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Introduction

Your comments on this draft are invited and will assist in the preparation of the consequent standard.

For international and European standards, comments will be reviewed by the relevant UK national committee before submitting the consensus UK vote and comments. If the draft standard is approved, it is usual for the resulting published standard to be adopted as a British Standard.

For national standards, comments will be reviewed by the relevant UK national committee and the resulting standards published as a British Standard.

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Please indicate whether you consider the UK should submit a negative (with supporting technical reasons) or positive vote on this draft. Please indicate if you are aware of any reason why this draft standard should not be published as a British Standard.

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BS 6349-8, Maritime structures – Part 8: Code of practice for the design of Ro-Ro ramps, linkspans and walkways

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Foreword

Publishing information

This part of BS 6349 is published by BSI Standards Limited, under licence from The British Standards Institution, and came into effect on **XX Month 202X**. It was prepared by Technical Committee CB502XXX.

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Maritime structures, under the authority of Technical Committee CB502XXX, *Building and civil engineering structures*. A list of organizations represented on this committee can be obtained on request to its secretary.

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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 is intended to be read in conjunction with EN 1992-2 (concrete bridges) or BS EN 1993-2 (steel bridges) or other applicable Eurocode design standards and the associated national annexes. If utilizing BS 5400 as a supplementary document to this standard, users can interpret the word “bridge” as “structure”. The various loads and load factors to be used when assessing the ultimate limit state and serviceability limit state are given in Clause 8 of this part of BS 6349.

An alternative approach to the design of Ro-Ro ramps, linkspans and Sea Port Boarding Bridges is given in the Lloyd’s Register Rules and regulations for the classification of linkspans [N1] (hereinafter referred to as Lloyd’s Rules). BS EN 1992 and BS EN 1993 are ultimate limit state codes and Lloyd’s Rules is a working stress design code, and the treatment of load factors and vehicle impact factors is markedly different between the two codes. It is permissible to use both Lloyd’s Rules and BS EN 1992 and BS EN 1993 in the design of the same structure, provided that the designer takes the full implications of each code into account.

Both Lloyd’s Rules [N1] and BS EN 1992 and BS EN 1993 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 [N2] provides an extensive discussion on the coverage and limitations of Lloyd’s Rules [N1].

Information about this document

This is a major re-drafting of the document, and introduces the following principal changes.

- General updating of reference documents to reflect latest practice.
- Enhanced applicability of content generally with reference to the whole asset lifecycle of both the vehicle linkspan and Sea Port Boarding Bridge infrastructure.
- Users familiar with the previous Part 8 will find that a major change within the document is the separating of the vehicle linkspan design requirements to that of the Sea Port Boarding Bridges. This commences at Section 7.
- Within Section 0 a new clause highlights the importance of the vehicle linkspan and Sea Port Boarding bridge as a Complex Machine and the need to incorporate the requirements of a complex machine within the design.
- The Consequence Class and Execution Class for these structures is now defined in Section 4.
- The use of a Basis of Design statement at the commencement of a new or refurbishment project has been added to Section 4.
- Section 5: Now incorporates loads, movements and factors including vehicle restraint barriers and pedestrian handrailing.
- Section 6: focuses on structural analysis and design with specific design guidance on bearing including the use of bearing materials
- Section 7, 8 and 9 solely deal with all aspects of vehicle linkspan design including types and descriptions of various structures, geometry, and a revised guidance on transitions. There is a new recommendation for the treatment of the deck surfacing at the vessel ramp interface.
- From Section 10: onwards are new sections and marks the beginning of the Sea Port Boarding Bridge design requirements which continue through Section 11 and 12. These clauses describe the various types of structure, geometry, gradients and construction materials.
- Addition of a new Section 13 provides the designer with guidance and recommendations on setting the new / refurbished vehicle linkspan or Sea Port Boarding Bridge to work. Including the independent design process and site load testing requirements.

Section 14 relates to the Supply of Machinery (Safety) Regulations [N3] which is a new section for guidance to the linkspan or SPBB designer as both are legislated as a Complex Machine under the Supply of Machinery (Safety) Regulations.

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 verify that claims of compliance are not misleading.

Users may substitute any of the recommendations in this British Standard with practices of equivalent or better outcome. Any user claiming compliance with this 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.

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

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

Attention is drawn to the regulations listed in the Note to 2.1

0 Introduction

0.1 Design traditions

BS 6349-8 was first issued in 2007 and provided vehicle linkspan and seaport boarding bridge designers with a specific design standard for the first time. Before this date designers would use either BS 5400 or Lloyd’s Rules [N1], or a combination of both, supported by CIRIA Report C518 Safety in Ports - ship-to-shore linkspans and walkways, A guide to procurement, operation and maintenance, which was published in 1999 [N2].

This part of BS 6349 includes recommendations for several issues that are not covered by either the Eurocodes or Lloyd’s Rules. In particular, the Eurocodes (BS EN 1990, BS EN 1991 – all parts, BS EN 1993 – all parts, etc.) do not cover:

- pontoons or floating structures;
- overall hydrostatic stability;
- wave, current and vessel-induced loadings.

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.

The 2007 version of Part 8 has universally become the cornerstone of linkspan and seaport boarding bridge design but has more recently fallen behind in several key areas, particularly regarding loading criteria and the need to integrate the mechanical and electrical aspects into overall design, testing and safety of what is now classified as a Complex Machine. i.e. a vehicle linkspan and seaport boarding bridge.

NOTE Complementary design advice can be taken from PIANC document WG167 *The Design of Terminals for RoRo and Ro-Pax Vessels* [1].

0.2 Design of complex machinery

The integration of mechanical and electrical elements and control systems is crucial for the success of the overall design of Ro-Ro ramps, linkspans and seaport boarding bridges.

A design should take into account the whole lifecycle from manufacture through to decommissioning, with the machinery elements requiring careful consideration in order to:

- achieve safe operation;
- provide a design life for all components as agreed with the owner; and
- facilitate efficient maintenance and replacement of elements.

Safe and effective operation of the facility is another fundamental requirement which should be factored into all aspects of the design.

Risk management should be at the heart of the design process, with all designers taking responsibility for the minimising of risk through design. A holistic approach is paramount to the success of the design, with integration of the multiple disciplines being fundamental.

Reliability of machinery is an important design factor; in many port facilities the consequence of failure can have significant repercussions. In these installations, design for high reliability is essential; undertaking a robust and systematic assessment is highly recommended to optimise the design, and to enable owners to understand the higher risk areas of their installations.

The determination of loading upon, and caused by, mechanical elements is fundamental to safe design of the installation. It is essential that loads are accurately calculated, and that loads are shared and agreed by all relevant designers. The range of loadings upon Ro-Ro ramps, linkspans and walkways varies significantly, and great care should be taken in ensuring that the upper bound magnitudes of loading, and load combinations is taken into account for all foreseeable eventualities. Of particular importance is assessment of the large inertial forces which can be generated in large moving structures, particularly when accelerating or decelerating large masses. Machinery should be designed to permit quick response by operators to potentially hazardous situations, and so that foreseeable mechanical, electrical or control and instrumentation failures do not result in gross failure of the system. Different drive mechanisms respond in greatly different ways, with the potential for large amplifications of loads from the dynamic response.

Additionally, the geometric compatibility of mechanical elements with the associated structural elements is a key requirement of the design. Mechanical elements with their moving parts often require tight installation tolerances for correct functioning; it is of vital importance that the interface with structural elements facilitate this, with provision for adjustment often being essential. From the outset of the design process, users should design structures to enable maintenance activities to be safely achieved.

In summary, the design of complex machinery relies on careful integration of mechanical, structural, control and instrumentation, and electrical elements. Many Ro-Ro ramps, linkspans and seaport boarding bridges feature complex machinery, with the additional complexities of maritime and highways design. Due assessment should be carried out regarding operation, maintenance, and reliability aspects. The potential for significant loss of life associated with these structures further compounds the importance of the highest

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standard of interdisciplinary integration and risk reduction throughout the design, with a holistic overview being always taken.

NOTE Attention is drawn to the following regulations: Supply of Machinery (Safety) Regulations 1992 [N3]; and Management of Health and Safety at Work Regulations 1992.

DRAFT

Section 1: General

1 Scope

This part of BS 6349 gives recommendations for the design of Ro-Ro linkspans, ramps and seaport boarding bridges used for the transfer of vehicles and foot passengers between the shoreside facilities and a vessel.

It applies to the structural elements and integration of the mechanical systems only and does not cover the detailed design of any operational equipment, traffic control, mechanical or electrical equipment, heating, lighting, lifesaving, or rescue equipment. However, as stated in Section 1.1 an actuated vehicle linkspan or seaport boarding bridge is considered a complex machine and therefore an integrated and comprehensive design process should be undertaken which fully takes into account the structural, mechanical, electrical and control system elements of the design. Geometrical aspects of fixed shore ramps are covered in this part of BS 6349.

This part of BS 6349 does not apply to rail-enabled linkspans used for loading and unloading rail carriages and wagons, as it does not give recommendations for railway loading and associated ramp gradients etc. However, some recommendations are applicable to such 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 U.K. Although most of the contents are directly applicable elsewhere, local conditions might necessitate modifications, e.g., environmental effects and vehicle loading.

2 Normative References

The following documents are referred to in the text in such a way that some or all of their content constitutes provisions of this 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 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 6349-1-1, *Maritime works – General – Code of practice for planning and design for the asset lifecycle*

BS 6349-1-2, *Maritime works – General – Code of practice for assessment of actions*

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

BS 8004, *Code of practice for foundations*

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

BS 6349-1-4, *Maritime works – General – Code of practice for materials*

BS 6349-5, *Maritime works – Code of practice for dredging and land reclamation*

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

BS 8002, *Code of practice for earth retaining structures*

BS 2573, *Rules for the design of cranes – Specification for classification, stress calculations and design criteria for structures*

BS EN 1997, *Eurocode 7 – Geotechnical design*

BS EN 60204-1, *Safety of machinery – Electrical equipment of machines, Part 1: General requirements*

BS EN 62061, *Safety of machinery – functional safety of safety-related electrical, electronic, and programmable electronic control systems*

BS EN 13135, *Cranes – Safety – Design – Requirements for equipment*

BS EN 13001, *Cranes – General design*

BS EN 1990, *Eurocode – Basis of structural and geotechnical design*

BS EN 1991-1, *Eurocode 1 – Actions on structures – General actions – Densities, self-weight, imposed loads for buildings*

BS EN 1991-1-7, *Eurocode 1 – Actions on structures – General actions – Accidental actions*

BS EN 1991-1-5, *Eurocode 1 – Actions on structures – General actions – Thermal actions*

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

BS EN 1993-1-10, *Eurocode 3 – Design of steel structures – Material toughness and through-thickness properties*

BS EN 1991-2, *Eurocode 1 – Actions on structures – Traffic loads on bridges*

BS EN 1991-7, *Eurocode 1 – Actions on structures – General actions – Accidental actions*

BS EN 1991-1-6, *Eurocode 1 – Actions on structures – General actions – Actions during execution*

BS EN 1998-2, *Eurocode 8 – Design of structures for earthquake resistance – Bridges*

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

BS EN 1993, *Eurocode 3 – Design of steel structures*

BS EN 1993-1-1, *Eurocode 3 – Design of steel structures – General rules and rules for buildings*

BS EN 1317-1, *Road restraint systems – Terminology and general criteria for test methods*

BS EN ISO 12944, *Paints and varnishes – Corrosion protection of steel structures by protective paint systems – Protective paint systems*

BS EN ISO 4413, *Hydraulic fluid power – General rules and safety requirements for systems and their components*

BS EN ISO 12100, *Safety of machinery – General principles for design. Risk assessment and risk reduction*

BS EN ISO 9000, *Quality management systems – Fundamentals and vocabulary*

BS EN ISO 13849-1, *Safety of machinery – Safety-related parts of control systems – Part 1: General principles for design*

BS EN ISO 13850, *Safety of machinery – Emergency stop function – Principles for design*

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

DIN 19704, *Hydraulic steel-structures*

Other publications

[N1] LLOYD'S REGISTER. *Rules and regulations for the classification of linkspans*. London: Lloyd's Register, 2023.

[N2] CIRIA. *Safety in ports - ship-to-shore linkspans and walkways. A guide to procurement, operation and maintenance (C518)*. London: CIRIA, 1999.

[N3] OFFICE FOR PRODUCT SAFETY AND STANDARDS. *The Supply of Machinery (Safety) Regulations*. London: Office for Product Safety and Standards, 2021.

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- [N4] NATIONAL HIGHWAYS. *Design manual for roads and bridges*. Birmingham: National Highways, 2020.
- [N5] PIANC Working Group 34. *Seismic design guidelines for port structures*. Brussels: PIANC, 2001.
- [N6] LLOYD'S REGISTER. *Code for Lifting Appliances in a Marine Environment*. London: Lloyd's Register, 2024.
- [N7] HEALTH AND SAFETY EXECUTIVE. Provision and Use of Work Equipment Regulations 1998 (PUWER). London: HSE, 1998.

3 Terms, Definitions & Symbols

3.1 Terms and definitions

For the purposes of this part of BS 6349, the definitions given in BS 6349-1-1 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 revetment reclamation.

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

3.1.2 actuated ramp

lifted and lowered structural steel ramp at the berth end of a pontoon or quay which is designed to accept a vessel ramp

3.1.3 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.

3.1.4 approach span

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

3.1.5 Basis of Design

the document in which the design parameters are agreed with the Owner.

3.1.6 belting

protective strip along the side and stern of a Ro-Ro vessel 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.

3.1.7 berthing line

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

3.1.8 blunt-ended vessel ramp

vessel ramp that is not equipped with flaps

3.1.9 boarding pod

housing (generally covered) that is mechanically lifted and lowered to the same level as the passenger deck on a vessel. A telescopic final link or brow is stored within the boarding pod when the berth is not in use

3.1.10 brow

bridge that is hinged from a boarding pod or telescopic final link, and either rests on the vessel coaming or is support on the vessel deck

3.1.11 coaming

upstand from a vessel deck plate at the passenger entrance through the hull shell plate or raised edge, along an open deck on a vessel

3.1.12 designer

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

3.1.13 design water level variation

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

3.1.14 elephant foot

plate on the underside of a quarter ramp that bears onto the quayside/pontoon and generates pressure loading

3.1.15 extreme water level

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

3.1.16 facility

part of a port that deals with RoRo vessels, ferries, or cruise vessels

3.1.17 finger flap

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

3.1.18 fixed shore ramp

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

3.1.19 fixed walkway

covered walkway structure that has no moving parts

3.1.20 flap

extension, normally hinged to a vessel or to the shore end of a linkspan also within a seaport boarding bridge, that provides a transition with an adjacent road or walkway where relative articulation or movement could occur

3.1.21 final hinged link

bridge (normally covered) that is supported inside the vessel on the deck while the landward end is hinged and supported on either the telescopic final link or boarding pod. Should be stored within the boarding pod when not in use

3.1.22 fixed high-level walkway.

a fixed bridge (normally covered) or a series of fixed bridge spans that connect the terminal building with the berth. Requires hinged walkway tunnels / hinged link connection to cater for the level difference to the moored vessel.

3.1.23 gantry frame

a fixed structure that supports the lifting and lowering equipment for a seaport boarding bridge

3.1.24 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 while enabling it to move up and down with the rise and fall of the tide

3.1.25 hoist tower

structure mounted on the shore or on a dolphin for supporting the lifting equipment of a mechanically lifted and lowered type of linkspan

3.1.26 interface

boundary between a vessel ramp, vessel vehicle access opening or vessel passenger access opening and a linkspan or seaport boarding bridge

3.1.27 interface limit line

seaward end of a vessel ramp landing area

3.1.28 lifting frame

fixed or carriage-mounted frame that supports the lifting equipment

3.1.29 linkspan

articulating structure, which can be a floating or a lifted bridge structure, that links a RoRo vessel either directly to the shore, a fixed structure, or a pontoon, or that links a pontoon with the shore.

NOTE 1 The term "linkspan" can also refer to facilities comprising a pontoon and link bridge combined.

NOTE 2 A linkspan can comprise of more than one deck in order to facilitate quicker unloading and loading times.

3.1.30 machinery

For the purpose of this standard machinery is as defined in the Supply of Machinery (safety) Regulations [N3]. However, movement induced by environmental loads (e.g. wave and tide) is not considered to be a drive system

3.1.31 mobile gantry frame

rail-mounted or rubber tyre-mounted structure that supports the lifting and lowering equipment for a seaport boarding bridge.

3.1.32 operating water level

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

3.1.33 operator

person responsible for operating a piece of machinery

3.1.34 operational envelope

vertical and horizontal range on the berthing line to which the seaport boarding bridge should operate in order to serve all the design vessels included within the design

3.1.35 owner

person or organisation responsible for operating and maintaining the facility

3.1.36 passenger walkway

seaport boarding bridge facility for the transfer of foot passengers, capable of vertical and/or horizontal adjustment at the vessel end and capable of connecting to any fixed walkway.

3.1.37 PLC

programmable logic controller

3.1.38 pontoon

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

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

3.1.39 restraint systems

structural framework used to guide and hold a pontoon or linkspan while allowing it to float freely

3.1.40 PAX

passengers

3.1.41 PAX opening

opening in the vessel shell plate that forms the passenger access point

3.1.42 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 an adequate distance from unsafe terminal or vehicle movement activities

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

3.1.43 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.

3.1.44 RoRo ramp

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

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

3.1.45 semi-submersible linkspan

linkspan that derives its seaward support from a fully submerged underwater tank, usually with narrow legs between tank and bridge deck, but which is additionally supported by the vessel or other means during operation.

3.1.46 service walkway

designated route for use by service operational personnel only

3.1.47 Seaport Boarding Bridge (SPBB)

single or series of walkway tunnels mounted onto a supporting gantry frame used by foot passengers to access a vessel

3.1.48 secondary load path

mechanical system and associated structural elements that are designed to carry dead and live loads in case of a failure in the primary lifting/lowering system

3.1.49 secondary pod

lifted and lowered housing supported by the gantry frame (mobile or fixed) that allows multi-hinge tunnels to be used in the design of a seaport boarding bridge

3.1.50 Splayed end

wider end of linkspan at interface with vessel. Also known as spade end

3.1.51 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

3.1.52 telescopic final link

bridge sections (typically covered) that are retracted and stored in the boarding pod when not in use. Can be extended to serve directly into the vessel or could include a final link section at the vessel end

3.1.53 terminal interface pod

housing (typically covered) attached to the SPBB gantry frame and interfacing with a fixed high-level walkway or terminal building. Also provides entry/exit point into or from a hinged walkway tunnel.

3.1.54 threshold height

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

3.1.55 vessel

any vessel, boat, barge, pontoon, or floating structure that is independent of the port facility

3.1.56 vessel ramp

adjustable structure fitted to a vessel at the bow and/or the stern that when lowered to and resting on the approach structure, quayside, or linkspan, forms the connecting roadway between the vessel and approach structure, quayside, or linkspan

NOTE a vessel ramp is located to serve the main vehicle deck (bow or stern); upper decks generally do not have a ramp and rely on the linkspan upper deck to have a hinged ramp which is deployed onto the vessel's upper vehicle deck.

3.1.57 well deck

platform on the vessel end of a linkspan or pontoon, set at a lower level than the roadway, onto which a blunt-ended vessel's ramp can rest.

3.2 Symbols

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

AEP Annual Exceedance Probability. The probability that a condition (typically environmental) is exceeded in any one year

E	Young's modulus of a material, in Newtons per square metre (N/m^2)
$H_{\max}$	maximum design wave height, in metres (m)
n	number of effective longitudinal members in a parapet
T	magnitude of proof test load, in newtons (N)
V	velocity of impact, in metres per second (m/s)
ρ	density of a material, in kilograms per cubic metre (kg/m^3)

4 General Recommendations

4.1 Limit States

4.1.1 General

This standard follows the limit state principles set out in BS EN 1990.

Design should be for Ultimate Limit State (ULS), Serviceability Limit State (SLS), Accidental Conditions and, in line with BS 6349-1-1 and BS 6349-1-2, a Normal Operating Condition is added.

Different load factors and combinations are used in the structural and mechanical design processes. Both processes should be based on a coherent and compatible set of component characteristic loads.

4.1.2 Consequence class

The consequence class for the structure, in accordance with BS EN 1990 Annex B, should be agreed with the owner and defined.

The execution class for structures should be EXC3 or as agreed with the owner.

NOTE 1 The principles for setting the consequence class are set out in Annex B.3 of BS EN 1990. Typically, this will be consequence class CC2 for public infrastructure. Where the facility is considered to be a piece of critical national or local infrastructure, for instance having an emergency use or required for disaster recovery, the consequence class might need to be increased to CC3. For facilities that are used infrequently or only for freight consequence class 1 might be considered.

NOTE 2 In general, the nature of the loading and the structures (high fatigue cycles, lightweight structure, high occupancy) indicates the higher execution class even for consequence class CC2. The execution class can be relaxed to EXC2 in simpler more lightly utilised structures, where fatigue is not critical. Execution class EXC3 can be limited to critical elements for fatigue or reliability.

4.1.3 Ultimate Limit State

The Ultimate Limit State (ULS) typically covers:

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

4.1.4 Serviceability Limit State

The Serviceability Limit State (SLS) typically covers:

- excessive deflection, slip within components, cracking of concrete, yielding, damage to finishes or protective coatings;

- 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; and
- traps/pinch points.

4.1.5 Accidental conditions

Accidental conditions should be interpreted as defined in BS EN 1990 and BS EN 1991-1-7. Credible accidental conditions should be established by risk assessment as described in BS 6349-1-1. Emergency access to or evacuation of a vessel should be factored into accidental operating conditions outside the normal operating conditions when agreed with the owner.

Where practicable for creditable accidental conditions failure of a single structural or mechanical element should be treated as an accidental condition that does not lead to collapse of the structure, or disproportionate failure. The variable loads associated with the failure should be for the operational or design conditions. Where this is not practicable the reliability class should be increased.

Accidental conditions should take account of any normal constraints on positioning port equipment and SBB during operations. Constraints on positions should mitigate accidental conditions.

The condition of the structure after each accidental condition should be agreed with the owner and defined. These are:

- a) serviceable, minor or no damage, little or no loss of serviceability;
- b) repairable, controlled, and repairable damage, short term loss of serviceability;
- c) near collapse, extensive damage, long-term or complete loss of serviceability; and
- d) collapse, complete loss of structure, complete loss of serviceability.

NOTE 1 These conditions have been adapted from the degree of damage definitions in the recommendations for seismic design by PIANC [MarCom Working Group 34].

NOTE 2 Typically, controlled and repairable damage would be acceptable unless consequence class CC3 is applicable, where loss of serviceability is not tolerable.

4.1.6 Design conditions

The design operational and environmental conditions, including water levels, should be agreed with the owner, and defined.

NOTE Typically, the design environmental condition is those with a joint probability of exceedance of the design working life of the structure using a minimum return period for characteristic actions of 1 in 50 years. This might be increased if consequence class CC3 is applicable.

Maintenance conditions, e.g., temporary supports for replacement or inspection of hydraulic cylinders, with the associated limiting environmental and water level conditions, should also be agreed with the owner and defined.

The Normal Operational Condition is set at the environmental conditions where normal operations at the facility stops. This should include wind speed, wave height, water level and anticipated vessel movements that makes operations potentially unsafe. Loading, berthing and mooring operations could each have different normal operational limits. Some structures have out of service and stowed conditions for increasingly severe environmental conditions above the normal operational conditions, which should be defined. Port equipment and the SPBB might be in specific positions during some operations, and these constraints on loading should be agreed with the owner. All the Normal Operating and any out of service or stowed conditions should be agreed with owner and defined.

4.2 Quality systems

Users of this British Standard should assess 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.

4.3 Planning

The purpose of a Ro-Ro ramp, vehicle linkspan or seaport boarding bridge is to enable the safe transfer of vehicles/foot passengers between the shore and the designated vessel, taking account of relevant environmental considerations, for the design working life of a facility. When planning a RoRo facility, account should be taken of current vehicle requirements, the number and type of vessels, and also the possibility of future developments including the effects of sea level rise which could economically be met by adaption or relocation of part or all of the facility.

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.

4.4 Risk assessment

Risk assessments should be undertaken prior to establishing the exact type of facility to be provided. This should assess the hazards, risks and consequences of all credible uses and failure modes of the facility.

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 and accidental conditions should be included in the assessment.

4.5 Basis of design

After being awarded a contract, the designer should produce a Basis of Design (BoD), detailing the parameters to be used in the design. The owner should review, amend or discuss the details with the designer and record acceptance of the BoD as necessary. The owner should engage consultants to provide the necessary expertise regarding this document if this does not exist within their organization.

4.6 Design parameters

4.6.1 General

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

4.6.2 Layout of facility

The overall layout of the facility should be established early in the procurement process and before detailed design of the facility commences. It should include the required numbers and relative location of linkspans and seaport boarding bridges, taking account of the anticipated vehicle flows, passenger numbers, type of vessels, and location of loading and discharge points onto the vessels.

In the design of the facility an adequate means of escape in the event of emergency, including fire escape arrangements, should be included.

4.6.3 Vessels

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

- Draught;
- Beam;

- Length;
- Displacement;
- threshold height dimensions;
- dimensions and positions of openings and deck accesses;
- height of vessel belting;
- propulsion system forces;
- vessel ramp details (e.g., dimensions, flaps, permitted gradients and mass);
- variation of vessel trim and roll during the unloading and loading cycle;
- passenger and vehicle access door positions;
- information for shore power provision;
- swept geometry of bow visors or clamshell doors;
- the geometry of bulbous bows;
- whether multi-deck access is required; and
- overhangs.

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

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

4.6.4 Usage and design life

The frequency of berthing and required speed of turn-around should be agreed with the owner, together with any demands for priority berthing for a particular vessel or shipping line or where seasonal use (e.g. summer only) is required. 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. An operational design life for structural elements within the facility is typically taken as 50 years for the purposes of verifying fatigue endurance. Mechanical and electrical systems generally have a shorter life and should be designed to be replaceable. The number of load cycles for the mechanical design should be agreed with the owner.

4.6.5 Method of vessel control

The method of control of vessel movements, including berthing and mooring procedures, should be established for all vessels that might use or could affect the facility. This can influence a decision as to whether the facility is required to perform any function in the berthing and mooring of vessels. Wherever practicable the arrangements for berthing and mooring of vessels should use independent elements such as berthing fenders or mooring dolphins that do not involve the transfer of loads through linkspans or seaport boarding bridges. The facility should be designed to factor in the possibility of accidental impact and to minimize any adverse effects from such an impact.

4.6.6 Degree of automation in operation of facility

The degree of automation of the linkspan or seaport boarding bridge 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.

4.6.7 Types of vehicles

The types of vehicles that are likely to use the facility should be agreed with the Owner.

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

4.6.8 Passenger traffic

The number of passengers who are likely to be using a passenger walkway at a given time should be agreed with the owner, as this will affect the extent and widths of walkways. The facility should be designed for inclusive access, where practicable, details of typical gradients are given in 11.4. It should be noted that, in some facilities, passengers may be carrying luggage.

4.6.9 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 in Section 4.4.2 should be identified.

4.6.10 Services

The requirements for services on the facility, e.g.:

- water;
- firefighting;
- fuel;
- sewage;
- electrical supply;
- shore power;
- telecommunications;
- stores;
- refuse/waste disposal; and
- baggage facilities,

should be established and quantified as these can affect the overall dimensions of the facility and loadings carried.

4.6.11 Operational equipment

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

- method of sensing for automatic operations;
- degree of redundancy in controls; and
- extent and forms of traffic control to regulate the use of vessels on the facility.

4.6.12 Effect of passing vessels

The effect of wash and other displacement effects on the facility and the berthed vessel should be factored into the design of the facility.

4.7 Environmental conditions

4.7.1 Environmental impact

The potential impact of the construction, operation, maintenance, and decommissioning of the facility upon the marine and terrestrial environment should be assessed (see BS 6349-1-1:2013, 4).

4.7.2 Water levels

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

- percentage of AEP high water, flood defence level or highest recorded tide (HRT);
- operational high water (10% AEP high water is suggested but should be defined for the facility.);
- highest astronomical tide (HAT);
- mean high water springs (MHWS);
- mean low water springs (MLWS);
- lowest astronomical tide (LAT);
- lowest recorded tide (LRT);
- highest impounded level for an enclosed basin (HIL); and
- lowest impounded level for an enclosed basin (LIL).

The water level variation should be based on the mean spring tide between MHWS and MLWS, or HIL and LIL for an impounded basin, for the limiting gradients.

Linkspans should be designed to operate, with steeper gradients, between operational high water/HAT and LAT. Free movement of linkspans should be designed for between 2% AEP/Flood defence level/highest recorded tide and lowest recorded tide.

Sea Port Boarding Bridges should be designed to operate between operational high water/HAT and LAT with further allowance before the mechanical stop.

All the above-mentioned levels should be agreed with the Owner.

4.7.3 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 6349-1-1.

4.7.4 Meteorology and climatology

Meteorological and climatological data should be taken into account (see BS 6349-1-1). For wind speeds and air temperatures at coastal and inland locations in the UK, guidance can be obtained from the UK National Annexes to BS EN 1991-1-4 and BS EN 1991-1-5, however data should be collected where possible relevant to the specific location of the facility. Additionally, Attention is drawn to the effects of temperature on the selection of appropriate steel grades (see BS EN 1993-1-10). Fracture toughness should be selected for the environmental conditions.

4.7.5 Bathymetry

Bathymetric information should be obtained, including any updating to allow for changes in water depth due to siltation, dredging, etc. (see BS 6349-1-1, 5.2).

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

4.7.6 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 (see BS EN 1997; BS 6349-1-3). This should include any adjacent dredging or reclamation (see BS 6349-5, 6.2).

4.7.7 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], including:

- a) a water sample to determine at least the following:
 - maximum and minimum water temperatures;
 - PH;
 - conductivity;
 - Langelier Index;
 - sulphate content;
 - chloride content; and
 - water density.
- 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.; and
- d) any history of microbiological-induced corrosion.

NOTE For information regarding water quality and sediment transport, refer to BS 6349-1-1, 11 and 12.

4.8 Operation and maintenance manual

Each facility should have an operation and maintenance manual. The contractor should coordinate production of this document incorporating information provided by the suppliers of the components of the facility. This document should be provided to the owner, and should contain all the information that the owner needs concerning the overall capability and limitations of the facility owner.

4.9 Fire

In general, open structures, as with bridges, do not need to be designed for fire resistance.

Where the response to a fire on the vessel is always to depart from the berth before evacuating passengers and crew then no fire safety provisions are required on the vehicle linkspan or SPBB.

NOTE This is not a typical scenario and would need to apply to all vessels and all circumstances.

Where a vehicle linkspan or SPBB is to be used to evacuate passengers or crew from a vessel in the event of a fire, as part of the facilities fire management plan, then the provisions of fire escape routes in the local building codes and fire regulations will apply. The linkspan should be treated as an external route.

The top deck of an open structure should be fire resistant where either deck provides a fire escape route. Pedestrian shelters on pontoons should meet the provisions of local building codes and fire regulations.

5 Loads, movements & factors

5.1 General

Loading should be in accordance with the relevant parts of BS EN 1991-1, including the applicable National Annexes, but additional loads and load combinations should be taken from:

- BS 6349-1-2 for marine specific environmental loads and combinations;
- BS 6349-1-2 for tidal loads on abutments;

- BS EN 1991-2 for vehicle and pedestrian loads; and
- BS EN 1991-7 for accidental loads

This section gives modifications to the load application rules and extends the load combination tables for application to link spans and link bridges. Only credible load combinations need to be taken into account. The treatment of loads specific to linkspans such as lifting forces, drag forces at interfaces and movement induced loads are defined.

Where Lloyd's Rules [N1] 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 Lloyd's Rules.

Vehicle collision loads should be in accordance with BS EN 1991-2 where speeds higher than 25 kph are likely. Where it is assumed that vehicle speeds for road traffic will be strictly limited to speeds below 25 kph, the loadings described in 7.13 should be used in the absence of specific guidance.

5.2 Permanent actions

Where mechanical lifting equipment is used for buoyant linkspans an upper and lower bound of the characteristic permanent action should be determined.

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.

5.3 Snow

Snow loading should be agreed with the operator.

On open structures, unless otherwise agreed with the owner, snow loading should not be combined with operational vehicle loading. Snow loading should be combined with loading from vehicles, people or machinery deployed to clear the snow and the operational loads of other environmental effects.

Where an open structure is used for emergency use snow loading in combination with an emergency vehicle should be taken into account.

For enclosed structures snow loading should be taken into account.

For lower decks of a multi deck structure snow load does not need to be taken into account.

5.4 Wind

An operational wind speed should be defined for the facility. Where the facility is used for emergency use an emergency operational wind speed should also be defined.

Vehicle and passenger loads should be combined with the operational wind load along with coexistent environmental loads.

The accidental vehicle load should be combined with the operational wind load as an accidental case.

Emergency vehicle and pedestrian loads should be combined with the emergency operational wind speed where applicable.

5.5 Marine

Loads and movements from marine environmental effects should be identified as set out in BS 6349-1-2.

An operational wave condition should be defined for the facility. Where the facility is used for emergency use an emergency operational wave condition should be defined.

Vehicle and passenger loads should be combined with the operational wave condition along with coexistent environmental loads.

Emergency vehicle and pedestrian loads should be combined with the emergency operational wave condition where applicable.

5.6 Berthing

Berthing loads and movements should be derived in accordance with BS 6349-4 where the linkspan or pontoon forms part of the berthing system.

Abnormal berthing loads should be treated as accidental loads combined with the operational environmental conditions.

Berthing loads should be combined with the operational environmental conditions.

5.7 Mooring

Mooring loads and movements should be derived in accordance with BS 6349-4 where the linkspan or pontoon forms part of the mooring system.

Mooring loads should be combined with the operational environmental conditions.

5.8 Operational movements

Vessel movements, at the vessel interfaces, should be taken into account by the designer for both the linkspan/pontoon design and the SPBB design. Specific vessel movements for RoRo, RoPAX, passenger ferry and cruise vessels are provided in Tables I.7 & I.8 of BS 6349-1-1.

5.9 Thermal movements

Where the linkspan is restrained against thermal movements an operational temperature range should be defined and stated in the Basis of Design.

5.10 Temporary and erection loads

Erection and maintenance loads should be included in accordance with BS EN 1991-1-6.

Environmental conditions coexistent with these loads should be defined.

Loads on the linkspan caused by temporary conditions in the adjacent areas of the port (e.g., dock draw-down during maintenance) should be included.

5.11 Traffic

5.11.1 General

Traffic loading should be applied in accordance with BS EN 1991-2. Load modification factors should be applied to represent the restricted loading for traffic classes defined in Table 1, as experienced on some linkspans.

The operational procedures that affect the loading on linkspans should be agreed with the owner. Possible changes in use over the expected lifetime of the facility should be estimated and taken into account. Whether multiple lanes and multiple levels are used to their full capacity simultaneously should be agreed with the owner. Where simultaneous use is not normal operational procedure its occurrence should be treated as an accidental load.

Six generic classes of loading are defined. The reduction factors were derived from considering a convoy of the heaviest vehicle in the class along one lane. The vehicles were taken from the set of equivalent lorries for fatigue loading in BS EN 1991-2 and from the standard UK lorry configurations in CS 454 of the *Design manual for roads and bridges* [N4]. In both cases 'good' surfacing conditions were considered. If the likely maintenance regime at the port means that the surfacing will deteriorate, then 'medium' conditions should be taken into account, and the loads increased by $1.6/1.3=1.1$ (see Annex B of BS EN 1991-2).

Load model LM1 is used with the modification factor in Table 1 for spans greater than 3m. For shorter spans, for instance for transverse beams and transition flaps, LM2 should be used or single axles from Table 2.

Table 1 – Load reduction factors

Class	Weight restriction signage	Vehicles considered	L1	A1	L2 (m)	A2	L3 (m)	A3	A_max	Comment
Cars	3t	'O' from CS 454 DMRB	11	0.12	27	0.17			0.26	This class refers only to cars and does not include camper vans or pick-ups or vans that carry cargo, etc.
Light vans	7.5t	'N' from CS 454 DMRB	11	0.29	27	0.43			0.64	Camper vans, pick-ups and vans are generally in this classification
Light lorries and coaches	18t	'M' from CS 454 DMRB and 2 axle rigid (17t) from EC1-2 Table 47	20	0.47	40	0.69			0.84	Coaches in this class are defined as large long distance coaches. Some busses are only 7.5t and would not fall under this class.
Medium lorries	26t	'I' to 'L' from CS 454 DMRB Table B.1 and 3 axle rigid (31t) from EC1-2 Table 47	8	0.54	18	0.75	33	1	1.27	Only increase to 1.27 if a queue of fully laden trucks more than 33m long is credible
Heavy lorries	Not required (54t)	5 axle artic (48t) and 4 axle artic (54t) from EC1-2 Table 47	18	0.75	33	1			1.27	Only increase to 1.27 if a queue of fully laden trucks more than 33m long is credible
Mixed unrestricted traffic	Not required (54t)	Any legal road vehicle	18	0.75					1	