Part 5 Ship types

Chapter 3 RO/RO Ships
FOREWORD

DNV GL rules for classification contain procedural and technical requirements related to obtaining and retaining a class certificate. The rules represent all requirements adopted by the Society as basis for classification.

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CHANGES – CURRENT

This document supersedes the October 2015 edition.
Changes in this document are highlighted in red colour. However, if the changes involve a whole chapter, section or sub-section, normally only the title will be in red colour.

Main changes January 2016, entering into force as from date of publication

• Sec.2 Hull
  — [3.3.3]: Design load sets for beam analysis (PSM) defined
  — [3.3.4]: Load combinations for partial ship FE analysis (PSM) defined
  — [4.1.4]: Modelling and strength of cross-joints included
  — [7]: Buckling ship type requirements included for side shell in racking condition, light car decks and pillars

Editorial corrections

In addition to the above stated changes, editorial corrections may have been made.
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SECTION 1 GENERAL

1 Introduction

1.1 Introduction
These rules apply to vessels intended for loading and unloading the cargo by Roll on/ Roll off (RO/RO), i.e. with class notations Car carrier or RO/RO ship.

1.2 Scope
The rules in this chapter give requirements specific to RO/RO vessels.

1.3 Application
The requirements in this chapter are supplementary to the rules in Pt.2, Pt.3 and Pt.4 applicable for the assignment of the main class.

General reference is made to the Society's document DNVGL CG 0137, Strength analysis of hull structure in RO/RO ships and car carriers for general ship type information, design concepts and a description of an acceptable approval procedure.

2 Class notations

2.1 Ship type notations
Vessels built in compliance with the requirements as specified in Table 1 will be assigned the class notations as follows:

Table 1 Ship type notations

<table>
<thead>
<tr>
<th>Class notation</th>
<th>Description</th>
<th>Design requirements, rule reference</th>
</tr>
</thead>
<tbody>
<tr>
<td>RO/RO Ship</td>
<td>Vessels intended for loading and unloading the cargo by Roll on/ Roll off (RO/RO)</td>
<td>Sec.1 and Sec.2</td>
</tr>
<tr>
<td>Car Carrier</td>
<td>Vessels intended for carriage of vehicles</td>
<td>Sec.1 and Sec.2</td>
</tr>
</tbody>
</table>

2.2 Additional notations
The following additional notations, as specified in Table 2, are typically applied to RO/RO ships and car carriers:

Table 2 Additional notations

<table>
<thead>
<tr>
<th>Class notation</th>
<th>Description</th>
<th>Application</th>
</tr>
</thead>
<tbody>
<tr>
<td>MCDK</td>
<td>Requirements for movable car decks</td>
<td>All ships</td>
</tr>
</tbody>
</table>
3 Definitions

3.1 Terms

Table 3 Definitions

<table>
<thead>
<tr>
<th>Terms</th>
<th>Definition</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>RO/RO equipment</strong></td>
<td>Ramps, doors, hatch covers and movable decks and ramps for loading/off-loading of RO/RO cargo or acting as cargo decks at sea, designed to:</td>
</tr>
<tr>
<td></td>
<td>— load/off-load the ship’s cargo during port operations</td>
</tr>
<tr>
<td></td>
<td>— function as cargo deck space where applicable, i.e. movable decks, ramp covers/inner ramps</td>
</tr>
<tr>
<td></td>
<td>— function as watertight/weathertight boundary at sea where applicable, e.g. external doors/ramps, internal watertight hatches.</td>
</tr>
<tr>
<td><strong>Racking constraining structure</strong></td>
<td>The structure that will constrain deflections in transverse direction. Typical examples of racking constraining structures are engine room</td>
</tr>
<tr>
<td></td>
<td>bulkheads, collision bulkhead, engine- and stairway casings and partial racking bulkheads/deep vertical web structure.</td>
</tr>
<tr>
<td><strong>Uniformly distributed load (UDL)</strong></td>
<td>A defined distributed design load for cargo decks given in t/m², representing the maximum distributed load for a deck or part of a deck.</td>
</tr>
</tbody>
</table>

4 Documentation

4.1 Documentation requirements

General requirements for documentation, including definition of the Info codes, see Pt.1 Ch.3 Sec.1.
For a full definition of the documentation types, see Pt.1 Ch.3 Sec.3.
### Table 4 Documentation requirements

<table>
<thead>
<tr>
<th>Object</th>
<th>Documentation type</th>
<th>Additional description</th>
<th>Info</th>
</tr>
</thead>
<tbody>
<tr>
<td>Ship hull structure</td>
<td>H081 - Global strength analysis</td>
<td>When required by Sec.2 [1.2]</td>
<td>FI</td>
</tr>
<tr>
<td></td>
<td>H085 - Fatigue analysis</td>
<td>When required by Sec.2 [1.2]</td>
<td>FI</td>
</tr>
<tr>
<td></td>
<td>H050 - Structural drawing</td>
<td>Connections between door frames and bulkheads in racking constraining structure.</td>
<td>AP</td>
</tr>
</tbody>
</table>
| Cargo securing arrangement  | Z030 - Arrangement drawing | — securing points for lashing with data regarding position, type, design of fittings and Maximum Securing Load (MSL)  
— stowage and securing arrangement for all vehicles to be carried  
— maximum axle load and number of axles of vehicles. | FI   |
| Movable car deck arrangements | Z030 - Arrangement drawing | — car deck pontoons and their weights  
— stowing arrangement for deck pontoons not in use. This should include all stressed strength members, such as racks on deck, securing devices, reinforcement of supporting hull structures, etc. | FI   |
|                             | H050 - Structural drawing | — supports or suspensions  
— connections to hull structure with information regarding reaction forces from hoisting devices. | AP   |
|                             | Z253 - Test procedure for quay and sea trial |                                                                                  | FI   |
| Internal movable ramps      | H050 - Structural drawing |                                                                                                   | AP   |

AP = For approval; FI = For information

---

### 5 Product certificates

#### 5.1 Certification requirements

For products that shall be installed on board, the Builder shall request the Manufacturers to order certification as described in Table 5.
### Table 5 Certification requirements

<table>
<thead>
<tr>
<th>Object</th>
<th>Certificate type</th>
<th>Issued by</th>
<th>Certification standard</th>
<th>Additional description</th>
</tr>
</thead>
<tbody>
<tr>
<td>Cargo securing devices, fixed</td>
<td>PC</td>
<td>Society</td>
<td>Standard for Certification No. 2.23</td>
<td></td>
</tr>
<tr>
<td>Cargo securing devices, portable</td>
<td>PC</td>
<td></td>
<td></td>
<td>If certification by the Society, Standard for Certification No. 2.23, shall be applied.</td>
</tr>
</tbody>
</table>

For general certification requirements, see Pt.1 Ch.3 Sec.4.
For a definition of the certificate types, see Pt.1 Ch.3 Sec.5.
SECTION 2 HULL

1 Racking

1.1 General
A racking strength assessment shall be carried out following the requirements given in this sub-section. Special attention shall be given to the connections between transverse structural members to the bulkhead deck or the uppermost deck level with high racking rigidity. Intersections between horizontal and transverse members shall be assessed in areas subjected to high racking deformations, i.e. response caused by roll motion acting on the cargo at multiple decks combined with selfweight of structure and equipment.

1.2 Calculation scope for racking

1.2.1 General
The transverse strength shall be checked against:

1) the ultimate limit state (ULS) under extreme loading as described in [3.2]
2) the fatigue limit state (FLS) under variable cyclic loading as described in [8].

The extent of the calculation scope depends on the vessel's arrangement and complexity. Two categories, based on structural configuration, are used to group the scope and the calculation requirements for ULS and FLS:

Category I, ref. [1.2.2]:
— designs with not more than two RO/RO decks above bulkhead deck
— designs with evenly distributed self-supporting side web frames, e.g. frames able to restrain the racking response from all decks based on given frame spacing.

Category II, ref. [1.2.3]:
— designs with multiple decks and few effective transverse strength members such as engine casing box, stair casing box and deep racking frames/ bulkheads.

1.2.2 Scope of racking calculations for category I vessels
Transverse strength is provided by deep vertical web frames in the ship’s side and/or transverse bulkheads in the accommodation area. A simplified racking assessment model using beam elements will be accepted for the evaluation of the adequacy of the transverse strength for the ULS scope. Acceptable calculation and modelling methods and criteria are given in Pt.3 Ch.7.

A simplified FLS assessment for racking will be required on a case by case basis depending on the nominal stress.

1.2.3 Scope of racking calculations for category II vessels
A global FE strength analysis is required to document the racking response and to demonstrate that the stresses are acceptable under ULS load conditions. Acceptable calculation methods and criteria are given in Ch.7 Sec.3 and [4.3]. Supporting documentation for the direct strength analysis is described in the Society's document DNVGL CG 0127 Sec.2. A separate FLS analysis shall be carried out according to [8].

For vessels with length \( L < 120 \) m, a reduced calculation scope according to [1.2.2] may be accepted on a case-by-case basis.
2 Docking

For large RO/RO ships and car carriers that may have large docking weight, special strength calculation of
the bottom structure in way of the docking blocks may be required. Reference is made to the rules Pt.3 Ch.3
Sec.5 [3.4] regarding requirements for docking.

Acceptance criteria for direct docking analysis for beam- or FE analysis, to be taken according to:
— beam analysis: Pt.3 Ch.6 Sec.6 [2.2], AC-I
— FE analysis: Pt.3 Ch.7 Sec.3 Table 1, AC-I.

3 Loads

3.1 Design still water bending moments

The still water bending moment limits shall be based on an extreme non-homogenous loading condition. For
the hogging limit, an increased load density shall be assumed in the aft ship and fore ship area.

Guidance note:
Based on a homogeneous loading condition on scantling draught, 25% of the load within 0.4 L should be redistributed equally to
the load area aft of 0.3 L and forward of 0.7 L, without exceeding the maximum specified uniformed distributed load (UDL) for the
heavy RO/RO decks.

---e-n-d---of---g-u-i-d-a-n-c-e---n-o-t-e---

A sagging still water bending moment limit value lower than the minimum rule sagging moment may be
accepted, provided this can be documented. A negative still water sagging limit (i.e. minimum hogging)
may be accepted provided that it can be demonstrated that the vessel will not experience static sagging. In
such case, an extreme but realistic still water sagging condition with increased load density within 0.4 L and
decreased load density outside 0.4 L, shall be taken into account.

Guidance note:
Based on a homogeneous loading condition on scantling draught, load density within 0.4 L should be increased with 25%, without
exceeding the maximum specified uniformed distributed load (UDL) for the heavy RO/RO decks. Increased load density within 0.4 L
shall be compensated by reduction of load density aft of 0.3 L and fwd of 0.7 L to obtain the same cargo deadweight.

---e-n-d---of---g-u-i-d-a-n-c-e---n-o-t-e---

3.2 Loads for global racking strength assessment

3.2.1 Loading condition for racking

The loading condition, which in combination with relevant dynamic load cases defined in [3.2.3] results in
the maximum racking moment about the bulkhead deck, shall be chosen for the ULS transverse strength
analysis. The racking moment shall be calculated according to [3.2.2].

The actual GM value for this design load case shall be determined and applied since it has a significant
influence on the dynamic load cases. In no case shall the GM value for the design still water loading condition
be smaller than 0.05 B.

3.2.2 Racking moment calculation

The racking moment is calculated using both cargo weight \(m_c\) and the self weight \(m_s\) to obtain the total
mass. For unloaded weather decks, it is sufficient to include the load corresponding to the self-weight if no
deadweight is specified. The transverse force on each deck level is obtained as the total mass times the
transverse acceleration corresponding to the relevant equivalent design wave (EDW) given in [3.2.3]. Thus,
the racking moment, \(M_R\), may be estimated as:

\[
M_R = \sum_{i} (m_{c,i} + m_{s,i}) \cdot a_{y,i} \cdot (z_i - z_{\text{main}})
\]
\[ m_{c,i} = \text{mass on deck number } i \]
\[ m_{s,i} = \text{self weight of deck number } i \]
\[ a_{y,i} = \text{transverse acceleration at deck number } i \text{ for the dynamic load cases specified in [3.2.3]} \]
\[ z_i = \text{vertical distance above base line for deck number } i \]
\[ z_{\text{main}} = \text{vertical position above base line for bulkhead deck.} \]

If the maximum allowable cargo mass has been assumed for the heavy cargo decks, movable cargo decks installed directly above such decks should be assumed empty, and in the stowed position.

Lower decks shall be assumed loaded until the design draught is reached.

Guidance note:
A high racking moment is achieved if the load is located on the upper decks. However this results in lower GM values and thus also lower transverse accelerations which will reduce the racking moment. Usually, several loading conditions for racking analysis should be reviewed using the simplified racking moment calculation described in this paragraph.

---e-n-d---of---g-u-i-d-a-n-c-e---n-o-t-e---

3.2.3 Dynamic load cases
The design wave load cases which shall be used to evaluate the transverse strength of the ship structure are the beam sea load cases, BSR (1P/2P) and/or BSR (1S/2S), as defined in Pt.3 Ch.4 Sec.2 [1.1.1]. For ship structures with symmetrical arrangement of racking constraining elements, only BSR(1P/2P) or BSR(1S/2S) needs to be examined.

3.2.4 Load combinations for ULS
The loading condition from [3.2.1] shall be combined with the dynamic load cases as described in [3.2.3]. The external sea pressure shall be applied according to Pt.3 Ch.4 Sec.5 Table 8. Load combination factors for hull girder loads and accelerations shall be applied according to Pt.3 Ch.4 Sec.2 Table 3 with the internal cargo, equipment and steel weight loads.

3.2.5 FE load application
The deck load may generally be applied as distributed vertical and transverse loads based on load combination as described in [3.2.4].
Self-mass of the upper light car decks including accommodation- and garage decks must be included.
Movable car decks shall be included as point loads in way of support positions.

3.3 Loads for primary supporting members

3.3.1 Design load sets for prescriptive rule check
Design load sets and load combinations of static and dynamic loads for tank and watertight boundary structure, external shell envelope structure e.g. bottom structure, side shell primary members and deck structure is given in Pt.3 Ch.6 Sec.2 Table 2.

3.3.2 Loading patterns for direct analysis
The load pattern described in Table 1 below shall be assessed to ensure that the primary support members have sufficient strength.
### Table 1 Load patterns

<table>
<thead>
<tr>
<th>Load pattern</th>
<th>Description</th>
<th>Draught</th>
<th>Strength members</th>
</tr>
</thead>
<tbody>
<tr>
<td>LC 1</td>
<td>Normal ballast draught with no cargo</td>
<td>$T_{BAL}$</td>
<td>Bottom structure</td>
</tr>
<tr>
<td>LC 2</td>
<td>Maximum uniform cargo on lower decks until $T_{SC}$ is reached</td>
<td>$T_{SC}$</td>
<td>Lower cargo decks</td>
</tr>
<tr>
<td>LC 3</td>
<td>Maximum uniform cargo on upper decks until $T_{SC}$ is reached</td>
<td>$T_{SC}$</td>
<td>Upper cargo decks</td>
</tr>
<tr>
<td>LC 4</td>
<td>Transversely unsymmetrical deck loads</td>
<td>$T_{SC}$</td>
<td>Transverse deck girders at midspan</td>
</tr>
<tr>
<td>LC 5</td>
<td>Longitudinally unsymmetrical deck loads</td>
<td>$T_{SC}$</td>
<td>Longitudinal deck girders at midspan</td>
</tr>
<tr>
<td>LC 6</td>
<td>Heavy cargo unit (e.g. MAFI) on single girder</td>
<td>$T_{SC}$</td>
<td>Transverse and longitudinal girders</td>
</tr>
<tr>
<td>LC 7</td>
<td>Flooded condition</td>
<td>$T_{DAM}$</td>
<td>Transverse and longitudinal girders</td>
</tr>
</tbody>
</table>

1) Self weight shall be included.
2) Special load case to evaluate strength of individual strength members under heavy cargo units. Load distribution/comination must be based on information from a cargo stowage plan, see the Society's document DNVGL CG 0137, Strength analysis of hull structure in RO/RO ships and car carriers.
3) No cargo load on the watertight deck shall be applied, only selfweight.

### 3.3.3 Design load sets for beam analysis

Relevant design load sets are described in the rules Pt.3 Ch.6 Sec.2 Table 2 and Pt.3 Ch.6 Sec.8 Table 1 are to be applied to the model.

For internal decks, the UDL design load sets applies and the $P_{dl-d}$ may be based on envelope acceleration according to Pt.3 Ch.4 Sec.3 [3.3]. The following design load sets then applies:

- **a)** UDL-1h: $(P_{dl-s} + P_{dl-d})$ combined with maximum hull girder vertical bending moment in hogging,
  - i.e. $M_{wv-h} + M_{sw-h}$ based on HSM-2
- **b)** UDL-1s: $(P_{dl-s} + P_{dl-d})$ combined with maximum hull girder vertical bending moment in sagging,
  - i.e. $M_{wv-s} + M_{sw-s}$ based on HSM-1

Optionally, the accelerations for the considered dynamic load case may be applied. Then the number of applicable load sets will double, in order to maximize both local pressure and hull girder vertical bending moment, as described in Pt.3 Ch.6 Sec.2 Table 2.

### 3.3.4 Load combinations for partial ship FE analysis

Table 1 in combination with Table 2 provide design loads for finite element analysis. When unsymmetrical loading conditions are used on a partial ship structural finite element then the additional stresses induced by racking shall be particularly considered.
### Table 2 Load input for FE analysis

<table>
<thead>
<tr>
<th>Loading pattern</th>
<th>Structural members to be assessed&lt;sup&gt;1)&lt;/sup&gt;</th>
<th>Dynamic load cases</th>
<th>Accelerations on cargo</th>
<th>Draught</th>
<th>Acceptance criteria</th>
</tr>
</thead>
<tbody>
<tr>
<td>LC1</td>
<td>Double bottom structure</td>
<td>FSM-1&lt;sup&gt;2)&lt;/sup&gt;</td>
<td>NA</td>
<td>$T_{BAL}$</td>
<td></td>
</tr>
<tr>
<td>LC2</td>
<td>Lower cargo decks</td>
<td>HSM-1 and HSM-2</td>
<td>$a_z$&lt;sup&gt;env&lt;/sup&gt;</td>
<td></td>
<td>AC-II</td>
</tr>
<tr>
<td>LC3</td>
<td>Upper cargo decks</td>
<td>FSM-1&lt;sup&gt;2)&lt;/sup&gt;</td>
<td>$a_z$&lt;sup&gt;(FSM-2)&lt;/sup&gt;</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>Double bottom structure</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>LC4</td>
<td>Transverse girder at midspan</td>
<td>HSM-1 and HSM-2</td>
<td>$a_z$&lt;sup&gt;env&lt;/sup&gt;</td>
<td>$T_{SC}$</td>
<td>AC-II</td>
</tr>
<tr>
<td>LC5</td>
<td>Longitudinal girder at midspan</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>LC6</td>
<td>Heavy cargo decks</td>
<td>HSM-2</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>LC7</td>
<td>Watertight decks</td>
<td>NA</td>
<td>NA</td>
<td>$T_{DAM}$</td>
<td>AC-III</td>
</tr>
</tbody>
</table>

1) The assessment shall also cover connection to other primary supporting members, such as side web frames and pillars
2) FSM-1 applies aft of 0.3L from AE. For cargo area forward of 0.3 L from AE, FSM-2 applies.

where,

- $a_z$<sup>env</sup> = as defined in Pt.3 Ch.4 Sec.3 [3.3.3]
- $a_z$<sup>(FSM-2)</sup> = vertical acceleration at any point as defined in Pt.3 Ch.4 Sec.3 [3.2.3] for FSM-2

**Guidance note:**
LC1 assessment of double bottom area is normally only applicable from aft of 0.2L from FE, from where the cargo area on inner bottom terminates and the bottom girder grill becomes limited.

---e-n-d---of---g-u-i-d-a-n-c-e---n-o-t-e---

### 3.3.5 Load combinations for global FE analysis

For designs where global FE racking assessment is required according to [1.2], the global analysis may be used for a complete strength assessment of primary supporting members. The analysis shall cover the load patterns, LC1 to LC5, defined in Table 1 and these are to be combined with the dynamic load cases described in Pt.3 Ch.4 Sec.2.

### 3.3.6 Cargo loading

In addition to the uniform design load as given by the designer, the deck girder structure shall be checked for the most severe combination of axle(s) positioning of cargo handling vehicles in harbour and for vehicles as cargo in sea-going conditions.

### 3.4 Fatigue loads for FE models

#### 3.4.1 Loading condition

The loading condition resulting in the highest transverse racking moment according to [3.2.2] should normally be selected as basis for the fatigue analysis. In addition it should represent the most frequently used loading condition, as the load case with all decks loaded with personal cars. The $GM$ to be used in the analysis shall be the actual $GM$ of the load case, but not less than 0.035 $B$.

**Guidance note:**
It should be noted that using a lower $GM$ value means that the predicted fatigue life will be increased. The $GM$ value representative for the departure condition should therefore be used as basis for the fatigue analysis.
3.4.2 Dynamic load cases
For the fatigue analysis of local connections of transverse elements the dynamic load cases BSR (1P/2P) and/or BSR (1S/2S) as given in Pt.3 Ch.4 Sec.2 Table 8, shall be applied. For ship designs with symmetrical arrangement of racking constraining elements, only BSR(1P/2P) or BSR(1S/2S) needs to be examined.

3.4.3 Load combinations for FLS
The loading condition from [3.4.1] shall be combined with the dynamic load cases in [3.4.2]. External sea pressure shall be applied according to Pt.3 Ch.4 Sec.5 Table 23. Load combination factors for hull girder loads and accelerations shall be applied according to Pt.3 Ch.4 Sec.2 Table 9 with the internal cargo, equipment and steel weight loads.

4 Hull local scantling

4.1 Primary supporting members

4.1.1 Pillars
The pillars shall be fitted in the same vertical line, from bottom to upper most deck. If not possible, the pillars shall be effectively supported by box girder or bulkhead structures, and direct strength analysis will be required.

4.1.2 Double bottom structure in way of pillars
The double bottom structure in way of pillar endings, in ships with multiple cargo decks supported by pillars, shall be investigated for all relevant seagoing conditions and maximum ballast draught with no cargo loads on decks above, \( T_B \) (min) = 0.6\( T_{sc} \). Counteracting forces due to ballast in double bottom may be taken into account in the analysis.

4.1.3 Slenderness of primary support members
Where a primary structure member is intended mainly for interfacing structure of RO/RO equipment and not contributing to major structural strength, e.g. a stringer in superstructure side for movable car deck, a slenderness coefficient \( C_w = 125 \) to be applied for the web plate requirement given in Pt.3 Ch.8 Sec.2 [4.1.1].

4.1.4 Modelling and strength of cross-joints
The flange discontinuity at cross joints of highly stressed girders may be compensated for by brackets. If the fitting of such brackets is not possible (e.g. between deck transverse and ship side vertical girders), high shear stresses in the web area that combines the girders may be the consequence. This is illustrated in Figure 2.

As an alternative to the rules Pt.3 Ch.3 Sec.6 [3.4.4], the mean shear stress in N/mm² may be derived directly as follows:

\[
\tau = \frac{P_{fi} - 0.5F_{si}}{12D_i^2w - n50}
\]

and

\[
\tau = \frac{P_{fi} - 0.5F_{si}}{12D_i^2w - n50}
\]

\( F_{si} \) = shear force in girder in N
\( P_{fi} \) = flange force in girder in N
\( D_i \) = web thickness of girder in mm
Guidance note:
For racking conditions, shear force, \( F_{S1/2} \), might give a positive contribution to the total shear force, hence - to be replaced by + if applicable.

---e-n-d---o-f---g-u-i-d-a-n-c-e---n-o-t-e---

For evaluation of T-joint, the flange force \( P_F \) is to be taken as the sum of the flange forces of adjoining girders. Similarly, the shear force \( F_S \) is to be taken as the sum of the shear forces (absolute value) of the adjoining girder webs. This means that (Ref. Figure 2):

\[
P_{F1} = P_{F1a} + P_{F1b}
\]
\[
F_{S1} = |F_{S1a}| + |F_{S1b}|
\]

In case the shear stresses are taken from a finite element analysis, the average shear stress of the elements within the cross joint may be applied and compared against allowable stresses. The allowable shear stress of the web plate is to be taken in accordance with the rules Pt.3 Ch.3 Sec.6 [2.2] The welding of the web plate of cross joints is to be based on the rules Pt.3 Ch.13 Sec.1.

The flange thicknesses of non-bracketed cross joints is generally not to be less than half of the required web plating thickness of the cross joint.

The shear flexibility of the web plates within girder cross joints gives rise to rotational deformation of the transverse deck girders relative to the vertical girders of the ship side. This flexibility may in the beam model be represented as a rotational spring between the deck girder element and the vertical web frame, see Figure 3. The spring stiffness \( K_{RC} \) in Nmm/rad may be determined as:

\[
K_{RC} = G \cdot h_1 \cdot h_2 \cdot t_{w-N50}
\]

where:

\( h_1, h_2, t_{w-N50} \) = as given in Figure 1 in mm

\( G \) = shear modulus, \( 0.7 \times 10^5 \) N/mm\(^2\) (steel).

**Figure 1 Geometry cross joint**
Figure 2 Analysis of cross joint
4.2 Securing points for lashing

4.2.1 General
Decks intended for carriage of vehicles shall be equipped with a satisfactory number of securing points (cargo securing device) for lashing of the vehicles. The arrangement of securing is left to the discretion of the owner, provided the minimum requirements in [4.2.2] through [4.2.6] are satisfied.

4.2.2 Scantling
Stiffeners and girders are subject to direct analysis according to Pt.3 Ch.6 Sec.5 [1.2] and Pt.3 Ch.6 Sec.6 [2.2], respectively, applying the maximum securing load defined in [4.2.3] to [4.2.6].

\[ \beta_s, \alpha_s \text{ and } C_{s-max} \text{ may be taken as for acceptance criteria AC-II.} \]

4.2.3 Maximum securing load
Unless otherwise specified, each lashing point shall have a Maximum Securing Load (MSL) of not less than:

\[ MSL = kQg_0 \]

\[ \text{max, } 0.5 \ P_m \]

\[ \text{min, } 100 \text{ kN in decks for heavy cargo, e.g. busses, road- and MAFI trailers} \]

\[ \text{min, } 15 \text{ kN in decks for cars only} \]

\[ k = \frac{n}{r} \]

\[ P_m = \text{minimum breaking load of the considered cargo securing device} \]

\[ r = \text{number of effective lashing points at each side of the vehicle for the number } n \text{ of axles in group.} \]

---

**Figure 3 Spring representation of deck and side girder cross joint**

"STRUCTURE:

Deck girder

Side shell

MODEL:"
If $r$ is different from 1, $k$ shall be increased by 10%.

$$Q = \text{the maximum axle load given in tons.}$$

For MAFI road trailers, $Q$ can be calculated as the total weight with $n = 1$ and $r = \text{the total number of lashings at each side.}$

### 4.2.4 More than one lashing

If the securing point is designed to accommodate more than one lashing, the magnitude and direction of the lashing loads shall be taken into account when determining the total MSL of the securing point.

### 4.2.5 MSL less or equal to 15 kN

Lashing points intended for a maximum working load of 15 kN can normally be arranged without any strengthening of the deck plating.

### 4.2.6 MSL more than 15 kN

The strength of lashing points intended for a maximum working load of more than 15 kN shall be documented by either structural analysis or mock-up tests.

### 4.3 Special strength considerations

#### 4.3.1 2-stack MAFI trailers

Strength of decks intended for carrying MAFI trailers or other vehicles carrying more than one tier of containers must be checked for possible tension loads and increased vertical compression load due to rolling. Additional load cases shall be included in beam- or FE analysis.

#### 4.3.2 Door openings in racking constraining structure

In case of door openings in racking constraining structure, especially transverse structure, it is important to provide radius in the corners to obtain acceptable local stresses in the corners. Rectangular door frames without radius shall not be welded directly to the bulkhead plate. It is recommended to introduce recess structure in order to avoid unnecessary stress concentrations in way of the door frame.

#### 4.3.3 Deck openings in way of ramps/ ramp covers

Special consideration is required for girder structure forming the framing around deck ramp openings. Direct strength analysis shall be used to demonstrate that rule requirements are satisfied.

#### 4.3.4 Watertight integrity of trunks

Where a ventilation trunk passing through a structure penetrates the bulkhead deck, the trunk shall be capable of withstanding the water pressure that may be present within the trunk, after having taken into account the maximum heel angle allowable during intermediate stages of flooding, in accordance with SOLAS Ch. II-1/8.5.

Where all or part of the penetration of the bulkhead deck is on the main ro-ro deck, the trunk shall be capable of withstanding impact pressure due to internal water motions (sloshing) of water trapped on the ro-ro deck.

#### 4.3.5 Flexible hinge member

The longitudinal flexible hinge in the hinged deck design Car carriers shall have low torsional stiffness (i.e. flat bar is preferred) and the distance between the flexible hinge and the face plate of the side girder should be made as small as possible, see the Society's document DNVGL CG 0137 Sec.1 Figure 2.
5 Beam analysis

5.1 Effective flange
Effective breadth for the PSM of attached plating should be calculated according to the rules Pt.3 Ch.3 Sec.7 [1.3.2].
The effective breadths, \( b_e \), in mm, of the plate- and the free flanges of transverse deck girders and vertical side girders in way of deck- and side girder cross joints are not to be taken larger than:

\[
b_e = \begin{cases} 
1.15h_s + kh_d & \text{for deck girders} \\
1.15h_d + kh_s & \text{for side girders} 
\end{cases}
\]

\[b_{e-max} = b\]

\( h_s \) = web height of side girder in mm
\( h_d \) = web height of deck girder in mm
\( k \) = 0.25 for plate flanges
\( k \) = 0 for free flanges
\( b \) = flange (free flange or plate flange) with in mm

5.2 Acceptance criteria
Acceptance criteria for yield and buckling are given in Pt.3 Ch.6 Sec.6 [2.2.2] and Pt.3 Ch.6 Sec.6 [2.2.3], respectively.

6 FE analysis

6.1 General
Reference is made to Pt.3 Ch.7 Sec.4, supporting the Society’s document DNVGL CG 0127, Finite element analysis and the Society’s document DNVGL CG 0137, Strength analysis of hull structure in RO/RO ships and car carriers, for FE model procedures.

6.2 ULS racking acceptance criteria
Stresses in plating of transverse racking constraining structure shall not exceed the permissible values as given in:

<table>
<thead>
<tr>
<th>Permissible axial &amp; principal stress</th>
<th>Permissible shear stress</th>
<th>Permissible von Mises stress</th>
</tr>
</thead>
<tbody>
<tr>
<td>200/k</td>
<td>120/k</td>
<td>220/k</td>
</tr>
</tbody>
</table>

6.3 Yield criteria for PSM's
Acceptance criteria for yield strength assessment of primary supporting members based on partial ship structural FE analysis is given in Pt.3 Ch.7 Sec.3 [4.2].
7 Buckling

7.1 Side shell buckling for racking
Panel buckling assessment of ship side in way of racking constraining structure, such as racking casings/boxes, shall be carried out.

7.2 Light car decks
Buckling assessment of light car decks shall be performed according to Pt.3 Ch.3 Sec.7 [1.3].

7.3 Pillars

7.3.1 General
Buckling strength of pillars shall be assessed according to Pt.3 Ch.8 Sec.4 [5] and DNVGL CG 0128 Sec.3 [4].

7.3.2 Buckling load
The actual compression stress in the pillar shall be calculated by summarizing the accumulated forces based on maximum design loads of all the decks above the pillar in question.

7.3.3 Acceptance criteria for buckling
Acceptance criteria for pillar buckling is given in Pt.3 Ch.8 Sec.1 [3.4]

8 Fatigue strength

8.1 Application
A prescriptive fatigue check according to [8.2] is mandatory for all vessels with \( L > 150 \) m. Fatigue assessment by hot spot models according to [8.3] is mandatory for category II vessels, defined in [1.2.1] and will be required on a case by case basis for category I vessels.

8.2 Prescriptive fatigue
Local structure that shall be assessed by the prescriptive fatigue method, according to Pt.3 Ch.9 are the end connections of longitudinal stiffeners in outer shell below freeboard deck. Relative deflections may be ignored.

8.3 FE analysis

8.3.1 Application
With reference to Pt.3 Ch.9 Sec.3 [4], standard critical details, defined in [8.3.2], shall be assessed by hot spot fatigue analysis. Local models shall be made according to Pt.3 Ch.7 Sec.4.
Fatigue assessment for other details will be required on a case by case basis, determined based on the nominal stress level from the global ULS analysis. Example of such details are given in [8.3.3].

8.3.2 Standard critical details
Connection of main racking constraining structure to bulkhead deck, typically:
— engine room casing
— stairway/lift casings, if continuous up to weather deck
— deep racking frames
— partial bulkheads.

8.3.3 Other critical areas
Other critical areas with respect to fatigue are represented by typical details in way of:
— connection between transverse deck girders and racking constraining structure such as casings and/or racking boxes
— connections of vertical web frames to bulkhead deck
— connection between vertical side frames and transverse deck girders
— connection between pillars and transverse deck girders
— pillar connection to top deck and inner bottom
— other rigid structure, such as staircase or ventilation ducts and their connection to PSM’s
— vertical side frames connection to collision bulkhead.

8.4 Fatigue damage calculations

8.4.1 Zero-crossing frequency
The zero-crossing frequency for the roll response shall be taken as:

\[ \nu_{0, r} = \frac{\sqrt{GM}}{2.3 k_r} \]

when calculating the fatigue damage accumulation according to the Society’s document DNVGL CG 0129 Sec.3.

8.4.2 Stress range
With reference to the Society’s document DNVGL CG 0129 Sec.3 [2.5], the stress range \( \Delta \sigma \) needed for the fatigue damage evaluation shall be calculated as:

\[ \Delta \sigma = \Delta \sigma_p = \sigma_{HS-2P} - \sigma_{HS-1P} \]

for symmetric designs, where,

— \( \Delta \sigma_p \) = Hot spot stress range for BSR-P
— \( \sigma_{HS-1P} \) = Hot spot stress for BSR-1P
— \( \sigma_{HS-2P} \) = Hot spot stress for BSR-2P

For un-symmetric designs, also stress range for BSR-1S and BSR-2S must be calculated as:

\[ \Delta \sigma = \Delta \sigma_s = |\sigma_{HS-2S} - \sigma_{HS-1S}| \]

where,

— \( \Delta \sigma_s \) = Hot spot stress range for BSR-S
— \( \sigma_{HS-1S} \) = Hot spot stress for BSR-1S
— \( \sigma_{HS-2S} \) = Hot spot stress for BSR-2S

For un-symmetrical design, the fatigue damage shall be calculated based on:

\[ \Delta \sigma = \text{Max}(\Delta \sigma_p, \Delta \sigma_s) \]
9 RO/RO equipment

9.1 General

9.1.1 Introduction
RO/RO equipment shall satisfy the requirements in this section in addition to general requirements for shell doors and ramps given in Pt.3 Ch.12 Sec.4 and internal doors as given in Pt.3 Ch.12 Sec.2.

9.1.2 Local scantling
Requirements for plate and stiffener are given in Pt.3 Ch.6 Sec.4 and Pt.3 Ch.6 Sec.5, respectively. Decks and ramps subject to wheel loading shall comply with requirements in Pt.3 Ch.10 Sec.5 under port operations and at sea. Minimum thicknesses are given in Pt.3 Ch.6 Sec.3.

Guidance note: It is particularly important that all vehicle information is available, together with footprint data and axle arrangements since these are the main parameters to determine the design loads for the plating and stiffeners.

---e-n-d---of---g-u-i-d-a-n-c-e---n-o-t-e---

Scantlings of decks, ramps, lifts etc. for railway carriages will be specially considered in each case.

9.1.3 Damage condition
The maximum deflection of the ramp/ramp cover edge under damage condition shall be carefully examined and documented, in order to ensure watertightness.

9.2 External vehicle ramps/ doors

9.2.1 General
Requirements for side- or stern doors and bow doors are given in Pt.3 Ch.12 Sec.5 [1] and Pt.3 Ch.12 Sec.5 [2], respectively.

9.3 Hoistable internal vehicle ramps/ ramp covers

9.3.1 General
For internal ramp covers, requirements in Pt.3 Ch.12 Sec.4 applies.

9.3.2 Loads at sea
If the ramp/ramp cover is acting as a watertight deck opening cover, it shall be designed against the deepest damage waterline according to Pt.3 Ch.12 Sec.3 [2].

9.3.3 Girders
A direct strength analysis is generally required to analyse and check the strength of the primary girder system.

9.4 Movable car deck panels

9.4.1 General
Ships arranged with movable car decks or deck pontoons shall be built in compliance with relevant requirements given in Pt.6 Ch.4 Sec.6

9.4.2 Additional class notation
Upon compliance with requirements given in Pt.6 Ch.4 Sec.6, additional class notation MCDK may be given.
9.5 Function test of RO/RO equipment

Every RO/RO equipment item shall be function tested to demonstrate that all expected operations are functioning properly. Load testing as part of function testing is required for RO/RO equipment which is lifted with cargo. The test load shall be the maximum design load of the equipment. Testing and certification requirements according to 2.21 Lifting Appliance Standard is required if the ILO 152 certificate shall be issued by the Society.
CHANGES – HISTORIC

October 2015 edition

General
This is a new document.
The rules enter into force 1 January 2016.
Driven by our purpose of safeguarding life, property and the environment, DNV GL enables organizations to advance the safety and sustainability of their business. We provide classification and technical assurance along with software and independent expert advisory services to the maritime, oil and gas, and energy industries. We also provide certification services to customers across a wide range of industries. Operating in more than 100 countries, our 16 000 professionals are dedicated to helping our customers make the world safer, smarter and greener.