<table>
<thead>
<tr>
<th>Document Date</th>
<th>Notes</th>
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<tbody>
<tr>
<td>July 2007</td>
<td>General release.</td>
</tr>
<tr>
<td>July 2016</td>
<td>Corrigenda update as identified in ‘Notice 1 – Assessment of Steel Hatch Covers using FEA, July 2012 version’.</td>
</tr>
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</table>
Section 1

Application

1.1 General

1.1.1 This document provides a procedure, acceptable to Lloyd’s Register (hereinafter referred to as LR), for carrying out the structural assessment of steel hatch covers using three-dimensional linear finite plate element analysis.

1.1.2 The assessment comprises two parts:

(i) PART A: Assessment of hatch covers of cargo holds of ore carriers, combination carriers and ‘Non-CSR Bulk Carriers’.

(ii) PART B: Assessment of hatch covers of cargo holds of all ships except ore carriers, combination carriers and bulk carriers.

‘CSR Bulk Carriers’ and ‘Non-CSR Bulk Carriers’ are defined in Pt 4, Ch 7, 1.2 Application of the Rules and Regulations for the Classification of Ships (hereinafter referred to as the Rules for Ships).

1.1.3 Requirements given in the Rules for Ships, where applicable, are also to be complied with.

1.1.4 The assessment of hatch covers of ‘CSR Bulk Carriers’ as specified in Pt 4, Ch 7, 1.2 Application of the Rules for Ships is to be in accordance with IACS Common Structural Rules for Bulk Carriers and Oil Tankers.

1.1.5 A detailed report of the analysis is to be submitted for the approval of the hatch cover and must include the information listed in Ch 1, 3 Direct calculation procedures report. The report must show compliance with the specified structural design criteria given in the relevant PART(s) of this procedure.

1.1.6 If the computer programs employed for the analysis are not recognised by LR, full particulars of the programs used will also require to be submitted, see Pt 3, Ch 1, 3.1 Alternative arrangements and scantlings of the Rules for Ships.

1.1.7 LR may, in certain circumstances, require the submission of computer input and output to further verify the adequacy of the calculations carried out.

1.1.8 Where alternative procedures are proposed, these are to be agreed with LR before commencement.

Section 2

Symbols and units

2.1 Symbols

2.1.1 The symbols used in this document are as follows:

\[ l_g = \text{greatest span of primary supported members} \]

\[ t_c = \text{corrosion addition} \]

\[ X = \text{longitudinal axis, positive forward} \]

\[ Y = \text{transverse axis, positive to port} \]

\[ Z = \text{vertical axis, positive upwards} \]
\( \delta_x \) = displacement along X axis
\( \delta_y \) = displacement along Y axis
\( \delta_z \) = displacement along Z axis
\( \theta_x \) = rotation about X axis
\( \theta_y \) = rotation about Y axis
\( \theta_z \) = rotation about Z axis
\( \lambda \) = buckling factor of safety
\( \sigma_{cr} \) = critical buckling stress corrected for plasticity
\( \sigma_c \) = elastic critical buckling stress
\( \sigma_0 \) = minimum yield stress of material as specified in Pt 3, Ch 2, 1.2 Steel of the Rules for Ships.

2.1.2 Consistent units are to be used throughout the analysis.

Section 3
Direct calculation procedures report

3.1 Direct calculation procedures report
3.1.1 The report submitted to LR is to contain the following information:

- List of plans used, including dates and versions;
- Detailed description of structural modelling including modelling assumptions;
- Plots to demonstrate correct structural modelling and assigned properties;
- Details of material properties used;
- Details of boundary conditions applied;
- Details of applied loading and confirmation that individual and total applied loads are correct;
- Plots and results that demonstrate the correct behaviour of the structural model in response to the applied loads;
- Summaries and plots of deflections;
- Summaries and sufficient plots from output to demonstrate that design criteria are not exceeded in any member;
- Result of plate buckling analysis;
- Tabulated results showing compliance with the design criteria;
- Proposed amendments to structure, where necessary, including revised assessment of stresses and buckling properties.
CHAPTER 1 INTRODUCTION

CHAPTER 2 FINITE ELEMENT ANALYSIS
  SECTION 1 FINITE ELEMENT MODEL
  SECTION 2 BOUNDARY CONDITIONS

CHAPTER 3 PART A ASSESSMENT

CHAPTER 4 PART B ASSESSMENT
Section 1

Finite element model

1.1 Finite element model

1.1.1 The three-dimensional (3-D) finite element (FE) model is to represent the geometric shape of the single-skin or double-skin hatch cover as appropriate. The following structural members and attachments are to be represented in the model:

- Top plate and secondary stiffeners;
- Longitudinal and transverse girders;
- Bottom plate and secondary stiffeners, where applicable;
- Skirt plate and supporting brackets;
- Hinges in folding type hatch covers. These may be represented as rigid links which tie together displacements in the Z direction. Alternative modelling methods may also be used to achieve this objective.

1.1.2 The FE model is to be defined using a right-handed Cartesian coordinate system (see Figure 2.2.1 Typical boundary conditions on a quarter finite element model of a hatch cover) with:

- the X axis measured in the longitudinal direction, positive forward;
- the Y axis measured in the transverse direction, positive to port from the centreline;
- the Z axis measured in the vertical direction, positive upwards.

1.1.3 The idealisation may represent a quarter or half of the hatch cover providing the structure and the applied loads are symmetrical about the appropriate longitudinal and/or transverse centrelines. The properties of elements located on the boundaries representing lines of symmetry are to be halved and the symmetry boundary conditions specified in Ch 2, 2 Boundary conditions are to be applied. Figure 2.2.1 Typical boundary conditions on a quarter finite element model of a hatch cover shows a quarter hatch cover idealisation.

1.1.4 All plating, including webs and face plates of girders, is to be represented by linear shell elements of constant thickness with biaxial in-plane stiffness and out-of-plane bending stiffness. The stresses are to be read from the centre of the individual element. It is to be observed that, in particular, at flanges of unsymmetrical girders, the evaluation of stress from element centre may lead to non-conservative results. Thus, a sufficiently fine mesh is to be applied in these cases or the stress at the element edges (both the free edge of the flange and the intersection of the flange and web) shall not exceed the allowable stress.

1.1.5 Where FE analysis programs do not supply accurate nodal stresses, a line element (e.g. rod element) of small nominal area is to be incorporated at the plating free edge to obtain the peak edge stresses. Where shell elements are used, the stresses are to be evaluated at the mid plane of the element. Triangular elements are to be avoided where possible.

1.1.6 Secondary stiffeners may be modelled using shell or line elements. Line elements are to be positioned in the plane of the plating having axial and bending properties (bars) representing the stiffener with the eccentricity of the neutral axis modelled.

1.1.7 The width of the elements is not to be greater than the stiffener spacing. The height of the elements in way of the web of primary supporting members is not to be greater than one third of the web’s depth. Asymmetrical face plates of primary girders are to be represented by at least three elements across the breadth. A finer mesh may be required to represent the structure in way of force transfer points and cutouts. A uniform mesh following the stiffening arrangement is to be maintained wherever possible.

1.1.8 The ratio of element length to width should not exceed 4. Triangular and distorted quadrilateral elements with corner angles less than 60 degrees and greater than 120 degrees are to be avoided.

1.1.9 The FE model is to be constructed based on net thickness, obtained as the gross thickness minus the corrosion addition given in Table 2.1.1 Corrosion addition, \( t_c \), of steel hatch covers for Part A assessment and Table 2.1.2 Corrosion addition, \( t_c \), of steel hatch covers for Part B assessment.
Table 2.1.1 Corrosion addition, $t_c$, of steel hatch covers for Part A assessment

<table>
<thead>
<tr>
<th>Hatch cover type</th>
<th>$t_c$ (mm)</th>
</tr>
</thead>
<tbody>
<tr>
<td>(a) Single skin</td>
<td>2,0</td>
</tr>
<tr>
<td>(b) Double skin</td>
<td></td>
</tr>
<tr>
<td>(i) top and bottom plate</td>
<td>2,0</td>
</tr>
<tr>
<td>(ii) internal structures</td>
<td>1,5</td>
</tr>
</tbody>
</table>

Table 2.1.2 Corrosion addition, $t_c$, of steel hatch covers for Part B assessment

<table>
<thead>
<tr>
<th>Hatch cover type</th>
<th>Structure</th>
<th>$t_c$ (mm)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Weather deck hatches of container ships, car carriers, paper carriers, passenger vessels</td>
<td>Hatch covers</td>
<td>1,0</td>
</tr>
<tr>
<td>Weather deck hatches of all other ship types</td>
<td>Hatch covers in general</td>
<td>2,0</td>
</tr>
<tr>
<td></td>
<td>Weather exposed plating and bottom plating of double skin hatch covers</td>
<td>1,5</td>
</tr>
<tr>
<td></td>
<td>Internal structure of double skin hatch covers and closed box girders</td>
<td>1,0</td>
</tr>
<tr>
<td>Tween deck hatch covers</td>
<td>Hatch covers in general</td>
<td>1,0</td>
</tr>
</tbody>
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Section 2

Boundary conditions

2.1 Boundary conditions

2.1.1 The boundary conditions to be applied for the PART A and PART B assessments are to be in accordance with this Section (see also Figure 2.2.1 Typical boundary conditions on a quarter finite element model of a hatch cover).

2.1.2 Boundary nodes in way of bearing pads on the hatch coamings are to be fixed against displacement in the vertical direction (i.e. $\delta_z = 0$).

2.1.3 At boundary nodes in way of lifting stoppers and wedges, predetermined Z direction displacements are to be imposed to reflect anticipated maximum clearances between the cover and the stoppers.

2.1.4 Ground springs are to be used to represent cleats which are designed to secure a hatch cover under internal pressure. The spring constant should be provided by the manufacturers for the type and arrangement of the cleat considered.

2.1.5 On model boundaries representing lines of symmetry, the following conditions are to be applied:

- For symmetry of the hatch cover about its centreline in the Y direction, i.e. CL-Y as shown in Figure 2.2.1 Typical boundary conditions on a quarter finite element model of a hatch cover, rotations about the Y and Z axes and the displacement along the X axis are to be constrained (i.e. $\theta_y = \theta_z = 0$ and $\delta_x = 0$);

- For symmetry of the hatch cover about its centreline in the X direction, i.e. CL-X as shown in Figure 2.2.1 Typical boundary conditions on a quarter finite element model of a hatch cover, rotations about the X and Z axes and displacement along the Y axis are to be constrained (i.e. $\theta_x = \theta_z = 0$ and $\delta_y = 0$).
Figure 2.2.1 Typical boundary conditions on a quarter finite element model of a hatch cover
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Section 1

Introduction

1.1 General
1.1.1 Assessment of the strength capability of steel hatch covers of cargo holds of ‘Non-CSR Bulk Carriers’, ore carriers and combination carriers is to be in accordance with the requirements in this Chapter.

1.1.2 The finite element model of the hatch cover is to be constructed in accordance with Ch 2, 1 Finite element model. The boundary conditions specified in Ch 2, 2 Boundary conditions are to be applied to the model.

Section 2

Loads

2.1 Vertical weather loads
2.1.1 Weather deck hatch covers are to be assessed against the vertical weather loads given in Pt 4, Ch 7, 12.4 Load model of the Rules for Ships.

2.1.2 The weather loads need not be combined with other cargo and internal pressure loads in this assessment.

2.2 Cargo and internal pressure loads
2.2.1 Hatch covers subjected to loads due to cargo or internal pressure resulting from fluid are to be assessed against the loads given in Ch 4, 2.2 Cargo and internal pressure loads.

2.2.2 Cargo and internal pressure loads need to be combined with weather loads in this assessment.

2.3 Structural weight of the hatch cover
2.3.1 The weight of the hatch cover structure is to be included in the analysis.

2.3.2 The effect of dynamic acceleration on the structural mass may be ignored.

Section 3

Assessment against acceptance criteria

3.1 Acceptance criteria
3.1.1 Stress levels, buckling factors and primary girder vertical deflections are to comply with the acceptance criteria given in Table 3.3.1 Acceptance criteria for Part A assessment.

3.1.2 Vertical deflections are to be evaluated at the mid span of longitudinal and transverse girders.

3.1.3 Membrane stresses are to be determined at the centroid and at the middle plane of shell elements.

3.1.4 For weather loads, uniaxial compressive buckling of cover plate panel, shear buckling of girder web and buckling of secondary stiffeners are to be carried out in accordance with Pt 4, Ch 7, 12.10 Hatch cover plating, Pt 4, Ch 7, 12.11 Hatch cover secondary stiffeners and Pt 4, Ch 7, 12.12 Web panels of hatch cover primary supporting members of the Rules for Ships.
Combined biaxial and shear buckling assessment of hatch cover top and lower plating, webs and flanges of primary supporting members should be carried out in accordance with the method described in Pt 3, Ch 11, 2.11 Buckling strength of hatch cover structures of the Rules for Ships, particularly the webs of primary supporting members near the ends of supports are to be assessed using a panel size of \( d \times \alpha d \) (see Note 4 of Ch 4, 3.1 Acceptance criteria 3.1.5). The area-weighted average stresses for biaxial and shear stresses within the panel are to be used and the safety factor, \( S \), given in Table 3.3.1 Acceptance criteria for Part A assessment.

3.1.5 Assessment for cargo load and internal pressure should be carried out according to Ch 4 Part B Assessment and the acceptance criteria of Table 3.3.1 Acceptance criteria for Part A assessment.

### Table 3.3.1 Acceptance criteria for Part A assessment

<table>
<thead>
<tr>
<th>Load case</th>
<th>Permissible membrane stresses</th>
<th>Permissible deflection (mm)</th>
<th>Buckling factor of safety</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Direct stress ((N/mm^2))</td>
<td>Shear stress ((N/mm^2))</td>
<td>Von Mises stress ((N/mm^2))</td>
</tr>
<tr>
<td>Weather load</td>
<td>0.80( \sigma_\alpha )</td>
<td>0.46( \sigma_\alpha )</td>
<td>–</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Cargo load/internal pressure</td>
<td>–</td>
<td>–</td>
<td>0.90( \sigma_\alpha )</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

**Note 1.** Where the deflection due to structural weight of the hatch cover is removed by a suitable process during construction, the deflection caused by the structural weight need not be considered in the comparison against the deflection acceptance criteria.

**Note 2.** Direct and shear stresses are to be taken as element axial and shear stresses in accordance with the X, Y and Z axes specified in Ch 2, 1.1 Finite element model 1.1.2.
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<td>SECTION</td>
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</tr>
</tbody>
</table>
Section 1

Introduction

1.1 General

1.1.1 Assessment of the capability of steel hatch covers of cargo holds of all ships except bulk carriers, ore carriers and combination carriers is to be in accordance with the requirements in this Chapter.

1.1.2 The finite element model of the hatch cover is to be constructed in accordance with Ch 2, 1.1 Finite element model. The boundary conditions specified in Ch 2, 2.1 Boundary conditions are to be applied to the model.

Section 2

Loads

2.1 Vertical weather loads

2.1.1 Weather deck hatch covers are to be assessed against the vertical weather loads given in Pt 3, Ch 11, 2.3 Load model and Table 11.2.1 Design pressure $p_{H}$ of weather deck hatches of the Rules for Ships.

2.1.2 The weather loads need not be combined with other cargo and internal pressure loads in this assessment.

2.2 Cargo and internal pressure loads

2.2.1 Container stack loads are to be derived based on standard 20 ft and/or 40 ft containers as appropriate to the design requirements. The following load cases are to be analysed (see Pt 4, Ch 8, 11.2 Direct calculations of the Rules for Ships):

- Full homogeneous container loads due to the ship’s heave and pitch motions;
- Full homogeneous container loads due to the ship’s heave, pitch and roll motions;
- Partial non-homogeneous container loads due to the ship’s heave, pitch and roll motions.

2.2.2 Container stack loads applied at the container foundations due to the ship’s heave, pitch and roll motion are to be calculated in accordance with Pt 4, Ch 8, 11.2 Direct calculations 11.2.4 of the Rules for Ships. These loads are to be applied as point loads at appropriately located grid points in the finite element model.

2.2.3 The magnitudes of container stack loads are to be derived based on the most onerous stack weight combination, see Pt 4, Ch 8, 11.2 Direct calculations 11.2.4 of the Rules for Ships.

2.2.4 Pressure and point loads on hatch covers due to distributed and single mass resulting from the ship’s heave and pitch motions are to be calculated in accordance with Pt 3, Ch 11, 2.3 Load model 2.3.4 and Pt 3, Ch 11, 2.3 Load model 2.3.5 of the Rules for Ships.

2.2.5 Internal pressure resulting from ballast in holds is to be applied in accordance with item (c) in Pt 4, Ch 7, 12.4 Load model 12.4.1 of the Rules for Ships.

2.2.6 Weather loads need not be considered in the assessment of hatch covers against cargo and internal pressure loads.

2.3 Structural weight of the hatch cover

2.3.1 The weight of the hatch cover structure is to be included in the analysis.

2.3.2 The effect of dynamic acceleration on the structural mass may be ignored.
Section 3
Assessment against acceptance criteria

3.1 Acceptance criteria

3.1.1 Stress levels, buckling factors of safety and primary girder vertical deflections are to comply with the acceptance criteria specified in Table 4.3.1 Acceptance criteria for Part B assessment.

3.1.2 Vertical deflections are to be evaluated at the mid span of longitudinal and transverse girders.

3.1.3 Membrane stresses are to be determined at the centroid and at the middle plane of shell elements.

3.1.4 Combined biaxial and shear buckling assessment of hatch cover top and lower plating, webs and flanges of primary supporting members should be carried out in accordance with the method described in Pt 3, Ch 11, 2.11 Buckling strength of hatch cover structures of the Rules for Ships, particularly the webs of primary supporting members near the ends of supports are to be assessed using a panel size of \( d \) by \( \alpha d \) (see Note 4 of Table 4.3.1 Acceptance criteria for Part B assessment). The area-weighted average stresses for biaxial and shear stresses within the panel are to be used and the safety factor, \( S \), given in Table 4.3.1 Acceptance criteria for Part B assessment.

3.1.5 Secondary stiffener assessment should be carried out in accordance with Pt 3, Ch 11, 2.15 Lateral buckling of secondary stiffeners and Pt 3, Ch 11, 2.16 Torsional buckling of secondary stiffeners of the Rules for Ships.

Table 4.3.1 Acceptance criteria for Part B assessment

<table>
<thead>
<tr>
<th>Load case</th>
<th>Permissible Von Mises membrane stress (N/mm²)</th>
<th>Permissible deflection (mm)</th>
<th>Biaxial buckling factor of safety (see Ch 4, 3.1 Acceptance criteria 3.1.4 and Ch 4, 3.1 Acceptance criteria 3.1.5)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Weather load</td>
<td>0,8( \sigma_0 )</td>
<td>0,0056 ( l_y ) (see Note 1)</td>
<td>( S = 1,25 )</td>
</tr>
<tr>
<td>Cargo load/internal pressure (weather deck hatch covers)</td>
<td>0,9( \sigma_0 )</td>
<td>–</td>
<td>( S = 1,1 )</td>
</tr>
<tr>
<td>Cargo load (tween deck hatch covers)</td>
<td>0,9( \sigma_0 )</td>
<td>0,007 ( l_y ) (see Note 1)</td>
<td>( S = 1,1 )</td>
</tr>
</tbody>
</table>

Note 1. Where the deflection due to structural weight of the hatch cover is removed by a suitable process during construction, the deflection caused by the structural weight need not be considered in the comparison against the deflection acceptance criteria.

Note 2. Where hatch covers are arranged for carrying containers and mixed storage is allowed, i.e. a 40’ container stowed on top of two 20’ containers, particular attention is to be paid to the deflections of hatch covers. Further, the possible contact of deflected hatch covers with in-hold cargo is to be considered. See Pt 4, Ch 8, 11.2 Direct calculations 11.2.7 of the Rules for Ships.

Note 3. No addition is to be given for the effect of cargo securing loads.

Note 4. Illustration for buckling assessments of the webs of primary supporting members.

![Diagram](image)

where

\[ \alpha = 0,74\beta - 0,54 \] and \( 1,0 \leq \alpha \leq 2,0 \)

\[ \beta = \left( \frac{d}{t} \right) \left( \frac{\sigma_0}{E} \right)^{0.5} \]

\( d \) = web depth

\( t \) = web thickness

\( E \) = Young’s modulus