

# MARINE CONCRETE STRUCTURES

Engineering services for concrete structures  
in hostile environments

Multiconsult

# A GLOBAL PRESENCE



CONCRETE  
STRUCTURES

Multiconsult is a global player in the oil, gas and renewable energy sector, offshore and onshore.

Multiconsult is a leader in design and engineering of marine offshore concrete structures for the Oil and Gas industry. For the last 40 years, we have been involved in the majority of gravity based and floating concrete structures.

- **Consulting and engineering with project management focus**
- **Strategic experience onshore, coast, sea front and offshore**
- **Cold climate and arctic conditions**
- **1550 employees**

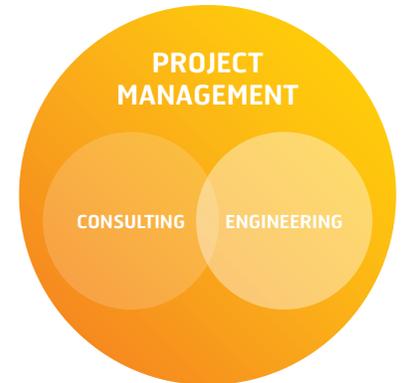
When the oil and gas projects moved north, Multiconsult developed in-house expertise in the area of Marine Concrete Engineering in cold climate. Today, we are serving projects in the Arctic regions of Norway, Russia and Canada.

Concrete structures have proven well suited for marine facilities in the oil and gas industry. Even in the most hostile offshore environments with extreme waves, ice loads, earthquakes and water pressures, and these structures are almost maintenance free.

A large portion of the offshore concrete structures have been developed, planned and built by Kvaerner with partners. Today, this Norwegian cluster represent a world class offshore concrete competence, covering concept development, engineering, material selection, construction and installations. As part of this industry and as a close partner with Kvaerner, Multiconsult has been heavily involved in the design of offshore concrete structures for more than 40 years. This long standing experience also enable Multiconsult to include experience from the many concrete platforms in operations in our design and engineering activities.

Multiconsult offer services related to all phases and disciplines required for engineering of offshore concrete structures. The company is well situated with several offices along the Arctic coastline of Norway, as well as an office on Svalbard and internationally.

**Photo:**  
(Statoil) Helge Hansen, Harald Pettersen, Øyvind Hagen, Kvaerner, Sakhalin Energy



# SERVICES BY MULTICONSULT

**Multiconsult offers development and design of various concrete structures for hostile marine environments. In addition to near shore structures, Multiconsult represents an extensive expertise in the development and design of offshore structures for the Oil and Gas industry. For these projects, Multiconsult offers services to the EPC contractors, and has operated as a close partner with Kvaerner and its predecessors for 40 years.**

## OBJECTS

- Gravity Base Structures (GBS)
- Offshore Liquefied Natural Gas (LNG) Terminals
- Tension Leg Platforms (TLP)
- Offshore foundations
- Concrete floaters
- Coastal concrete structure (Jetties)

## PROJECT PHASES

- Feasibility studies/Concept development
- Front-End Engineering Design (FEED)
- Detail engineering
- Follow-on engineering
- Site supervision
- As-built documentation

## SERVICES

- Soil investigation programs and geotechnical design
- Ice load simulations and abrasion of concrete facing dynamic ice drift
- Design of dry docks for construction
- Development and design of concrete structures from conceptual design to detail engineering
- Preparation of tender documents and technical specifications for the international market
- Follow-on engineering, engineering support on construction site, construction supervision
- Design evaluations of structures during operation
- Design verification and engineering support to client's engineering organization
- Design of mechanical outfitting
- Engineering management

## DISCIPLINES

- Soil mechanics
- Engineering geology
- Area planning and layout
- Civil engineering
- Environmental engineering
- Environmental loads
- Marine operations
- 3D-modelling
- Engineering management
- Site supervision





# CHALLENGES

**The Norwegian coast and the North Sea represent a number of engineering challenges. Concrete structures have a long track record in hostile marine environments along the Norwegian coast, and through the years extensive expertise in design solutions has been developed. The structures are located in remote areas, and are constructed and operated in challenging conditions with freezing temperatures, wind and waves.**

This expertise is the basis for designing large offshore concrete platforms for the oil and gas industry. The structures have operated the North Sea for 40 years with excellent service records. They are characterized by their ability to resist extreme loads, and the concrete structure need little or no maintenance.

The structures generally are shell and plate based, with great inherent structural strength. Combined with their ability to be floated out for operation, this has made them attractive for challenging environments worldwide.



# TECHNOLOGY

**Concrete platforms intended for the North Sea, Arctic or similar waters face a number of loading conditions during construction, towout, installation, operation and removal. Large hydrostatic pressures act in all phases, whereas the platform structure is subject to severe environmental loads (wave, current, wind, ice and earthquake) during operation. Large topsides and functional loads may occur during construction, installation and operation.**

## STRUCTURAL ANALYSES

Functional requirements and harsh environmental loads lead to large structures, requiring comprehensive analyses as the basis for design. Finite Element Analyses (FEA) – vi burde forklare hva L star for – are essential to handle the large number of load combinations. The LFEA results are combined to derive at required load combinations being basis for the concrete design.

Multiconsult has developed the market leading postprocessor and design program MultiCon; a preferred program for designing offshore concrete platforms worldwide.

## POST-PROCESSING AND DESIGN USING MULTICON

The detail engineering process for a typical offshore concrete platform takes approximately one year. A continuous design process taking account of new load combinations, rearranged reinforcement systems and geometry adjustments in an efficient way, are part of the process. MultiCon is tailor-made to deal with large amounts of calculations, using a modular, flexible and systematic design process to meet the efficiency demands.

The MultiCon design approach includes all parameters in a global model, enabling a complete and easy-to-follow design process. Stress and displacement obtained by LFEA are used to calculate the design parameters. With user-defined input files, all required material and program control data are specified. MultiCon includes state of the art non-linear design for concrete shell sections based on a number of international codes, including codes for offshore concrete structures.

MultiCon is a program applicable for all types of structures, including bridges, buildings and industrial plants. The system is an efficient tool for complete design of large and complicated structures, solving local design problems in limited areas. The design output includes reinforcement layouts and material utilization ratios.

For 30 years, MultiCon has been continuously developed to meet the industry's requirements while preserving user control over calculated results.

Since 2002, MultiCon has been used for all our offshore concrete projects, such as Sakhalin 1 and 2 in Russia, and the Adriatic LNG Terminal. These structures are installed and in operation. The detail design of a concrete platform for the Hebron project offshore Newfoundland and Labrador is presently ongoing. MultiCon was also used for the Heidrun TLP and Troll A offshore concrete substructures during the 1990's. The Troll A is the biggest Gravity Based Concrete platform ever installed.



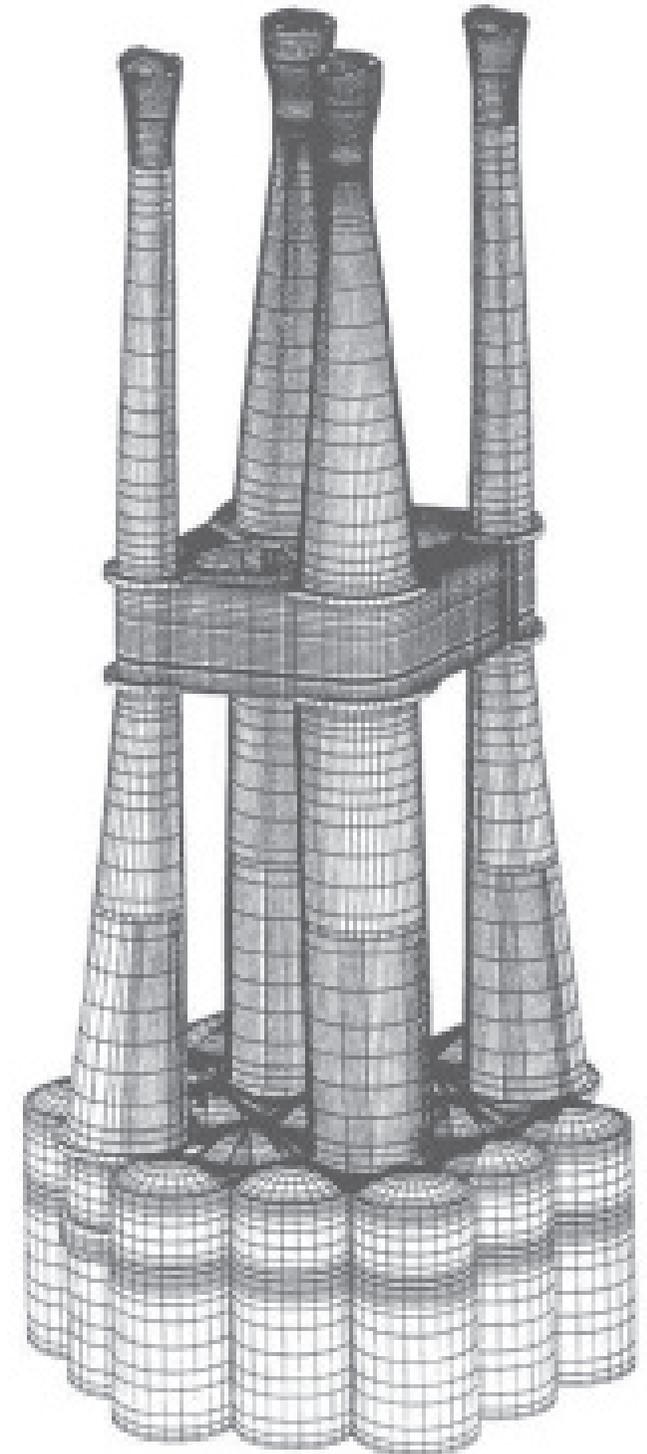
#### FOUNDATION DESIGN

Throughout the last 40 years, Multiconsult has gained a broad experience with geotechnical design of several offshore foundation concepts worldwide including concept studies and detail design .

With the foundation transferring the load action from the structure into the soil volume, the geotechnical analyses document satisfactory capacity of the foundation/soil. Foundation width, on-bottom weight and penetrating skirts are the major structural parameters affecting the foundation capacity. These global parameters are preferably decided during early project phases, and optimized through the detail design phase.

The analyses are carried out in the early stage of the projects using analytical tools and 2D programs. Advanced 3D analyses for soil-structure interaction are performed in the detail design phase.

Multiconsult is one of few companies having in-house foundation design expertise, combined with a broad specter of services in engineering and site supervision. In addition, we are heavily involved in foundation design for steel structures, subsea production systems and moorings.





### TROLL - A

The Troll A platform is an offshore platform in the Troll gas field off the west coast of Norway. It is the tallest structure that has ever been moved to another position and is among the largest and most complex engineering projects in history. The Troll A platform has an overall height of 481 metres, water depth 302 metres. Troll A was installed in 1995.



### SAKHALIN - 2

The Sakhalin 2 project is an oil and gas development in Sakhalin Island, Russia. The LUN-A platform was installed in June 2006 at a water depth of 48 metres, the PA-B platform was installed in July 2007 in a water depth of around 30 metres.



### ADRIATIC LNG

The Adriatic LNG Terminal is the first ever offshore Gravity Based Structure (GBS) for unloading, storing and regasifying Liquefied Natural Gas (LNG). The GBS is 180 metres long, 88 metres wide and 47 metres high. The GBS was installed at a depth of about 29 metres in the autumn of 2008, in operation in the mid 2009.



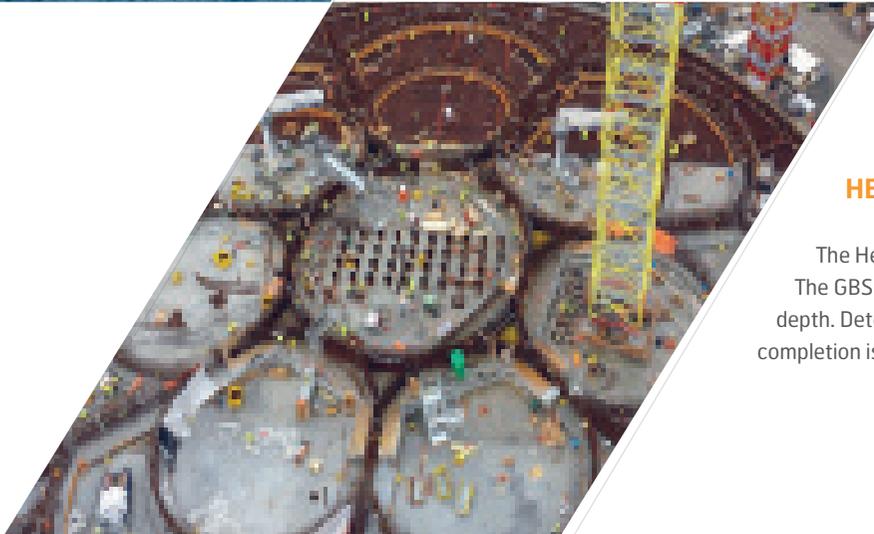
### HEIDRUN TLP

The Heidrun field in the Norwegian Sea, at 350 metres water depth, has been producing oil and gas since October 1995. The field has been developed with the world's first concrete Tension Leg Platform (TLP), and represented a significant step forward in deepwater production technology. Multiconsult, in cooperation with our partners, performed the detail engineering of the concrete foundations and the concrete TLP substructure.



### SAKHALIN 1 GBS

The Sakhalin 1 project is an oil and gas development in Sakhalin Island, Russia. The Sakhalin 1 Arkutun-Dagi platform was installed in 2012 at 34 metres water depth.



### HEBRON GBS

The Hebron oil field is located offshore Newfoundland and Labrador. The GBS platform will be installed in approximately 93 metres water depth. Detail engineering and construction is ongoing and planned completion is in 2017.

# RESEARCH AND DEVELOPMENT

**In Multiconsult we are in contious search for creating new knowledge to add value for our clients. Participation in research programs is crucial for developing our business. Through close relations with different universities and research institutions we are currently involved in several Joint Industry Projects (JIP's) and Centers for Research based Innovation (CRI's). Much of our research is performed in co-operation with our clients.**

## ARCTIC AND COASTAL TECHNOLOGY

Through the CRI SAMCoT (Sustainable Arctic Marine and Coastal Technology), Multiconsult is heavily involved in the development of arctic and cold climate technology. The program was initiated by the Research Council of Norway, and the main research activities are:

- Collection and analysis of full scale field data
- Constitutive modelling
- Loads on fixed- and floating structures in ice
- Ice management
- Coastal technology

Multiconsult employees are directly involved in the research activities, with planning, execution and analysis of ice tank testing and participation in scientific expeditions in ice.

Multiconsult has a comprehensive in-house simulation package for analyzing the response of fixed and floating structures in ice. The simulation tools have been correlated with model test data and have been successfully used in several projects for the oil & gas industry.

## CONCRETE TECHNOLOGY FOR THE ARCTIC

Concrete offshore structures have proven attractive in ice infested waters. Ice abrasion is a degradation mechanism which may reduce the service life of concrete structures if not handled properly. Ice abrasion expertise is vital for a robust design solution.

Multiconsult and our close business partner Kvaerner Concrete Solutions have contributed to the development of a new design- and construction philosophy for the ice abrasion zone which contributes to prolong the service life. The method involves abrasion testing as an integrated part of the design process.

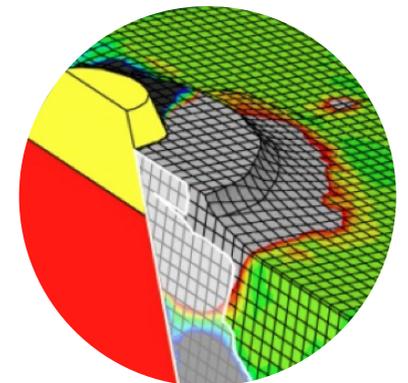
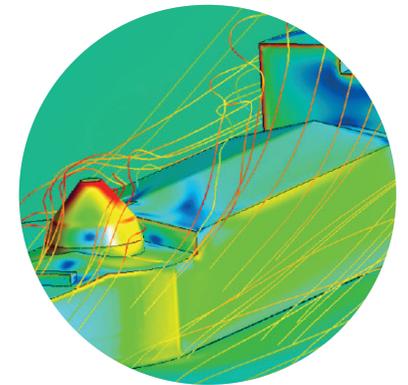
The new construction method secures a smooth surface in the ice zone which contributes to reduce abrasion. Additional concrete cover is prescribed in this zone, allowing some abrasion to occur while still complying with the service life requirements in the ISO standards. The proposed method has already been implemented the petroleum industry.

### NON-LINEAR FINITE ELEMENT ANALYSES OF REINFORCED CONCRETE STRUCTURES

Large scale Non-linear Finite Element Analyses (NLFEA) of reinforced concrete structures is the subject in an ongoing PhD project in Multiconsult. The research aims to further develop the method for performing large scale NLFEA of reinforced concrete structures, both with respect to material behavior and assessment of the structural safety.

For practical and economical reasons, the design of complex concrete structures today are mostly based on linear FEA (LFEA) with relatively large elements. Cracking of concrete and yielding of reinforcement results in an inelastic material response. A design process based on LFEA is not able to predict such redistributions, but is considered safe when equilibrium is satisfied, the material capacity is not exceeded and sufficient ductility is achieved.

Multiconsult has been heavily involved in the design of offshore concrete structures for more than 40 years. The in-house program system "MultiCon" is developed for post-processing of results from FEA of complex concrete structures. The program has been used in all concrete GBS projects on the Norwegian continental shelf since early nineties, and has been continuously developed since.



### Key References

- Ekofisk Tank
  - Statfjord B and C
  - Oseberg A
  - Gullfaks C
  - Snorre TLP
  - Hibernia GBS
  - Troll A GBS
  - Heidrun TLP
  - Sakhalin 1 GBS, LUN-A, PA-B
  - Sakhalin 2 GBS
  - Adriatic LNG
  - Hebron GBS
- 
- LNG Jetty, Snøhvit
  - Harbour Facilities, Shtokman
  - Jetties, Ormen Lange

## ABOUT MULTICONSULT

### ABOUT MULTICONSULT

Multiconsult is a leading consulting engineering company in Norway and Scandinavia. We offer multi-disciplinary consulting, design, engineering, project monitoring, verification, inspection and supervision. With more than 105 years of experience, we continue to create history together with our customers, focusing on expertise and the right balance of skills among our 1550 employees.

Both our staff and our customers are encouraged to see opportunities where others see problems. This way, we aim to break the barriers that other people are tempted to go around.

Multiconsult has 30 offices in Norway and overseas. Our head office is in Oslo, but all of our expertise is available through all of our offices. Multiconsult offers design and consulting services for all project phases. Multiconsult's international business continues to grow. We are working on projects in Africa, Asia, South America, Canada and various parts of Europe.

Multiconsult's business areas:

- Buildings and properties
- Industry
- Oil and gas
- Transportation and infrastructure
- Energy
- Environment and natural resources



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