

PETRONAS TECHNICAL STANDARDS

DESIGN AND ENGINEERING PRACTICE

PROCEDURAL SPECIFICATION

DESIGN OF STEEL SUBSTRUCTURES FOR FIXED OFFSHORE PLATFORMS (AMENDMENTS/ SUPPLEMENTS TO API RP 2A-LRFD)

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PART I INTRODUCTION

1.1 SCOPE

This new PTS provides guidance on engineering principles and practices relating to the design of steel substructures for fixed offshore platforms. Guidance is also provided on issues relating to planning and construction to the extent that these are relevant to design.

This PTS is based on API RP 2A-LRFD. Part II of this PTS amends, supplements and replaces various clauses/sections of API RP 2A-LRFD. Part III provides corrections to typographical errors in API RP 2A-LRFD.

This PTS does not cover design of the topside structure. This PTS is also limited to structures whose extreme response is predominantly quasi-static.

1.2 DISTRIBUTION, APPLICABILITY AND REGULATORY CONSIDERATIONS

Unless otherwise authorised by PETRONAS, the distribution of this PTS is confined to companies forming part of PETRONAS group and to Contractors nominated by them.

This PTS is intended for use by PETRONAS companies involved in the design, construction and operation of fixed offshore platforms, and by Contractors working on their behalf.

If national and/or local regulations exist in which some of the requirements may be more stringent than in this PTS the Principal and/or the Contractor shall determine by careful scrutiny which of the requirements are the more stringent and which combination of requirements will be acceptable as regards safety, environmental, economic and legal aspects. In all cases the Contractor shall inform the Principal of any deviation from the requirements of this PTS which is considered to be necessary in order to comply with national and/or local regulations. The Principal may then negotiate with the Authorities concerned with the object of obtaining agreement to follow this PTS as closely as possible.

1.3 DEFINITIONS

1.3.1 General definitions

The **Contractor** is the party which carries out all or part of the design, engineering, procurement, construction, commissioning or management of a project or operation of a facility. The Principal may undertake all or part of the duties of the Contractor.

The **Principal** is the party which initiates the project and ultimately pays for its design and construction. The Principal will generally specify the technical requirements. The Principal may also include an agent or consultant authorised to act for, and on behalf of, the Principal.

The word **shall** indicates a requirement.

The word **should** indicates a recommendation.

1.3.2 Specific definitions

A **fixed platform** is a bottom founded installation which supports facilities above the water surface and is not normally re-located during its service life.

Owner is a title used in API RP 2A-LRFD and in [Part II](#) of this PTS, which has the same meaning as Principal.

The **substructure** consists of a welded tubular spaceframe and foundation piles. The piles permanently anchor the platform to the sea floor and carry both lateral and vertical loads. The substructure normally supports a topside structure.

The **topside structure** consists of trusses and decks which support operational and other loads.

1.4 CROSS-REFERENCES

The clause/section numbering used in Part II and III of this PTS corresponds with that used in API RP 2A-LRFD. Other documents referenced by this PTS are listed in [Part IV](#).

PART II AMENDMENTS/SUPPLEMENTS TO API RP 2A-LRFD

SECTION A PLANNING

A.2 Platform Types

A.2.1 Fixed Platforms

Replace clauses A.2.1.1 and A.2.1.2 with:

A.2.1.1 Jacket Structures

A jacket is a spaceframe structure in which the piles are inserted through the legs and are connected to the legs at the top.

A.2.1.2 Tower Structures

A tower is a spaceframe structure in which the piles are inserted through and attached to sleeves at the base of the structure.

A.3 OPERATIONAL CONSIDERATIONS

A.3.5 Access and Auxiliary Systems

Add to this clause:

Installation, maintenance and inspection requirements should be considered in determining access platform and walkway locations at the top of the substructure. Access should be provided to the water level for sea escape and to facilitate self rescue in man-overboard situations.

A.3.8 Wells and Risers

Add to this clause:

Wells and risers should be positioned to minimise exposure to accidental damage due to vessel collision or other causes.

Add new clause:

A.3.13 Accidental Events

The design should account for the possibility of accidental events including vessel collision, accidental flooding, dropped objects, fire and explosion. Criteria for designing against accidental events should take account of the operational conditions, and the type, function, criticality, service life and location of the platform.

Add new clause:

A.3.14 Abandonment

Consideration should be given to the requirements for abandonment of the platform at the end of its operating life. Specific design or analysis for abandonment is not generally required; however, if removal or dismantling will be necessary it is desirable that the design should make provision for this. For example, consideration should be given to designing installation aids and lifting points so that they can be re-used when the platform is removed or dismantled.

A.4 ENVIRONMENTAL CONSIDERATIONS

Add new clause:

A.4.9.7 Seabed Subsidence

The nature of the soil conditions, reservoir and extraction processes should be investigated to establish whether subsidence of the seabed is likely to occur during the field life. Where subsidence is a possibility it should be accounted for in design.

A.7 REGULATIONS

Replace this section with:

A country will typically have its own set of regulations concerning offshore activities. These should be considered when designing offshore platforms for the waters of that country.

Add new section:

A.8 QUALITY ASSURANCE

A.8.1 Application of Quality Assurance

Quality systems conforming to ISO 9000 or an equivalent standard should be established and used for the design by the Contractor. Independent audits of the quality systems should be commissioned by the Contractor and performed prior to and during the design to ensure adherence to the stipulated requirements.

A.8.2 Responsibilities

Responsibilities should be clearly defined and documented for both the Contractor's and the Owner's organisations, covering all activities and their interfaces during all phases of development. Scopes of individual responsibility should be made known to all concerned.

A.8.3 Documentation

The full extent of all drawings, specifications, reports and documents to be prepared during design and the responsibilities for their preparation and approval should be established. The responsibilities for preparing and maintaining as-built drawings, and for maintaining up-to-date design documentation during construction and during the service life, should be established by the Owner.

A.8.4 Software

For design and analyses, only validated software should be used.

Add new section:

A.9 DIMENSIONAL SYSTEM

A.9.1 Units

All calculations, dimensions and weights should be in Systeme Internationale (SI) units (see PTS 00.00.20.10.).

A.9.2 Reference System

A consistent dimensional reference system including orientation of Platform North and angle to True North should be established for the platform and used for all calculations, drawings, and weight control computations. The horizontal reference axes on drawings should be the transverse and longitudinal centrelines at the level of lowest astronomical tide (LAT). All vertical elevations on drawings should be relative to LAT.

SECTION B DESIGN REQUIREMENTS

B.2 DESIGN FOR IN-PLACE CONDITIONS

Add to this section:

Combinations of the loads described in [Sections C.2 to C.6](#) should be selected in a rational manner. These combinations should be such that the most onerous conditions for all structural components are covered.

B.3 DESIGN FOR CONSTRUCTION CONDITIONS

Add to this section:

Methods for fabrication, assembly and load-out of the structure should be considered during design in order to identify potential difficulties and limitations for available equipment and facilities. Load conditions for which partially fabricated components of the structure and the assembled structure as a whole need to be checked should be established. Fabrication and assembly tolerances assumed in design should be compatible with those specified in the construction specifications and should be achievable during construction.

B.6 REDUNDANCY

Replace second paragraph with:

The resistance and load factors in API RP 2A-LRFD have been verified for conventionally configured pile founded jacket or tower spaceframe structures. These configurations generally have three or more straight legs, several levels of triangulated plan framing, with all panels in the main 'vertical' frames being braced with diagonal members between plan levels. The factors have not been verified for different types of structural configurations such as mono-columns, braced mono-columns or other novel configurations. Modifications of these factors, or development of new factors suitable for a different type of structural framing should be based on a rational system reliability analysis. See also [Section Q](#).

B.7 CORROSION PROTECTION

Replace this section by:

The corrosion protection system should be designed in accordance with the provisions of [Section H.7](#).

Add new section:

B.9 EFFICIENCY

The structure should be designed to provide for efficient and cost effective fabrication, installation, operation and abandonment. The structural design should be optimised in order to minimize total life cycle cost. The requirements for in-service above water and under water inspection and maintenance should be optimised to achieve cost effective operation during the service life.

SECTION C LOADS

C.2 GRAVITY LOADS

C.2.4 Live Load 1, L_1

Replace first sentence with:

Live Load 1 includes the weight of consumable supplies and fluids in pipes, tanks and stores, the weight of transportable vessels and containers used for delivering supplies, and the personnel on the platform. Where appropriate, the weight of ice should be included in L_1 . The weight of scaffolding or other temporary access systems used during operations and maintenance of the platform should also be included in L_1 .

C.2.5 Live Load 2, L_2

Add to this clause:

The additional weight of liquids used for testing of vessels and pipes is included in Live Load 2.

Add new clause:

C.2.10 Weight Estimates

Weights used in design should be based on a rational weight estimating procedure which takes account of potential changes during design and construction. Allowances should be included for potential future changes which may result from operational or maintenance requirements in-service. These allowances should be developed and agreed with the operations department prior to adoption for design. Contingencies should also be considered for potential changes in platform function or facilities, for example due to unexpected reservoir performance or future changes/extensions to the field development. These contingencies should be agreed with management prior to adoption for design.

The dead and live loads used for design should be reconciled with the weights derived using the weight estimating procedure.

C.3 WIND, WAVE AND CURRENT LOAD

C.3.1.2 Extreme Wind, Wave and Current Load, W_e

Replace this clause with:

W_e is the force applied to the structure due to the combined action of extreme wind, current and waves. Where information on the joint occurrence of wind, current and waves is not available, W_e should be calculated using the 100 year return period wind, the 100 year return period current and the 100 year return period wave conditions; the 100 year extreme magnitude for each phenomenon being determined independently. Where information on joint occurrence is available, it is recommended that it should be used to justify alternative combinations which give more appropriate overall load levels, as described in [Comm. C.3.1.2](#).

C.3.1.3 Direction of Wind, Wave and Current

Add to this clause:

Normally, the directions of the extreme wind, wave and current should be assumed to coincide for determining W_e . However, in some locations, geographic features provide fetch limitations on wave heights from specific directions, or tidal or general circulation currents may be in a predominant direction. In these situations, if reliable data are available to derive different extreme wave and/or current magnitudes for different approach directions, then

these may be used in design. Normally, the extreme wave and current magnitudes should be combined with the extreme wind specified irrespective of approach direction. Where directional wave and/or current magnitudes are used the possibility of the installed orientation of the platform deviating from the design orientation, due to installation tolerances, should be accounted for.

C.3.2 Static Wave Analysis

Add after third sentence:

For other areas, wave, current and water depth data for the platform location should be provided by the Owner. These should be determined in accordance with the guidance given in [Section A.4](#).

C.3.2.2 Two - Dimensional Wave Kinematics

Add to this clause:

Breaking waves may occur in storm conditions in shallow water and when the ratio of wave height to water depth is large. The type of breaking wave (e.g. plunging or spilling) and the wave height / water depth limits are dependent on local environmental and topographical conditions such as the presence of current and seabed slope.

C.3.2.12 Local Member Design

Add to this clause:

For the local design of smaller members adjacent to larger members, the kinematics used should take account of the effect of flow enhancement around the larger member.

Add new clause:

C.3.2.13 Recommended Static Wave Analysis

Sections C.3.2.1 to C.3.2.8 address the calculation of wave kinematics and selection of force coefficients for establishing the deterministic static wave load based on a traditional regular periodic wave theory. An alternative wave theory, called NEWWAVE has been developed within the Group to provide wave kinematics which more accurately represent the maximum conditions in a realistic complex random sea. NEWWAVE theory, used in conjunction with realistic hydrodynamic force coefficients, has been validated for calculating extreme wave loads for drag dominant structures for which the maximum waveload occurs with the wave crest positioned at the structure. For such structures it is recommended to use NEWWAVE instead of the provisions of Sections C.3.2.1 to C3.2.8 to calculate the deterministic static wave load for design. NEWWAVE is valid in the range of water depths where the Stokes V order wave theory is valid. EP 94-0161 gives a detailed description of the application of NEWWAVE to spaceframe substructures. See also [Commentary C.3.2.13](#)

C.3.3 Extreme Wave Dynamic Analysis

C.3.3.1 Extreme Inertial Load D_n

Replace second paragraph with:

For platforms with sufficiently short natural periods, dynamic amplification is negligible. D_n can normally be neglected if the fundamental natural periods of the structure are less than three seconds and less than one fifth of the peak period of the design wave spectrum.

The provisions of this Section for the calculation and use of the extreme inertial load are only applicable to structures which exhibit moderate levels of dynamic response. A moderate level of dynamic response is defined such that the inertial part of the maximum global response D_n (e.g. base shear or overturning moment) is less than one half of the corresponding component due to W_e .

C.3.3.2.1 Dynamic Analysis Methods

Replace this clause with:

The wave and other time varying loads should be realistic representations of the frequency content of the loading. Random time domain methods allow the frequency content and the nonlinear characteristics of the extreme loading and response to be explicitly modelled. Frequency domain techniques provide a computationally efficient means to represent the frequency content providing appropriate linearisations of the extreme loading (drag wave load and free surface inundation) and response are used. EP 87-0170 provides a review of alternative dynamic analysis methods and gives guidelines on their application. EP 93-2525 describes specific simplified techniques which may be used to estimate extreme response accounting for the non linearity due to drag wave loading.

C.3.3.3 Member Design

Add to the end of this clause:

Guidance on the representation of the distribution of the extreme inertial load is given in EP 93-2525.

C.3.4 Wind Force

C.3.4.2.5 Spatial Coherence

Replace last three sentences with:

The one minute sustained wind is appropriate for calculating total static superstructure windloads applied in conjunction with maximum wave and current loads.

C.3.4.4 Local Wind Force Considerations

Add to this clause:

All slender members exposed to winds should be investigated for the possibility of vibration due to periodic vortex shedding as discussed in [Comm C.3.2.12](#).

C.3.4.5 Shape Coefficients

Add to this clause:

Further values for shape coefficients are given in DNV.

C.3.4.6 Shielding Coefficients

Add to this clause:

Guidance on values for shielding coefficients is given in DNV.

C.3.5.2 Current Associated with Waves

Replace last sentence with:

Where there is adequate and reliable data available on currents and waves, their magnitudes and directions may be determined in combination in accordance with [C.3.1.2](#) and [C.3.1.3](#).

C.3.6 Deck Clearance

Replace this clause with:

C.3.6 Platform Elevation

C.3.6.1 Substructure Elevation

Variations and uncertainties in the water depth and platform elevation should be considered when evaluating wave and current forces on the platform and when designing items sensitive to the final elevation of the structure. Account should be taken of variations in water depth due to astronomical tide and storm surge, and allowances should be made for uncertainties in the methods used to determine the water depth. The effects of seabed subsidence and uncertainties on the penetration of the structure into the seabed should be considered when evaluating the range of final platform elevations. For extreme conditions the range of water depths between the maximum and minimum associated with the 100 year storm should be investigated and the upper and lower limits of platform elevation should be considered when evaluating local and global loading on the platform. For operating conditions the mean sea level should be used.

C.3.6.2 Deck Elevation

Large forces may result when waves strike the platform deck or the equipment thereon. An air gap of at least 1.5 metres should be provided above the maximum wave crest elevation in order to determine the minimum acceptable level to avoid waves striking the deck. The maximum wave crest elevation should include the 100 year return period maximum wave plus the associated storm surge and astronomical tide, in addition to allowances for water depth uncertainty, seabed penetration and subsidence. Components or equipment placed within or below the air gap should be designed for wave impact and loading.

Reliability studies indicate that the very large forces which occur if the wave crest hits the deck frequently control the overall reliability of the structure. For this reason the crest elevation of the maximum wave with a return period equal to the reciprocal of the target annual reliability of the structure should be examined, and if necessary the air gap increased, to ensure that excessive wave forces on the deck do not result. This crest elevation should be determined using expected values for water depth, tide, surge, settlement and subsidence. Use of the maximum values for these parameters would be conservative beyond the intent of this requirement.

C.4 EARTHQUAKE LOADS

C.4.1.2 Evaluation of Seismic Activity

Add after first paragraph:

The site specific assessment should evaluate the intensity of seismic activity for appropriate return periods. The return period of the ground motions used for the strength level and ductility level events should be selected by the Owner based on an evaluation of the acceptable risks and consequences for the type of operation intended.

C.4.1.3 Evaluation for Zones of Low Seismic Activity

Delete this clause.

C.4.2.4 Response Analysis

Add to the first paragraph:

The response analysis should include ground motions in vertical and horizontal directions.

The methods used for evaluating and combining responses in both horizontal directions should be compatible with the approach used to include directionality in the derivation of the input ground motion spectra.

C.4.2.5 Response Assessment

Add to this clause:

The possibility of soil liquefaction occurring during the strength level earthquake should be evaluated. Where liquefaction is a possibility it should be accounted for when determining the stiffness and capacity of the pile foundation.

C.4.4.2 Deck Appurtenances and Equipment

Delete this clause.

C.5 FABRICATION AND INSTALLATION FORCES

C.5.2 Dynamic Effects

Replace last paragraph with:

Unless special investigations are performed to substantiate lower values the following minimum factors should be applied to account for dynamic effects during lifting:

- 1.30 for offshore lifts,
- 1.15 for lifts onshore or in sheltered waters.

C.5.3 Load Factors

Add after last paragraph:

During installation operations the behaviour of the structure and the magnitude and distribution of the forces in the structure may be sensitive to the position of the centre of gravity. Allowances should be made for uncertainties and potential changes in the centre of gravity position during design.

C.5.5 Lifting Forces

C.5.5.1 General

Add after first paragraph:

Lifting forces depend on the nature of the object being lifted (size, weight, stiffness, etc.), particulars of the lifting equipment (crane stiffness, hook speed, sling arrangement, etc.) and on the conditions and procedures under which the lift is made (e.g. onshore, sheltered inshore or exposed offshore). The general guidance on lifting loads in this Section and Sections C.5.2 and C.5.3 assumes typical lifts in reasonably controlled conditions (see Commentary).

Critical offshore lifting operations such as those involving heavy loads approaching the capacity of the lifting equipment, those involving transfer of the lifted object to or from a transportation barge at an exposed location, or those using dual crane operations should be subject to special investigation. This should investigate the dynamic lifting forces in cranes, rigging, lifting points and in the lifted structure, and the impact forces during lift-off and setting down of the load and should account for the limiting weather conditions in which the operation may proceed. Frequency domain and/or time domain techniques may be used to analyse the relative motions of the lift vessel, the transportation barge and the structure to determine the magnitude of these forces.

Specific lifting criteria used for final design should be determined in conjunction with the installation contractor.

C.5.6.2 Horizontal Movement onto Barge

Add before last sentence:

The effect of the forces on the structure during loadout should be investigated taking account of the tolerances on the levels of supports on the land and the barge. The effect of twisting of the structure due to differential horizontal jacking or winching during loadout should be considered.

C.5.7 Transportation Forces

C.5.7.2 Environmental Criteria

Add to this clause:

The environmental conditions used in determining the motions of the tow should be established by the Owner (in consultation with the marine warranty surveyor if appropriate) taking account of the expected tow route and season. For long ocean tows where the structure and barge are unmanned the extreme environmental conditions are typically selected to have a probability of exceedence during the tow duration in the range 1 to 10 percent. The specific value will depend on an evaluation of acceptable risks and consequences. For short duration tows, the environmental conditions should generally have a return period not less than 1 year for the season in which the tow takes place.

C.5.7.3 Determination of Forces

Add to first paragraph:

These should use spectral analysis techniques to account for the spread of wave energy in tow storm conditions. Seastates with peak periods corresponding to the natural periods of the barge and peak periods corresponding to wave lengths which are critical in relation to the length of the barge should be considered as they may represent governing conditions. The analysis should correctly account for relative phasing between motion components (heave, pitch, roll, etc.) when combining responses.

Change first sentence in second paragraph to:

Beam, head and quartering wind and seas should be considered to determine maximum transportation forces in the structure, the barge and the seafastenings.

C.5.7.4 Other Considerations

Change second sentence to:

Submerged members should be investigated for slamming, buoyancy and collapse forces. These forces should be included in the local and overall design of the structure and seafastenings.

C.5.8 Launching Forces and Uprighting Forces

C.5.8.1 Launched Structures

Add to first paragraph:

The environmental conditions considered should be consistent with the limiting environmental conditions specified in the launch procedures.

C.5.9 Installation Foundation Forces

C.5.9.1 General

Add to this clause:

The loads determined following the provisions of this section should be used to check the foundation capacity of footings or mudmats against sliding or bearing failure, for checking the strength of mudmat components and for checking against overturning of the structure.

The structure should also be checked in a piled condition without topsides loads if placement of the deck does not follow shortly after substructure installation.

C.5.9.2 Environmental Conditions

Replace this clause with:

The wind, wave and current conditions used to determine the environmental loads should be established for the installation season and are typically selected to have a probability of exceedence during the exposure period in the range 1 to 10 percent. The specific value will depend on an evaluation of the acceptable risks and consequences. The exposure period used should take account of the installation sequence and the structure configuration for the various phases, considering relevant operations such as buoyancy tank removal, pile stabbing, driving and securing, conductor installation and deck placement. For short exposure durations, the seasonal environmental conditions should generally have a return period not less than 1 year unless restrictions are imposed in installation procedures to limit the conditions in which operations may proceed.

Add new clause:

C.5.11 Fabrication Forces

The effects on long slender members of vortex induced vibrations due to wind during fabrication should be investigated as discussed in [Commentary C.3.2.12](#).

C.6 ACCIDENTAL loads

Replace this section with:

C.6.1 Vessel Collisions

C.6.1.1 General

The risk of vessel collisions with the structure should be evaluated, taking account of the nature of all vessel operations in the platform vicinity. Depending on the risk of collision and the consequences on the overall operability and structural integrity of the platform, a rigorous analysis of vessel impact conditions may be required following the provisions of clauses [C.6.1.2 to C.6.1.4](#). Irrespective of whether a rigorous analysis is required, vessel collisions should be provided for in the design by indirect means such as providing redundancy, avoiding weak elements in the structure (particularly at joints), selecting materials with sufficient toughness, and ensuring that critical components are not placed in vulnerable locations. Further guidance on the assessment of the risk of collisions and on methods of design and analysis for vessel impact is provided in EP 89-0230.

C.6.1.2 Collision Events

The energy level used for the impact analysis should account for the vessel mass and added mass and for its velocity of approach. Two energy levels should be considered for a rigorous impact analysis:

1. Low energy level, representing a serviceability condition, based on the type of vessel which would routinely approach alongside the platform (e.g. a supply boat) with a velocity representing normal manoeuvring of the vessel approaching, leaving or standing alongside the platform;
2. High energy level, representing an ultimate condition, based on the type of vessel which would operate in the platform vicinity, drifting out of control in the worst seastate in which it may operate close to the platform.

The impact zone should be established based on the dimensions and geometry of the structure and the vessel and should account for tidal ranges, operational seastate restrictions and motions of the vessel. Impact scenarios should be established representing bow, stern and beam-on impacts on the platform legs and braces as appropriate. Operational restrictions on vessel approach sectors may limit the exposure of some areas of the structure to impacts.

C.6.1.3 Collision Process

The energy absorbing mechanisms during the collision should be evaluated accounting for local member denting, elastic and plastic deflection of the impacted member, global elastic response of the structure, buckling and plastic deformation of any other members and denting of the ship. The forces generated during the collision should be evaluated ensuring that the energy dissipated by these mechanisms plus the kinetic energy gained by the structure (manifested as dynamic response) is equal to the kinetic energy lost by the vessel. Global non-linear analyses may be required in order to avoid over estimation of impact loads, particularly for high energy impact conditions. When the duration of the collision is large compared with the periods governing the motion, dynamic effects are not significant and the collision process can be analysed using quasi-static methods. If the duration of the collision is of the same order as, or shorter than the periods governing the motion, then dynamic effects may be significant and should be considered in the design.

C.6.1.4 Structural Performance

The failure sequence of the structure should be investigated considering the various deformation mechanisms involved to evaluate the extent of damage caused by the collision.

The design should be such that the damage caused by a low energy impact can be readily repaired or would not require repair. In the damaged condition following a low energy impact, the structure should be able to withstand environmental conditions which can be expected to occur during the period required for planning and implementing a repair, using loads and resistances calculated in accordance with [Sections C, D, E, G and H](#).

The structure should be designed such that progressive collapse does not occur as a result of a high energy collision. In the damaged condition following a high energy impact the structure should be able to withstand environmental conditions which can be expected to occur in the period required to shut-down and evacuate the platform.

C.6.2 Dropped Objects

The possibility of dropped objects impacting on the structure should be considered in design. Resistance to dropped objects should be provided for by indirect means such as using redundant framing patterns and materials with sufficient toughness in vulnerable areas. Design of the structure against vessel impact will provide resistance to dropped object impact in the more vulnerable external members at the top of the structure. With conventionally configured steel structures, impacts with main legs are likely to be oblique and therefore less damaging. Normal impacts on bracing members are more likely and should be designed against by appropriate means. Further guidance on methods for design against dropped objects is provided in EP 89-0230.

C.6.3 Explosions

Conventional steel framed substructures which do not have enclosed compartments containing flammable fluids or ignition sources do not generally require direct design against explosion. The consequential effects of explosions in the topsides may require consideration in the substructure design. If explosion studies performed in the topsides design indicate unusual loading conditions on the substructure, or indicate specific support requirements to ensure that topsides integrity is maintained, then these should be provided for in the substructure design.

C.6.4 Fire

The possibility of the structure above water level being subjected to fire should be considered during design. Hydrocarbon pool fires on the sea surface can cause heating and degradation in the properties of structural elements. Guidance on methods for assessing the effects of fires, and on protecting against them is provided in EP 89-0230 and SCI-P-112.

SECTION E CONNECTIONS

E.3 TUBULAR JOINTS

E.3.1.2 Design Practice

Add to this clause:

If the offset between outermost centreline intersections at the joint exceeds $D/4$, the moments due to loads in the eccentric braces should be accounted for.

The arrangement of members at joints should allow adequate access for welding and inspection. Angles between primary structural members should be greater than 30 degrees. Wherever possible, simple joints should be used without overlap of braces with minimum clear distances between braces as specified above. The 51 mm minimum dimension should be measured between the weld toes of the braces. Greater spacing may be required to allow for welding access. Where overlap cannot be avoided, the joint should be detailed to avoid interference of welds and to allow access for welding and inspection. Stiffened joints should be avoided in favour of joints with greater wall thickness, unless the equivalent stiffened joint is demonstrably cheaper to fabricate or if weight constraints dictate their use.

E.3.5 Other Complex Joints

Add to this clause:

Guidance on methods for design of cross joints with diaphragms and overlapping joints is provided in EP 92-0595.

SECTION F FATIGUE

Replace this section with:

F.1 FATIGUE DESIGN

Fatigue design should be performed in accordance with the guidelines in EP 93-2005.

SECTION G FOUNDATION DESIGN

Replace second sentence with:

Design considerations and recommendations for the foundation design of mudmats are given in [Sections G.12 to G.15](#).

G.1 GENERAL

Replace last sentence with:

The possibility of active geologic processes, discussed in Section A.4.9, in particular earthquake, sea floor instability, scour, shallow gas and seabed subsidence should be investigated, and, if anticipated, these effects should be considered in the foundation design.

G.2 PILE FOUNDATIONS

G.2.1 Driven Piles

Add to the first paragraph of this section:

It is not recommended to use vibratory hammers for installing axially loaded foundation piles, due to lack of data with respect to the effect of the installation method on the pile axial bearing capacity. Vibratory hammers may be considered for piles which are subject to horizontal loads alone. Conductor piles may be installed using vibratory hammers.

Replace second and subsequent sentences below ' 1. Plug Removal ' with:

If plug removal results in inadequate pile capacities, the removed soil plug should be replaced by a grout or concrete plug. The minimum load carrying capacity of the plug should be equal to the pile end bearing capacity in a plugged condition.

Replace last sentence below ' 2. Soil Removal Below Pile Tip' with:

Considering the uncertainties with respect to the pile bearing capacity, it is not recommended to remove the soil below the pile tip in order to reduce the soil resistance during driving in uncemented soils. Under special circumstances, in the case of an intermediate layer of strong cemented material, undersized drilling may be applied to remove the hard layer. The depth of drilling should be restricted to the thickness of the hard layer. Where soil removal below the pile tip during placement has been undertaken by undersized drilling, the contribution of the relevant zone of soil to the pile capacity should be ignored.

G.3 PILE DESIGN

G.3.4 Foundation Capacity

Replace first sentence with:

1. Pile Strength: The pile strength should be verified using the steel tubular strength checking equations given in Section D.3. for conditions of combined axial and lateral load and bending.

Add after last sentence:

The above pile resistance factors apply for design of foundations comprising isolated piles and for groups of closely spaced piles. For pile groups Φ_{PE} and Φ_{PO} apply to the overall capacity of the group, determined in accordance with [Section G.9](#). For individual piles within a group Φ_{PE} and Φ_{PO} may be taken as 1.0, providing it can be shown that loads can be redistributed to other piles within the cluster in the event that the individual pile is overloaded.