IACS Common Structural Rules for Double Hull Oil Tankers, January 2006

Background Document

SECTION 2 – RULE PRINCIPLES

NOTE:

- This TB is published to improve the transparency of CSRs and increase the understanding of CSRs in the industry.
- The content of the TB is not to be considered as requirements.
- This TB cannot be used to avoid any requirements in CSRs, and in cases where this TB deviates from the Rules, the Rules have precedence.
- This TB provides the background for the first version (January 2006) of the CSRs, and is not subject to maintenance.

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1 INTRODUCTION

1.1 Rule Principles

1.1.0 Introduction

1.1.0.a The Rules are based on a set of top-level goals and objectives. The framework shows how these Rules have been developed to ensure that ships built in compliance with these Rules meet these top-level goals and objectives.

1.1.0.b To demonstrate that the top-level goals and objectives have been met, the Rules were developed using a hierarchical framework as shown in *Figure 2.1a*. The framework of the Rules represents a 'top-down approach' that provides transparency and ensures that the structural requirements developed reflect the overall objectives.

The term transparency with respect to the framework is to:

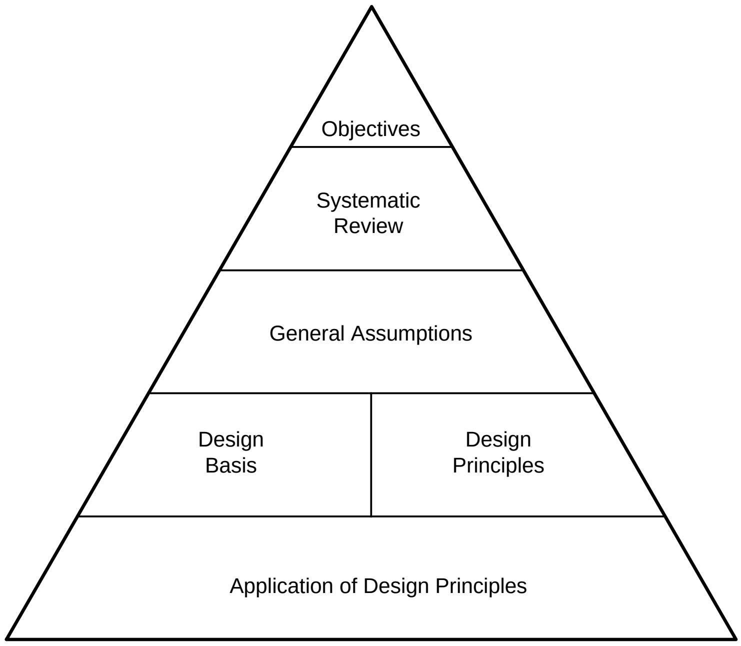
(a) be clear about the safety objective of the Rules

(b) demonstrate how the top-level objectives cascade downward through the Rule framework, see *Figure 2.1.a*

(c) show how the identified hazards and their structural consequences are covered by the Rules

(d) give the user of the Rules an understanding of the purpose and background behind the individual requirements, and to the extent possible provide a link to the physical principles of the problem.

Figure 2.1.a
Rules Framework



1.1.0.c The levels of the Rule framework address the following issues:

(a) the **Objectives** state the clear and unambiguous goals of the Rules with respect to safety and performance aspects. These objectives provide the basis for deriving the detailed structural acceptance criteria. More details of the Objectives are given in 1.1.1

(b) the **Systematic Review** identifies and evaluates the hazards due to operational and environmental influences and the likely consequences of these on the structure of a ship, in order that these can be addressed in the Rules and thereby minimised. The consequences include those that have an effect on the safety of life, the environment and property (ship and cargo). The Systematic Review also identifies whether some of the risks or hazards to the structure are controlled by other standards or regulations (e.g. *MARPOL)*. More details of the Systematic Review is given in 1.1.3

(c) the **General Assumptions** specify aspects that are beyond the scope of the Rules, but affect the application and effectiveness of the rules. Typically, these include references to other international regulations and industry standards, e.g. *SOLAS* and *MARPOL*. The General Assumptions also includes information on the shared responsibilities of Classification Societies, builders and owners.

(d) the **Design Basis** specifies the premises that the Design Principles of the Rules are based on, in terms of design parameters and the assumptions about the ship operation.

(e) the **Design Principles** define the fundamental principles used for the structural requirements in the Rules with respect to loads, structural capacity and assessment criteria. The principles are based on sound engineering practise to provide suitable safeguards against the hazards identified by the systematic review.

(f) the **Application of the Design Principles** describes how the Design Principles and methods are applied and what criteria are used to demonstrate that the structure meets the Objectives. It includes definition of load and capacity models along with the corresponding acceptance criteria.

1.1.1 Rule Objectives

1.1.1.a The objectives of the Rules are to mitigate the risks of structural failure in relation to safety of life, environment and property and to ensure adequate durability of the hull structure for its intended life. See *Figure 2.1.b*. The Rule Objectives were categorised as given below.

1.1.1.b Safety objectives

The overall safety of the hull structure and hence structural requirements are specified in such a way so that:

(a) the ship's structural strength and watertight integrity are adequate for the intended service of the ship

(b) the minimum state of the structure is specified so that the minimum acceptable structural safety level is adequate and the status of the structure with regard to renewal criteria is known throughout the ship's life.

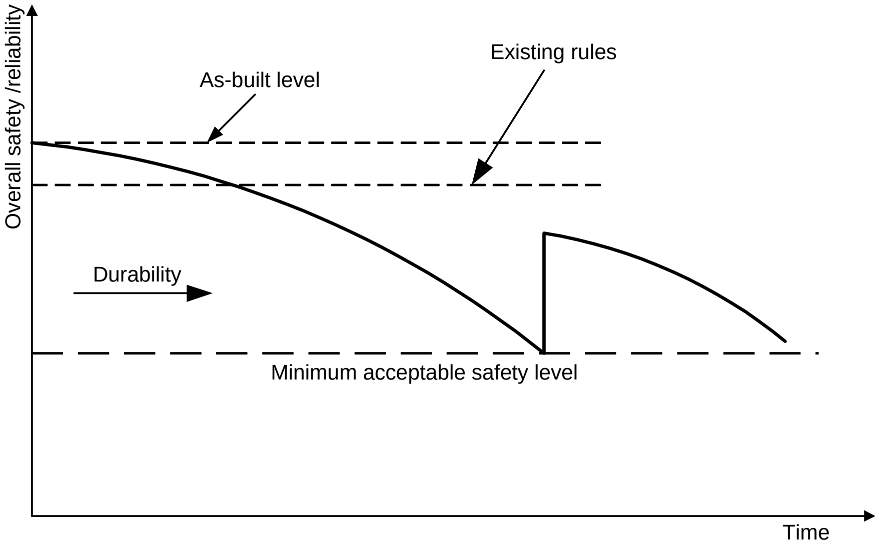
1.1.1.c Performance and durability objectives

The Rules include structural requirements related to the satisfactory durability of the ship. This implies that:

(a) the ship is capable of carrying the intended cargo with the required flexibility in operation to fulfil its design role

(b) the structure has sufficient durability in terms of corrosion margin and fatigue endurance.

Figure 2.1.b
Structural Safety and Durability



1.1.2 General

1.1.2.a It is considered that for this topic, no information in addition to that shown in the Rules, is necessary to explain the background.

1.1.3 Systematic Review

1.1.3.a For ship designs that are within the scope of the Rules the risks, hazards and consequences were evaluated using a systematic review process to ensure that the Rules provided appropriate risk control measures.

1.1.3.b The Systematic Review identified and evaluated the hazards on the structure due to operational and environmental influences as well as the likely consequences of these hazards on a ship's structure. The consequences included those that would have an effect on safety of life, environment or property (ship and cargo). The results from the Systematic Review were used to define the risks, hazards and consequences that are controlled by the Rules and hence define the scope of the Rules.

1.1.3.c The Systematic Review dealt with structural configurations and arrangements covered by the Rules and covered all phases of a ship life. The following design situations or phases are identified:

(a) design;

(b) construction;

(c) operation - at sea; loaded and ballast voyages between ports;

(d) operation – harbour; operations in harbour, sheltered waters, ports and terminals;

(e) operation - through life; degradation issues such as corrosion and fatigue;

(f) repair; repair and maintenance of ship structure;

(g) scrapping.

1.1.3.d The method used for the Systematic Review was a qualitative risk assessment in order to provide a categorisation of the overall risk due to structural failures. The systematic review process comprised three stages as follows:

(a) Hazard Identification; denoted as the Ship In a System (SIS) stage:
Examination of the hazards to the hull structure as a consequence of it being exposed to the marine environment. These risks might be due to internal or external influences acting on a ship in a marine environment. The aspects covered were as follows:

- hazard identification, reviewing the hazards a tanker is exposed to during all phases of its life as defined above. The hazards identified in this context were limited to events that had a consequence on the structural integrity;
- qualitative assessment of probabilities of failure events;
- identification of additional hazards if progressive structural failure occured.

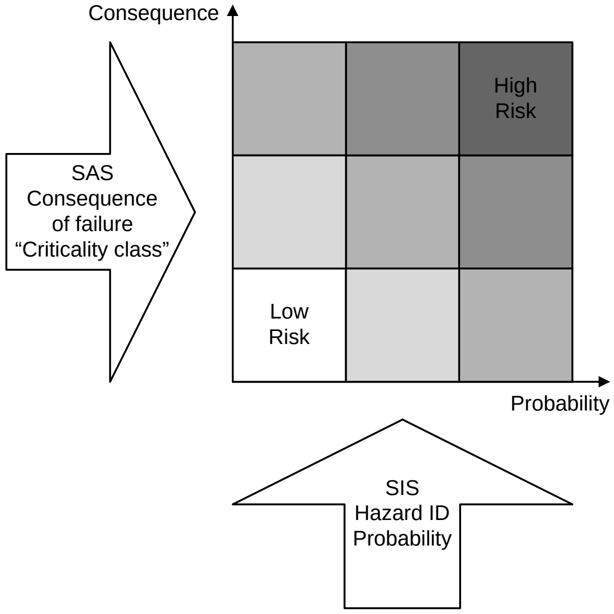
(b) Consequence Evaluation; denoted as the Ship as a Structural System (SAS) stage:
The consequences of structural failure with respect to safety of life, environment or property were used as the basis for assessing the relevant limit states and the corresponding acceptance criteria to be applied to each structural element. The purpose was to identify the relative importance of the structural element and focus the rule requirements on the most critical structural elements and failure modes. The ship as a structural system included the following steps:

- definition of structural hierarchy of a typical double hull tanker;
- identification of the possible failure consequences, e.g. loss of strength, for all structural elements in the hierarchy;
- assignment of a criticality class to the failure consequence, with respect to life, property and environment, for each structural element;
- identification of possible progressive structural failure paths.

(c) Critical Hazard Management (CHM):
The CHM stage was a risk evaluation process which identified the most critical hazards with respect to structural failure consequences. The CHM process linked the hazards identified in the SIS stage to the structural failure consequence from the SAS stage in order to identify appropriate safeguards to mitigate the hazards. The critical hazard management is illustrated by the risk matrix in *Figure 2.1.c*.

1.1.3.e The risks controlled by the Rules are considered in the assessment of the structural capability and hence reflected in assumptions incorporated in the Design Basis and Design Principles sections. Risks not controlled by the Rules are included as General Assumptions.

Figure 2.1.c
Critical Hazard Management

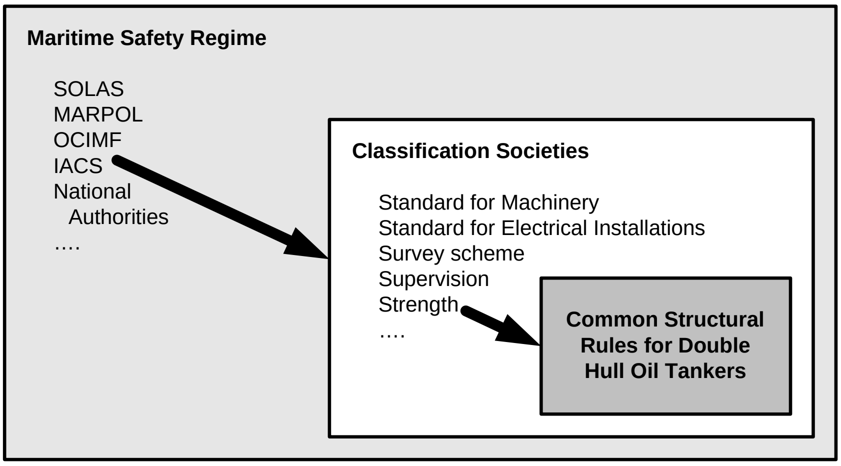


2 GENERAL ASSUMPTIONS

2.1 General

2.1.0.a The boundaries and relationship between the Rules and the Maritime Safety Regime is addressed in this section. The Maritime Safety Regime regulates the design, construction and operation of oil tankers through a diverse set of requirements including international, national and industry Standards. *Figure 2.2.a* illustrates how the Rules conceptually fit into the Maritime Safety Regime.

Figure 2.2.a
Relationship of the Standard to the Maritime Safety Regime



2.1.0.b The purpose of the section is to list aspects that influence the structural performance of a ship, but are outside the scope of the Rules.

2.1.1 International and national regulations

2.1.1.a Ships are designed, constructed and operated in a complex regulatory framework laid down by IMO and implemented by flag states or by classification societies on their behalf. Statutory requirements set the standard for statutory aspects to ships, such as life saving, subdivisions, stability, fire protection, etc. These requirements influence the operational and cargo carrying arrangements of the ship and may therefore affect its structural design.

2.1.1.b The Rules compliment the international regulations for strength of double hull tankers of length greater than or equal to 150m. The principal regulations typically applicable are given below:

International Convention for Safety Of Life At Sea (SOLAS)

Part 1, Chapter II-1 Construction - Subdivision and stability, machinery and electrical installations

(a) *Regulation 3-2, Corrosion prevention of salt water ballast tanks*

(b) *Regulation 3-3, Safe access to tanker bows*

(c) *Regulation 3-4, Emergency towing arrangements on tankers*
(d) *Regulation 3-6, Access to and within spaces in, and forward of, the cargo area of oil tankers and bulk carriers*
(e) *Regulation 11, Peak and machinery bulkheads and stern tubes in cargo ships*
(f) *Regulation 12-2, Access to spaces in the cargo area of oil tankers*
(g) *Regulation 14, Construction and initial testing of watertight bulkheads*
(h) *Regulation 17-1, Openings in shell plating below the bulkhead deck of passenger ships and the freeboard deck of cargo ships*
(i) *Regulation 18, Construction and initial testing of watertight doors, side scuttles, etc., in passenger ships and cargo ships*
(j) *Regulation 19 Construction and initial testing of watertight decks, trunks, etc., in passenger ships and cargo ship*

Part 1, Chapter II-2 Construction – Fire protection, fire detection and fire extinction:

(a) *Regulation 56 Location and separation of spaces*
(b) *Regulation 4.5.1, Cargo areas of tanker*

Part 1, Chapter V Safety of Navigation

(a) *Regulation 22, Navigation bridge visibility*

2.1.2 Classification Societies

2.1.2.a It is considered that for this topic, no information in addition to that shown in the Rules, is necessary to explain the background.

2.1.3 Responsibilities of Classification Societies, builders, and owners

2.1.3.a This section identifies what the primary responsibilities of each party is in the design and construction of a ship. In particular, it should be noted that industry also set requirements (e.g. OCIMF, INTERTANKO) which affect the structural design and the responsibility to implement these requirements is between the owners and designers/shipbuilders.

2.1.4 Limitations

2.1.4.a The Rule requirements are based on the risks identified in the Systematic Review process and are related to the current requirements of the Maritime Safety Regime. Hence, any changes in this regime that may affect the hazards could result in changes to Rule requirements.

2.1.4.b Requirements related to the chemical composition of materials and to the testing of the mechanical properties are not covered by the Rules and are addressed by the individual Classification Society. It should be noted that significant unification of these requirements is achieved through IACS.

2.1.4.c Welding procedures, qualification of personnel and requirements related to the construction of a ship are not covered in the Rules and are addressed by individual Classification Society.

2.1.4.d The Rules assume that material testing, sub-structure testing and tank testing, for strength and tightness, is carried out in accordance with requirements given by the individual Classification Society. It should be noted that significant unification of the testing requirements is achieved through IACS.

2.1.4.e It is assumed that steel renewals and structural repairs are carried out in accordance with requirements given by the individual Classification Society. The Rules do not cover requirements for maintenance of coatings and other corrosion protection systems.

2.1.4.f The Rules do not include requirements for Ice Class. The individual Classification Society Rules are to be referred to for Ice Class requirements.

2.1.4.g The following load scenarios are not covered in the Rules:

(a) loadings as a consequence of accidents other than flooding;
(b) assessment of global strength in the flooded condition;
(c) wind loads;
(d) tug and berthing loads;
(e) docking loads;
(f) mooring loads (if requested, evaluation of mooring arrangement will be based on loads provided by the designer);
(g) unloading or loading aground;
(h) docking in a partially loaded condition;
(i) loadings as a result of helicopter operations.

3 DESIGN BASIS

3.1 General

3.1.1 The design basis

3.1.1.a The requirements in the Rules are developed for ships covered by the scope and in compliance with the Design Basis as specified in the Rules. Deviations from the Design Basis are to be subject to special consideration. Typical deviations to be subject to special consideration are:

(a) double hull oil-tankers outside the scope of the Rules and with arrangements and layouts outside the assumptions given in S*ection 2/3.1.2 of the Rules* ;

(b) ships intended to operate regularly on a trading pattern with a more severe wave environment than allowed for in S*ection 2/3.1.7 of the Rules.* The design loads are then to be specially considered. No special consideration will be given to ships which are intended to operate regularly on a trade pattern with a less severe wave environment;

(c) design life of more than 25 years (Owner's extra). Special consideration is given to increasing the wave loads and the number of wave cycles for assessment of the fatigue resistance and also to an increase in corrosion margins;

(d) requested enhanced fatigue resistance performance. Special consideration is given to the fatigue assessment procedure.

3.1.2 Arrangement and Layout

3.1.2.a It is considered that for this topic, no information in addition to that shown in the Rules, is necessary to explain the background.

3.1.3 Design life

3.1.3.a The design life is the nominal period that the ship is assumed to be exposed to operating and/or environmental conditions and/or the corrosive environment and is used for selecting appropriate ship design parameters. The ship's actual service life may be longer or shorter depending on the actual operating conditions and maintenance of the ship throughout its life cycle.

3.1.3.b The relationship between the design life that is specified for a ship at the time of design and construction and the actual safe working life is very clearly dependent on the operational history and the maintenance regime. It follows that two identical ships that are operated differently or maintained under different maintenance regimes may have very different actual lives.

3.1.4 Design speed

3.1.4.a It is considered that for this topic, no information in addition to that shown in the Rules, is necessary to explain the background.

3.1.5 Operating conditions

3.1.5.a It is considered that for this topic, no information in addition to that shown in the Rules, is necessary to explain the background.

3.1.6 Operating draughts

3.1.6.a It is considered that for this topic, no information in addition to that shown in the Rules, is necessary to explain the background.

3.1.7 External environment

3.1.7.a It is considered that for this topic, no information in addition to that shown in the Rules, is necessary to explain the background.

3.1.8 Internal environment (cargo and water ballast tanks)

3.1.8.a The reason for having a different value of SG for fatigue and strength assessment lies in the way that the fatigue and strength assessment capacities are evaluated.

3.1.8.b The objective with the strength assessment is to ensure satisfactory structural behaviour for a "worst case scenario" and a value equal to seawater density is to be used unless a higher value is specified by designer/owner.

3.1.8.c The objective with the fatigue assessment is to capture an average value for the entire trading life of a vessel, hence a conservative mean SG value of 0.9 is selected for this purpose. The specified cargo SG of 0.9 for fatigue assessment is a minimum value. A higher value may be specified by the owner or designer.

3.1.9 Structural construction and inspection

3.1.9.a It is considered that for this topic, no information in addition to that shown in the Rules, is necessary to explain the background.

3.1.10 Owner's extras

3.1.10.a It is considered that for this topic, no information in addition to that shown in the Rules, is necessary to explain the background.

4 DESIGN PRINCIPLES

4.1 Overall Principles

4.1.1 Introduction

4.1.1.a It is considered that for this topic, no information in addition to that shown in the Rules, is necessary to explain the background.

4.1.2 General

4.1.2.a It is considered that for this topic, no information in addition to that shown in the Rules, is necessary to explain the background.

4.2 Loads

4.2.1 Load scenarios

4.2.1.a It is considered that for this topic, no information in addition to that shown in the Rules, is necessary to explain the background.

4.2.2 Design load combinations

4.2.2.a It is considered that for this topic, no information in addition to that shown in the Rules, is necessary to explain the background.

4.2.3 Load categorisation

4.2.3.a It is considered that for this topic, no information in addition to that shown in the Rules, is necessary to explain the background.

4.2.4 Characteristic load values

4.2.4.a It is considered that for this topic, no information in addition to that shown in the Rules, is necessary to explain the background.

4.2.5 Operational loads

4.2.5.a It is considered that for this topic, no information in addition to that shown in the Rules, is necessary to explain the background.

4.2.6 Environmental loads

4.2.6.a It is considered that for this topic, no information in addition to that shown in the Rules, is necessary to explain the background.

4.2.7 Accidental loads

4.2.7.a It is considered that for this topic, no information in addition to that shown in the Rules, is necessary to explain the background.

4.2.8 Deformation loads

4.2.8.a It is considered that for this topic, no information in addition to that shown in the Rules, is necessary to explain the background.

4.3 Structural Capacity Assessment

4.3.1 General

4.3.1.a The structural capacity models used in the Rues are classified according to limit state principles. The criticality class as identified in the Systematic Review for each structural component is applied to link the specified design load scenario to the structural requirement.

4.3.1.b Yielding and buckling are controlled explicitly by the application of structural strength criteria. Rupture is controlled implicitly by limits applied to the yielding failure modes. Brittle fracture is controlled implicitly by the selection of suitable materials associated with location of the structural component.

4.3.1.c Fatigue cracks are caused by cyclic loads and are controlled explicitly by the application of fatigue strength criteria for selected critical structural elements. The nature of fatigue cracking is different to the strength failure modes and consequently assessed using different capacity models.

4.3.2 Capacity models for strength

4.3.2.a The strength failure modes are controlled by means of structural capacity models. Capacity models are considered to include two related parts:

(a) Selection of structural response model. The means of determination of stresses and deformations is related to the selected strength assessment method and the magnitude of the design loads.

(b) Selection of strength assessment criteria. The strength assessment method is capable of analysing the failure mode in question to a suitable degree of accuracy. The assessment method for the various rule requirements may be different, even for the same failure mode, as the degree of utilisation of the capacity may differ.

4.3.2.b The ultimate capacity of the hull girder or structural member is assessed by methods that are capable of determining the structural capacity beyond the elastic response range. This implies that these methods account for redistribution of forces, large deformations and non-linearities. The acceptance criteria regulate the permissible extent of plasticity and deformation.

4.3.2.c Other methods used are capable of assessing the structure beyond the elastic range, but not to the full utilisation of the capacity. The acceptance criteria regulate the permissible extent of plasticity and force redistribution.

4.3.2.d The load effects in terms of structural responses are determined by analytical methods on a prescriptive format or by direct calculations. Direct calculations usually refer to 3D analysis based on linear finite element methods. The method adopted to determine the structural response matches the requirements given by the assessment methods.

4.3.3 Capacity models for fatigue

4.3.3.a The accumulated damage caused by the cyclic loads over the entire design life is considered. The fatigue life depends on the local hot spot stress and hence is related to the design of structural details and quality of workmanship.

4.3.3.b The fatigue assessment method is based on the expected number of cyclic loads and structural response from trading based on the design life in the design external environment (25 years in the North Atlantic environment). The method is based on a linear cumulative damage theorem (i.e. Palmgren-Miner's rule) in combination with S-N curves, a characteristic stress range and an assumed long-term stress distribution curve. The long-term stress distribution range curve is assumed to follow a Weibull probability distribution.

4.3.3.c The method accounts for the combined effect from global and local loads.

4.3.4 Net thickness approach

4.3.4.a It is considered that for this topic, no information in addition to that shown in the Rules, is necessary to explain the background.

4.3.5 Intact structure

4.3.5.a It is considered that for this topic, no information in addition to that shown in the Rules, is necessary to explain the background.

4.4 Materials and Welding

4.4.1 Materials

4.4.1.a It is considered that for this topic, no information in addition to that shown in the Rules, is necessary to explain the background.

4.4.2 Welding

4.4.2.a It is considered that for this topic, no information in addition to that shown in the Rules, is necessary to explain the background.

4.5 Assessment/Acceptance Criteria

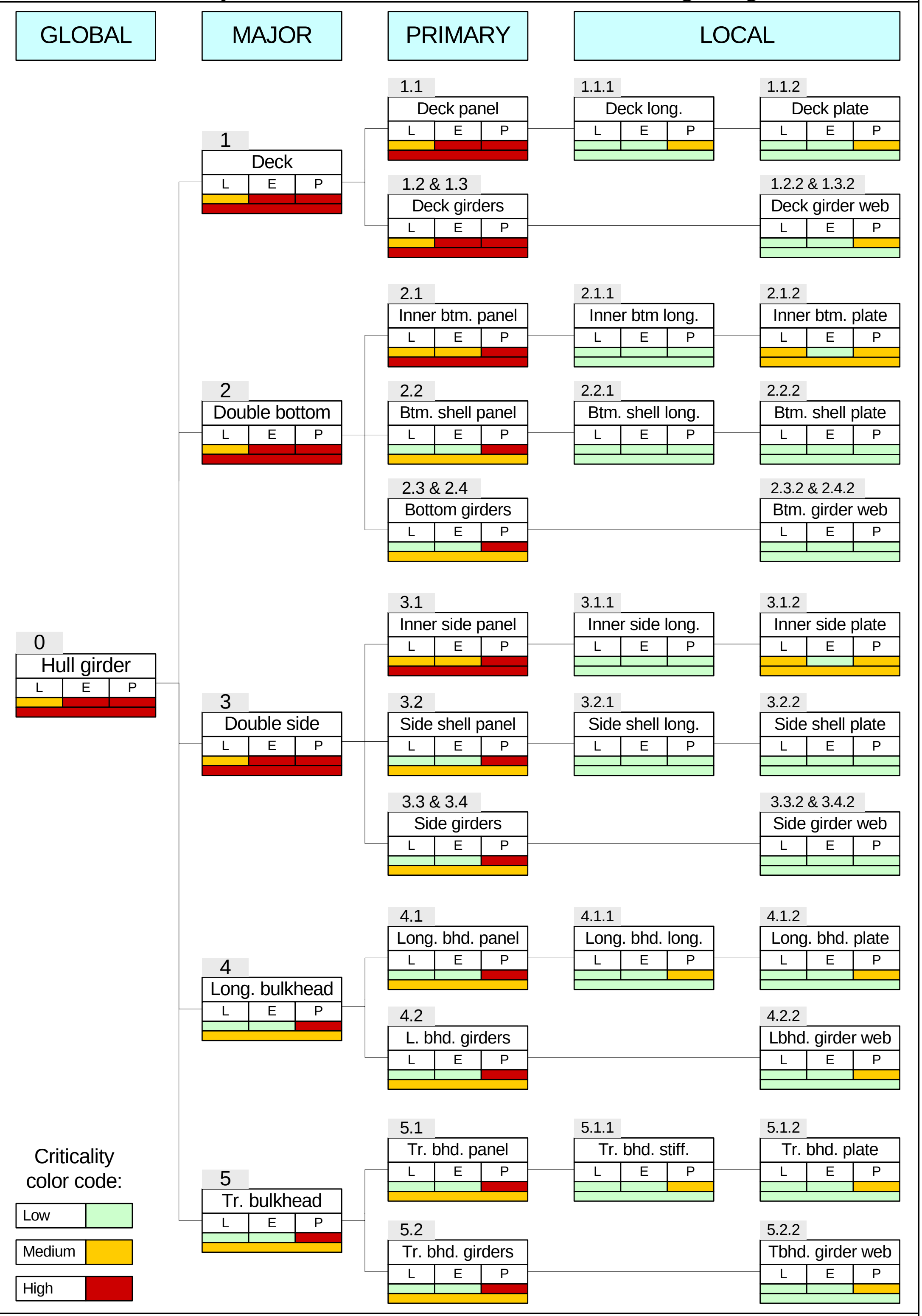
4.5.1 Design methods

4.5.1.a The purpose of the various design methods is to ensure satisfactory levels of safety, serviceability and durability. To verify this, calculations are performed according to a chosen design method. The safety margins for the various elements reflect the consequence of a failure.

4.5.1.b The classification of the criticality of each structural component with respect to the consequences to Life, Environment and Property in the hierarchical tree allowed each structural component to be assigned a "criticality class". This facilitated the selection of acceptance criteria and capacity models such that the more critical elements have stricter requirements and hence a lower probability of failure than less critical elements.

4.5.1.c A schematic diagram of the "criticality class" for all structural elements in the cargo region is shown in *Figure 2.4.a*. A "top-down" approach is used; i.e. starting at the top level (hull girder) of the hierarchy (i.e the hull girder) and working downwards through all levels of the hierarchy to the plates and stiffeners. The criticality at the next higher level is always set to be equal to or higher than the level below.

Figure 2.4.a
Criticality Class of Structural Elements in the Cargo Region



Symbols

L Life
E Environment
P Property

4.5.1.d The following design methods are considered in the Rules:

(a) the working stress design (WSD) method, also known as the permissible or allowable stress method;
(b) the partial factor (PF) method, also known as load and resistance factor design method (LRFD).

4.5.1.e The PF method separates the influence of uncertainties and variability originating from different causes by means of partial factors for each load and capacity component. The WSD method addresses the same limit states as the PF method but accounts for the influence of uncertainty by a single usage factor as an allowable stress or similar such criteria. The PF method allows for a more flexible and optimal design assessment when complex load and structural models are employed.

4.5.1.f The working stress design (WSD) format is used as the main method to verify the structural design in the Rules.

4.5.1.g Both the WSD and PF methods have to ensure a consistent and acceptable safety level for all combinations of static and dynamic load effects. The acceptance criteria for both the WSD method and PF method were calibrated for the various rule requirements such that a consistent and acceptable safety level for all combinations of "S" (static) and "S + D" (static plus dynamic) load effects were achieved.

4.6 Principle of Safety Equivalence

4.6.1 General

4.6.1.a It is considered that for this topic, no information in addition to that shown in the Rules, is necessary to explain the background.

5 APPLICATION OF PRINCIPLES

5.1 Overview of the Application of Principles

5.1.1 General

5.1.1.a It is considered that for this topic, no information in addition to that shown in the Rules, is necessary to explain the background.

5.2 Structural Design Process

5.2.1 Overview of the structural design process

5.2.1.a It is considered that for this topic, no information in addition to that shown in the Rules, is necessary to explain the background.

5.3 Minimum Requirements

5.3.1 General

5.3.1.a It is considered that for this topic, no information in addition to that shown in the Rules, is necessary to explain the background.

5.4 Load-capacity Based Requirements

5.4.1 General

5.4.1.a It is considered that for this topic, no information in addition to that shown in the Rules, is necessary to explain the background.

5.4.2 Design loads for scantling requirements and strength assessment (FEM)

5.4.2.a It is considered that for this topic, no information in addition to that shown in the Rules, is necessary to explain the background.

5.4.3 Design loads for fatigue requirements

5.4.3.a It is considered that for this topic, no information in addition to that shown in the Rules, is necessary to explain the background.

5.4.4 Structural response analysis

5.4.4.a It is considered that for this topic, no information in addition to that shown in the Rules, is necessary to explain the background.

5.4.5 Structural capacity assessment

5.4.5.a It is considered that for this topic, no information in addition to that shown in the Rules, is necessary to explain the background.

5.4.6 Acceptance criteria

5.4.6.a It is considered that for this topic, no information in addition to that shown in the Rules, is necessary to explain the background.

5.5 Materials

5.5.1 General

5.5.1.a It is considered that for this topic, no information in addition to that shown in the Rules, is necessary to explain the background.

5.6 Application of Rule Requirements

5.6.1 Minimum requirements

5.6.1.a It is considered that for this topic, no information in addition to that shown in the Rules, is necessary to explain the background.

Load based prescriptive requirements

5.6.1.b It is considered that for this topic, no information in addition to that shown in the Rules, is necessary to explain the background.

5.6.2 Design verification – hull girder ultimate strength

5.6.2.a It is considered that for this topic, no information in addition to that shown in the Rules, is necessary to explain the background.

5.6.3 Design Verification – global finite element analysis

5.6.3.a It is considered that for this topic, no information in addition to that shown in the Rules, is necessary to explain the background.

5.6.4 Design Verification – fatigue assessment

5.6.4.a It is considered that for this topic, no information in addition to that shown in the Rules, is necessary to explain the background.

5.6.5 Relationship between the prescriptive scantling requirements and the strength assessment (FEM)

5.6.5.a It is considered that for this topic, no information in addition to that shown in the Rules, is necessary to explain the background.