28.2 Operational factors

Berthing actions as the basis for structural design of marine facilities should take into account the operating philosophy established with the operator at the planning and design phases, and the DSOL in accordance with the recommendations in BS 6349-1-1:2013, Clause **22**.

Conditions of normal use for marine facilities appropriate to assessment of berthing actions in a persistent design situation should include normal operating conditions as defined in BS 6349-1-1:2013.

Berth design and planning for operations should in all cases seek to reduce risk of an accident (e.g. in layout, terminal and port operating procedures, and safety equipment such as berth monitoring systems, navigation aids, etc.) and to then to mitigate any residual risk to acceptable levels (by protective measures/systems, additional operational procedures). If, despite this approach, site and operationally specific risk assessment indicate a residual risk of collision, then credible accidental scenarios should be established, and accidental impact actions assessed. Such loads should then be taken into account as an accidental design situation.

28.3 Actions from fenders

Berthing actions from fendering systems during vessel berthing should be assessed in accordance with the recommendations of BS 6349-4:2014 for both characteristic and design berthing energy, based upon the fender type and properties, taking into account the effects of variation of fender mechanical properties and reaction characteristics with temperature, berthing velocity, angle of impact and manufacturing tolerances. The allowances for such effects should be established by reference to the fender manufacturer's test or performance data and the prevailing conditions for the facility.

Fendering systems should be capable of sustaining both the resulting loads perpendicular to the fender faces and any component parallel to the berthing face, both horizontally and vertically, which can result from ship berthing and movement.

The design friction load acting parallel to the berthing face should be taken as μ times the fender reaction, where μ is the coefficient of friction between the two faces in contact. In the absence of a more detailed assessment, the frictional load should be assumed to act in the most adverse direction in the plane of the berthing face.

29 Mooring and breasting actions

29.1 General

Actions from moored vessels, both on mooring points and on fenders and breasting structures, should be assessed using one of the calculation methods described in BS 6349-4:2014, Clause **9** as appropriate to the vessel and berth type and the prevailing environmental conditions, taking into account the following.

- Method 1 (elastic static mooring analysis using a computer program) should be used to assess actions where wave or swell penetration or passing ship effects do not cause significant mooring line loads due to ship dynamic response.
- Methods 2 and 3, together with Method 1 with simplified hand calculation approach, may only be used to provide preliminary estimates of actions for vessels less than 20 000 t loaded displacement.
- Method 4 (fully dynamic numerical mooring analysis using a computer simulation program) should be used to assess actions where wave or swell penetration or passing ship effects cause

significant mooring line loads due to ship dynamic response. Where necessary, numerical simulation should be supplemented by physical modelling.

*NOTE 1 The operational aspects of mooring are discussed in BS 6349-1-1:2013, Clause **20**, which gives guidance on methods for assessment of acceptable conditions for moored vessels including the use of numerical and physical models.*

NOTE 2 In the absence of other site-specific assessments for large tankers, bulk carriers and container ships, it is typically found that significant mooring line loads due to ship dynamic response are unlikely to occur:

- *in the following range of wave conditions (the range of wave height for each period depends upon ship type and wave direction):*
  - H_s *<0.50 to 1.0 m and peak periods <6 s;*
  - H_s *<0.25 to 0.50 m and peak periods <12 s;*
  - H_s *<0.10 to 0.20 m and peak periods >12 s; and/or*
- *in shipping channels for which the following conditions apply with respect to passing ships:*
  - *hull to hull separation distance of at least 4 times the passing ship's beam, at speeds of 6 knots or less; or*
  - *hull to hull separation distance of at least 2 times the passing ship's beam, at speeds of 4 knots or less.*

*NOTE 3 Recommendations for estimation of wind and current forces on moored vessels are given in **29.3**.*

29.2 Operational factors

Mooring actions as the basis for structural design of marine facilities should take into account the operating philosophy established with the operator at the planning and design phases, and the DSOL according to the recommendations in BS 6349-1-1:2013, Clause **22**.

Conditions of normal use for marine facilities appropriate to assessment of mooring actions in a persistent design situation should include normal operating conditions as defined in BS 6349-1-1:2013. Extreme operating conditions should also be taken into account if it is proposed that vessels are required to remain moored in such conditions.

NOTE 1 For many large ships, and large oil and gas carriers, bulk carriers and container ships, it is unlikely that the ship would stay at a berth under events of 50-year to 100-year return periods. The exception might be very protected harbours in regions with relatively benign environmental conditions. In most cases, however, the capacity of the mooring equipment on the ship would be insufficient for holding the vessels in extreme storms. In such cases the extreme operating condition would be for a vacant berth. In such cases it is often recommended to establish maximum credible sets of wind speed, wave height and current velocity consistent with the capacity of the mooring equipment of the design vessels, and to use this as a potential extreme operating situation for the occupied berth.

As recommended in BS 6349-4:2014, **9.3**, mooring equipment on the berth should be designed for a persistent design situation to have a safe working load (SWL) equal to or greater than the calculated loads.

Actions from mooring line overload, whether from operator error, mooring equipment malfunction, or collision with a moored vessel, should be treated as accidental design situations. Credible accidental design situations may be established by risk assessment for the specific operations proposed and the prevailing environmental conditions.

For quick release hooks, each hook should have a rated SWL of not less than the minimum breaking load (MBL) of the largest capacity line anticipated to be used for mooring of the design vessels, with the assumption (consistent with recommended mooring practice) that each hook will receive only a single mooring line.

For mooring bollards, each bollard should have a rated SWL of not less than the minimum breaking load (MBL) of the largest capacity line anticipated to be used for mooring of the design vessels. The designer should make an assessment of the number of lines likely to be connected to a single bollard.

The design mooring load on the mooring point structure should be assessed with respect to the likely joint probability of maximum line forces, or upon limiting loads from vessel's mooring equipment with appropriate partial factors as indicated in **29.4**.

NOTE 2 The requirement for the mooring equipment SWL to exceed individual line MBL is based upon the practice that, in the event of accidental overload of moorings, mooring system components need to fail progressively such than the breaking load of the mooring line is less than the rated SWL of the mooring equipment (hook, etc.); its fixings to the mooring point structure; and the design strength and stability of the structure itself.

NOTE 3 In the design of any failure device pursuant to BS 6349-2:2010, **9.5** *(such as break off foundation bolts) incorporated into a mooring point to limit the maximum load on mooring point, attention is also drawn to the related provisions of BS 6349-4:2014 regarding the mode and type of mooring failure so that risks to personnel, the vessel and quay structure are minimized.*

NOTE 4 There is an increasingly large variety of synthetic mooring line materials available to ship operators and furthermore there can be a lack of available data on lines for new types or classes of ships (e.g. very large ore carriers). Design based upon rated MBL of mooring lines requires high confidence in the definition of line characteristics at the design stage, which in turn emphasises the importance of obtaining reliable data from ship owners, designers or operators as set out in BS 6349-1-1:2013, Clause **18**.

29.3 Evaluation of wind and current forces

If a detailed assessment of mooring loads as recommended in BS 6349-4:2014 is not possible, then bollards for vessels up to 20 000 t loaded displacement should be provided along a continuous quays at intervals of 0.15 times the L_{OA} of the smallest most likely vessel to use the quay. The load capacity should be as given in Table 7, which allows for more than one rope to be attached to each bollard.

Table 7 — *Nominal bollard loadings for vessels up to 20 000 t displacement*

Vessel loaded displacement t	**Bollard loading** kN
Up to 2 000	100
Up to 10 000	300
Up to 20 000	600

For vessels larger than 20 000 t loaded displacement, specific calculations should be carried out to determine the probable maximum mooring loads, taking into account:

- the number, patterns, characteristics and pre-tensions of the mooring lines;
- prevailing environmental conditions;
- proposed operations and DSOL for environmental conditions for the moored vessel.

For sheltered harbour environments where wave or swell penetration or passing ship effects do not cause significant ship response, mooring loads may be estimated by static mooring analysis based on the prevailing wind and current conditions using Method 1 described in BS 6349-4:2014 (see **29.1**).

Wind speeds for the evaluation of wind forces acting indirectly on structures from moored vessels should be assessed in accordance with BS 6349-1-1:2013, taking into account the size and response period of the vessel as noted in BS 6349-1-1:2013, **7.2**.

Current velocities for the evaluation of current forces acting indirectly on structures from moored vessels should be assessed in accordance with BS 6349-1-1:2013, using the depth-averaged current over the draught of the moored vessel based upon the current-velocity depth profile for the location as noted in BS 6349-1-1:2013, Clause **9**.

In the absence of other data, for large ships and where wave and current loading are expected to be significant, wind and current forces should be established by the testing of scale models.

*NOTE 1 The method of calculation of wind and current forces based upon the charts and empirical formulae included in Annex G may be used as a guide to the magnitude of wind and current forces on ships for concept design purposes. Subclause **G.4** also contains further guidance on wind speed averaging periods and spectra appropriate to vessel response.*

For VLCCs and other oil and product tankers down to 16 000 DWT, and for gas carriers in the range 75 000 m^3 to 125 000 m^3, wind and current drag coefficients should be assessed based upon the guidance contained in OCIMF MEG 3 [N2], Appendix A.

Comprehensive details and characteristics of the proposed design ships should be obtained as set out in BS 6349-1-1:2013, Clause **18** and used for detailed designs.

NOTE 2 Typical values for the lengths, draughts and lateral areas of bulk carriers and container vessels are given in BS 6349-1-1:2013 and in Annex G. These figures can be taken as guides for preliminary design in the absence of specific vessel data.

NOTE 3 Recommendations for the evaluation of wind, wave and current forces from moored wall-sided box shaped floating structures, such as pontoons, are expected to be included in the revision of BS 6349-6, which is currently in preparation.

NOTE 4 Wind and current forces vary considerably, depending on both type and size of vessel. In particular, the wind forces upon container vessels and other high-sided ships are influenced greatly by the particular design of different ships and the extent of cargo loaded on the deck. Very large tankers show marked variations in longitudinal force depending upon the design of the bow.

NOTE 5 Attention is drawn to the different empirical formulations of wind and current forces as explained in Annex G. Designers need to ensure that drag coefficients used are consistent with the formulation adopted.

29.4 Actions on mooring and breasting structures

As noted in **29.2**, mooring structures for large ships with multiple mooring points should be designed based upon the capacity of the mooring systems used to moor vessels to the structures. The overall mooring point capacity should be sufficiently robust to accommodate the dynamic nature of environmental response of vessels, including when under the influence of passing ships.

Credible accidental actions can arise from human error, individual mooring line failure, equipment malfunction or other such circumstances. The objective of the berth design and planning for operations should in all cases be to minimize the risk of an accident (e.g. by appropriate design of layout, terminal and port operating procedures, and by providing safety equipment such as berth monitoring systems and navigation aids) and then to mitigate any residual risk to acceptable levels (e.g. by the provision of protective measures/systems, additional operational procedures or contingency plans).

In the case of mooring structures designed to support more than one item of mooring equipment, and especially for large ships such as oil and gas tankers, container ships and bulk carriers, designers should assess the maximum credible total load on mooring points based on:

- risk assessment based on the specific operations proposed and the prevailing environmental conditions;
- capacity of the mooring equipment on the vessel;
- whether the mooring loads represent persistent or accidental design situations.

Table 8, to be read in conjunction with Table 1, shows different methods of assessment of loads on mooring structures for large ships and the corresponding values of the partial factor for actions, γ_Q, that should be adopted, taking into account the operating conditions and prevailing environment. All operating and accidental conditions should be assessed.

NOTE 1 For assessment of credible maximum mooring point loads for vessels moored using quick release hooks in exposed environments (when mooring line forces due to dynamic ship response are significant, e.g. due to wave exposure or passing ship effects), a practical approach to the maximum force on the supporting mooring point for the accidental operating condition that has been proposed for two, three and four hook assemblies is shown in Table 9.

NOTE 2 Annex H gives additional background guidance on assessment of design situations and loads, and in particular information on the selection of appropriate partial load factors in this clause.

Table 8 — *Basis of loads on mooring structures with partial factors for actions*

Operating condition	**Method of assessment of loads**	**Partial factor for actions, γ_Q** **EQU,Set A and STR/GEO Set B**	**Partial factor for actions, γ_Q** **STR/GEO Set C**
Normal operating condition (berth occupied, and cargo handling and other operations ongoing)	Probable maximum calculated loads for specified normal environmental conditions (in combination with breasting loads and/or other consistent operating loads where applicable)	1.5	1.3
Extreme operating condition (berth occupied)	Probable maximum calculated loads for specified extreme operating environmental conditions (in combination with breasting loads where applicable)	1.5	1.3
Extreme operating condition (berth occupied)	Extreme operating condition – load is based on rated capacity[A)] of vessel's mooring equipment, A1⟩ or quayside mooring equipment, ⟨A1 when this is known at the design stage and when appropriate to operating requirements	1.3	1.15
Accidental condition (berth occupied)	Assessment of the maximum credible total load on mooring points for accidental scenarios based on: • risk assessment for specific operations proposed and the prevailing environmental conditions; and • the limiting capacity[B)] of the vessel's mooring equipment and lines used to moor the vessel and berth mooring equipment multiplied by not less than 1.18	—	—

[A)] For example, when the future berth operator prescribes oil and gas carriers conforming to OCIMF MEG 3 [N2] the rated capacity A1⟩ of the vessel's ⟨A1 mooring equipment and fittings is usually defined as the SWL which typically incorporates a safety margin over the yield. For winches, the brake holding load is set to render at 60% of MBL of the vessel lines and the rated capacity would be the design holding load equivalent to 80% of MBL of the vessel lines.

[B)] The limiting capacity of a vessel's mooring equipment and mooring lines may be taken as the MBL of the mooring lines. The limiting capacity of the berth mooring equipment may be taken as the SWL. The factor of 1.18 allows for typical margins between nameplate or design limiting capacities of lines, winches and fittings and upper yield strength.

Table 9 — *Accidental loads for multiple hooks*

Number of mooring hooks per mooring point	Total accidental mooring point load as multiple of rated hook SWL (or rated MBL of vessel's mooring line, where appropriate)
2	2.1
3	2.8
4	3.5

30 Docking and slipping

In addition to the vertical components of berthing, vessels are capable of generating significant direct vertical loads which, for certain maritime structures such as dry docks, floating docks, ship lifts and slipways, can constitute one of the major design loading considerations, and should therefore be taken into account by the designer.

Although the total static vertical load is limited to the docking displacement of the vessel, when determining the application and distribution of that load, the designer should take account of the operational criteria and the relative strengths and stiffnesses of both the structure and the expected vessels.

NOTE Further guidance on the selection of design loadings for these types of structure is given in BS 6349-3.

31 Cargo storage

31.1 General

The requirements for cargo storage should be provided by the port or terminal operator or in consultation with the port or terminal operator.

NOTE Cargo may be stored in the open or within sheltered structures such as silos, tanks or sheds.

Any procedures and instructions established by the operator to define procedures, environmental operating limits and other such matters to ensure safe and efficient operation of the maritime works and facilities in the operation and maintenance phase should be listed in the facility operating manual as described in BS 6349-1-1:2013.

In all cases, the persistent and transient actions on the sub-structure should be calculated taking into account the actions from the storage structure, the material stored, the cargo handling equipment and the effects of wind pressure and any snow loading. The testing of pipelines is usually carried out using water, which should be taken into account in the loading calculations. Where the loading might be increased or its distribution altered due to dynamic effects of setting down, filling or discharging, then these effects should also be taken into account.

31.2 Dry bulk stacks

For open stacks of bulk materials, the actions from the stacked material should be calculated based on the maximum heights, angles of repose and densities of the materials to be stored. For materials that are not free-draining and where no protection is provided or where sprinklers are used, the saturated weight of the material should be used.

NOTE Storage heights of 3 m to 15 m are commonly used. The use of edge-retaining walls can lead to increased heights. Some typical values of dry bulk densities and angles of repose are given in Annex I.

31.3 Other commodities

For other storage areas, the actions imposed should be calculated based on the height of stacking and effective density of the commodities as packaged, including space between stacks.

NOTE 1 The height of stacking can be limited by:

a) *the height attainable with the stacking equipment;*

b) *the strength of the packaging;*

c) *the available height within sheds;*

d) *regulations or trade practice.*

NOTE 2 In the absence of more specific information, the typical values of stacking height given in Table 10 may be adopted for concept design. Typical values of effective stacked densities for some common commodities are given in Annex I. If better information is not available, the loading from general cargo can be taken as 30 kN/m² in operational areas or 50 kN/m² in stacking areas.

Table 10 — *Typical stacking heights*

Cargo type	Open storage stacking height m	Sheltered storage stacking height m
General palletized cargo	2	3 to 5
Timber or timber products	3	6 to 7
Metal products	2	3
Fish	2	2.5
Vegetables and fruit	2	4

31.4 Containers

COMMENTARY ON ***31.4***

Containers are supported by corner castings that are 178 mm × 162 mm in plan dimension and which transmit the load from the container and any containers stacked above to the ground. These corner castings give highly concentrated loads that have to be taken locally by the pavement. When designing for global loads, e.g. in settlement calculations, it is appropriate to treat the loads from containers as an uniformly distributed load. Containers are usually stacked in separate areas for empty and full containers, and the height and density of the stacks depends on the stacking equipment.

Typically average container gross weights are less than half their maximum gross weight per twenty-foot equivalent unit (TEU). It is unlikely that containers will be stacked by weight and hence it is unlikely that all of the containers within a stack will be the maximum weight. The designer should establish from the container terminal operator, if possible, the distribution of loaded containers to establish statistically the local (corner casting) and global actions.

If statistical data is not available for concentrated loads then Table 18 of the Interpave document *The structural design of heavy duty pavements for ports and other industries* [28] may be used. This table should be corrected for an increase in maximum container weights since its publication.

If statistical data is not available for global loading, the distribution of loads with stacking height given in Table 18 of the Interpave document *The structural design of heavy duty pavements for ports and other industries* [28] may be used based on a gross weight of 320 kN for a 20 ft. full container. The calculation of the uniformly distributed load should allow for the stacking density that varies between stacks formed using different types of stacking equipment.

31.5 Other loads

An allowance of an additional transient dynamic load, equal to the maximum unit load handled, should be made for setting down impacts where cranes operate.

When storing commodities that are above or below ambient temperatures, the effect of temperature on the ground or structure should be taken into account.

Storage areas for dangerous and/or leaking cargoes should allow for containment or other protective measures.

32 Cargo handling and transport systems

32.1 General

*COMMENTARY ON **32.1***

Cargo handling and transport systems operating within ports can be classified as:

a) *fixed and rail-mounted equipment;*

b) *conveyors and pipelines;*

c) *rail traffic;*

d) *road traffic;*

e) *rubber-tyred port vehicles operating on their tyres within the confines of the port, with or without lifting capacity;*

f) *rubber-tyred port vehicles operating on their supporting pads or legs within the confines of the port, with or without lifting capacity;*

g) *tracked cranes.*

Any procedures and instructions established by the operator to define the cargo handling and transport systems, including operating procedures, environmental operating limits and other such matters to ensure safe and efficient operation of the maritime works and facilities in the operation and maintenance phase, should be listed in the facility operating manual as described in BS 6349-1-1:2013.

The actions imposed on structures should be taken into account in both vertical and horizontal directions.

When designing the superstructure in working areas, the effects of collision impacts should be taken into account.

The persistent design situation should take account of the fact that the operations of cranes are usually halted at high wind speeds, and while a crane is handling cargo, the wind speed acting on the crane can be limited accordingly. All environmental limits should be provided by the equipment designer together with the applicable actions. For maximum wind conditions for the transient design condition, account should be taken of any special measures for stowage of the crane.

32.2 Fixed and rail-mounted equipment

For fixed and rail-mounted cargo handling equipment, actions should be calculated for the equipment to be installed for the permanent and imposed loads. Both vertical and horizontal actions should be taken into account. Imposed loads should include dynamic effects, including travelling, slewing, braking and lifting. Collision loads between items of rail-mounted equipment, or between one item of rail-mounted equipment and buffers, should be treated as an accidental design situation and should be calculated using a relative speed at impact of 1.0 m/s.

32.3 Ship to shore container cranes

Because the size and loads from container cranes are likely to increase within the working design life of the structures, allowance for increasing loads from ship to shore container cranes should be made by the designer in consultation with the terminal operator and owner.

The design of structures supporting container cranes should include the actions from container cranes including self-weight, operational loads including dynamic loads, environmental loads including wind, and jacking loads for erecting and maintenance.

The combination load cases should include for operational design situations when the wind speed is limited and non-operational design situations that include the design wind speed. Wind directions should include from the front, rear, side and diagonally from each direction.

NOTE 1 Corners of container cranes can be subject to uplift in non-operational conditions. In the case of uplift, cranes are fitted with holding down links that are linked into connectors cast into the supporting structure.

NOTE 2 Brakes on container cranes are not usually designed to prevent the movement of the cranes along the crane rails under non-operational wind loads. This motion is usually prevented by pins attached to the cranes that engage into connectors cast into the supporting structure. The connectors transfer the horizontal wind loads acting along the direction of the rail into the supporting structure.

NOTE 3 It is usual to fix the locations where the jacking of cranes takes place by providing jacking plates on the surface of the supporting structure.

NOTE 4 Based on recent increases in crane sizes, a load factor of 1.5 can be used to allow for possible future increases in equipment specification over those current at the publication date of this standard. This load factor does not include the partial factors used in the design.

NOTE 5 Figure 2 gives typical dimensions for rail-mounted ship to shore container cranes current at the publication date of this part of BS 6349.

NOTE 6 Typically under the in-service condition the maximum loads are applied by the seaward two legs. In the out-of-service condition and under storm conditions, the maximum loads are typically applied by the landward legs.

NOTE 7 Wheel loads can be limited by increasing the number of wheels in each bogie subject to any restrictions on the overall dimension between buffer faces.

32.4 Conveyors, pipelines and loading arms/hoses

Actions from conveyors, pipelines and loading arms/hoses should be calculated for each installation, taking account of permanent loads and factors that apply to the imposed loads, including material densities, rates of flow, changes of direction, temperature effects and the spacing and nature of the support framework.

32.5 Rail traffic

Actions from rail traffic in ports should be taken from BS EN 1991-2:2003.

Within ports, rail traffic might be within segregated or non-segregated routes and within rail sidings, and the following factors should be taken into account.

a) Train speeds are restricted when compared to main line installations.

b) Train vehicle movements might have to take place in mixed working environments where non-railway activity is taking place. The design situations should therefore allow for mixed use.

c) Where rail is segregated there might be a higher number of crossing points with roadways and highways. Internal port crossings are unlikely to have full barrier protection, which results in low speeds.

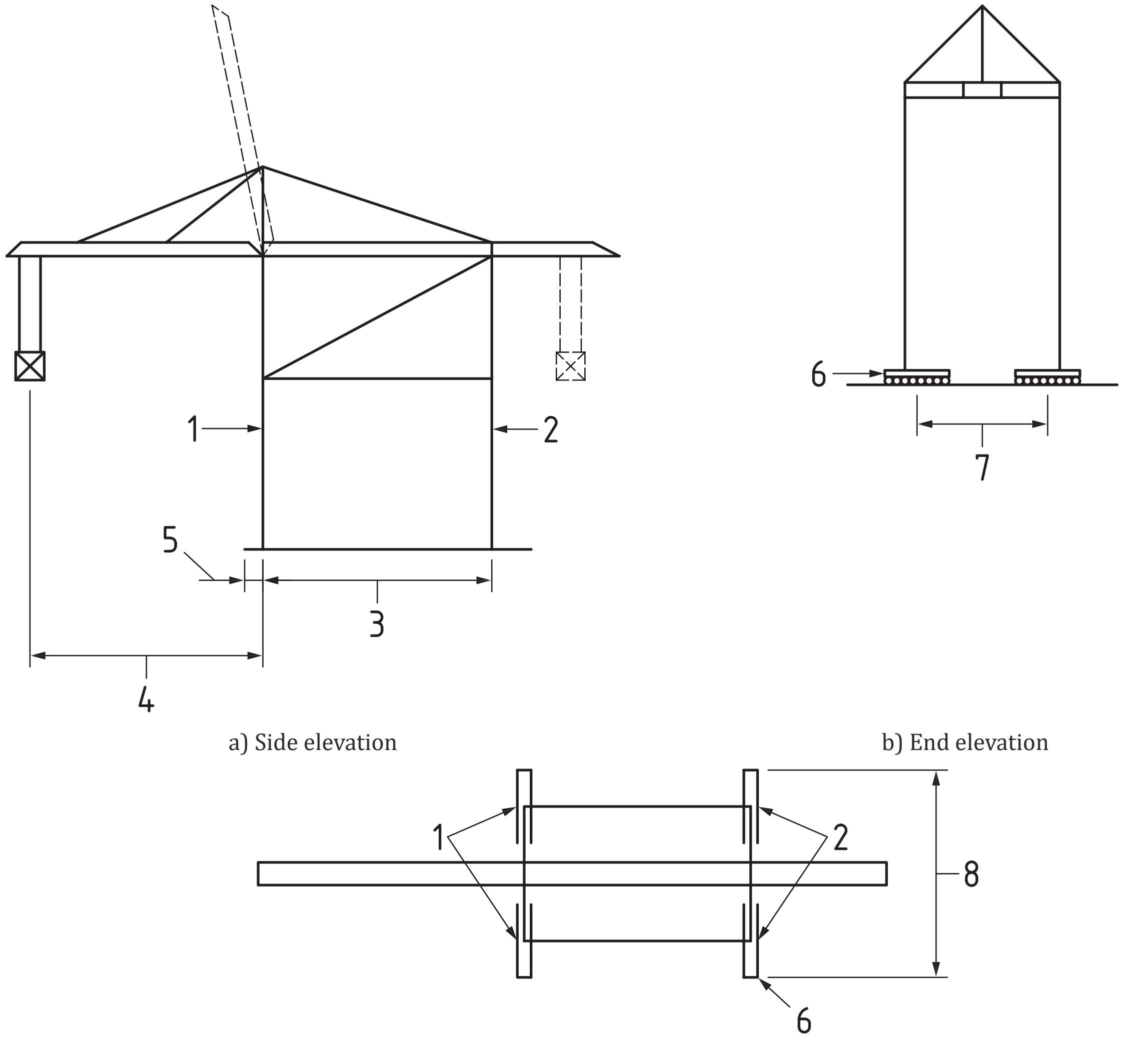
d) Curve radii might be tighter than on main lines owing to space constraints within port sites, leading to lower speeds and greater risk of noise generation. This might increase dynamic effects and lateral loads.

e) For constrained layouts the breaking up of trains in reception areas might be required. This might require additional equipment to shunt wagons into place, increasing the duration of operations and possibly leading to increased standing static loads in rail yards and more frequent dynamic effects and lateral loads.

f) Rail wagons provide dynamic effects from setting down impacts.

g) Accidental design situations might include derailment damage, which might impact the surface infrastructure that is used for other activity when trains are not present.

Figure 2 — *Typical container crane dimensions*



a) Side elevation b) End elevation c) Plan

Key

1	Front portal leg	5	Front rail to vessel (typically 5 m to 7 m)
2	Rear portal leg	6	Multiple wheel bogie (six to ten wheels, typically eight wheels)
3	Rail gauge (typically 15 m to 35 m)	7	Distance between centre of the wheel groups (typically 14.5 m to 17 m)
4	Outreach from front rail (typically 28 m to 72 m)	8	Distance between buffers (typically 27 m)

