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INITIATIVES ON STRUCTURAL INTEGRITY MANAGEMENT OF AGEING NORTH SEA INSTALLATIONS

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ABSTRACT

With an ever-increasing population of ageing offshore installations in the North Sea, the Health and Safety Executive's (HSE's) Offshore Safety Division has focused its front-line operational activity in recent years on the structural integrity management process and establishing the extent of any deterioration in structural integrity. The current phase of work, the Structural Integrity Management Inspection Programme (SIMIP), is described and the findings to date are presented in this paper.

INTRODUCTION

The North Sea provides many challenges with respect to ensuring that oil and gas production is achieved in an environment with high standards of health and safety. After forty years of oil and gas production, the combination of a range of factors, namely declining reserves which has necessitated in recent years exploration and production in deeper waters, a hostile environment, an ageing infrastructure and workforce, shortages of skilled and competent staff and the influx of many new, smaller, duty holders with little or no internal expertise all combine to create a complex situation and its impact on safety requires assessment.

The ageing infrastructure of offshore installations, in particular, presents the industry with a constant and growing challenge. Structural failure could cause the immediate total loss of an installation, with little chance of survival. Reliability studies suggest that as built failure frequency could be as high as 10^{-3} per annum. Hence, the aged failure frequency could be expected to be higher. Failure could arise through:

- overloading and /or inherent weakness;
- deterioration due to ageing;
- damage due to accidental or rare events.

Structural integrity and its management is the principal barrier to safeguarding the offshore workforce.

The older installations were designed to earlier, since superseded, technical standards and their conditions have deteriorated. Deterioration has a detrimental effect on the resistance of the structure, causing an increase in the probability of failure. Inspection is intended to detect, monitor and quantify this deterioration with a view to providing information relevant to its safe management. Thus, structural integrity management is of great importance.

Influences on structural integrity practice include:

- **The regulatory regime** – prior to the introduction of the Design and Construction Regulations [1], reliance was placed on certification; today risk-based, goal-setting regulations, which include independent verification, require duty holders to devise their own strategies for securing structural integrity.
- **Industry standards** – the risk-based regulatory regime requires the assurance of safety to be achieved by combining installation-specific assessments of risk and the setting of performance

standards with prescriptive generic international engineering codes and standards in the absence of UK equivalents.

- **Owner / operator policies** – corporate investment in the skill-base and offshore assets is susceptible to oil & gas price fluctuations resulting, today, in a stretched technical resource challenged to extend field life and make marginal fields economic despite ageing infrastructure. Changes have occurred in the supply chain and its delivery, requiring changes to existing management processes. Lack of investment similarly means there is no longer an industry forum for advancing structural integrity issues involving all stakeholders (i.e. HSE, Oil & Gas UK, trades unions, etc.), leaving individual duty holders within the UK offshore industry to define their own structural integrity management practice. The need for an agreed structural integrity management framework and associated standards is addressed in [2].
- **Installation types** – seabed-founded or floating; fixed or mobile.
- **The nature of the hazards and threats to integrity** – extreme weather, seismicity, vessel impact, fire & explosion, material degradation etc..

Further background to the influence of these factors on structural integrity is presented in [3].

HSE's structural integrity strategy [4] has been revised recently to encompass all the known key issues and current activities of the Offshore Division with respect to structural integrity management [5]. It is a five-year strategy and is summarised below.

STRATEGY FOR STRUCTURAL INTEGRITY

Objectives

The aim of the structural integrity strategy is to ensure that the life-cycle structural integrity of offshore installations is secured in order to safeguard the offshore workforce requires - this aim forms the basis of the integrity provisions of the Design and Construction Regulations (DCR) [1]. The Health and Safety Executive's Offshore Safety Division is concerned primarily that:

- design, construction, in-service integrity maintenance and decommissioning are properly managed;
- appropriate information and criteria are available and used in the associated analysis and assessments.

The above translates into two primary objectives:

(a) to secure appropriate standards of integrity through a programme of assessment, inspection and enforcement of the relevant provisions of the Design and Construction Regulations (DCR) [1] and the Safety Case Regulations (SCR) [6];

STRUCTURAL INTEGRITY		
Objective		**Description**
(a) Assessment, inspection & enforcement	**SI-01**	Inspecting and enforcing the integrity provisions of the DCR on all major design, construction and modification projects.
	SI-02	Assessing all safety cases for design and first operation to ensure appropriate treatment of structural integrity, and the setting of appropriate performance standards.
	SI-03	Inspecting and enforcing the integrity maintenance provisions of DCR by examining the corporate arrangements of each Duty Holder and the particular arrangements for a representative sample of installations.
	SI-04	Reassessing a sample of safety case re-submissions from each duty holder to secure continuous improvement, particularly in areas where significant new information has become available (e.g. response to blast loading).
	SI-05	Investigating all reports of a significant threat to integrity made under the DCR.
(b) Information, guidance & standards	**SI-06**	Establishing and maintaining guidance to Inspectors to enable the above to be carried out effectively and consistently.
	SI-07	Carrying out a programme of research to provide and disseminate improved information on certain aspects of the behaviour of offshore structures.
	SI-08	Assisting and influencing the development of the new international standards for offshore structures under ISO/TC67/SC7 and other to ensure suitability for UKCS applications.
	SI-09	Working with industry to identify the need for and to provide any guidance required pending completion of the ISO programme.

Table 1: Structural integrity strategy objectives

(b) to ensure that appropriate information, guidance and standards are in place by working with industry groups and standards bodies wherever possible.

The structural integrity objectives (SI-01 to SI-09) are listed in Table 1. Objectives SI-01 to SI-05 relate to primary objective (a), i.e. assessment, inspection and enforcement. Objectives SI-07 to SI-09 relate to primary objective (b), i.e. information, guidance and standards.

Implementation of Structural Integrity Strategy

The structural integrity strategy has been delivered by balanced intervention, entailing direct contact in relation to individual installations, through concerted action with industry on specific themes, to wider engagement with industry representatives and intermediaries on generic technical matters. Whilst quantified methods have a role in maintaining structural integrity the primary focus has been on embedding 'good practice'.

For any given theme, multiple complementary interventions are required. Specific interventions and their contribution include:

- **Safety case assessment** providing a basis for inspection and, where appropriate, enforcement, as well as new intelligence enabling movement in safety culture to be monitored.
- **Themed inspections** combing tools dealing with managerial as well as cultural aspects through which insight to safety culture is gathered.
- **Standards work,** including through ISO, ensuring good practice is identified and disseminated
- **Internal documentation** (e.g. technical policy) seeking to achieve consistency in approach by OSD.
- **Research** keeping interventions alive and focused.

This paper focuses on the themed inspections.

Development of Topic Strategy

In developing the topic strategy, an approach was taken utilising (with reference to Figure 1) both bottom-up, data-driven and top-down, organisation-driven aspects. The data-driven approach uses the significant amount of information available from the assessment of safety cases, inspection and audit findings, as well as accident and incident information, whilst the top-down, organisational-driven aspects derive from a review of all industry sectors across HSE.

The current strategy is designed to meet the requirements of [7] and the placement of OSD activity in the Major Hazards Strategic Programme. The structural integrity activities have been grouped into seven specific areas:

(1) Ageing installations and integrity management (for all types of structure – floaters, fixed and jack-ups; topsides and underwater);

(2) Understanding uncertainties in extreme weather hazards;

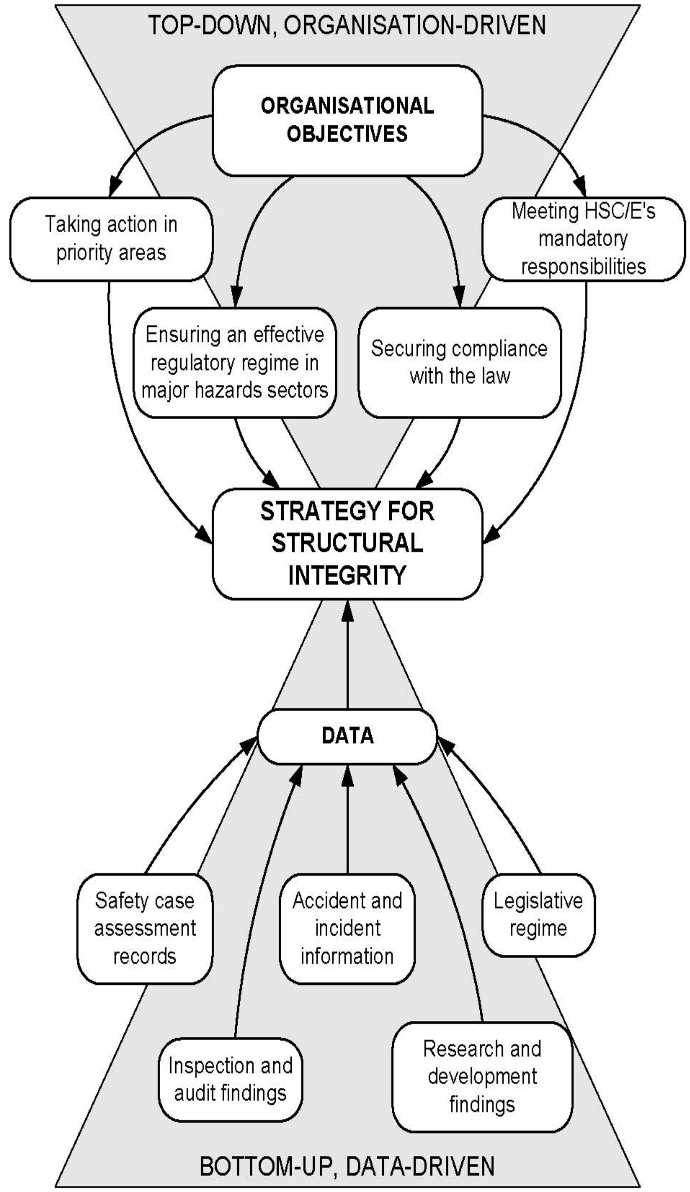

Figure 1: Development of Topic Strategies

(3) Foundation failure (including jack-up site investigation);

(4) Fire & explosion response;

(5) Improved understanding of dynamic loading (including seismic & boat impact) and response;

(6) Materials (e.g. corrosion, high strength steels, ship steels, concrete, cold climate effects, etc.);

(7) Reliability techniques (quantification and performance standards).

The strategy describes OSD's planned activities to address generic concerns arising from knowledge about the population of offshore installations on the UKCS derived from safety case assessment, inspections and incidents.

STRUCTURAL INTEGRITY ISSUES

Floating Installations

FPSOs and FSUs

FPSO (Floating Production Storage and Offloading) and FSU (Floating Storage Unit) installations of monohull form (i.e. ship-like) are used particularly for marginal fields and for deep water locations. Over twenty installations of this type are currently in operation, with more likely to come on stream for future projects. Most of these installations have been built in the last fifteen years, although a few have been converted from tankers over fifteen years old at the time of conversion and hence now approaching a 'structural age' of between twenty and twenty five years, Many of these installations will continue to be operated for several years to come.

Much effort has been expended in assessing the effects of a wide range of hazards on other types of installations, due in part to the large numbers of these installations compared to monohulls. Further work is required in assessing the effects of certain hazards for the small but growing number of monohull installations.

The use of monohull structures as offshore installations has been supported by the use of existing class and international ship standards for design, construction and in-service inspection. There are concerns and a certain amount of evidence that some aspects of these standards may not be wholly adequate for use as offshore installations. For example, the approach to inspection for a tanker subject to periodic dockyard visits may not be appropriate for an installation that is expected to remain on station for 10 years.

Semi-submersibles

Semi-submersible installations are used widely in UK waters in drilling, accommodation, production or construction support roles. A number of the installations are over 25 years old; some date from 1973. It is likely that many of these installations will continue to be operated for several years to come.

Semi-submersible structures are a hybrid between a fixed jacket and a ship, and so have attributes of both to varying degrees. Previous accidents such as those that occurred to the Alexander Kielland, Ocean Ranger, West Vanguard and Ocean Odyssey show the range of hazards faced by these installations and the consequent risk to life. The ship-type attributes of semi-submersibles lead to a number of interactions between structural and marine hazards.

Key issues

More effort is currently being directed towards FPSOs and FSUs than semi-submersibles as design standards and management arrangements are considered to be less developed than in many other areas whereas semi-submersibles have a longer track record. The primary objectives for the two generic floating installation types are as follows:

- improved knowledge regarding the potential for escalation from hydrocarbon explosions:
  - on FPSOs / FSUs: in turret areas, pump rooms, cargo tank decks and machinery spaces utilising HP fuel gas (especially located below accommodation / TR spaces)
  - on semi-submersibles: in mud-processing areas on MODUs and understanding of the implications of damage to main bulkheads on the integrity of deep box-type deck structures;
- the consequences of hydrocarbon fires on the sea surface (in the case of semi-submersibles);
- for FPSOs / FSUs, the adequacy of current design methodologies for monohulls, including design for ultimate conditions, to enable improved knowledge of severe events;
- improved guidance concerning reliability-based design and harmonised guidance regarding global actions and structural design;
- improved knowledge on the continued integrity of installations and the associated inspection implications and procedures and the development of harmonised guidance;
- for FPSOs / FSUs, the factors associated with green water on deck incidents and the implications for structural integrity to establish a view on the adequacy of current practice regarding design criteria for wave impact and improved guidance concerning design for wave impact; for semi-submersibles, the factors associated with loss of air gap incidents and structure blockage effects;
- the consequences of higher energy vessel collisions, including the energy absorption characteristics of monohull structures;
- improved understanding of the design, materials, fabrication and deployment of marine risers.

Jack-up Installations

The jack-up configuration is being utilised in deeper waters and for innovative forms of production system on the UKCS. This results in exposure to greater loading and increased difficulties regarding in-service inspection. Increased understanding of the performance of this generic type of structure in aspects such as foundations, materials properties, dynamic response and systems strength is required. In addition, the ISO standard for jack-ups [8] which will replace current working stress (deterministic) codes with limit state ones (based upon structural reliability) will impact inspection and intervention aspects as it becomes used as the measure of good practice.

Fixed Installations

General Background

The majority of oil and gas production in the North Sea takes place from fixed platforms. There are about 150 of these platforms and over 70% of the total workforce is employed on them. Fixed installations depend on adequate structural integrity for their existence and about 60% of them are over 20 years old and beyond their original design life. Manning levels range from being normally unmanned, entailing occasional visits by small teams to platforms accommodating over 250 people alongside the process and drilling facilities. Over 90 platforms have permanent manning levels in excess of 20 people.

The integrity of fixed structures is determined by design and reassessment standards and an appropriate inspection and maintenance strategy encapsulated in a sound safety management system.

The current regulatory regime has replaced the certification requirement with duties as described in the Safety Case Regulations and Design and Construction Regulations. Thus, duty holders are required to rethink their own strategy for securing structural integrity, rather than relying on the rolling system. This major change of emphasis took place at a time when the oil price was low, as a consequence of which duty holders reduced in-house technical capability. In addition to this, there is a lack of standardised methods.

Recent developments have seen the influx of many new, smaller, duty holders with little or no internal expertise and hence reliance on a knowledge based and competent supply chain becomes important.

The structural integrity of fixed installations can be categorised into the following topic areas:

- technical guidance and standards
- fixed structures (steel)
- concrete structures
- structural safety management system
- reassessment process
- response to extreme weather
- foundations safety
- fire response
- explosion response
- helideck safety
- inspection, maintenance and repairs
- dismantlement
- new technology
- seismic response
- accidental dynamic loads and responses (e.g. boat impact).

These subdivisions formed the framework for safety case assessment and mirror the subdivisions of matters derived from safety cases and intervention plans. Strategies for each were developed with areas of concern firmly based on the outcome of safety case assessment. Wherever possible, themes have been combined to enable focused intervention plans to be developed. This methodology proved successful in the 2001 - 2007 strategy and has been adopted in the 2008 - 2013 strategy

Ageing Fixed Structures

Ageing fixed structures have been built to a range of different standards, for different duties, and have suffered from different aspects of deterioration. Technologically, existing structures always lag behind current best-practice as major modifications are not always practicable and rarely reasonably practicable. Thus, assessing tolerability is a complex process.

Information regarding the deteriorated quality of each installation was lost with the change to verification from certification, which required reassessment for fitness-for-purpose at five-yearly intervals. This has highlighted the need to improve the information flow between duty holders and the regulator, particularly in the absence of any UK standards for new design or reassessment of offshore installations until the publication in November 2007 of ISO 19902, the international standard for fixed steel offshore structures [9].

Some work performed in 1997 / 1998 began to address this area and additional guidance has been provided by incidents as they have arisen. The ability to assess residual safety and effective repair strategies in the overall inspection, maintenance and repair policy for individual installations has been continued in a planned themed inspection intervention which is ongoing. In addition, the role of these aspects within the overall safety management system for the installation and work force involvement needs further investigation.

New Technology Trends in Fixed Structures

Recent and ongoing drives to reduce costs on new fixed installations have seen installations where traditional methods have been extrapolated with minimum underpinning research. For steel structures, framing patterns and redundancies have been optimised, and for concrete structures higher strength mixes and lightweight aggregates introduced. These new trends will have an effect on underlying safety levels when compared to existing installations. Analytical technological advances have seen the development of quantitative measures of structural integrity and there is a need to ensure that such advances are understood, sound, and used in a competent and informative manner. Work in this area is also linked to the need to apply risk management techniques within the structural engineering sector.

The non-prescriptive legislation has also caused a refocus on topics of extreme weather, response to accidental events and foundations, areas of high uncertainty and technical competence. Work is continuing in these areas to ensure competence and verification is not lost to the safety management system in an environment of multi-skilling and industry reorganisation, resulting in a transfer of responsibility in general.

A recent area of concern is the technology associated with dismantlement and the necessary understanding of structural integrity in determining safe and appropriate techniques. Although specific concerns have yet to be identified, a base level of activity is being carried out.

Inspection Requirements for Topsides Structures

There is also a need to make an assessment of the adequacy of current inspection requirements and practices for topside structural components. A topside survey, in many instances, consists only of an annual general visual survey where deviations from as-built drawings are considered. The topsides structure consists of a number of structural components which are important to the overall integrity of the structure and consequence of failure, e.g. deck legs, deck trusses and girders.

A wide range of codes / standards is available until the publication of the ISO Standard on this theme. There is a need to critically appraise the inspection approaches recommended by existing UK, US and Norwegian codes / standards, including NORSOK [10-14] and the provisions of ISO/DIS 19901-3 [15], and identify areas of uncertainty where the various practices differ significantly in their approach to inspection (e.g. techniques and procedures) and categorisation of components. There is also a need to:

(a) identify changes in the design of topside structural details and in inspection practices which may have occurred over the past decade to enable an understanding of how the changes to inspection requirements may be important for the assessment of both new and existing (particularly ageing) structures;

(b) review the classification of topside structural details into categories depending on their structural significance with respect to global integrity and the consequence of failure and to identify areas where the degree of redundancy and the stress predictability influence the material selection and inspection requirements.

Foundations Integrity

Work on the integrity of foundations is aimed at determining whether the foundation system is sufficient to support the structure and provide acceptable levels of safety during all phases of the life cycle of the installation.

The key issues being addressed are:

- protective measures (usually implemented during original site investigation and subsequent design and construction);
- the structural integrity management system, particularly for dynamically sensitive foundation systems for fixed (pile) and mobile (jack-up) installations;
- structure / foundation feedback systems to ensure the overall structural system performance is understood should any change in performance of the foundation system be predicted;
- the monitoring of integrity in-service during any modifications to fixed offshore installations that may increase loads on the foundation systems (usually by a re-evaluation of the foundation safety utilizing current best practice and standards);
- the evaluation of the site assessment practices for mobile (jack-up) installations to ensure that the installation’s structural integrity is not compromised during set-up, operation and departure;
- the assessment of any anomalies found so as to determine appropriate action, e.g. deviations to predictions of pile installation driveability and jack-up spud-can load penetration during pre-loading.

It should be noted that, although the above relates primarily to foundation assessment processes, the ultimate objective is to ensure that a suitable failure probability for the global structural system is maintained throughout the life cycle of the installation, taking into account the total risks to personnel on the installation.

Response to Rare and Accidental Events

Background

In the UK, the design duties have traditionally concentrated on gravity (dead and live loads) and extreme weather, with the demand for extreme weather set at the 50-year condition. Recognition of the repetitive nature of wave loading increased the design duty in the late 1970s to encompass design for fatigue. A further design requirement for ***ship impact*** was introduced in the early 1980s, through the Fourth Edition Guidance Notes [16], as the first accidental-type generic duty. Following from the Cullen Inquiry, the design duty also sought to explicitly include other accidental events such as ***fire and explosion***, particularly for the topsides structure.

The goal-setting regime has highlighted the need for the assessment of structural response to and integrity requirements for accidental and rare hazards, requiring the integration of risk assessment and structural engineering techniques. This is a developing area. The prescriptive generic nature of engineering codes and standards, with their implicit performance standards, is not necessarily compatible with the need for installation-specific risk assessment and the setting of explicit performance standards.

An early outcome from safety case assessment was the almost universal neglect of rare events (above the previously prescribed level), and of the ***seismic hazard*** in its entirety, along with its effects on sub-structure and topsides. There is no UK guidance for the seismic hazard offshore. As a result, the safety cases submitted were seriously devoid of assessment for this hazard and of all other hazards above traditionally-considered design levels.

UK custom and practice in design is to set the extreme weather design level events at duties which are much lower, usually around the 100-year return period, than the reasonably foreseeable level. Norwegian practice has been to test the design at a higher duty (around the 10,000-year return period), relaxing the acceptance criteria in recognition of this.

The scope of accidental events is currently confined to the areas of fire, explosions and ship impact. The key issues related to general aspects, accidental events and rare events are presented below.

Fire and Explosion
The following topics require further attention:

- the development of performance standards and design guidance for structural response to each hazard (and particularly for the scenario of fire / explosion);
- for explosions, there is the need for understanding both the modelled overpressures and their translation into design loading, along with the consequent effect of strong vibration on structural details;
- studies to address concerns regarding the use of non-linear software and its benchmarking;
- investigation of the structural response of higher strength materials used in blast and fire wall design;
- studies to address concerns regarding the behaviour of materials at high strains (fracture initiation and failure);

There is a need to examine the management of fire and explosion risks to determine:

(1) whether the orginal assumptions regarding integrity are valid, e.g. whether the load and response analyses are sufficiently robust to support technical ALARP arguments in the safety cases;

(2) physical changes to the installation that may impact on the risk and require additional risk reduction measures to be reviewed / adopted;

(3) deterioration in the structure's condition, in particular the weathering of passive fire protection (PFP) systems and failures in the pressurised containment of the temporary refuge (TR) and its effect on the continuing suitability of the installation.

(4) Whether the management system that captures the above is suitably robust and enables critical changes to be incorporated into the duty holder review and instructions given to key personnel.

Ship Impact
The following topics require further attention:

- the inadequacy of current software and design methodologies for ship impact for the calculation (at the appropriate accuracy) of the structural response;
- the further development of guidance on generic loading due to ship impact and consequent structural response.

Rare Events
Rare events relate to extreme weather and the seismic hazard:

- for the extreme weather hazard, there is a need to extend UK practice to investigate structural integrity at rare event levels similar to Norwegian practice, i.e. the 10,000-year wave.
- there is a need to address concerns regarding the lack of UK offshore seismic guidance and low consideration of this hazard in safety cases, building on existing collaboration with Norway, with a view to developing a UK regional annex to ISO 19902 [9].

Materials Performance

North Sea offshore facilities are subject to severe conditions which pose stringent performance requirements on engineering materials. Such conditions include: high pressures and high temperatures, corrosive effects from reservoir fluids, accidental loading conditions (impact, fire and blast) and the severe weather conditions of an exposed marine environment.

Industry is seeking further cost-effective solutions, wherever possible, and this has resulted in looking toward new technologies to achieve cost reductions. This requirement has resulted in the demand for lightweight high strength concretes, high strength to weight ratio alloys, corrosion resistant alloys, flexible hose materials, anticorrosion and thermal insulating coatings, and polymeric materials including seals, fibre reinforced plastics for both structural and piping applications and 'high-tech fibres' (polyesters) for deepwater tethers and moorings. Materials and their associated joining technologies must be qualified under realistic conditions to provide confidence in their operational limits and long-term performance.

With vessels entering UK waters having been built overseas, the material manufacture and specification may not satisfy familiar standards, presenting challenges for the control of deterioration and assurance of structural integrity.

Metocean Parameters

Background

A good understanding of the metocean climate in which an installation is to operate is essential if the risks to personnel engaged in work related activities on the installation are to be properly controlled. It is well established that the reliability of a structure is highly sensitive to the metocean parameters used in its design, and that these parameters have high levels of both natural and modelling uncertainties associated with their estimation.

The introduction of DCR, and a general move away from the use of independent 50-year criterion in design, has placed into question the value of the metocean information provided in Section 11 of [17].

The metocean information presented in safety cases is often insufficient to assess whether the design conditions to which the installation has been subjected are adequate to ensure long-term safe operations. In a number of safety cases, the information presented is incorrect, usually suggesting a lack of knowledge of metocean terminology and methodologies.

OSD has been involved in a number of significant activities in the metocean arena, namely:

- review of the hindcasting effort by the North European Storm Study (NESS) User Group (NUG) to determine whether there existed any evidence of increasing wave heights in the North Sea, resulting from changes in the world's climate [18].
- development of the limit state approach in ISO 19902 [9] with regard to the provision of metocean information for use in design. It should be noted that the ISO standard has moved away from traditional North Sea practice of basing the design of a structure on independent 50 / 100-year metocean parameters, to one of presenting the designer with a range of design inputs to choose from. Of the options available, the most challenging is likely to be that associated with the use of the 100-year response.

During the 1998 / 1999 winter period, metocean-related damage was experienced by all types of floating installation. The problem, in part, results from a failure to recognise and/or address the full range of (metocean-related) limit states to which a floating installation is subjected. A particular problem, which also has a bearing on the design of fixed installations, is that there is a lack of understanding associated with the probability of occurrence of steep waves and the impact these have on the structural strength of installations.

Key Issues

HSE is required to ensure that the industry:

(a) has adequate data from which to derive operating and design parameters

(b) uses appropriate tools to estimate operational and extreme conditions

(c) takes adequate account of the uncertainties associated with the metocean parameters being estimated

(d) has in place adequate means of independently verifying the metocean element of safety critical systems

(e) has available appropriate means of monitoring the environment in which structures operate

(f) makes appropriate use of the forecast tools available for weather sensitive operations.

INTERVENTION STRATEGY

The deployment of interventions to tackle the current structural integrity priorities is summarised below. This activity has been implemented formally initially through a topic theme associated with OSD's Key Programme 3 (KP3) [19] and subsequently, since 2007**,** the Structural Integrity Management Inspection Programme (SIMIP) - both of these initiatives are described further below.

Ageing Installations & Integrity Management

This is the primary structural integrity strategic intervention building individual duty holder and installation inspections together on intelligence from safety case assessments. Examination of facilities' condition offshore, where appropriate, combines with scrutiny of structural integrity management systems (whether in relation to topside fabric maintenance and structural integrity, underwater structural integrity or structural integrity concerns specific to floating installations). The specific approaches are as follows:

Topsides Inspections

Topside fabric maintenance and structural integrity inspections are undertaken on installations prioritised based on age and manning level. The topside structural integrity management system (if documented) within the safety case is examined prior to the inspection. The research for this was completed in 2005 and internal guidance produced as part of the inspection documentation. Future work includes: completion of inspections; analysis of findings and production of future plans for this aspect. This themed inspection programme is due for completion in 2008 / 2009.

Underwater integrity

Inspections on underwater structural integrity are performed at duty holder offices onshore and all fixed manned installation duty holders are being inspected. Safety cases for the installations give a general view of the duty holder's underwater structural integrity management process. The aim of the subsequent inspection is to: validate the relevant information in the safety case; ascertain the stakeholders involved in the underwater inspection process; ascertain the major means of inspection and the inspection strategy; and, for older installations, the preparedness and process for reassessment of the installation.

Current work involves research into: tools for reassessment; efficacy of inspection methods; and management frameworks for ensuring appropriate activities associated with ageing are undertaken. Future work will include further inspections and analysis of outcomes from these inspections resulting in sharing information with the industry.

Floating Installation structural integrity

Floating installations are selected for inspection by the date of the last inspection with the overall aim of probing the inspection processes, especially seeking information on the next major inshore inspection.

These themed inspections are driving towards a generic approach to structural integrity management. A technical policy on the management of deterioration provides a parallel intervention mechanism through which to communicate expectations across the industry, complementing the installation / duty holder specific interventions. Standards work, research and internal documents consolidating experience and good practice form an integral part of this aspect of the strategy.

Extreme Weather Hazards

Major inspection activity has been carried out in 2007 / 2008 and further inspections will be performed in 2008 / 2009, albeit at a lower level of activity. The themed inspections with key duty holders aimed at ensuring the inputs and outputs on extreme hazard control were current and also provided the opportunity to disseminate important data changes and standardisation issues in the metocean area. Dissemination of the research through internal documents and industry standards will continue with safety case assessment and inspection activity being subsumed within the underwater activity. The ISO standard concerning this hazard was published in 2007 and its use and effect on OSD intervention work will be assessed.

Foundation Failure (Including Jack-ups)

The interventions in 2008 / 2009 are prioritised in relation to the resurgence of jack-up failures and reflect the inherent challenge of the unoberservable nature of incipient foundation failure. A multi-pronged approach, drawing on the investigations and undertaking research both on failure and the adequacy of new industry standards, will inform the development of a technical policy against which a targeted inspection programme will be devised. This will combine onshore and offshore elements, in accordance with the existing successful theme inspection model, in relation to structural integrity management, its communication and practice.

Fire & Explosion Response

Intervention activity centres on collaborative work with internal stakeholders to ensure a coherent and holistic approach to this fire and explosion threat to structural integrity. This will build on the findings from explosion and fire response themed inspections on and offshore undertaken through 2007 / 2008. The inspections are being performed for installations prioritised with respect to leak frequency and may in future be based on findings from earlier themed duty holder inspections. The issues being addressed are:

(1) the suitability of mitigation barriers to prevent escalation and to protect the TR.

(2) the suitability of structures to allow escape to the TR and embarkation points and evacuation from the installation.

(3) in-service performance testing, inspection and assessment of fire and explosion safety critical elements.

(4) The DH management system to control the above.

Research in this area is related to development and production of the technical policy.

Dynamic Loading & Response

The primary intervention in relation to dynamic response and the effects on structural integrity have been through follow-up inspection in light of incidents (e.g. boat impacts). With increasing combined operations activity, the focus is turning to a more proactive approach, assimilating the experience from incidents and intelligence from the inspections. Work is required on development of a technical policy and documentation which will form the baseline for planned installation-related inspections and the inspection requirements of combined operations through a new themed inspection activity, assimilating safety case information and its translation into specific measures offshore. It is anticipated the technical policy, documentation and duty holder interventions will develop iteratively as the interaction on this technically challenging issue develops. Research is required to cement the technical policy.

Materials Technology

The demand for intervention is determined, in part, by the vessels entering UK waters and recent incidents associated with, what to date have been, ‘non-standard’ materials in the sector and effects of their ageing on structural integrity. The strategy is to utilise the full range of interventions to gather intelligence from safety case assessment and inspection and through research, to develop the understanding to inform internal guidance on which targeted inspection can build. In parallel, standards work on the range of relevant materials will help accelerate improved industry practices.

The intervention strategy includes a corrosion inspection programme. Its purpose is to reduce risks from corrosion on offshore installations by securing of improvements to duty holder management systems and the physical condition of offshore installations.

Reliability Techniques & Performance Standards

Reliability as a statistical concept is associated with the notion of dependability and survival of offshore installations in the face of structural integrity threats. Reliability is determined using quantitative measures of failure which can be complex and opaque and the priority is to develop internal guidance on the appropriate use of reliability techniques. Dependability may also be defined by performance standards providing a common currency for verification and inspection. For structural integrity, performance standards and verification activity in general have focused on survival criteria with insufficient attention given to fitness-for-purpose or other limiting criteria for safe continued operation.

THE KP3 PROGRAMME

Overview

The Health and Safety's Offshore Division undertook a programme of work, Key Programme 3 (KP3), in the period 2004 - 2007 to investigate asset integrity, targeting the management of the risk of failure of structure, plant, equipment and systems. The focus in the period 2007 - 2008 is on internal audit systems. Almost 100 installations (i.e. about 40% of the total) were inspected across the spectrum of manned and normally unattended installation types, i.e. fixed, floating production, floating production storage and offloading vessels and mobile drilling rigs. KP3 was aligned with the Step Change in Safety initiative [20] aimed at improving safety on the UKCS and involves various stakeholders:

- International Association of Drilling Contractors (IADC)
- British Rig Owners Association (BROA)
- Offshore Contractors Association (OCA)
- Independent Verification Bodies (IVBs).

Aim

The overall aim of KP3 [19] was to:

> *'Ensure that dutyholders effectively manage the risk of any failure of structure, plant, equipment or systems, which could either cause or contribute to, or prevent or limit the effect of, a major accident and / or cause fatalities.'*

Thus, it concentrated on the integrity management of safety critical elements (SCEs), which provide the barriers to major accident hazards, and installations were given an overall integrity rating.

Scope

HSE had evidence from its enforcement activities, i.e. inspection and investigation, on some companies and installations that:

- there were weaknesses in the implementation of the independent verification process;
- emphasis on costs (resulting in reduced manning and multi-tasking) was affecting potential safety performance;
- there was a backlog of maintenance work;
- a number of significant incidents had been due to maintenance or integrity failures.

KP3 examined asset integrity with respect to all relevant major accident hazards and focused on the effectiveness of maintenance management systems, including verification issues, i.e.

- system testing of SCEs;
- maintenance of safety critical elements (SCE);
- defined life (i.e. temporary) repairs;
- corrective maintenance;
- recording of completed maintenance work;
- supervision;
- backlogs;
- deferrals;
- communication between onshore support staff and offshore maintenance technicians;
- competence assurance of maintenance technicians and their supervisors;
- measurement of the effectiveness of the maintenance system;
- examples of best practice.

This paper focuses on the structural aspects examined in a parallel topic programme to the main KP3 programme but making use of many of the template categories and methods of KP3. It is also useful to mention other HSE intervention projects currently being undertaken by HSE since the completion of KP3, to determine how effectively duty holders are managing some key issues, namely

(a) the effectiveness of audit arrangements, with particular emphasis on risk control barriers;

(b) corrosion management;

(c) management of change with regard to risk control barriers;

(d) effectiveness of verification systems;

(e) development of performance indicators in collaboration with the offshore industry.

STRUCTURAL INTEGRITY MANAGEMENT INSPECTION PROGRAMME (SIMIP)

Background

The Structural Integrity Management Inspection Programme (SIMIP) supports OSD's Structural Integrity Strategy on the major accident hazard area of 'loss of integrity', in line with the HSE Strategic Programme on Major Hazards. It has followed on from the inspections undertaken in parallel with KP3. The content of SIMIP is based on technical themes derived from

(a) the outcomes of safety case assessment;

(b) historical structural integrity inspections undertaken to date (in line with the DCR regulations and GASCET [21];

(c) research intelligence gathered from recent technology developments.

Scope

The components of the programme are:

(1) identification of discrete technical themes from (a) to (c) above;

(2) development of technical policy and assessment to guide the internal inspection quality and consistency for each theme;

(3) development of the inspection framework;

(4) prioritisation of installations for each theme;

(5) inspection of and feedback on both duty holders and specific installations;

(6) analysis of (positive and negative) generic inspection findings which identify safety gaps in process and knowledge to further develop inspection strategies;

(7) prioritisation of inspections from inspection findings.

The current structural integrity inspection programme is based on the seven themes presented above. The programmes are continuous and are developed or changed as necessary, using the results and findings from inspections, along with information from incidents and investigations which may reveal underlying issues worthy of generic inspection. Indeed, the SIMIP programme is being expanded from the original themes of underwater integrity, topsides integrity, fire and explosion response, metocean awareness and floating installations integrity to include the other areas mentioned above.

Inspections are performed both onshore and offshore. Some are duty-holder-specific and some are installation-specific. Installation and duty holder selection have been prioritised on a qualitative risk basis.

Specific practical aspects of the structural integrity management process that are being addressed are:

- the suitability and identification of SCEs;
- communication between support and offshore technicians;
- competence of technicians and consultants;
- maintenance of SCE design suitability and repair techniques;
- supervision of SCE repairs and consultants;
- recording of completed maintenance / consultancy work;
- deferrals and reassessment of structural SCEs;
- corrective maintenance revised analyses;
- defined life barriers;
- measuring compliance with performance standards;
- measuring quality of maintenance and assessment work;
- review of ICP recommendations;
- reporting to senior management on integrity status;
- acceptance criteria for maintenance effectiveness and SCE suitability.

FINDINGS OF SIMIP STRUCTURAL INTEGRITY INSPECTIONS

Overview

The current content of SIMIP inspections is as follows:

- Fire & explosion response (ER);
- Topsides fabric maintenance & structural integrity (T);
- Underwater structural integrity (UW);
- Metocean awareness (M);
- Floating structural integrity (FL).

Further structural integrity themes for foundations and dynamic response are being developed.

The current status of the inspection work is summarized in Table 2. The results of inspections on 16 duty holders of fixed platforms in the three sectors of the North Sea are shown. This is only a sample of results: inspections on other duty holders are either currently underway or planned. This paper presents general results. Detailed findings for each technical theme will be disseminated as SIMIP progresses.

The results are presented in terms of a traffic light system, each traffic light representing an assessment of the installation at the time of the inspection based on the inspection report. Traffic light systems give a very general measure and cannot capture the various nuances required in this complex area. For structural integrity, however, they can be used to give some indication of priority for the next HSE inspection.

Duty Holder	Platform	M	ER	T	UW
DH1	P1				2
DH2	P2		1		3
DH3	P3		3		
DH4	P4				3
DH5	P5			3	3
	P6				3
	P7			2	3
	P8		3	3	
	P9			2	3
DH6	P10		2	3	3
	P11		2		
DH7	P12		1		
	P13		2	2	2
DH8	P14		3	2	3
DH9	P15	3			
	P16			2	
	P17		3	3	3
DH10	P18	3	3		3
	P19			2	
	P20			3	
DH11	P21				3
DH12	P22	2		2	1
DH13	P23				1
DH14	P24			3	3
	P25		2	3	
	P26		3		
	P27		3	3	
	P28		2		
	P29		2		
DH15	P30			3	2
	P31	3			
	P32	1		2	2
DH16	P33			3	
1	*Serious deficiencies requiring immediate attention*				
2	*Matters raised formally, mainly results of ongoing work or change*				
3	*No matters formally raised with the DH*				

Table 2: Traffic light coding for structural integrity themes

The following definitions were applied:

- **Green** - the inspection did not result in any further matters to be formally raised with the duty holder; next inspection to be performed within two to three years;
- **Amber** - some matters were raised formally for duty holder response, mainly the results of ongoing work or change; next inspection to be performed within one to two years depending on the seriousness of the matter;
- **Red** - the inspection revealed some serious deficiencies which require immediate attention; next inspection to be performed within one to six months depending on the deficiency.

The individual findings are variable but it is apparent that there is a need to improve management systems. There is considerable variation in the performance of management systems and delivery of appropriate standards both across the UKCS and often in the same company. The following elements of the management system were found, in general, to require improvement:

- maintenance of SCEs;
- handling of backlogs;
- handling of deferrals;
- measurement of compliance with performance standards;
- corrective maintenance.

Maintenance Management Systems

The following trends can be identified from the information obtained from inspection of duty holders' management systems:

- the concept of barriers in major hazard risk control is not well understood;
- different structural integrity hazards and themes are managed differently and to different standards;
- there is a documented structural integrity management system but its implementation differs both between duty holders and between assets in the same company;
- there is limited technology appreciation, e.g. the SCI guidance [22] and the ISO standards for offshore structures [9. 23];
- there are unclear periodic and risk-based integrity management philosophies and matching to techniques;
- there is a need for better key performance indicators to be available to senior managers to achieve a clear understanding of the risks associated with degraded SCEs and of the key performance indicators associated with asset integrity to enable better informed decision making and allocation of appropriate levels of resources to ongoing maintenance;
- visits by the technical authority to installations is limited;
- the technical authority role needs to be strengthened in many companies - there is some evidence that this has been recognized and is being addressed;
- the engineering function needs to be sufficiently strong to enable major hazard control and maintenance of SCEs. It is apparent that, in many companies, the engineering function has declined to a minimum and is perhaps unacceptably low level.
- verifier involvement in the whole management process is somewhat limited and needs to be improved;

- audit and review arrangements are not being used effectively to deliver organisational learning and continuous improvement – in many cases, there is a need for improved arrangements for auditing and monitoring performance;
- there is a need to disseminate good practice both within organisations and across the industry;
- there is a need to establish or improve systems that ensure corporate memory is secured;
- the industry needs to share good / best practice.

Overall Condition of the Infrastructure

Changes within the offshore industry arising from cost-cutting and low investment at the time of low oil prices, as well as changes of ownership, have had detrimental effects:

- there is wide variation across the industry in the structural condition of installations – asset maintenance has not always been a priority and some installations are showing substantial deterioration, particularly those that are likely to be sold;
- logistical problems, e.g. skills shortages, long lead times for delivery of materials and equipment, insufficient accommodation offshore and limited availability of accommodation vessels, are restricting the industry's ability to achieve rapid improvements.
- there is inadequate monitoring of deferrals / maintenance – outstanding work is not necessarily clearly defined.

CONCLUSIONS

(1) The KP3 and SIMIP inspections have indicated a certain similarity in findings. A number of improvements in the structural integrity management process are generally required, assisted by the following actions:

- tightening of structural integrity management systems;
- increased involvement of the verifier in the structural integrity management process;
- integration of structural integrity themes and disciplines;
- improvement of understanding and usage of barrier controls to the major hazards control loop.

(2) There is a need to achieve improved clarity on good structural integrity management practice and the development of an appropriate structural integrity management policy for each installation, especially ageing installations. HSE will continue to gather and use evidence to secure improvements in the structural integrity management process.

(3) Using the findings from SIMIP and its supporting research / technology programme, HSE will continue to develop and promote good practice for structural integrity management.

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