JACKET REPAIR & STRENGTHENING SOLUTIONS

CAPABILITIES STATEMENT

Combining Disruptive Technologies and Proven Engineering Capabilities

ASSET INTEGRITY MANAGEMENT

IEV – REPAIR & STRENGTHENING SOLUTIONS

Platforms

- Structural Analysis
- Repair Solutions
- & Strengthening Solutions
- Structural Health Monitoring (Optional)

Pipelines

- Free Span Correction

JACKET REPAIR & STRENGTHENING SOLUTION

In collaboration with ABYSSAL TECHNOLOGIES core Grouting Services YUG UTP UNIVERSITI TEKNOLOGI PETRONAS

JACKET REPAIR & STRENGTHENING SOLUTIONS

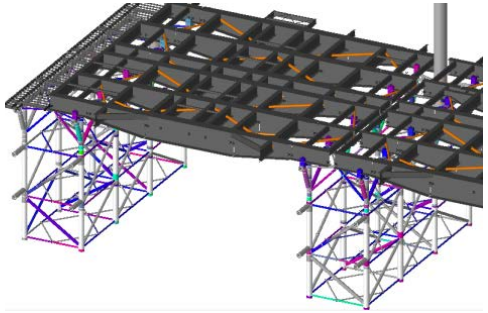
PHASE 1	PHASE 2	PHASE 3
		
STRUCTURAL ANALYSIS	STRENGTHENING SOLUTIONS	STRUCTURAL HEALTH MONITORING

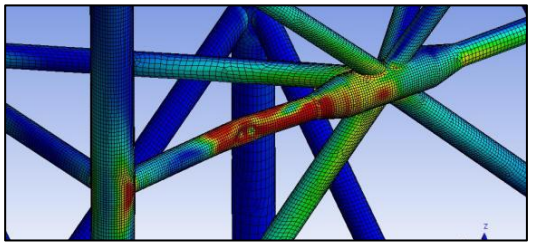
PHASE 1 – STRUCTURAL ANALYSIS

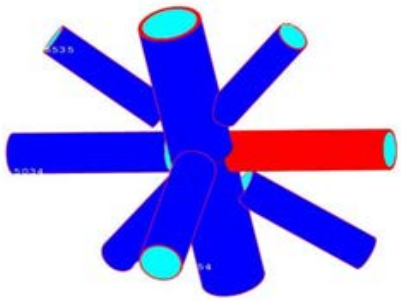
In collaboration with ABYSSAL TECHNOLOGIES

TYPES OF ANALYSIS

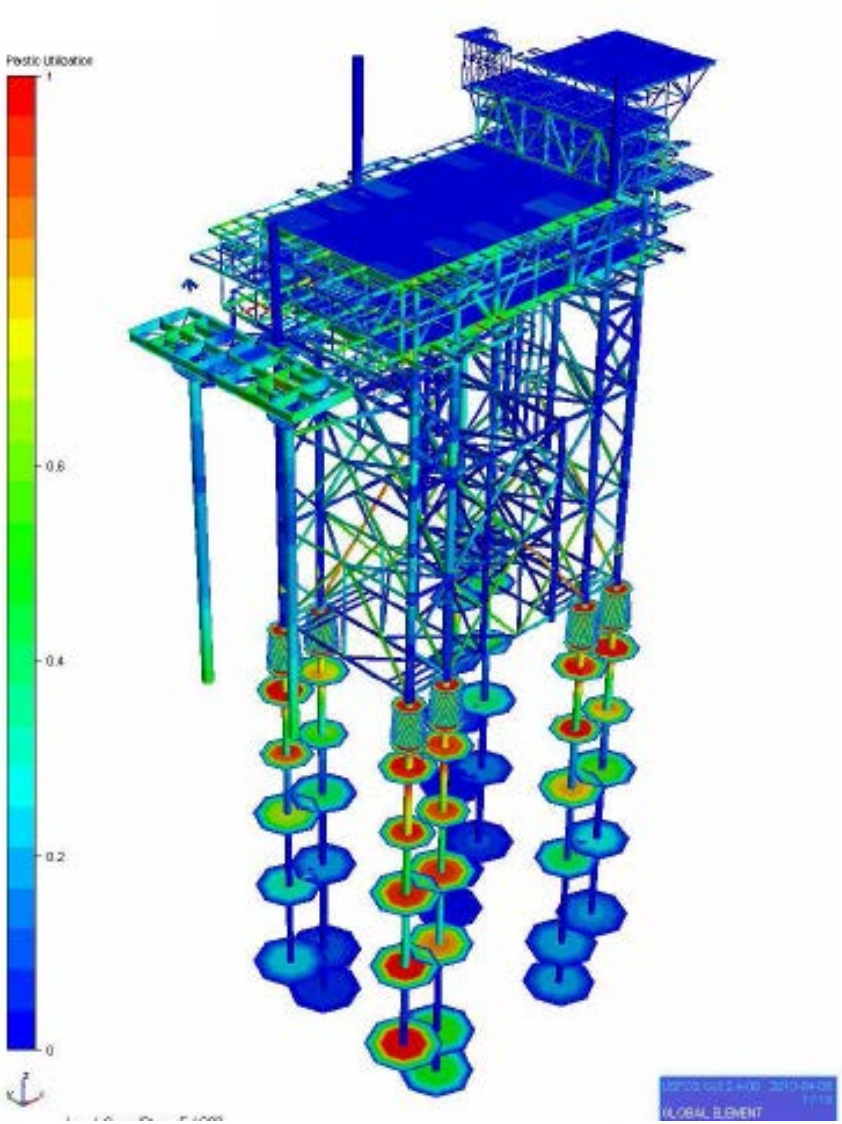
STRUCTURAL	In-Services	• Dynamic Response Analysis • Wave Slam Analysis • In-place Strength Analysis • In-place Fatigue Analysis • Vortex Induced Vibration
	Accidental	• Seismic Analysis • Dropped Object Analysis • Ship Impact Analysis • Blast Analysis • Redundancy Analysis • Pushover Analysis
	Finite Element Analysis	• Linear & Non-Linear Strength Analysis • Thermal Analysis • Stress Concentration Factor • Pipe Stress Analysis • Buckling Analysis
	Specific Requirement	



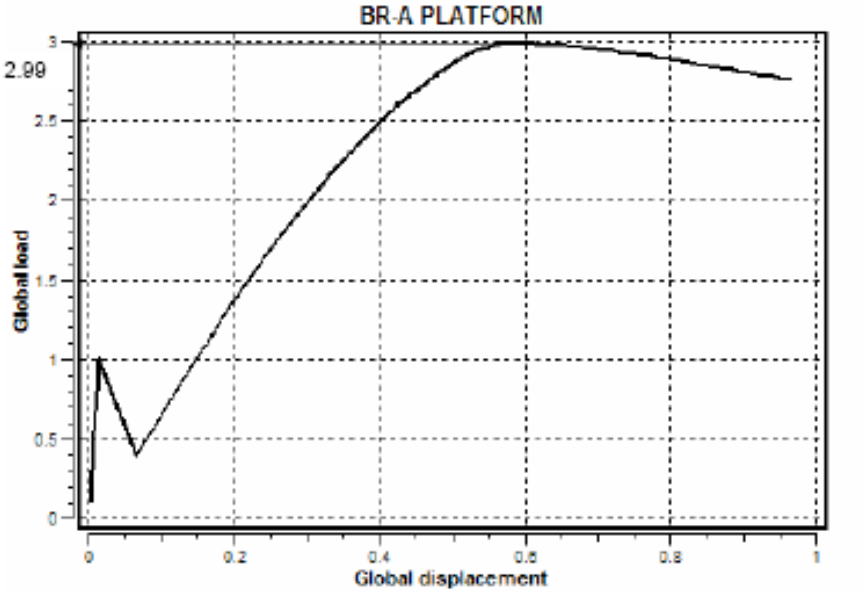




GLOBAL & REFINED LOCAL ANALYSIS

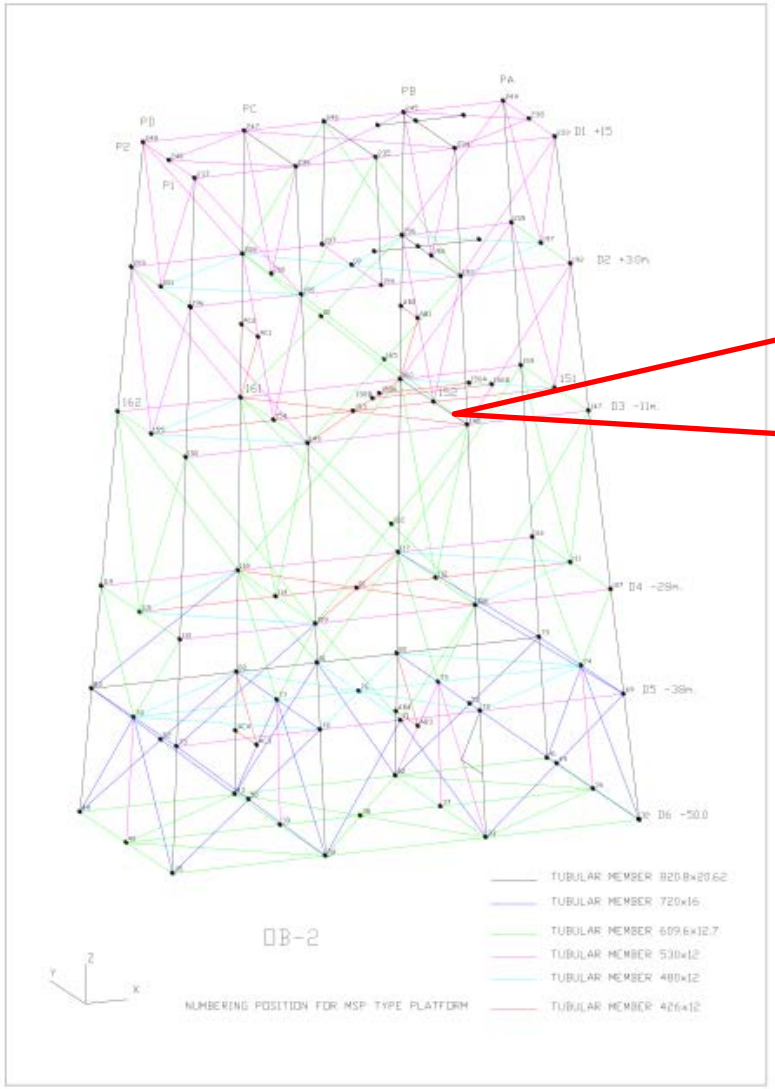


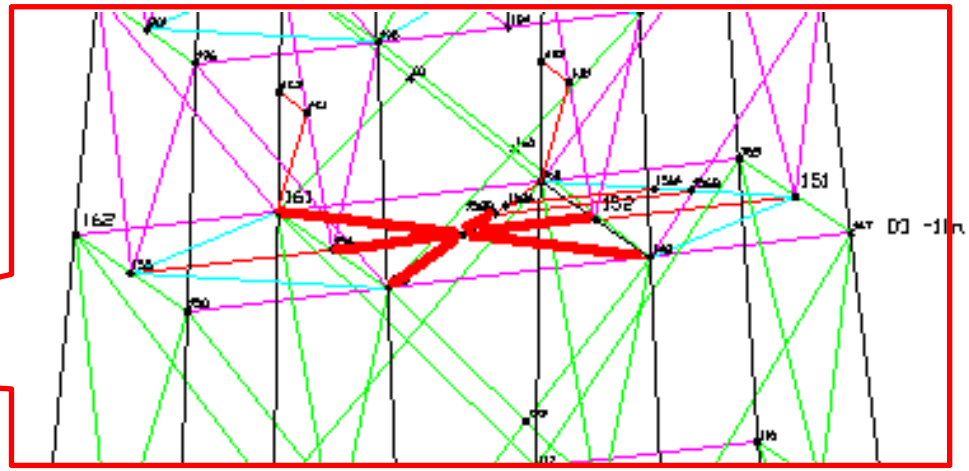
PUSHOVER ANALYSIS



Global Load (MN) Vs Global Displacement (m)

GLOBAL & REFINED LOCAL ANALYSIS





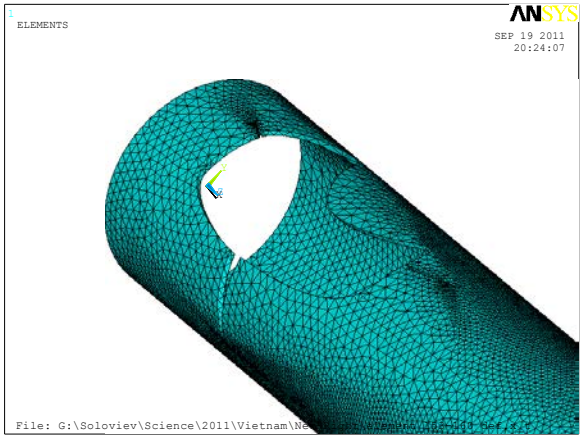


Illustration - a part of the finite element model with defect

INDUSTRY STANDARDS

Codes & Standards

Software

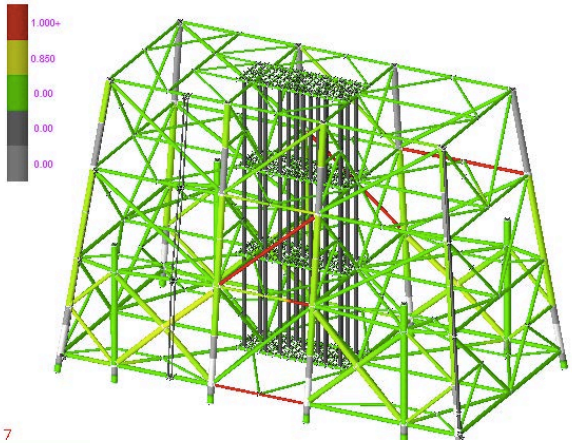
CASE STUDY: Middle East

Scope: Strengthening modification & repair of Jacket

To perform detailed structural assessment of a drilling platform. The purpose is to ensure immediate and future structural integrity and to check fit for purpose of the intended life and beyond

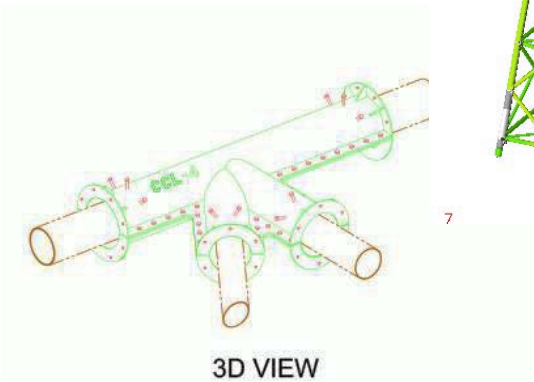
Details

- 8 Leg with 8 main piles and 4 skirt piles
- Four corner legs are double battered at 1:8 and four legs are
- single battered at 1:8
- Working point Leg spacing 41.15m x 13.72m;
- Water Depth 61.50m MSL;
- 12 No. 36" OD Pile will be used;
- 15 No. 30" OD Conductor;
- Risers 1 No. 18" and 1 No. 6"
- Caissons 1 No. 26" and 2 No. 18"
- J Tubes 2 No. 8"
- Jacket weight is 2000t & Topside weight is 2600t.
- Jacket Height is 66 m.
- Design Life extension of 25years
- Grouted Clamp



Scope

- ✓ In service Strength Analysis
- ✓ In service Spectral Fatigue Analysis
- ✓ Accidental Analysis (Ship Impact)
- ✓ Pushover Analysis
- ✓ Seismic Analysis

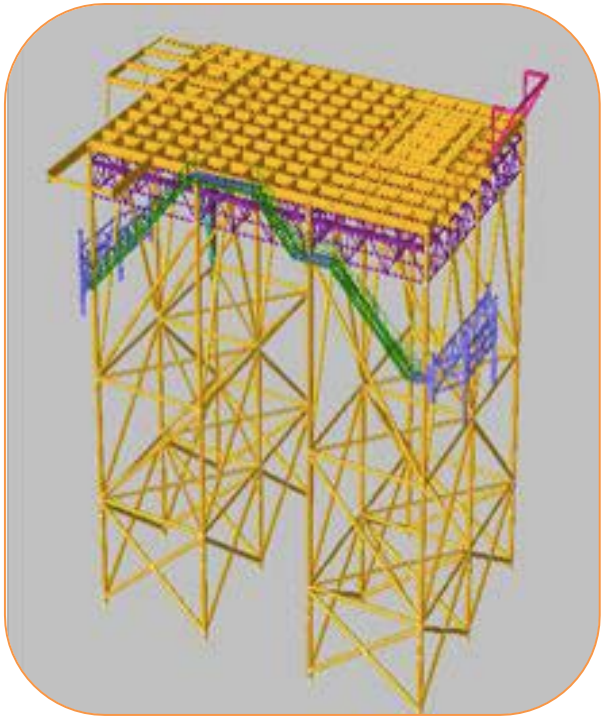


3D VIEW

CASE STUDY: Caspian Sea

Scope: Re-Certification of Jackets

To perform detailed structural assessment of 2 drilling platforms to ensure immediate and future structural integrity and check fit for purpose of the platforms to quality for the the re-certification program.



Details

- 8 Leg with 8 main piles and 4 skirt piles
- 6 Leg with 6 main piles
- All Corner legs are straight
- An Accommodation platform 20m x 30m;
- Water Depth 19.0m MSL;
- Jacket & Topside weight is 800t.
- Jacket Height is 29 m.
- Design Life extension of 10years

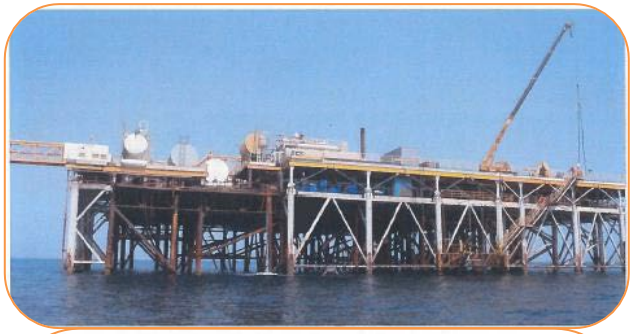
Scope

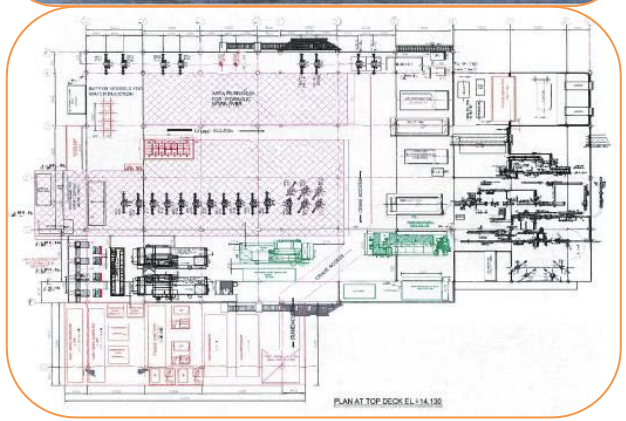
- ✓ In service Strength Analysis
- ✓ In service Spectral Fatigue Analysis
- ✓ Accidental Analysis (Ship Impact)
- ✓ Pushover Analysis
- ✓ Seismic Analysis
- ✓ Clamp Design

CASE STUDY : Turkmenistan

Scope: Structural Verification & Certification of Production Platforms

To conduct perform detailed structural assessment of a Production Platforms to ensure immediate and future structural integrity and check fit for purpose of the platforms to quality for the the re-certification program





Output

- ✓ In service Strength Analysis
- ✓ In service Spectral Fatigue Analysis
- ✓ Accidental Analysis (Ship Impact)
- ✓ Pushover Analysis
- ✓ Seismic Analysis
- ✓ Clamp Design

PHASE 2 - REPAIR & STRENGTHENING SOLUTIONS

In collaboration with

REPAIR & STRENGTHENING SOLUTIONS

REPAIR & STRENGTHENING

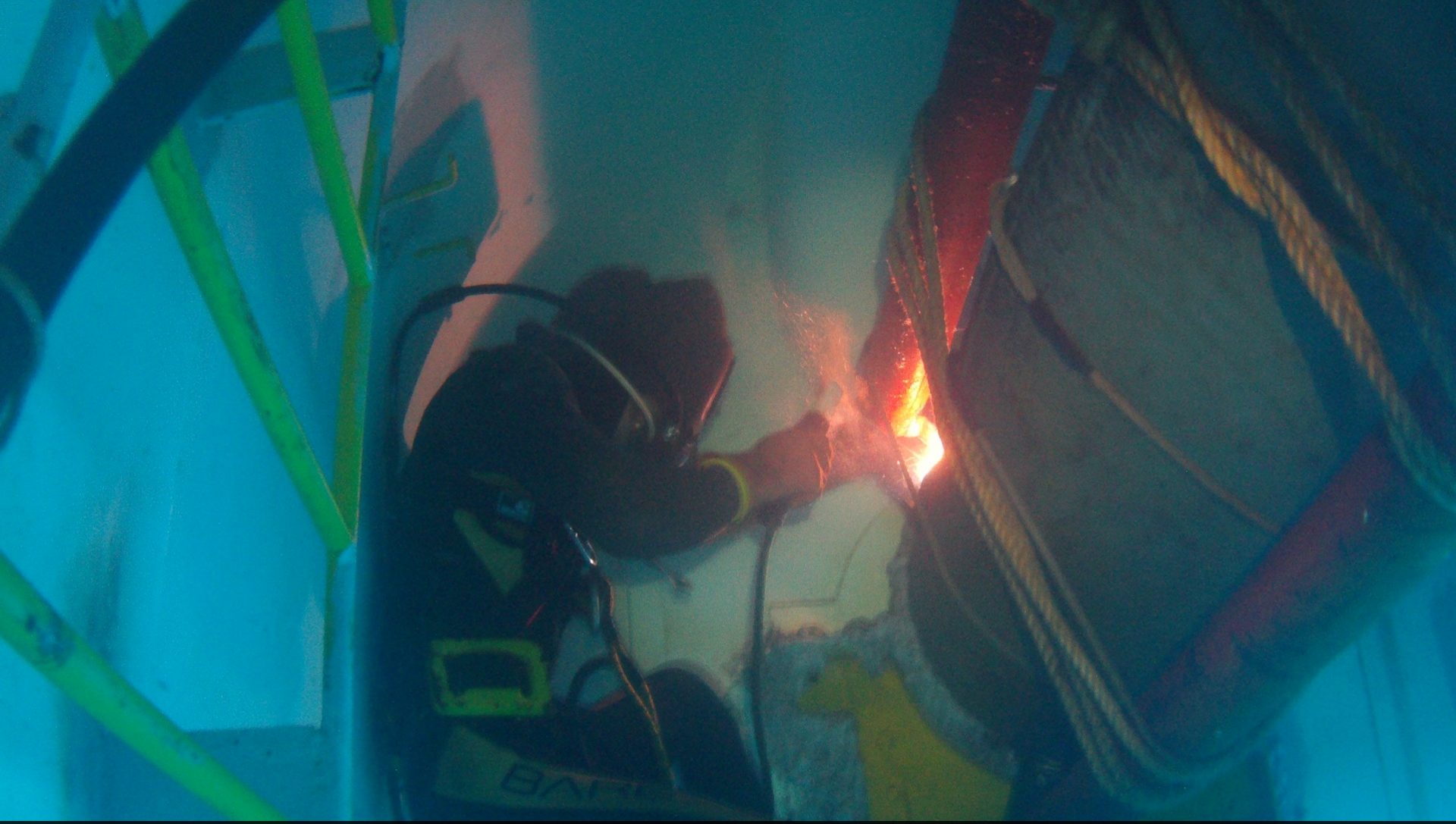
For dents, cracks, tears and member replacements in shallow water

To strengthen members under compression or low UC

To strengthen nodes

ENVIRONMENTAL LOAD REDUCTION

Reduce platform hydrodynamic loading through a permanent change in marine growth profile in the wave zone – solely powered by ocean-forces.



UNDERWATER DRY WELDING BY HABITAT (UDW)

REPAIR SOLUTIONS FOR DAMAGED SUBSEA STRUCTURES USING UNDERWATER DRY WELDING IN HABITAT

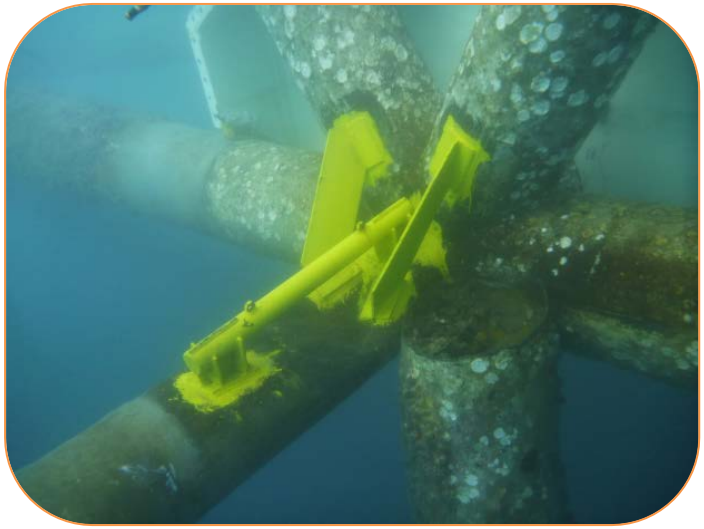
UDW : APPLICATIONS

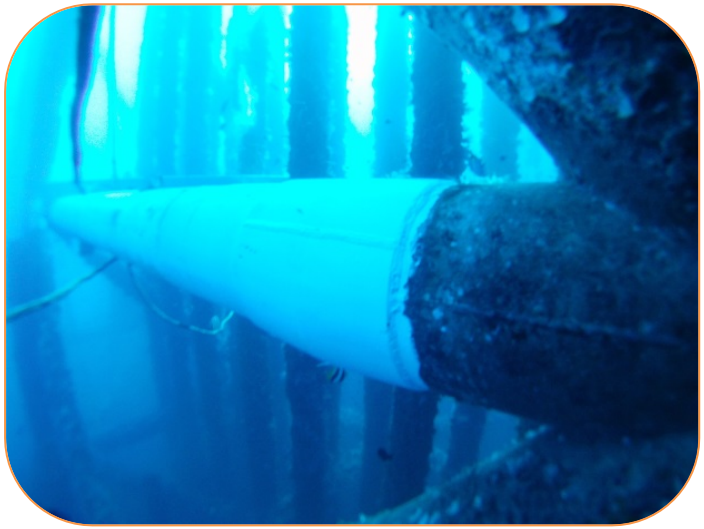
(1) **Member rectification** repairing/strengthening of damaged/under-strength member

(2) **Nodal rectification** repairing/strengthening of damaged/under-strength joint

(3) **Defects repair** dent, tears, holes, crack, parted members

(4) **Member replacement or new member** connected to existing member

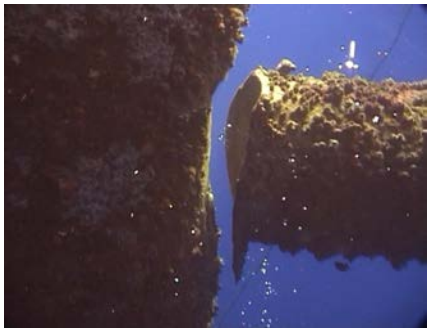




UDW : HABITAT

Mock-up Trial Fit

CASE STUDY: JACKET LEG REPAIR



1. Damage at main leg

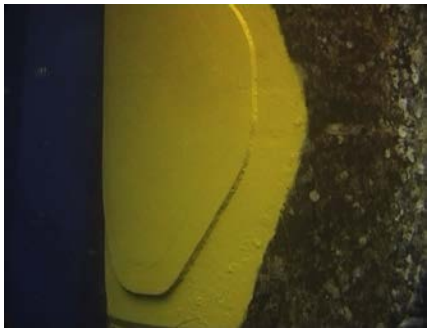
2. Preparation & Deployment of divers

3. Underwater cutting of damaged section

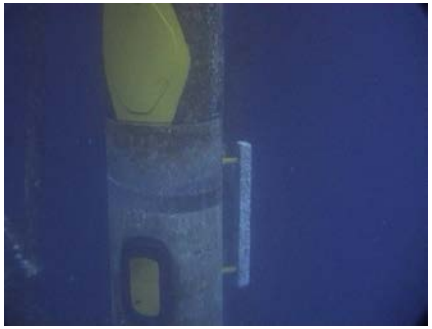
4. Position of plates

5. Habitat installed

6. Underwater dry welding inside habitat



7. Plates welded



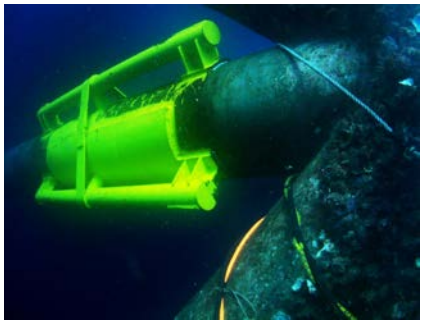
8. Jacket leg after repair

CASE STUDY: DAMAGED MEMBERS REPAIR

1. Defect on structural member

2. Repaired section

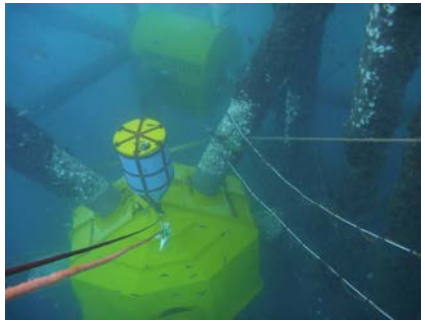
3. Defect on structural member



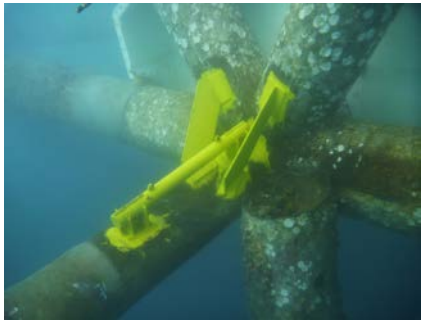
4. Repaired section

5. Defect on structural member

6. Sleeve repair



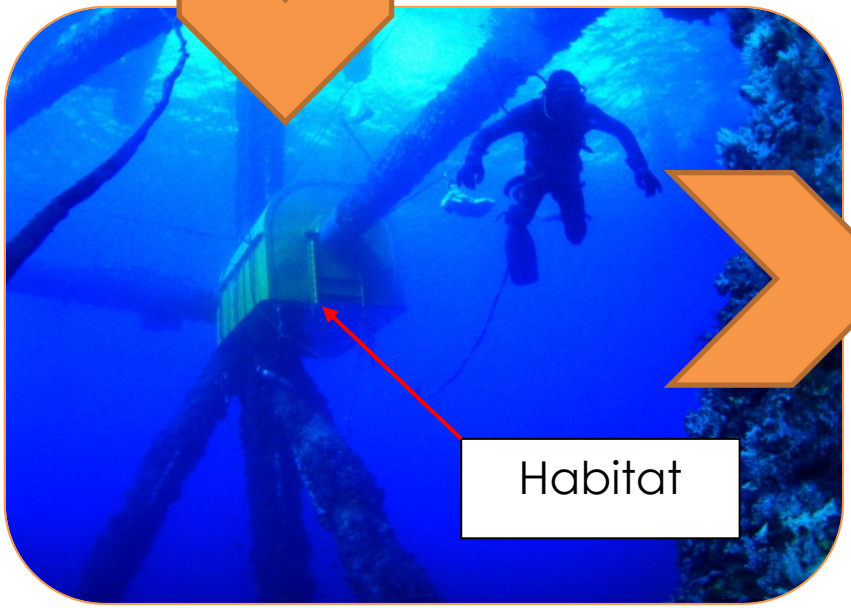
7. Habitat installed



8. Repaired joint

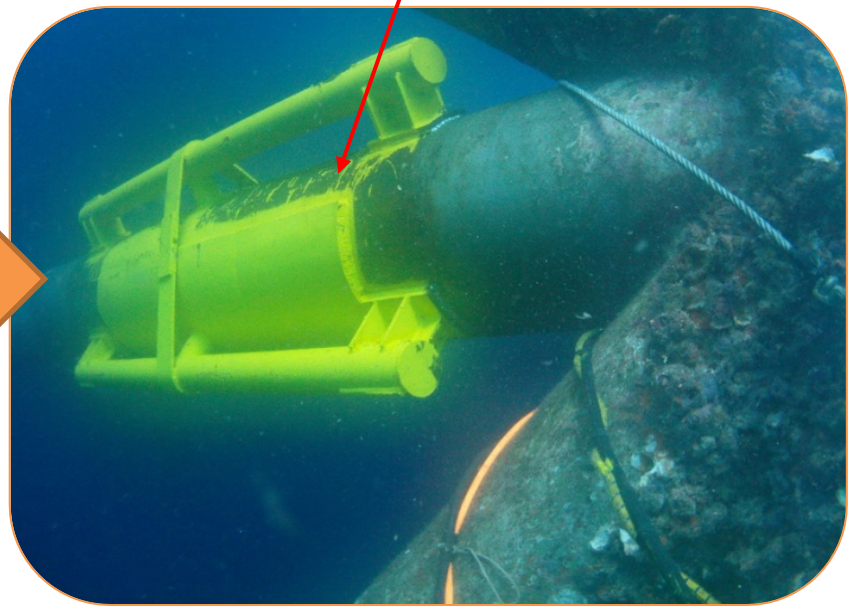
CASE STUDY: REPAIR OF DAMAGED MEMBER

Tear in member at 11 m of water depth



Habitat

After repair



TUBULAR GROUTING

TECHNIQUE TO STRENGTHEN MEMBERS UNDER COMPRESSION

TUBULAR GROUTING

Repair/Strengthening method used as a solution for;

1. Dent/Buckling
2. Corrosion
3. Inadequate static strength
4. Inadequate fatigue strength (high load)

This repair methodology

- Increases **axial compressive strength** of the member
- Improves overall **member strength and stability**
- Improves **strength at a tubular joint**

GROUTED CLAMPS

GROUTED CLAMP TECHNIQUE TO STRENGTHEN NODAL JOINTS

GROUTED CLAMPS

REPAIR & STRENGTHENING USING CLAMPS

(1) Common types:

- Member clamp – repairing/strengthening a damaged/under-strength member
- Nodal clamp – repairing/strengthening a damaged/under-strength joint

(2) A technique to connect new member to existing structure

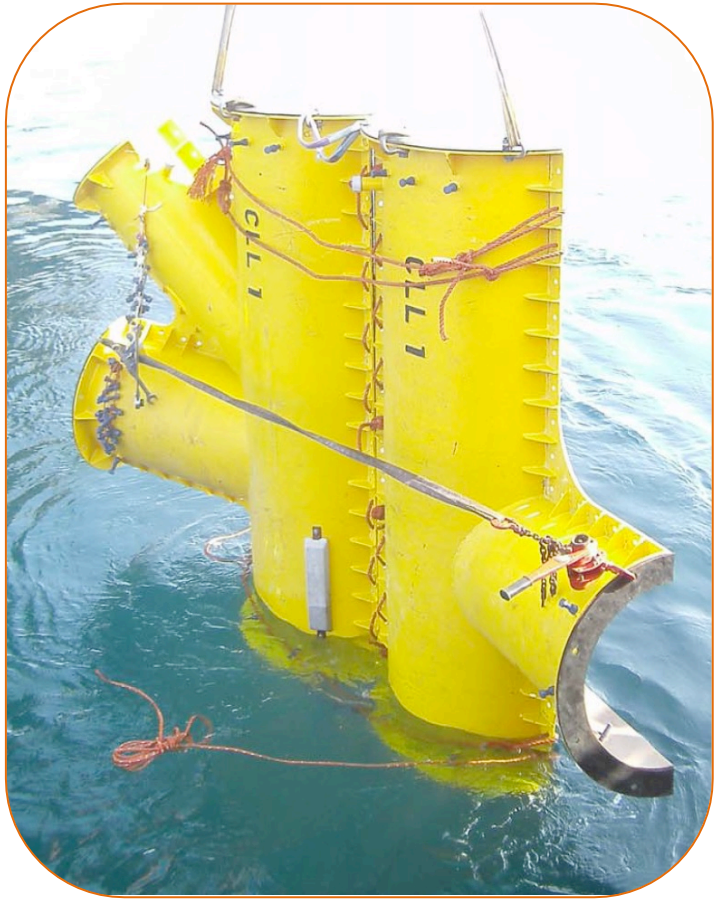
(3) Provides a length adjustment for a new or replacement member

(4) Also used as a means to support a new guide

GROUTED CLAMPS– NODE REPAIR

Clamps are used for strengthening and repair tubular members of joints or to connect tubular members. The common features among these clamps are that they are deployed in two or more pieces, are fastened by bolts, and typically surround a structural component, such as a joint or a member; the surrounded component is further denominated as the substrate component. However, a key distinction can be made on the basis of the function and effect of the bolts, resulting in two generic types of clamps: split sleeve clamps and pre-stressed clamps

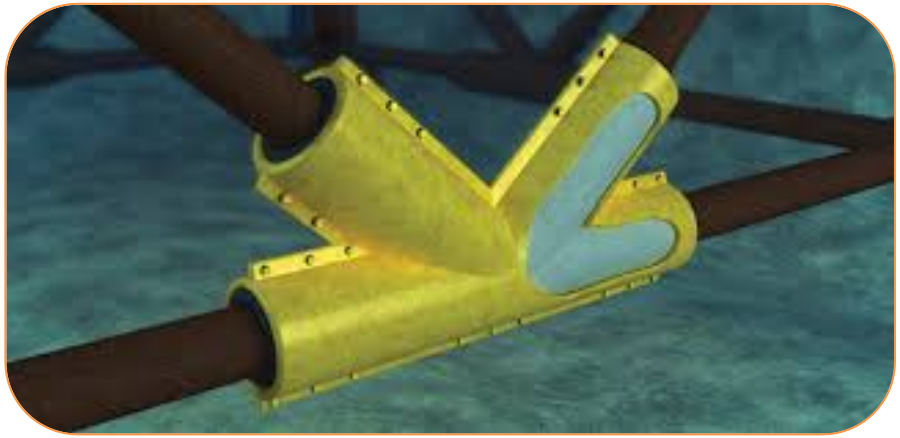
Several types of clamps have been successfully used, such as friction, grouted, and long-bolted clamps.



EXAMPLE REPAIR SOLUTION – NODE REPAIR

General

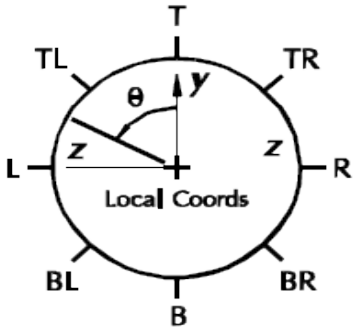
Structural global analysis of the jacket for fatigue design conditions has been performed using the SACS structural analysis package. SACS model is a beam element analysis, which is quite adequate for the design of the jacket members, but which is not capable of accurately model the detail of the connection and plate assembly; hence FEM model is utilized for SCF estimation.



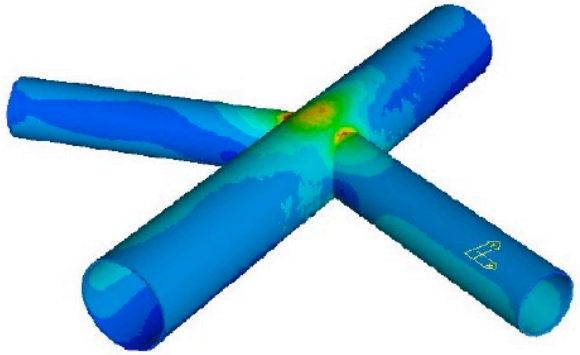
EXAMPLE REPAIR SOLUTION – NODE REPAIR

Methodology

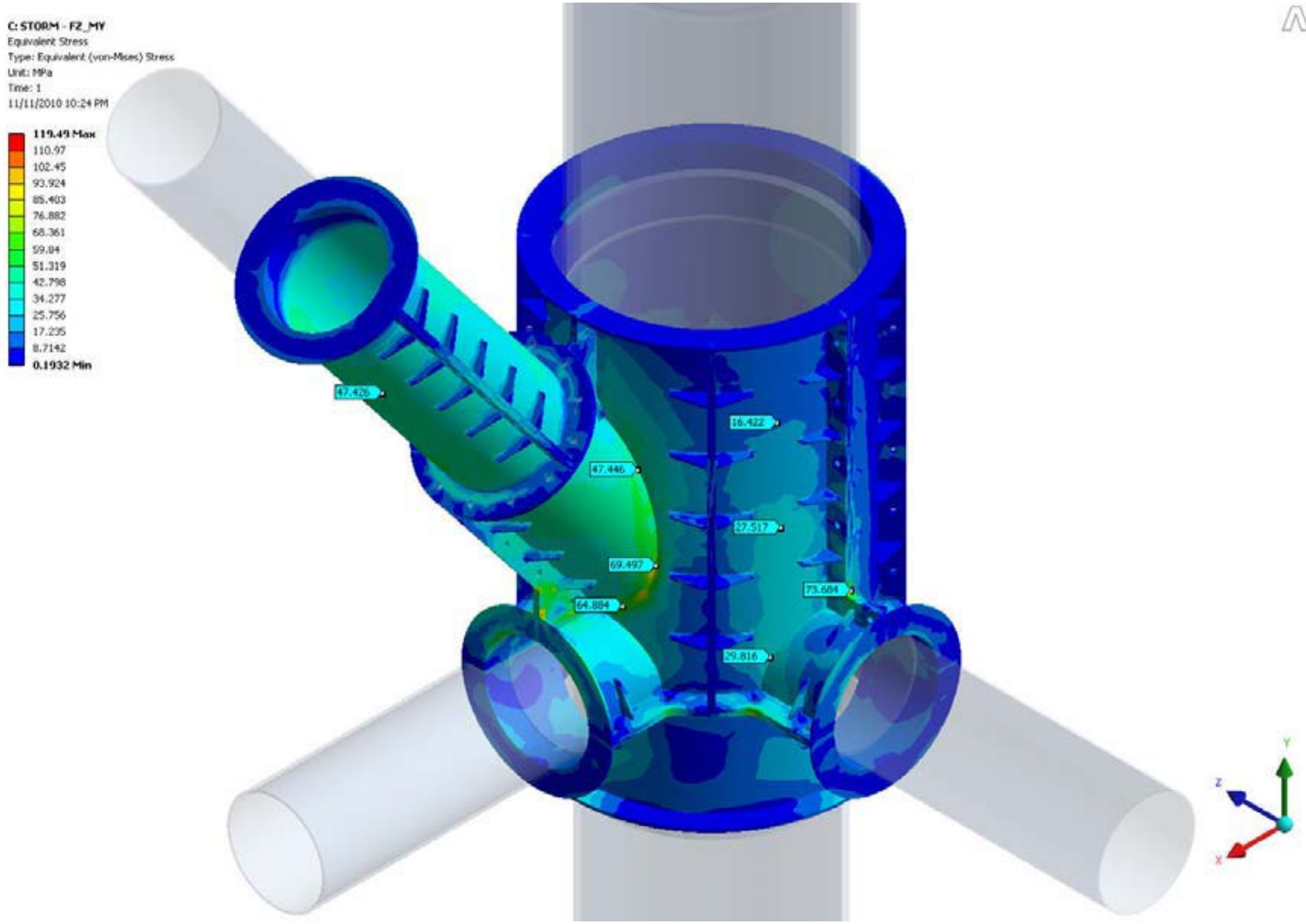
- SCF calculation is done in accordance in DNV RP C203.
- For axial SCF, brace is applied with force equivalent to axial nominal stress calculated by brace cross section area.
- For bending SCF, brace is applied with force equivalent to bending nominal stress calculated by brace moment of inertia.
- In the DNV approach for brace-chord connection, maximum stresses are extracted all around the brace footprint, since due to the complexity of the structure the location of maximum stress is unlikely to be exactly at one of the eight locations shown below.



- Recommended stress evaluation points in accordance with DNV criteria are located at distances 0.5t and 1.5t away from the hot spot, where t is the plate thickness at the member. These locations are also denoted as stress read out points.
- Using the read out points at 0.5t and 1.5t, a linear extrapolation is performed to calculate SCF at the hot-spot location.



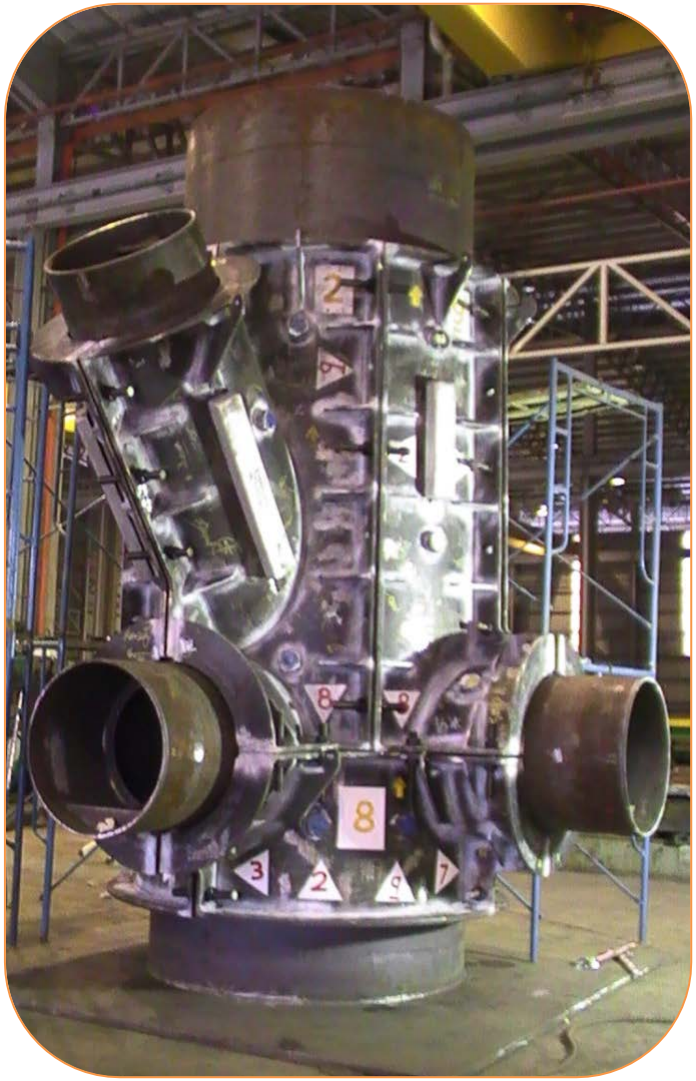
EXAMPLE REPAIR SOLUTION – NODE REPAIR



CASE STUDY : CPP, Malaysia

Challenge

Repairs on cracks appearing on the junction weld between vertical diagonal member and main leg A1 at Northeast corner of the steel jacket structure at seabed level EL (-) 53.5m, without suspending production



Solution

Sealed the cracks by welding of plates around the node and further enhance the sealing by applying grout-filled clamps of 2 meters height on the vertical diagonal member and 3 meters height through its connection on the jacket leg

Sequence of work:

- Excavation of seabed & cleaning on node surface,
- Underwater wet welding of 9 pieces Shear Key on VDM.
- Divers were used to install 14 pieces of individual clamp
- Clamps tightened by using hydro tight equipment.
- "Green-Dye" test to ensure no leaks in the clamp
- grouting works carried out to seal the clamps.

MARINE GROWTH PREVENTERS (MGP)

REDUCE PLATFORM HYDRODYNAMIC LOADING WITH MARINE GROWTH PREVENTION TECHNOLGY

REDUCE HYDRODYNAMIC LOADING WITH MGP

MARINE GROWTH + WAVES

= **ADDS SIGNIFICANT LOAD**

= **SHORTENS PLATFORM LIFE**

= **INCREASES RISK OF FAILURE**

1. Strengthening of jacket can achieved by:

   - **Load reduction** or

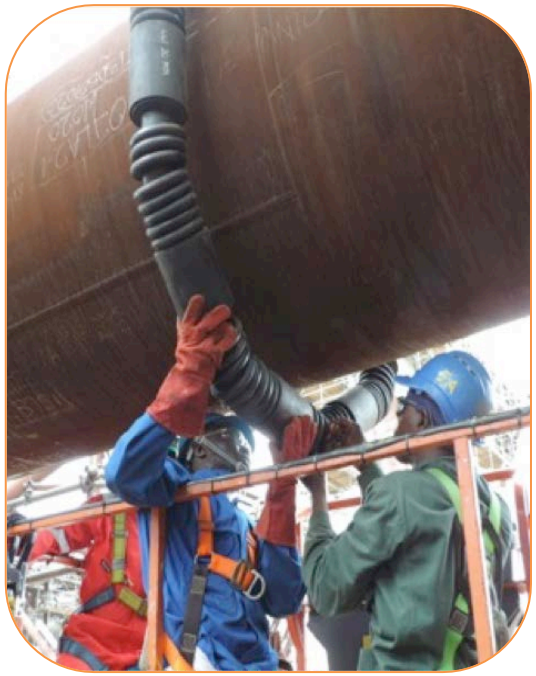
   - **Structural strengthening**

2. **Reduction of marine growth thickness is a load reduction solution**
3. This can be achieved through a, **permanent change in marine growth profile**
4. The combination between thick marine growth settlement and significant wave loading contributes a huge level of environmental loads on offshore platforms.

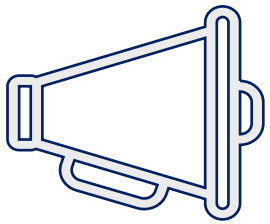
REDUCE HYDRODYNAMIC LOADING WITH MGP

WITH THE PATENTED MGP-*i* SOLUTION

- ✓ A **30-year old** technology developed and owned by **IEV**
- ✓ Targets marine fouling in the **wave zone**
- ✓ Cleans and prevents marine growth in **one single deployment**
- ✓ Powered solely by **ocean energy**
- ✓ Can be applied to all marine structures, **new or old**
- ✓ **Eliminates** and/or significantly reduces the need for periodical cleaning
- ✓ **No diver / ROV** intervention
- ✓ **No structural modification** required
- ✓ Allows **incremental marine growth thickness below the wave zone**



API RP 2SIM RECOMMENDED PRACTICE



The method of cleaning by IEV's MGP was **recognised** in API RP 2SIM Recommended Practice for Structural Integrity Management of Fixed Offshore Structures, as a measure to reduce hydrodynamic loads

"Such measures may include installation of sliding marine growth preventers and/or adding periodical removal to the SIM program for the platform"

Section 13.3.4.2.3, pg 53, API RP 2SIM, First Edition of November 2014 publication

TRACK RECORD

MARINE GROWTH CONTROL - TRACK RECORD

Year	Client / Operator	Location	Project Description	Quantity	Remarks
2020	Kerth Port Sdn Bhd	Malaysia	MGC for Kerth Port (Phase 3) Removal and Prevention Jetty	50	Onshore Installation
2019	Kebabangan Petroleum Operating Company (KPOC)	Malaysia	MGC for KBB Platform Removal and Prevention 1 existing platform	48	Offshore Installation
2019	Sabah Port Sdn Bhd	Malaysia	MGC for Sepangar Bay Terminal Jetty Removal and Prevention Jetty	178	Onshore Installation
2019	PetroVietnam Exploration Production Corporation Ltd (PVEP)	Vietnam	MGC for Thang Long and Dong Do Jackets Removal and Prevention 2 existing platforms	54	Offshore Installation
2019	Kerth Port Sdn Bhd	Malaysia	MGC for Kerth Port (Phase 2) Removal and Prevention Jetty	60	Onshore Installation
2019	Hoang Long Joint Operating Company (HLJOC)	Vietnam	MGC for TGT-H1 and CNV Wellhead Jackets Removal and Prevention 2 existing platforms	80	Offshore Installation
2019	Fly Lot Investment Co. Limited	Vietnam	MGC for Jacket-02, Jacket-07 and Jacket-08 Removal and Prevention 3 existing platforms	38	Offshore Installation
2019	Kerth Port Sdn Bhd	Malaysia	MGC for Kerth Port Removal and Prevention Jetty	50	Onshore Installation
2018	Bintulu Port Sdn Bhd	Malaysia	MGC for Bintulu Port (Pilot Project) Removal and Prevention Jetty	2	Onshore Installation
2018	CNOOC	China	MGC for CFD11-6 Platform (Pilot Project) Removal and Prevention 1 newly fabricated platform	3	Onshore Installation
2018	Civil Engineering Department Ministry of Defence	Vietnam	MGC FOR DK14 & DK15 PLATFORMS Removal and Prevention 2 existing platforms	34	Offshore Installation
2017	Premier Oil, Indonesia	Indonesia	MGC FOR ANOA AND AGX PLATFORM (PILOT PROJECT) Removal and Prevention 2 existing platforms	8	Offshore Installation
2017	Pateh Sanat Kimia Co.	Iran	MGC FOR P17 PLATFORM (PILOT PROJECT) Removal and Prevention 1 existing platform	2	Offshore Installation
2017	Abu Dhabi Marine Operating Company (ADMA-OPCO)	Abu Dhabi	MGC FOR ZK280 PLATFORM (PILOT PROJECT) Removal and Prevention 1 existing platform	2	Offshore Installation
2017	PTSC M&C LTD. CO.	India	MGC for Daman Development Project (Season 2) - B12-17 & B12-11 Platform Removal and Prevention 2 existing platform	4	Offshore Installation
2017	L&T Hydrocarbon Engineering Limited / ONGC	India	MGC for Neelam Re-Development Project - NLG Platform Removal and Prevention 1 newly fabricated platform	49	Onshore Installation
2017	Murphy Sarawak Oil Co. Ltd	Malaysia	MGC for Serendah Oil And Gas Development Project (Pilot Project) Removal and Prevention 2 caissons	2	Offshore Installation
2017	Royal Malaysian Navy	Malaysia	MGC for TLDM- Pusat Hidrografi Nasional Jetty (Pilot Project) Removal and Prevention Jetty	2	Onshore Installation
2017	Freeport McMoran	California	MGC for Irene Platform (Pilot Project) Removal and Prevention 1 existing platform	3	Offshore Installation
2017	Dagang ZhaoDong Oil Company of Petrochina	China	MGC for Offshore Conductor Removal and Prevention 15 existing conductor	15	Offshore Installation

Over 36,000 products installed since 1990

The latest generation MGP-*i*

A patented **typhoon-proof** and **self-cleaning** Marine Growth Preventer engineered to operate in extreme ocean environments and can **remove** and permanently **prevent** marine growth in a **single deployment**.

RESULT 1

Marine Growth Prevention Sensitivity Study (MGPSS) results

IMPROVEMENT in Fatigue Life and Reserved Strength Ratio

Joint Fatigue Life improvement was up to **3 folds** and Reserved Strength Ratio (RSR) improvement was up to **11.1%** in evaluating MGP-*i* benefits for platforms in the Middle East and South East Asia.

Platform Loc.	RSR With Marine Growth	RSR w/MGP-i	RSR(%) Improvement
Middle East	1.71	1.80	5.3
S.E. Asia	6.20	6.89	11.1

Platform Location	No of Joints Assessed	Fatigue Life Range (Years)		Fatigue Life Improvement
		With Marine Growth	MGP-i	
Middle East	16	13 – 109	26 – 345	2 – 3 folds
S.E. Asia	6	14 - 165	35 - 212	1.2 – 3 folds

RESULT 2

Marine Growth Prevention Sensitivity Study (MGPSS) results

REDUCTION in Probability of Failure

The reduction in probability of failure (PoF) due to fatigue and platform collapse ranges between 4 and 8 folds from the MGP- i application to a platform investigated for the Middle East.

The PoF figures in the table were derived as per the methodology prescribed in OTC-7755 - Risk Analysis Methodology for Developing Design and Assessment Criteria for Fixed Offshore Structures.

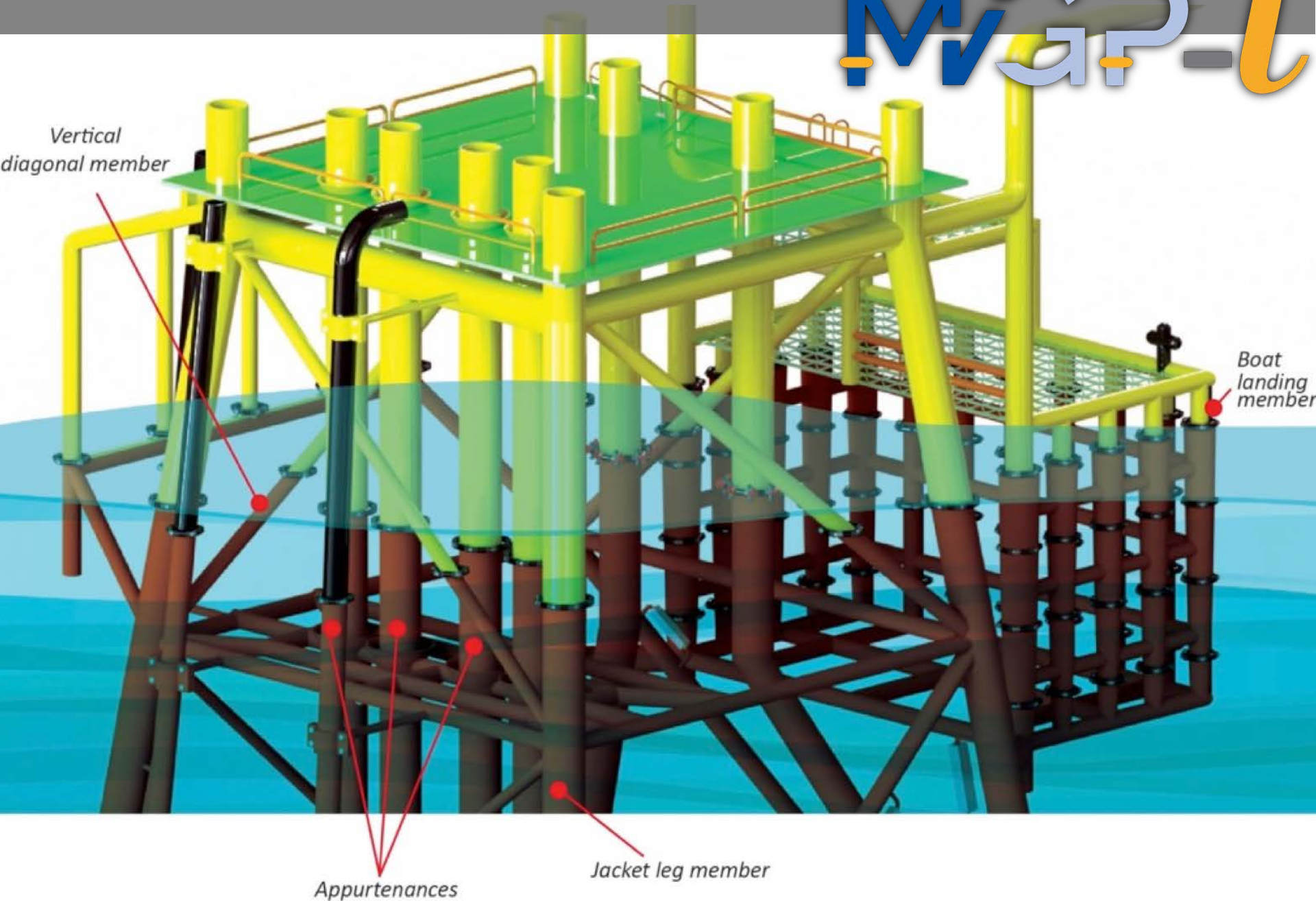
Joint No.	Fatigue PoF		RSR PoF		PoF (Original)	PoF w/MP	PoF Reduction
	Original	w/MP	Original	w/MP	$P_{f\text{-}acc} \times P_{f\text{-}collapse}$	$P_{f\text{-}acc} \times P_{f\text{-}collapse}$	
501L	3.04E-1	7.83E-2	1.65E-3	1.09E-3	5.02E-4	8.51E-5	6 folds.
419L	2.32E-1	5.52E-2	1.65E-3	1.09E-3	3.83E-4	6.00E-5	6 folds.
599L	2.02E-1	3.87E-2	1.65E-3	1.09E-3	3.34E-4	4.21E-5	8 folds.
581L	1.42E-1	4.52E-2	1.65E-3	1.09E-3	2.35E-4	4.91E-5	4 folds.
519L	7.70E-2	1.87E-2	1.65E-3	1.09E-3	1.27E-4	2.03E-5	6 folds.

DIVERLESS OFFSHORE INSTALLATION BY RAT TEAM

MGP-i

DIVERLESS OFFSHORE INSTALLATION

CONFIGURATION ON A 4-LEGGED PLATFORM



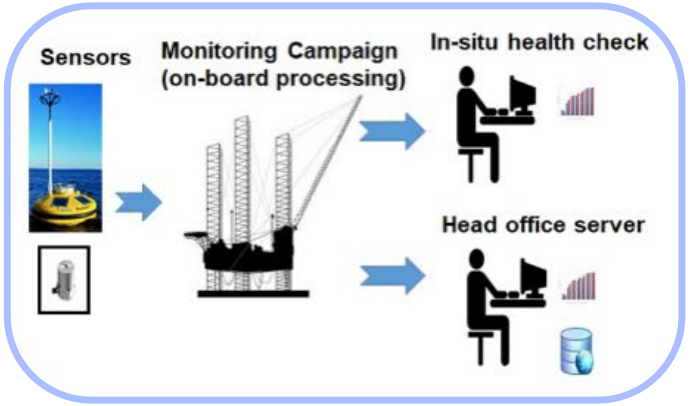
PHASE 3 - STRUCTURAL HEALTH MONITORING

In collaboration with UTP UNIVERSITI TEKNOLOGI PETRONAS

STRUCTURAL HEALTH MONITORING (SHM)

Pre-emptive Offshore Structural Evaluation and Integrity DecisiOn Network - POSEIDON™

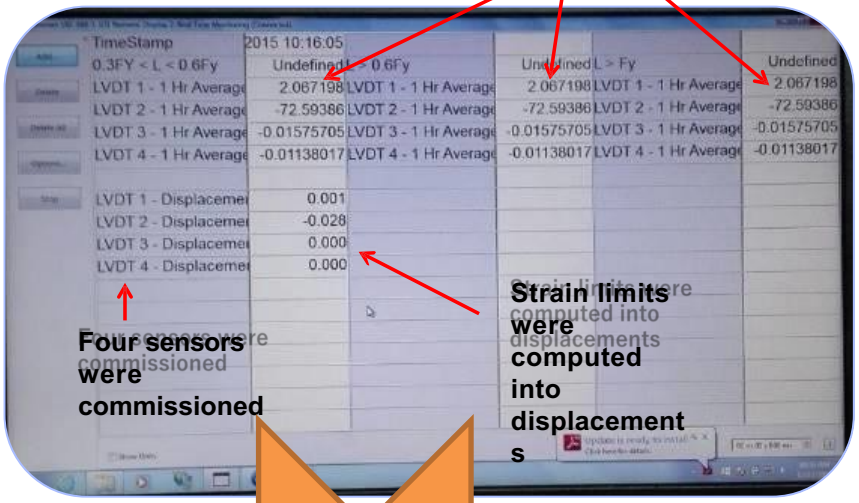
- ✓ A system consisting of **structural sensory arrays** and **data acquisition system**
- ✓ Integrated via **a software platform** that incorporates research solutions i.e. expert decision system.
- ✓ Monitoring is **autonomou**s from topside and onshore – thus facilitating instant decision-making. Defects monitored **10 times per second, 24-7**
- ✓ **Alarm system** is integrated onboard with **analytical verification**.
- ✓ Built in accordance to **offshore and industry standards** (ISO, ASTM, API)
- ✓ Can be **customised** to suit client requirement

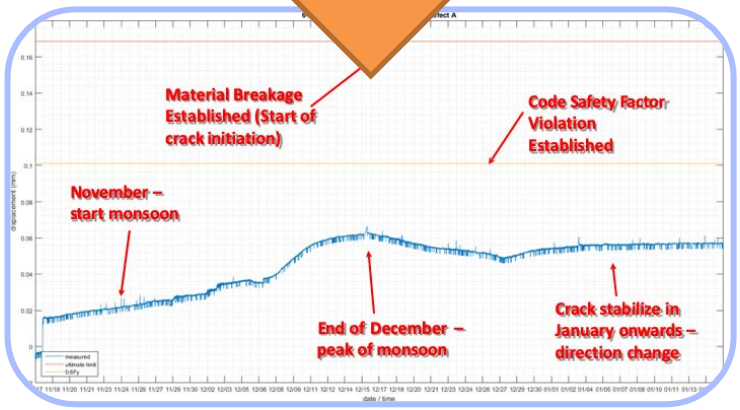


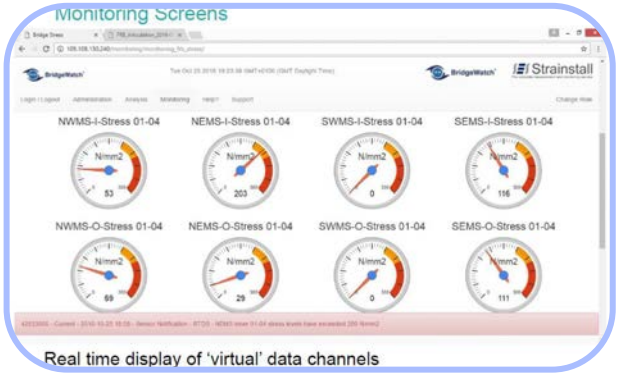
SHM – APPLICATIONS TO STRUCTURAL REPAIRS

- ✓ **POSEIDON™** can be used to determine structural defects such as cracks would propagate and/or affect the integrity of platform structure
- ✓ **POSEIDON** can measure the effects of the repair by monitoring the platform natural frequency pre and post repair programs.
- ✓ **POSEIDON** can monitor if the repairs solution implemented provide long term structural adequacy to the platform or further remedy action would be required.

STRUCTURAL HEALTH MONITORING (SHM)







SHM : CASE STUDIES

Structure had undergone significant platform swaying due to a broken shim plate, endangering the riser structure

Case Study: Minimal structure monitoring Sarawak Operations

Minimal structure had undergone severe strucrural motion. Monitoring campaign had set out 2 objectives:

a. Determination of in-situ structural performance (100-year wave condition)

b. Determination of riser integrity / stifness due to a failed shim plate (averting catastrophic HSE incident

To monitor structural crack propagation at the legs - 63 meters underwater

Case Study: Cracked MOPU leg (subsea) Peninsular Malaysia Operations

Key higlights of campaign:

a. Monitoring of cracked MOPU tubular leg in-lieu of costly underwating diving inspection

b. Accepted by class audit society as an alternative method of autonomous inspection

c. Cracked data was streamed real-time to client head offices

WHY IEV?

We are capable of providing a **full range of jacket repair and strengthening** solutions

We can perform **scope optimisation and recommend the optimum repair methodology** for each damage

We offer a **complete system**, from structural analysis to design, fabrication, installation, reporting and structural health monitoring (optional)

We can offer a **highly cost-effective and proprietary solution for environment load reduction** as a stand-alone or part of the jacket strengthening solutions.

We always optimise cost by **maximizing localisation programs**

We follow all **applicable standards** in delivering our engineering services

We can supply **ultra high strength grouting materials** to meet client specifications

Our combined subsea grouting global experience spans over **15 years**

We are an experienced **subsea and EPC contractor**

We are supported by several experienced and competent strategic alliance partners and can mobilise multiple spreads to meet tight project schedule.

Our Strategic Alliance Partners

core Grouting Services

ABYSSAL TECHNOLOGIES

UTP UNIVERSITI TEKNOLOGI PETRONAS

YUG

"COMBINING DISRUPTIVE TECHNOLOGIES AND PROVEN ENGINEERING CAPABILITIES"

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