Subsea structures: current state of the art

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WOOD GROUP
KENNY

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Subsea structures are an integral part of an overall subsea field development as they support and protect vital pressure containing piping and equipment. Operational conditions, installation methods, ROV intervention and constructability should be considered for a robust subsea structure design.

Particular attention must be paid to constructability to reduce material and fabrication cost, and to installation requirements in order to reduce vessel time. While subsea developments are approaching ultra-deep waters and higher pressure and temperature systems are required, classical structural engineering techniques are still employed for the analysis and design of subsea structures.

Further to this, all structural solutions should be developed in accordance with recognized engineering principles; supported with competent professional examination and verified for accuracy, reliability, and suitability.

Since subsea developments are ever advancing into deeper water, innovative installation approaches and advancements in subsea structure designs are required to ensure projects are economically feasible and easily executed while considering health, safety, and the environment.

The following are examples of some challenges that are encountered in these deep/ultra-deep water environments:

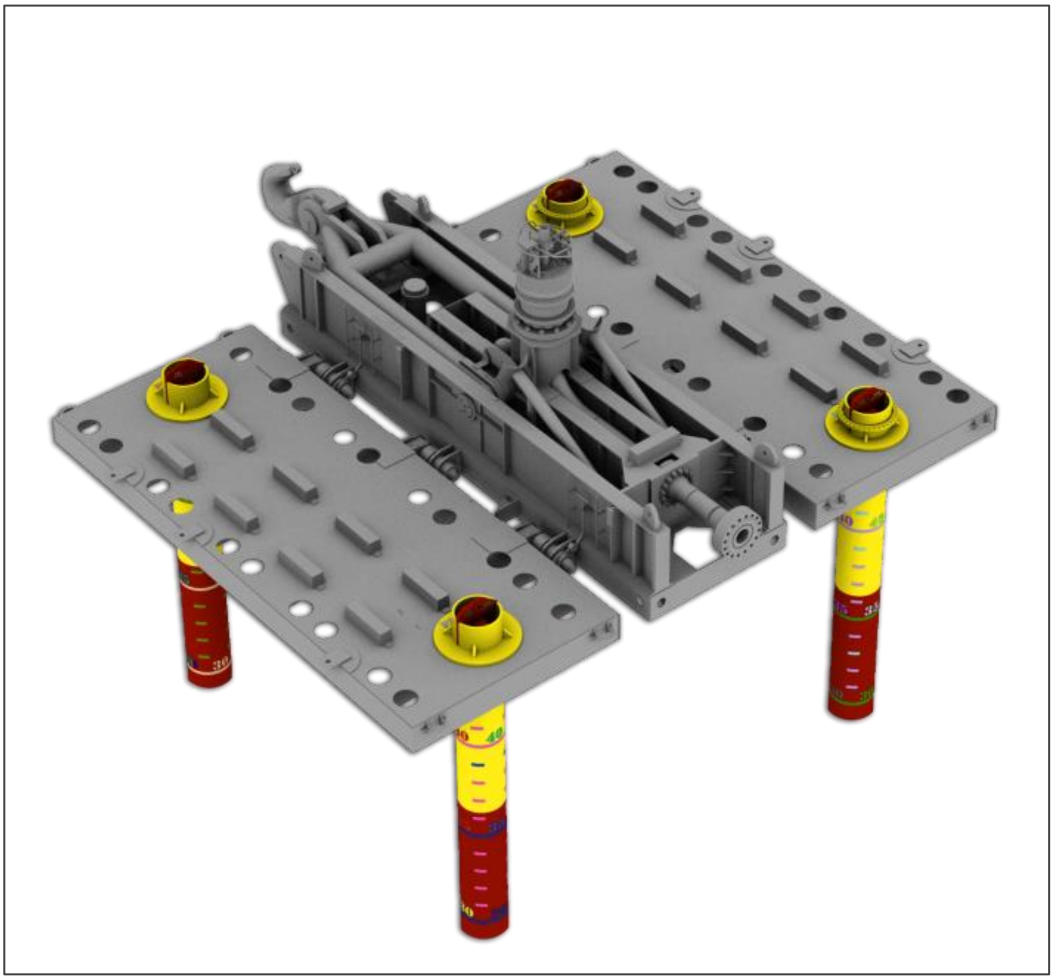
- Higher flowline/pipeline expansion forces
- Increased riser/flowline/pipeline walking displacements
- Installation of larger PLETs/PLEMs due to increased lay tensions in deeper water
- Designing rigid jumpers to resist ever-increasing flowline/pipeline expansions
- Higher pressures and temperatures require larger and heavier components i.e. valves, connectors, line pipe, fittings, etc.

The following are some examples of novel installation approaches and innovative subsea structure designs that Wood Group Kenny has implemented to address the current challenges associated with the deep/ultra-deep water environments encountered in the new frontier of subsea field developments.

Pipeline end termination (PLET) retrofit holdback system

Axial pipeline forces can often exceed the sliding capacity of pipeline end terminations (PLETs). One such case was found in an existing development in the Gulf of Mexico. In lieu of installing suction piles to resist the pipeline axial forces, pin piles were installed through existing holes on a PLET mud mat. Although driven piles have been used in civil engineering applications for hundreds of years, they are not common in deep water environments due to the water depth limitations of subsea pile driving hammers. Another consideration for the use of pin piles is that sliding can be resisted in all directions along the horizontal plane. A suction pile anchoring system typically only anchors the pipeline in one direction.

The pin piles were installed by a static driven clump weight system. Lowering procedures and fine alignment were controlled by an ROV and vessel crane. Some of the advantages of using pin piles over commonly used suction piles include; lower installation weight, less deck space, and lower fabrication costs.



Rigid jumper installation without spreader bars

Wood Group Kenny designed a novel jumper lifting configuration which eliminates the necessity of spreader bars. The approach uses a pipe that acts as a brace between the two goose necks of the jumper. The pipe, or strong-back, is connected to the jumper via clamps. The main purpose of the strong-back system is to resist the compression forces induced by the rigging configuration and reduce the overall jumper deflection during lifting.

Some of the advantages gained by removing the spreader bar include; less rigging and lower overall rigging height (and hook height), lower overall jumper lifting weight, reduced vessel deck space requirements, and the elimination of spreader bar fabrication and qualification/testing requirements. This ultimately made offshore lifts safer by reducing the components to be handled, transported and installed. The strong-back installation approach has been executed successfully and safely in deep water Gulf of Mexico.

It should be noted that this jumper installation method is only suitable for connection systems that do not require a running tool.

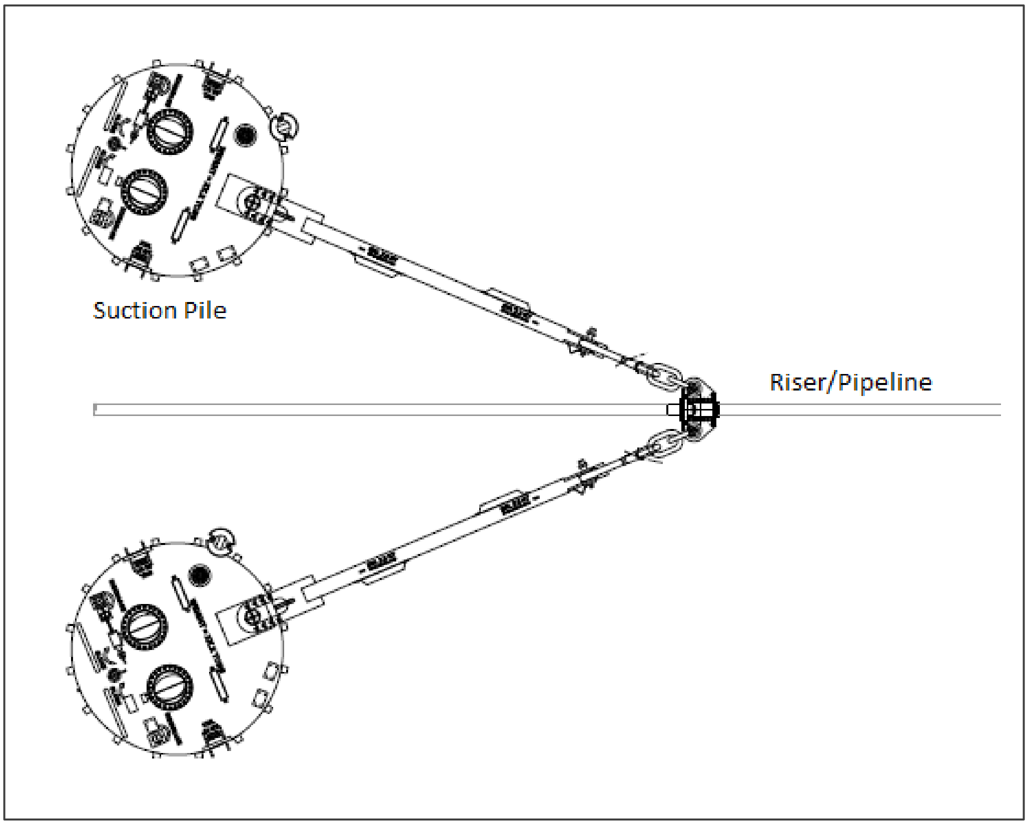
Riser base structure holdback system

Wood Group Kenny designed a riser base holdback system to resist high riser tensions while anchoring the riser base PLET in its required location. The suction pile was designed with a structure interface frame which captured the PLET upper module structure as well as accommodating for angular heading tolerance during riser initiation. The design served two purposes; initiation anchor for first end installation and holdback anchor to resist high riser tensions during host offset conditions.. Some of the advantages of the holdback system included:

- A single suction pile was required for both initiation and holdback anchor:
    - Less fabrication cost
    - Lower installation time
- No mud mat required:
    - Lower fabrication cost
    - Smaller vessel installation envelope
    - Lighter structure

Riser/flowline holdback system

A holdback system was required to resist riser/flowline tension and walking for a deep water Gulf of Mexico field. Two suction piles were installed adjacent to the flowline. The holdback force was transferred to the piles using a rigid member instead of chains/wires. The use of a rigid member circumvents the requirement of chain tightening occasionally required for holdback systems, thus reducing system complexity and ultimately installation time.

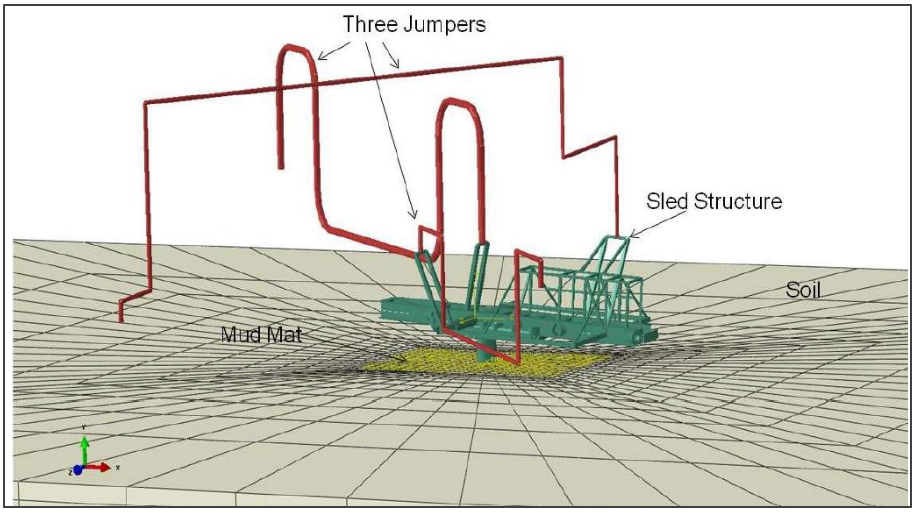


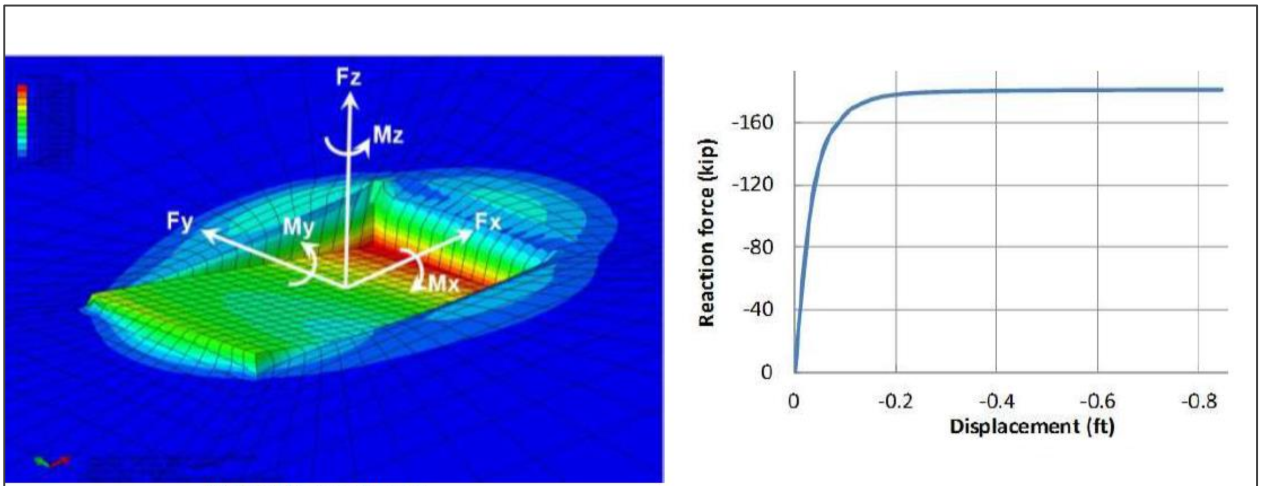
Brown field subsea structure foundation assessment

A new well was tied in to an existing field in the Gulf of Mexico. A foundation assessment of the existing subsea structure for the new jumper loads was required. The bearing capacity factor of safety computed using the classical bearing capacity analysis approach was below the allowable factor of safety as specified in the governing industry codes and standards.

In order to capture a more accurate soil/structure interaction and calculate a more accurate bearing capacity factor of safety, a full 3D finite element (FE) model of the soil, structure, pipeline and jumpers was built. The FE analysis required ramping up the temperature and pressure of the pipeline and jumpers to induce a bearing failure in the mud mat.

The factor of safety was then computed considering the ratio of the maximum applied force to structure weight. The updated factor of safety computed using the more advanced analysis approach was found to be greater than the conservative classical bearing capacity analysis approach.





(ABAQUS, von Mises)