FOUNDOCEAN

Strengthening, Modification and Repair Solutions for Offshore Assets

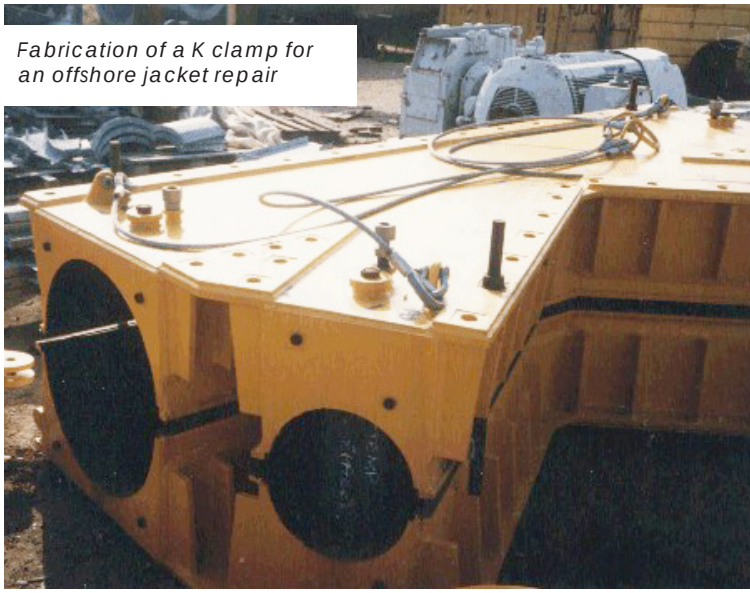
The experts in life extension solutions for ageing or damaged structures

Why assets may need strengthening, modifying or repairing

There are many reasons why an asset may need to undergo strengthening, modification or repair intervention. Findings from routine inspections can uncover damage or fabrication defects requiring repairs. Alternatively, the need for additional conductors, or life extension solutions to enable a field to continue production after its intended design life could result in a requirement for strengthening or modification.

Common issues faced by offshore structures:

- **Corrosion of members and/or joints**
- **Fatigue damage**
- **Dented members**
- **Need for increased fatigue life**
- **Life extension requirements**



Fabrication of a K clamp for an offshore jacket repair

Design code updates
The lessons learned and better understanding of environmental loads of decades-old offshore structures has shown that design codes have needed updating. For example, the wave loads which offshore installations need to withstand have increased - dramatically in some cases.

Other loading parameters and marine growth allowances are better understood leading to design-code updates.

Design error
Missed critical loads or load combinations such as overlooked transportation fatigue, incorrect structural modelling or poor detailing are examples of design error.

Referencing structural designs from other regions can also lead to design errors, with primary loadings different between, for example, the Gulf of Mexico where hurricanes are prevalent versus the North Sea where fatigue due to wave loadings is the priority.

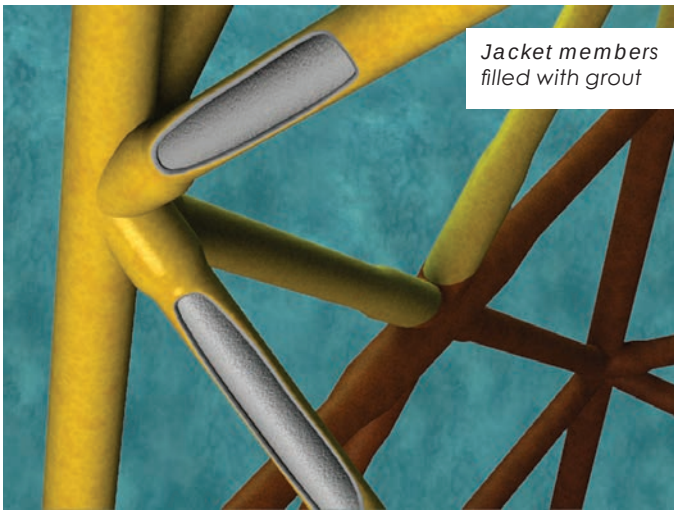
Fabrication defect
Accurate conversion of a design from drawing to reality is critical. Errors can occur when for example welds are poorly made or are misaligned, steel properties are out-of-specification or construction access is tight. All of these can contribute to over-stressed members and joints.

Damage
Jackets can be damaged during loadout, transportation and installation, causing weakened welds or dented members.

Once in situ, the structure is susceptible to objects that are accidentally dropped overboard, causing damage to the jacket on their way to the seabed. Ship impacts can typically result in bent or buckled members, or crack developments at member/joint connections.

Fatigue
Fatigue damage typically takes the form of cracks at the end of members where they frame into joints. The design of early jackets was heavily dependent on experience in the Gulf of Mexico. In the North Sea, these designs are unable to withstand the 6 million wave loadings per year. Many structures, or some component of them, have required fatigue damage repairs, or have needed to be strengthened to prevent anticipated damage.

Corrosion
General excessive corrosion can result from an under-designed or failed cathodic protection system, but localised corrosion can occur for example due to galvanic corrosion as is the case when carbon steel caissons house stainless steel pump or strainer components. In either cases, thinning or perforations of the carbon steel can occur.



Jacket members filled with grout

GROUT FILLING

Grouting a member offers the advantage of not increasing member diameter and therefore wave loading.

Filling a tubular member with grout may be carried out for one or more of the following reasons:

- to increase axial compressive (squash) strength of the member
- to improve overall member stability and resistance to buckling
- to improve strength or reduce the stress concentration factor (SCF) at a tubular joint chord.

Member grout filling

Where members may have suffered local buckling, dents or bends during installation or once in-situ by a vessel or dropped object, filling the member with grout provides it with incremental compression loading capacity. This technique is also used to increase the capacity of members in vulnerable areas (e.g. adjacent to boat landings) to resist local damage.

Joint grout filling

Filling joints with grout leads to reduced chord wall deformations and results in increased fatigue resistance.

Pile-Leg annulus grout filling

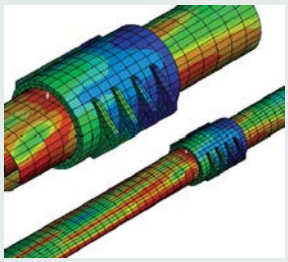
Filling the annulus between a pile and leg with grout forms a double skin member with increased strength and fatigue resistance at incoming brace connections.

YOUR EXPERIENCED SMR DESIGN PARTNER

FoundOcean is experienced in designing an extensive catalogue of SMR techniques and fully understands their merits and challenges, as well as their effect on an asset's overall structural integrity. We understand that every structure is unique and that the correct choice of SMR technique is crucial to providing a cost effective and reliable long-term solution.

Offshore work, particularly subsea work, can be expensive and risky, and our key objective is to ensure ease of installation and minimum offshore working time, with safety at all times.

FoundOcean offers either our full turnkey solution that includes structural analysis through to the offshore installation of the solution, or alternatively, one of several individual modules depending on your specific requirements.



Modules includes:

- Structural analyses
- Identification and selection of optimum SMR technique(s)
- FEED and detailed design of SMR scheme
- Certification Authority approvals
- Construction support
- Offshore execution/supervision

These specialist skills are a result of our active involvement in developing SMR designs through R&D programmes, and many years of global experience in SMR schemes.

CLAMPING

There are many types of structural clamp, each type having its own merits according to the intended application it is designed to solve. Some are designed specifically to carry load whereas others are designed to provide stability. If a tubular member is dented or requires strengthening, there are a number of clamping options. A clamped connection is typically fabricated in two sections, split to accommodate installation around an existing member or joint.

Unstressed grouted connection

The annular space created by the clamp is filled with grout. Bolts are fully tightened prior to injection of grout into the annular space between the sleeve and the existing tubular member: the grout/steel interface is not therefore stressed.

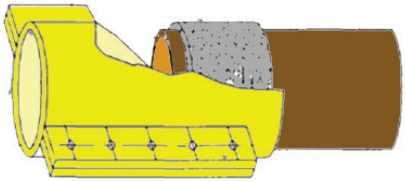
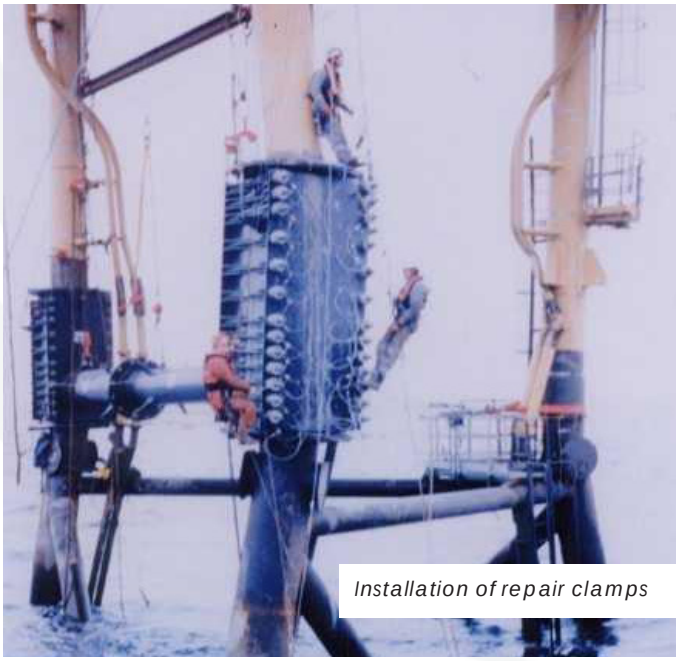


Figure 1: Unstressed grouted connection

Using grout allows for larger annular tolerances, along damaged or member imperfections, enabling even load transfer along the repair. The means of load transfer is via bond and interlock between the grout/steel interface. Although bond and interlock may be sufficient in certain conditions, it is often necessary to use a long connection, to generate sufficient load transfer capacity.



Installation of repair clamps

Stressed mechanical clamp

Stressed mechanical clamps provide a connection between two concentric tubulars. This type of clamp relies on the friction capacity of the interface between the two tubulars for load transfer. The outer saddles are stressed together to generate a force normal to the friction surface. This is created through long bolts which apply load to the saddle halves that produce friction grip onto the base member.

Stressed grouted clamp

The stressed grouted clamp is a hybrid of the unstressed grouted connection and stressed mechanical clamp. Cementitious material is placed into the annular space between the tubulars and once it reaches a predefined strength an external force is applied by tightening the long studbolts holding the casings together, stressing the grout. Base member obstructions such as weld beads or small doubler plates can be accommodated within the grout annulus.

The strength of a stressed grouted clamp comes from a combination of plain pipe bond and grout/steel friction that develops from compressive radial stress at the grout-to-tubular member interface.

Stressed grouted clamps exhibit high strength-to-length ratio and combined with its ability to absorb significant tolerances, make this repair technique very popular.

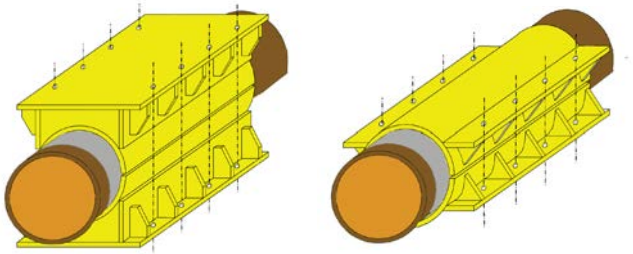


Figure 2: Stressed grouted connections

Stressed elastomer-lined clamp

Much like the stressed grouted clamp in design, however the inside of the clamp saddle is lined with an elastomer material, creating the friction-based connection. The long studbolts holding the casings together are tightened, stressing the connection.

The strength of an elastomer-lined clamp is significantly lower than that of a stressed grouted clamp because of the low stiffness of elastomer lining compared to that of steel.

COMPARISON OF ASSOCIATED DEMANDS

COMPARING SMR SOLUTIONS

Not all techniques work for all problems.

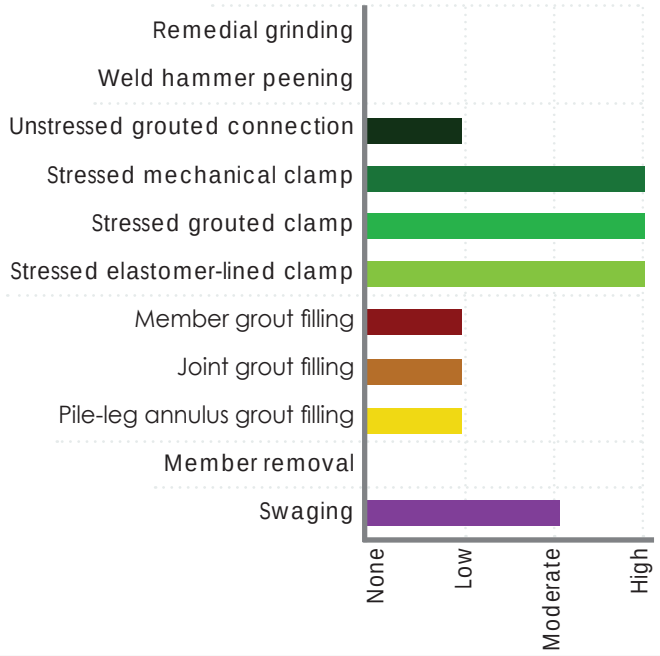
Once a range of possible SMR techniques have been identified these then have to be assessed relative to each other to determine the optimum solution for the project factors.

These graphs facilitate identification of common factors which should be considered when selecting possible SMR design solutions.

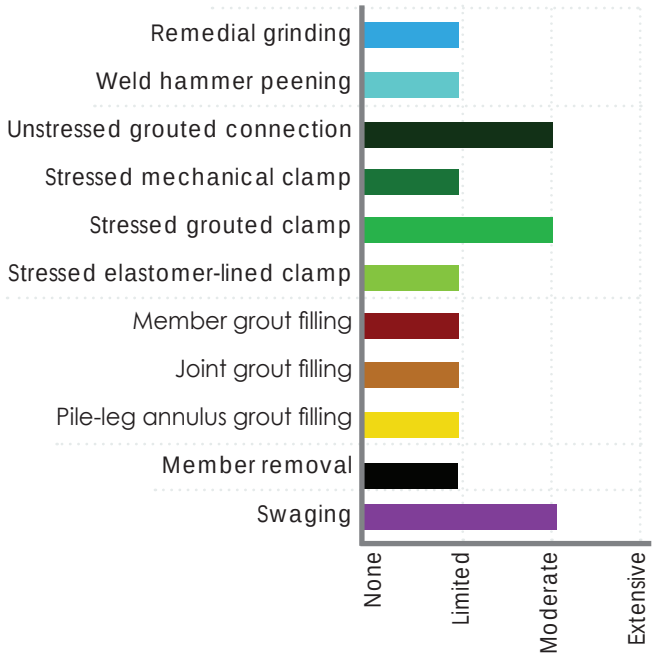
As experts in life extension solutions for ageing or damaged structures, FoundOcean considers these, amongst other factors, when advising clients on their options.

>> For further information about our full range of SMR solutions, visit www.foundocean.com or call us on +44 1628 567 000

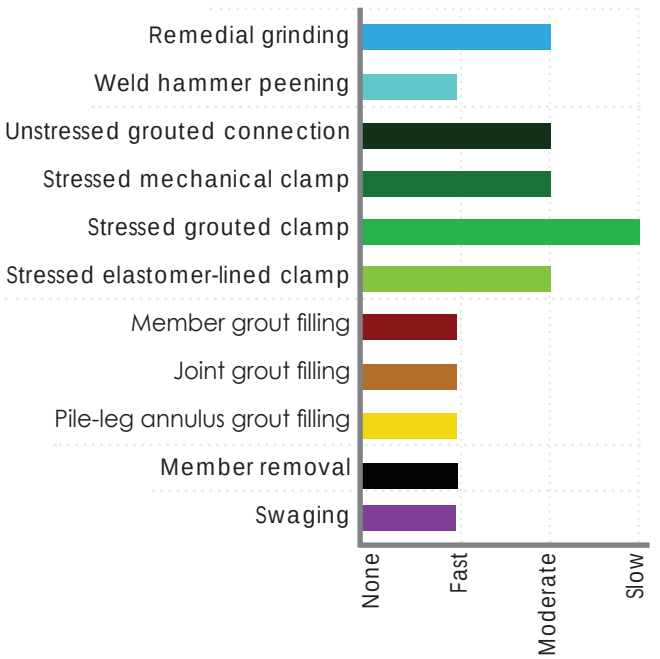
Onshore Fabrication Costs



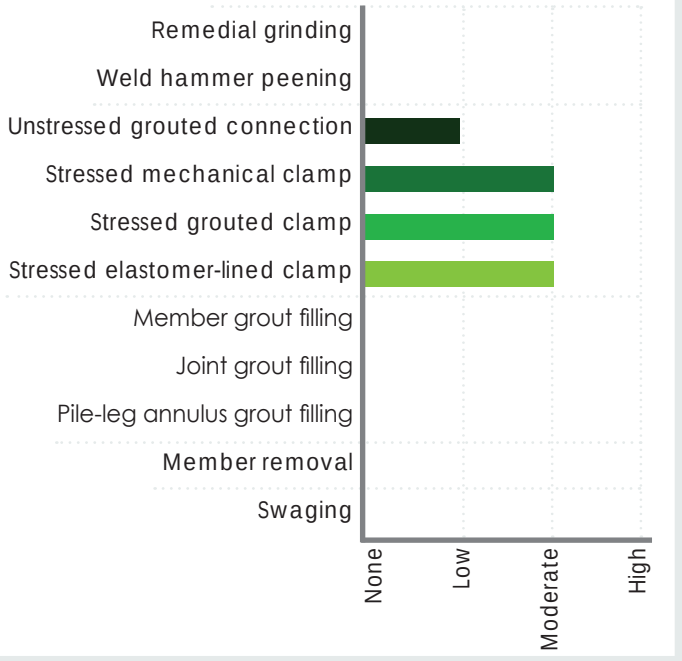
Offshore Installation Equipment



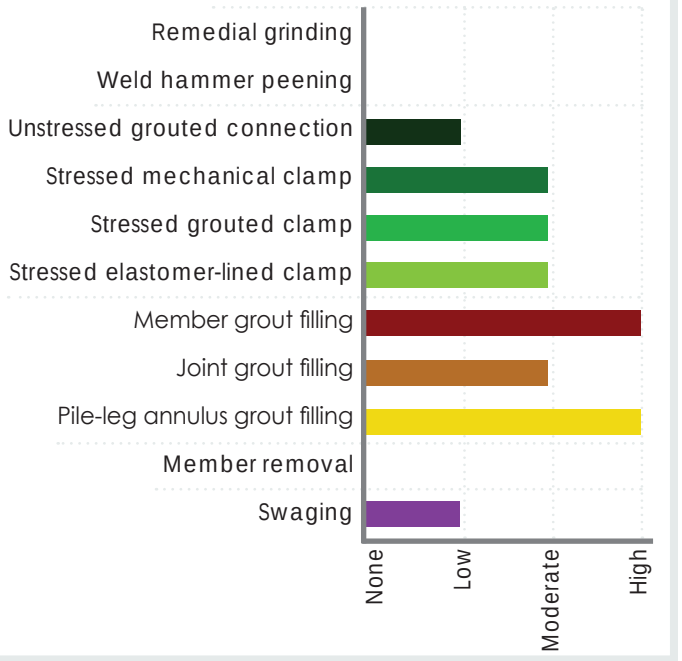
Offshore Installation Timescales



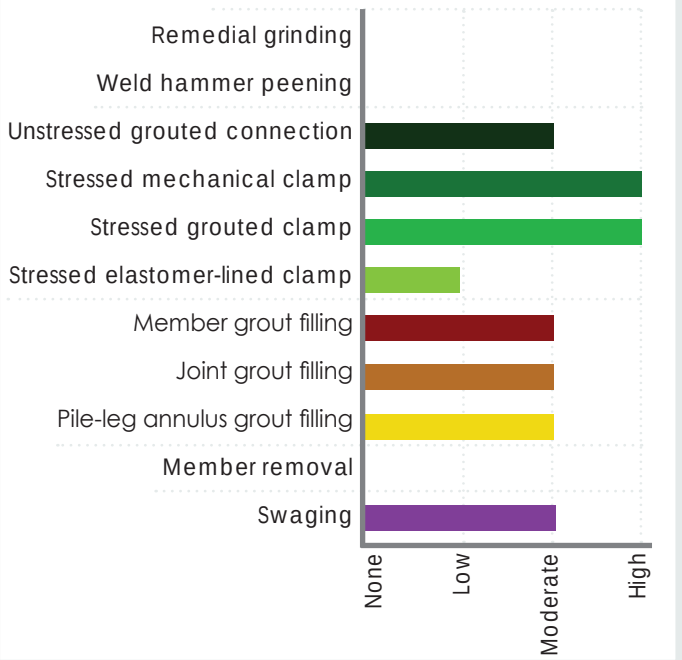
Wave Load Penalty



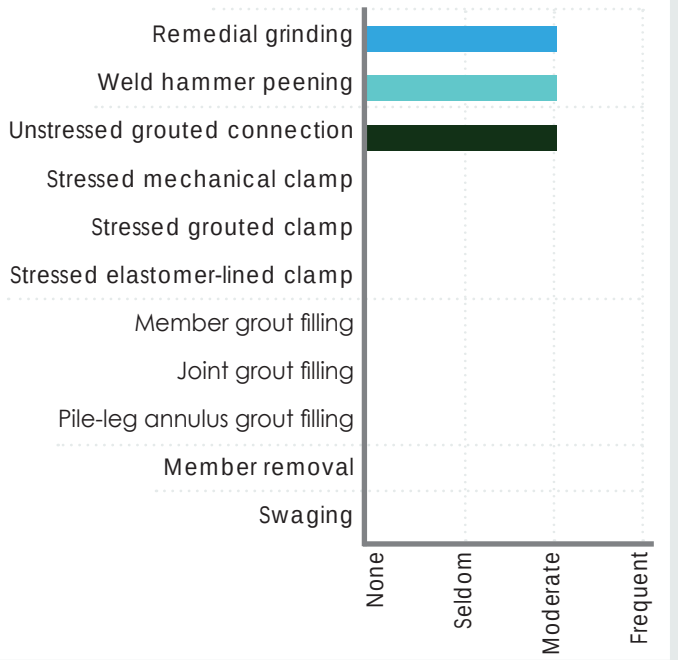
Weight Load Penalty



Load Carrying Capacity



Post-installation Inspection Requirements



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About FoundOcean

FoundOcean is the world's largest dedicated offshore construction grouting company with nearly 50 years' experience of subsea grouting for oil and gas and offshore renewables construction firms.

FoundOcean also provides life extension solutions for offshore structures which include inspection, repair, and maintenance services, marine growth control products, fabric formwork grout bags, and pipeline/cable support and protection services.

And that's why, to offshore installation contractors, FoundOcean is the subcontractor of choice to reduce their project risks.

www.foundocean.com