilst in place and means for measuring the wear on the shaft of the bearings.

Bearings should be designed to resist uplift forces where these can develop under design loading, unless it can be demonstrated that overall stability and equilibrium of moments and forces within the structure and at the other supports can be maintained when positive restraint is not provided. Bearings should be designed to fail safe and should be provided with safety restraints where design movements could be exceeded in accident or overload conditions.

8.7 Guides

Guides that resist lateral loads over the adjustment height range should consist of continuous strips attached to the supporting structure. Suitable materials for rubbing strips include carbon steel, stainless steel or ultra high density polyethylene. Hardwood, such as greenheart, may be used where loads and movements are not too severe. Sufficient side clearances should be provided to cater for debris, temperature changes and crabbing. Rubbing strips should be adjustable to cater for construction tolerances and should be capable of replacement if worn or damaged.

8.8 Prevention of collapse

When a linkspan or walkway is supported using Method I (see **0.3.3**), then the span should be spragged, or supported by the slip, during maintenance or operations, and the remainder of this subclause is not applicable.

Where the linkspan or walkway is to be supported by a mechanically lifted suspension system using Method II (see **0.3.3**) from a support structure, an alternative load path should be provided in the event of a failure in any element of the primary load support path of that system, inclusive of the connections to the support structure (see Figure 15).

When a failure occurs such that the alternative load path is called upon to support the linkspan or walkway, then the load factor should conform to **7.7.9**.

In addition, the detailing of the support structure, lifting beams and local detailing of connection brackets should aim to maximize the ductility of the structure so that any failure within the remainder of the support structure will be as a result of plastic action rather than a slender collapse or brittle tension failure.

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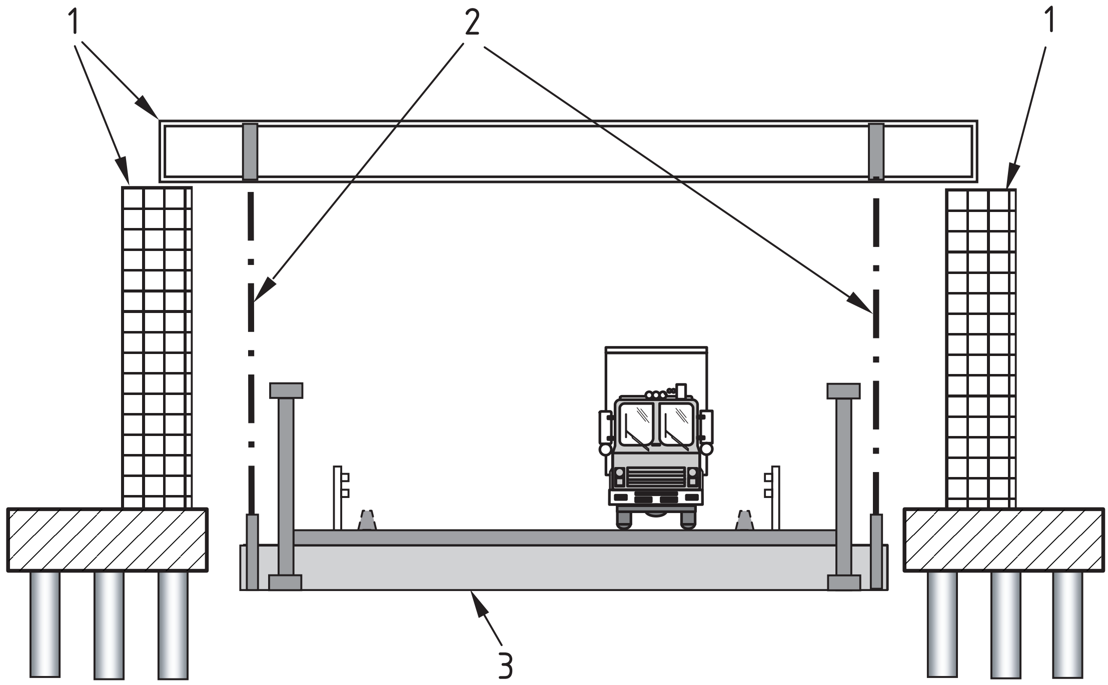
To that end, the members of the support structure and the lifting beam should be compact in accordance with BS 5400-3. Furthermore any stiffening, welded joints and members resisting local effects of the suspension loads should be designed with $\gamma_{f3} = 2.0$. The detailing should aim to mobilize the full plastic capacity of the support sections.

Figure 15 **Definition of primary support path for suspension system**



Key

1 Support structure

2 Primary load support path suspension system

3 Lifting beam

8.9 Integration with operational equipment

The designer should ensure that all loads from the structure that are to be transmitted to operational equipment are compatible with those assumed in the mechanical and engineering (M&E) design, and that proper load paths are provided. Similarly, the designer should ensure that all loads from operational equipment where attached to the structure can be safely transmitted, including the weight of such equipment. Such considerations should be taken into account in the risk assessment (see **4.2**) and the relevant information should be included within the operation and maintenance manual (see **4.3**).

For M&E design, nominal loads are normally used without factoring, but it is recommended that the nominal loads are multiplied by the factors γ_{fl} listed in the “Operational equipment and geotechnical” columns of Table A.1 before applying them to the design of operational equipment.

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Care should be taken in dealing with loads from part fall rope systems to ensure that the correct loads are transmitted to the structure. Loads should be separated into the different components of dead, live, wind and other loadings for the critical load combinations, and for the various relevant design conditions given in **0.3**.

The design should be carried out so that efficient integration is achieved to all operational equipment. At attachment points, sufficient space should also be provided to allow as far as practicable for late changes to the final details.

8.10 Maintenance and parking

Provision should be made in the design for inspection and maintenance of the structures to be carried out. Structures should incorporate a facility for replacement of bearings, guides and restraints and for replacement of operational equipment.

NOTE 1 The working life of these elements is often less than that of the structure.

Provision should be made in the design of adjustable linkspans for a spragging or parking position where the structure can be safely supported independently of the operational equipment under the maintenance condition as defined in **0.3.5**, whilst such equipment can be maintained or replaced. The location of the spragging or parking position should preferably be such that the linkspan will be sufficiently clear of water levels, although for maintenance purposes more than one parking position might be needed.

NOTE 2 Refer to BS EN ISO 14122 for further information on safe access to operational equipment.

Pontoon and link bridges should be provided with clearly locatable temporary support points for use when the pontoon is placed in dry-dock for maintenance.

8.11 Proprietary items

Where proprietary items are incorporated as part of the structure then the designer should ensure that these items are suitable for the purpose in a marine environment, and are correctly specified, designed and checked. Examples of such proprietary items include bearings, handrails, parapets, bollards, shackles or other lifting gear attachments and standard walkway flooring.

9 Furniture, finishes and corrosion protection

9.1 General

When selecting items of furniture and fittings, account should be taken of the intended use of the structure and its location in a marine environment. All items should be of robust construction and securely fixed in place taking into account the various movements, orientations, loads and vibrations to which they might be subjected.

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9.2 Corrosion protection

It is important to protect all elements of the structure from normal corrosion. Particular attention should be given to elements that might suffer from excessive corrosion such as microbiological-induced corrosion where this is appropriate.

9.3 Roadway and footway surfaces

Roadway and footway surfaces should be slip-resistant so as to reduce the possibility of skidding or slipping under the maximum gradients that can arise during use.

Surfaces upon which public pedestrians are to be permitted should be of solid construction. Surfaces that are to be used by vehicles and/or service personnel only may be of open mesh or grid construction provided this is suitably slip-resistant.

Non-structural surfacing materials should be securely bonded to the structure beneath.

Unsurfaced plates, either plain or with a raised pattern finish (whether painted or galvanized or not) should not be used by passenger or vehicular traffic.

Raised patterned plates may be used on service walkways up to 1.5 m wide where handrails are provided on both sides.

9.4 Vehicle and pedestrian restraint systems and kerbs

9.4.1 General

Vehicle and pedestrian parapets, safety barriers, handrails and kerbs should be provided wherever appropriate. These items should be securely fixed, or held in place where they need to be removed during operation of the facility. The fixings and their supporting structures should be designed to resist the specified loadings and effects to which the item might be subjected. All items and their fixings should be designed to allow replacement to be effected in case of accidental damage or other cause. Details should be arranged so that wherever practicable replacement can be effected without access being necessary to the soffit of the structure.

The details of parapets and kerbs should be arranged so that an upstand at least 100 mm high is provided at the edges of roadways or footways that are adjacent to the edge of a structure. Allowance should be made for the drainage of surface water at the free edges by way of local gaps in the upstand.

All vehicle and pedestrian parapets, safety barriers, handrails and kerbs should be finished or painted in prominent colours to enhance visibility.

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9.4.2 Parapets and safety barriers

Vehicle or pedestrian parapets should be provided at the free edges of all parts of the facility where the drop exceeds 100 mm to prevent vehicles or passengers from falling below. Where a passenger footway is provided at the edge of a roadway, an intervening safety barrier should be provided, unless a kerb at least 150 mm high is provided, together with a pedestrian parapet at the edge of the structure. Such footways with no intervening barriers are only for use where passengers are marshalled and controlled so that they do not use the footway unless there is either no traffic or the traffic queue is almost stationary. In all other cases, a safety barrier between the footway and roadway is essential. Where no intervening safety barrier is provided, a vehicle parapet should be provided at the free edge of the structure proportioned to act additionally as a pedestrian parapet. Where no passenger footway is incorporated at the edge of a roadway, a vehicle parapet should be provided at the edge of the structure. Parapets and safety barriers may be omitted at the edges of designated interface and ship landing areas (see Figure 9), but where these areas are used by pedestrians, suitable pedestrian restraint systems should be provided for the safety of persons during operation.

Vehicle parapets should be designed to conform to BS 6779-1, to loadings taken from Table 19.

Safety barriers may be either corrugated or box section, and should be designed for the loading taken from Table 19.

Pedestrian parapets should conform to the requirements for Class 3 pedestrian restraint systems as specified in BS 7818:1995, and should incorporate infilling members or cladding to maximize safety. Service walkway parapets should conform to the requirements for Class 2 pedestrian restraint systems as specified in BS 7818:1995, but need not incorporate infilling members or cladding.

Safety barriers that are intended to deflect errant road vehicles from footways and other solid areas at road level or from embankments steeper than 1 in 4 should be designed to resist loads as for load containment parapets as given by Table 19. Safety barrier rails should be at least 0.7 m high, but should otherwise conform to BS 6779-1.

The bridge structure itself may be designated as forming part of or the complete pedestrian restraint system where the structure is designed to resist the loads specified for pedestrian restraint systems in addition to its main function. For example, in a half through linkspan the main girders may form either part or all of the pedestrian restraint system. Vehicles should not be permitted to come into direct contact with the bridge structure and an intervening safety barrier should be provided. Such a barrier should be supported by the deck and not given lateral support by the main bridge girders when fully deflected.

For ship end fingers, as typically used to span from the upper decks of double deck linkspans to the ship, it is not possible to provide full containment barriers for traffic. In these circumstances, simple lightweight post and chain or similar provision should be made in order to provide some level of pedestrian safety without giving a false impression of security to other users.

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9.4.3 Pedestrian guardrails and handrails

Pedestrian guardrails should be provided to prevent pedestrians from straying into unauthorized areas, such as pontoon decks where parapets or safety barriers are not provided. Pedestrian guardrails should be at least 1 000 mm high. A sufficient number of horizontal or vertical members should be provided such that the space between them does not exceed 300 mm.

At the edges of interface and ship ramp landing areas which are not normally to be used by pedestrians, but which can be used by service personnel, guardrails may take the form of a chain for rapid placing and removal. Such chains should have a height of not less than 900 mm (measured at centre of sag) with the supporting posts and chain designed for loads equivalent to those recommended in Table 19 for service walkway parapets. Post spacing should not exceed 1.8 m and the chains should have a natural sag such that the posts are designed to resist the inward pull of the chain when loaded. The chain should be designed assuming $\gamma_m = 3$.

Handrails should be provided on all passenger footways when the gradient under the operating condition exceeds 1 in 20, and at steps or staircases.

9.4.4 Kerbs

Kerbs should be provided at the edges of roadways adjacent to footways where safety barriers are not provided, and are recommended for use throughout facilities where changes in direction of the roadway occur. Kerbs should have a height of not less than 150 mm with the front face sloped back at 1 horizontal to 3 to 5 vertical. There should be no projections such as bolt heads on the traffic face. They should be of robust construction, designed and fixed to resist the vertical and lateral loads recommended in this part of BS 6349.

9.4.5 Lifting barriers

A lifting barrier should be provided at the shore end of any linkspan in order to prevent unauthorized access.

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Annex A (informative) Load combinations and partial safety factors

Table A.1 shows the values of γ_{fL} for each combination of load.

Table A.1 Loads to be taken in each combination with appropriate value of γ_{fL} A)

Clause number	Load	Limit state	Values of γ_{fL} to be considered in combination							
			1	2	3	4	Operational equipment and geotechnical B)			
							Normal	Unusual wind	Unusual temperature	Exceptional
BS 5400-2: 2006, **5.1**	Dead: Steel	ULS C), D)	1.10	1.10	1.10	1.10	1.05	1.00	1.00	1.00
		SLS E)	1.00	1.00	1.00	1.00	—	—	—	—
	Concrete	ULS D)	1.20	1.20	1.20	1.20	1.05	1.00	1.00	1.00
		SLS	1.00	1.00	1.00	1.00	—	—	—	—
BS 5400-2: 2006, **5.2** BS 6349-8: 2005, **7.2.3**	Superimposed dead: Deck surfacing Also loads from ship ramps	ULS F)	1.75	1.75	1.75	1.75	1.05	1.00	1.00	1.00
		SLS F)	1.20	1.20	1.20	1.20	—	—	—	—
	Other loads Also loads from ship ramps	ULS	1.20	1.20	1.20	1.20	1.00	1.00	1.00	1.00
		SLS	1.00	1.00	1.00	1.00	—	—	—	—
BS 6349-8: 2005, **7.2.2**	Loads not evaluated accurately with no upper bound determined	ULS	1.75	1.75	1.75	1.75	1.05	1.00	1.00	1.00
		SLS	1.20	1.20	1.20	1.20	—	—	—	—
	Loads where upper bound values is used	ULS	1.20	1.20	1.20	1.20	1.00	1.00	1.00	1.00
		SLS	1.00	1.00	1.00	1.00	—	—	—	—
BS 5400-2: 2006, **5.1.2.2** and **5.2.2.2**	Reduced load factor for dead and superimposed dead load where this has a more severe total effect	ULS	1.00	1.00	1.00	1.00	—	—	—	—
		SLS	1.00	1.00	1.00	1.00	—	—	—	—
BS 5400-2: 2006, **5.3**	Wind: During erection	ULS	—	1.10	—	—	—	—	—	—
		SLS	—	1.00	—	—	—	—	—	—
	With dead plus superimposed dead load only, and for members primarily resisting wind loads.	ULS	—	1.40	—	—	—	—	—	—
		SLS	—	1.00	—	—	—	—	—	—
	With dead plus superimposed dead plus other appropriate combination 2 primary live loads G)	ULS	—	1.10	—	—	—	1.00	—	—
		SLS	—	1.00	—	—	—	—	—	—
	Relieving effect of wind	ULS	—	1.00	—	—	—	—	—	—
		SLS	—	1.00	—	—	—	—	—	—

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Table A.1 **Loads to be taken in each combination with appropriate value of γ_{fL} A)** (*continued*)

Clause number	Load	Limit state	Values of γ_{fL} to be considered in combination							
			1	2	3	4	Operational equipment and geotechnical B)			
							Normal	Unusual wind	Unusual temperature	Exceptional
BS 5400-2: 2006, **5.4**	Temperature: Restraint to movement, except frictional	ULS	—	—	1.30	—	—	—	1.00	—
		SLS	—	—	1.00	—	—	—	—	—
	Frictional bearing restraint	ULS	—	—	—	—	—	—	1.00	—
		SLS	—	—	—	—	—	—	—	—
	Effect of temperature difference	ULS	—	—	1.00	—	—	—	1.00	—
		SLS	—	—	0.80	—	—	—	—	—
BS 5400-2: 2006, **5.6**	Differential settlement	ULS	1.20	1.20	1.20	1.20	1.00	1.00	1.00	1.00
		SLS	1.00	1.00	1.00	1.00	—	—	—	—
BS 5400-2: 2006, **5.7**	Exceptional loads		To be assessed and agreed between the engineer and the appropriate authority. Particular recommendations for linkspans are given in this table.							
BS 6349-8: 2005, **7.7.1**	Snow loading H)	ULS	1.40	—	1.20	—	—	—	1.00	—
		SLS	1.00	—	1.00	—	—	—	—	—
BS 6349-8: 2005, **7.7.2**	Hydrostatic loads: Variable water load	ULS	1.10	1.10	1.10	1.10	1.00	1.00	1.00	1.00
		SLS	1.00	1.00	1.00	1.00	—	—	—	—
	Where an absolute maximum water level can be defined	ULS	1.00	1.00	1.00	1.00	—	—	—	—
		SLS	—	—	—	—	—	—	—	—
BS 6349-8: 2005, **7.7.3**	Water current loadings: Erection	ULS	—	1.10	1.10	—	—	—	—	—
		SLS	—	1.00	1.00	—	—	—	—	—
	With dead plus superimposed dead load only, and for members primarily resisting water current loads G)	ULS	—	1.40	1.40	—	—	—	—	—
		SLS	—	1.00	1.00	—	—	—	—	—
	With dead plus superimposed dead plus other appropriate combination 2 or 3 primary live loads	ULS	—	1.40	1.40	—	—	1.00	1.00	—
		SLS	—	1.00	1.00	—	—	—	—	—
BS 6349-8: 2005, **7.7.4**	Wave loading: Erection	ULS	—	1.10	—	—	—	—	—	—
		SLS	—	1.00	—	—	—	—	—	—
	With dead plus superimposed dead load only, and for members primarily resisting wave loads	ULS	—	1.40	—	—	—	—	—	—
		SLS	—	1.00	—	—	—	—	—	—
	With dead plus superimposed dead plus other appropriate combination 2 primary live loads G)	ULS	—	1.10	—	—	—	1.00	—	—
		SLS	—	1.00	—	—	—	—	—	—

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Table A.1 **Loads to be taken in each combination with appropriate value of γ_{fL} A)** (*continued*)

Clause number	Load	Limit state	Values of γ_{fL} to be considered in combination							
			1	2	3	4	Operational equipment and geotechnical B)			
							Normal	Unusual wind	Unusual temperature	Exceptional
BS 6349-8: 2005, **7.7.5**	Berthing loads: Normal berthing (as defined in BS 6349-4) I)	ULS	—	1.10	—	1.40	—	1.00	—	—
		SLS	—	1.00	—	1.10	—	—	—	—
	Abnormal berthing (as defined in BS 6349-4)	ULS	—	—	—	1.20	—	—	—	1.00
		SLS	—	—	—	1.00	—	—	—	—
	Accidental berthing	ULS	—	—	—	1.00	—	—	—	1.00
BS 6349-8: 2005, **7.7.6**	Mooring loads: Erection	ULS	—	1.10	—	—	—	—	—	—
		SLS	—	1.00	—	—	—	—	—	—
	With dead plus superimposed dead load only, and for members primarily resisting mooring loads	ULS	—	1.40	—	—	—	—	—	—
		SLS	—	1.00	—	—	—	—	—	—
	With dead plus superimposed dead plus other appropriate combination 2 primary live loads	ULS	—	1.10	—	—	—	1.00	—	—
		SLS	—	1.00	—	—	—	—	—	—
	Relieving effect of wind-induced mooring loads G), I)	ULS	—	1.00	—	—	—	—	—	—
BS 6349-8: 2005, **7.7.7**	Other ship-induced loads: Secondary loads from ship interface	ULS	1.50	1.25	1.25	—	—	1.00	—	—
		SLS	1.00	1.00	1.00	—	—	—	—	—
	Inertial loads due to movement of linkspan, ship ramp, fingers etc.	ULS	—	1.25	—	—	—	1.00	—	—
		SLS	—	1.00	—	—	—	—	—	—
	Forces from ship propulsion Considered with berthing loads or separately to give the worst effect	ULS	—	—	—	1.50	1.00	—	—	—
		SLS	—	—	—	1.00	—	—	—	—
	Mooring or impact from small vessels	ULS	—	—	—	1.50	—	—	—	1.00
		SLS	—	—	—	1.00	—	—	—	—
BS 6349-8: 2005, **7.7.9**	Accidental damage to suspension system:									
	HRo loads, port vehicles or 3 t vehicle loads	ULS	—	—	—	1.25	—	—	—	1.00
	HB loads	ULS	—	—	—	1.1	—	—	—	1.00
	Wind, water current and wave loading	ULS	—	—	—	1.0	—	—	—	1.00
BS 5400-2: 2006, **5.8**	Earth pressure		As BS 5400-2 and not usually required for linkspans.							

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Table A.1 **Loads to be taken in each combination with appropriate value of γ_{fL} A)** (*continued*)

Clause number	**Load**	**Limit state**	**Values of γ_{fL} to be considered in combination**							
			1	**2**	**3**	**4**	**Operational equipment and geotechnical B)**			
							Normal	**Unusual wind**	**Unusual temperature**	**Exceptional**
BS 5400-2: 2006, **5.9**	Erection: Temporary loads	ULS	—	1.15	1.15	—	—	—	—	—
		SLS	—	1.00	1.00	—	—	—	—	—
BS 5400-2: 2006, **6.2** BS 6349-8: 2005, **7.9**	Highway bridge live loading: HRo alone Also for reduced HRo loading on weight restricted structures	ULS	1.50	1.25	1.25	—	1.00	1.00	1.00	1.00
		SLS	1.20	1.00	1.00	—	—	—	—	—
BS 5400-2: 2006, **6.3**	HRo with HB or HB alone	ULS	1.30	1.10	1.10	—	1.00	1.00	1.00	1.00
		SLS	1.10	1.00	1.00	—	—	—	—	—
BS 6349-8: 2005, **7.9.8**	Port vehicles	ULS	1.50	1.25	1.25	—	1.00	1.00	1.00	1.00
		SLS	1.10	1.00	1.00	—	—	—	—	—
BS 6349-8: 2005, **7.9.7**	Maintenance and emergency vehicles	ULS	1.30	1.10	1.10	—	1.00	1.00	1.00	1.00
		SLS	1.10	1.00	1.00	—	—	—	—	—
BS 5400-2: 2006, **6.5**	Footway and cycle track loading	ULS	1.50	1.25	1.25	—	1.00	1.00	1.00	1.00
		SLS	1.20	1.00	1.00	—	—	—	—	—
BS 5400-2: 2006, **6.6** BS 6349-8: 2005, **7.12**	Accidental wheel loading Also for reduced HRo loading on weight restricted structures	ULS	1.50	—	—	—	—	—	—	—
		SLS	1.20	—	—	—	—	—	—	—
The remaining values are given in BD 37/01 [11].										

A) Developed from BS 5400-2:2006, Table 1.

B) Refer to **8.2** and **8.9**.

C) Ultimate limit state.

D) γ_{fL} may be reduced to 1.05 for steel and 1.15 for concrete when the loads have been accurately assessed.

E) Serviceability limit state.

F) γ_{fL} may be reduced to 1.2 for ULS and 1.0 for SLS subject to approval of the appropriate authority.

G) Operational limits might apply to wind, water current, wave and mooring loads when combined with live loads.

H) Snow loading need not be combined with vehicle loading.

I) Normal berthing should be combined with the operational limits in combination 2 but need not be combined with vehicle, pedestrian or mooring loads.

Annex B (informative) Vehicle loadings

B.1 Type HRo loading

HRo loading has been modified from BS 5400-2 (and BD 37/01 [11]) to allow for the particular circumstances pertaining on a linkspan. The main changes are the use of marked lanes, the omission of the 5 kN/m^2 load on single lane structures wider than 2.5 m, the use of specified vehicle loadings in convoy, and no reduced lane factors for third and subsequent lanes.

Marked lanes are considered appropriate as the traffic is always being controlled and any lateral bunching that might occur, for instance to pass a broken down vehicle or due to roadworks, does not apply. Similarly on a single lane linkspan there will only be a single line of vehicles and no substantial additional load.

The treatment of notional lanes for unmarked areas, such as splays, is identical to that in BS 5400-2 except that lanes are measured perpendicular to the centre of the linkspan rather than to the kerb line.

The clauses in BS 5400-2 relating to spread of loads through surfacing have been omitted as linkspans generally only have a thin high grip surfacing.

Where any of these assumptions is not appropriate, reference may be made to BS 5400-2.

The impact factors are from two different sources. The 1.25 factor is considered appropriate for the comparatively low speeds of Ro-Ro traffic. The 1.8 factor is from BD 21/02 [10]. It is considered that 1.25 is too low for local effects adjacent to discontinuities in view of the research leading to the publication of Canadian Standard CAN/CSA-S826.1-01. The factor giving the greatest load on the loaded length under consideration is generally used, typically the 1.25 factor for loaded lengths of more than 10 m.

The treatment of cusped influence lines is taken from BD 21/02 [10] as it is not present in BS 5400-2.

B.2 Reduced 3 t loading

Maintenance vehicles might have to be taken into account separately.

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