University of
Stavanger

Faculty of Science and Technology

MASTER'S THESIS

Study program/ Specialization:

Konstruksjoner og materialer, bygg
(Structures and materials)

Spring semester, 2011

Restricted access

Writer:
Svanhild Alsvik

Svanhild alsvik
(Svanhild Alsvik)

Faculty supervisor:
Jasna Bogunovic Jakobsen

External supervisor(s):
Gunnar Gjerde

Titel of thesis:

Method Study – Jacket removal

Credits (ECTS): 30

Key words: - Decommissioning of jacket
- Linear analysis using GeniE
- Non-linear analyses using Usfos

Pages: 84
Enclosure: 40 + 2 CDs

Stavanger, 15/ 06 / 2011

Frontpage for master thesis
Faculty of Science and Technology
Decision made by the Dean October 30th 2009

Summary

Decommissioning is a new marked in the petroleum industry. Many offshore installations are coming to the end of their planned lifetime. Hence, it will be a significant increase in decommissioning activity in the next couple of decades. When petroleum activities ceases the main rule is that everything has to be cleared and removed.

There exists only limited experience on the scale and nature of the decommissioning marked. A considerable increase in demand for competence and equipment for decommissioning of facilities is expected to arise. The marked is already developing; new technology has emerged and various removal concepts are under study.

Three different removal methods for jackets are studied in this document:
- Heavy lift removal method
- Vertical split of jacket
- Reversed launching

The jacket that is investigated consist of eight legs and has a steel weight of about 7 500 tonnes, and is seen as an ordinary jacket. Only inshore operations are investigated, and the jacket is assumed transported to a location in sheltered waters.

Heavy lift method is a removal method using heavy lifting vessels to lift and transport the jacket to shore. This method has been executed before and is well documented. A linear elastic analysis is carried out to investigate the structural integrity of the jacket during a lift operation. Sesam - GeniE software program is used to carry out the analysis.

The vertical split and the reversed launching operation has the aim to be alternative removal methods to the use of heavy lift vessels. Buoyancy Tank Assemblies (BTAs) developed under the Frigg Cessation Project are used in these alternative operations. Both the vertical split and the reversed launching method are developed on the idea to use buoyancy forces and float the jacket to quay were it can be dismantled.

The idea behind the vertical split method is to cut the jacket into two vertical sections and float them, using the BTAs, to quay. The reversed launching is based on the idea to use the same procedure to remove the jacket as used when it was installed. The BTAs and a Purpose Made Barge will provide the necessary buoyancy force to float the jacket in one section to shore. Nonlinear, dynamic analyses are carried out for both the alternative jacket removal methods. Usfos software program are used to perform the analyses.

How to execute the different removal methods are studied and the structural integrity of the jacket has been analysed and documented. The structural integrity of the jacket is kept in the heavy lift removal method and the reversed launching method. Measures have to be taken to do the vertical split removal method feasible for the type of jackets that is analysed. In further studies additional analysis is necessary to verify if the reversed launching method is feasible. The reversed launching method has, in this study, turned out to have a larger possibility to be a competitive removal method than the vertical split method. Heavier jacket may be easier to remove using the reversed launching method, and hence it is more competitive with regards to the use of heavy lift vessels.

Preface

The decommissioning marked is up-and-coming. New technology and techniques are developing to increase the efficiency of removal work and to do it more cost-effective. Aker Solution has already executed decommissioning projects and wishes to develop this new field inside the petroleum industry.

This master thesis represents the final part of my master degree in structural engineering. The topic of this work was offered in December 2010 by Aker Solutions, who also provided facilities and access to software. It has been instructive and challenging to work with this document.

It is a pleasure to extend my gratitude to Aker Solution that has provided me with all necessary material, software and information. Jasna B. Jakobsen has been a helpful support at UiS. Special thanks are given to my supervisor at Aker Solutions, Gunnar Gjerde, for his guidance during the entire process, for always being available and for taking the time to discuss my many questions.

Stavanger, 15.06.2011

Table of Contents

Summary **1**
Preface **2**
Table of Contents **3**
Definitions and abbreviations **6**

1 Introduction **7**
1.1 Background 7
1.2 Regulations 8
1.2.1 International legislation 8
1.2.2 National legislation 9

2 Decommissioning **11**
2.1 The decommissioning process 11
2.1.1 Removal and marine operations 11
2.2 Frigg Cessation 12
2.2.1 Buoyancy Tank Assemblies (BTA) 14
2.3 Crane vessels 15

3 Removal of jacket **16**
3.1 Introduction 16
3.2 Scope of present work 16
3.2.1 Heavy lift 16
3.2.2 Vertical split of jacket using BTAs 16
3.2.3 Reversed launching method 17
3.3 Regulations, design codes and standards 17

4 Geometry and properties of the jacket structure **18**
4.1 Main characteristics 19
4.2 Global coordinate system 19
4.3 Units 19
4.4 Member and joint modelling 19
4.5 Section types 21
4.6 Material description 21
4.7 Model inaccuracies 22

5 Analyses software **23**
5.1 Software 23
5.1.1 Linear elastic analysis using Sesam software 23
5.1.2 Non-linear plastic analysis using Usfos software 24

6 Decommissioning by heavy lift method **27**
6.1 General 27
6.1.1 Design and load factors for heavy lift 29
6.1.2 Rigging arrangement 32
6.1.3 Actions. 33
6.1.4 Lift capacity 34
6.2 Analysis setup 37

6.2.1 Structural analysis 37
6.2.2 Centre of gravity and CoG shift 37
6.2.3 Action combination 39
6.2.4 Boundary conditions 40
6.3 Analysis results 41
6.3.1 General. 41
6.3.2 Member code check 41
6.3.3 Joint code check 43

7 Decommissioning by vertical split method using BTAs 46
7.1 General 46
7.1.1 Model of the Buoyancy Tank Assemblies (BTAs) 47
7.1.2 Float-up 47
7.1.3 Vertical split 48
7.1.4 Actions. 49
7.2 Analyses setup 51
7.2.1 Structural analyses 51
7.2.2 Material- and load factors 52
7.2.3 Boundary conditions 52
7.3 Analyses results 52
7.3.1 General. 52
7.3.2 Float-up 52
7.3.3 Vertical split 54
7.4 Evaluation of the analyses 62

8 Decommissioning by reversed launching method 65
8.1 General 65
8.1.1 Model of the purpose made barge (PMB) 66
8.1.2 Actions. 67
8.2 Analyses setup 68
8.2.1 Structural analyses 68
8.2.2 Material- and load factors 69
8.2.3 Boundary conditions 69
8.3 Analyses results 69
8.3.1 General. 69
8.3.2 Rotation of grounded jacket 70
8.3.3 Float-up and rotation of jacket 72
8.4 Evaluation of the analysis 77

9 Decommissioning by use of heavy lift, vertical split of jacket or reversed launching 79
9.1 Discussion 79
9.2 Conclusion 80

References 81

Appendices

Appendix A

A.2 Geometry of jacket model 1
A.2.1 View of finite element model 1
A.2.2 Member names 2
A.2.3 Cross sections.. 9

Appendix B

B.2 Input files…. 1
B.2.1 Input file to GeniE, jacket structure 1
B.2.2 Input files to Usfos, vertical split removal method 8

Appendix C

C.2 Control of Usfos' calculations of buoyancy forces 1
C.2.1 Buoyancy of a horizontal pipe dependent on draft 1
C.2.2 Buoyancy of a submerged box 3

Appendix D

D.2 Results from analyses 1
D.2.1 Heavy lift analysis, frame code check 1
D.2.2 Analysis of vertical split removal method, results from Usfos 11
D.2.3 Analysis of reversed launching removal method, results from Usfos 13

Definitions and abbreviations

- Decommissioning: the process of physical removal and disposal of structures at the end of their working life
- Jacket: a truss framed steel base anchored to seabed to serve as a foundation for the topsides of a fixed platform
- Fixed Platform: an immobile hydrocarbon-producing structure with a concrete or steel base (jacket) anchored to the seabed
- Topside: the surface hardware installed on an offshore platform, including the production plant, the accommodation block and the drilling rig
- Heavy lift vessel: an offshore support vessel fitted with a large crane capable of installing and decommissioning heavy topside modules and jackets
- S7000: Saipem 7000, a semi submersible crane vessel
- BTA: Buoyancy Tank Assembly developed by Aker Solutions
- PMB: Purpose Made Barge. A barge that can be filled with water and it can be de-watered and is used to give additional buoyancy force
- GeniE: A software program in the Sesam package developed by DNV
- USFOS: A software program developed to execute nonlinear analyses
- Flooded members: Members filled with water
- Buoyant members: Non-flooded members
- CoG: Center of Gravity
- CoB: Center of Buoyancy
- OSPAR: The Oslo and Paris Convention
- IMO: The International Maritime Organisation
- MPE: Ministry of Petroleum and Energy
- DNV: Det Norske Veritas
- NORSOK standard: Design codes developed for the Norwegian petroleum industry

1 Introduction

1.1 Background

In connection with cessation of an oil field a jacket has to be removed and brought to shore for demolition. This document will describe three different removal methods for a jacket, and present the results from the analyses. One method is a traditional heavy lift operation. The two next methods to be studied are vertical split by use of Buoyancy Tank Assemblies (BTAs) and reversed launching.

On the Norwegian continental shelf there are nearly 500 facilities. In 2010 the Norwegian Petroleum Directorate gave a number of 12 concrete facilities, 19 floating steel facilities, 88 steel facilities resting on the seabed and nearly 350 subsea systems [01]. These facilities have a total weight of roughly 7 million tonnes [03, table 4.1]. The 88 fixed steel installations, or jackets, have a weight of about 1 million tonnes, nearly 15% of the total weight. The concrete substructures constitute for the largest share of the total weight with about 5 million tonnes. Many of these facilities have been producing oil and gas for 30-40 years and are now approaching the end of their lifespan which they were designed for.

The first Norwegian offshore installation removal of some extent was in 1996 (North-east Frigg). In the subsequent years additional removal projects have been carried out, where the largest has been the Frigg Cessation Project. Over the next couple of decades the number of old and redundant oil and gas installations that have to be taken out of service will grow, and most of these installations have to be completely removed. In 2002 Det Norske Veritas (DNV) drew up an overview of offshore installations on the Norwegian shelf that were to be closed down and removed [04]. The time of removal given in DNV's report is expected in the given time lag based on dialogues with operators. The report split installations to be removed into superstructures (topsides) and substructures for different platform designs. According to DNVs report (2002) 13 substructures are assumed to be removed from the Norwegian continental shelf during the period 2010 to 2015, and 11 during the period 2015 to 2020, Table 1-1. Removal of concrete sub-structures is disregarded.

Type	Number of facilities	
	2010-2015	2015-2020
Steel jacket platform	10	9
Floaters	2	1
FPSOs - floating production, storage and offloading units	1	1
Tension leg platform		
Concrete platforms		
Total	13	11

Table 1-1 Number of substructures assumed to be removed from the Norwegian continental shelf in the period 2010-2020 [04]

In a report, "Decommissioning of offshore installations", written by the climate and pollution agency [03] it is estimated that the costs of decommissioning the nearly 500 installations will amount to NOK 160 billion. The estimate is uncertain and does not contain the removal of fixed concrete substructures, but the amount gives an idea of the aspect of this new field in the petroleum industry. The jacket removal market accounts for a large amount of the decommissioning expenditure. This is a result of the high cost of the equipment and lift vessels that are required to handle such large pieces of structure.

Decommissioning costs and time consumption vary widely from project to project, depending on factors such as water depth and type, size and weight of the structure. Complexity and age of the installation will also have an impact to the extent of work that has to be done, and of course the expenses. The timescale of a physical removal of a decommissioning project might vary from 1 year to 4-6 years or even more.

1.2 Regulations

The process of decommissioning is very strictly regulated by international, regional and national legislation. These regulate both removal of the installations and the disposal. The regulations primary concerns are the safety of navigation and preventing pollution. When the government reaches a decision regarding disposal of an installation on the Norwegian continental shelf both national and international regulations apply.

1.2.1 International legislation

Two international regimes are particularly relevant in connection with the decommissioning of offshore installations. The Oslo and Paris Convention (OSPAR) is the most important, but some guidelines given by The International Maritime Organisation (IMO) are also relevant to the offshore industry.

OSPAR is a legal international regulating cooperation on protection of marine environment of the North-Sea Atlantic and has fifteen contracting parties. It is drawn up to extend and replace the 1972 Oslo Convention on dumping from ships and the 1947 Paris Convention on discharges from land.

In July 1998, at the OSPAR Ministerial meeting in Sintra, Portugal it was passed that “dumping, and leaving wholly or partly in place, of disused offshore facilities within the maritime area is prohibited” [16, page 2]. The Convention came into force in February 1999. Derogation from the prohibition may be granted for individual installations, or parts of installations according to the Decision 98/3. Concrete substructures, concrete anchor foundations and steel jackets weighing more than ten thousand tonnes in air can, if permission is granted, be left in place [16, annex 1]. The main rule is that when petroleum activity ceases everything must be cleared and removed to shore for reuse, recycle or for disposal on land. OSPAR Decision 98/3 lays down guidelines for the various disposal alternatives that are acceptable for various types of marine installations.

IMO is a specialized agency with responsibility for the safety and security of shipping and the prevention of marine pollution by ships. The Convention defines “ships” in a way that includes offshore installations. IMO conventions fall into three main categories; maritime safety, prevention of pollution and the third concerning liability and compensation. The compensation is especially in relation to damage caused by pollution. Many of the IMO guidelines are superseded by OSPAR 98/3, but some of their guidelines still remain relevant.

1.2.2 National legislation

In Norway there are several national acts and regulations which apply to decommissioning of offshore installations, and authorities in several sectors are involved in different parts of the decommissioning process. Dismantling of installations offshore is considered to be part of “petroleum activities” and with that regulated by the petroleum legislation. Once modules have been loaded on to a barge, they come under the rules of maritime transport. Recycling and demolition are regulated by other legislations.

Decommissioning of offshore oil and gas installations and pipelines is regulated by the Ministry of Petroleum and Energy (MPE) utilising the legislation under the Petroleum Activities Act of 1996. MPE is a Norwegian ministry responsible for energy, including petroleum and natural gas production in the North Sea. The department must report to the legislature, the Storting.

The Petroleum Activities Act applies to “petroleum activities in connection with subsea petroleum deposits under Norwegian jurisdiction” [19, section 1-4]. Chapter 5 in the Petroleum Activities Act considers activities when petroleum production ceases. Section 5-1 in the Act requires the licensee to draw up a comprehensive decommissioning plan when production on a field and the use of the facilities is to cease permanently. Chapter 6 concerns the decommissioning plan described below under section 1.2.2.1.

Decisions on disposal and approval of the decommissioning programme are made by the MPE according to the Petroleum Act. Any exceptions must be reasoned and the case must be presented to OSPAR before the Storting makes a decision. Different parties may be consulted and contribute in a decommissioning process, but the final decision of approval is always made in agreement with the government.

When an installation is to be towed to coast for onshore decommissioning or anchored outside a decommissioning yard, a permit from the municipality (Norwegian Coastal Administration) is required. An onshore decommissioning yard for offshore installations is classed as a waste treatment plant and is regulated by the County Governors utilising the Pollution Control Act. It will also be subjected to the EU Directive concerning integrated pollution prevention and control. All the various types of waste which is generated have to be treated in accordance with regulations for waste handling. Other legislations take into account factors of importance for health and environment in different stages at the decommissioning process.

1.2.2.1 Decommissioning plan

Before a production licence expires the licensee shall submit a decommissioning plan to the Ministry of Petroleum and Energy (MPE) in accordance with the Petroleum Activities Act 1996. The plan shall contain proposal for continued production or shutdown of production and disposal of facilities.

Planning a decommissioning programme will take place before any physical removal has begun, and the disposal must be processed by the authorities. Under section 5-1 in the Act the

MPE states that a decommissioning plan shall be submitted earliest five years and latest two years prior to the expected time when the use of a facility is to be permanently shut down. The plan shall be submitted to the MPE, the Ministry of Labour and Social Inclusions, the Norwegian Petroleum Directorate and the Petroleum Safety Authority Norway.

"Unless the Ministry consents to or decides otherwise, the decommissioning plan shall be submitted at earliest five years, but at the latest two years prior to the time when the use of a facility is expected to be terminated permanently." [19, Section 5-1]

A decommissioning plan shall, in accordance with chapter 6 in the Petroleum Act, consist of one part dealing with disposal and one impact assessment. The program should cover the proposed disposal, and also the practical availability and potential impact of other options followed from OSPAR's 1998 decision. The disposal part of the decommissioning program shall contain a description of the facilities to be removed, relevant disposal alternatives, recommended disposal solutions i.a. Technical, safety, environmental and economic aspects shall follow each of the relevant disposal alternatives. The impact assessment shall provide an overview of the expected consequences, containing a description of the effect that each of the relevant disposal alternatives may have. Measures that can be done to reduce discharges and emissions in connection with disposal shall be included in the impact assessment. Documents regarding cost and schedule, preparation and clean-up, management of special waste are also part of a cessation programme.

To date, the Ministry of Petroleum and Energy has approved more than ten decommissioning plans [07]. In most cases it has been decided that facilities where the production has ceased permanently must be removed and taken ashore.

2 Decommissioning

2.1 The decommissioning process

All offshore and gas installations are unique but the fundamental decommissioning processes for all fixed platforms are the same. The various phases given in Figure 2-1 illustrate the various activities from a platform ceases production to it is onshore for demolition.

After the final decision of a field cessation, the platform production and operation will be shut down; the platform production system will be closed and platform equipment will be cleaned. The engineering activity may start 12-18 months prior to offshore activity, and is a major part within the decommissioning chain. Various contractors will develop their preferred removal method, and based on the result the operator will choose the final contracting strategy, which may include several contractors. After the removal method is selected and the decommissioning plan is approved, the offshore activities will begin. Offshore activities include safety preparations, logistic, inspection, testing, weighing, offshore cutting, offshore dismantling, lifting and transportation. The offshore marine activities follow as a direct consequence of the defined methods for removal and may include heavy lifts or buoyancy float off operations. Inshore marine activities and onshore offloading are also included under the removal and marine operations. Inshore marine operations are executed in sheltered waters and are depending on the selected decommissioning method. If a float-off and tow method is selected as the offshore transportation method, the facility will be transported inshore and safely moored in a sheltered position for further processing. The depth along the quay side is often the limiting factor for the off-loading method. The structures will be lifted, skidded or trailed over the quayside using the demolition yard's offloading facilities. The physical demolition work is to cut and reduce the structure into manageable sizes for transport for final destruction or reuse. The cost of marine operations, are approximately 50% of the total decommissioning project cost according to the Scottish Enterprise [20].

Figure 2-1 Decommissioning chain

2.1.1 Removal and marine operations

Under current regulations and requirements, over 90% of offshore structures will have to be completely removed from their marine sites and brought to shore. If a structure is too difficult or dangerous to be removed to shore, an exception from the rule can be granted.

Up to date, the removal methods have been:

- Use of Heavy lift vessels. Whole modules are removed in the reverse of the installation sequence. The method is used for removal of topside modules, jackets, flares, bridges and various sub sea installations. The modules are loaded on to a barge or a crane vessel and transported to a decommissioning plant or anchored inshore outside off a decommissioning plant for further dismantling.

- Use of Construction vessels for pre-removal operations, like inspections, diving operations and sub sea cutting.

- Use of Construction vessels for removal. The installation is dismantled offshore and cut into small sections that are shipped onshore in containers.

- Re-floating method by use of Buoyancy Tank Assemblies (BTA), see section 2.1, and construction vessels. A method used to remove jackets from offshore to inshore location.

- Re-floating of Maureen platform. Maureen platform was designed to be re-floated. Maureen was a unique steel gravity base platform since it was designed to be re-floated and moved for reuse or recycling. Six tugs towed the re-floated Maureen platform to the decommissioning yard at Stord in 2001.

Many oil and gas installations were designed and installed at a time where the requirements for future removal were low. Methods for removal must therefore be developed at an early stage, preferably at engineering and study, with respect to the condition and capacity of the structure. All the different removal methods require its individual detail engineering and planning. The Petroleum industry has to manage the considerable technical, economic, environmental, health and safety issues that follows such a complex decommissioning project.

In recent years specialist companies offering niche expertise have emerged, and new technology is being developed to make the decommissioning work more cost-effective. Aker Solutions have in many years carried out removal studies. In recent years they have also executed real removal projects, such as Frigg Cessation.

2.2 Frigg Cessation

Gas production ceased at the Norwegian – British Frigg field in October 2004 after 27 years of operation. One year earlier, in March 2003, the final decommissioning plan was approved by the Norwegian and the British authorities. It was agreed to coordinate the disposal of the facilities on both sides of the border in one single agreed decommissioning program. The Frigg Cessation Project was the first major gas field decommissioning to be carried out in Europe, and has been the largest removal project on the Norwegian shelf. If the work to prepare the cessation plan is accounted for, the Frigg Cessation Project has taken more than ten years. Preparation and obtaining approval of the Cessation Plan took more than four years. The removal operations offshore started in 2004 and the final lifts took place during the summer 2009.

Total E&P Norge AS was the operating company for the Frigg Cessation Project. Aker Solutions was given the contract for engineering, preparation, removal and disposal.

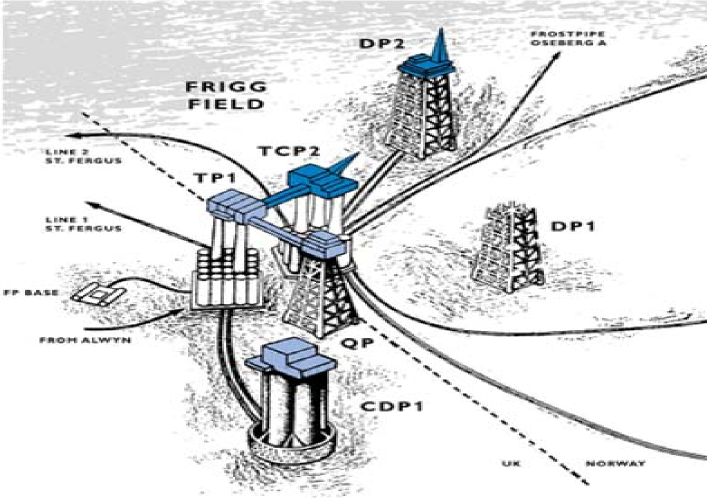


Figure 2-2 The Frigg field [23]

The Frigg field consisted of six platforms, three steel platforms (QP, DP1 and DP2) and three concrete structures (CDP1, TP1 and TCP2). One concrete substructure and two steel substructures were located on the Norwegian sector. In accordance with the OSPAR convention all the topside facilities was removed to shore for disposal, as was the steel substructures (jackets). Permission to leave the concrete substructures in place, after the removal of the external steel work, was granted.

90 000 tonnes of steel were removed for disposal from the Frigg field [24]. Different approaches were applied to remove the steel structures. The semi-submersible heavy lift vessel, Saipem 7000 (S7000), were used for lifting operations and transport to onshore disposal yard for topside facilities and Main Support Frames (MSFs). DP2 and QP steel jackets were removed in one piece and transported in vertical position to shore as showed in Picture 2-1.

Picture 2-1 Transport of jacket using S7000 [24]

New technology was developed and used for removal of the DP2 jacket. Four Buoyancy Tanks Assemblies (BTA) were designed and fabricated for this purpose. The BTAs were developed with the aim of using a re-floating method for the jacket, Picture 2-2. One BTA attached at each corner leg was used in the patented re-floating technique. The BTAs were de-ballasted and lifted the jacket up when it was no longer fixed to the seabed. The jacket was floated clear of the seabed and towed to shore to Aker Solutions' decommissioning plant at Stord. The new jacket removal method was going to be an alternative to the use of expensive heavy lift vessels.

Picture 2-2 Tow of the DP2 jacket to Stord by use of the BTAs [24]

2.2.1 Buoyancy Tank Assemblies (BTA)

The total original height of each BTA is 65 meter and has a dry weight of about thousand tonnes. A ballasted BTA has a weight of roughly three thousand tonnes. Each BTA consist of two cylindrical buoyancy tanks and a pyramidal top-section. The main tanks are divided into an upper and a lower compartment that consists of a series of valves. The valves are allowing sea water to enter during ballasting and expel water during de-ballasting by pumping in pressurized air.

The BTAs will be towed in floating horizontal position to the operation location. The BTAs will be upended to a vertical position by filling the ballast compartments with sea water. After the BTA is floating in vertical position it is guided into contact with the jacket by a set of towing lines attached to a vessel. One BTA is installed at a time under restricted weather conditions. An upper and a lower guide are ensuring correct position of the BTA against the jacket leg. Two clamps in the mid-section of the BTA are closing around the jacket leg when the BTA is positioned and is used for load transfer between the BTA and jacket. Roll Stoppers at each side of the BTA has the function to prevent the BTA from rotation.

The BTAs are ballasted during the positioning and attachment to the jacket legs, and de-ballasted when the BTAs are installed. The de-ballasting will cause a vertical movement when the jacket is no longer fixed to seabed. The buoyancy force will lift the jacket

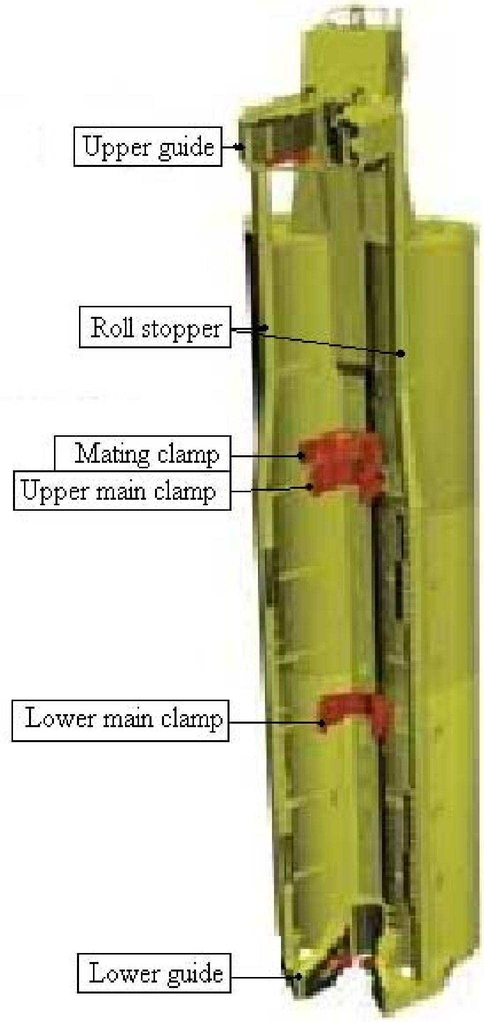


Figure 2-3 Buoyancy Tank Assembly [25]

upwards to satisfactory bottom clearance. Satisfactory clearance was approximate 10 meter over the seabed for the jacket removal in the Frigg Cessation Project. The jacket with the attached BTAs can now be towed using towing-vessels to a decommission plant. The towing route is dependant on the water depth. The jacket was towed inshore and parked outside the decommissioning plant at Stord. The DP2 jacket was cut into pieces before disposed on land.

During the Frigg Cessation Project Aker Solution started to develop an alternative dismantling method using the BTAs. This work stopped before conclusion when the team decided to dissect the jacket in water.

The BTAs was developed to suit various jacket-structures and are available for re-use. They can be modified to suit different requirements. Different methods for using the BTAs to effectively transfer a jacket to a disposal quay are under research. Two possible removal methods using the BTAs are a vertical split of the jacket and reversed launching.

2.3 Crane vessels

The largest cranes in the world operate on offshore crane vessels. There exist monohull and semi-submersible crane vessels. A monohull crane vessel has the advantage of a higher transit speed whereas a semi-submersible crane vessel has the highest maximum lifting capacity. Thialf (Heerema Marine Contractors) and Saipem 7000 (Saipem Contractors) are semi-submersible vessels and the worlds largest deepwater construction vessels. The semi-submersible vessels, or heavy lifters, are equipped with two fully revolving cranes that provide them with a multi-functional dynamic and a high lifting capacity. They have a maximum lifting capacity of 14,200 tonnes (Thialf) [27] and 14, 000 tonnes (Saipem 7000) [26]. The given capacity is for a combined lift with both cranes using the main block. S7000 has a capacity of 7000 tonnes for a main block single hook lift. The lifting capacity is dependant on the lift radius and how deep the vessel floats. The maximum lifting capacity requires operation draft, which for Saipem 7000 is a depth of 27,5 meters. This water depth is not always possible under inshore operations. Operations on shallow waters require a lower operation draft which may reduce the lift capacity. The price for renting this type of heavy lift vessel is approximately 5 millions NOK per day.

Picture 2-3 Saipem 7000 at Stord, Norway, [28]

3 Removal of jacket

3.1 Introduction

In connection with decommissioning of an oil field a jacket has to be removed from its location to shore for dismantling. It is an eight-legged jacket that was located offshore on 101 meter water depth. Topside modules and the main support frame (MSF) have been removed. The jacket is to be removed from offshore location to sheltered waters were the removal operation to be studied will take place.

3.2 Scope of present work

This document is a study of different removal methods. Drawings from Aker Solutions have been used to model a jacket. The jacket is seen as an ordinary jacket, pursuant to size and weight. The different removal operations will be studied and evaluated. The jackets strength and capacity in relevant stages will be verified to evaluate if the method is feasible. The results from the analyses will be presented in this document. Three removal methods have been chosen to study;

Method 1:	Heavy lift
Method 2:	Vertical split of jacket using BTAs
Method 3:	Reversed launching

3.2.1 Heavy lift

A section of the jacket is to be heavy lifted from inshore location by the semi-submersible vessel Saipem 7000 (S7000) and transported to quay on Stord. Crane capacity, lift arrangement, water depths, onshore loading and structural integrity will be evaluated, by means of a linear elastic analysis. The lift analysis will be done for the upper part of the jacket only.

3.2.2 Vertical split of jacket using BTAs

The four BTAs are attached to each of the corner legs. A vertical cut will be done approximately around the centre line of the jacket. The jacket sections will rotate to a horizontal floating position with help of strand jacks and buoyancy from the BTAs. The jacket sections will be towed to shore for dismantling. Analyses will be performed to evaluate how the jacket will float in vertical position before and after the vertical split, how each part will float after the rotation. The required forces in strand jacks will be found and the structural integrity will be evaluated.

3.2.3 Reversed launching method

The idea behind the reversed launching method is, as the name implies, to use the same procedure as when the jacket was installed just in a reversed order; to reverse the original launching from a barge and a load in of the jacket onshore by skidding.

The whole jacket will be lifted and rotated by use of BTAs, barges and winches. A Purpose Made Barge (PMB) is planned to be connected against the launch runners of the jacket. The PMB together with two of the BTAs and some winches will rotate the jacket and float the arrangement to pier. The jacket will be positioned and pulled up onto an onshore skid way. The last part of the operation, the float-up and final rotation, will be analysed to see how the jacket will behave and to investigate if it may be a feasible removal method.

3.3 Regulations, design codes and standards

- Det Norske Veritas (DNV): Rules for Planning and Execution of Marine Operations 1996/2000 [36]
- Det Norske Veritas (DNV): Recommended Practice DNV-RP-H102 Marine Operations During Removal of Offshore Installations [37]
- NORSOK Standard N-003: Action and Action Effects [38]
- NORSOK Standard N-004: Design of Steel Structures [39]
- Eurocode NS-EN 1993-1-1: Design of Steel Structures [40]

The rules of Det Norske Veritas have the objective to ensure that marine operations are performed within defined safety levels. Marine operations are normally defined as operations “related to temporary phases of load transfer, transportation, installation and/or securing of units at sea” [36 part 0, chapter 1]. Both the NORSOK standards and the DNV-RP-H102 refer to the DNVs rules for marine operations, ref. [36].

DNV-RP-H102 has its basis from DNVs Marine Operations rules, but includes special considerations for removal operations. For removal of offshore installations DNV-RP-H102 normally accept damage to the removed object, but it requires the same safety level for a removal operation as for other marine operations. The guideline classifies the objects as either reuse or scrap.

NORSOK N-003, ref. [38, page 3], “specifies general principles and guidelines for determination of actions and action effects for the structural design and the design verification of structures”.

The structural analyses will be performed in ultimate limit state (ULS) according to NORSOK N-004, ref. [39], and the Eurocode, ref. [40]. Chapter 6 in NORSOK N-004 gives “provisions for checking of ULSs for typical structural elements in offshore steel structures, where ordinary building codes lack relevant recommendations. Such elements are tubular members, tubular joints…” [39].

4 Geometry and properties of the jacket structure

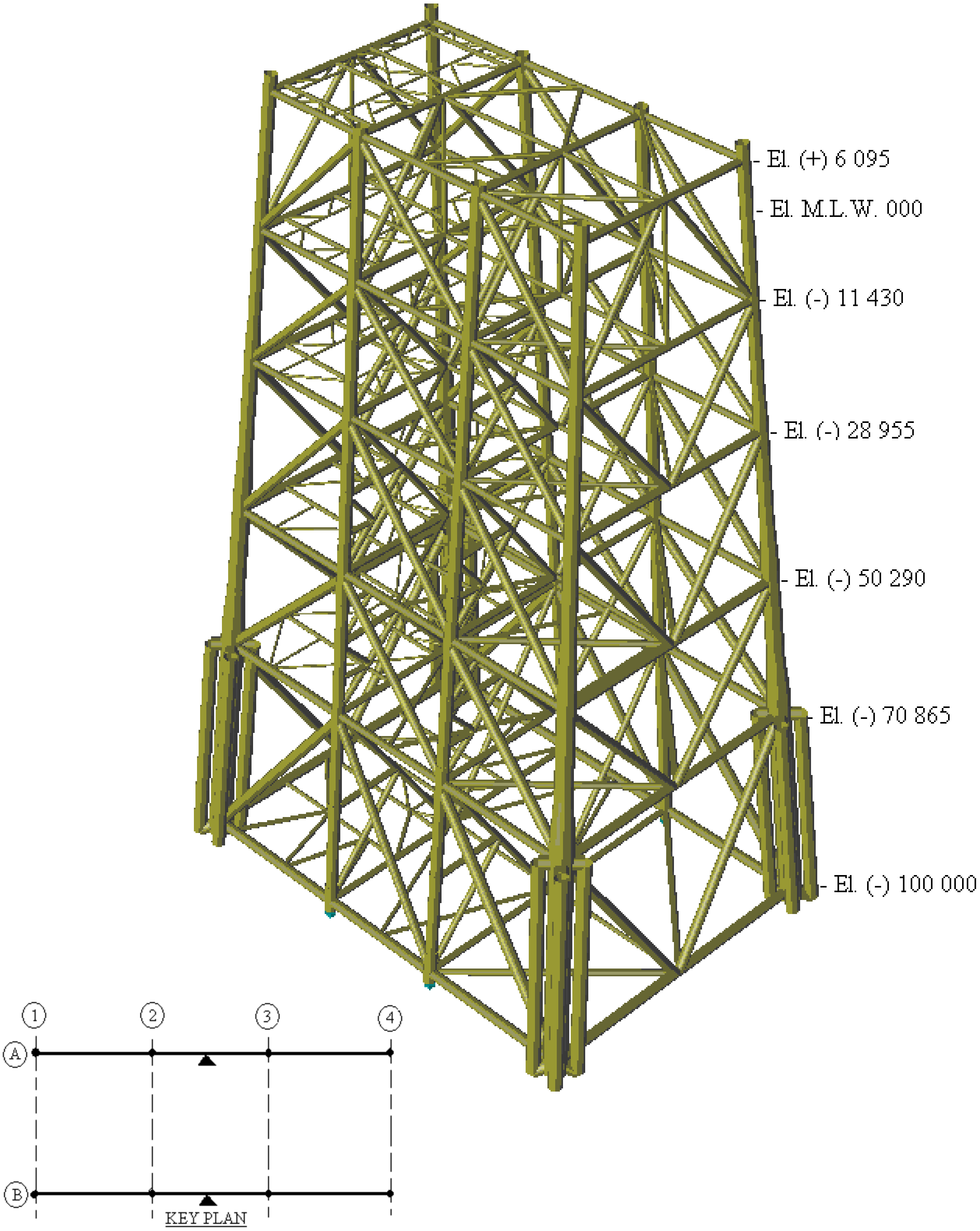


Figure 4-1 Isometric view of the analysis model showing reference elevations

4.1 Main characteristics

The jacket is a truss framed structure consisting of 8 jacket legs and vertical, horizontal and cross bracing. The jacket is constructed with pipe members. The geometry of the jackets legs and incoming braces have been modelled by use of cans and stubs. The jacket legs are also refined by use of cones. The jacket is modelled in GeniE using input files. Appendix B, section B.1.1 gives an extract of the input file used for modelling the jacket.

The main characteristics of the jacket are:

- Net weight	7494,4 tonnes
- Total height	109,600 m
- Width bottom	43,420 m
- Width top	25,110 m
- Length bottom	61,734 m
- Length top	48,074 m

4.2 Global coordinate system

In the horizontal plane (xy) the global coordinate system has its centre point in the middle of the jacket structure, in the middle between the four main legs. The origo is placed at the reference elevation 0, at the mean water level (MWL). The z-axis is pointing upwards.

4.3 Units

The fundamental S.I. units are used in the analyses:

- Length: meters (m)
- Mass: kilogram (kg)
- Time: second (s)
- Force: Newton (N)
- Stress: N/m^2 (Pa)

4.4 Member and joint modelling

A systematic approach to model points, members and joints is adopted. Structural points will have names starting with P followed by a six digit number as follows:

Pxxyyzz

The xx, yy and zz are numbers in a range between 00 and 99 indicating the position in the model, Figure 4-2.

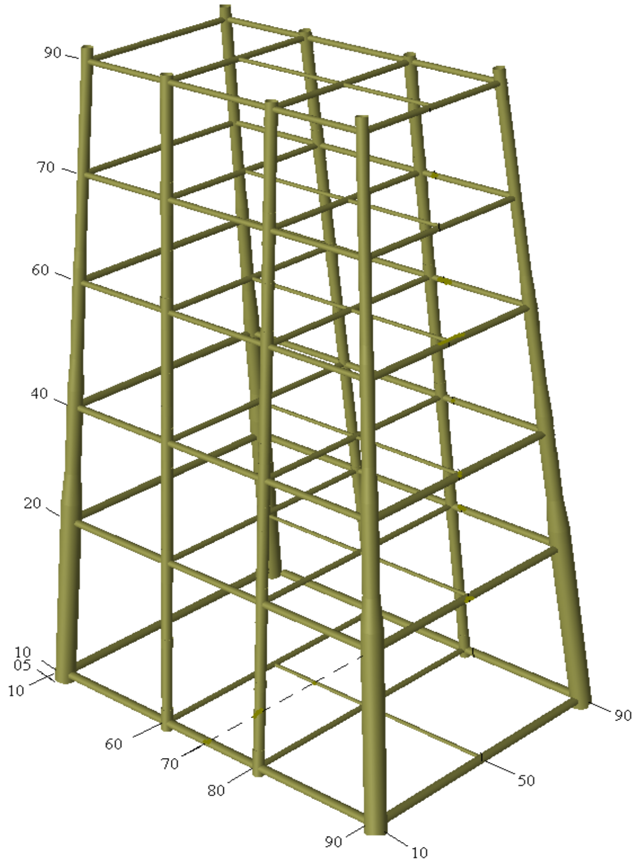


Figure 4-2 Overview of point and member modelling, jacket structure

All members' names start with B or L, depending if it is a brace member or a leg member. The member notation is in the same way as for points, but in addition a letter is used to explain the member's direction as follows:

Bαxxyyzz or Lαxxyyzz

where α is the direction letter. X,Y and Z is used for members in positive X-, Y-, and Z-direction only. A and B are used for braces in xy-plane running in positive x-direction and positive (A) or negative (B) y-direction. C and D are used for braces in xz-plane running in positive x-direction and positive (C) or negative z-direction (D). E and F are used for braces in yz-plane running in positive y-direction and positive (E) or negative (F) z-direction. Plots showing the members' names are given in Appendix A, section A.1.2.

All joints' names start with the letter J and are using the same six digit notation as for points, as follows:

Jxxyyzz

4.5 Section types

The jacket is constructed using pipe profiles. An extract with names of section and dimensions used in the jacket computer model is given below in Table 4-1. All cross-sections are given in Appendix A, section A.1.3.

Name	Section type	Dimension (m)
P3048x57	Pipe section	3.048 x 0.0572
P3048x50	Pipe section	3.048 x 0.0508
P3048x38	Pipe section	3.048 x 0.0381
P3048x25	Pipe section	3.048 x 0.0254
P3048x15	Pipe section	3.048 x 0.0159
P2286x57	Pipe section	2.286 x 0.0572
P1829x50	Pipe section	1.829 x 0.0508
P1800x75	Pipe section	1.800 x 0.0750
P1689x82	Pipe section	1.689 x 0.0829
P1683x79	Pipe section	1.683 x 0.0791
P1676x82	Pipe section	1.676 x 0.0826
P1676x79	Pipe section	1.676 x 0.0794
P1676x76	Pipe section	1.676 x 0.0762
P1664x69	Pipe section	1.664 x 0.0699
P1638x57	Pipe section	1.638 x 0.0572
P1638x31	Pipe section	1.638 x 0.0318
P1626x50	Pipe section	1.626 x 0.0508
P1600x38	Pipe section	1.600 x 0.0381
P1588x31	Pipe section	1.588 x 0.0318

Table 4-1 Extract of cross-sections used in the jacket computer model

4.6 Material description

The following material properties apply for all steel structures:

- Young's modulus: E = 210 000 N/mm^2
- Density: ρ = 7 850 kg/m^3
- Poisson's ratio: ν = 0,3
- Temperature expansion coefficient: α = 1,2 x 10^{-5} °C^{-1}

The jacket is designed using material with yield strength of 345 N/mm^2, Table 4-2.

Material reference name	Yield strength (N/mm^2)
S345	345
S345_braceH	345
S345_braceV	345
S345_star	345
S_sleeve_pile	345

Table 4-2 Yield strength

4.7 Model inaccuracies

To simplify the model and shortening the modelling time it is used an automatic approach for can length, stub length and gap in GeniE. The GeniE settings are set in accordance with NORSOK N-004 section 6.4, ref. [39].

The eccentricities vary in some degree from the detail drawings. The eccentricities are mostly larger in the computer model than given in the drawings. The reinforcement length, can and stub length, is mostly shorter, which is to the safe side.

The weight of the piles is included in the sleeve members. The diameter and the thickness of the sleeve are estimated to be 1,800 m and 0,025 m. In order to adjusted for the weight of the piles and the grout that will be inside the sleeves the sleeve thickness is increased. The diameter of the piles is assumed to be 0,050 m. On the basis of this the sleeves are modelled with a thickness of 0,075 m.

Ring stiffeners are neglected in the computer model and may result in some derogation from the true rigidity. The variation is assumed to be small and will have negligible effect on the analyses.

The automatic can, stub and gap approach and the weight estimation of piles and grout gives variances from the real jacket. Since the studies in this document are based on a general jacket and not a specific one the variances are assumed not to be important for the studies and for the results.

5 Analyses software

5.1 Software

All structural elements, including the jacket structure, are modelled in Sesam-GeniE. The analyses are executed using the same base model of the jacket structure. The jacket model is modified in GeniE to fit the different removal methods by dividing the jacket, attaching lift arrangement, strand jacks, chain, Buoyancy Tank Assemblies (BTAs) or/and attaching a Purpose Made Barge (PMB). Lift arrangement is used in the heavy lift removal method. BTAs, strand jacks and chain are used in the vertical split removal method and BTAs and the PMB are used in the reversed launching removal method.

For the heavy lift removal method a linear elastic analysis has been performed. The linear-elastic analyses are carried out using Sesam software; GeniE and Sestra. For the vertical split method and the reversed launching method nonlinear analyses are performed. The nonlinear plastic analyses are carried out using USFOS software. StruMan software is a structural file manipulator and used to manipulate the FEM files created in GeniE. StruMan converts the FEM file to an easier readable UFO format.

The Sesam package is developed by DNV Software. Sesam – GeniE is a tool for designing and analysing offshore and maritime structures made of beams and shells. Sesam – Sestra is the “equation solver” in the Sesam system.

USFOS software tool is developed by SINTEF marintek and the Norwegian University of Science and Technology (NTNU). The core team in the development group was prof. Jørgen Amdahl, dr. Tore Holmås, dr. Øyvind Hellan and dr. Ernst Eberg. USFOS is a program for nonlinear static and dynamic analysis of space frame structures. It is designed for analyses of offshore structures. The program simulates the collapse process, from the initial yielding, through formation of plastic hinges and the hardening process, to the complete collapse of a structure.

5.1.1 Linear elastic analysis using Sesam software

It is most common to determine the internal forces and moments in a structure by using linear elastic analyses. The failure criterion is then usually yielding of outer fibre in the most loaded cross-sections, or buckling of any individual member as an isolated beam. The yielding or buckling is often referred to as a component failure. The adequacy of each individual component is for a typical linear analysis determined by comparing the applied element forces with parametric code-check capacity formulas. Each component is described by its stiffness and capacity.

In a linear analysis occurring displacements and strains are assumed to be small. Based on these assumptions deformation of a loaded element is, for calculation purposes, neglected and a linear strain relation may be used. Linear strain is known as engineering strain and can be defined as:
$\varepsilon_x = (ds - ds_0) / ds_0$

When a loaded structure is in the linear range, the elastic analysis ceases to represent the actual structural behaviour. Hence, the linear elastic failure criterion is established as a matter of convenience.

The Sesam software is based on a concept based Finite Element (FE) modelling. FEM is a method for finding approximate solutions of partial differential equations and integral equations in the analysis of structures. In Sesam both interactive graphic geometry modelling and command input modelling can be used with automatic finite element mesh generation. The Sesam software package consists of independent programs with different task. Data is automatic transferred between the programs trough the Sesam interface file. The Finite Element (FE) model is generated in a pre-processing program. Analysis programs are used to do a structural analysis or an environmental analysis, and post-processing programs presents and evaluate the results. GeniE is a new design analysis tool in Sesam. GeniE can be used together with other Sesam programs or on its own. Modelling, structural analysis and result presentation can be done using only GeniE interface. Sestra is a linear structural analysis tool integrated in GeniE. The analyses are based on the displacement formulation of the FE technique. Sestra gives the results in terms of displacements, stresses and forces and stores them in a separate file. The analysis and evaluation of the results are done within GeniE. Under a linear static analysis GeniE will automatically create a finite element mesh, perform the analysis using Sestra and produce a result file that can be accessed by GeniE. A strength assessment is performed using a code check. A member check of a frame structural member is performed to assess whether the member is subjected to acceptable stress levels. The code check may be done according to different standards, among them is Norsok. The check is performed through the use of the equations given in the standard and the results are given in form of a usage factor. If the usage factor is less than 1.0 then the member is regarded to be "safe". A member with a usage factor greater than 1.0 is seen as an "overloaded" member.

The code checking in GeniE is based on finite element results from a linear analysis. For a straight beam, the displacements and forces are computed at the finite element nodes. Forces are computed at additional positions along the beams:

- For regular straight beams: At beam ends, middle position, 25% and 75% positions
- For segmented beams: In addition to above at positions where change in section or material properties
- Where the maximum moment occur

5.1.2 Non-linear plastic analysis using Usfos software

While a linear elastic analysis treats individual components, a non-linear analysis measures the performance of the system as a whole and describes how each component interacts with the surrounding structure. Investigation of plastic deformation, failure and redundant capacity shall be based on non-linear analyses. A non-linear plastic analysis gives a more realistic simulation of the behaviour of a structure during collapse. All structures will in general behave nonlinear when the structure is loaded close to its ultimate capacity.

A beam is elastic and the load distribution obeys the elastic linear theory during the first stages of an on-loading. Yield occurring in the outer fibres of the section with largest load value is referred to as the "first fibre yield". Prior to the first fibre yield the material will behave linearly and the deformation will be elastic; the material will return to its original shape when the applied stress is removed. Once the first fibre yield has occurred additional loading will lead to permanent and non-reversible deformation; a plastic region is gradual spreading trough the cross-section and regions denoted as plastic hinges occurs. A structure will fail when sufficient number of plastic hinges has formed; the ultimate capacity has been reached. Hence, first fibre yield is of little concern as a global failure criterion for a non-linear analysis.

The assumption about small deformations that a linear analysis is based on is not valid for a non-linear analysis. During on-loading in a non-linear analysis large deformation may occur; the element geometry is nonlinear, it changes during on-loading. In order to give an accurate representation of the element behaviour the displacement have to be accounted for. Usfos is valid for large displacements by including the non-linear strain-displacement relation given by Green's strain, E_x, as follows:

$$E_x = (ds^2 - ds_0^2) / 2*ds_0^2 \leftrightarrow E_x = \varepsilon_x + ½\, \varepsilon_x^2$$

ε_x represents the engineering strain given under section 5.1.1. For small strains the higher order term in the second equation may be neglected and Green's strain and engineering strains coincide.

The idea behind Usfos is to use only one finite element per element of the structure such that a relative small number of elements may be necessary to model a large structure. Hence, the plastic hinge beam-column model has been derived in Usfos. Plastic hinges are used to model the material nonlinearties. The plastic hinge beam-column model use element stress resultants, i.e. forces and moments, to model the behaviour of a cross section. Interactions between element forces are represented by yield surfaces, see Figure 5-1.

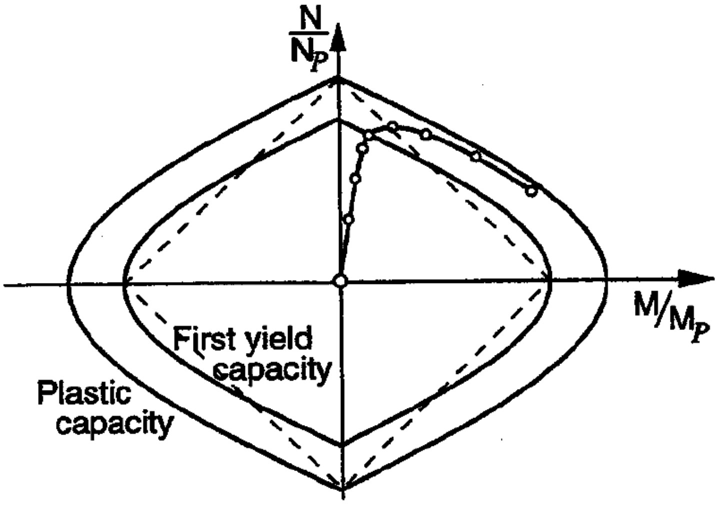


Figure 5-1 Plastic interaction surfaces [29, page 41]

The inner yield surface demarcates elastic behaviour. The bounding surface identifies the absolute plastic capacity. When the stress state is lying on the inner surface (the unbroken surface-line according to flow theory, and the dotted surface-line according to conventional linear yield criterion) the material has reached the yield point, and the material is said to have become plastic. The yield surfaces represent a material's elastic behaviour when loaded to first fibre yield and a gradual plastification of the cross-section. Usfos is based on the plastic flow theory that requires the two surfaces to have the same shape (unbroken lines in Figure 5-1). During the loading process the inner yielding surface approach the bounding surface. A small translation of the bounding surface is used to model strain hardening. When the force state has reached the bounding surface the cross-section has reached full plastification. Material model for both elastic-perfectly-plastic and gradual plastification-strain hardening characteristics are included in Usfos. Figure 5-2 illustrates the linear first yield surface and the bounding surface with and without strain hardening. By introducing strain hardening the material's capacity increases.

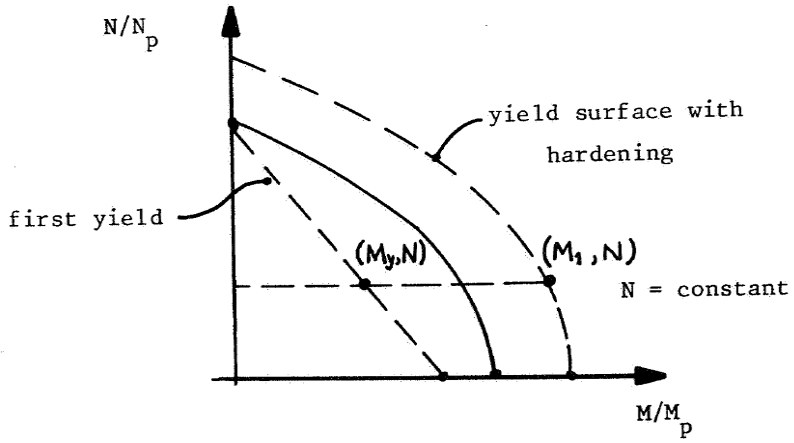


Figure 5-2 Axial force – bending moment interaction [31, page 10.13]

Usfos assumes a perfectly ductile material in the progressive collapse analysis; hence it follows that the capacity as predicted by Usfos may be overestimated.

In a dynamic analysis both the effective stiffness and the effective load are functions of time, they are non-linear. Usfos solves the dynamic equilibrium equations in each time step and take the nonlinearties into consideration. The length of the time steps is determined from given time increments. Time-histories and load-histories are used to implement the load and to describe it as a function of time.

6 Decommissioning by heavy lift method

6.1 General

The jacket is assumed to be removed from its offshore location to sheltered waters using Saipem 7000. The jacket is too high to be set directly onto the quay side. The jacket is assumed to be set down at Stord at 50 meter water depth. Thereafter it will be cut into two sections, see Figure 6-1. Saipem 7000 will lift the top jacket section from the (-) 50 m setdown pad onto the quayside on Stord for further demolition.

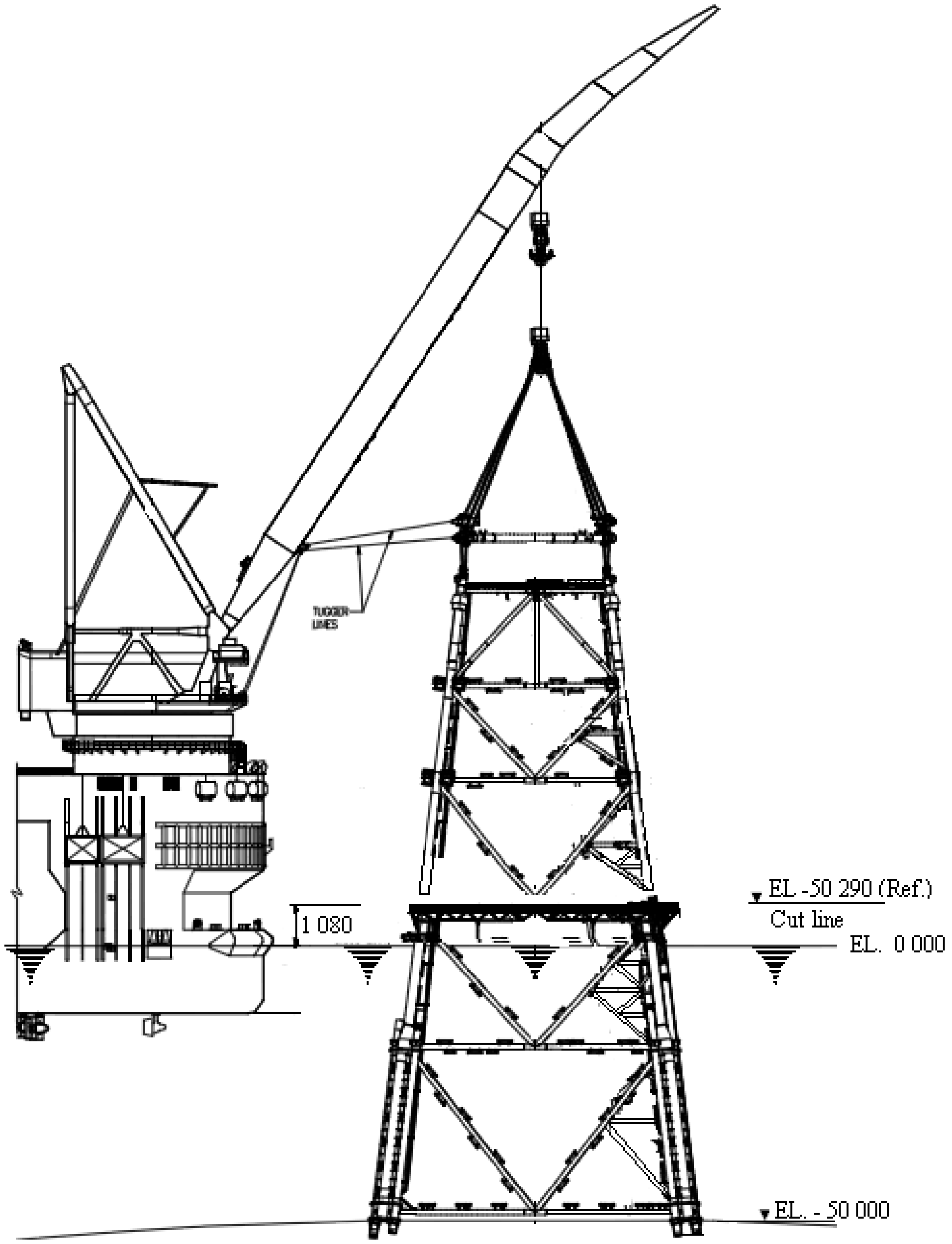


Figure 6-1 Jacket upper section – Inshore lift-off from lower section

The section heights have been chosen in accordance with S7000s capacity and the water depth at the set down pad. The necessary draft, crane radius and lift height to execute the lifting operation are taken into consideration.

- Height of upper section of the jacket: 58,52 m
- Height of lower section of the jacket: 51,08 m

S7000 has to transfer the jacket section to quay at an average draft to ensure adequate clearance to seabed. The average draft is 12,62 meter. Additionally, thrusters have to be retracted to allow S7000 into quay with the upper section of the jacket. It has to be a clear length of 10 meter from the bow to the quayside. The chosen transfer corridor has been used for jacket removal under the Frigg Cessation Project. It is only possible to use a single crane lift, if the jacket is to be set down at a preferred site.

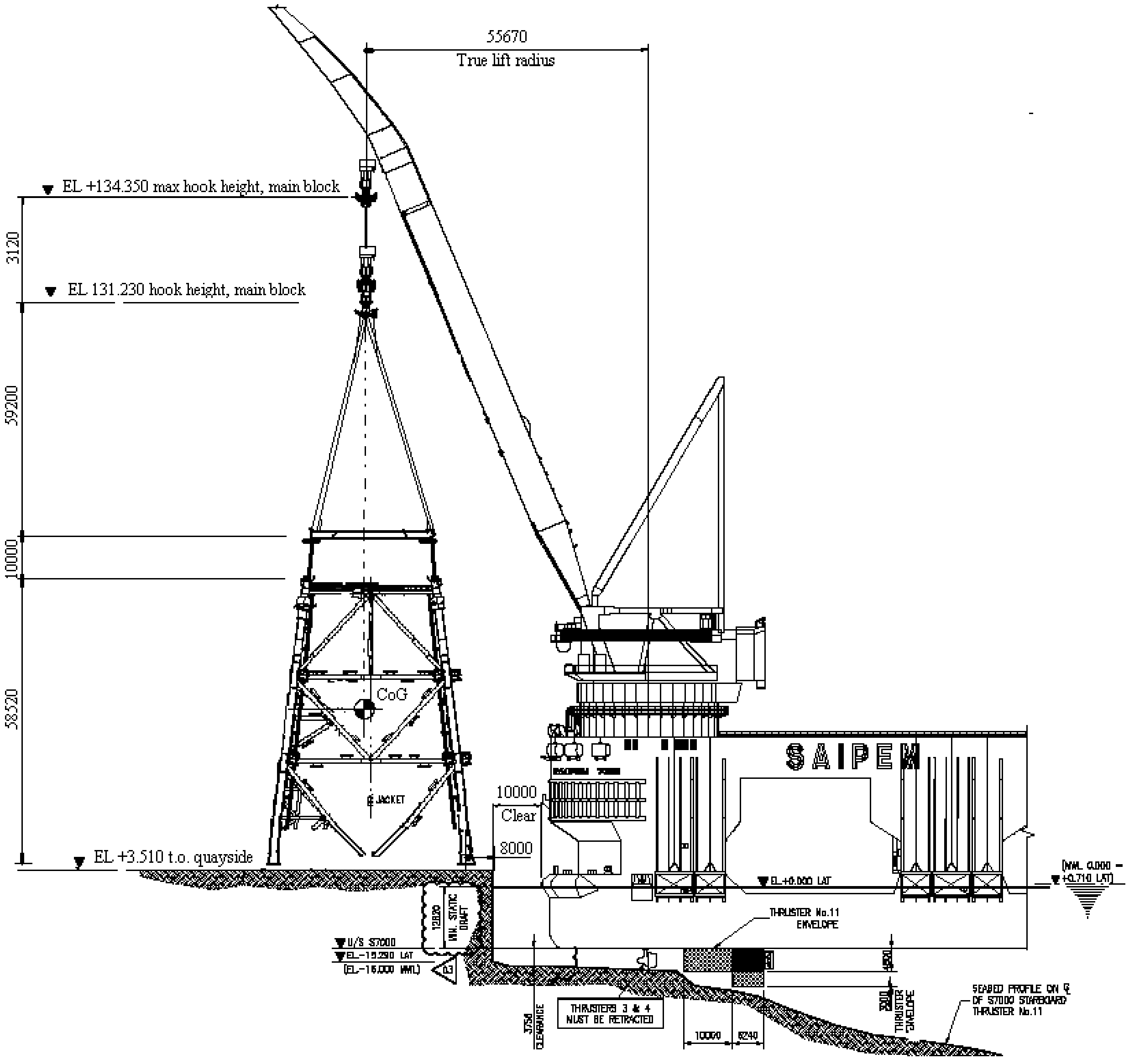


Figure 6-2 Jacket upper section. Offload at Stord

The model for the lift section is based on the SESAM jacket model shown in Figure 4-1. The jacket model is divided into the chosen jacket sections in GeniE. Figure 6-1 shows the two jacket sections that are to be lifted to shore.

6.1.1 Design and load factors for heavy lift

DNV's rules for maritime operations, reference [36] part 2 chapter 5 gives "specific guidance and recommendations for well controlled lifting operations, onshore, inshore and offshore, of objects with weight exceeding 50 tonnes".

There are load correction factors and safety factors that have to be accounted for in a lift analysis. The load correction factors will take into account the additional loads that occur during lifting.

"All lifts are exposed to dynamic effects due to variation in hoisting speeds, crane and motions, cargo barge movement, object movement etc." [36, chapter 5 section 2.2.1.1].

Dynamic loads are accounted for by using a 'Dynamic Amplification Factor' (DAF). The load correction factors also include correction for skew loads; sling skew load (SKL_{sl}), yaw skew load (SKL_y) and tilt skew load (SKL_t). The static load is factored to obtain the maximum load in rigging, structure and crane.

"Skew loads are the extra loading caused by equipment and fabrication tolerances and other uncertainties with respect to the force distribution in the rigging arrangement" [36, chapter 5 section 2.3.1.1].

The safety factors are applied to account for uncertainties in materials, structural elements, loads and load effects. Inaccuracies in the estimated position of centre of gravity and the vertical weight distribution are also taken into account in separated safety factors.

Det Norske Veritas, ref. [36], gives factors that may be applied under certain conditions and using certain arrangement. The given factors are alternatives to more accurate evaluations.

6.1.1.1 Safety factors

In the DNV's rules it is stated that "weight and position of centre of gravity should preferably be determined by weighing" [36]. Under some operations weighing is not found feasible. The weight and centre of gravity should then be established based on data from construction and installation of the platform. If modification has been done during a platform's lifetime this should also be accounted for under the weight and CoG estimation.

To reach the maximum expected weight a Weight Contingency Factor (WCF) is added to the load. An overview of different WCFs that can be used is given in table 2-3 ref. [37]. If nothing else is documented they should be seen as minimum contingency factors. For object where no modifications have taken place all object parts can be calculated with a WCF of 1,10. If there exist drawings and records of history WCF of 1,10 can still be used on structural part of the object. A contingency factor of 1,05 is the minimum factor, but requires as as built drawings including modifications and a thorough inspection. For more detail see table 2-3 ref. [37]. For the weight estimate a WCF of 1,20 will be used on the marine growth because the uncertainty is large.

Inaccuracies in the CoG position shall be considered in the design load. DNV, ref. [36] part 1 chapter 3, recommends using a CoG envelope or box to allow for the CoG inaccuracies. The size of the envelope or box should reflect the structural and operational sensitivity to variation in the CoG position. The factor should normally not be taken less than 1,05. Hence, the CoG Envelope is defined as an envelope of 5% of the length, width and height of the unit centered on the CoG coordinates. The CoG shift envelope will be applied in the computer analysis as a factor to all permanent loads. The factor relates to the maximum increase of the support reactions when considering CoG shift to each corner of the envelope.

In addition to the CoG Envelope, a CoG inaccuracy factor (CIF) shall be applied to allow for the inaccuracies in the prediction of centre of gravity. CIF is normally set equal to 1,02.

A consequence factor, γ_c, shall be applied to increases the safety of the main members supporting the load during a lift operation. The consequence factors presented in Table 6-1 are to be applied in structural checks in lifting analysis and are in accordance with ref. [36] table 3-2.

Structural element	**Consequence factor, γ_c**
Lift points including attachments to object.	1.30
Lifting equipment (e.g. spreader frames and beams, plate shackles).	1.30
Main elements supporting lift points, single critical.	1.30
Main elements supporting lift points, redundant.	1.15
Other element of lifted object.	1.00
Elements not contributing to the overall structural integrity of a lifted object that will be scrapped.	0.80

Table 6-1 Consequence factors for lifting analysis

The safety shall be largest for the most loaded members. Hence, the maximum value 1,3 is applicable to the lift points since 100% of the load will be supported by these points. For the rest of the structure the rules allow to decrease the factor to 1,15 and 1,0.

6.1.1.2 Load correction factors

The design load is found by multiplying the characteristic load with the appropriate load factors. According to DNV, ref. [37] table 2-7, a load factor, γ_f, of 1,3 is applicable for permanent load for a ULS a) design. A reduced factor of 1,2 may be used if the load and load effect are well controlled. Hence, if the lift weight is determined by weighing or ‘conservatively’ calculated and if compliance with use of a reduced load factor are confirmed by a 3rd party verification a load factor of 1,2 can be used.

The dynamic amplification factor (DAF) for offshore and inshore lifting operations are in general selected in accordance with ref [36], part 2 chapter 5. Table 6-2 presents minimum DAF for lifts in air, provided that the lifting operations do not take place under adverse conditions.

Static hook load	DAF inshore
50 – 100t	1.15
100-1000t	1.10
1000-2500t	1.05
> 2500t	1.05

Table 6-2 Dynamic amplification factor for inshore lifts

Yaw effect only applies for tandem crane lifts. It accounts for increased sling load due to rotation of the object around a vertical axis. A yaw effect factor of 1,05 is normally sufficient.

A tilt effect has to be accounted for in both a tandem lift analysis and a single crane lift analysis. The tilt effect factor, SKL_t, accounts for increased sling loading due to rotation of the object about horizontal axes. A limit of 3° for tandem and 2° for single crane lifts. The tilt effect for single crane lifts caused by tilt angles less then 2° are covered by the CoG inaccuracy and the CoG shift factor. Larger tilt angles than 2° can be accounted for by adding horizontal loads.

Sling skew load factor SKL_{sl} is dependant on the rigging geometry and the utilisation of the slings. The fabrication sling and lift point tolerances will also effect the SKL_{sl}. The sling skew load will decrease with increasing load since the relative differences between the sling loads will decrease. DNV Rules for Planning and Execution of Marine Operations, ref. [36], gives sling effect factors for some lifting arrangement that is normally acceptable:

- For statically determined lifts with sling lengths within the specified tolerances:
  $SKL_{sl} = 1,0$
- For single crane four point lifts, statically indeterminate:
  $SKL_{sl} = 1,25$
- For single crane four point lifts with “floating” spreader bars:
  $SKL_{sl} = 1,10$
- For tandem crane four point lifts:
  $SKL_{sl} = 1,00$

Alternatively SKL_{sl} can be calculated in accordance with ref. [37] part 2 chapter 5.

6.1.1.3 Code check parameters

Code check of the members and joints for lifting condition will be performed for ULS by use of GeniE in accordance with NORSOK N-004 and Eurocode, ref. [39] and ref. [40].

Values of effective length factor, k, and moment reduction factor, C_m, used for member strength checking are to be taken from NORSOK N-004, ref. [39] table 6-2.

Structural element	k	C_m
Jacket legs and piling		
-Grouted composite section	1.0	(c)
-Ungrouted jacket legs	1.0	(c)
-Ungrouted piling between shim points	1.0	(b)
Jacket braces		
-Primary diagonal and horizontals	0.7	(b) or (c)
-K-braces	0.7	(c)
-Longer segment lengths of X-braces	0.8	(c)
Notes: (b) For members with no transverse loading: $C_m = 0,6 - 0,4M_{1,Sd}/M_{2,Sd}$ (c) For members with transverse loading: $C_m = 1,0 - 0,4N_{Sd}/N_E$ or $C_m = 0,85$		

Table 6-3 Effective length factors, k, and moment reduction factors, C_m

GeniE will automatically calculate the moment amplification in accordance with NORSOK N-004 using the selected rules for the different structural members.

6.1.1.4 Material factor

NORSOK N-004, ref [39], section 6.1 gives material factors used for offshore steel structures in ultimate limit states. It includes both tubular members and tubular joints. The material factor γ_m is 1,15 for ULS unless noted otherwise. In table 6.1 material factors for calculation of structural resistance is given. Material factor for resistance of class 1, 2 and 3 cross-sections, γ_{M0}, is 1,15. Also for resistance calculation of class 4 cross-section a material factor, γ_{M1}, of 1,15 can be used.

6.1.2 Rigging arrangement

The lifting gear is added to correct the simulation of load distribution during the lift operation. Lifting gear includes Internal Lifting Tools (ILTs), slings, shackles, spreaderbars, tugger lines and hook. Fully revolving main hook will be used since it requires less work up front and the capacity is sufficient.

The method chosen for lifting the jacket utilize four Internal Lifting Tools (ILTs) owned by Saipem. The equipment uses hydraulic grippers acting on the inside of the jacket leg. New pup pieces will be welded onto the existing jacket legs in order to ensure the necessary capacity. Lifting point is designed to be at the top end of each corner leg. The pup pieces are added as an extension to the jackets corner legs to account for the higher moment effect due to angled legs and vertical slings. The pup pieces are designed to be 2,5 meter including the lift points.

The lifting arrangement consist of 10 meter long vertical slings, a spreader frame of four spreader bars and angled slings with a true angle of 65 degrees, see Figure 6-3. The slings and the spreader bars have been simulated with steel pipe sections in the analysis. Hinges are applied at lower end of the vertical slings towards the applied pup pieces. The design is undetermined and a sling skew load factor is required.

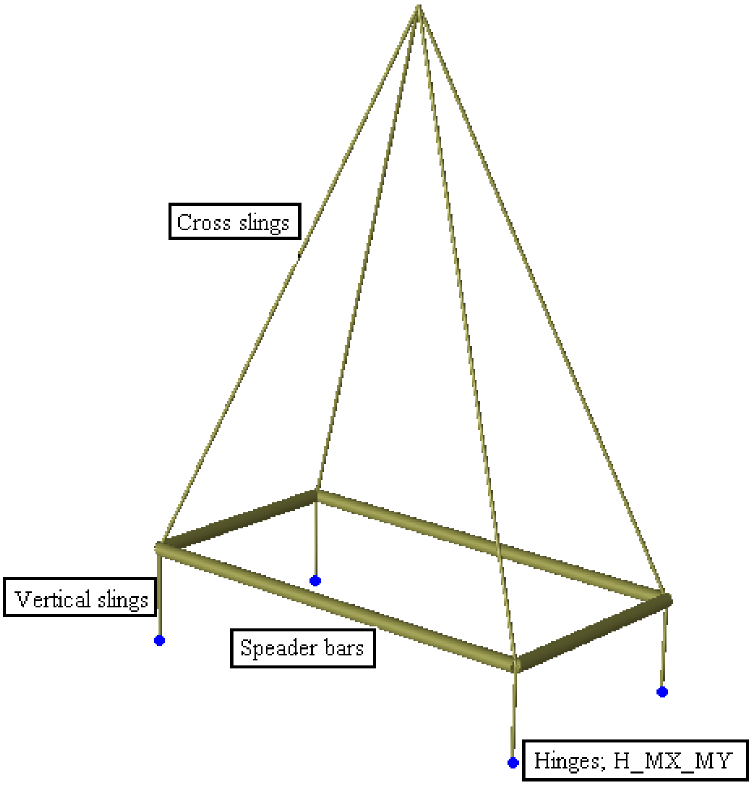


Figure 6-3 Lifting arrangement

6.1.3 Actions

The hook load consists of the steel weight, including weight of piles and grout, weight of marine growth and weight of the rigging gear.

Weight of marine growth is estimated in accordance with the weight estimate done in conjunction with the DP2 Jacket removal, and NORSOK N-003, ref. [38] section 6.6. Marine growth is taken into account by specifying a modified mass density using different scale factors for different parts of the jacket. Weight of rigging includes slings, the four spreader bars and four welded pup pieces.

The Best Estimate (BE) weight, the contingency factor and the Maximum Expected Weight (MaxW) are given for the whole jacket and for the upper section of the jacket in Table 6-4 and Table 6-5. The Best Estimate is the weight of the unit without rigging excluding weight contingency factors (WCF). The maximum weight is the weight of the unit without rigging including weight contingency factors. A contingency factor of 20% is included in the estimated weight of marine growth due to high uncertainty. A weight contingency factor of 10 % is included in the weight estimate for steel and grout.

The rigging design is based on the Best Estimate Weight (BE) including weight contingency factors, which gives the max weight, plus the weight of the rigging. In Table 6-5 the rigging is included in the total weight sum and is the weight to be lifted.

Description	BE weight [t]	Contingency factor	Max weight [t]
Steel/Grout	7494	1,100	8244
Marine growth	605	1,200	726
Total weight of jacket	**8099**		**8970**

Table 6-4 Best estimate and max weight for the whole jacket

Description	BE weight [t]	Contingency factor	Max weight [t]
Steel/Grout	2401	1,100	2641
Marine growth	345	1,200	414
Sub total	2746		3055
Rigging	417	1,050	438
Total weight of upper jacket section, including rigging	**3163**		**3493**

Table 6-5 Best estimate and max weight for upper jacket section

6.1.4 Lift capacity

The lift capacity of the lift operator, in this case Saipem 7000, depends on the required lift radius and the required lift height. The maximum lift capacity also depends on the operating draft; the water depths were the lift operation takes place. Saipem 7000s operating draft is 27,5 meter. It is not feasible to use operation draft when setting the jacket on quay because of shallow water. An average draft of 12,62 meter is chosen in accordance with former performed heavy lift operations at Stord.

The required lift radius is a measure of the maximum length from the crane centre to the position of the hook, which occurs when the jacket is to be placed on shore. The required height is a measure of the height of the object to be lifted including lifting arrangement. The quay height over sea level, where the jacket is to be set down, must also be taken into consideration.

Required lift radius:

- Jacket width at reference level (-) 50 290: 34,84 m
- Clear length from jacket leg to quay side: 8,00 m
- Clear length from quay side to bow: 10,00 m
- Length from bow to crane centre: 20,25 m

Required lift radius = 38,84/2 + 8,00 + 10,00 + 20,25 = 55,67 m

Required lift height:

- Height of upper section of jacket: 58,52 m
- Slings in elongation of jacket legs: 10,00 m
- Vertical length of cross-slings with true angel 60 degrees: 57,57 m
- Vertical height of pup pieces: 2,49 m
- Height of quay over sea level: 3,51 m

Lift height = 58,52 + 10,00 + 57,57 + 2,49 = 128,58 m
Required lift height = Lift height + quay height = 132,09 m

Saipem 7000's capacity at a lifting radius of 55,7 meters, see capacity chart Figure 6-4:

- Maximum hook height: 103,50 m
- Maximum lift height: 103, 5+ 30,88 = 133,88 m
- Maximum crane capacity at operation draft: 4330 tonnes
- Crane capacity at average draft 12,62 m: 4330 tonnes

- Maximum lift height is larger than required lift height; 133,88 m > 132,09 m
- Crane capacity at average draft is higher than max weight; 4330 tonnes > 3493 tonnes

- Hook utilisation: Max weight/Crane capacity = **0,81**

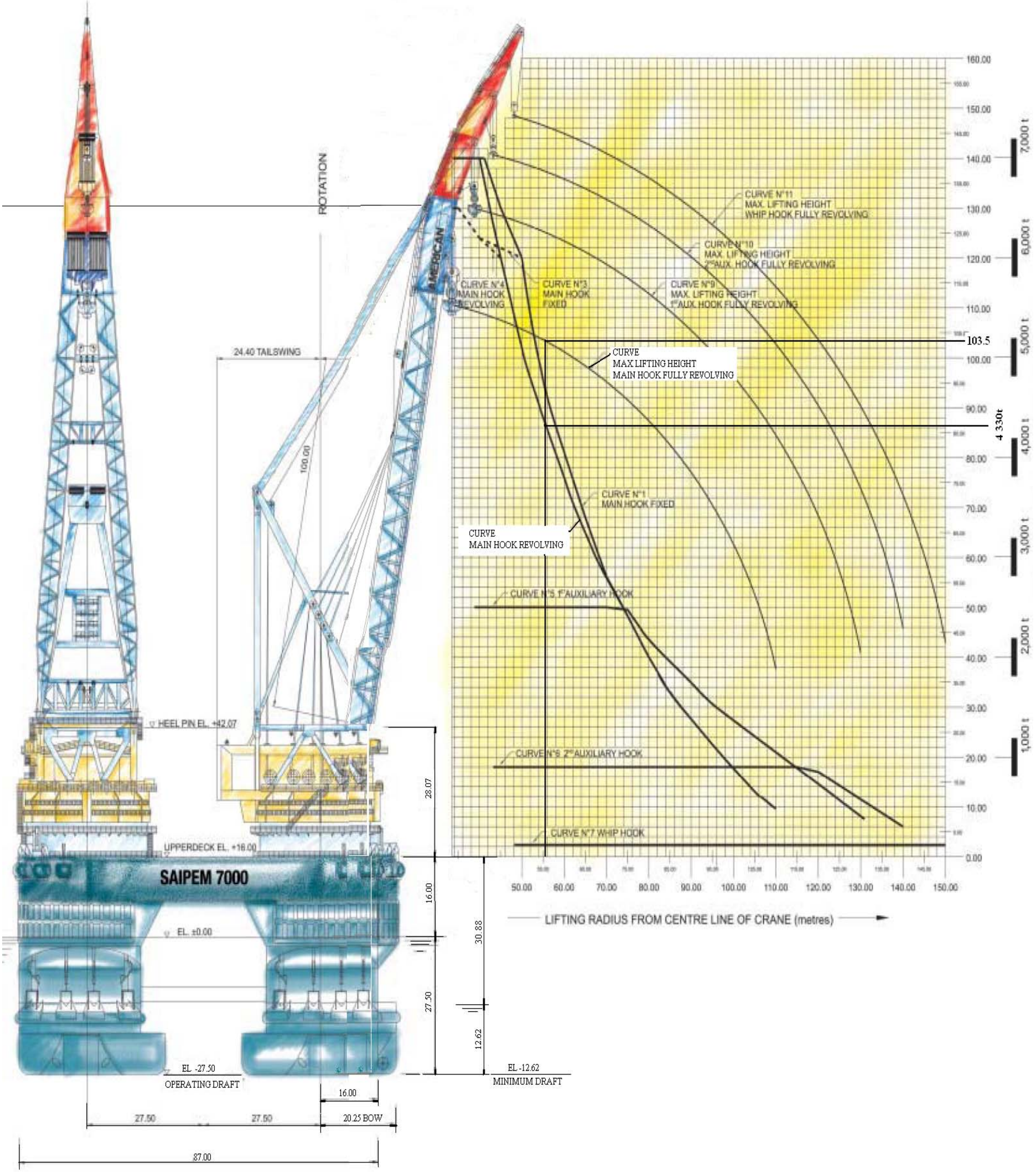


Figure 6-4 Saipem 7000 maximum capacity and lift height chart [26]

6.2 Analysis setup

6.2.1 Structural analysis

The analyses to be performed are in ultimate limit state (ULS) and are executed by use of GeniE. Only a capacity check of the upper part of the jacket during the lift operation will be performed. The lift arrangement will not be analysed, but is included to give a more accurate simulation. It is therefore sufficient that the rigging weight is estimated and supplied in the model by using a higher material density for the steel used for designing slings and spreader bars.

It shall be proven that the upper section of the jacket has sufficient structural integrity to be lifted from inshore location to shore using single hook lift. A static linear analysis is run followed by a code check. The code check calculates an utilisation factor and performs a geometry check.

6.2.2 Centre of gravity and CoG shift

The position of the CoG is calculated by GeniE. The design considers the CoG of the jacket section at the extremes of the design CoG envelope. The envelope is taken as a box with sides equal to 5% of the dimension of the jacket at reference level (+) 6 095. Using the dimensions at reference level (+) 6 095 gives a little more conservative shift factor than using the dimensions at (-) 50 290. A definition figure and calculations of the CoG shift factor are shown below.

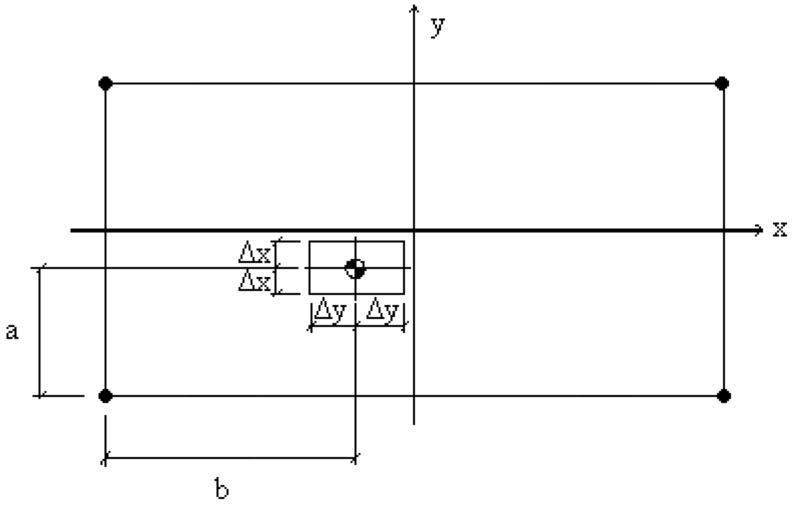


Figure 6-5 CoG shift factor definition (z-direction)

el. (+) 6 095

	X	Y
Geometrical centre between lift points	0	0
CoG position	-0,277	-0,515

Table 6-6 Geometrical centre and CoG position

Distance between lift points:

A_1 = 48,074 m
B_1 = 25,110 m

Module dimensions:

Length: A = 48,074 m
Width: B = 25,110 m

Shortest distance to lift points:

a = 23,760 m
b = 12,040 m

Envelope size (5% of module dimensions):

Δx = 1,202 m
Δy = 0,628 m

Shift factor:

$$\mathbf{fCoG=(a+\Delta x)/a*(b+\Delta y)/b = 1{,}105}$$

The CoG shift factor will ensure validity of the results as long as the position of the CoG is within the defined envelope. More refined method for taking CoG shift factor into account in the analysis may be used. The CoG may for example be moved to the corners of the envelope by use of unit loads applied to the jacket.

The position of the crane hook shall be positioned accurately over the centre of gravity of the lifted object, ref. [36] part 2 chapter 5. The lift weight is both the weight of the jacket and the weight of the lifting arrangement. The added rigging weight will move the position of the CoG. Iteration has been executed to find the final CoG position.

	X	Y	Z
CoG position for upper jacket section and lift arrangement:	-0,24410	-0,45445	-15.1293

Table 6-7 CoG position of lifted object including lift arrangement

6.2.3 Action combination

Table 6-8 gives an overview over factors to take into consideration for different structural parts. The total product is the factors used in the code check. The weight contingency factor for marine growth is 1,2 and is included when computing the marine growth. The load factor for marine growth is included by adjusting the marine growth density. A load factor of 1,2 is chosen assuming the load and the load effect are well controlled.

Single crane lift with S7000 to quay at Stord, four spreader bars	Selection of shackle	Lifting point local design	Design of main single critical elements supporting lift point	Design of main redundant elements supporting lift point	Design of other structural elements
Weight contingency factor, WCF	1.100	1.100	1.100	1.100	1.100
CoG Envelope, CoGE (shift factor xy-plane)	1.105	1.105	1.105	1.105	1.105
CoG Inaccuracy factor, CIF	1.020	1.020	1.020	1.020	1.020
Consequence factor, γ_c		1.300	1.300	1.150	1.000
Load factor, γ_f		1.200	1.200	1.200	1.200
Dynamic Amplification Factor, DAF		1.050	1.050	1.050	1.050
Yaw factor, SKL_y	1.000	1.000	1.000	1.000	1.000
Tilt angle	1.000	1.000	1.000	1.000	1.000
Sling skew load factor, SKL_{sl}	1.250	1.250	1.250	1.250	1.250
Total product of factors on best estimate weight:	**1.550**	**2.412**	**2.412**	**2.134**	**1.856**

Table 6-8 Action combination

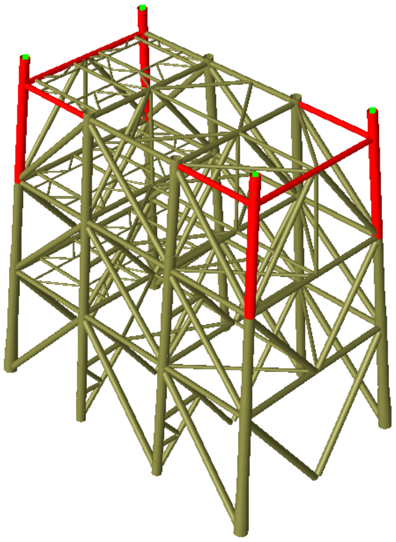


Figure 6-6 Members marked red have been given a consequence factor of 1.3

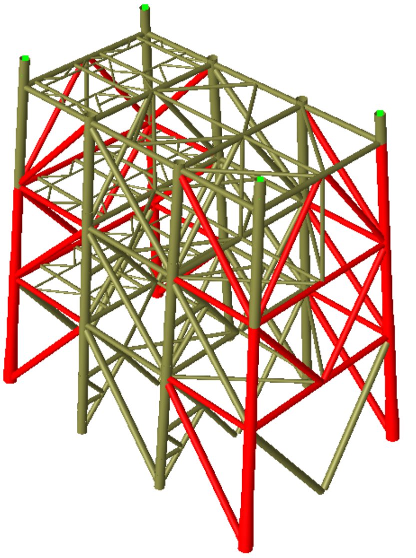


Figure 6-7 Members marked red have been given a consequence factor of 1.15

The member selection for the consequence factor 1,3, Figure 6-6, is a conservative choice. A consequence factor of 1,15 may be applicable for the leg and brace members and only the actual lifting brackets are given a consequence factor of 1,3. The beam code check is first executed with a consequence factor of 1,3 on all members and is done to simplify the analyse procedure. If the capacity is sufficient using a consequence factor of 1,3 on all members no further analyses are necessary.

6.2.4 Boundary conditions

To secure that no artificial stiffness is introduced and to prevent stiff body displacement of the model boundary conditions are applied. Pinned boundary conditions will be applied at the location of the hook. To prevent rigid body translation/rotation the jacket will be guided at two of the lift points, as follows from Figure 6-8.

Hinges are inserted at the end of the pup pieces with the purpose to release local degrees of freedom and to avoid undesired bending moments. The applied hinges are fixed from moments around x- and y-axis, see Figure 6-3.

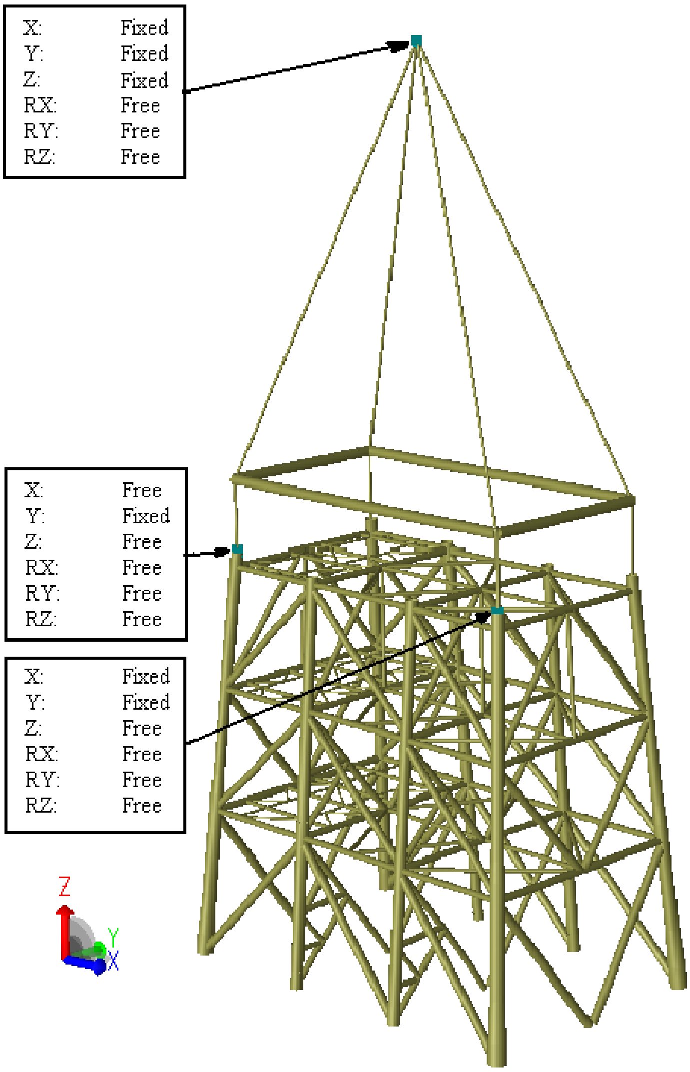


Figure 6-8 Boundary conditions

6.3 Analysis results

6.3.1 General

A linear analysis has been performed for the upper section of the jacket for the lifting conditions. Code checks are performed in Sesam – GeniE in accordance with NORSOK N-004, ref. [39].

6.3.2 Member code check

The jackets tubular members must satisfy the conditions given in section 6.3 in N-004, ref. [39]. Relevant conditions are axial tension (eq. 6.1, N-004), axial compression (eq. 6.26, N-004), axial compression and bending (eq. 6.27, N-004), and local buckling under axial compression (eq. 6.64, N-004).

Figure 6-9 shows the capacity model of the upper jacket section during lifting. The sea green leg members have the largest usage factors which varies from 0,45 to 0,40. Table 6-9 gives an overview of members with an utilisation factor (UfTot) above 0,25 in the jackets upper section. Complete code check list for lifting condition is given in Appendix D, section D.1.1. All members that have been checked have passed the code check.

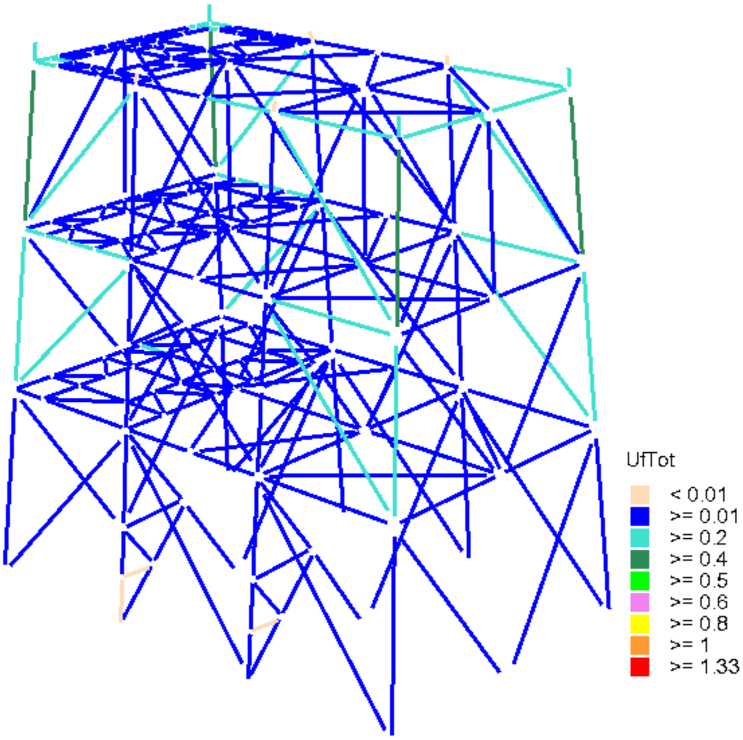


Figure 6-9 Upper jacket section. Usage factor for the lifting conditions, ULS

Member	Position	LoadCase	Status	UfTot	Formula	GeomCheck	SubCheck
LZ101070	0.48	LC101	OK	0.45	uf6_1	Geom OK	Norsok member
LZ901070	0.48	LC101	OK	0.44	uf6_1	Geom OK	Norsok member
LZ109070	0.48	LC101	OK	0.41	uf6_1	Geom OK	Norsok member
LZ909070	0.48	LC101	OK	0.40	uf6_1	Geom OK	Norsok member
BX101090	0.00	LC101	OK	0.37	uf6_26	Geom OK	Norsok member
BC101070	0.00	LC101	OK	0.35	uf6_27	Geom OK	Norsok member
BX109090	0.00	LC101	OK	0.34	uf6_26	Geom OK	Norsok member
BX801090	1.00	LC101	OK	0.34	uf6_26	Geom OK	Norsok member
BD801090	1.00	LC101	OK	0.33	uf6_27	Geom OK	Norsok member
BC109070	0.00	LC101	OK	0.32	uf6_27	Geom OK	Norsok member
BY101090	0.00	LC101	OK	0.32	uf6_26	Geom OK	Norsok member
BX809090	1.00	LC101	OK	0.32	uf6_26	Geom OK	Norsok member
BD809090	1.00	LC101	OK	0.31	uf6_27	Geom OK	Norsok member
BY107090	1.00	LC101	OK	0.30	uf6_26	Geom OK	Norsok member
BY901090	0.14	LC101	OK	0.30	uf6_26	Geom OK	Norsok member
LZ101090	0.00	LC101	OK	0.29	uf6_26	Geom OK	Norsok member
BD801070	1.00	LC101	OK	0.29	uf6_27	Geom OK	Norsok member

Member	Position	LoadCase	Status	UfTot	Formula	GeomCheck	SubCheck
LZ901090	0.00	LC101	OK	0.28	uf6_26	Geom OK	Norsok member
BY905090	0.86	LC101	OK	0.28	uf6_26	Geom OK	Norsok member
BC101060	0.00	LC101	OK	0.27	uf6_27	Geom OK	Norsok member
BY103090	0.00	LC101	OK	0.27	uf6_26	Geom OK	Norsok member
BD809070	1.00	LC101	OK	0.27	uf6_27	Geom OK	Norsok member
LZ109090	0.00	LC101	OK	0.27	uf6_26	Geom OK	Norsok member
LZ909090	0.00	LC101	OK	0.26	uf6_26	Geom OK	Norsok member

Notes:		
1:	Member:	Capacity model name
2:	Position:	Relative position along member longitudinal axis (start = 0, end = 1)
3:	Load case:	Name of load case under consideration. Load including factors
4:	Status:	Status regarding outcome of code check (OK or Failed)
5:	UfTot:	Value of governing usage factor
6:	Formula:	Reference to the formula/check type in N-004 causing the governing usage factor.
7:	GeomCheck:	Status regarding any violation of geometric limitations.
8:	SubCheck:	Which check causes the result, here NORSOK N-004 member check

Table 6-9 Upper jacket section – members. Usage factor for the lifting conditions, ULS Uf>0,25

6.3.3 Joint code check

Joint resistance shall satisfy the interaction equation 6.57 in NORSOK N-004, ref. [39], for axial force and/or bending moment in the brace. Section 6.4.3 in N-004, ref. [39], defines geometrical parameters for different joint type. The validity range for application of the equations given in section 6.4.3, which is used in the code check, is given as follows:

Validity range:
$0.2 \leq \beta \leq 1.0$
$10 \leq \gamma \leq 50$
$30° \leq \theta \leq 90°$
$g/D \geq -0.6$ (for K-joints)

Definitions of geometrical parameters:
$\beta = d/D$
$\gamma = D/(2T)$
$\tau = t/T$

d – brace diameter
D – chord diameter
t – brace thickness
T – chord thickness
θ – angle between chord and brace

Figure 6-10 shows the joint capacity model of the upper jacket section during lifting. The pink coloured joints have the largest usage factors which varies from 0,62 to 0,72. Table 6-10 gives an overview of joint with an utilisation factor (UfTot) above 0,40 in the jacket's upper section. Complete code check list for lifting condition is given in Appendix D, section D.1.1. All joints that have been checked have passed the utilisation check. Two equal joints have failed the geometry check, joints J805060 and J605060, for gamma (γ). The geometry parameter gamma is a value for the ratio between the chords diameter (D) and thickness (t).

The two joint that failed the geometry check had a γ = 9,14 and is therefore outside the given validity range. The derogation from the validity check is small and is therefore disregarded seeing that the automatic approach has been used for can length, stub length and gap which involves a variance.

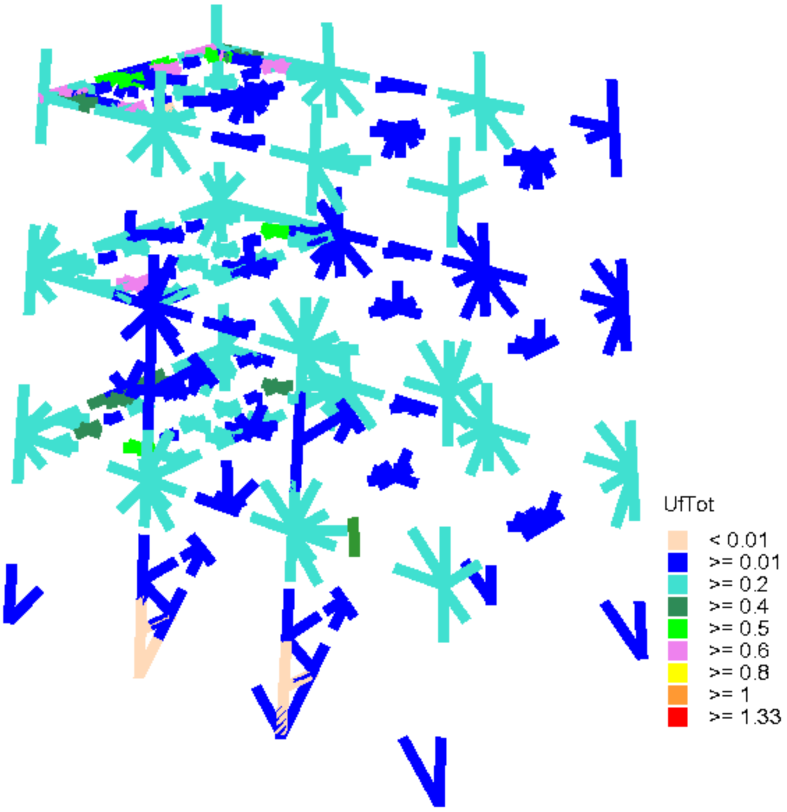


Figure 6-10 Upper jacket section, joints. Usage factor for the lifting conditions, ULS

Joint	LoadCase	Member	Status	UfTot	Formula	GeomCheck	SubCheck	JointType
J103090	LC101	BX103090	OK	0.72	uf6_57	Geom OK	Norsok joint	100% YT
J303090	LC101	BY303090	OK	0.67	uf6_57	Geom OK	Norsok joint	100% YT
J503090	LC101	BY503090	OK	0.67	uf6_57	Geom OK	Norsok joint	77% X, 23% YT
J107090	LC101	BX107090	OK	0.65	uf6_57	Geom OK	Norsok joint	100% YT
J306090	LC101	BY306090	OK	0.63	uf6_57	Geom OK	Norsok joint	100% X
J507090	LC101	BY506590	OK	0.63	uf6_57	Geom OK	Norsok joint	80% X, 20% YT
J503070	LC101	BY503070	OK	0.62	uf6_57	Geom OK	Norsok joint	100% X
J307090	LC101	BY306590	OK	0.60	uf6_57	Geom OK	Norsok joint	100% YT
J304090	LC101	BY303890	OK	0.59	uf6_57	Geom OK	Norsok	100% X

Joint	LoadCase	Member	Status	UfTot	Formula	GeomCheck	SubCheck	JointType
							joint	
J104090	LC101	BX104090	OK	0.58	uf6_57	Geom OK	Norsok joint	97% YT, 3% K
J507070	LC101	BY506570	OK	0.56	uf6_57	Geom OK	Norsok joint	100% X
J106090	LC101	BX106090	OK	0.55	uf6_57	Geom OK	Norsok joint	100% YT
J503060	LC101	BY503060	OK	0.54	uf6_57	Geom OK	Norsok joint	100% X
J303060	LC101	BY301060	OK	0.47	uf6_57	Geom OK	Norsok joint	87% X, 13% YT
J331090	LC101	BY331090	OK	0.45	uf6_57	Geom OK	Norsok joint	100% YT
J106060	LC101	BX106060	OK	0.42	uf6_57	Geom OK	Norsok joint	100% K
J104060	LC101	BX104060	OK	0.42	uf6_57	Geom OK	Norsok joint	100% K
J507060	LC101	BY506560	OK	0.42	uf6_57	Geom OK	Norsok joint	100% X
J339090	LC101	BY337090	OK	0.41	uf6_57	Geom OK	Norsok joint	100% YT

Table 6-10 Upper jacket section – joints. Usage factor for the lifting conditions, ULS Uf>0,40

7 Decommissioning by vertical split method using BTAs

7.1 General

The re-float method, used in the Frigg Cessation Project, is assumed used to remove the jacket from its original offshore location and float it inshore. The jacket is standing offshore at an elevation of about (-) 100 meters. The four BTAs are connected to each corner leg. To reduce the impact of water plane area and wave loads the BTA is installed with the main part of the BTA submerged. The top of the main tanks are about 4 meters below the surface. The jacket's piles will be cut and a float-up of the jacket using the BTAs will be performed. After the floating equilibrium position has been found the jacket with the attached BTAs will be towed to a determined location where a vertical cut will be executed. Strand jacks pull the two jacket sections apart into horizontal floating positions. Chains will be used to hold the bottom part of the sections together, but still allow rotation. After the jacket sections have reached their floating positions they will be towed to dock for dismantling using cranes from shore.

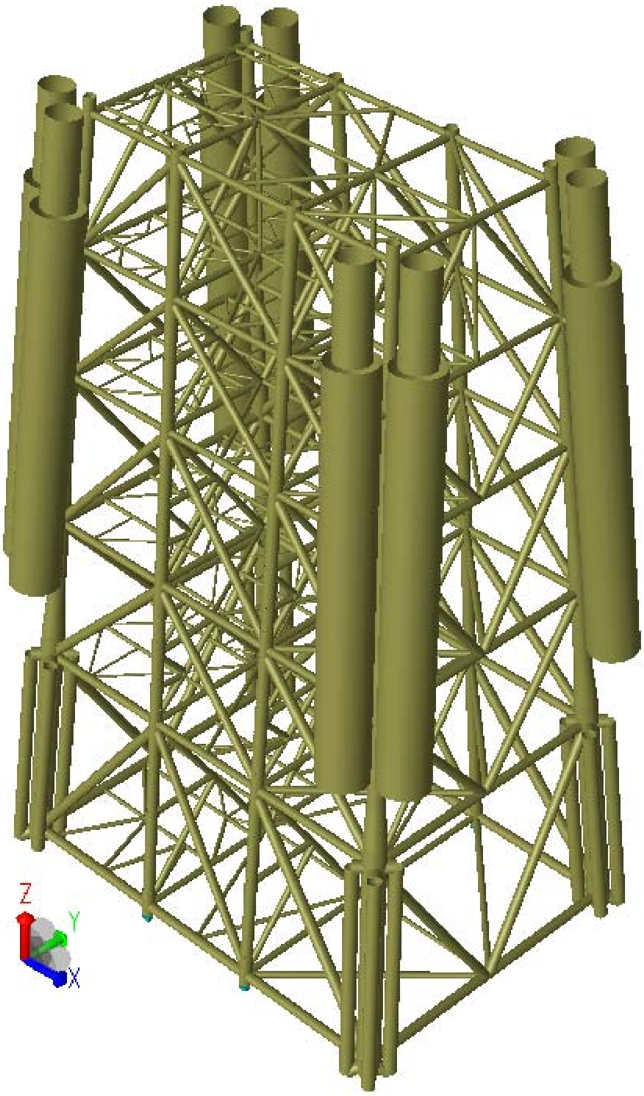


Figure 7-1 Jacket with BTAs

7.1.1 Model of the Buoyancy Tank Assemblies (BTAs)

The total height of each BTA is 65 meters, as the original BTAs used in the Frigg Cessation Project. The pyramid has a length of 12 meters and the main tanks a length of 53 meters. The assemblies are modelled by use of pipe profiles. In order to make it possible to regulate and control the ballasting and de-ballasting the tanks are divided into several elements. The main tanks are modelled with beam elements of a length of five meters. The element towards the pyramid has a length of three meters. The pyramid is modelled with two smaller pipes, and has element lengths of six meters. As a simplification the roll stoppers and the guides, described under section 2.2.1, are neglected in the model.

The BTAs are connected to the jacket leg at nodes in reference elevation (-) 11 430 and (-) 50 290, see Figure 4-1. By connecting the BTAs to the nodes the forces is assumed to also be distributed into the braces and partly account for the lack of roll stoppers.

The BTAs are modelled with material properties applicable for steel structure, and designed using material with yield strength of 355 MPa. The cross sections used in the computer model of the Buoyancy Tank Assemblies follow in Table 7-1.

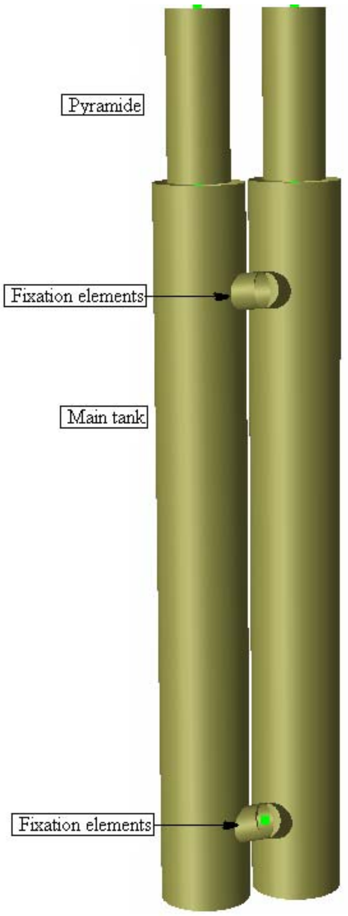


Figure 7-2 BTA

Name	Section type	Dimension (m)	Item
P6600x53	Pipe section	6.600 x 0.0530	Main tank
P4500x40	Pipe section	4.500 x 0.0400	Pyramid
P2600x53	Pipe section	2.600 x 0.0530	Fixation element

Table 7-1 Sections used in the BTA model

7.1.2 Float-up

When all the BTAs are installed, the jacket will be cut free from its piles. The buoyancy tank assemblies will be de-ballasted; compressed air will be pumped into the ballast compartment to displace ballast water. The de-ballasting will lift the jacket upwards until satisfactory bottom clearance is achieved. The BTAs are assumed to be fully de-ballasted so that all the compartments are empty. The float-up simulation is performed to find the floating equilibrium position. This position will be the starting position for the vertical split operation.

All elements that will be flooded after the vertical split has been set as flooded in the float-up simulation to give the correct starting position for the vertical split operation.

7.1.3 Vertical split

The jacket is to be cut vertical into two sections. The chosen cut is made from reference plan 1 to reference plan 4, see Figure 7-3. The cut from plan 1 to 4, normal to the width, requires more beams to be cut than to split the jacket from plan A to plan B. Cut 1-4 gives a larger distance between the BTAs and therefore a better stability than the cut A-B. The weight distribution between the two BTAs in the same jacket section, after the vertical split, is more equal because of symmetry. Uneven weight distribution may be possible to balance by using the ballast system of the BTAs. For further analyses of the vertical split and re-float method both the cuts should be analysed and evaluated in the view of costs, water depths and stability.

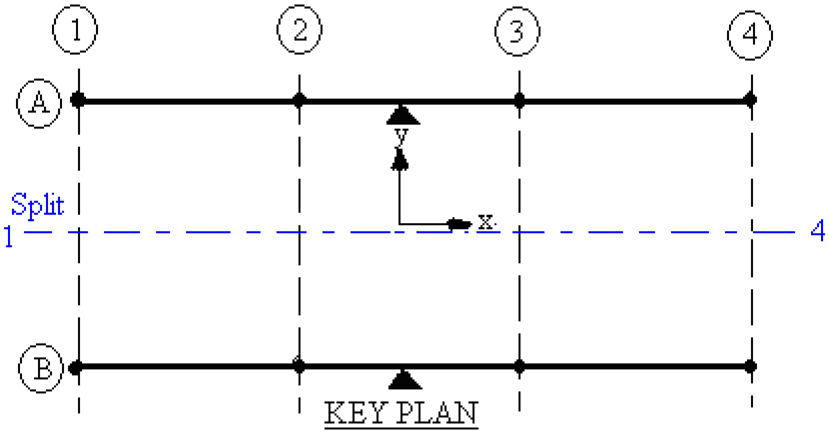


Figure 7-3 Vertical split of jacket, cut 1-4

The cut is to be made 2,1 meter in negative y-direction. The split is made about two meters to the side of the centre to get clear of the nodes and make an easier cut operation. The lowest level, reference el. (-)100 000, is cut at centre through the nodes at reference plan 1 and 4 only. It is possible to cut trough nodes, but this is assumed to be a more time- and cost-demanding procedure. Only where it is necessary to have closed end, no free brace elements, this method is chosen. At the lowest level chains will be used to hold the two sections together to they have reached their vertical floating positions. Then the chain may be cut and the two jacket sections float freely or they may be chained when the sections are towed to shore. The chain is modelled by use of one meter long beam members. In reality the chain will go around the braces at the two nodes and fastened on a higher level on the jacket. There are different ways the connection with the chain can be done. One alternative way is to guide the chain trough the braces at the nodes and into a cross before the two ends are fastened on a higher level of the jacket. The chain will prevent that the lower parts of the two jacket section move apart, but allow the jacket sections to rotate to horizontal position.

External forces have to be applied to pull the two jacket sections apart after the vertical split is performed. Four strand jacks are attached to each of the jackets middle-legs at the top level, reference level (+) 6 095. The strand jacks are modelled with pipe sections.

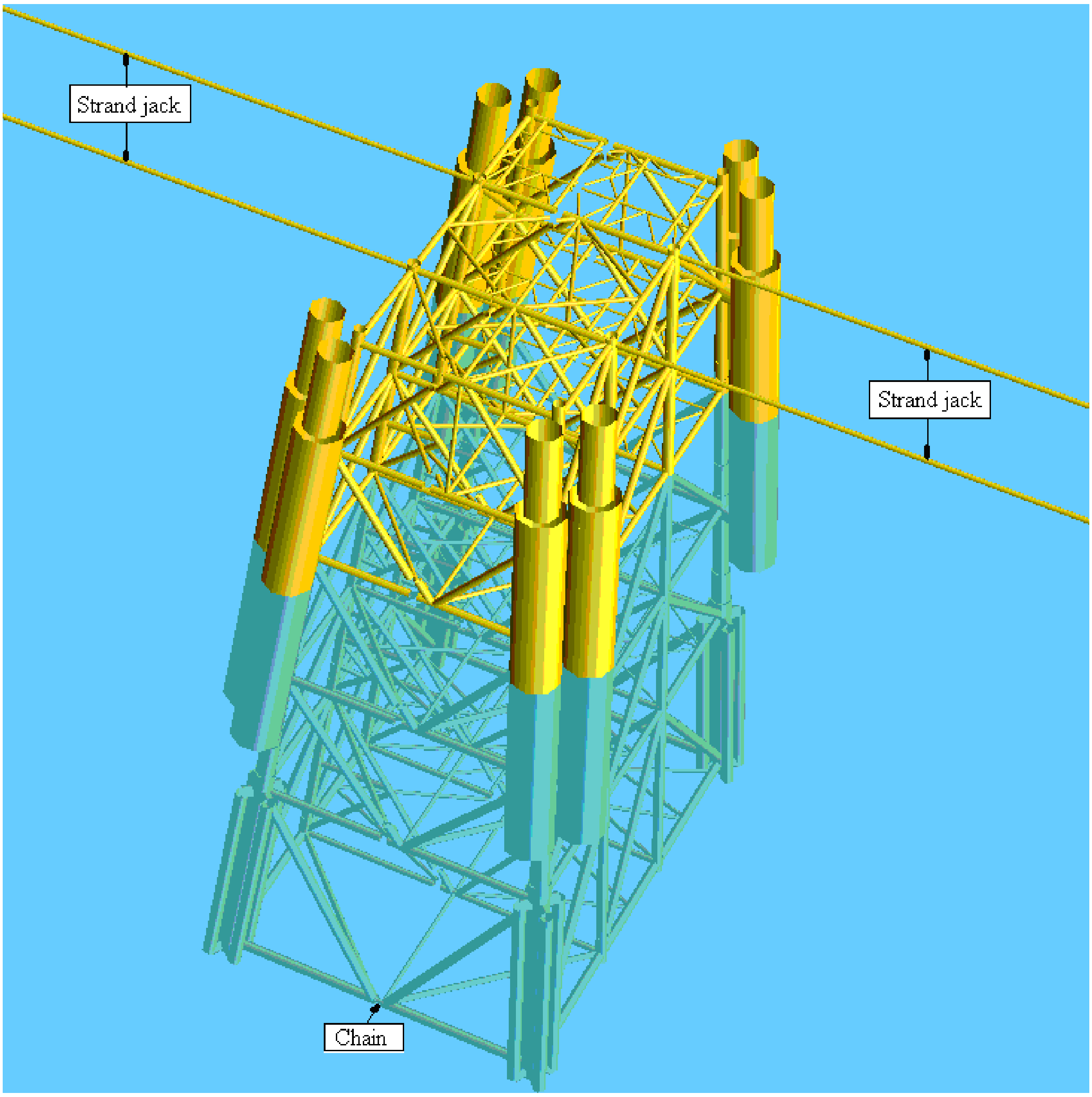


Figure 7-4 After cut – jacket floating in vertical position

7.1.4 Actions

The loads consist of steel weight of the jacket, the piles and the BTAs, the grout weight and buoyancy forces. Marine growth is not included, submerged marine growth does not influence the total weight; the density of marine growth is equal to the buoyancy. The marine growth on the jacket over sea (in air) will have an effect on the total weight, but this weight contribution is neglected.

Buoyancy is computer generated and based on water depth and members defined as buoyant, which means not flooded members. The jacket legs and sleeves are assumed to be flooded. All braces that are cut are assumed flooded. It is assumed that the flooded members are dewatered over water surface. It will be drilled holes in members to drain the water. This assumption is done as an approach to the analyses done by Usfos which does not account for flooding of member over sea water level.

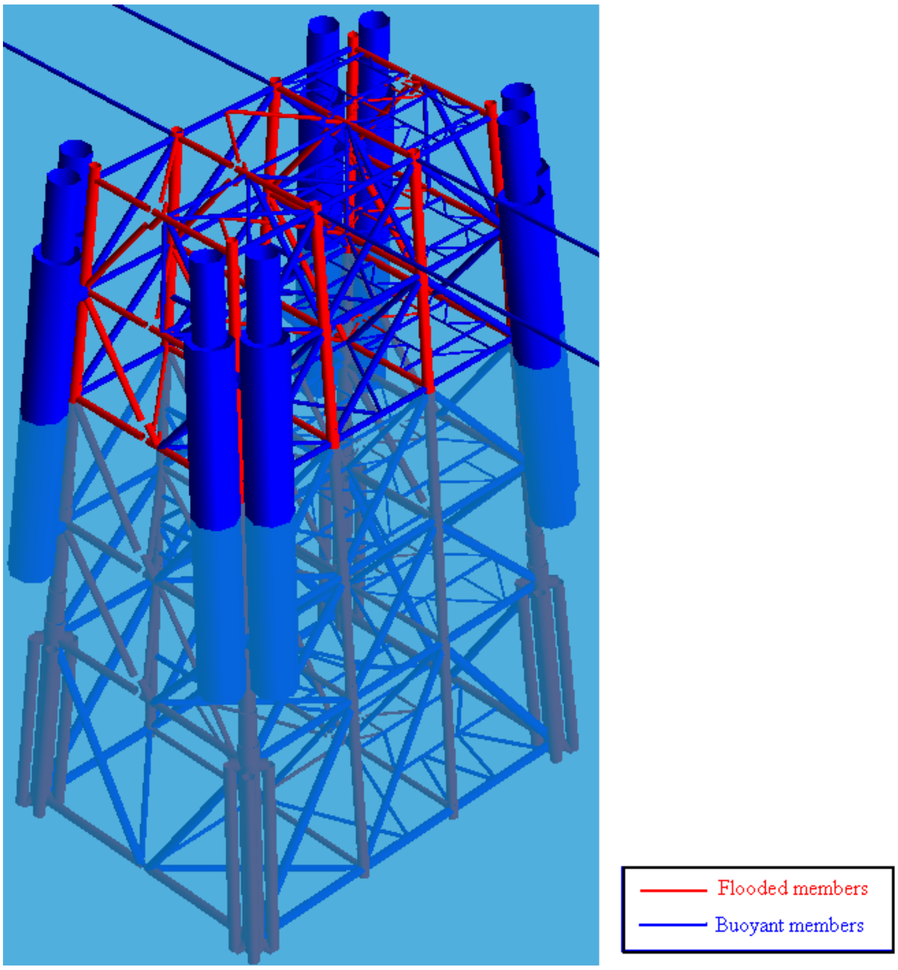


Figure 7-5 Flooded members

Buoyancy in the BTAs is integrated in Usfos by use of element histories. The assemblies' main tanks are set to have maximum buoyancy which means that they are completely de-ballasted. The pyramids have a 10% acting buoyancy force which means that only 10% of the pyramids' volume is de-watered.

It is assumed that the sleeves, including piles and grout, will be removed before the rotation operation starts since this will be required in order to get each jacket section into the wanted floating position. The weight of sleeves, piles and grout to be removed is 1 853 tonnes. Table 7-2 presents a summary of the weights for the whole jacket that is accounted for in the analyses.

Description	GeniE (tonne)	Usfos (tonne)
Jacket steel/Grout	7494	5641
Marine growth	605	0
BTAs		4*1080 = 4318
Total		**9959**

Table 7-2 Summary of loads

7.2 Analyses setup

7.2.1 Structural analyses

The analyses are performed using Usfos software program. The Bouyancy Tank Assemblies (BTAs) are modelled in Sesam-GeniE and connected to the jacket legs. The computer models from GeniE are transformed to Usfos format. All analyses have been run dynamically.

Three analyses are executed:
- Float-up of jacket with BTAs
- Rotation after vertical split using strand jacks
- Last part of rotation from a starting angle, without strand jacks

The operations are assumed to be performed under restricted weather conditions. The vertical split is executed in water with minimal to no currents and with flat sea.

Without using strand jacks and chains the jacket sections will float up over one another with the BTAs at top and the braces pointing downwards. The entire load of the jacket is then held by the clamps only. When the jacket section floats up with the BTAs at the bottom and the braces pointing upwards, the jacket will be resting more against the buoyancy tanks not only held by the clamps.

The strand jacks are modelled to start to pull after 90 seconds with an increasing velocity. 0,25 meter per second is reached after 190 seconds. After 190 seconds the strand jacks pulls with constant velocity of 0,25 meter per second.

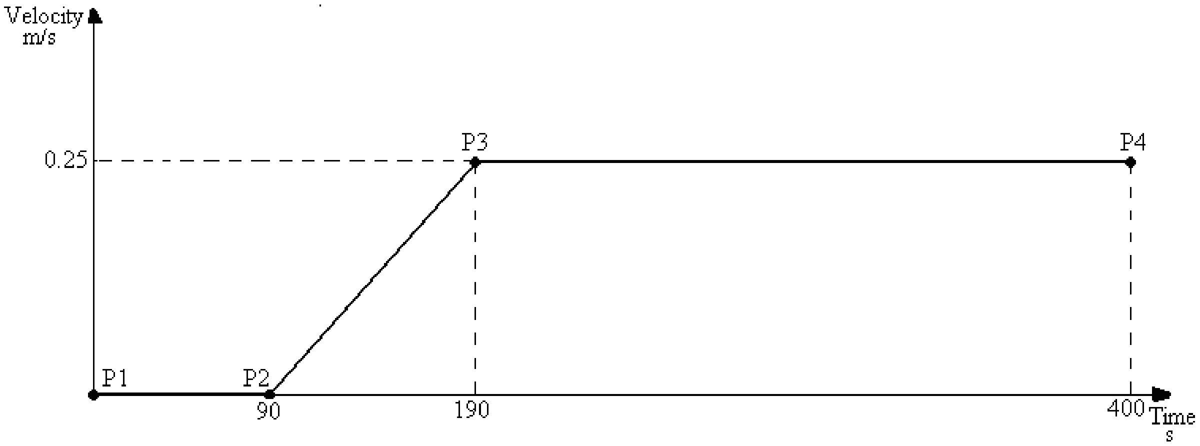


Figure 7-6 Strand jack velocity as a function of time

The simulations are much faster than the actual operations would be. Actual strand jack speed is for instance around a couple of meter per hour and indicates that the rotation operation will take a whole day. The speed up in the simulations will increase the dynamic. A damping of 15% is assumed in order to balance the unrealistic dynamics. 1% damping is used for the analysis were the jacket floats up and rotates without any strand jacks.

7.2.2 Material- and load factors

The structural integrity of the jacket will be evaluated in the ultimate limit state (ULS). According to DNV, ref. [37] table 2-7, a load factor of 1,3 shall be used for a ULS design. A material factor of 1,15 applies in accordance with NORSOK N-004, ref. [39], for ultimate limit state. The factors are applied in the Usfos input file by dividing the yield stress for the jacket structure by the total factor of 1,5 (1,3*1,15=1,5).

Load*1,3 < Resistance/1,15
Load < Resistance/(1,3*1,15)

7.2.3 Boundary conditions

Before the piles are cut the eight jacket legs are fixed to the seabed with pinned connections. Under the float-up and the vertical split no boundary conditions applies.

Hinges are introduced to the chain connection in one end and to the strand jacks. Rotation in local y- direction is allowed.

7.3 Analyses results

7.3.1 General

The analyses are non-linear dynamic analyses. Structural integrity is investigated for the vertical split operation. The float-up analysis is only a simulation of the operation. The simulation presented below is when the BTAs are fully de-ballasted. Simulations are also executed with partly ballasted BTAs.

The analyses are done in accordance with NORSOK N-004, ref. [39].

7.3.2 Float-up

By de-ballasting the BTAs completely the buoyancy force lift the jacket up a maximum height of 31 meters in vertical direction. Equilibrium is reached at a floating position at about 24 meters over the seabed. Figure 7-7 shows the vertical displacement in meter along the y-axis as a function of time (seconds). When the sleeves, including the piles, are removed the jacket will have the equilibrium position five meters higher, a float-up of about 29 meters.

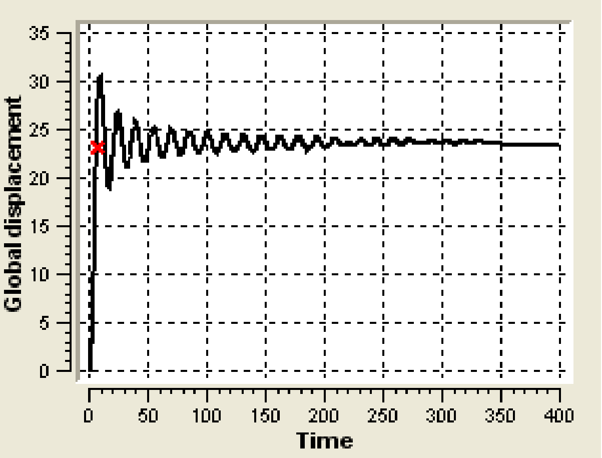


Figure 7-7 Float-up - vertical displacement

The picture series Figure 7-8, Figure 7-9 and Figure 7-10 given below show the float-up of the jacket from the fixed position at seabed to the floating equilibrium position.

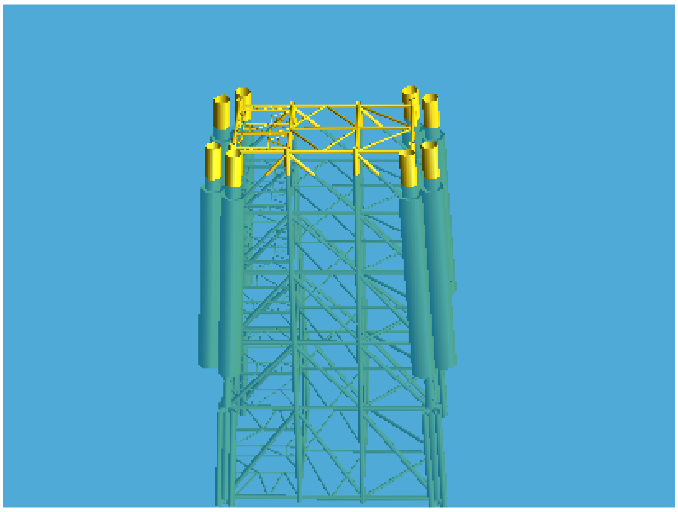


Figure 7-8 Jacket fixed to seabed

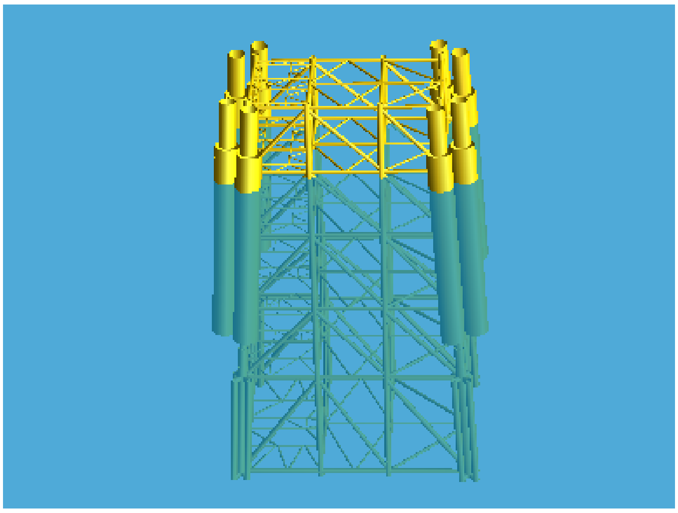


Figure 7-9 Float-up

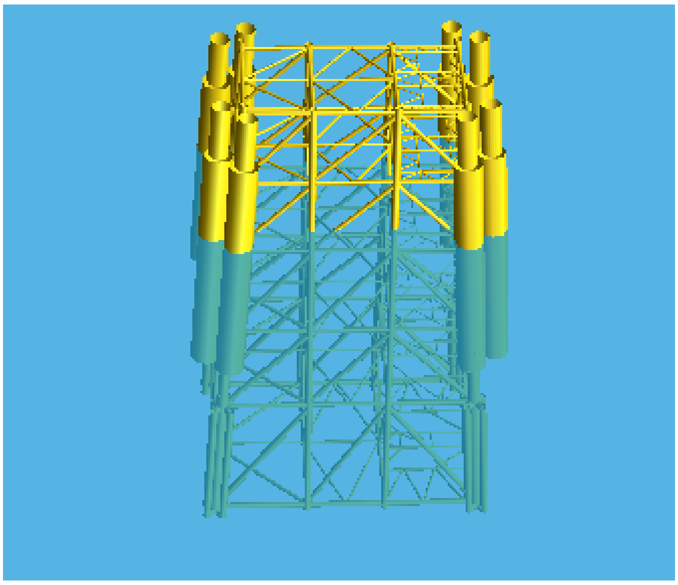


Figure 7-10 Equilibrium position

7.3.3 Vertical split

The strand jacks pull the jacket section apart and the bottom part secured with chain ensures a controlled rotation to the final floating situation. Figure 7-11, Figure 7-12 and Figure 7-13 below show plots from the performed simulation.

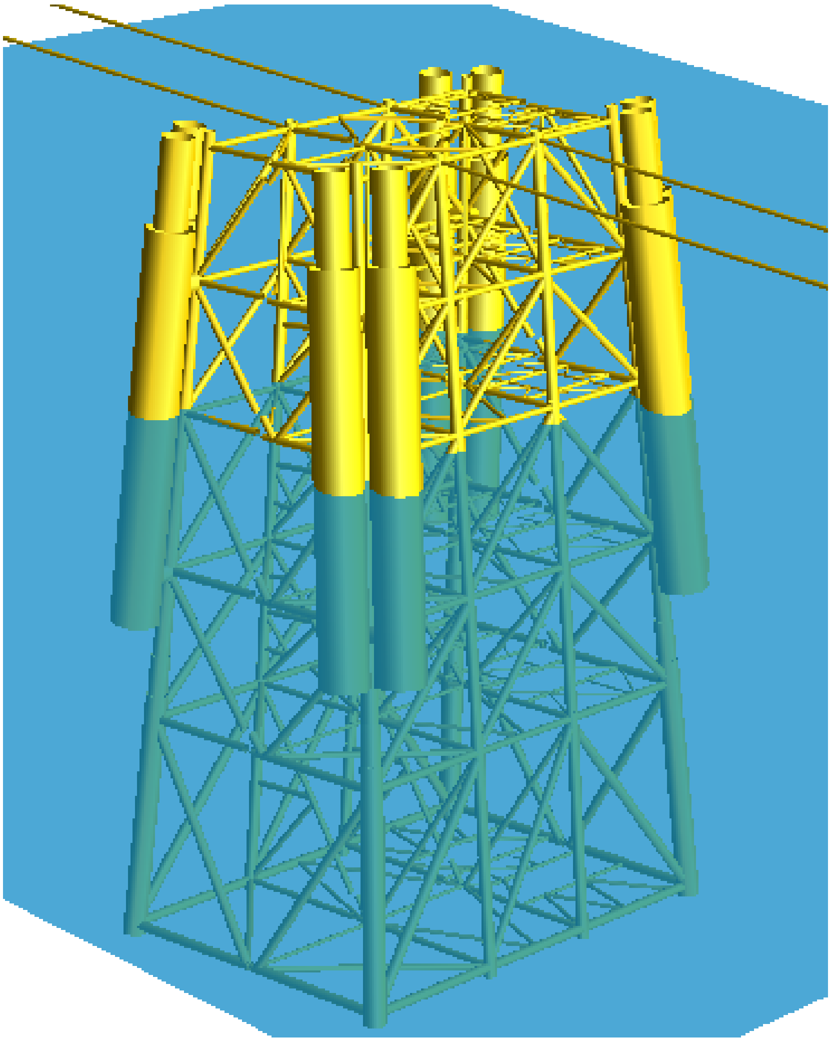


Figure 7-11 Floating situation after cut

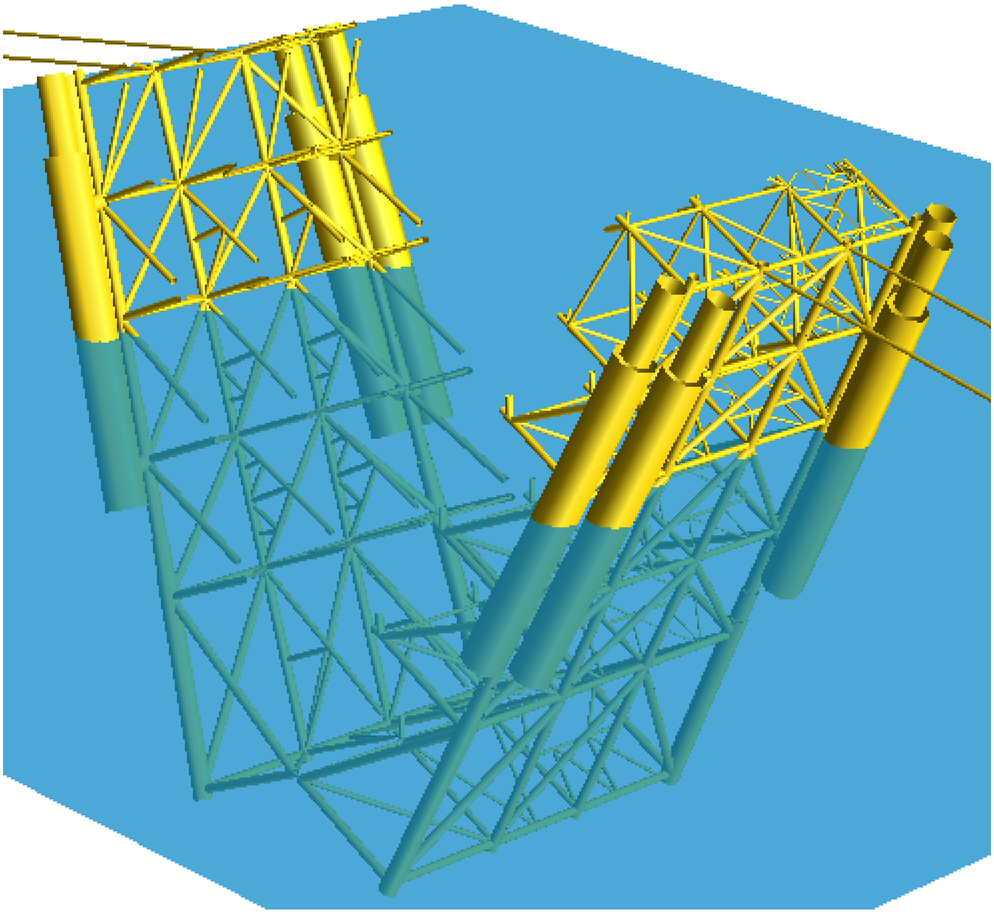


Figure 7-12 Floating situation during rotation

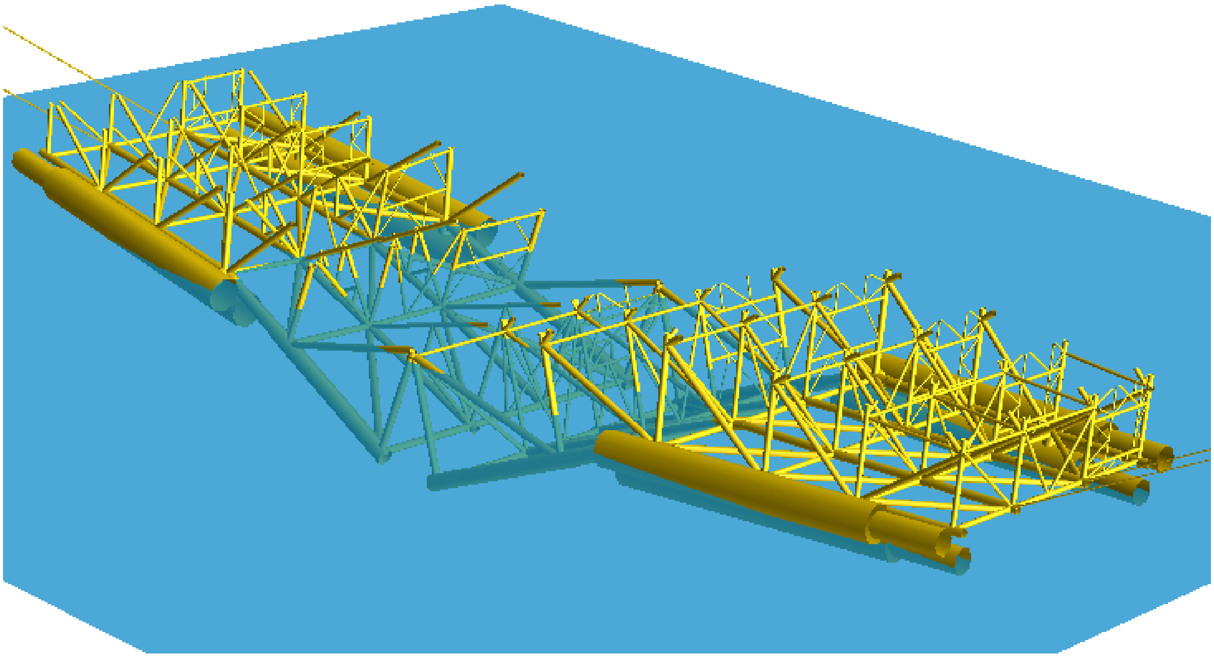


Figure 7-13 Final floating situation

The forces in the strand jacks increase in the beginning until a negative force, tension force, of about 1 MN or 100-120 tonnes, see Figure 7-14. From this maximum point the force in the strand jack decreases and after nearly 300 seconds compression appears. The compression force arises after the jacket sections have rotated an angle of about 25 degrees from vertical position. The jacket will from this rotation angle rotate to the vertical position without any external forces needed. An analysis without strand jacks where the jacket sections have been rotated a start angle of 25 degrees has been executed to verify.

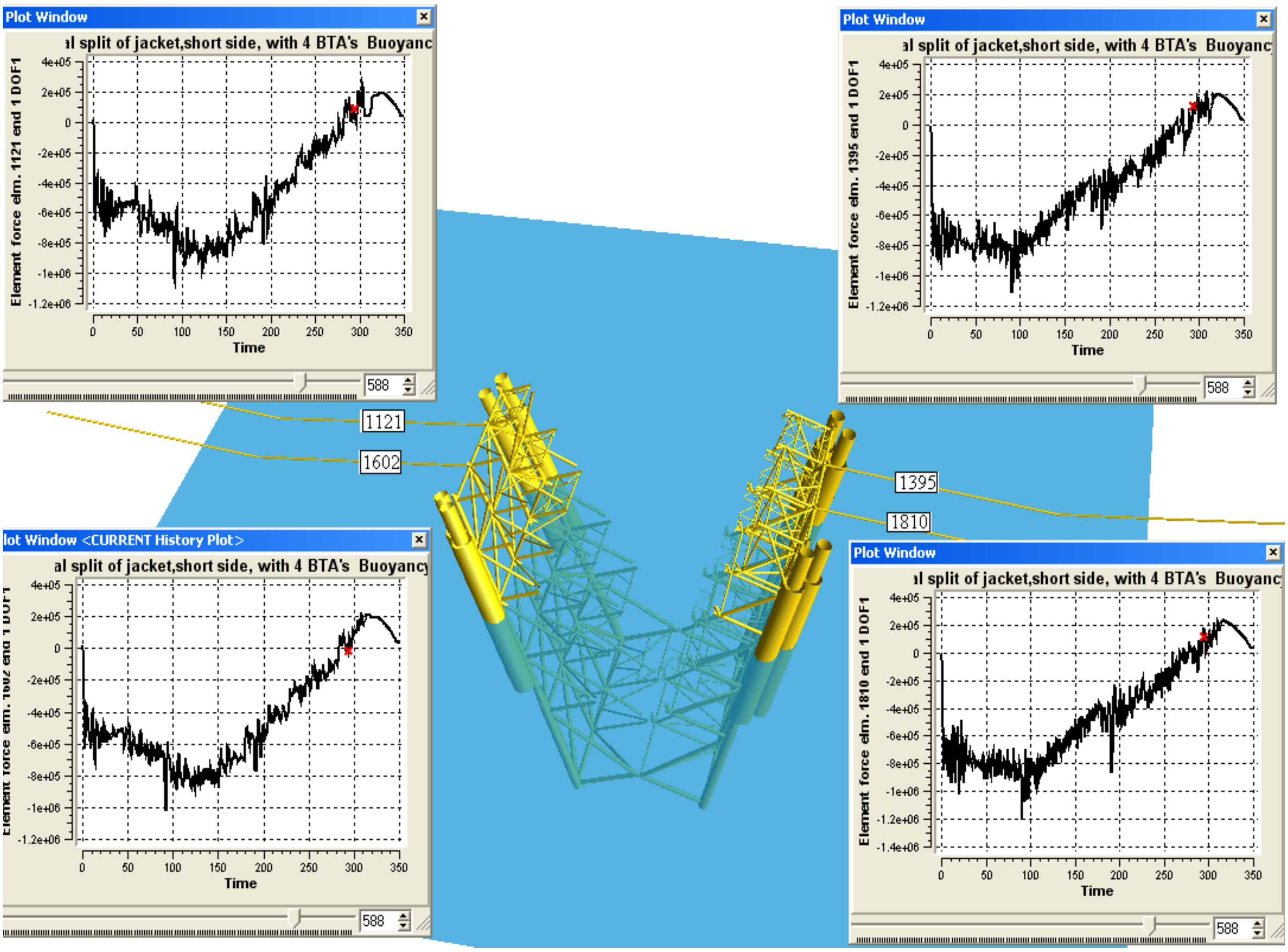


Figure 7-14 Strand jack forces

7.3.3.1 Jacket utilization

In the following plots plastic utilization are presented. Figure 7-15 presents a plot for the plastic utilization after cut, Figure 7-16 and Figure 7-17 presents plastic utilization during rotation, and Figure 7-18 presents plastic utilization in the final floating position.

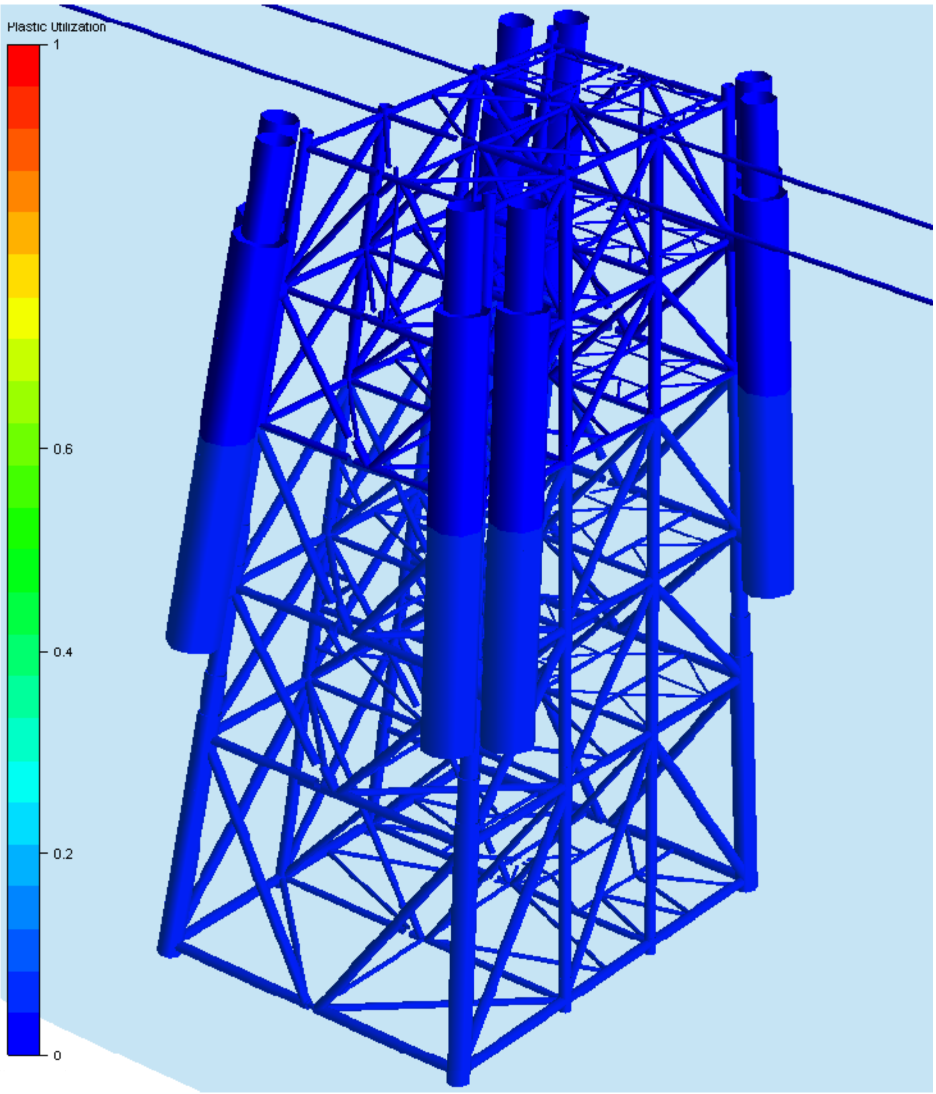


Figure 7-15 Plastic utilization after cut

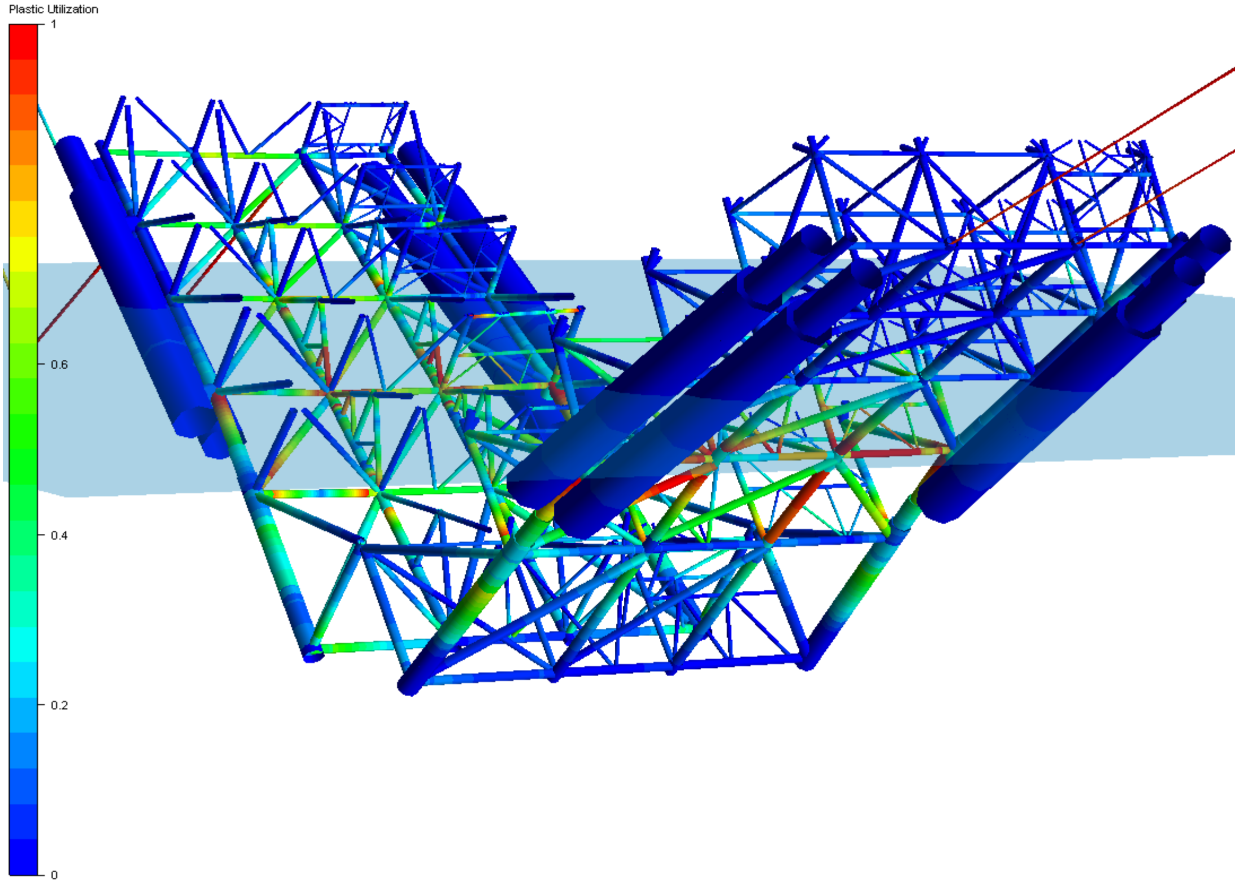


Figure 7-16 Plastic utilization during rotation

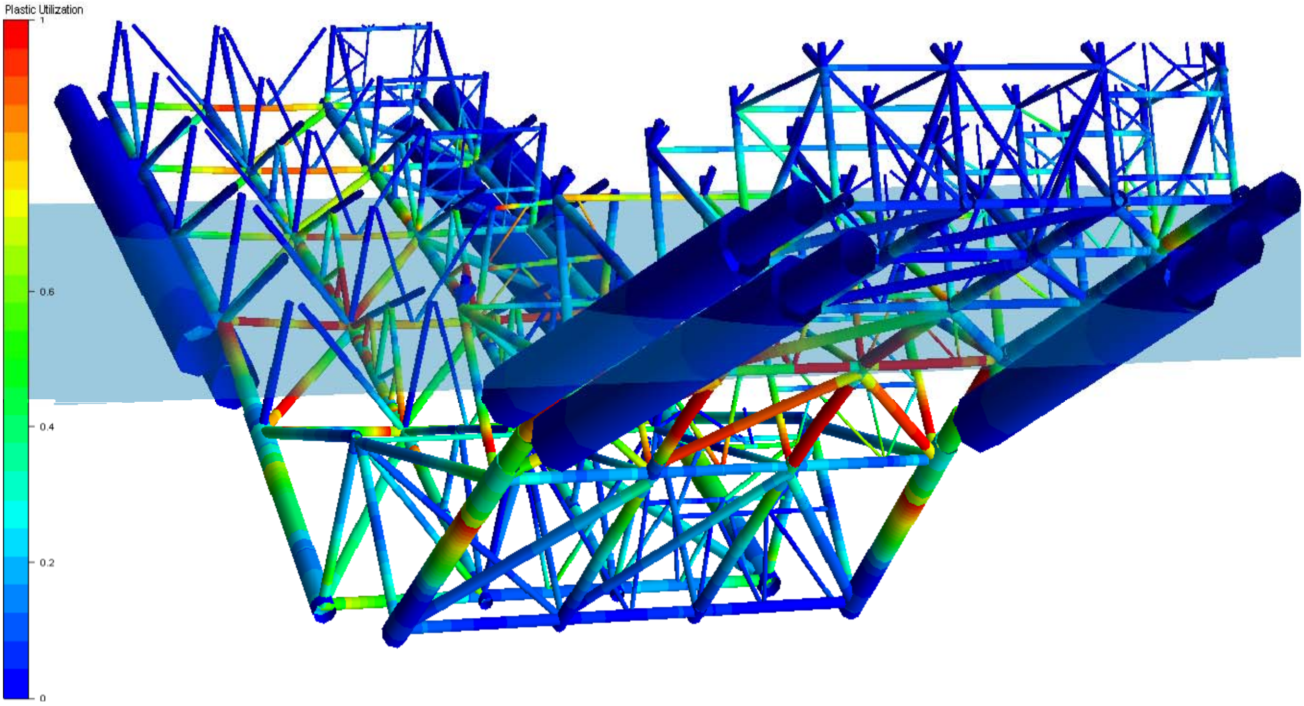


Figure 7-17 Plastic utilization during rotation

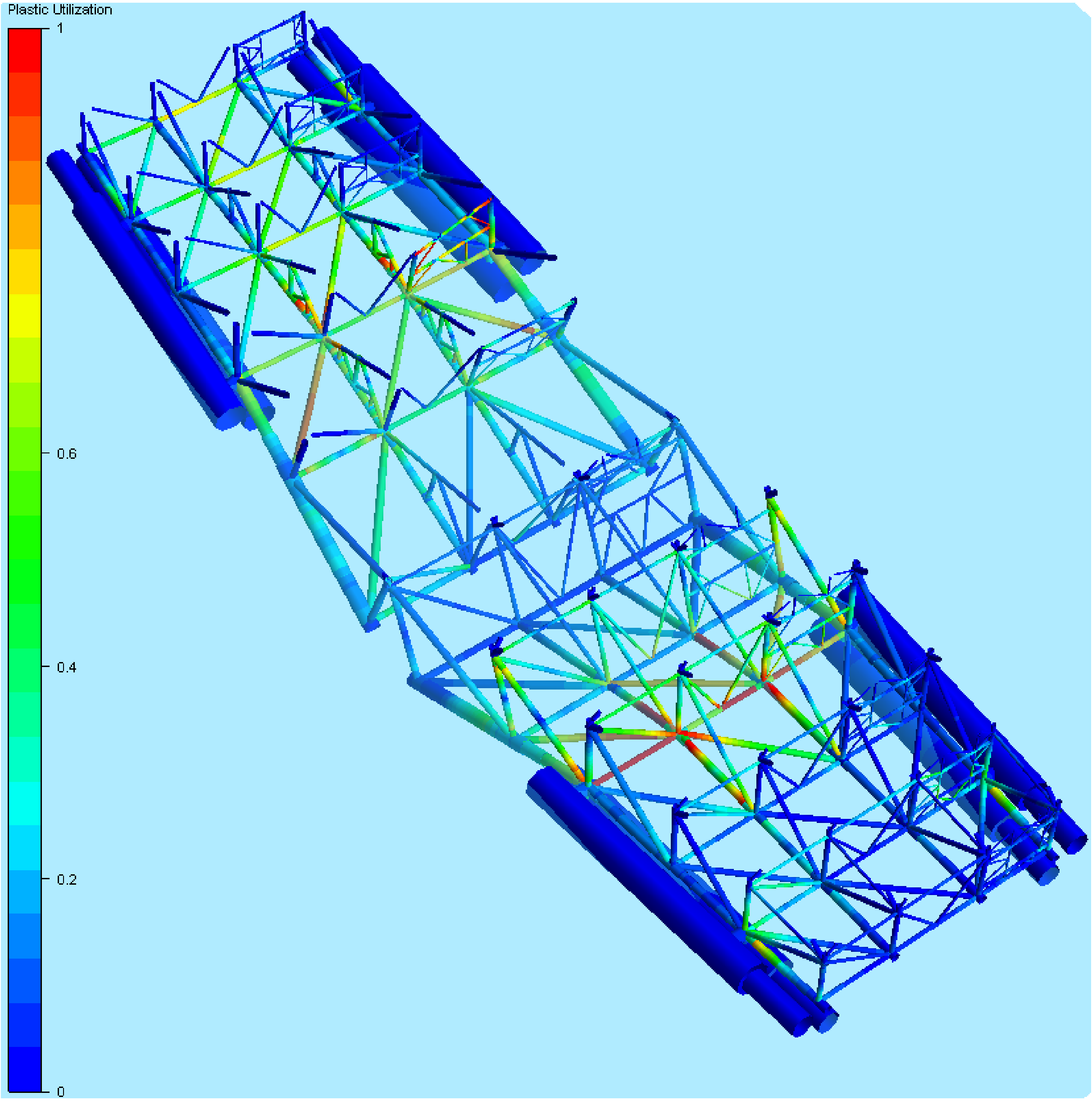


Figure 7-18 Plastic utilization in final floating situation

The jacket will have rotation (deflection) in the jacket legs around the lower part where the BTAs end, at reference level (-) 50 290, where a plastic zone appears. The rotation of the legs reaches an angle of about 15 degrees due to yield in the material. The buoyancy in the BTAs and the un-flooded members lift the jacket up while the gravity forces try to pull the jacket down. Large weights in the lower part of the jacket and little buoyancy forces to lift the lower part up leads to formation of plastic hinges where the BTAs end. Hence, the jacket legs bends down as figure 7-17 shows. Leg members and brace members around this area attain a plastic utilization factor close to 1 and some members exceed the plastic utilization. The plastic utilization is at the most exceeded with 10% - 15 %, see Appendix D section D.1.2.

Von Mises stresses are plotted in Figure 7-19 and Figure 7-20. The plot shows the highest stresses that appear during the operation. The stress value exceeds the reduced yield strength which is 230 MPa (345MPa/1.5 = 230MPa) in several members. Maximum stresses have a value of 320-350 MPa and appears in the middle legs at reference elevation (-) 50 290. The Von Mises stresses support the plastic utilization results.

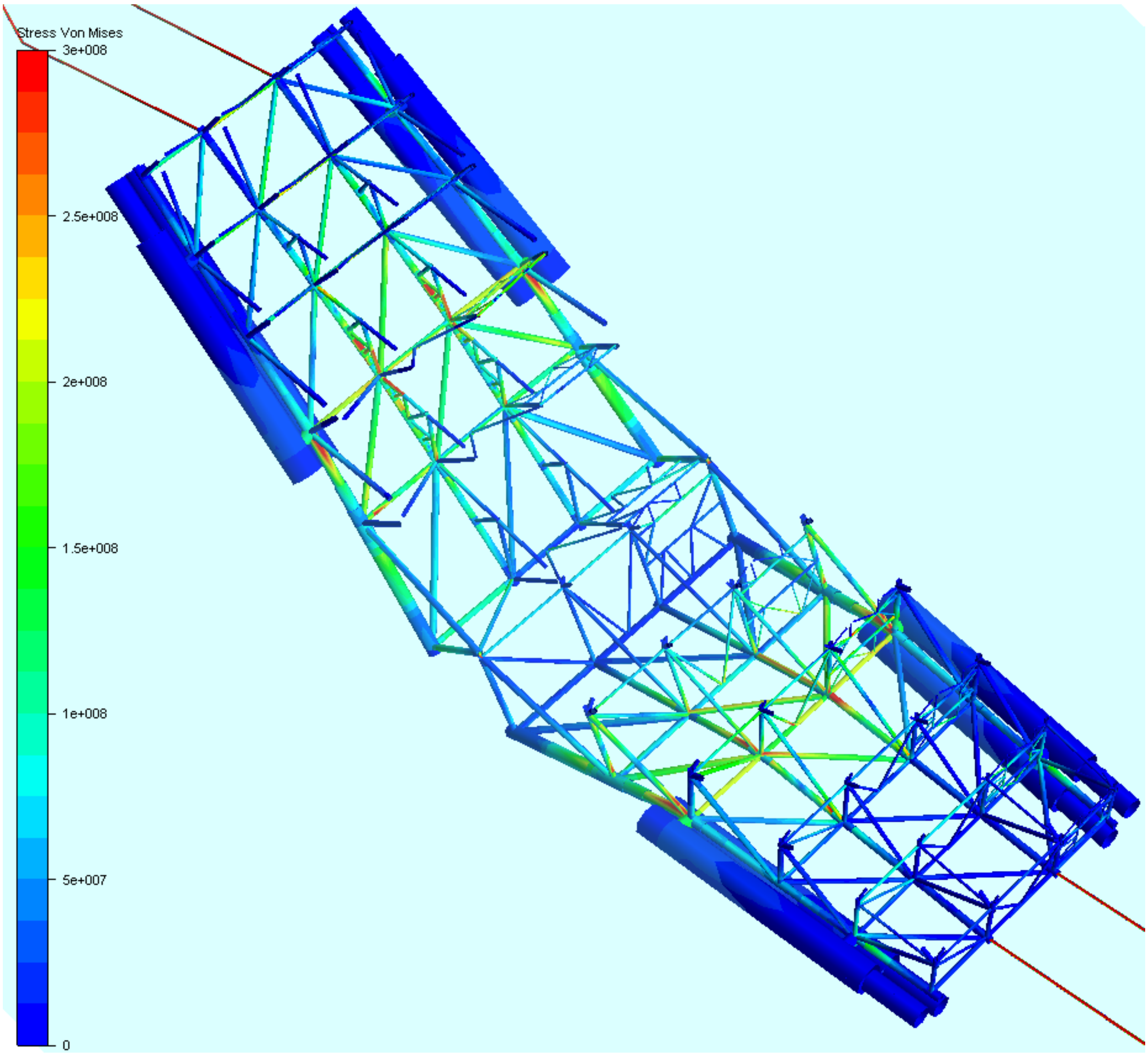


Figure 7-19 Von Mises stresses, during float-up and rotation

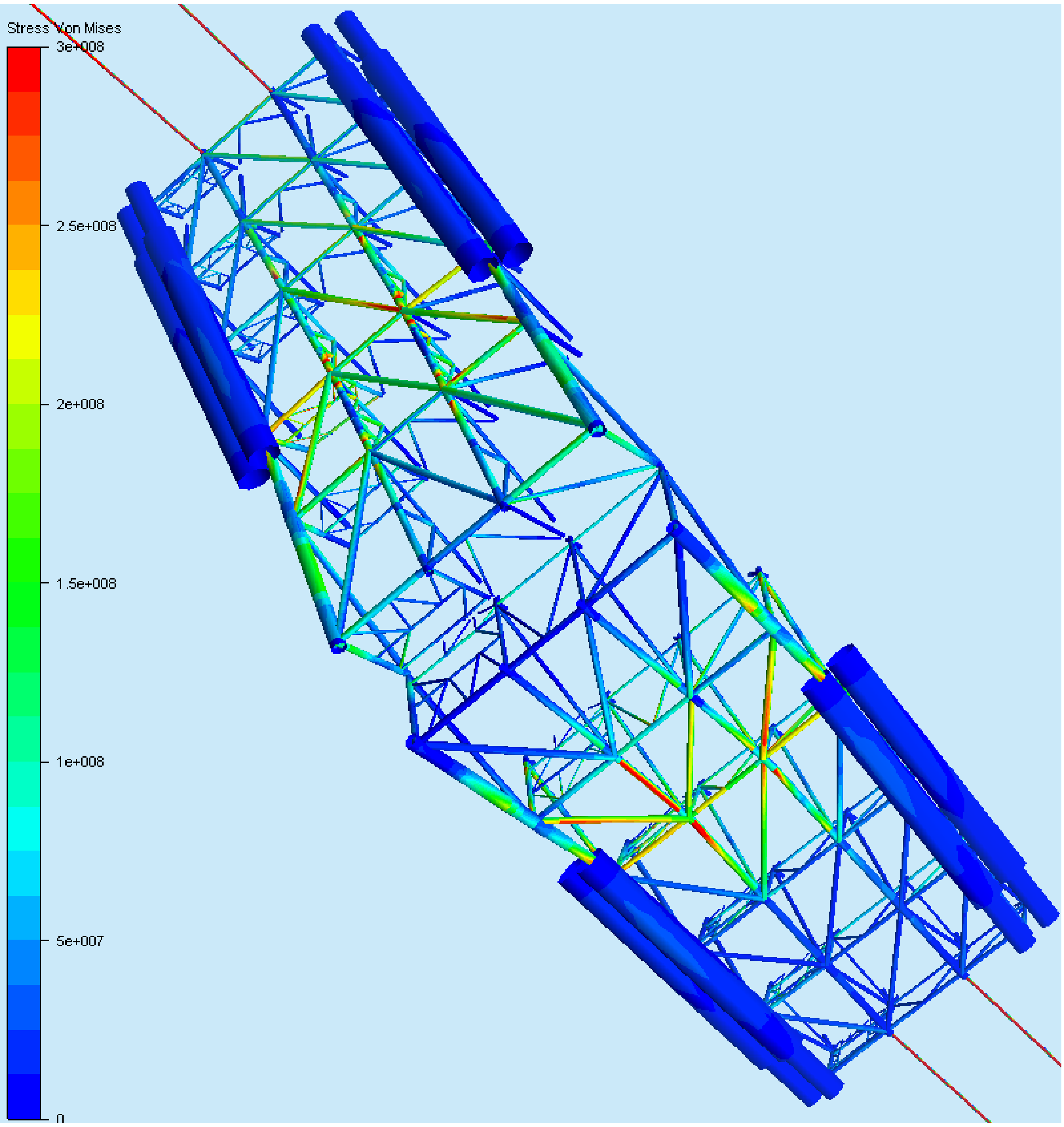


Figure 7-20 Von Mises stresses, during float-up and rotation. Seen from below

Figure 7-21 presents the beam strain attending in the jacket under the final floating situation, which is the situation where the largest strains occur. NORSOK N-004, ref. [39] proposes critical strain values, ε_{cr}, for different steel material grades in table A.3-4. Steel grade S 355 is proposed to have a critical strain value of 15%, while S 235 is given a critical strain value of 20%. The critical strain value given is assumed to be conservative. Under the vertical split operation the maximum strain occurs in the leg members where the rotation appears. The highest occurring strain has a value about 20% and the failure criterion in accordance to N-004 has been reached.

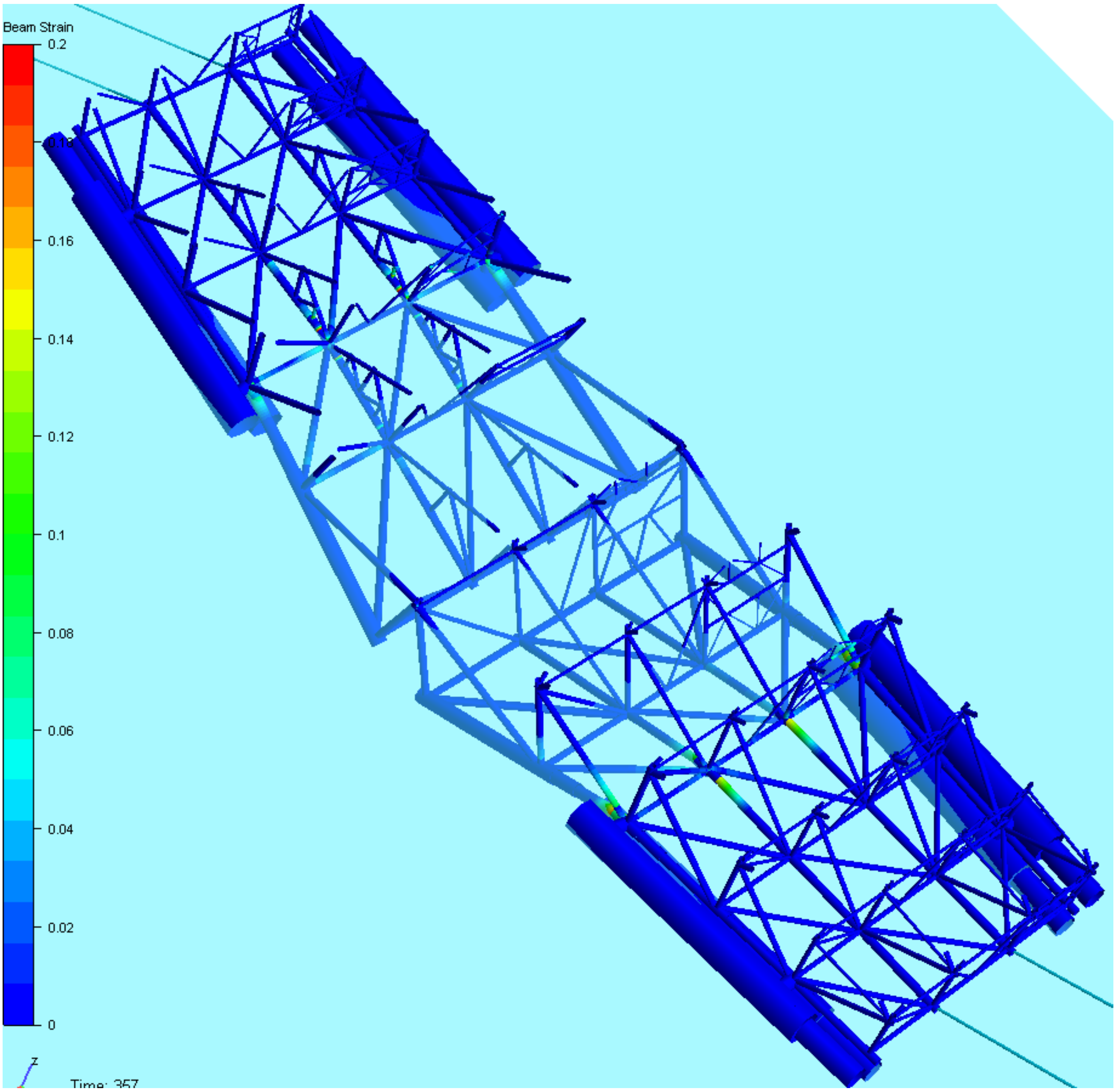


Figure 7-21 Beam strain in final floating situation. Fringe range 0 – 0,2

7.4 Evaluation of the analyses

To verify how Usfos software program calculates buoyancy forces in partly submerged horizontal elements a control has been performed, Appendix C section C.1.1. The control is executed by use of a fixed pipe similar to a BTA's main tank, and the draft is varied. Both static and dynamic analyses are carried out and compared to hand calculations. The control confirms that Usfos calculates the buoyancy forces in a dynamic analysis correctly; the buoyancy force value is a function of the submerged volume depending on draft. For a static analysis on the other hand Usfos understand the pipe to be empty as long as the water surface is under the system line of the pipe. Hence, Usfos calculates the buoyancy forces to be zero as long as the water surface is under the pipe's system line. When the water surface is on the pipes system line or over Usfos calculates the buoyancy force correctly. Since only dynamic analyses have been carried out, Usfos' buoyancy calculation is seen as exact.

The float-up simulation is performed with fully de-ballasted BTAs which results in a high floating position. Offshore the jacket would presumably not be lifted a height of 25-30 meters over seabed but closer to a height of 10-15 meters. Inshore the BTAs could be additionally de-ballasted and lift the jacket to the wanted position. Since the aim of the float-up simulation is to find the floating position the jacket will have before the vertical split, the BTAs are de-ballasted as they will be under the vertical split operation. The operation is also analysed to be feasible using partly ballasted BTAs. The presented results for the vertical split operation are chosen to be based on fully de-ballasted BTAs.

The BTA model and the corresponding connections to the jacket introduce uncertainties to the analyses and require more details. In the performed analyses the pyramids are set to have 10% buoyancy capacity which is assumed to be a conservative choice. This assumption should be more closely evaluated. The pyramids are modelled with two pipes which is a simplification that presumably gives the pyramids a larger volume than actual. In addition the pyramids have a “control room” and this may also reduce the buoyancy capacity because of reduced “free” area. In the simulation of the vertical split removal method the pyramids are only just submerged and the assumption about reduced buoyancy capacity in the pyramids does not have large influence on the results from the analyses.

The BTA main tank that is facing out will contribute with a moment force because of the position of the tank beside the jacket leg, Figure 7-22. Reducing the buoyancy force in the main tanks furthest out will reduce the acting moment force and the utilisation of the exposed brace members. The assembly beside the jacket leg will be only partly submerged which reduces the moment force considerable. The analysis results indicate that the moment forces from the BTAs are not a factor of vital importance for the feasibility of the vertical split removal method, but they may increase the utilisation and the appearing strains in some degree. The moment force from the BTA should be evaluated in further studies of this removal method.

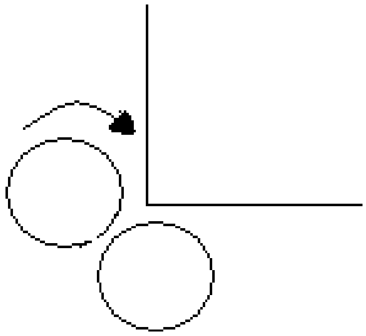


Figure 7-22 Moment force from BTA

For large rotations strain hardening will occur in the jackets leg members. The strain hardening effect enlarges the plastic zone and will with that distributes the strains. With no strain hardening the high strains will be very localised. The strain hardening is a result of formation of dislocations entanglement that make motion of the dislocations more difficult and higher stresses are needed to push new dislocations through these entanglement. Hence, the resistance increases. Usfos calculates for strain hardening, see section 5.1.2, and strain hardening contributes to the bending moment as illustrated in Figure 7-23.

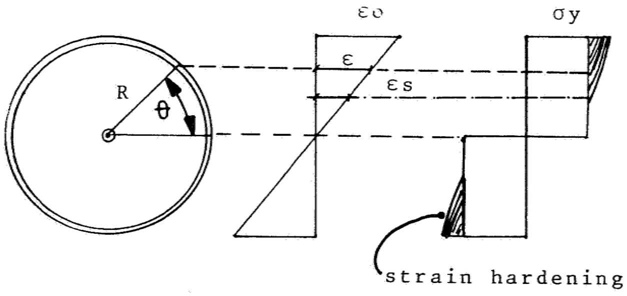


Figure 7-23 Strain/stress distribution for a tubular cross-section [31, page 10.7]

The jacket is in a critical zone both regarding to plastic utilization and strain. The analyses reveal that the most critical stage, with the largest utilization and strain values, is in the last stage of the float-up and rotation (after approximate 350 seconds). The plastic utilization and the failure criterion are exceeded; hence the capacity of the structure has been exceeded.

The vertical split removal method will not be feasibly for many jackets without doing any assessing measures. The lower part of the jacket is often to heavy and has too little buoyancy. Measures have to be done to achieve the wanted floating situation. Removal of sleeves, including piles and grout, is a measure done in this study. The results show that even if the wanted floating position has been reached the structural integrity may still not be satisfactory. Alternative or additional measures can be:

- Increasing the length of the BTA-cylinders
- Add buoyancy at the lower part of the structure, for instance by providing inherent buoyancy in the legs or by adding a buoyancy body
- Cut the jacket in the other direction (cut from reference plane A to B)
- Make the cut through the nodes
- Reinforcements

The BTAs may be modified to obtain sufficient buoyancy. By increasing the length of the BTA-cylinders additional buoyancy will be provided and the moment force will be reduced, hence the beam strain and the plastic zone may decrease. A modification of the BTAs to allow a deeper installation-draft may also be an alternative to make the vertical split method feasible for a larger range of jackets.

Another alternative is to do the vertical split from reference plane A to B, see Figure 7-3. The jacket will then have a deeper float position, but there will be trusses in the whole length of the jacket that may distribute the forces and reduce the moment and hence the deformation of the jacket legs.

A cut through nodes gives less flooded members than a cut to the side of the nodes and with that larger buoyancy force. In order to achieve less flooded members the cut through nodes have to keep the braces intact.

Reinforcements around the exposed areas may be a measure to decrease the jackets utilisation. A simple truss-frame may be built to reduce the bending moment in the jacket legs.

8 Decommissioning by reversed launching method

8.1 General

The jacket will be moved from its offshore location to an inshore location using the BTAs and the re-float method. The jacket is assumed set down inshore outside the Stord decommissioning yard at a water depth of approximate 80-90 meters. The plan is to install a Purpose Made Barge (PMB) to the jackets launch runners, see Figure 8-1. The PMB will be mobilised and pulled down along the launch runners.

The idea with the reversed launching method is to use buoyancy from the BTAs and from the PMB to rotate and lift the jacket so it is possible to tow the arrangement to pier and on to a load in jetty. The BTAs and the PMB will contribute to the lift and rotation operation by a controlled ballasting and de-ballasting of different chambers. From the load in jetty the jacket will be pulled on shore by use of strand jacks. The PMB and the BTAs must be disconnected when the jacket is lying on the jetty. Onshore the jacket is ready to be dismantled.

At the first stage of the rotation all four of the BTAs are connected to each corner leg of the jacket. Strand jacks on a barge will be connected to the jacket footings and help to tilt the jacket. When the jacket is rotated an angle of about 10 degrees, from the vertical axis, two of the BTAs will be disconnected and removed. The strand jacks on the barge and the remaining two BTAs will lift and rotate the jacket until approximate 60 degrees. Simultaneously with the lift/rotation the jacket will be pulled and guided along a defined towing route using mooring winches. The distance between jacket footings and seabed will be kept to a minimum. The jacket will be moved from a water depth of 80-90 meters to a water depth of about 50 meters. The PMB are assumed to have minimum buoyancy in this first part of the operation. When the jacket is rotated an angle of about 60 degrees the rotation will be stopped and the four legs facing the shore will be grounded at 50 meter water depth. When the jacket is in this grounded position the PMB will be de-ballasted and the jacket will float up from the seabed. Buoyancy forces from the two remaining BTAs and the PMB will lift the jacket up to a horizontal floating position. Not-flooded braces give additional buoyancy. When the jacket is in a horizontal floating position it will be towed to the load in jetty.

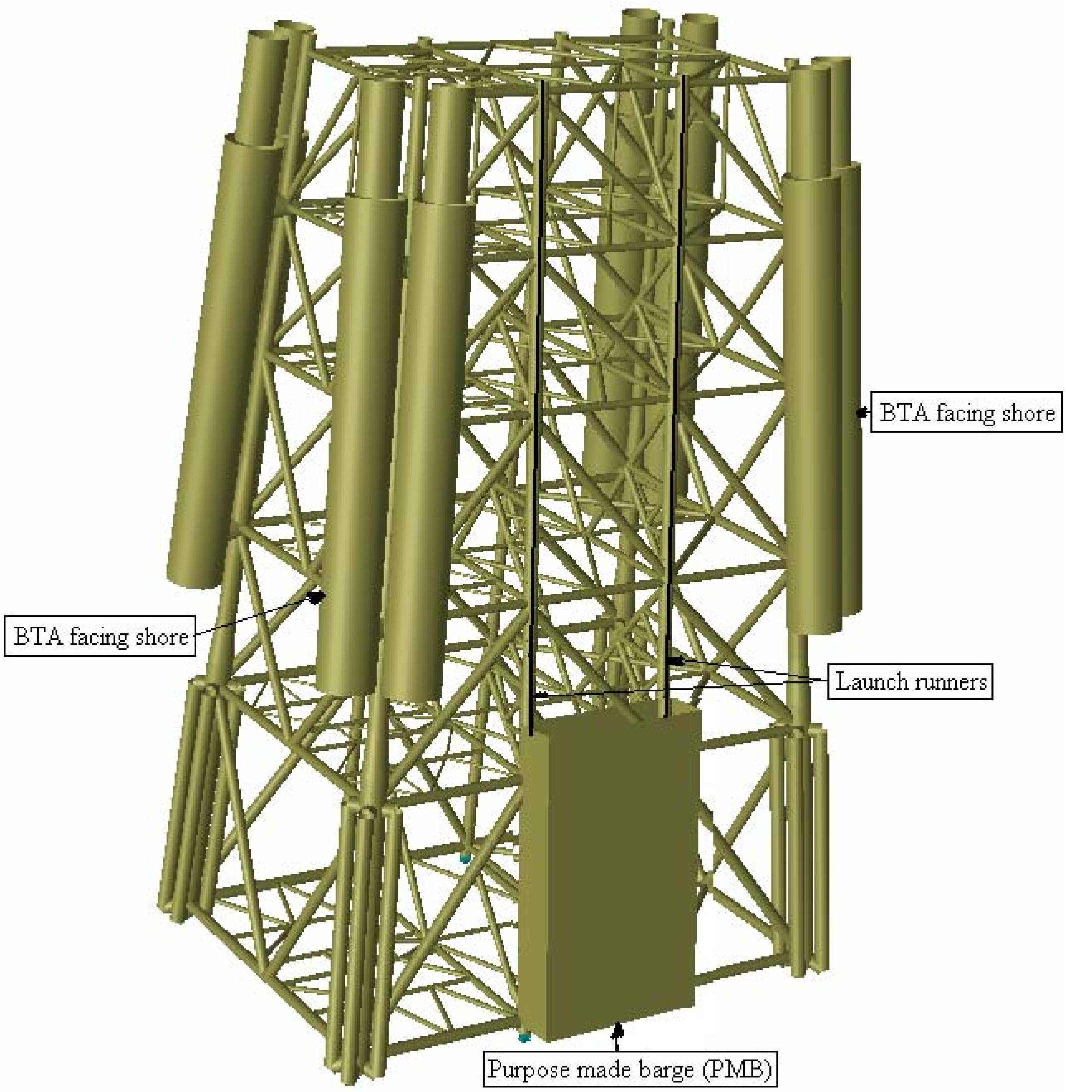
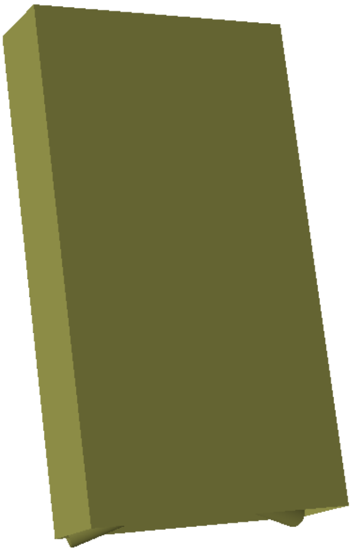


Figure 8-1 BTAs and the Purpose Made Barge (PMB) connected to jacket

8.1.1 Model of the purpose made barge (PMB)



The purpose made barge (PMB) is modelled in the same manner as the BTAs. The barge (PMB) is modelled by use of a box profile. It is connected to the jacket in nodes at the lowest levels, at reference elevation (-) 70 865 and (-) 100 000, by use of pipe profiles. The fixation elements are modelled as dummy elements to avoid overestimating the barge weight. The PMB's dimensions are decided in relation to the buoyancy force needed. The PMB is set to have a length of approximate 36 meter, a height and a width of 6 and 22 meters.

The PMB is divided into five elements of lengths of about 3, 7, 10, 10 and 6 meters. By dividing the element it is possible to regulate and control the de-ballasting of the barge.

Figure 8-2 Purpose Made Barge (PMB)

All material in the purpose made barge (PMB) are assumed to have a yield stress of 355 MPa. The PMB are modelled with material properties applicable for steel structures. The cross-sections used in the computer model of the Buoyancy Tank Assemblies follow in Table 8-1.

Name	Section type	Dimension (m)	Item
Barge	Box section	6.00 x 22.00 x 0.03	Barge (PMB)
Barge_Pipe	Pipe section	2.00 x 0.040	Fixation element

Table 8-1 Sections used in the PMB model

8.1.2 Actions

The weight load input is the same as for the vertical split method; the loads consist of steel weight of jacket, piles and BTAs, the grout weight and buoyancy forces. Marine growth is neglected. An addition is the weight of the barge (PMB). The PMB will give buoyancy in the last part of the float-up and rotation of the jacket, in addition to the two remaining BTAs. The BTAs' pyramids are assumed to have 10% buoyancy capacity, refers to section 7.3.4.

Description	GeniE (tonne)	Usfos (tonne)
Jacket steel/Grout	7 494	7 494
Marine growth	605	0
BTAs		2*1080 = 2 160
Barge		477
Total		**10 131**

Table 8-2 Summary of loads

The jacket legs and the piles are set as flooded members, Figure 8-3. The braces are assumed to be intact and are with that buoyant. The fixation elements for the BTAs and the PMB are set as flooded in such a way that they will not contribute to additional buoyancy force. The flooded jacket elements are assumed to be drained when they come over sea water level. This is done by drilling holes in the jackets flooded members so that the water can expel. The ballast water in the BTAs and the PMB will not be drained, but contribute to the total weight when the ballasted chambers are over sea water level. Node-mass are used to implement the weight of the ballast water in the BTAs in the Usfos' analysis. The PMB are assumed to be totally submerged during the entire process, which is a good approach in relation to the simulation performed. One chamber in the BTA model is five meter long, and give a maximum buoyancy force of approximate 1,72 MN or 175 tonnes. Hence, three chambers with a total length of 15 meters give a maximum buoyancy force of about 5,16 MN or 525 tonnes. The node-mass applied for the ballasted chambers balance the active buoyancy force and give the weight of water when the buoyancy force decreases as the BTAs break the water surface.

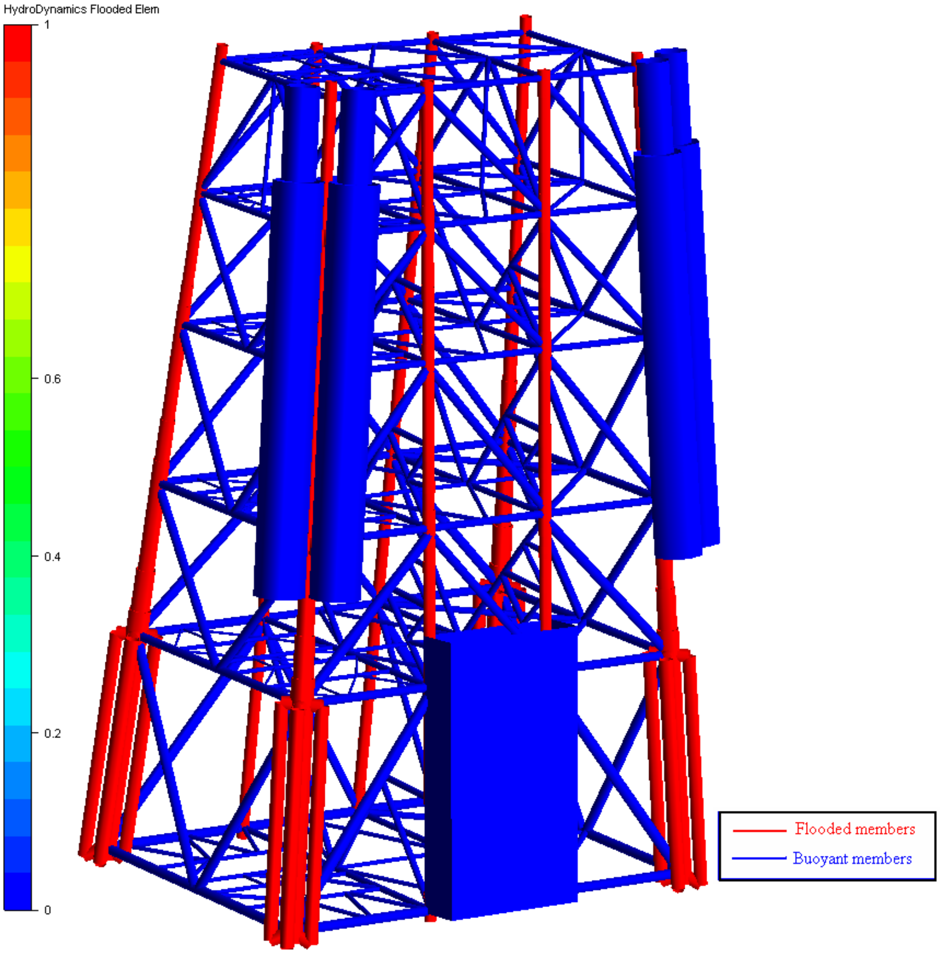


Figure 8-3 Flooded members

8.2 Analyses setup

8.2.1 Structural analyses

The jacket and BTA models from Sesam-GeniE are used. The purpose made barge (PMB) are modelled in GeniE and connected to the jacket inner legs. The jacket structure with two BTAs and the barge (PMB) are tilted in a start angle and in the equilibrium angle in GeniE. The models are converted to Usfos. Dynamic analyses have been executed. The main concern in this study has been the float-up phase which is the part that has been simulated.

Two analyses are carried out:
- Rotation of grounded jacket from a tilted angle of 50 degrees using BTAs only
- Jacket float-up from equilibrium position using BTAs and PMB

The analyses are carried out after the jacket has been rotated and grounded on 50 meters water depth. The first analysis is executed to find the rotation angle where equilibrium between gravity forces and buoyancy forces are achieved. A start angle of 50 degrees is used. Only the two remaining BTAs are de-ballasted, the PMB is still completely ballasted. The equilibrium angle of the tilted jacket is found at different values of the buoyancy force. By de-ballasting and ballasting different chambers in the BTAs the value of the buoyancy force can be varied. Vertical forces appearing at the boundary conditions give the value of the necessary buoyancy force needed to lift the jacket up from the seabed.

A new analysis is carried out where the jacket starts in its equilibrium position, the PMB are de-ballasted and the jacket floats up into a horizontal floating position. The jacket float-up analysis is performed to simulate the jackets behaviour during this operation sequence. Structural integrity is investigated and documented.

In the performed dynamic analysis the PMB is de-ballasted in three seconds. In a real operation the de-ballasting will be gradual and hence the float-up will be slower and will cause "minimal dynamic". A 5% damping is assumed to compensate for the extra dynamic caused by the rapid de-ballasting.

The operations are assumed to be performed under restricted weather conditions. The reversed launching is assumed to be executed in water with minimal to no currents and with flat sea.

8.2.2 Material- and load factors

The structural integrity of the jacket is evaluated in ultimate limit state (ULS) in accordance with DNV, ref. [37], and NORSOK N-004, ref. [39].

Material factor = 1,15
Load factor = 1,30

The factors are implemented in the analyses by dividing yield stress by 1,5.

8.2.3 Boundary conditions

The four jacket legs facing the fjord are grounded when an angle of about 60 degrees is achieved. The grounded legs are modelled with pin connections; movement in x-, y- and z-direction are fixed and it is free to rotate. Boundary conditions are removed in the float-up analysis. To prevent rotation of the jacket after a horizontal floating position is achieved the jacket is held in x-direction at top and bottom end of the jacket. Movement in z- and y-direction are allowed. The fixation in x-direction is an approach to the tugs that will hold the jacket during the operation.

8.3 Analyses results

8.3.1 General

The analyses are non-linear dynamic analyses and are performed using the Usfos software program. Structural integrity is investigated for the vertical split operation. The analyses are done in accordance with NORSOK N-004, ref. [39].

8.3.2 Rotation of grounded jacket

The magnitude of ballasted chambers in the BTAs control how large the rotation angle will be before the jacket finds its equilibrium position. This report presents the result when the three lowest chambers in the BTAs are fully ballasted, which means that the buoyancy force in the main tanks are 71-72% of maximum value (when all chambers are de-ballasted). The PMB contributes with minimal buoyancy force since it is entirely ballasted. The analysis starts with the jacket tilted an angle of 50 degrees on 50 meter water depth, see Figure 8-4. The jacket rotates to an angle of 58-59 degrees where equilibrium is achieved, Figure 8-5. Full buoyancy, all chambers are de-ballasted, will give an equilibrium angle of 52-53 degrees.

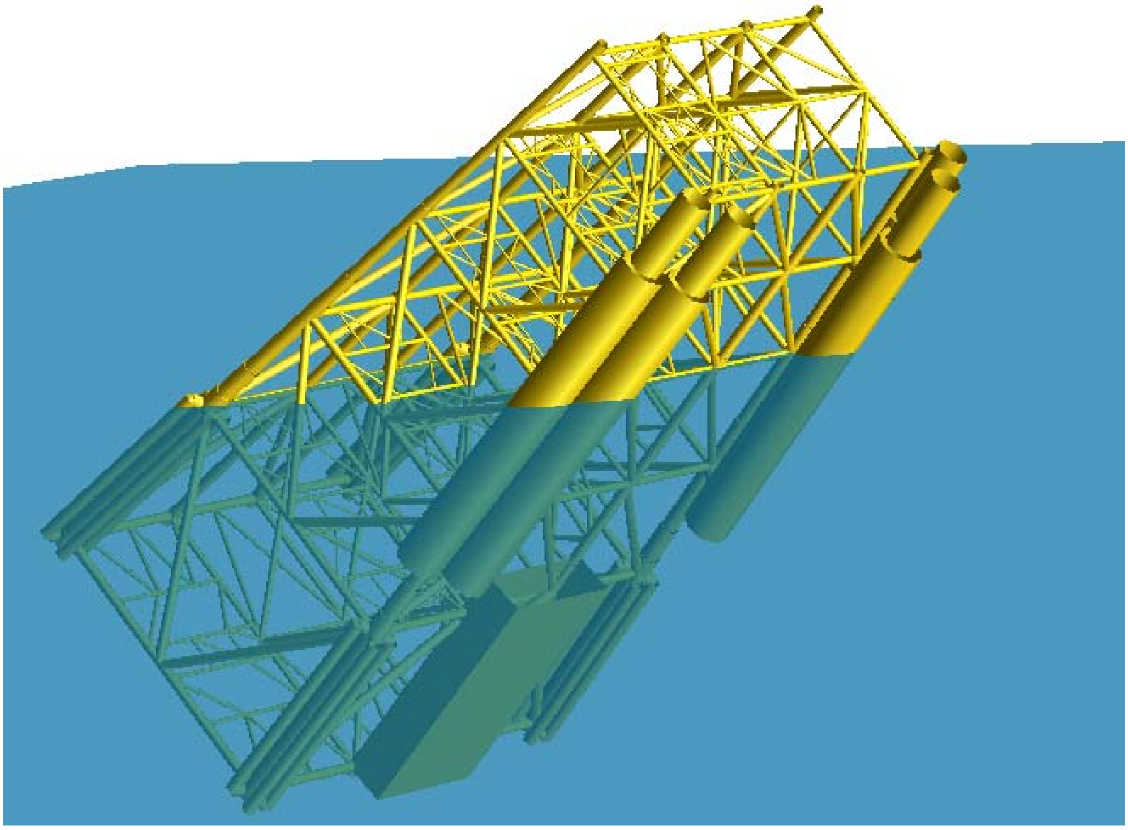


Figure 8-4 Jackets start position, rotated 50 degrees

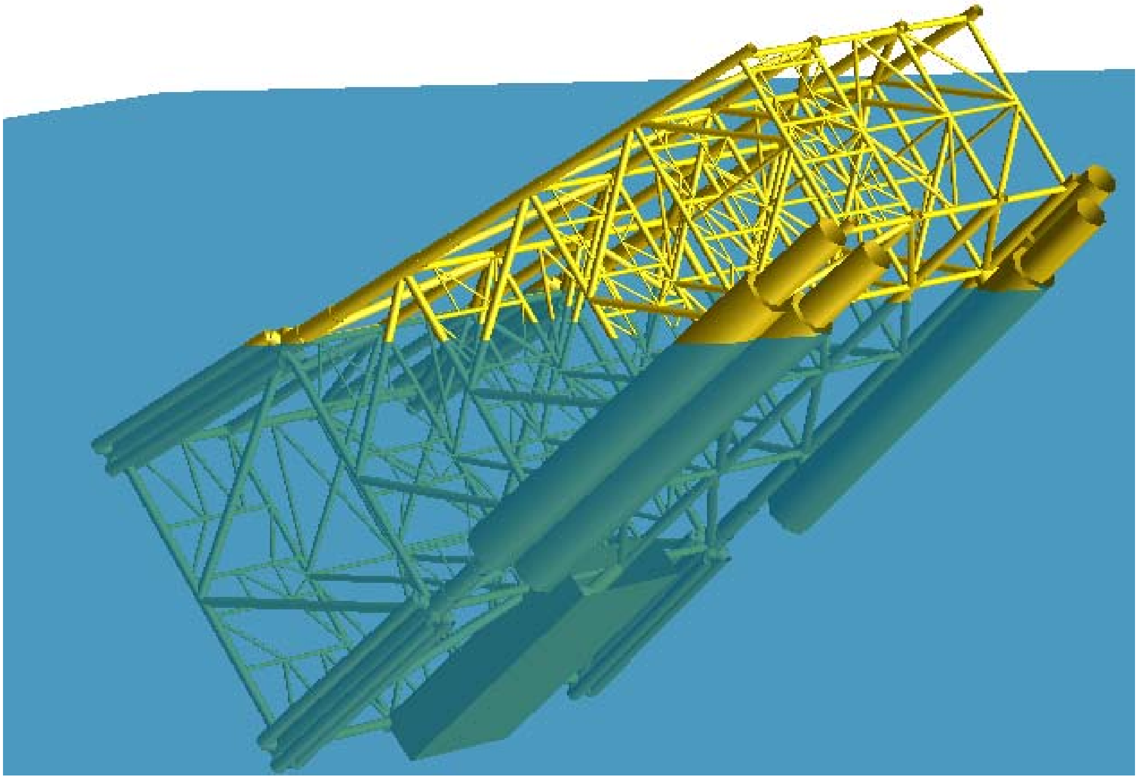


Figure 8-5 Equilibrium position, rotated approx 58 degrees

When the jacket is fixed to the seabed and has found its equilibrium position the reaction forces in vertical direction is about 30 MN, Figure 8-6. The jacket's corner legs are taking 2/3 of the force and the two mid legs 1/3. Hence, a buoyancy force of over 30 MN is necessary to lift the jacket up from the seabed. With the dimensions chosen for the Purpose Made Barge it can, when it is completely de-ballasted, contribute with a buoyancy force of nearly 48 MN, see Appendix C section C.1.2 for calculations.

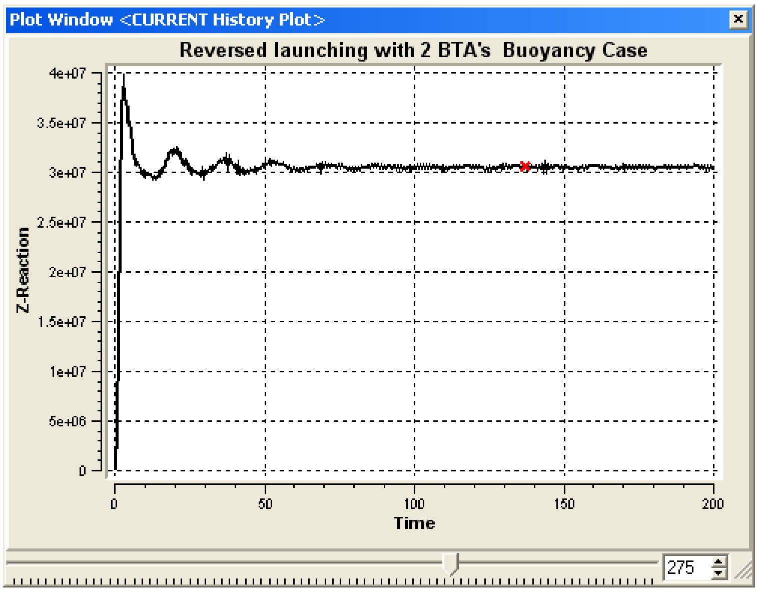


Figure 8-6 Reaction forces in jacket legs, z-direction

8.3.3 Float-up and rotation of jacket

The analysis starts when the jacket is tilted an angle of 58 degrees and is in an equilibrium position. When the PMB is de-ballasted the additional buoyancy force lifts the jacket up. No further de-ballasting of the BTAs are necessary. If it is a wish that the jacket will float higher de-ballasting of the BTAs can be done. Figure 8-7, Figure 8-8 and Figure 8-9 shows plot from the simulation. Figure 8-7 shows the position of the jacket when de-ballasting of PMB starts. Figure 8-8 shows the jacket during the float-up and rotation, and Figure 8-9 indicates the final floating position.

Boundary conditions are applied in one direction as an approach to the tugs that will hold the jacket, see section 8.2.3. If the boundary conditions were not applied the jacket will move and turn at the water surface after the float-up is completed. After a while the jacket starts to tilt and one side of the jacket is forced down in the water and the whole jacket rotates and turns upside down. The applied boundary conditions prevent the jacket to turn freely around at the water surface and the jacket floats without turning upside down. The reaction forces are approximately +0,1 MN and -0,1 MN, and indicate that the jacket floats stable and that it is a singularity problem rather than a stability problem. A closer investigation of the stability should be carried out in further studies of the reversed launching removal method.

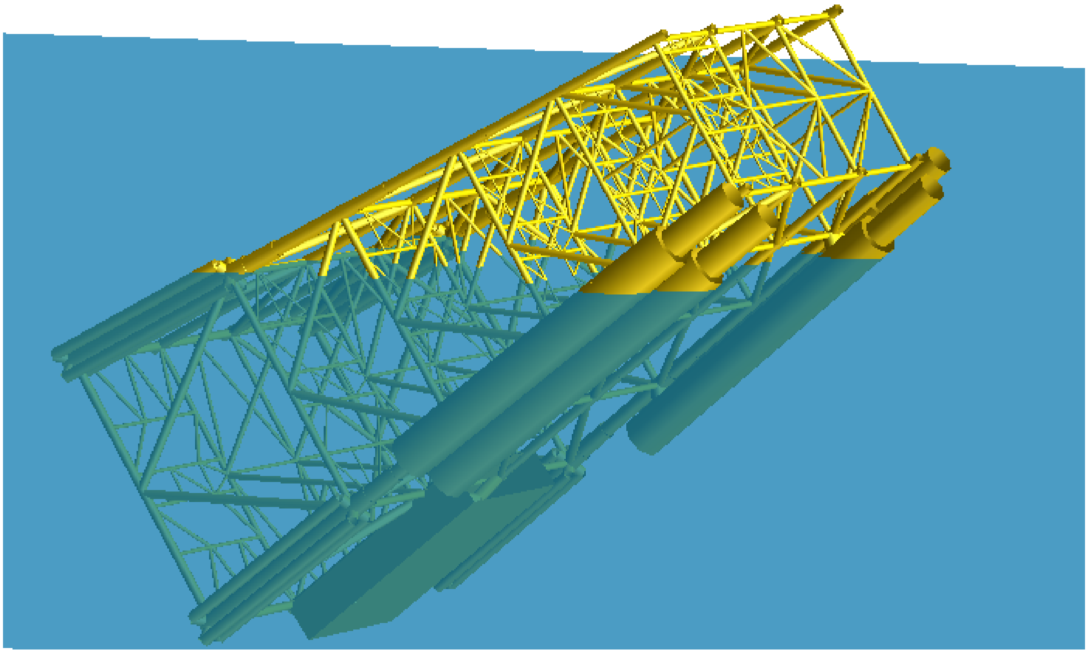


Figure 8-7 Starts to dewatering the barge (PMB)

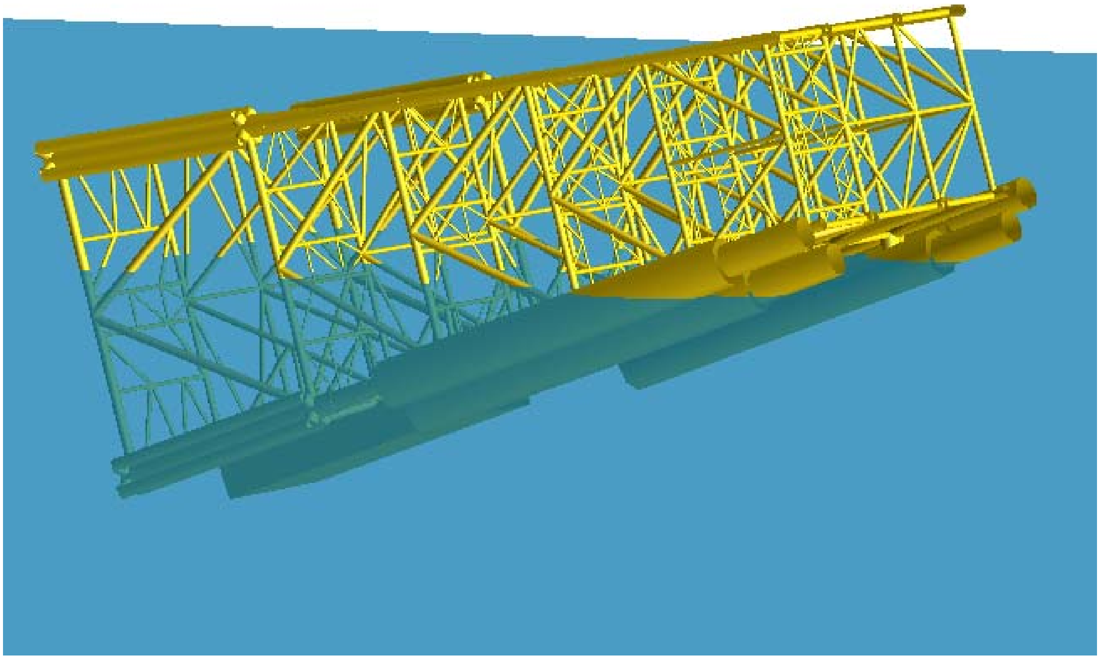


Figure 8-8 Jacket floats up and rotates

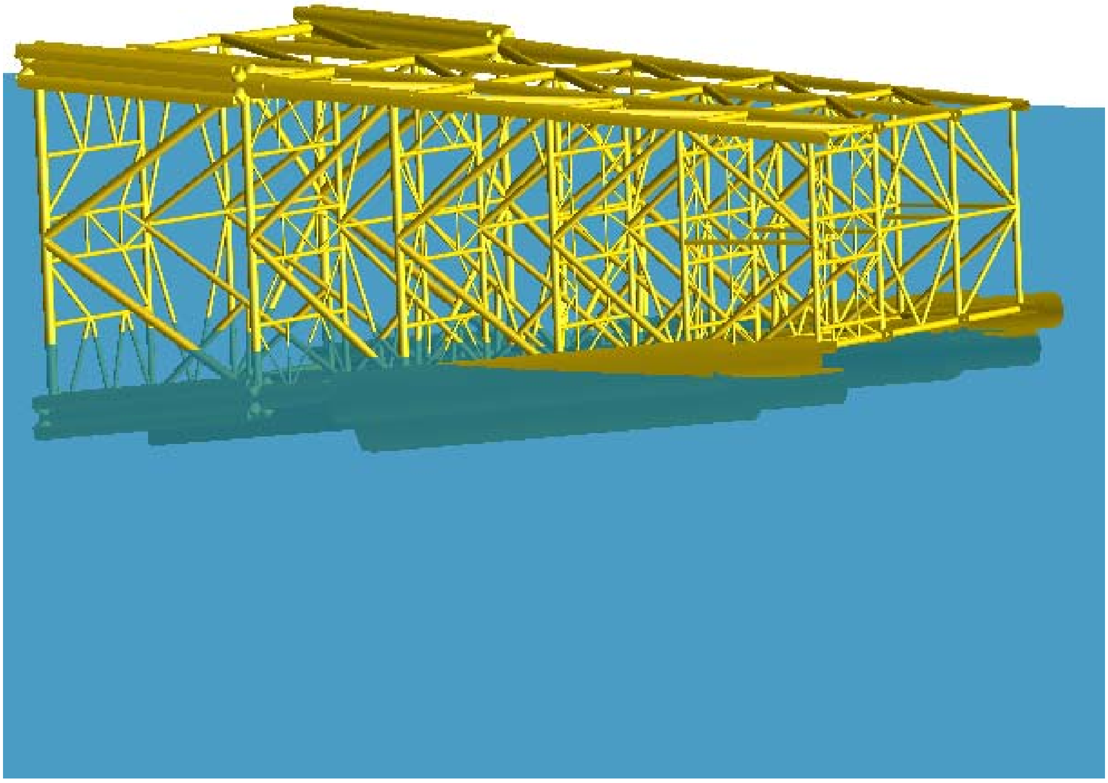


Figure 8-9 Final floating position

8.3.3.1 Jacket utilization

The jacket utilization is less for the reversed launching removal method than for the vertical split removal method. It is where the PMB is attached, braces and the mid legs at the two lowest levels, the highest plastic utilization factor of about 0,40-0,75 occurs. No members exceed their plastic capacity, refer to Appendix D, section D.1.3. Figure 8-10 shows a plot of the plastic utilization during float-up and rotation, and figure 8-11 shows a plot from the final floating position. The PMB is connected to the jacket in nodes, see section 8.1.1, and distributes the forces to the surrounding elements which are illustrated in the figures below. Figure 8-11 indicates a higher utilization in the braces attached to the nodes where the BTAs are connected, coloured green-blue. Reducing the buoyancy force in the BTA main tanks that are beside the jacket legs reduce the moment force and may reduce these members utilization.

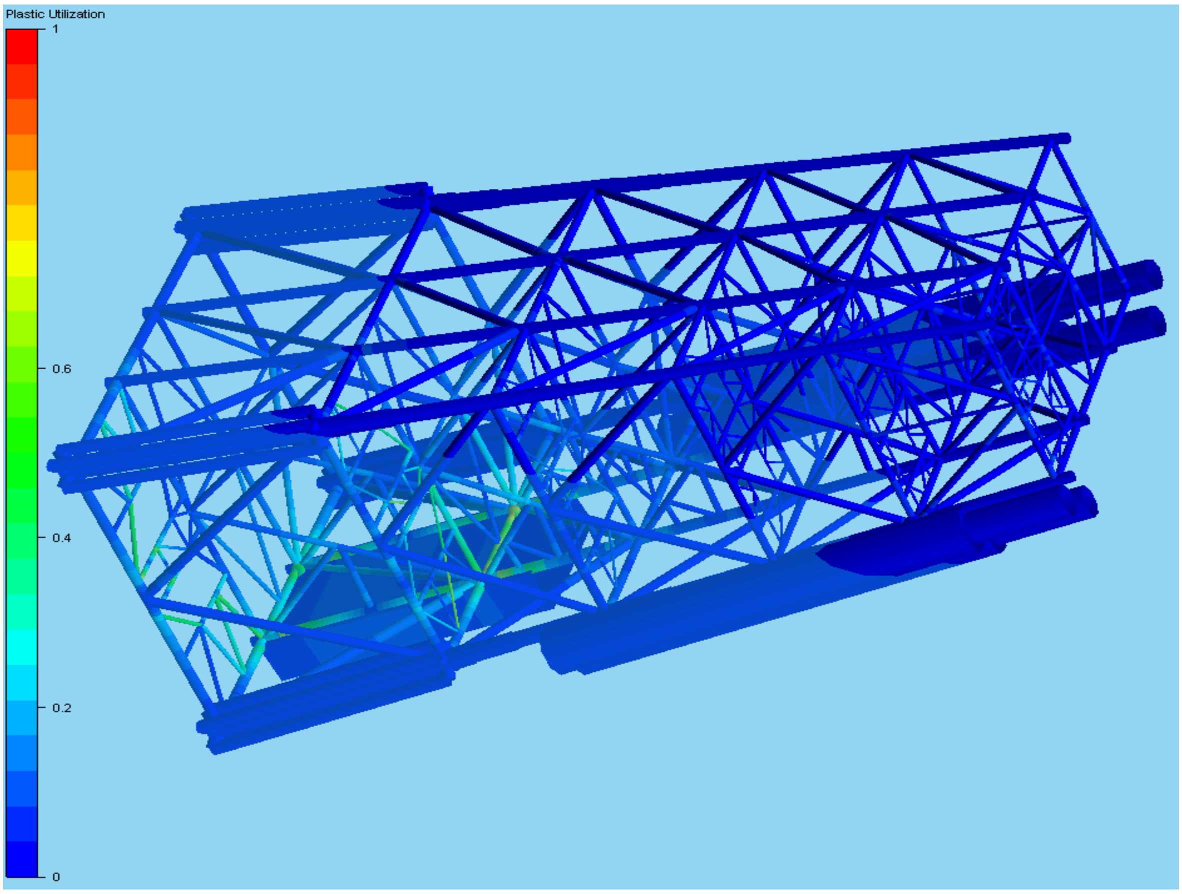


Figure 8-10 Plastic utilization during float-up and rotation

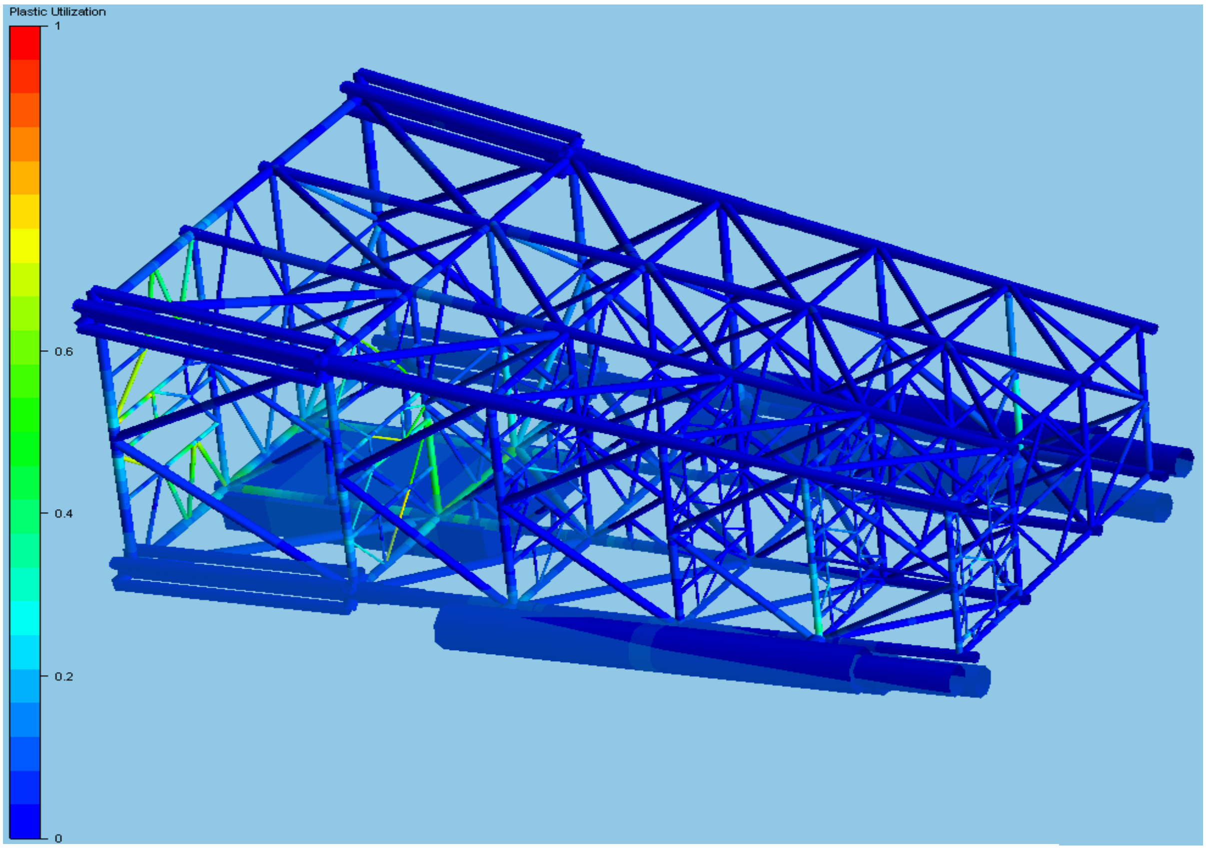


Figure 8-11 Plastic utilization in final floating position

Figure 8-12 presents Von Mises stresses occurring in the jacket in the final stage of the float-up and rotation. The Von Mises stresses have only small variances during the simulation. Largest changes in the stresses during the operation takes place in the braces were the BTAs are connected to the jacket, at reference elevation (-) 11 430. At the same time as the jacket rotates into a horizontal position the moment created by the BTA tank beside the jacket leg increases. Figure 8-11 and Figure 8-12 imply that the moment forces are transferred to the jacket and cause higher utilization and stresses.

The reduced yield strength of 230 MPa is exceeded in several members and plastic hinges are introduced. Maximum stresses have a value of 250 – 300 MPa. The Von Mises stresses support the plastic utilization results.

Figure 8-13 illustrates the beam strain occurring in the final stage of the float-up and rotation. The beam strain value does not exceed 0,2 % and is. with large safety margin, within the failure criterion given in N-004 [39, table A.3-4].

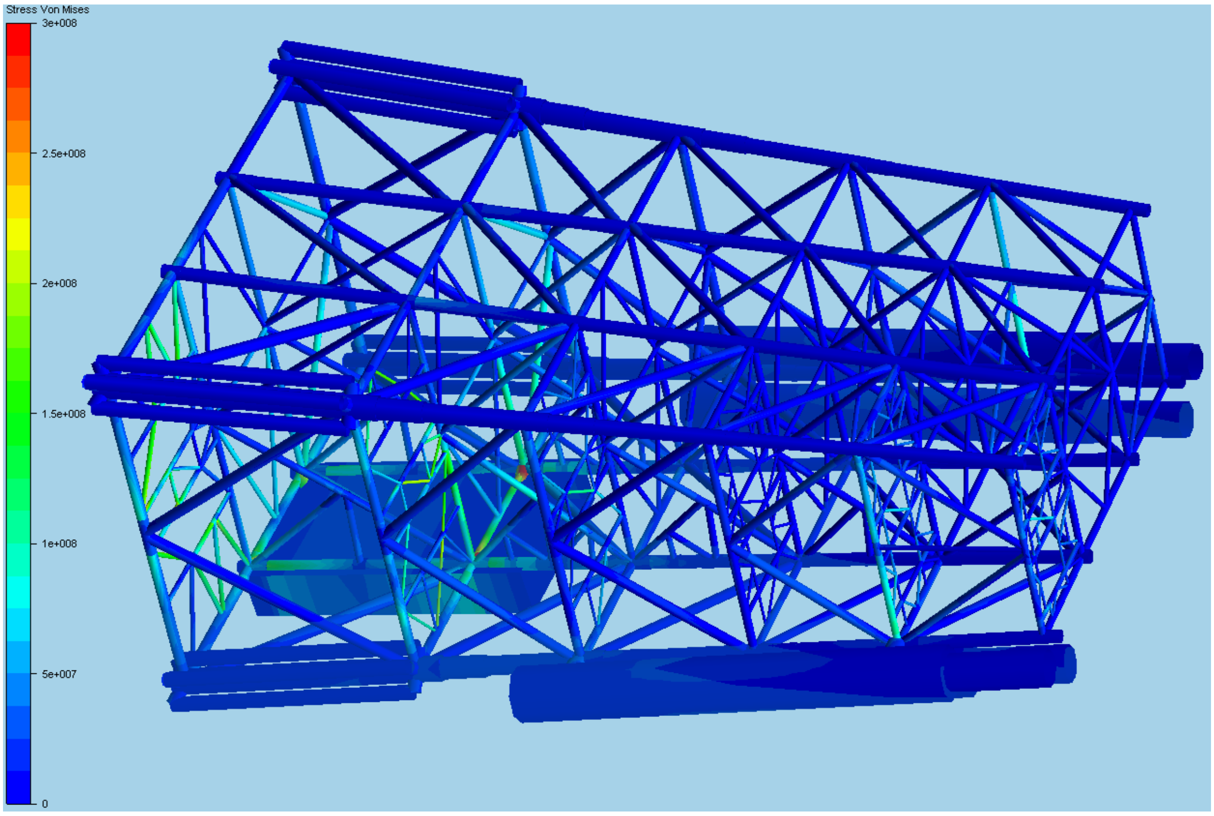


Figure 8-12 Von Mises stresses, during float-up and rotation

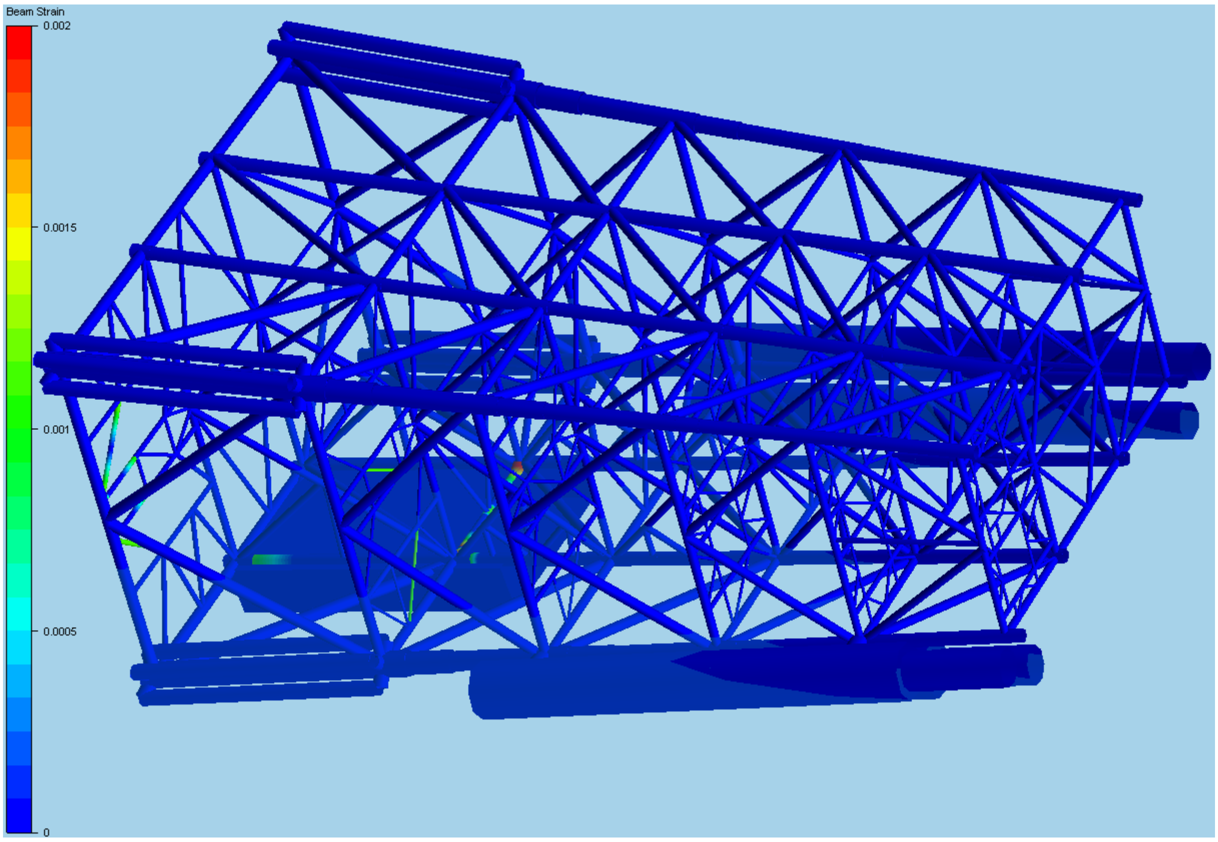


Figure 8-13 Beam strain, during float-up and rotation. Fringe range 0 - 0,002

8.4 Evaluation of the analysis

To verify how Usfos software calculates buoyancy forces in box sections a control has been performed, Appendix C section C.1.2. The control is executed by using a box profile identical to the Purpose Made Barge. The dimensions of the control box are varied as the dimensions of the PMB were changed. The box profile is fixed and is fully submerged. A dynamic analysis is carried out. Usfos' results are compared to hand calculations of the total buoyancy force. It seems like Usfos calculates the buoyancy force as if the box profile was a pipe with a diameter equal to the width of the box. To approach the correct buoyancy force for the PMB in the analyses a scaling factor is applied. A factor of 0,34 is used when the PMB have the given dimensions and is seen as completely de-ballasted.

Only a part of the reversed launching method is analysed in this document. In further studies analyses have to be carried out for the first sequences of the method as well. A limiting factor for the first tilting operation can be the barge with the strand jacks (lifting barge). A lifting barge has limited lifting capacity. The necessary lift force may be reduced by de-ballasting the PMB in some degree also in this first phase of the operation. The structural integrity of the jacket when loaded on to the load-in jetty must be verified. A hydrostatic evaluation of the stability of the jacket in the horizontal floating condition should be performed in order to validate Usfos' analysis results.

The analyses presented are carried out using partly de-ballasted BTAs. By de-ballasting or ballasting the BTAs the simulation changes; the jacket floats higher or lower or rotate upside down if the buoyancy force is to small. The BTAs are chosen to be de-ballasted in the three lowest chambers because the necessary buoyancy is achieved and the jacket ends in a presumably stable position. The assemblies are partly over the water surface and contribute to increase the stability because of the water plane area.

The BTA models and the corresponding connections to the jacket are the same as used in the analyses of the vertical split removal method. Hence, the same uncertainties are introduced in the analyses of the reversed launching removal method, refers to section 7.3.4. In addition uncertainties are introduced in connection with the Purpose Made Barge (PMB). A more detailed model and corresponding connections to the jacket may be required to give a correct simulation.

10% buoyancy capacity is assumed in the BTAs' pyramids on the same basis as discussed under section 7.3.4

Wind, waves and currents are assumed to be insignificant and are neglected in the removal analyses. These simplifications may introduce elements of uncertainty to the results. The removal operations will be performed under very strict weather conditions in sheltered waters. But analyses should be carried out including some wind, waves and current so that the behaviour of the structure can be investigated under these conditions.

During the study of the reversed launching removal method three additional analyses were performed. These simulations were an alternative approach to the reversed launching method which is presented in this document. By changing where the BTAs and the PMB were connected to the jacket different approaches to the reversed launching method emerged:

- BTAs below (on the side facing shore) and PMB on top (on the side facing the fjord)

- BTAs and PMB on top
- The BTAs on top and the PMB below

The reversed launching method that is presented and documented is the method assumed to be the best alternative. The three other simulations with the different approach to the reversed launching method had different difficulties and disadvantages. They had a deeper draft, since almost the entire jacket is submerged. The draft is about 50 meter deep and is a limiting factor. The methods can be used to float the jacket in a horizontal position on to a bank for dismantling. The methods require the BTAs, the PMB or both to hold the jacket from above which results in high requirements to the clamps and PMB's connection to the jacket. The advantages with these methods are that the floating jacket is stable because the Centre of Gravity (CoG) is below the Centre of Buoyancy (CoB), and the tilt operations may be easier to execute. Only the preferred approach to the reversed launching removal method is presented and discussed in this document. If a floating draft of about 50 meter is tolerated new studies must be performed to see if the mentioned alternative approaches may be potential removal methods.

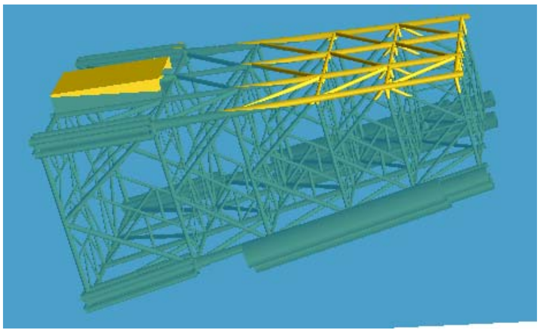


Figure 8-14 BTAs below and PMB on top

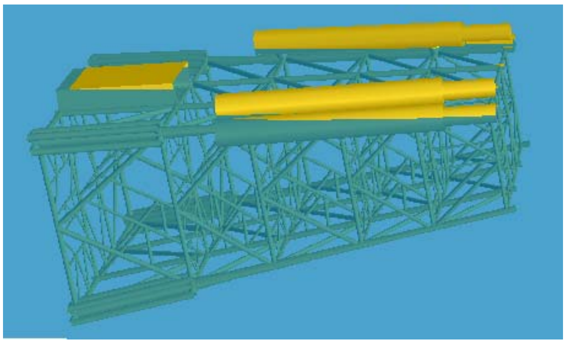


Figure 8-15 BTAs and PMB on top

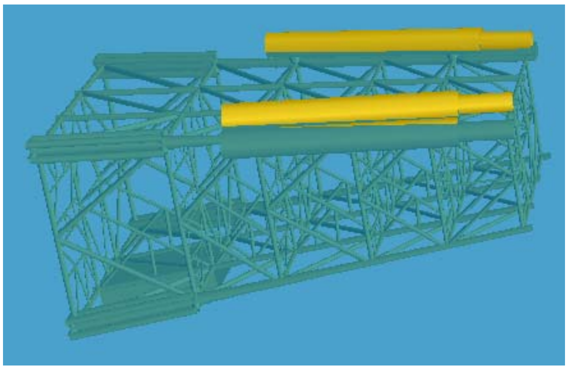


Figure 8-16 BTAs on top and PMB below

9 Decommissioning by use of heavy lift, vertical split of jacket or reversed launching

9.1 Discussion

The heavy lift method is a removal method which is well known and documented, and is used many times for removal of jackets. Hence, the procedure is well evolved; the amount of work, working hours and cost is easier to estimate and more reliable owing to the fact that the data can be compared to earlier executed operations. The removal of a jacket using heavy lift is still no easy operation to carry out. A jacket is a large structure to remove and many measures and precautions have to be made. The largest disadvantage with the heavy lift removal method is the high costs associated with the use of heavy lift vessels. It costs millions of NOK per day, approximately 5 million NOK, to rent one of the semi submersible heavy lift vessels that is required to execute the operation. This means that a large amount of the removal budget goes to Saipem or Heereema.

The BTAs and the re-float technique were developed to be an alternative to use of heavy lift vessels. So far have the BTAs and the re-float method been used to remove one jacket from offshore to inshore location, but heavy lift vessels have still been needed to transport the jacket from inshore to quay. The vertical split method and the reversed launching method have been studied as alternatives to use of heavy lift vessels for removal of a jacket to shore. Since neither of these alternative jacket removal methods have yet been done, larger uncertainties are connected to them than to the heavy lift removal method:
- It is harder to estimate the amount of work, working hours and costs for the operations.
- Unforeseen events are more difficult to take into account when planning the operation.
- It requires more engineering work upfront.

Both vertical split removal method and reversed launching method use the Buoyancy Tank Assemblies (BTAs). Measures have to be done to fit the BTAs to different jackets; the clamps have to be designed for the individual jacket legs. The reversed launching also requires a Purpose Made Barge which is an additional item in the cost estimate for this removal method. It is also uncertainties about the manner of installation of the PMB to the jacket, and how to remove the BTAs and the PMB when the jacket is on the load-in jetty. For large, heavy jackets the PMB has to be larger to provide enough buoyancy to lift the jacket up. The necessary dimensions of the PMB and the corresponding connections to the jacket may be a limitation. For the vertical split removal method the sleeves is assumed to be removed to reduce the weight and this insert an additional cost. The vertical cut (the split) operation will also be an item in the cost estimate.

According to the studies carried out in this document the jacket's integrity is kept during the heavy lift operation and in the sequence that is analysed in the reversed launching operation. Since only a part of the reversed launching method has been analysed, evaluation of the method due to many uncertainties regarding the execution and the feasibility of the operation is lacking. For the vertical split removal method additional measures have to be performed before this method is feasible for the type of jacket that is studied here. For a smaller jacket the vertical split removal method would probably be feasible without extensive measures. The largest draw back in the vertical split method is that there is little buoyancy in the lower part of the jacket where the jacket is heaviest, which results in high strains and utilization.

Measures that can contribute to keep the structural integrity in the jacket may be to increase buoyancy in the lower part of the jacket, reduce weight, reinforce the exposed area or a combination of the alternatives. The vertical split removal method requires cutting the jacket into two sections which reduces the strength of the structure. In the reversed launching method the jacket is kept in one piece during the operation and the strength in the jacket is retained.

The argument for using an alternative to a heavy lift removal, when that is feasible, is that the alternative is cheaper. Hence, the operating expenses for a vertical split removal or a reversed launching removal have to be lower than using a heavy lift vessel. Large and heavy jackets have to be dismantled offshore and removed piece by piece by a heavy lift vessel, which increases the cost considerable. If the alternative method can remove the jacket in one piece the cost would probably be lower than using a heavy lift vessel. Of this it follows that in order to be a competitive removal method it must be able to remove large jackets.

9.2 Conclusion

The vertical split and the reversed launching removal methods will be alternatives to the existing heavy lift removal method. They will be new removal techniques developed by Aker Solutions using their own technology. This will be a huge advantage on the decommissioning marked and Aker Solutions will be seen as a specialist company providing niche expertise.

The reversed launching method keeps the jacket in one piece during the entire process; no cut is necessary and the complete strength in the jacket is kept. Cutting the jacket in two is time demanding and hence a cost addition, as well as it reduces the jacket’s strength. The reversed launching removal method has so far been proven feasible, but additional analyses are required. If additional analyses verify that the reversed launching method is a feasible method it may be an alternative to use of heavy lift vessels. If the vertical split removal method shall be used for larger and heavier jackets modifications must be made. Cost estimate for each removal method is necessary in order to give a more accurate evaluation and comparison of the three alternative jacket removal methods.

References

[01] Norwegian Petroleum Directorate. *Responsible removal of old facilities*. Published September 21, 2010, 1-2. Retrieved February 09, 2011, from http://www.npd.no/en/Topics/Shutdown-and-removal/Temaartikler/Responsible-removal- of-old-facilities/

[02] Norwegian Petroleum Directorate. *Disused equipment transported to land*. Published 21.09.2010, 1. Retrieved February 09, 2011, from http://www.npd.no/en/Topics/Shutdown-and-removal/Temaartikler/Disused-equipment-transported-to-land/

[03] Øen, S, Iversen, P E, Stokke, R, Nielsen, F, Henriksen, T, Natvig, H et al. (2011). *Decommissioning of offshore installations*. Report published by Climate and Pollution Agency. Retrieved February 09, 2011 from http://www.klif.no/no/Publikasjoner/Publikasjoner/2011/Februar/Decommissioning-of-offshore-installations/

[04] DNV (2002). Mottak og opphogging av utrangerte offshore installasjoner. Vurdering av norsk verkstedkapasitet for perioden 2011-2020 (Decommissioning of offshore installations. Assessment of capacity at Norwegian yards in the period 2001-2020). Report NO.01-4063, rev 02.

[05] Oil and Gas UK. *Oil & Gas UK – 2010 Decommissioning Insight*. Brochure published 2010, 1-25. Retrieved February 09, 2011, from http://www.oilandgasuk.co.uk/cmsfiles/modules/publications/pdfs/OP049.pdf?bcsi_scan_106ABDFCE01E65E8=0&bcsi_scan_filename=OP049.pdf

[06] Department of Energy & Climate Change (DECC), Oil and Gas. *Decommissioning, Overview*. 1-2. Retrieved February 09, 2011, from https://www.og.decc.gov.uk/upstream/decommissioning/intro.htm

[07] Nordvik F M (Ministry of Petroleum and Energy), Berg Verlo, S and Zenker, E (Norwegian Petroleum Directorate). *Facts 2010 – The Norwegian Petroleum sector*. Chapter 5 – Decommissioning, 49-51. Retrieved February 21, 2011, from http://www.npd.no/en/Publications/Facts/Facts-2010/

[08] Decom North Sea, Market info. *Introduction*. Page 1. Retrieved February 12, 2011, from http://www.decomnorthsea.com/market.cfm

[09] Decom North Sea, Market info. *Market Projection*. Page 1-2. Retrieved February 12, 2011, from http://www.decomnorthsea.com/market2.cfm?main_ID=5

[10] Decom North Sea, Market info. *Legislation*. Page 1-3. Retrieved February 12, 2011, from http://www.decomnorthsea.com/market2.cfm?main_ID=8

[11] OSPAR Commission. *About OSPAR*. Retrieved February 17, 2011, from http://www.ospar.org/content/content.asp?menu=00010100000000_000000_000000

[12] OSPAR Commission. *Introduction by the Executive Secretary*. Retrieved February 17, 2011, from http://www.ospar.org/content/content.asp?menu=00310108000000_000000_000000

[13] OSPAR Commission. *The OSPAR Convention*. Retrieved February 17, 2011, from http://www.ospar.org/content/content.asp?menu=00340108070000_000000_000000

[14] OSPAR Commission. *History*. Retrieved February 17, 2011, from http://www.ospar.org/content/content.asp?menu=00350108080000_000000_000000
Sjekk om någe her skal tas med!

[15] OSPAR Commission. *Offshore installations*. Retrieved February 17, 2011, from http://www.ospar.org/content/content.asp?menu=00120000000057_000000_000000

[16] OSPAR Commission. *OSPAR Decision 98/3 on the Disposal of Disused Offshore Installations*. OSPAR convention for the protection of the marine environment of the North-East Atlantic, Sintra 22-23 July 1998, 1-10. Retrieved February 17, 2011, from http://www.ospar.org/documents/DBASE/DECRECS/Decisions/od98-03e.doc

[17] International Maritime Organization (IMO). *Introduction to* IMO. Retrieved February 18, 2011, from http://www.imo.org/About/Pages/Default.aspx

[18] International Maritime Organization (IMO).Brief History of IMO. Retrieved February 18, 2011, from http://www.imo.org/About/HistoryOfIMO/Pages/Default.aspx

[19] *Petroleum activities act*. Regulation last amended by Act 19.June 2009 No 104. Retrieved February 21, 2011, from http://www.npd.no/en/Regulations/Acts/Petroleum-activities-act/

[20] Scottish Enterprise. *Decommissioning break down structure*. Report published November 2008, 1-33. Retrieved January 27, 2011, from http://www.decomnorthsea.com/downloads/Decom_segmentation_final.pdf

[21] Oil and Gas UK, Knowledge Centre. *Case Studies*. Published 2010, 1-6. Retrieved February 09, 2011, from http://www.oilandgasuk.co.uk/knowledgecentre/case_studies.cmf

[22] Norwegian Petroleum Directorate. *Frigg cessation took ten years*. Published September 21, 2010, 1-2. Retrieved February 09, 2011, from http://www.npd.no/en/topics/shutdown-and-removal/temaartikler/frigg-cessation-took-ten-years/

[23] SCANMET – Demolition and Decommissioning Professionals. *The Frigg Cessation Project*. Retrieved March 2, 2011, from http://www.scanmet.no/eng/sider/REFERENCES/FRIGG_FIELD_CESSATION/

[24] Total E&P Norge AS. *Frigg And MCP-01 Cessation News*. Newsletter highlights, December 2009 NO 12, 1-11. Retrieved May 18, 2011, from http://www.total.no/en/Resources/Scripts/GetResource.ashx?resource=c413339d-9091-4740-8358-6254ae4c6575

[25] Terdre, N (April 1, 2009). *Frigg jacket removed to shore via novel re-float method*. Offshore Magazine. Retrieved March 4, 2011, from http://www.offshore-mag.com/index/article-display/359646/articles/offshore/supplements/norway/articles/frigg-jacket-removed-to-shore-via-novel-re-float-method.html

[26] Saipem S.p.A. *Saipem 7000*. Brochure last amended January 30, 2010. Retrieved February 28, 2011, from http://www.saipem.com/site/article.jsp?idArticle=5397&instance=2&node=2012&channel=2&ext=template/37DueColonne&int=article/1DefaultArticolo

[27] Heerema Marine Contractors. *Thialf*. Data sheet 2011. Retrieved February 28, 2011, from http://hmc.heerema.com/About/Fleet/Thialf/tabid/378/language/en-US/Default.aspx

[28] Beata Skóra (2009). *Saipem 7000 at Stord, Norway*. Picture. Retrieved May 24, 2011, from http://www.oilrig-photos.com/picture/number2036.asp?intent=redo

[29] Solland, G, Hellan, Ø, Bolt, H, Fuglum, H, Yasseri, S (1999). *Ultiguide*. Prepared by DNV, SINTEF and BOMEL.

[30] *Input Description USFOS Control Parameters*. Usfos user's manuals, document No.1. Retrieved March, 2011 from http://www.usfos.no/manuals/usfos/users/documents/Usfos_UM_06.pdf

[31] Søreide, T, Amdahl, J, Eberg, E, Holmås, Hellan, Ø (1988). *USFOS – A Computer Program for Progressive Collapse Analysis of Steel Offshore Structures. Theory Manual*. Revised April 02, 1993. A report describing Usfos' theoretical basis. Retrieved from http://www.usfos.no/manuals/usfos/theory/documents/Usfos_Theory_Manual.pdf

[32] Det Norske Veritas (2010). *GeniE – Engineering for the future*. User Manual for GeniE V5.2-04, retrieved January, 2011

[33] Det Norske Veritas. *Sesam^{TM} Managing your offshore structure through its life cycle*. Sesam brochure retrieved from http://www.dnv.com/binaries/Sesam_brochure_06.06.13_tcm4-80294.pdf

[34] Det Norske Veritas. *GeniE*. Retrieved May 10, 2011 from http://www.dnv.com/services/software/products/sesam/sesamfixedstructures/genie.asp

[35] Det Norske Veritas. *Sestra – linear structural analysis*. Retrieved May 10, 2011 from http://www.dnv.com/services/software/products/nauticus/hull/sestra.asp

[36] Det Norske Veritas (1996). *Rules for Planning and Execution of Marine Operations*.

[37] Det Norske Veritas (2004). *Recommended Practice DNV-RP-H102 Marine Operations During Removal of Offshore Installations*.

[38] NORSOK (2007). *NORSOK Standard N-003: Action and Action Effects*. Standard, second edition.

[39] NORSOK (2004). *NORSOK Standard N-004: Design of Steel Structures*. Standard, second revision.

[40] Eurocode. *NS-EN 1993-1-1: Design of Steel Structures*

Appendices

Appendix A

A.2 Geometry of jacket model ... 1
A.2.1 View of finite element model ... 1
A.2.2 Member names ... 2
A.2.3 Cross sections... 9

Appendix B

B.2 Input files… ... 1
B.2.1 Input file to GeniE, jacket structure ... 1
B.2.2 Input files to Usfos, vertical split removal method ... 8

Appendix C

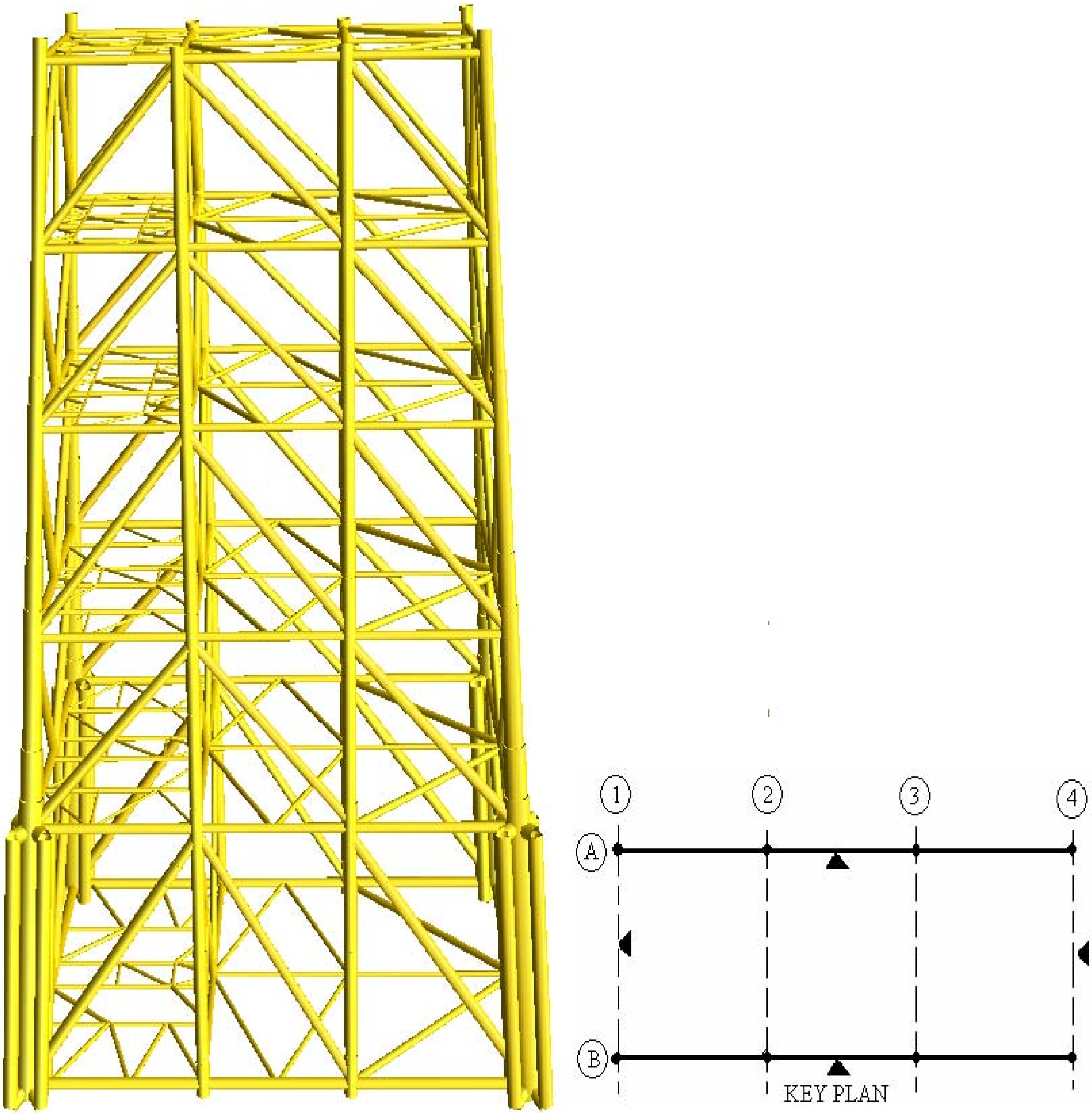
C.2 Control of Usfos' calculations of buoyancy forces ... 1
C.2.1 Buoyancy of a horizontal pipe dependent on draft ... 1
C.2.2 Buoyancy of a submerged box ... 3

Appendix D

D.2 Results from analyses ... 1
D.2.1 Heavy lift analysis, frame code check ... 1
D.2.2 Analysis of vertical split removal method, results from Usfos ... 11
D.2.3 Analysis of reversed launching removal method, results from Usfos ... 13

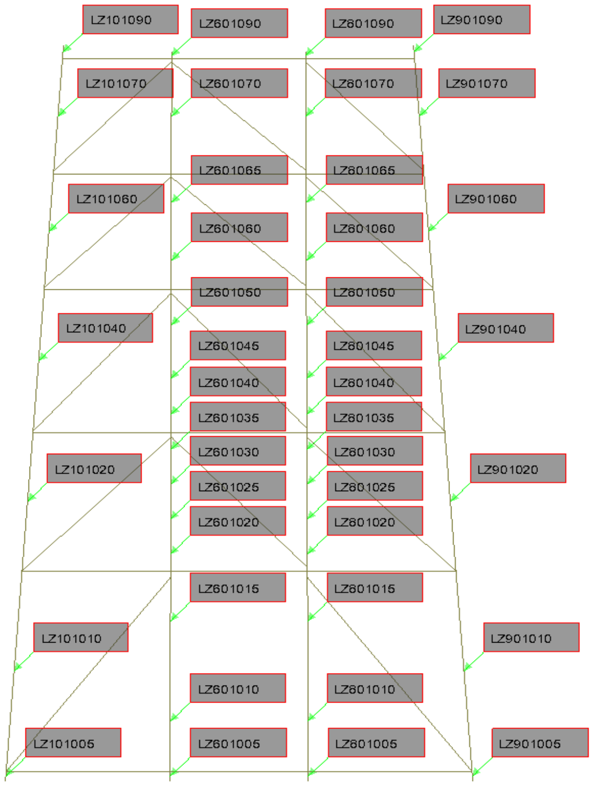
A.2 Geometry of jacket model

A.2.1 View of finite element model

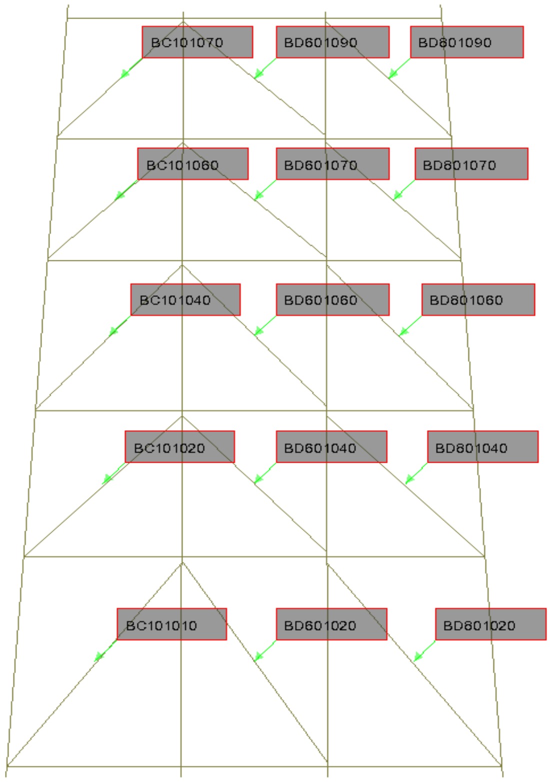


Appendix figure A-1 Finite element model of jacket, and view of key plan

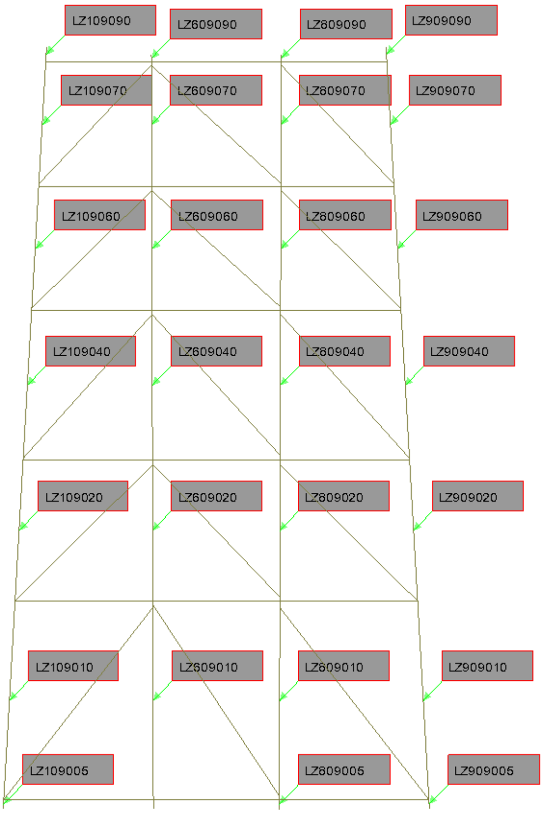
A.2.2 Member names



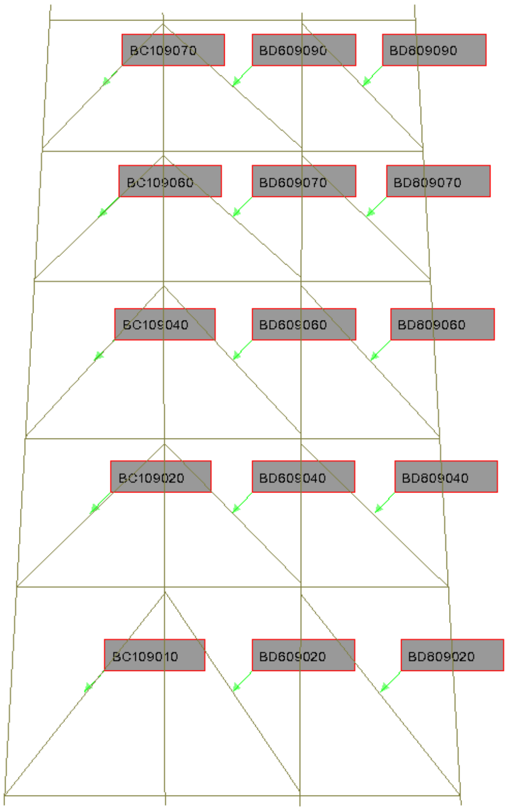
Appendix figure A-2 Leg members, col.line (A)



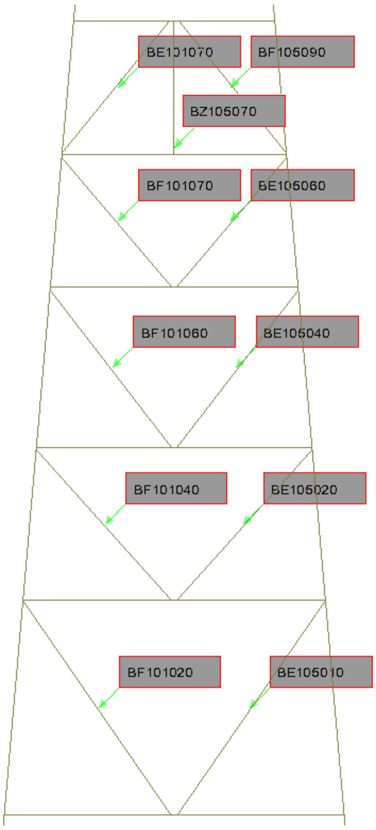
Appendix figure A-3 Braces, col.line (A)



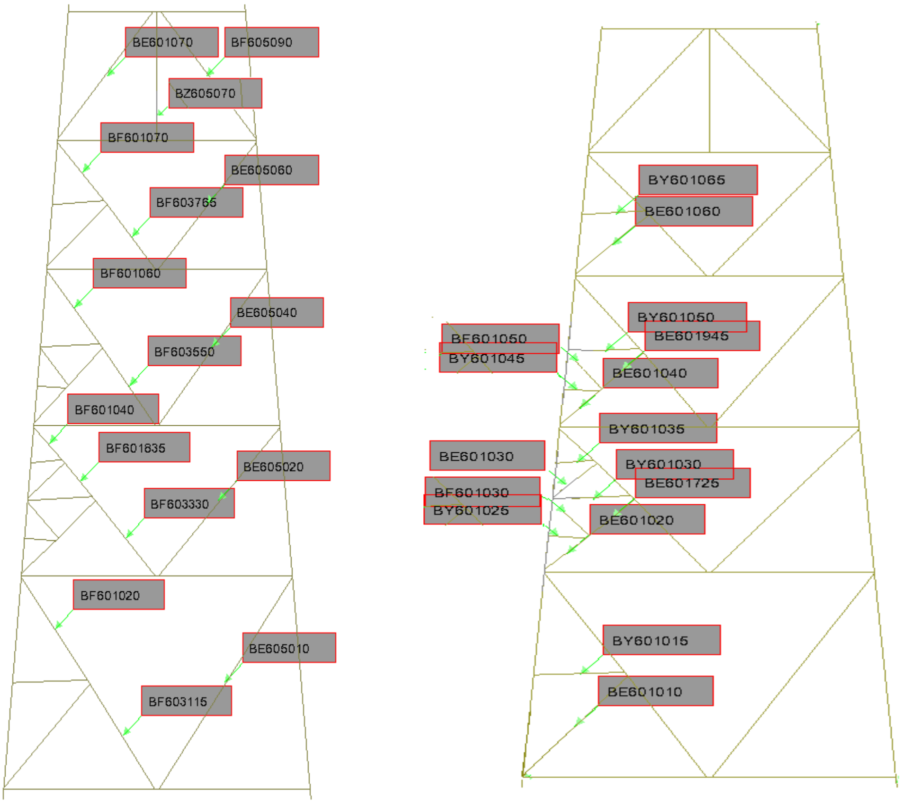
Appendix figure A-4 Leg members, col.line (B)



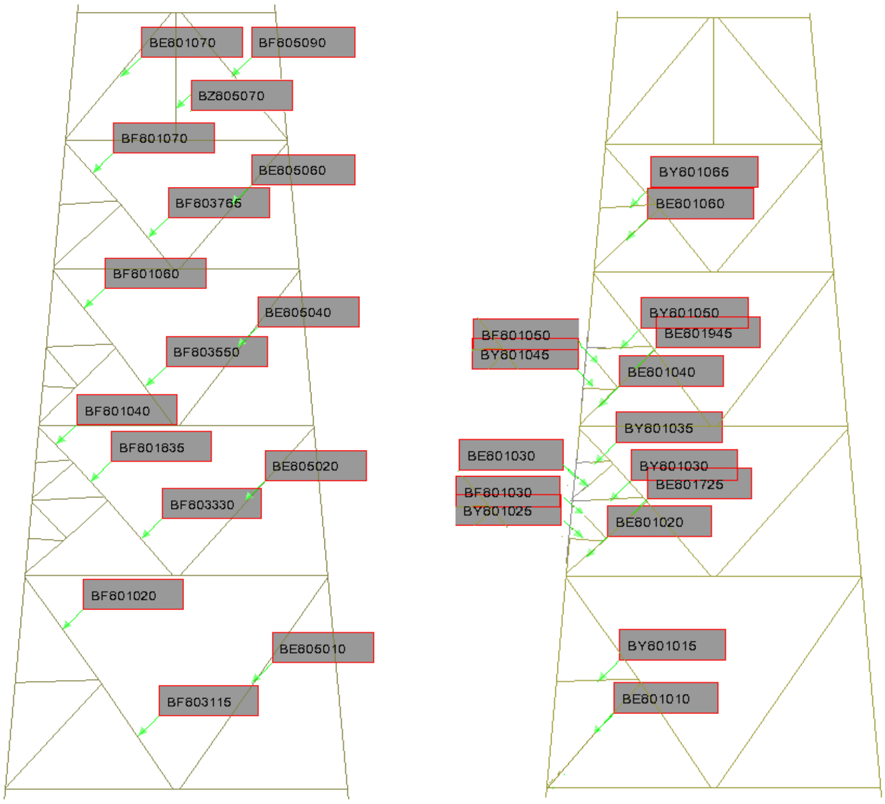
Appendix figure A-5 Braces, col.line (B)



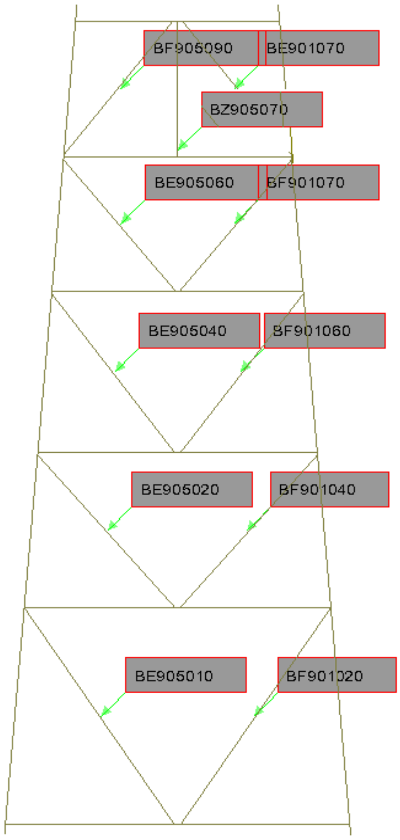
Appendix figure A-6 *Braces, col.line (1)*



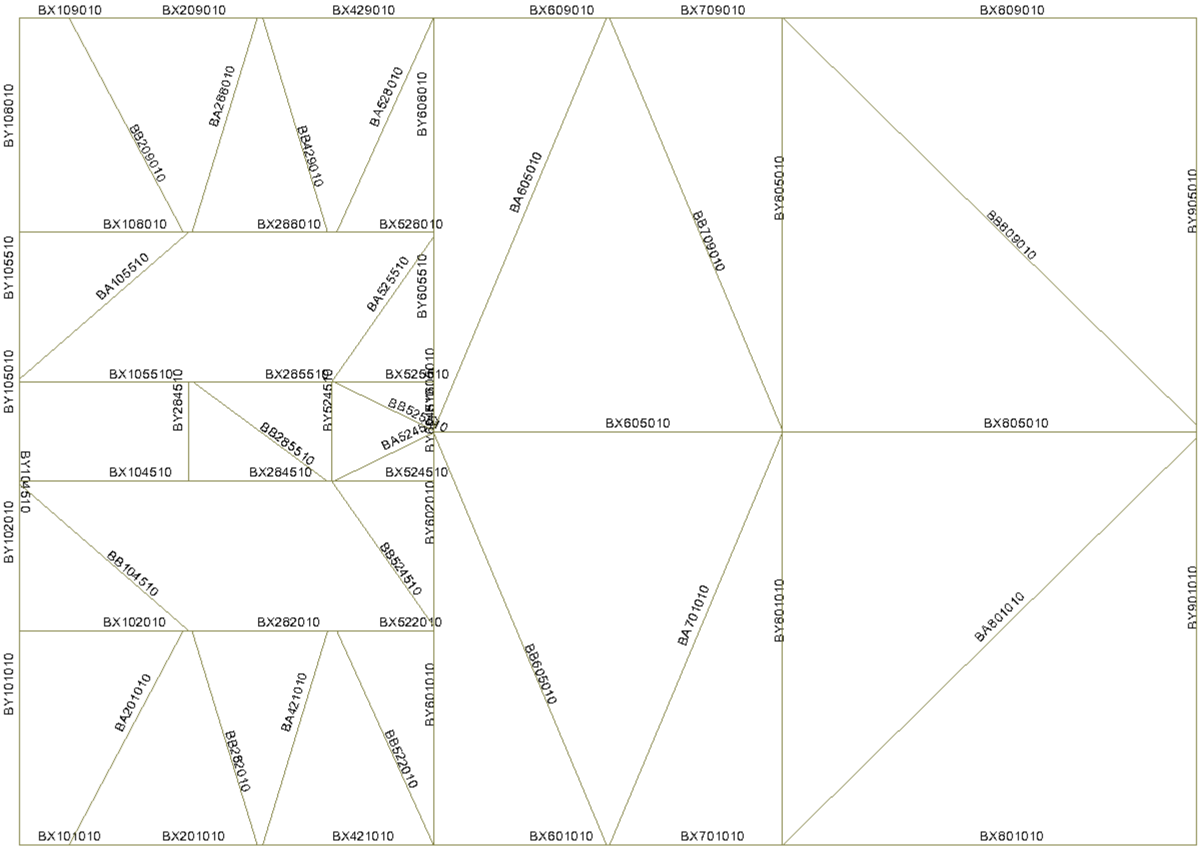
Appendix figure A-7 *Braces, col.line (2)*



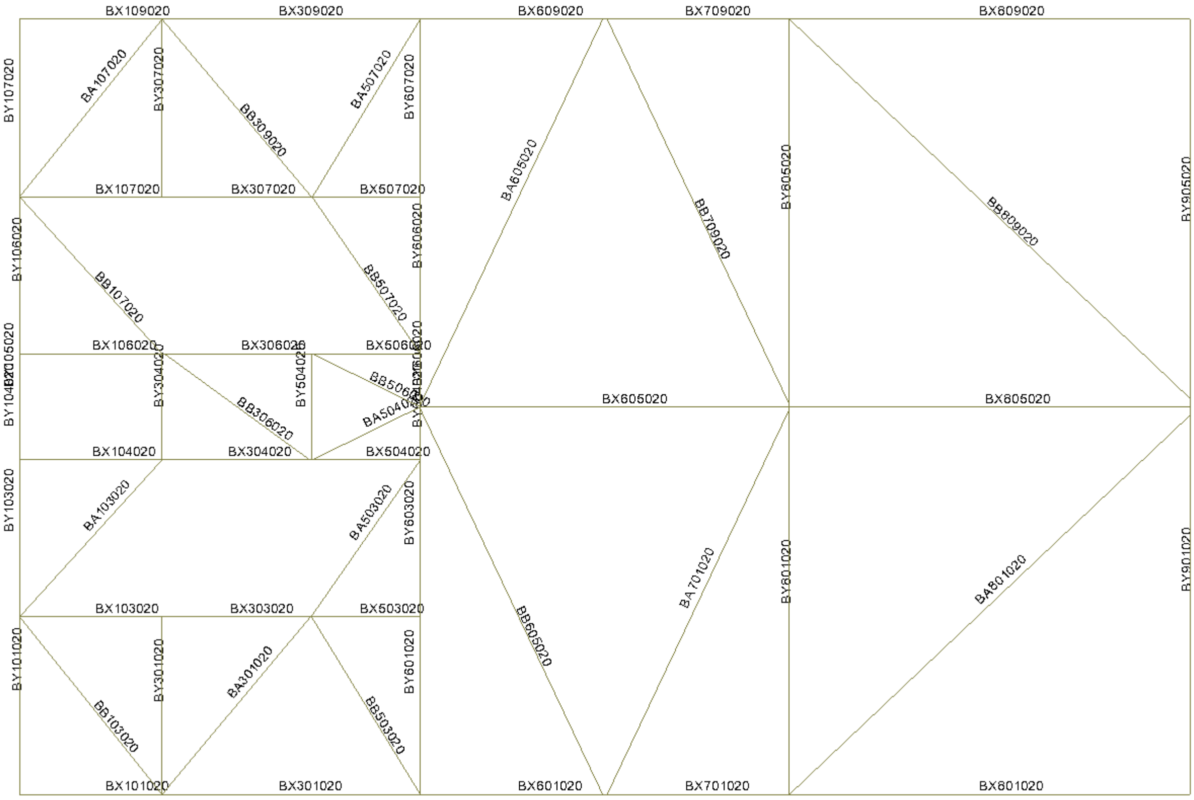
Appendix figure A-8 *Braces, col.line (3)*



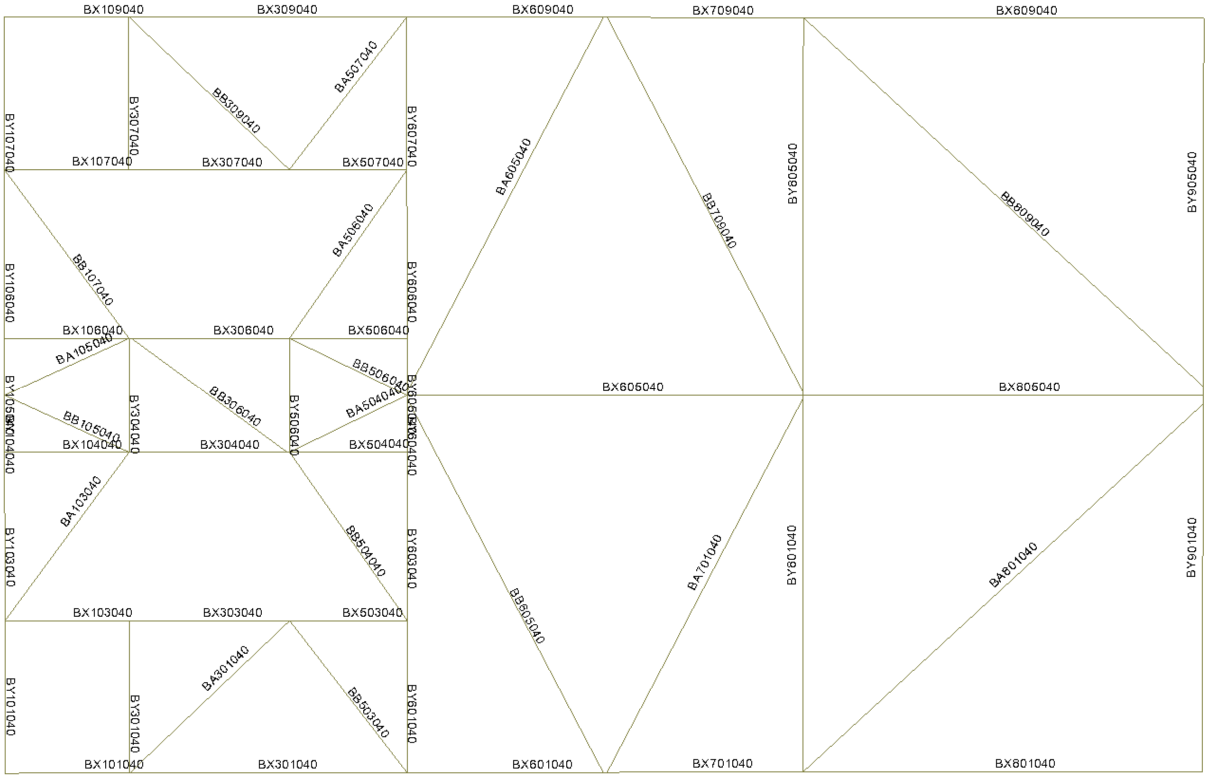
Appendix figure A-9 *Braces, col.line (4)*



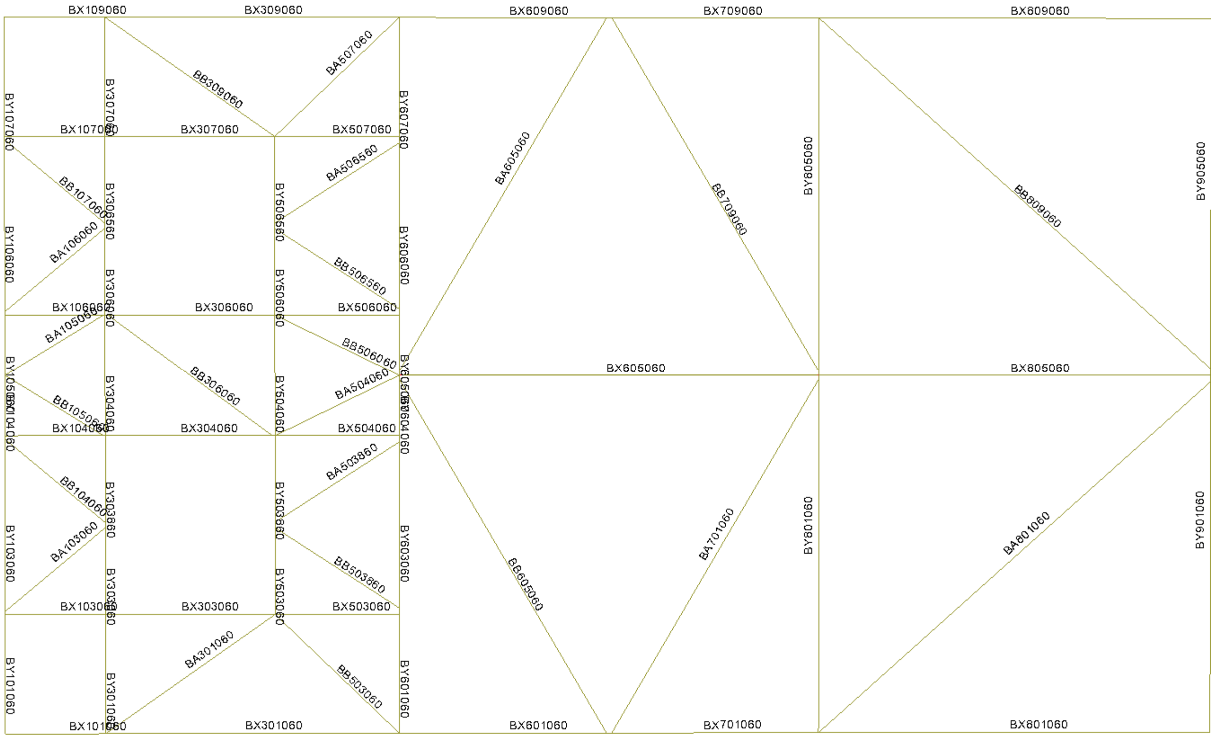
Appendix figure A-10 Horizontal braces, reference el. (-) 100 000



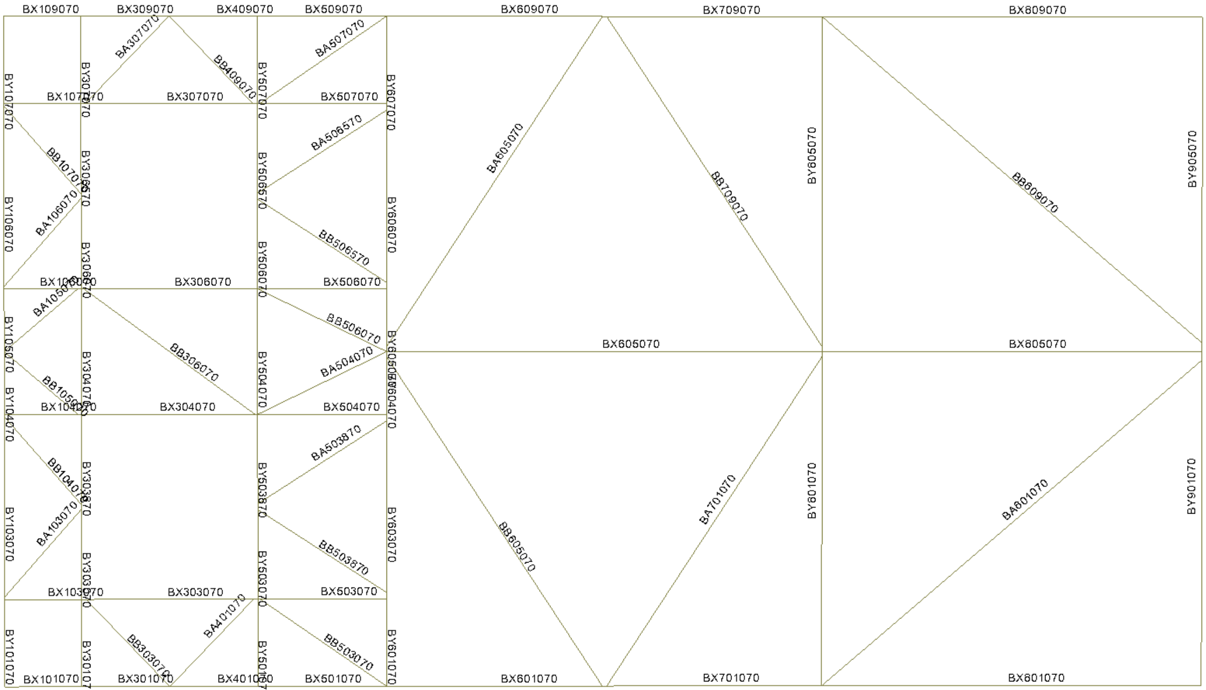
Appendix figure A-11 Horizontal braces, reference el. (-) 70 865



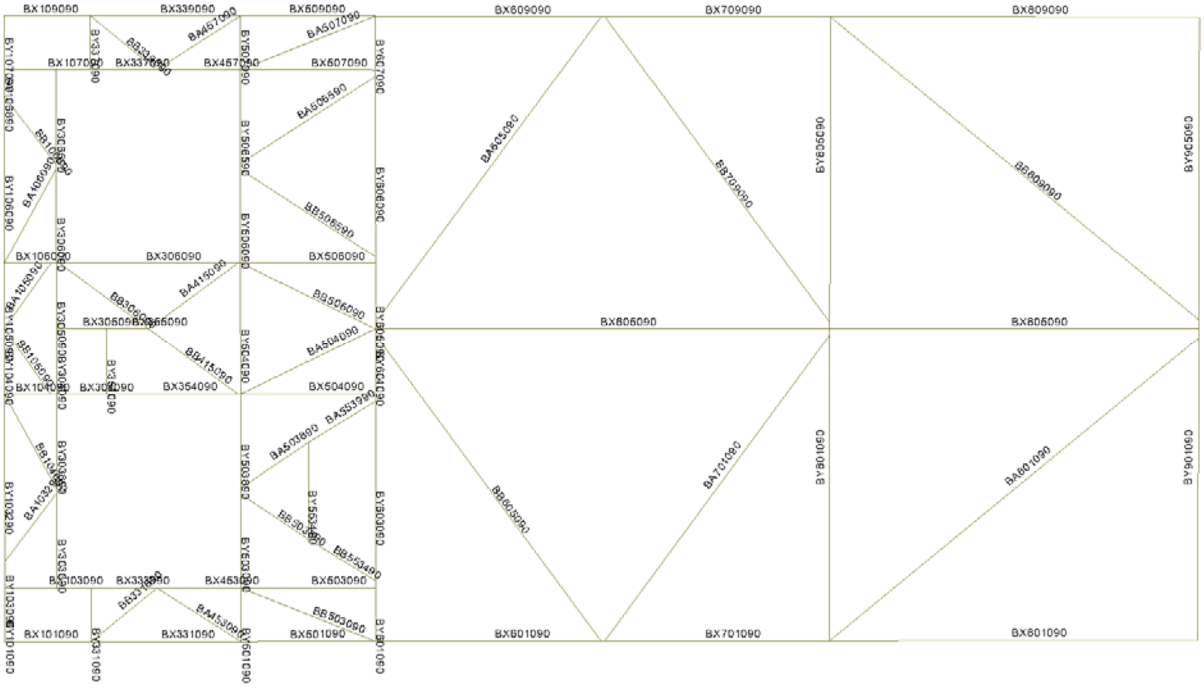
Appendix figure A-12   Horizontal braces, reference el. (-) 50 290



Appendix figure A-13   Horizontal braces, reference el. (-) 28 290



Appendix figure A-14   Horizontal braces, reference el. (-) 11 430



Appendix figure A-15   Horizontal braces, (+) 6 095

A.2.3 Cross sections

Name	Section type	Dimension (m)
P3048x57	Pipe section	3.048 x 0.0572
P3048x50	Pipe section	3.048 x 0.0508
P3048x38	Pipe section	3.048 x 0.0381
P3048x25	Pipe section	3.048 x 0.0254
P3048x15	Pipe section	3.048 x 0.0159
P2286x57	Pipe section	2.286 x 0.0572
P1829x50	Pipe section	1.829 x 0.0508
P1800x75	Pipe section	1.800 x 0.0750
P1689x82	Pipe section	1.689 x 0.0829
P1683x79	Pipe section	1.683 x 0.0791
P1676x82	Pipe section	1.676 x 0.0826
P1676x79	Pipe section	1.676 x 0.0794
P1676x76	Pipe section	1.676 x 0.0762
P1664x69	Pipe section	1.664 x 0.0699
P1638x57	Pipe section	1.638 x 0.0572
P1638x31	Pipe section	1.638 x 0.0318
P1626x50	Pipe section	1.626 x 0.0508
P1600x38	Pipe section	1.600 x 0.0381
P1588x31	Pipe section	1.588 x 0.0318
P1581x79	Pipe section	1.581 x 0.0794
P1575x60	Pipe section	1.575 x 0.0603
P1575x38	Pipe section	1.575 x 0.0381
P1575x25	Pipe section	1.575 x 0.0254
P1524x85	Pipe section	1.524 x 0.0857
P1524x69	Pipe section	1.524 x 0.0699
P1373x63	Pipe section	1.373 x 0.0635
P1373x25	Pipe section	1.373 x 0.0254
P1372x85	Pipe section	1.372 x 0.0857
P1372x63	Pipe section	1.372 x 0.0635
P1372x60	Pipe section	1.372 x 0.0603
P1372x57	Pipe section	1.372 x 0.0572
P1372x54	Pipe section	1.372 x 0.0540
P1372x50	Pipe section	1.372 x 0.0508
P1372x44	Pipe section	1.372 x 0.0445
P1372x31	Pipe section	1.372 x 0.0318
P1372x25	Pipe section	1.372 x 0.0254
P1220x25	Pipe section	1.220 x 0.0254
P1219x57	Pipe section	1.219 x 0.0572
P1219x54	Pipe section	1.219 x 0.0540
P1219x50	Pipe section	1.219 x 0.0508
P1219x47	Pipe section	1.219 x 0.0476
P1219x44	Pipe section	1.219 x 0.0445
P1219x41	Pipe section	1.219 x 0.0413
P1219x38	Pipe section	1.219 x 0.0381
P1219x34	Pipe section	1.219 x 0.0349
P1219x31	Pipe section	1.219 x 0.0318

P1219x25	Pipe section	1.219 x 0.0254
P1068x25	Pipe section	1.068 x 0.0254
P1067x50	Pipe section	1.067 x 0.0508
P1067x47	Pipe section	1.067 x 0.0476
P1067x44	Pipe section	1.067 x 0.0445
P1067x41	Pipe section	1.067 x 0.0413
P1067x38	Pipe section	1.067 x 0.0381
P1067x34	Pipe section	1.067 x 0.0349
P1067x31	Pipe section	1.067 x 0.0318
P1067x28	Pipe section	1.067 x 0.0286
P1067x25	Pipe section	1.067 x 0.0254
P0915x38	Pipe section	0.915 x 0.0381
P0915x31	Pipe section	0.915 x 0.0318
P0915x25	Pipe section	0.915 x 0.0254
P0915x19	Pipe section	0.915 x 0.0191
P0914x54	Pipe section	0.914 x 0.0540
P0914x50	Pipe section	0.914 x 0.0508
P0914x44	Pipe section	0.914 x 0.0445
P0914x41	Pipe section	0.914 x 0.0413
P0914x38	Pipe section	0.914 x 0.0381
P0914x34	Pipe section	0.914 x 0.0349
P0914x31	Pipe section	0.914 x 0.0318
P0914x25	Pipe section	0.914 x 0.0254
P0914x19	Pipe section	0.914 x 0.0191
P0762x19	Pipe section	0.762 x 0.0191
P0610x31	Pipe section	0.610 x 0.0318
P0610x25	Pipe section	0.610 x 0.0254
P0610x19	Pipe section	0.610 x 0.0191
P0610x12	Pipe section	0.610 x 0.0127
P0457x12	Pipe section	0.457 x 0.0127
P0356x19	Pipe section	0.356 x 0.0191
P0356x12	Pipe section	0.356 x 0.0127
Note: Notations for dimension are as follows; PipeSection – (diameter, thickness)		

Appendix table A-1 Cross sections, jacket structure

B.2 Input files

Only an extract of input files are given below. They are included to give an understanding of how the modelling and analyses have been performed.

B.2.1 Input file to GeniE, jacket structure

```
//*************************************************************************
//-------------------------------------------------------------------------
//                        Input File To: GENIE
//-------------------------------------------------------------------------
//
//              AKER SOLUTIONS, STAVANGER
//
// Project:          : Master thesis
// Structure         : Jacket
// Analysis Condition: General geometry
// Superelement No.  : 1
// Description       : Jacket model
//
// File name      : jacket.js
//-------------------------------------------------------------------------
//
// Made By    : SA          Date: Feb-2011
//
//-------------------------------------------------------------------------
//*************************************************************************
// Rules
//*************************************************************************
//
//-------------------------------------------------------------------------
// Unit definitions
//-------------------------------------------------------------------------
//
Genierules.Units.setDatabaseunits("m","N","delC");
GenieRules.Units.setInputUnit(Length, "m");
GenieRules.Units.setInputUnit(Force, "N");
GenieRules.Units.setInputUnit(TempDiff, "delC");
GenieRules.Units.setInputUnit(Mass,"kg");
//
//-------------------------------------------------------------------------
// Joint design
//-------------------------------------------------------------------------
//
GenieRules.JointDesign.setDefaultCanRule(0.25, 0.3 m);
GenieRules.JointDesign.setDefaultStubRule(1, 0.6 m);
GenieRules.JointDesign.minimumGap = 0.0508 m;
GenieRules.JointDesign.gapTolerance = 0.001 m;
GenieRules.JointDesign.planeTolerance = 1 deg;
GenieRules.JointDesign.braceAngleMoveLimit = 10 deg;
GenieRules.JointDesign.chordAlignmentTolerance = 5 deg;
GenieRules.JointDesign.flushBraces = false;
GenieRules.JointDesign.iterations = 2;
//
AutoCan = Reinforcement(0.25,0.3 m);
GenieRules.JointDesign.canReinforcement = AutoCan;
AutoStub = Reinforcement(1,0.6 m);
GenieRules.JointDesign.stubReinforcement = AutoStub;
GenieRules.Tolerances.angleTolerance = 0 deg;
GenieRules.Tolerances.pointTolerance = 0.01 m;
GenieRules.Tolerances.useTolerantModelling = true;
//
```

```
//*************************************************************************
// Material library (units: kg, N, metres)
//*************************************************************************
//
//-------------------------------------------------------------------------
// Command syntax
//-------------------------------------------------------------------------
//
// name = Material(yield, density, young, poisson, thermal, damping)
// name = MaterialShear(axialRed, density, young, poisson, thermal, damping)
//
S345 = Material(345E6, 7850, 2.1E11, 0.3, 1.20006E-5, 0);
S345_braceH = Material(345E6, 7850, 2.1E11, 0.3, 1.20007E-5, 0);
S345_braceV = Material(345E6, 7850, 2.1E11, 0.3, 1.20008E-5, 0);
S345_star = Material(345E6, 7850, 2.1E11, 0.3, 1.20009E-5, 0);
S_sleeve_pile = Material(345E6, 7850, 2.1E11, 0.3, 1.20010E-5, 0);
//
//*************************************************************************
// Cross section library (units: metres)
//*************************************************************************
//
//-------------------------------------------------------------------------
// Command syntax
//-------------------------------------------------------------------------
//
// name=PipeSection(diameter,thickness);
//
//-------------------------------------------------------------------------
// Cross section properties
//-------------------------------------------------------------------------
//
// ** Pipe profiles **
//
P3048x57 = PipeSection(3.048, 0.0572);
P3048x50 = PipeSection(3.048, 0.0508);
P3048x38 = PipeSection(3.048, 0.0381);
P3048x25 = PipeSection(3.048, 0.0254);
P3048x15 = PipeSection(3.048, 0.0159);
P2286x57 = PipeSection(2.286, 0.0572);
P1829x50 = PipeSection(1.829, 0.0508);
P1800x75 = PipeSection(1.800, 0.0750);
P1689x82 = PipeSection(1.689, 0.0829);
P1683x79 = PipeSection(1.683, 0.0791);
P1676x82 = PipeSection(1.676, 0.0826);
P1676x79 = PipeSection(1.676, 0.0794);
P1676x76 = PipeSection(1.676, 0.0762);
P1664x69 = PipeSection(1.664, 0.0699);
P1638x57 = PipeSection(1.638, 0.0572);
P1638x31 = PipeSection(1.638, 0.0318);
P1626x50 = PipeSection(1.626, 0.0508);
P1600x38 = PipeSection(1.600, 0.0381);
P1588x31 = PipeSection(1.588, 0.0318);
P1581x79 = PipeSection(1.581, 0.0794);
P1575x60 = PipeSection(1.575, 0.0603);
P1575x38 = PipeSection(1.575, 0.0381);
(text removed)
......
//
//*************************************************************************
//
GlobXz = LocalSystem( Vector3d(1,0,0), Vector3d(1,0,1));

X_vect = Vector3d(1,0,0);
Y_vect = Vector3d(0,1,0);
Z_vect = Vector3d(0,0,1);
//
//*************************************************************************
//*************************************************************************
```

```
// GEOMETRY
//*************************************************************************
//
//*************************************************************************
// Point definitions
//*************************************************************************
//
// Origo in X-Y plane is defined at centre
// z = 0 at M.L.W.
//
// Pxxyyzz = Point(xxx.xxx, yyy.yyy, zzz.zzz)
//
//-------------------------------------------------------------------------
// Horizontal plan at el (-) 101 370 mm
//-------------------------------------------------------------------------
//
P101005 = Point(-30.9552 m,      -21.8282 m,  -101.37 m);
P601005 = Point( -9.1450 m,      -21.8282 m,  -101.37 m);
P801005      = Point(  9.1450 m, -21.8282 m,  -101.37 m);
P901005      = Point( 30.9552 m, -21.8282 m,  -101.37 m);
P109005      = Point(-30.9552 m,  21.8282 m,  -101.37 m);
P609005      = Point( -9.1450 m,  21.8282 m,  -101.37 m);
P809005      = Point(  9.1450 m,  21.8282 m,  -101.37 m);
P909005      = Point( 30.9552 m,  21.8282 m,  -101.37 m);
P880505 = Point( 29.0878 m,      -23.6916 m,  -101.37 m);
P950505      = Point( 32.8192 m, -23.6916 m,  -101.37 m);
P951505      = Point( 32.8192 m, -19.9602 m,  -101.37 m);
P881505      = Point( 29.0878 m, -19.9602 m,  -101.37 m);
P958505      = Point( 32.8192 m,  19.9602 m,  -101.37 m);
(text removed)
......
//
//*************************************************************************
// Element definitions
//*************************************************************************
//
// ** Name explanation **
//
// L - Leg
// B - Bracing and sleeves
//
// Laxxyyzz = Beam(P1xxyyzz, P2xxyyzz)
// Baxxyyzz = Beam(P1xxyyzz, P2xxyyzz)
//
//-------------------------------------------------------------------------
// Hoizontal bracing elements
//-------------------------------------------------------------------------
//
//-------------------------------------------------------------------------
// Horizontal framing plane at el (-) 100 000 mm
//-------------------------------------------------------------------------
//
S345_braceH.setDefault();
P1372x44.setDefault();
//
BX101010 = Beam(P101010, P201010);
BX109010 = Beam(P109010, P209010);
//
P1372x31.setDefault();
//
BX201010 = Beam(P201010, P421010);
BX421010 = Beam(P421010, P601010);
BX601010 = Beam(P601010, P701010);
BX701010 = Beam(P701010, P801010);
BX801010 = Beam(P801010, P901010);

BX209010 = Beam(P209010, P429010);
BX429010 = Beam(P429010, P609010);
```

```
BX609010 = Beam(P609010, P709010);
BX709010 = Beam(P709010, P809010);
BX809010 = Beam(P809010, P909010);
//
P1372x25.setDefault();
//
BY101010 = Beam(P101010, P102010);
BY102010 = Beam(P102010, P104510);
BY105510 = Beam(P105510, P108010);
(text removed)
......
//
//------------------------------------------------------------------------
// Sleeves included piles, el (-) 70 865 mm - (-) 101 370mm
//------------------------------------------------------------------------
//
P1800x75.setDefault();
S_sleeve_pile.setDefault();
//
BB901020 = Beam(P901020, P930720);
BA901020 = Beam(P901020, P931620);
BA870720 = Beam(P870720, P901020);
BB871620 = Beam(P871620, P901020);
BA878320 = Beam(P878320, P909020);
BB879320 = Beam(P879320, P909020);
BB909020 = Beam(P909020, P938320);
(text removed)
......
//
//************************************************************************
// Joint definitions
//************************************************************************
// Jxxyyzz = Joint(Pxxyyzz)
//------------------------------------------------------------------------
// Horizontal plan at el (-) 100 000 mm
//------------------------------------------------------------------------
//
J101010 = Joint(P101010);
J201010      = Joint(P201010);
J421010      = Joint(P421010);
J601010      = Joint(P601010);
J701010      = Joint(P701010);
J801010      = Joint(P801010);
J901010      = Joint(P901010);
J102010      = Joint(P102010);
J282010      = Joint(P282010);
J522010      = Joint(P522010);
J602010      = Joint(P602010);
J104510 = Joint(P104510);
(text removed)
......
//
//************************************************************************
// Joint gap definitions
//************************************************************************
//
for(i=1; i <= GenieRules.JointDesign.iterations; i++) {
//
J101010.autoGap();
J201010.autoGap();
J421010.autoGap();
J601010.autoGap();
J701010.autoGap();
J801010.autoGap();
J901010.autoGap();
J102010.autoGap();
J282010.autoGap();
J522010.autoGap();
```

```
(text removed)
......
}
//
//*************************************************************************
// Joint can definitions
//*************************************************************************
//
J101010.autoCan();
J201010.autoCan();
J421010.autoCan();
J601010.autoCan();
J701010.autoCan();
J801010.autoCan();
J901010.autoCan();
J102010.autoCan();
J282010.autoCan();
J522010.autoCan();
(text removed)
......
//
//*************************************************************************
//  Stub definitons
//*************************************************************************
//
J101010.autoStub();
J201010.autoStub();
J421010.autoStub();
J601010.autoStub();
J701010.autoStub();
J801010.autoStub();
J901010.autoStub();
J102010.autoStub();
J282010.autoStub();
J522010.autoStub();
J602010.autoStub();
J104510.autoStub();
J284510.autoStub();
J524510.autoStub();
J604510.autoStub();
J105010.autoStub();
(text removed)
......
//
//*************************************************************************
// Node reinforcement
//*************************************************************************
//
BY901010.SetSegmentSection(1, P1372x44);
BY905010.SetSegmentSection(3, P1372x44);
BY101010.SetSegmentSection(1, P1372x44);
BY108010.SetSegmentSection(3, P1372x44);
BY901010.SetSegmentSection(3, P1372x63);
BY905010.SetSegmentSection(1, P1372x63);
BY805010.SetSegmentSection(1, P0914x38);
BY801010.SetSegmentSection(3, P0914x38);
BY605010.SetSegmentSection(1, P0915x38);
(text removed)
......
//
//*************************************************************************
// Cone definitions
//*************************************************************************
//
AutoCone = ConeSection(1,true);
GenieRules.JointDesign.coneSection = AutoCone;
GenieRules.JointDesign.coneAngle = 3.9735 deg;
//
```

```
J901020.autoCone(LZ901020,1);
J101020.autoCone(LZ101020,1);
J109020.autoCone(LZ109020,1);
J909020.autoCone(LZ909020,1);
//
GenieRules.JointDesign.coneAngle = 2.3855 deg;
//
J101040.autoCone(LZ101040,1);
J901040.autoCone(LZ901040,1);
J109040.autoCone(LZ109040,1);
J909040.autoCone(LZ909040,1);
//
GenieRules.JointDesign.coneAngle = 2.64895 deg;
//
J101060.autoCone(LZ101060,1);
J901060.autoCone(LZ901060,1);
J109060.autoCone(LZ109060,1);
J909060.autoCone(LZ909060,1);
//
GenieRules.JointDesign.coneAngle = 1.586 deg;
//
J601020.autoCone(BC101010,3);
J801020.autoCone(BD801020,1);
J809020.autoCone(BD809020,1);
J609020.autoCone(BC109010,3);
//
//*************************************************************************
// Support points
//*************************************************************************
//
Sp909005 = SupportPoint(P909005);
Sp909005.boundary = BoundaryCondition(Fixed, Fixed, Fixed, Free, Free, Free);
//
Sp109005 = SupportPoint(P109005);
Sp109005.boundary = BoundaryCondition(Fixed, Fixed, Fixed, Free, Free, Free);
//
Sp901005 = SupportPoint(P901005);
Sp901005.boundary = BoundaryCondition(Fixed, Fixed, Fixed, Free, Free, Free);
//
Sp101005 = SupportPoint(P101005);
Sp101005.boundary = BoundaryCondition(Fixed, Fixed, Fixed, Free, Free, Free);
//
Sp601005 = SupportPoint(P601005);
Sp601005.boundary = BoundaryCondition(Fixed, Fixed, Fixed, Free, Free, Free);
//
Sp801005 = SupportPoint(P801005);
Sp801005.boundary = BoundaryCondition(Fixed, Fixed, Fixed, Free, Free, Free);
//
Sp809005 = SupportPoint(P809005);
Sp809005.boundary = BoundaryCondition(Fixed, Fixed, Fixed, Free, Free, Free);
//
Sp609005 = SupportPoint(P609005);
Sp609005.boundary = BoundaryCondition(Fixed, Fixed, Fixed, Free, Free, Free);
//
//*************************************************************************
// Load cases
//*************************************************************************
//-------------------------------------------------------------------------
// Marine Growth
//-------------------------------------------------------------------------
//
// ** Constant marine growth **
//
//Modify mass for UpperJacket_MG from 2204768.976 kg to 2618768.976
MassFactor1 = MassDensityFactor(1.187774776);
UpperJacket_MG.massDensityFactor = MassFactor1;
//
//Modify mass for LowerJacket_MG from 5092936.339 kg to 5404936.339
```

```
MassFactor2 = MassDensityFactor(1.061261319);
LowerJacket_MG.massDensityFactor = MassFactor2;
//
//-----------------------------------------------------------------------
// Self generated structural load
//-----------------------------------------------------------------------
//
LC1 = LoadCase();
LC1.setFemLoadcase(1);
LC1.setAcceleration(Vector3d(0 m/s^2,0 m/s^2,-9.80665 m/s^2));
LC1.includeSelfWeight();
//
// Using a consequence factor of 1.3
LC101 = Loadcombination();
LC101.addcase(LC1, 2.412);
//
//***********************************************************************
// Analysis
//***********************************************************************
//
Analysis1 = Analysis(true);
Analysis1.add(MeshActivity());
Analysis1.add(LinearAnalysis());
Analysis1.add(LoadResultsActivity());
LC101.setCurrent();
Analysis1.setActive();
SimplifyTopology();
Analysis1.execute();
```

B.2.2 Input files to Usfos, vertical split removal method

```
'=====================================================================
 Head      Vertical split of jacket,short side, with 4 BTA's  Buoyancy Case
                 Usfos Simulation
                 AkerSolutions 2011

'---------------------------------------------------------------------
'
' Usfos Head File. Buouancy Case for vertical split of jacket and re-float with
' BTAs
'
'     Master thesis; Float-up and rotation simulations:
'     Apr - 2011 Svanhild Alsvik
'
'=====================================================================
'
'                                              - Define Hist 1 for All First
'         Hist  DefType   ID list
 BuoyHist   1    Elem
'
'
' -------------------------------------------------------------------
'  Define buoyancy for tanks according to individual histories
' -------------------------------------------------------------------
'
' =============  T a n k  1  Histories ==============
'
'          ID      Type    t1  t2  fac    Pow
 TimeHist   102064  S_Curv  00  03  1.0e-1  2  ! History for Element    2064
 TimeHist   102081  S_Curv  00  03  1.0e-1  2  ! History for Element    2081
 TimeHist   102087  S_Curv  00  03  1.0e-0  2  ! History for Element    2087
 TimeHist   102091  S_Curv  00  03  1.0e-0  2  ! History for Element    2091
 TimeHist   102099  S_Curv  00  03  1.0e-0  2  ! History for Element    2099
 TimeHist   102108  S_Curv  00  03  1.0e-0  2  ! History for Element    2108
 TimeHist   102114  S_Curv  00  03  1.0e-0  2  ! History for Element    2114
 TimeHist   102125  S_Curv  00  03  1.0e-0  2  ! History for Element    2125
 TimeHist   102127  S_Curv  00  03  1.0e-0  2  ! History for Element    2127
 TimeHist   102129  S_Curv  00  03  1.0e-0  2  ! History for Element    2129
 TimeHist   102131  S_Curv  00  03  1.0e-0  2  ! History for Element    2131
 TimeHist   102133  S_Curv  00  03  1.0e-0  2  ! History for Element    2133
 TimeHist   102135  S_Curv  00  03  1.0e-0  2  ! History for Element    2135
'
 TimeHist   101900  S_Curv  00  03  1.0e-1  2  ! History for Element    1900
 TimeHist   101906  S_Curv  00  03  1.0e-1  2  ! History for Element    1906
 TimeHist   101924  S_Curv  00  03  1.0e-0  2  ! History for Element    1924
 TimeHist   101934  S_Curv  00  03  1.0e-0  2  ! History for Element    1934
 TimeHist   101943  S_Curv  00  03  1.0e-0  2  ! History for Element    1943
 TimeHist   101951  S_Curv  00  03  1.0e-0  2  ! History for Element    1951
 TimeHist   101971  S_Curv  00  03  1.0e-0  2  ! History for Element    1971
 TimeHist   101977  S_Curv  00  03  1.0e-0  2  ! History for Element    1977
 TimeHist   101985  S_Curv  00  03  1.0e-0  2  ! History for Element    1985
 TimeHist   101994  S_Curv  00  03  1.0e-0  2  ! History for Element    1994
 TimeHist   102011  S_Curv  00  03  1.0e-0  2  ! History for Element    2011
 TimeHist   102017  S_Curv  00  03  1.0e-0  2  ! History for Element    2017
 TimeHist   102023  S_Curv  00  03  1.0e-0  2  ! History for Element    2023
'
'
' =============  T a n k  2  Histories ==============
'
'          ID      Type    t1  t2  fac    Pow
 TimeHist   200386  S_Curv  00  03  1.0e-1  2  ! History for Element    386
 TimeHist   200367  S_Curv  00  03  1.0e-1  2  ! History for Element    367
 TimeHist   200330  S_Curv  00  03  1.0e-0  2  ! History for Element    330
 TimeHist   200316  S_Curv  00  03  1.0e-0  2  ! History for Element    316
```

```
 TimeHist   200295  S_Curv  00  03  1.0e-0  2  ! History for Element    295
 TimeHist   200283  S_Curv  00  03  1.0e-0  2  ! History for Element    283
 TimeHist   200243  S_Curv  00  03  1.0e-0  2  ! History for Element    243
 TimeHist   200235  S_Curv  00  03  1.0e-0  2  ! History for Element    235
 TimeHist   200221  S_Curv  00  03  1.0e-0  2  ! History for Element    221
 TimeHist   200210  S_Curv  00  03  1.0e-0  2  ! History for Element    210
 TimeHist   200177  S_Curv  00  03  1.0e-0  2  ! History for Element    177
 TimeHist   200173  S_Curv  00  03  1.0e-0  2  ! History for Element    173
 TimeHist   200161  S_Curv  00  03  1.0e-0  2  ! History for Element    161
'
 TimeHist   200097  S_Curv  00  03  1.0e-1  2  ! History for Element     97
 TimeHist   200068  S_Curv  00  03  1.0e-1  2  ! History for Element     68
 TimeHist   200064  S_Curv  00  03  1.0e-0  2  ! History for Element     64
 TimeHist   200058  S_Curv  00  03  1.0e-0  2  ! History for Element     58
 TimeHist   200050  S_Curv  00  03  1.0e-0  2  ! History for Element     50
 TimeHist   200038  S_Curv  00  03  1.0e-0  2  ! History for Element     38
 TimeHist   200032  S_Curv  00  03  1.0e-0  2  ! History for Element     32
 TimeHist   200011  S_Curv  00  03  1.0e-0  2  ! History for Element     11
 TimeHist   200009  S_Curv  00  03  1.0e-0  2  ! History for Element      9
 TimeHist   200007  S_Curv  00  03  1.0e-0  2  ! History for Element      7
 TimeHist   200005  S_Curv  00  03  1.0e-0  2  ! History for Element      5
 TimeHist   200003  S_Curv  00  03  1.0e-0  2  ! History for Element      3
 TimeHist   200001  S_Curv  00  03  1.0e-0  2  ! History for Element      1
'
'
' =============  T a n k  3  Histories ==============
'
'           ID      Type    t1  t2  fac     Pow
 TimeHist   300098  S_Curv  00  03  1.0e-1  2  ! History for Element     98
 TimeHist   300069  S_Curv  00  03  1.0e-1  2  ! History for Element     69
 TimeHist   300065  S_Curv  00  03  1.0e-0  2  ! History for Element     65
 TimeHist   300059  S_Curv  00  03  1.0e-0  2  ! History for Element     59
 TimeHist   300053  S_Curv  00  03  1.0e-0  2  ! History for Element     53
 TimeHist   300039  S_Curv  00  03  1.0e-0  2  ! History for Element     39
 TimeHist   300033  S_Curv  00  03  1.0e-0  2  ! History for Element     33
 TimeHist   300012  S_Curv  00  03  1.0e-0  2  ! History for Element     12
 TimeHist   300010  S_Curv  00  03  1.0e-0  2  ! History for Element     10
 TimeHist   300008  S_Curv  00  03  1.0e-0  2  ! History for Element      8
 TimeHist   300006  S_Curv  00  03  1.0e-0  2  ! History for Element      6
 TimeHist   300004  S_Curv  00  03  1.0e-0  2  ! History for Element      4
 TimeHist   300002  S_Curv  00  03  1.0e-0  2  ! History for Element      2
'
 TimeHist   300400  S_Curv  00  03  1.0e-1  2  ! History for Element    400
 TimeHist   300385  S_Curv  00  03  1.0e-1  2  ! History for Element    385
 TimeHist   300370  S_Curv  00  03  1.0e-0  2  ! History for Element    370
 TimeHist   300358  S_Curv  00  03  1.0e-0  2  ! History for Element    358
 TimeHist   300320  S_Curv  00  03  1.0e-0  2  ! History for Element    320
 TimeHist   300301  S_Curv  00  03  1.0e-0  2  ! History for Element    301
 TimeHist   300286  S_Curv  00  03  1.0e-0  2  ! History for Element    286
 TimeHist   300246  S_Curv  00  03  1.0e-0  2  ! History for Element    246
 TimeHist   300238  S_Curv  00  03  1.0e-0  2  ! History for Element    238
 TimeHist   300222  S_Curv  00  03  1.0e-0  2  ! History for Element    222
 TimeHist   300213  S_Curv  00  03  1.0e-0  2  ! History for Element    213
 TimeHist   300178  S_Curv  00  03  1.0e-0  2  ! History for Element    178
 TimeHist   300174  S_Curv  00  03  1.0e-0  2  ! History for Element    174
'
'
' =============  T a n k  4  Histories ==============
'
'           ID      Type    t1  t2  fac     Pow
 TimeHist   401896  S_Curv  00  03  1.0e-1  2 ! History for Element    1896
 TimeHist   401901  S_Curv  00  03  1.0e-1  2 ! History for Element    1901
 TimeHist   401905  S_Curv  00  03  1.0e-0  2 ! History for Element    1905
 TimeHist   401909  S_Curv  00  03  1.0e-0  2 ! History for Element    1909
 TimeHist   401930  S_Curv  00  03  1.0e-0  2 ! History for Element    1930
 TimeHist   401941  S_Curv  00  03  1.0e-0  2 ! History for Element    1941
 TimeHist   401950  S_Curv  00  03  1.0e-0  2 ! History for Element    1950
 TimeHist   401970  S_Curv  00  03  1.0e-0  2 ! History for Element    1970
```

```
 TimeHist   401974  S_Curv  00  03  1.0e-0  2 ! History for Element    1974
 TimeHist   401984  S_Curv  00  03  1.0e-0  2 ! History for Element    1984
 TimeHist   401991  S_Curv  00  03  1.0e-0  2 ! History for Element    1991
 TimeHist   402010  S_Curv  00  03  1.0e-0  2 ! History for Element    2010
 TimeHist   402014  S_Curv  00  03  1.0e-0  2 ! History for Element    2014
'
 TimeHist   402063  S_Curv  00  03  1.0e-1  2 ! History for Element    2063
 TimeHist   402080  S_Curv  00  03  1.0e-1  2 ! History for Element    2080
 TimeHist   402086  S_Curv  00  03  1.0e-0  2 ! History for Element    2086
 TimeHist   402090  S_Curv  00  03  1.0e-0  2 ! History for Element    2090
 TimeHist   402098  S_Curv  00  03  1.0e-0  2 ! History for Element    2098
 TimeHist   402107  S_Curv  00  03  1.0e-0  2 ! History for Element    2107
 TimeHist   402113  S_Curv  00  03  1.0e-0  2 ! History for Element    2113
 TimeHist   402124  S_Curv  00  03  1.0e-0  2 ! History for Element    2124
 TimeHist   402126  S_Curv  00  03  1.0e-0  2 ! History for Element    2126
 TimeHist   402128  S_Curv  00  03  1.0e-0  2 ! History for Element    2128
 TimeHist   402130  S_Curv  00  03  1.0e-0  2 ! History for Element    2130
 TimeHist   402132  S_Curv  00  03  1.0e-0  2 ! History for Element    2132
 TimeHist   402134  S_Curv  00  03  1.0e-0  2 ! History for Element    2134
'
' ---------------------------------------------------------------------
'  Connect elements to buoyancy histories
' ---------------------------------------------------------------------
'          Hist            Elem
 BuoyHist  102064  Elem    2064
 BuoyHist  102081  Elem    2081
 BuoyHist  102087  Elem    2087
 BuoyHist  102091  Elem    2091
 BuoyHist  102099  Elem    2099
 BuoyHist  102108  Elem    2108
 BuoyHist  102114  Elem    2114
 BuoyHist  102125  Elem    2125
 BuoyHist  102127  Elem    2127
 BuoyHist  102129  Elem    2129
 BuoyHist  102131  Elem    2131
 BuoyHist  102133  Elem    2133
 BuoyHist  102135  Elem    2135
'
 BuoyHist  101900  Elem    1900
 BuoyHist  101906  Elem    1906
 BuoyHist  101924  Elem    1924
 BuoyHist  101934  Elem    1934
 BuoyHist  101943  Elem    1943
 BuoyHist  101951  Elem    1951
 BuoyHist  101971  Elem    1971
 BuoyHist  101977  Elem    1977
 BuoyHist  101985  Elem    1985
 BuoyHist  101994  Elem    1994
 BuoyHist  102011  Elem    2011
 BuoyHist  102017  Elem    2017
 BuoyHist  102023  Elem    2023
'
'
'  Hist            Elem
 BuoyHist  200386  Elem    386
 BuoyHist  200367  Elem    367
 BuoyHist  200330  Elem    330
 BuoyHist  200316  Elem    316
 BuoyHist  200295  Elem    295
 BuoyHist  200283  Elem    283
 BuoyHist  200243  Elem    243
 BuoyHist  200235  Elem    235
 BuoyHist  200221  Elem    221
 BuoyHist  200210  Elem    210
 BuoyHist  200177  Elem    177
 BuoyHist  200173  Elem    173
 BuoyHist  200161  Elem    161
```

```
 BuoyHist  200097  Elem     97
 BuoyHist  200068  Elem     68
 BuoyHist  200064  Elem     64
 BuoyHist  200058  Elem     58
 BuoyHist  200050  Elem     50
 BuoyHist  200038  Elem     38
 BuoyHist  200032  Elem     32
 BuoyHist  200011  Elem     11
 BuoyHist  200009  Elem      9
 BuoyHist  200007  Elem      7
 BuoyHist  200005  Elem      5
 BuoyHist  200003  Elem      3
 BuoyHist  200001  Elem      1
'
'
'  Hist            Elem
 BuoyHist  300098  Elem    98
 BuoyHist  300069  Elem    69
 BuoyHist  300065  Elem    65
 BuoyHist  300059  Elem    59
 BuoyHist  300053  Elem    53
 BuoyHist  300039  Elem    39
 BuoyHist  300033  Elem    33
 BuoyHist  300012  Elem    12
 BuoyHist  300010  Elem    10
 BuoyHist  300008  Elem     8
 BuoyHist  300006  Elem     6
 BuoyHist  300004  Elem     4
 BuoyHist  300002  Elem     2
'
 BuoyHist  300400  Elem   400
 BuoyHist  300385  Elem   385
 BuoyHist  300370  Elem   370
 BuoyHist  300358  Elem   358
 BuoyHist  300320  Elem   320
 BuoyHist  300301  Elem   301
 BuoyHist  300286  Elem   286
 BuoyHist  300246  Elem   246
 BuoyHist  300238  Elem   238
 BuoyHist  300222  Elem   222
 BuoyHist  300213  Elem   213
 BuoyHist  300178  Elem   178
 BuoyHist  300174  Elem   174
'
'
'          Hist             Elem
 BuoyHist  401896  Elem    1896
 BuoyHist  401901  Elem    1901
 BuoyHist  401905  Elem    1905
 BuoyHist  401909  Elem    1909
 BuoyHist  401930  Elem    1930
 BuoyHist  401941  Elem    1941
 BuoyHist  401950  Elem    1950
 BuoyHist  401970  Elem    1970
 BuoyHist  401974  Elem    1974
 BuoyHist  401984  Elem    1984
 BuoyHist  401991  Elem    1991
 BuoyHist  402010  Elem    2010
 BuoyHist  402014  Elem    2014
'
 BuoyHist  402063  Elem    2063
 BuoyHist  402080  Elem    2080
 BuoyHist  402086  Elem    2086
 BuoyHist  402090  Elem    2090
 BuoyHist  402098  Elem    2098
 BuoyHist  402107  Elem    2107
 BuoyHist  402113  Elem    2113
 BuoyHist  402124  Elem    2124
```

```
 BuoyHist  402126  Elem    2126
 BuoyHist  402128  Elem    2128
 BuoyHist  402130  Elem    2130
 BuoyHist  402132  Elem    2132
 BuoyHist  402134  Elem    2134
'
' -------------------------------------------------------------------
'  Define node velocity for strand jacks
' -------------------------------------------------------------------
'
'        LCase        NodeID   dof_code   value
 NODEVELO  11       998     123        0 -1.0 0
 NODEVELO  11      1397     123        0 -1.0 0
 NODEVELO  11      1212      123       0  1.0 0
 NODEVELO  11      1569     123        0  1.0 0
'
' -------------------------------------------------------------------
'  Connect elements to load history
' -------------------------------------------------------------------
'        LCase        TimeHist
 LOADHIST   11          10
'
 TIMEHIST   10     1
 0    0
 90   0
 190  0.25
 400  0.25
'------------------------------------------------------------------
'  Define flooded members:
' -------------------------------------------------------------------
' All legs, piles and cutted braces are flooded :
'
'           ListType {Id_List}
 Flooded     Group 14                 !Legs
' Flooded     Group 18                 !Sleeves
 Flooded     Group 6                  !Braces
' --------------- e o f --------------------
'=====================================================================
'
'   Usfos optinal File.
'    Buouancy Case for vertical split of jacket and re-float with BTAs
'
'     Master thesis; FloatUp and rotation simulations:
'     Apr - 2011 Svanhild Alsvik
'
'=====================================================================
'
 Chg_Boun  0 0 0  0 0 0 All
 Chg_Boun  1 0 1  0 0 0 Node 998 1397 1212 1569
'
'
'
'         EndT    dT   dTRes   dTPri
 Dynamic  400.0  0.010   0.5    0.5
'
 Wet_elem       All
'
'            Ratio1  Ratio2   Freq1  Freq1
 DampRatio    0.15    0.15     0.1    10.0  ! 15% damping at 0.1 and 10 hz
'
'
'       ncnods  nodeID   dof   fact
 CNODES    4      350      3      1
                  349      3      1
                 1668      3      1
                 1670      3      1
'
'          Max_step
```

```
CMAXSTEP    2000
'
'
' ----------------------------------------------------------------------
'     Time Histories for Gravity and Wave
' ----------------------------------------------------------------------
'
'
'           ID     Type    t1  t2   fac   pow
TimeHist    1     S_Curve  0   3   1.0    2  ! History for Grav & Buoy
'
'           ID   <type>    Dtime  Factor  Start_time
TimeHist    2   Switch     0.0     1.0    0.0! History for Hydrodynamic
'
'
'
'           Ildcs Tim Hist
LOADHIST     1       1   !Activate load case 1 according to time history 1
LOADHIST     2       2   !Activate Hydrodynamics
'
' ----------------------------------------------------------------------
'     Wave and Current Definitions
' ----------------------------------------------------------------------
'        Ildcs  <type>  H  Period  Direction  Phase   Surf_Lev    Depth
WAVEDATA   2   Airy   0.0  10.0     0         0.0      -29     101.37
'
Rel_Velo      ! Account for relative motion  (Drag damping)
Buoyancy      ! Switch ON buoyancy for all members
'
' ----------------------------------------------------------------------
'
'    NIS  Elm_1 Elm_2 Elm_3 .........
Wave_Int  5
2064 2081 2087 2091 2099 2108 2114 2125 2127 2129 2131 2133 2135
1900 1906 1924 1934 1943 1951 1971 1977 1985 1994 2011 2017 2023
'
386 367 330 316 295 283 243 235 221 210 177 173 161
97 68 64 58 50 38 32 11 9 7 5 3 1
'
98 69 65 59 53 39 33 12 10 8 6 4 2
400 385 370 358 320 301 286 246 238 222 213 178 174
'
1896 1901 1905 1909 1930 1941 1950 1970 1974 1984 1991 2010 2014
2063 2080 2086 2090 2098 2107 2113 2124 2126 2128 2130 2132 2134
'
' ----------------------------------------------------------------------
'  F l o o d e d   M e m b e r s
' ----------------------------------------------------------------------
'
'   Flooded members are given in the HEAD-file
'
' ------------------ e o f ----------------
```

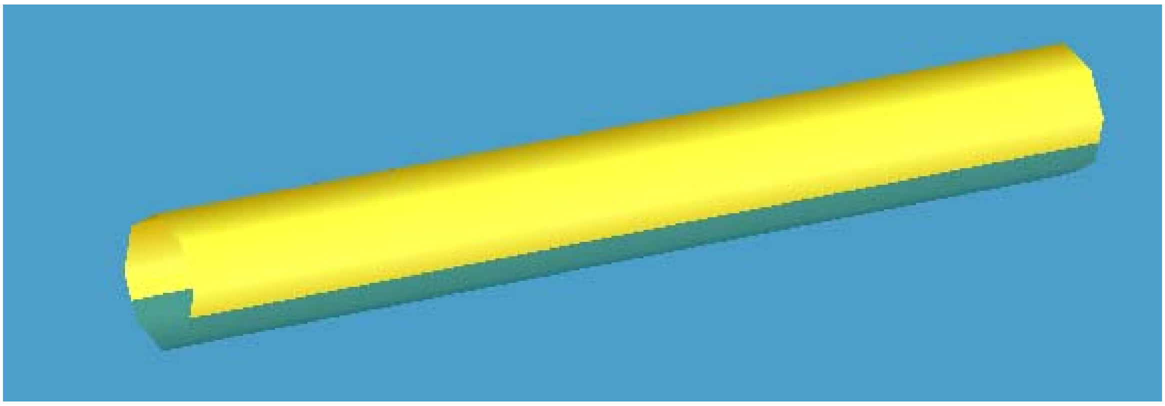
C.2 Control of Usfos' calculations of buoyancy forces

Buoyancy force calculations done by Usfos are compared with hand calculations.

C.2.1 Buoyancy of a horizontal pipe dependent on draft

A check has been performed to control how USFOS software program calculate buoyancy forces in a horizontal element. A 53 meter long pipe is modelled. The buoyancy is calculated manually, and static and dynamic analyses have been carried out in USFOS. The results are compared in a table.

The pipe is modelled with three nodes and two elements.



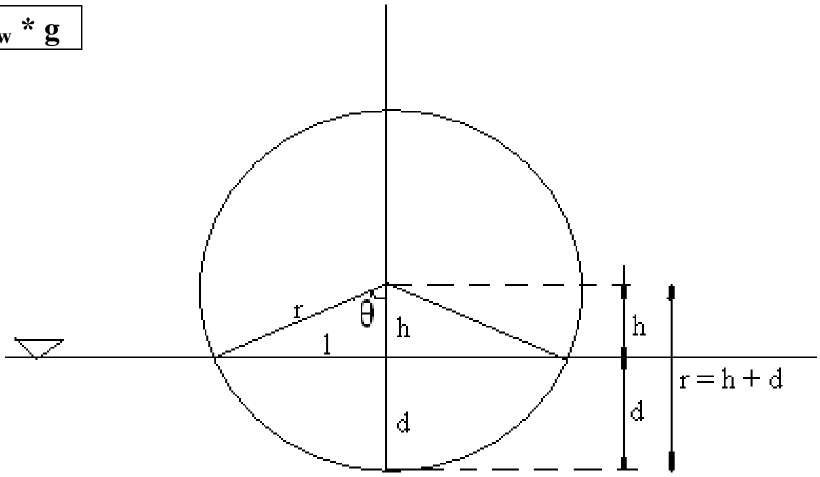
Model:
$\rho_w = 1025\ kg/m^3$
$D = 6{,}6\ m$
$r = 3{,}3\ m$
$L = 53\ m$

Formula:

$$\boxed{\mathbf{B = V_w * \rho_w * g = A_w(d) * L * \rho_w * g}}$$

B - Buoyancy force
V_w - Submerged volume
ρ_w - Water density
g - Gravity force
A_w - Submerged area
L - Length
d - Draft
D - Pipe diameter
r - Pipe radius

SQRT - square root



$A_w = A_{sector} \pm A_\Delta$

$A_{sector} = 2 * \theta/(2\Pi) * \Pi * r^2 = \theta * r^2$

$\theta = \arccos(h/r) = \arccos((r-d)/r) = \arccos (1 - d/r)$

$A_{sector} = r^2 * \arccos (1 - d/r)$

$A_\Delta = 2 * 0.5 * l * h = l * h$

$h = r - d$

$l = SQRT(r^2 - h^2) = ROT(r^2 - (r-d)^2) = ROT(2*r*d - d^2)$

$A_\Delta = SQRT (2*r^3*d - 5*r^2*d^2 + 4*r*d^3 - d^4) = SQRT (d* (2*r^3 - 5*r^2*d + 4*r*d^2 - d^3))$

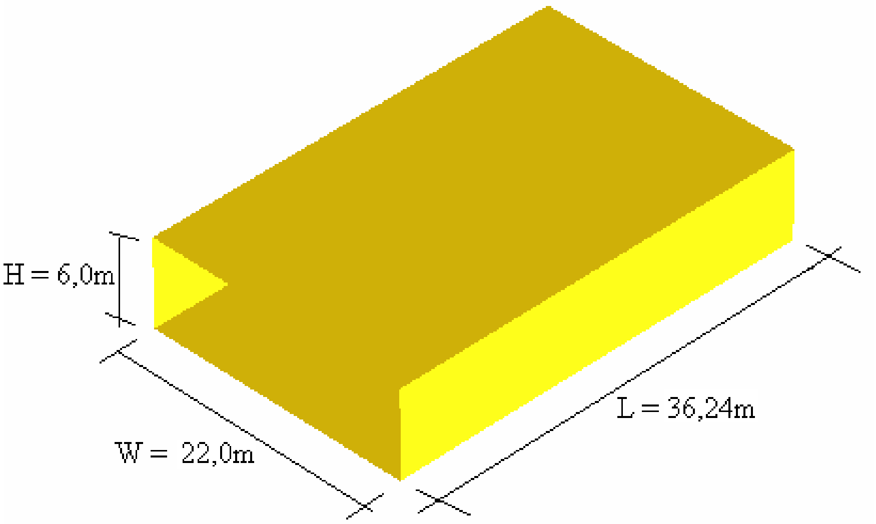
$A_w = A_{sector} \pm A_\Delta = r^2 * \arccos(1 - d/r) \pm ROT(d* (2*r^3 - 5*r^2*d + 4*r*d^2 - d^3))$

	Manual				USFOS	
Draft (m)	A_{sector}	A_Δ	A_w (m2)	B (MN)	B_{static} (MN)	$B_{dynamic}$ (MN) *
0	0,00	0,00	0,00	0,00	0	0,00
1	8,71	5,44	3,27	1,74	0	1,75
2	12,70	3,94	8,75	4,66	0	4,65
3	16,11	0,99	15,13	8,06	0	8,05
3,3	17,11	0,00	17,11	9,12	9,11	9,10
4	19,43	2,26	21,69	11,56	11,55	11,50
5	23,00	4,81	27,81	14,82	14,81	14,80
6	27,54	5,12	32,66	17,41	17,39	17,40
6,6	34,21	0,00	34,21	18,23	18,21	18,20

* Results from the dynamic analyses are read graphic

C.2.2 Buoyancy of a submerged box

A control has been carried out to check how Usfos calculates buoyancy forces for a dewatered box profile. A box section with same dimensions as the Purpose Made Barge (PMB) has been used in a dynamic analysis. The box is completely submerged and has maximum buoyancy (completely de-ballasted).



Model:
Height (H) = 6,00 m
Width (W) = 22,00 m
Thickness (t) = 0,03 m
Length (L) = 36,24 m

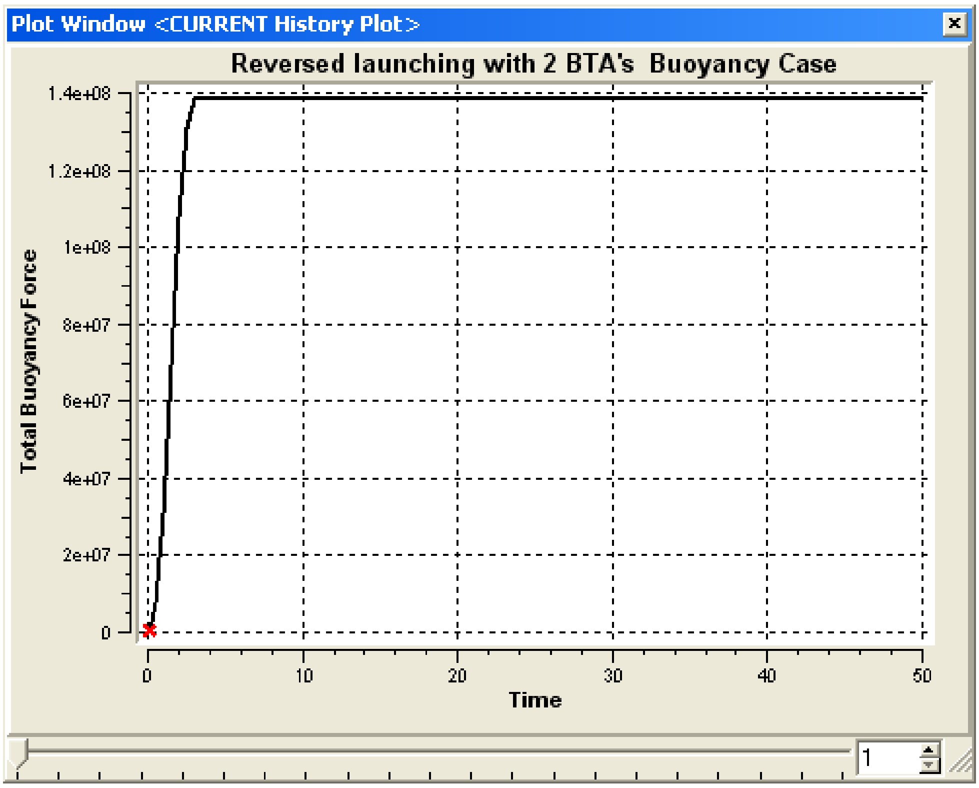
Formula:

$$\boxed{\mathbf{B = V_w * \rho_w * g}}$$

B - Buoyancy force
V_w - Submerged volume
ρ_w - Water density
g - Gravity force

Hand calculations:
$V_w = (H-2*t) * (W-2*t) * L = 4722{,}93 m^3$
$\rho_w = 1025 kg/m^3$
$\underline{B = 47{,}49 MN}$

Usfos' calculations:



Appendix figure C-1 Total buoyancy force calculated by Usfos

B_{usfos} = 139 MN

Usfos calculates the buoyancy force to be nearly 3 times higher than the buoyancy force calculated by hand.

Hand calculations to find maximum buoyancy for a fully submerged pipe with diameter 22m:

Formula:

$$\boxed{\mathbf{Bpipe = \Pi/4 * D2 * L * p_w * g}}$$

B_{pipe} = 138,5 MN

It seems like Usfos does not understand that the section is a box section and calculates it as it was a pipe with diameter 22 m instead. A correction factor must be used.

Correction factor: $c = B / B_{usfos}$

c = 0,342

D.2 Results from analyses

D.2.1 Heavy lift analysis, frame code check

All Runs: Member Result Brief

Description: Capacity Manager

Member	LoadCase	Position	Status	UfTot	Formula	GeomCheck	SubCheck	Run
LZ101070	LC101	0.48	OK	0.45	uf6_1	Geom OK	Norsok member	Cc3.run(1)
LZ901070	LC101	0.48	OK	0.44	uf6_1	Geom OK	Norsok member	Cc3.run(1)
LZ109070	LC101	0.48	OK	0.41	uf6_1	Geom OK	Norsok member	Cc3.run(1)
LZ909070	LC101	0.48	OK	0.40	uf6_1	Geom OK	Norsok member	Cc3.run(1)
BC101070	LC101	0.00	OK	0.36	uf6_27	Geom OK	Norsok member	Cc3.run(1)
BD801090	LC101	1.00	OK	0.34	uf6_27	Geom OK	Norsok member	Cc3.run(1)
BC109070	LC101	0.00	OK	0.33	uf6_27	Geom OK	Norsok member	Cc3.run(1)
BD809090	LC101	1.00	OK	0.32	uf6_27	Geom OK	Norsok member	Cc3.run(1)
BD801070	LC101	1.00	OK	0.29	uf6_27	Geom OK	Norsok member	Cc3.run(1)
BX101090	LC101	0.00	OK	0.28	uf6_26	Geom OK	Norsok member	Cc3.run(1)
BC101060	LC101	0.00	OK	0.28	uf6_27	Geom OK	Norsok member	Cc3.run(1)
BD809070	LC101	1.00	OK	0.27	uf6_27	Geom OK	Norsok member	Cc3.run(1)
BX109090	LC101	0.00	OK	0.26	uf6_26	Geom OK	Norsok member	Cc3.run(1)
BX101070	LC101	0.54	OK	0.26	uf6_1	Geom OK	Norsok member	Cc3.run(1)
BX801090	LC101	1.00	OK	0.25	uf6_26	Geom OK	Norsok member	Cc3.run(1)
BX301070	LC101	0.00	OK	0.25	uf6_1	Geom OK	Norsok member	Cc3.run(1)
BC109060	LC101	0.00	OK	0.25	uf6_27	Geom OK	Norsok member	Cc3.run(1)
BX809090	LC101	1.00	OK	0.24	uf6_26	Geom OK	Norsok member	Cc3.run(1)
BX801070	LC101	0.11	OK	0.24	uf6_1	Geom OK	Norsok member	Cc3.run(1)
BX401070	LC101	0.00	OK	0.24	uf6_1	Geom OK	Norsok member	Cc3.run(1)
BX501070	LC101	0.00	OK	0.24	uf6_1	Geom OK	Norsok member	Cc3.run(1)
BX109070	LC101	0.54	OK	0.23	uf6_1	Geom OK	Norsok member	Cc3.run(1)
BX309070	LC101	0.00	OK	0.23	uf6_1	Geom OK	Norsok member	Cc3.run(1)
BY101090	LC101	0.00	OK	0.22	uf6_26	Geom OK	Norsok member	Cc3.run(1)
BX809070	LC101	0.11	OK	0.22	uf6_1	Geom OK	Norsok member	Cc3.run(1)
LZ901060	LC101	0.30	OK	0.21	uf6_64	Geom OK	Norsok cone	Cc3.run(1)
BX409070	LC101	0.00	OK	0.21	uf6_1	Geom OK	Norsok member	Cc3.run(1)
BX509070	LC101	0.00	OK	0.21	uf6_1	Geom OK	Norsok member	Cc3.run(1)
LZ101060	LC101	0.30	OK	0.21	uf6_64	Geom OK	Norsok cone	Cc3.run(1)
BX701090	LC101	0.00	OK	0.21	uf6_27	Geom OK	Norsok member	Cc3.run(1)
BY107090	LC101	1.00	OK	0.21	uf6_26	Geom OK	Norsok member	Cc3.run(1)
BX106060	LC101	0.00	OK	0.21	uf6_26	Geom OK	Norsok member	Cc3.run(1)
LZ101090	LC101	1.00	OK	0.20	uf6_1	Geom OK	Norsok member	Cc3.run(1)
LZ909060	LC101	0.30	OK	0.20	uf6_64	Geom OK	Norsok cone	Cc3.run(1)
LZ109060	LC101	0.30	OK	0.20	uf6_64	Geom OK	Norsok cone	Cc3.run(1)
BA801060	LC101	0.00	OK	0.20	uf6_27	Geom OK	Norsok member	Cc3.run(1)
LZ901090	LC101	1.00	OK	0.20	uf6_1	Geom OK	Norsok member	Cc3.run(1)
BX104060	LC101	0.00	OK	0.20	uf6_26	Geom OK	Norsok member	Cc3.run(1)
BY901090	LC101	0.00	OK	0.19	uf6_26	Geom OK	Norsok member	Cc3.run(1)
BX709090	LC101	0.00	OK	0.19	uf6_27	Geom OK	Norsok member	Cc3.run(1)
BX801060	LC101	0.10	OK	0.19	uf6_1	Geom OK	Norsok member	Cc3.run(1)
LZ109090	LC101	1.00	OK	0.19	uf6_1	Geom OK	Norsok member	Cc3.run(1)
BY905090	LC101	1.00	OK	0.18	uf6_26	Geom OK	Norsok member	Cc3.run(1)
BX601090	LC101	0.19	OK	0.18	uf6_27	Geom OK	Norsok member	Cc3.run(1)
BX103090	LC101	0.00	OK	0.18	uf6_26	Geom OK	Norsok member	Cc3.run(1)
LZ909090	LC101	1.00	OK	0.18	uf6_1	Geom OK	Norsok member	Cc3.run(1)
BX107090	LC101	0.00	OK	0.17	uf6_26	Geom OK	Norsok member	Cc3.run(1)
BX103060	LC101	0.00	OK	0.17	uf6_26	Geom OK	Norsok member	Cc3.run(1)
BX101060	LC101	0.43	OK	0.17	uf6_1	Geom OK	Norsok member	Cc3.run(1)
BY103090	LC101	0.00	OK	0.17	uf6_26	Geom OK	Norsok member	Cc3.run(1)
BX609090	LC101	0.19	OK	0.17	uf6_27	Geom OK	Norsok member	Cc3.run(1)

Member	LoadCase	Position	Status	UfTot	Formula	GeomCheck	SubCheck	Run
BX809060	LC101	0.10	OK	0.17	uf6_1	Geom OK	Norsok member	Cc3.run(1)
BB809060	LC101	0.00	OK	0.17	uf6_27	Geom OK	Norsok member	Cc3.run(1)
BX107060	LC101	0.00	OK	0.16	uf6_26	Geom OK	Norsok member	Cc3.run(1)
BY106890	LC101	1.00	OK	0.16	uf6_26	Geom OK	Norsok member	Cc3.run(1)
LZ901060	LC101	0.86	OK	0.16	uf6_1	Geom OK	Norsok member	Cc3.run(1)
BX301060	LC101	0.00	OK	0.15	uf6_1	Geom OK	Norsok member	Cc3.run(1)
BX104090	LC101	0.00	OK	0.15	uf6_27	Geom OK	Norsok member	Cc3.run(1)
LZ101060	LC101	0.87	OK	0.15	uf6_1	Geom OK	Norsok member	Cc3.run(1)
BX109060	LC101	0.43	OK	0.15	uf6_1	Geom OK	Norsok member	Cc3.run(1)
BE901070	LC101	0.14	OK	0.15	uf6_27	Geom OK	Norsok member	Cc3.run(1)
BE101070	LC101	0.14	OK	0.15	uf6_27	Geom OK	Norsok member	Cc3.run(1)
LZ909060	LC101	0.86	OK	0.15	uf6_1	Geom OK	Norsok member	Cc3.run(1)
BX106090	LC101	0.00	OK	0.15	uf6_27	Geom OK	Norsok member	Cc3.run(1)
BB605060	LC101	0.00	OK	0.15	uf6_26	Geom OK	Norsok member	Cc3.run(1)
BF605090	LC101	0.86	OK	0.14	uf6_27	Geom OK	Norsok member	Cc3.run(1)
LZ109060	LC101	0.87	OK	0.14	uf6_1	Geom OK	Norsok member	Cc3.run(1)
BX309060	LC101	0.00	OK	0.14	uf6_1	Geom OK	Norsok member	Cc3.run(1)
BD601090	LC101	1.00	OK	0.14	uf6_27	Geom OK	Norsok member	Cc3.run(1)
BF805090	LC101	0.86	OK	0.14	uf6_27	Geom OK	Norsok member	Cc3.run(1)
BA605060	LC101	0.00	OK	0.14	uf6_26	Geom OK	Norsok member	Cc3.run(1)
BX605070	LC101	0.00	OK	0.14	uf6_26	Geom OK	Norsok member	Cc3.run(1)
BD609090	LC101	1.00	OK	0.13	uf6_27	Geom OK	Norsok member	Cc3.run(1)
BE601070	LC101	0.14	OK	0.13	uf6_27	Geom OK	Norsok member	Cc3.run(1)
BX103070	LC101	0.00	OK	0.13	uf6_26	Geom OK	Norsok member	Cc3.run(1)
BX805060	LC101	1.00	OK	0.13	uf6_26	Geom OK	Norsok member	Cc3.run(1)
BA701060	LC101	0.00	OK	0.13	uf6_27	Geom OK	Norsok member	Cc3.run(1)
BX504060	LC101	0.00	OK	0.13	uf6_27	Geom OK	Norsok member	Cc3.run(1)
BX605060	LC101	0.00	OK	0.13	uf6_26	Geom OK	Norsok member	Cc3.run(1)
BY105070	LC101	0.35	OK	0.13	uf6_27	Geom OK	Norsok member	Cc3.run(1)
BA301060	LC101	0.00	OK	0.13	uf6_26	Geom OK	Norsok member	Cc3.run(1)
BX701060	LC101	0.00	OK	0.13	uf6_1	Geom OK	Norsok member	Cc3.run(1)
BY604060	LC101	0.00	OK	0.13	uf6_27	Geom OK	Norsok member	Cc3.run(1)
BA801090	LC101	1.00	OK	0.12	uf6_26	Geom OK	Norsok member	Cc3.run(1)
BY104070	LC101	0.00	OK	0.12	uf6_27	Geom OK	Norsok member	Cc3.run(1)
BX107070	LC101	0.00	OK	0.12	uf6_26	Geom OK	Norsok member	Cc3.run(1)
BE801070	LC101	0.14	OK	0.12	uf6_27	Geom OK	Norsok member	Cc3.run(1)
BY301070	LC101	0.00	OK	0.12	uf6_26	Geom OK	Norsok member	Cc3.run(1)
BX601060	LC101	0.19	OK	0.12	uf6_1	Geom OK	Norsok member	Cc3.run(1)
LZ601065	LC101	0.73	OK	0.12	uf6_1	Geom OK	Norsok member	Cc3.run(1)
BY301060	LC101	0.00	OK	0.12	uf6_27	Geom OK	Norsok member	Cc3.run(1)
BB709060	LC101	0.00	OK	0.12	uf6_27	Geom OK	Norsok member	Cc3.run(1)
BA801070	LC101	0.00	OK	0.12	uf6_27	Geom OK	Norsok member	Cc3.run(1)
BA105060	LC101	0.00	OK	0.12	uf6_26	Geom OK	Norsok member	Cc3.run(1)
BX805090	LC101	0.00	OK	0.12	uf6_27	Geom OK	Norsok member	Cc3.run(1)
BY104060	LC101	0.00	OK	0.12	uf6_27	Geom OK	Norsok member	Cc3.run(1)
BB104060	LC101	0.00	OK	0.12	uf6_27	Geom OK	Norsok member	Cc3.run(1)
BA605070	LC101	0.00	OK	0.12	uf6_26	Geom OK	Norsok member	Cc3.run(1)
BB605070	LC101	0.00	OK	0.12	uf6_26	Geom OK	Norsok member	Cc3.run(1)
BY307070	LC101	1.00	OK	0.12	uf6_26	Geom OK	Norsok member	Cc3.run(1)
LZ801065	LC101	0.73	OK	0.12	uf6_1	Geom OK	Norsok member	Cc3.run(1)
BB809070	LC101	0.00	OK	0.12	uf6_27	Geom OK	Norsok member	Cc3.run(1)
BB809090	LC101	1.00	OK	0.12	uf6_26	Geom OK	Norsok member	Cc3.run(1)
BF105090	LC101	0.86	OK	0.12	uf6_27	Geom OK	Norsok member	Cc3.run(1)
BF905090	LC101	0.86	OK	0.12	uf6_27	Geom OK	Norsok member	Cc3.run(1)
BY103290	LC101	0.00	OK	0.12	uf6_26	Geom OK	Norsok member	Cc3.run(1)
BB309060	LC101	0.00	OK	0.12	uf6_26	Geom OK	Norsok member	Cc3.run(1)
BX709060	LC101	0.00	OK	0.12	uf6_1	Geom OK	Norsok member	Cc3.run(1)
BB503860	LC101	0.00	OK	0.11	uf6_27	Geom OK	Norsok member	Cc3.run(1)
LZ601070	LC101	0.48	OK	0.11	uf6_1	Geom OK	Norsok member	Cc3.run(1)
BX304060	LC101	0.87	OK	0.11	uf6_26	Geom OK	Norsok member	Cc3.run(1)
BX609060	LC101	0.19	OK	0.11	uf6_1	Geom OK	Norsok member	Cc3.run(1)
BY605060	LC101	0.71	OK	0.11	uf6_27	Geom OK	Norsok member	Cc3.run(1)
LZ601060	LC101	0.92	OK	0.11	uf6_1	Geom OK	Norsok member	Cc3.run(1)
BX106070	LC101	0.00	OK	0.11	uf6_27	Geom OK	Norsok member	Cc3.run(1)
BZ105070	LC101	0.06	OK	0.11	uf6_26	Geom OK	Norsok member	Cc3.run(1)

Member	LoadCase	Position	Status	UfTot	Formula	GeomCheck	SubCheck	Run
BY105060	LC101	0.65	OK	0.11	uf6_27	Geom OK	Norsok member	Cc3.run(1)
BX501090	LC101	0.95	OK	0.11	uf6_26	Geom OK	Norsok member	Cc3.run(1)
BY331090	LC101	0.00	OK	0.11	uf6_26	Geom OK	Norsok member	Cc3.run(1)
BY105090	LC101	0.69	OK	0.11	uf6_26	Geom OK	Norsok member	Cc3.run(1)
BY106090	LC101	0.00	OK	0.11	uf6_26	Geom OK	Norsok member	Cc3.run(1)
BX504070	LC101	0.00	OK	0.11	uf6_27	Geom OK	Norsok member	Cc3.run(1)
BY337090	LC101	1.00	OK	0.11	uf6_26	Geom OK	Norsok member	Cc3.run(1)
LZ801060	LC101	0.92	OK	0.11	uf6_1	Geom OK	Norsok member	Cc3.run(1)
BZ905070	LC101	0.06	OK	0.11	uf6_26	Geom OK	Norsok member	Cc3.run(1)
BY607060	LC101	0.00	OK	0.11	uf6_27	Geom OK	Norsok member	Cc3.run(1)
BX306060	LC101	0.80	OK	0.11	uf6_26	Geom OK	Norsok member	Cc3.run(1)
BX104070	LC101	0.00	OK	0.11	uf6_27	Geom OK	Norsok member	Cc3.run(1)
BX507060	LC101	1.00	OK	0.11	uf6_26	Geom OK	Norsok member	Cc3.run(1)
BX506060	LC101	0.00	OK	0.11	uf6_27	Geom OK	Norsok member	Cc3.run(1)
BY101070	LC101	0.48	OK	0.11	uf6_27	Geom OK	Norsok member	Cc3.run(1)
BA103290	LC101	0.00	OK	0.11	uf6_26	Geom OK	Norsok member	Cc3.run(1)
BY307060	LC101	0.00	OK	0.10	uf6_27	Geom OK	Norsok member	Cc3.run(1)
BA701070	LC101	0.00	OK	0.10	uf6_27	Geom OK	Norsok member	Cc3.run(1)
BY104090	LC101	0.31	OK	0.10	uf6_26	Geom OK	Norsok member	Cc3.run(1)
BY601070	LC101	0.48	OK	0.10	uf6_27	Geom OK	Norsok member	Cc3.run(1)
BY501070	LC101	0.00	OK	0.10	uf6_27	Geom OK	Norsok member	Cc3.run(1)
BB709070	LC101	0.00	OK	0.10	uf6_27	Geom OK	Norsok member	Cc3.run(1)
BX503060	LC101	1.00	OK	0.10	uf6_26	Geom OK	Norsok member	Cc3.run(1)
BY507070	LC101	0.00	OK	0.10	uf6_27	Geom OK	Norsok member	Cc3.run(1)
BY107070	LC101	0.00	OK	0.10	uf6_27	Geom OK	Norsok member	Cc3.run(1)
BB106890	LC101	0.00	OK	0.10	uf6_26	Geom OK	Norsok member	Cc3.run(1)
BX331090	LC101	0.00	OK	0.10	uf6_26	Geom OK	Norsok member	Cc3.run(1)
BB303070	LC101	0.00	OK	0.10	uf6_27	Geom OK	Norsok member	Cc3.run(1)
BX304070	LC101	0.00	OK	0.10	uf6_27	Geom OK	Norsok member	Cc3.run(1)
BA504060	LC101	1.00	OK	0.10	uf6_26	Geom OK	Norsok member	Cc3.run(1)
BY607070	LC101	0.00	OK	0.10	uf6_27	Geom OK	Norsok member	Cc3.run(1)
BY107060	LC101	0.00	OK	0.10	uf6_27	Geom OK	Norsok member	Cc3.run(1)
BX506070	LC101	0.00	OK	0.10	uf6_27	Geom OK	Norsok member	Cc3.run(1)
LZ609070	LC101	0.48	OK	0.10	uf6_1	Geom OK	Norsok member	Cc3.run(1)
BX701070	LC101	0.00	OK	0.10	uf6_27	Geom OK	Norsok member	Cc3.run(1)
BY101060	LC101	0.39	OK	0.10	uf6_27	Geom OK	Norsok member	Cc3.run(1)
BA507060	LC101	1.00	OK	0.10	uf6_26	Geom OK	Norsok member	Cc3.run(1)
BE805040	LC101	1.00	OK	0.10	uf6_26	Geom OK	Norsok member	Cc3.run(1)
BX805070	LC101	0.00	OK	0.10	uf6_26	Geom OK	Norsok member	Cc3.run(1)
BA106060	LC101	0.00	OK	0.10	uf6_27	Geom OK	Norsok member	Cc3.run(1)
BA103060	LC101	0.00	OK	0.10	uf6_26	Geom OK	Norsok member	Cc3.run(1)
BY601090	LC101	0.83	OK	0.10	uf6_27	Geom OK	Norsok member	Cc3.run(1)
LZ801070	LC101	0.48	OK	0.10	uf6_1	Geom OK	Norsok member	Cc3.run(1)
BB105060	LC101	0.00	OK	0.10	uf6_27	Geom OK	Norsok member	Cc3.run(1)
BB331090	LC101	0.00	OK	0.10	uf6_26	Geom OK	Norsok member	Cc3.run(1)
BE605040	LC101	1.00	OK	0.10	uf6_26	Geom OK	Norsok member	Cc3.run(1)
BX509090	LC101	0.84	OK	0.10	uf6_26	Geom OK	Norsok member	Cc3.run(1)
BX709070	LC101	0.00	OK	0.10	uf6_27	Geom OK	Norsok member	Cc3.run(1)
BX306070	LC101	0.00	OK	0.10	uf6_27	Geom OK	Norsok member	Cc3.run(1)
BY507090	LC101	1.00	OK	0.09	uf6_26	Geom OK	Norsok member	Cc3.run(1)
BA307070	LC101	0.00	OK	0.09	uf6_27	Geom OK	Norsok member	Cc3.run(1)
BB107060	LC101	0.00	OK	0.09	uf6_26	Geom OK	Norsok member	Cc3.run(1)
BB339090	LC101	0.00	OK	0.09	uf6_26	Geom OK	Norsok member	Cc3.run(1)
BX303060	LC101	0.88	OK	0.09	uf6_26	Geom OK	Norsok member	Cc3.run(1)
BA506560	LC101	0.00	OK	0.09	uf6_27	Geom OK	Norsok member	Cc3.run(1)
BX605090	LC101	0.00	OK	0.09	uf6_27	Geom OK	Norsok member	Cc3.run(1)
BB506060	LC101	1.00	OK	0.09	uf6_26	Geom OK	Norsok member	Cc3.run(1)
BX339090	LC101	0.00	OK	0.09	uf6_26	Geom OK	Norsok member	Cc3.run(1)
BX307060	LC101	0.86	OK	0.09	uf6_26	Geom OK	Norsok member	Cc3.run(1)
BY604070	LC101	0.00	OK	0.09	uf6_27	Geom OK	Norsok member	Cc3.run(1)
BY607090	LC101	0.00	OK	0.09	uf6_27	Geom OK	Norsok member	Cc3.run(1)
BB503060	LC101	1.00	OK	0.09	uf6_26	Geom OK	Norsok member	Cc3.run(1)
BA504070	LC101	1.00	OK	0.09	uf6_26	Geom OK	Norsok member	Cc3.run(1)
BY605070	LC101	0.67	OK	0.09	uf6_27	Geom OK	Norsok member	Cc3.run(1)
LZ609060	LC101	0.86	OK	0.09	uf6_1	Geom OK	Norsok member	Cc3.run(1)

Member	LoadCase	Position	Status	UfTot	Formula	GeomCheck	SubCheck	Run
BX601070	LC101	0.19	OK	0.09	uf6_27	Geom OK	Norsok member	Cc3.run(1)
BD801060	LC101	0.86	OK	0.09	uf6_27	Geom OK	Norsok member	Cc3.run(1)
BX609070	LC101	0.19	OK	0.09	uf6_27	Geom OK	Norsok member	Cc3.run(1)
LZ809060	LC101	0.86	OK	0.09	uf6_1	Geom OK	Norsok member	Cc3.run(1)
BA503860	LC101	1.00	OK	0.09	uf6_26	Geom OK	Norsok member	Cc3.run(1)
BD809060	LC101	0.86	OK	0.09	uf6_27	Geom OK	Norsok member	Cc3.run(1)
BY503090	LC101	0.00	OK	0.09	uf6_26	Geom OK	Norsok member	Cc3.run(1)
BB503870	LC101	0.00	OK	0.09	uf6_27	Geom OK	Norsok member	Cc3.run(1)
LZ809070	LC101	0.48	OK	0.09	uf6_1	Geom OK	Norsok member	Cc3.run(1)
BY501090	LC101	0.00	OK	0.09	uf6_27	Geom OK	Norsok member	Cc3.run(1)
BX503070	LC101	0.00	OK	0.09	uf6_26	Geom OK	Norsok member	Cc3.run(1)
BB506070	LC101	1.00	OK	0.09	uf6_26	Geom OK	Norsok member	Cc3.run(1)
BC101040	LC101	0.14	OK	0.08	uf6_27	Geom OK	Norsok member	Cc3.run(1)
BF901060	LC101	0.00	OK	0.08	uf6_26	Geom OK	Norsok member	Cc3.run(1)
BE905040	LC101	1.00	OK	0.08	uf6_26	Geom OK	Norsok member	Cc3.run(1)
BB503070	LC101	0.00	OK	0.08	uf6_1	Geom OK	Norsok member	Cc3.run(1)
BX354090	LC101	0.00	OK	0.08	uf6_27	Geom OK	Norsok member	Cc3.run(1)
BZ605070	LC101	0.48	OK	0.08	uf6_1	Geom OK	Norsok member	Cc3.run(1)
BD601070	LC101	0.00	OK	0.08	uf6_26	Geom OK	Norsok member	Cc3.run(1)
BA506570	LC101	0.00	OK	0.08	uf6_27	Geom OK	Norsok member	Cc3.run(1)
BF101060	LC101	0.00	OK	0.08	uf6_26	Geom OK	Norsok member	Cc3.run(1)
BA401070	LC101	0.00	OK	0.08	uf6_26	Geom OK	Norsok member	Cc3.run(1)
BC109040	LC101	0.14	OK	0.08	uf6_27	Geom OK	Norsok member	Cc3.run(1)
BX507070	LC101	0.00	OK	0.08	uf6_26	Geom OK	Norsok member	Cc3.run(1)
BE105040	LC101	1.00	OK	0.08	uf6_26	Geom OK	Norsok member	Cc3.run(1)
BX306090	LC101	0.00	OK	0.08	uf6_27	Geom OK	Norsok member	Cc3.run(1)
BD609070	LC101	0.00	OK	0.08	uf6_26	Geom OK	Norsok member	Cc3.run(1)
BY503070	LC101	1.00	OK	0.08	uf6_26	Geom OK	Norsok member	Cc3.run(1)
BY106070	LC101	0.00	OK	0.08	uf6_27	Geom OK	Norsok member	Cc3.run(1)
BY103070	LC101	0.00	OK	0.08	uf6_27	Geom OK	Norsok member	Cc3.run(1)
BB409070	LC101	0.00	OK	0.08	uf6_26	Geom OK	Norsok member	Cc3.run(1)
BB506560	LC101	1.00	OK	0.08	uf6_26	Geom OK	Norsok member	Cc3.run(1)
BA103070	LC101	0.00	OK	0.08	uf6_26	Geom OK	Norsok member	Cc3.run(1)
BY801060	LC101	0.00	OK	0.08	uf6_27	Geom OK	Norsok member	Cc3.run(1)
BX504090	LC101	0.00	OK	0.08	uf6_26	Geom OK	Norsok member	Cc3.run(1)
BY506590	LC101	1.00	OK	0.08	uf6_26	Geom OK	Norsok member	Cc3.run(1)
BY506570	LC101	0.00	OK	0.08	uf6_26	Geom OK	Norsok member	Cc3.run(1)
BB107070	LC101	0.00	OK	0.08	uf6_26	Geom OK	Norsok member	Cc3.run(1)
BY905060	LC101	0.11	OK	0.08	uf6_27	Geom OK	Norsok member	Cc3.run(1)
BY601060	LC101	0.00	OK	0.08	uf6_27	Geom OK	Norsok member	Cc3.run(1)
LZ809040	LC101	0.87	OK	0.08	uf6_26	Geom OK	Norsok member	Cc3.run(1)
BA507070	LC101	0.00	OK	0.08	uf6_1	Geom OK	Norsok member	Cc3.run(1)
BY901060	LC101	0.13	OK	0.08	uf6_27	Geom OK	Norsok member	Cc3.run(1)
BX303070	LC101	0.86	OK	0.07	uf6_26	Geom OK	Norsok member	Cc3.run(1)
BY801090	LC101	0.14	OK	0.07	uf6_27	Geom OK	Norsok member	Cc3.run(1)
BB709090	LC101	0.00	OK	0.07	uf6_27	Geom OK	Norsok member	Cc3.run(1)
BX453090	LC101	1.00	OK	0.07	uf6_26	Geom OK	Norsok member	Cc3.run(1)
BY805060	LC101	0.12	OK	0.07	uf6_27	Geom OK	Norsok member	Cc3.run(1)
BY905070	LC101	0.10	OK	0.07	uf6_27	Geom OK	Norsok member	Cc3.run(1)
BA605090	LC101	0.00	OK	0.07	uf6_26	Geom OK	Norsok member	Cc3.run(1)
BD601060	LC101	1.00	OK	0.07	uf6_27	Geom OK	Norsok member	Cc3.run(1)
BX307070	LC101	0.86	OK	0.07	uf6_26	Geom OK	Norsok member	Cc3.run(1)
BX506090	LC101	0.00	OK	0.07	uf6_27	Geom OK	Norsok member	Cc3.run(1)
BD609060	LC101	1.00	OK	0.07	uf6_27	Geom OK	Norsok member	Cc3.run(1)
BA503870	LC101	1.00	OK	0.07	uf6_26	Geom OK	Norsok member	Cc3.run(1)
BX457090	LC101	1.00	OK	0.07	uf6_26	Geom OK	Norsok member	Cc3.run(1)
BA105070	LC101	0.00	OK	0.07	uf6_27	Geom OK	Norsok member	Cc3.run(1)
BB506570	LC101	1.00	OK	0.07	uf6_26	Geom OK	Norsok member	Cc3.run(1)
BB605090	LC101	0.00	OK	0.07	uf6_26	Geom OK	Norsok member	Cc3.run(1)
BY901070	LC101	0.12	OK	0.07	uf6_27	Geom OK	Norsok member	Cc3.run(1)
BY503060	LC101	0.00	OK	0.07	uf6_1	Geom OK	Norsok member	Cc3.run(1)
BX333090	LC101	0.00	OK	0.07	uf6_26	Geom OK	Norsok member	Cc3.run(1)
BX304090	LC101	0.00	OK	0.07	uf6_27	Geom OK	Norsok member	Cc3.run(1)
BY303090	LC101	0.00	OK	0.07	uf6_26	Geom OK	Norsok member	Cc3.run(1)
BA701090	LC101	0.00	OK	0.07	uf6_27	Geom OK	Norsok member	Cc3.run(1)

Member	LoadCase	Position	Status	UfTot	Formula	GeomCheck	SubCheck	Run
BY805090	LC101	0.14	OK	0.07	uf6_27	Geom OK	Norsok member	Cc3.run(1)
LZ901040	LC101	0.40	OK	0.07	uf6_64	Geom OK	Norsok cone	Cc3.run(1)
BX503090	LC101	0.24	OK	0.06	uf6_26	Geom OK	Norsok member	Cc3.run(1)
BB105070	LC101	0.00	OK	0.06	uf6_27	Geom OK	Norsok member	Cc3.run(1)
LZ909040	LC101	0.40	OK	0.06	uf6_64	Geom OK	Norsok cone	Cc3.run(1)
BY306590	LC101	1.00	OK	0.06	uf6_26	Geom OK	Norsok member	Cc3.run(1)
LZ101040	LC101	0.40	OK	0.06	uf6_64	Geom OK	Norsok cone	Cc3.run(1)
BX337090	LC101	0.00	OK	0.06	uf6_26	Geom OK	Norsok member	Cc3.run(1)
BZ805070	LC101	0.48	OK	0.06	uf6_1	Geom OK	Norsok member	Cc3.run(1)
BX507090	LC101	0.19	OK	0.06	uf6_26	Geom OK	Norsok member	Cc3.run(1)
LZ109040	LC101	0.40	OK	0.06	uf6_64	Geom OK	Norsok cone	Cc3.run(1)
BY103060	LC101	0.00	OK	0.06	uf6_27	Geom OK	Norsok member	Cc3.run(1)
BY506560	LC101	0.00	OK	0.06	uf6_26	Geom OK	Norsok member	Cc3.run(1)
BY303060	LC101	0.00	OK	0.06	uf6_27	Geom OK	Norsok member	Cc3.run(1)
BB306060	LC101	0.00	OK	0.06	uf6_27	Geom OK	Norsok member	Cc3.run(1)
BY606060	LC101	0.00	OK	0.06	uf6_27	Geom OK	Norsok member	Cc3.run(1)
BF603550	LC101	1.00	OK	0.06	uf6_26	Geom OK	Norsok member	Cc3.run(1)
BE605060	LC101	1.00	OK	0.06	uf6_26	Geom OK	Norsok member	Cc3.run(1)
BB104070	LC101	0.00	OK	0.05	uf6_27	Geom OK	Norsok member	Cc3.run(1)
BY106060	LC101	0.00	OK	0.05	uf6_27	Geom OK	Norsok member	Cc3.run(1)
BF101070	LC101	0.90	OK	0.05	uf6_26	Geom OK	Norsok member	Cc3.run(1)
BY603060	LC101	0.00	OK	0.05	uf6_27	Geom OK	Norsok member	Cc3.run(1)
BF901070	LC101	0.90	OK	0.05	uf6_26	Geom OK	Norsok member	Cc3.run(1)
BB506090	LC101	0.00	OK	0.05	uf6_27	Geom OK	Norsok member	Cc3.run(1)
BA106070	LC101	0.00	OK	0.05	uf6_27	Geom OK	Norsok member	Cc3.run(1)
BY506070	LC101	1.00	OK	0.05	uf6_26	Geom OK	Norsok member	Cc3.run(1)
BE905060	LC101	0.10	OK	0.05	uf6_26	Geom OK	Norsok member	Cc3.run(1)
BA553990	LC101	0.00	OK	0.05	uf6_27	Geom OK	Norsok member	Cc3.run(1)
BE105060	LC101	0.10	OK	0.05	uf6_26	Geom OK	Norsok member	Cc3.run(1)
BY805070	LC101	0.13	OK	0.05	uf6_27	Geom OK	Norsok member	Cc3.run(1)
BY503870	LC101	0.00	OK	0.05	uf6_26	Geom OK	Norsok member	Cc3.run(1)
BY603070	LC101	0.00	OK	0.05	uf6_27	Geom OK	Norsok member	Cc3.run(1)
BE805060	LC101	1.00	OK	0.05	uf6_26	Geom OK	Norsok member	Cc3.run(1)
BY801070	LC101	0.12	OK	0.05	uf6_27	Geom OK	Norsok member	Cc3.run(1)
BA504090	LC101	0.00	OK	0.05	uf6_27	Geom OK	Norsok member	Cc3.run(1)
BB306070	LC101	0.50	OK	0.05	uf6_26	Geom OK	Norsok member	Cc3.run(1)
BF803550	LC101	1.00	OK	0.05	uf6_26	Geom OK	Norsok member	Cc3.run(1)
BA105090	LC101	0.00	OK	0.05	uf6_26	Geom OK	Norsok member	Cc3.run(1)
BB105090	LC101	0.00	OK	0.05	uf6_26	Geom OK	Norsok member	Cc3.run(1)
BY306090	LC101	0.00	OK	0.05	uf6_1	Geom OK	Norsok member	Cc3.run(1)
LZ801040	LC101	0.52	OK	0.05	uf6_26	Geom OK	Norsok member	Cc3.run(1)
BY606070	LC101	0.00	OK	0.05	uf6_27	Geom OK	Norsok member	Cc3.run(1)
BY305090	LC101	0.00	OK	0.05	uf6_26	Geom OK	Norsok member	Cc3.run(1)
BY506060	LC101	1.00	OK	0.05	uf6_26	Geom OK	Norsok member	Cc3.run(1)
BY303070	LC101	0.00	OK	0.05	uf6_27	Geom OK	Norsok member	Cc3.run(1)
BY503860	LC101	0.00	OK	0.05	uf6_26	Geom OK	Norsok member	Cc3.run(1)
BY306570	LC101	0.00	OK	0.05	uf6_27	Geom OK	Norsok member	Cc3.run(1)
BB503090	LC101	0.00	OK	0.05	uf6_1	Geom OK	Norsok member	Cc3.run(1)
BY604090	LC101	0.00	OK	0.05	uf6_27	Geom OK	Norsok member	Cc3.run(1)
BF601060	LC101	0.00	OK	0.05	uf6_26	Geom OK	Norsok member	Cc3.run(1)
LZ901040	LC101	1.00	OK	0.05	uf6_26	Geom OK	Norsok member	Cc3.run(1)
LZ909040	LC101	1.00	OK	0.05	uf6_26	Geom OK	Norsok member	Cc3.run(1)
BY603090	LC101	0.00	OK	0.04	uf6_27	Geom OK	Norsok member	Cc3.run(1)
LZ109040	LC101	1.00	OK	0.04	uf6_26	Geom OK	Norsok member	Cc3.run(1)
LZ101040	LC101	1.00	OK	0.04	uf6_26	Geom OK	Norsok member	Cc3.run(1)
BA503890	LC101	0.00	OK	0.04	uf6_27	Geom OK	Norsok member	Cc3.run(1)
BB553490	LC101	1.00	OK	0.04	uf6_26	Geom OK	Norsok member	Cc3.run(1)
BY303890	LC101	0.00	OK	0.04	uf6_1	Geom OK	Norsok member	Cc3.run(1)
BY605090	LC101	0.69	OK	0.04	uf6_27	Geom OK	Norsok member	Cc3.run(1)
BF601070	LC101	0.23	OK	0.04	uf6_1	Geom OK	Norsok member	Cc3.run(1)
BY304090	LC101	1.00	OK	0.04	uf6_26	Geom OK	Norsok member	Cc3.run(1)
LZ801050	LC101	0.74	OK	0.04	uf6_26	Geom OK	Norsok member	Cc3.run(1)
BA507090	LC101	0.00	OK	0.04	uf6_1	Geom OK	Norsok member	Cc3.run(1)
BB306090	LC101	0.00	OK	0.04	uf6_26	Geom OK	Norsok member	Cc3.run(1)
BF801060	LC101	0.00	OK	0.04	uf6_26	Geom OK	Norsok member	Cc3.run(1)

Member	LoadCase	Position	Status	UfTot	Formula	GeomCheck	SubCheck	Run
BY601065	LC101	0.00	OK	0.04	uf6_27	Geom OK	Norsok member	Cc3.run(1)
BY304060	LC101	0.00	OK	0.04	uf6_26	Geom OK	Norsok member	Cc3.run(1)
BY306560	LC101	0.00	OK	0.04	uf6_27	Geom OK	Norsok member	Cc3.run(1)
BY503890	LC101	0.00	OK	0.04	uf6_26	Geom OK	Norsok member	Cc3.run(1)
BY606090	LC101	0.00	OK	0.04	uf6_27	Geom OK	Norsok member	Cc3.run(1)
BY801065	LC101	0.00	OK	0.04	uf6_27	Geom OK	Norsok member	Cc3.run(1)
LZ601050	LC101	0.74	OK	0.04	uf6_26	Geom OK	Norsok member	Cc3.run(1)
BE601060	LC101	1.00	OK	0.04	uf6_26	Geom OK	Norsok member	Cc3.run(1)
BF801070	LC101	0.23	OK	0.03	uf6_1	Geom OK	Norsok member	Cc3.run(1)
BY504060	LC101	0.00	OK	0.03	uf6_27	Geom OK	Norsok member	Cc3.run(1)
BB415090	LC101	0.22	OK	0.03	uf6_26	Geom OK	Norsok member	Cc3.run(1)
BY504070	LC101	1.00	OK	0.03	uf6_26	Geom OK	Norsok member	Cc3.run(1)
BA457090	LC101	0.00	OK	0.03	uf6_27	Geom OK	Norsok member	Cc3.run(1)
BY304070	LC101	0.00	OK	0.03	uf6_26	Geom OK	Norsok member	Cc3.run(1)
BY506090	LC101	0.97	OK	0.03	uf6_26	Geom OK	Norsok member	Cc3.run(1)
LZ801045	LC101	0.15	OK	0.03	uf6_26	Geom OK	Norsok member	Cc3.run(1)
BE801060	LC101	1.00	OK	0.03	uf6_26	Geom OK	Norsok member	Cc3.run(1)
LZ609040	LC101	0.87	OK	0.03	uf6_26	Geom OK	Norsok member	Cc3.run(1)
BB506590	LC101	0.00	OK	0.03	uf6_27	Geom OK	Norsok member	Cc3.run(1)
BY504090	LC101	0.00	OK	0.03	uf6_1	Geom OK	Norsok member	Cc3.run(1)
BY601050	LC101	0.00	OK	0.03	uf6_27	Geom OK	Norsok member	Cc3.run(1)
BY303860	LC101	1.00	OK	0.03	uf6_26	Geom OK	Norsok member	Cc3.run(1)
BX355090	LC101	0.00	OK	0.03	uf6_27	Geom OK	Norsok member	Cc3.run(1)
BY801050	LC101	0.00	OK	0.03	uf6_27	Geom OK	Norsok member	Cc3.run(1)
BY303870	LC101	0.15	OK	0.03	uf6_26	Geom OK	Norsok member	Cc3.run(1)
BA506590	LC101	1.00	OK	0.03	uf6_26	Geom OK	Norsok member	Cc3.run(1)
BY354090	LC101	1.00	OK	0.03	uf6_26	Geom OK	Norsok member	Cc3.run(1)
BY306070	LC101	0.85	OK	0.03	uf6_26	Geom OK	Norsok member	Cc3.run(1)
BY306060	LC101	0.00	OK	0.03	uf6_26	Geom OK	Norsok member	Cc3.run(1)
BA415090	LC101	0.00	OK	0.03	uf6_27	Geom OK	Norsok member	Cc3.run(1)
BB503890	LC101	1.00	OK	0.03	uf6_26	Geom OK	Norsok member	Cc3.run(1)
BB104090	LC101	1.00	OK	0.03	uf6_26	Geom OK	Norsok member	Cc3.run(1)
BA106090	LC101	0.00	OK	0.02	uf6_27	Geom OK	Norsok member	Cc3.run(1)
BF603765	LC101	0.07	OK	0.02	uf6_1	Geom OK	Norsok member	Cc3.run(1)
BA453090	LC101	0.00	OK	0.02	uf6_27	Geom OK	Norsok member	Cc3.run(1)
BF803765	LC101	0.83	OK	0.02	uf6_26	Geom OK	Norsok member	Cc3.run(1)
BX305090	LC101	0.00	OK	0.02	uf6_27	Geom OK	Norsok member	Cc3.run(1)
BY553490	LC101	0.59	OK	0.02	uf6_26	Geom OK	Norsok member	Cc3.run(1)
BE801945	LC101	0.00	OK	0.02	uf6_26	Geom OK	Norsok member	Cc3.run(1)
BE601945	LC101	0.79	OK	0.02	uf6_26	Geom OK	Norsok member	Cc3.run(1)
BE801040	LC101	0.00	OK	0.01	uf6_27	Geom OK	Norsok member	Cc3.run(1)
BF801050	LC101	0.00	OK	0.01	uf6_1	Geom OK	Norsok member	Cc3.run(1)
LZ601045	LC101	0.63	OK	0.01	uf6_1	Geom OK	Norsok member	Cc3.run(1)
BF601050	LC101	0.00	OK	0.01	uf6_1	Geom OK	Norsok member	Cc3.run(1)
BE601040	LC101	0.00	OK	0.01	uf6_27	Geom OK	Norsok member	Cc3.run(1)
BY801045	LC101	1.00	OK	0.01	uf6_27	Geom OK	Norsok member	Cc3.run(1)
LZ601040	LC101	0.86	OK	0.01	uf6_1	Geom OK	Norsok member	Cc3.run(1)
BY601045	LC101	0.00	OK	0.01	uf6_26	Geom OK	Norsok member	Cc3.run(1)
LZ601090	LC101	0.00	OK	0.00	uf6_27	Geom OK	Norsok member	Cc3.run(1)
LZ801090	LC101	0.00	OK	0.00	uf6_27	Geom OK	Norsok member	Cc3.run(1)
LZ809090	LC101	0.00	OK	0.00	uf6_27	Geom OK	Norsok member	Cc3.run(1)
LZ609090	C101	0.00	OK	0.00	uf6_27	Geom OK	Norsok member	Cc3.run(1)

All Runs: Joint Result Brief

Joint	Load Case	Member	Status	UfTot	Formula	GeomCheck	SubCheck	Run	JointType
J503070	LC101	BY503070	OK	0.67	uf6_57	Geom OK	Norsok joint	Cc3.run(2)	100% X
J507070	LC101	BY506570	OK	0.60	uf6_57	Geom OK	Norsok joint	Cc3.run(2)	100% X
J103090	LC101	BX103090	OK	0.56	uf6_57	Geom OK	Norsok joint	Cc3.run(2)	100% YT
J503060	LC101	BY503060	OK	0.54	uf6_57	Geom OK	Norsok joint	Cc3.run(2)	100% X
J104090	LC101	BX104090	OK	0.54	uf6_57	Geom OK	Norsok joint	Cc3.run(2)	90% YT, 10% K
J503090	LC101	BY503090	OK	0.54	uf6_57	Geom OK	Norsok joint	Cc3.run(2)	77% X, 23% YT
J507090	LC101	BY506590	OK	0.52	uf6_57	Geom OK	Norsok joint	Cc3.run(2)	80% X, 20% YT
J106090	LC101	BX106090	OK	0.51	uf6_57	Geom OK	Norsok joint	Cc3.run(2)	100% YT
J107090	LC101	BX107090	OK	0.50	uf6_57	Geom OK	Norsok joint	Cc3.run(2)	100% YT
J303090	LC101	BY303090	OK	0.50	uf6_57	Geom OK	Norsok joint	Cc3.run(2)	100% YT
J306090	LC101	BY306090	OK	0.48	uf6_57	Geom OK	Norsok joint	Cc3.run(2)	100% X
J303060	LC101	BY301060	OK	0.48	uf6_57	Geom OK	Norsok joint	Cc3.run(2)	87% X, 13% YT
J307090	LC101	BY306590	OK	0.44	uf6_57	Geom OK	Norsok joint	Cc3.run(2)	100% YT
J304090	LC101	BY303890	OK	0.43	uf6_57	Geom OK	Norsok joint	Cc3.run(2)	100% X
J106060	LC101	BX106060	OK	0.42	uf6_57	Geom OK	Norsok joint	Cc3.run(2)	100% K
J104060	LC101	BX104060	OK	0.42	uf6_57	Geom OK	Norsok joint	Cc3.run(2)	100% K
J103070	LC101	BX103070	OK	0.42	uf6_57	Geom OK	Norsok joint	Cc3.run(2)	100% YT
J507060	LC101	BY506560	OK	0.42	uf6_57	Geom OK	Norsok joint	Cc3.run(2)	100% X
J107070	LC101	BX107070	OK	0.39	uf6_57	Geom OK	Norsok joint	Cc3.run(2)	100% YT
J106070	LC101	BX106070	OK	0.38	uf6_57	Geom OK	Norsok joint	Cc3.run(2)	100% YT
J101060	LC101	BX101060	OK	0.37	uf6_57	Geom OK	Norsok joint	Cc3.run(2)	100% K
J104070	LC101	BX104070	OK	0.36	uf6_57	Geom OK	Norsok joint	Cc3.run(2)	100% YT
J501070	LC101	BY501070	OK	0.36	uf6_57	Geom OK	Norsok joint	Cc3.run(2)	100% YT
J331090	LC101	BY331090	OK	0.36	uf6_57	Geom OK	Norsok joint	Cc3.run(2)	100% YT
J604070	LC101	BX504070	OK	0.36	uf6_57	Geom OK	Norsok joint	Cc3.run(2)	100% K
J509070	LC101	BY507070	OK	0.36	uf6_57	Geom OK	Norsok joint	Cc3.run(2)	100% YT
J107060	LC101	BX107060	OK	0.35	uf6_57	Geom OK	Norsok joint	Cc3.run(2)	100% YT
J504070	LC101	BY503870	OK	0.35	uf6_57	Geom OK	Norsok joint	Cc3.run(2)	96% X, 4% YT
J103060	LC101	BX103060	OK	0.35	uf6_57	Geom OK	Norsok joint	Cc3.run(2)	100% YT
J601090	LC101	BX601090	OK	0.34	uf6_57	Geom OK	Norsok joint	Cc3.run(2)	100% X
J301070	LC101	BY301070	OK	0.34	uf6_57	Geom OK	Norsok joint	Cc3.run(2)	100% YT
J809060	LC101	BX809060	OK	0.34	uf6_57	Geom OK	Norsok joint	Cc3.run(2)	85% X, 15% YT
J506070	LC101	BY506070	OK	0.34	uf6_57	Geom OK	Norsok joint	Cc3.run(2)	96% X, 4% YT
J606070	LC101	BX506070	OK	0.33	uf6_57	Geom OK	Norsok joint	Cc3.run(2)	100% K
J901060	LC101	BX801060	OK	0.33	uf6_57	Geom OK	Norsok joint	Cc3.run(2)	100% K
J307060	LC101	BY307060	OK	0.33	uf6_57	Geom OK	Norsok joint	Cc3.run(2)	73% X, 27% YT
J339090	LC101	BY337090	OK	0.33	uf6_57	Geom OK	Norsok joint	Cc3.run(2)	100% YT
J309070	LC101	BY307070	OK	0.33	uf6_57	Geom OK	Norsok joint	Cc3.run(2)	100% YT
J609090	LC101	BC109070	OK	0.32	uf6_57	Geom OK	Norsok joint	Cc3.run(2)	100% YT
J801090	LC101	BD801090	OK	0.32	uf6_57	Geom OK	Norsok joint	Cc3.run(2)	100% YT
J109060	LC101	BX109060	OK	0.32	uf6_57	Geom OK	Norsok joint	Cc3.run(2)	100% K
J801070	LC101	BD801070	OK	0.31	uf6_57	Geom OK	Norsok joint	Cc3.run(2)	100% YT
J401070	LC101	BA401070	OK	0.31	uf6_57	Geom OK	Norsok joint	Cc3.run(2)	61% K, 39% YT
J801060	LC101	BX701060	OK	0.30	uf6_57	Geom OK	Norsok joint	Cc3.run(2)	100% X
J809090	LC101	BX709090	OK	0.30	uf6_57	Geom OK	Norsok joint	Cc3.run(2)	99% X, 1% YT
J504090	LC101	BY503890	OK	0.30	uf6_57	Geom OK	Norsok joint	Cc3.run(2)	98% X, 2% YT
J303070	LC101	BB303070	OK	0.29	uf6_57	Geom OK	Norsok joint	Cc3.run(2)	39% X, 34% YT, 27% K

Joint	Load Case	Member	Status	UfTot	Formula	GeomCheck	SubCheck	Run	JointType
J601060	LC101	BX301060	OK	0.29	uf6_57	Geom OK	Norsok joint	Cc3.run(2)	99% X, 1% YT
J909060	LC101	BX809060	OK	0.29	uf6_57	Geom OK	Norsok joint	Cc3.run(2)	100% K
J609060	LC101	BX609060	OK	0.29	uf6_57	Geom OK	Norsok joint	Cc3.run(2)	100% X
J409070	LC101	BB409070	OK	0.29	uf6_57	Geom OK	Norsok joint	Cc3.run(2)	60% K, 40% YT
J509090	LC101	BY507090	OK	0.29	uf6_57	Geom OK	Norsok joint	Cc3.run(2)	100% K
J501090	LC101	BY501090	OK	0.28	uf6_57	Geom OK	Norsok joint	Cc3.run(2)	100% YT
J307070	LC101	BA307070	OK	0.27	uf6_57	Geom OK	Norsok joint	Cc3.run(2)	38% X, 36% YT, 26% K
J304060	LC101	BY304060	OK	0.27	uf6_57	Geom OK	Norsok joint	Cc3.run(2)	96% X, 4% K
J101070	LC101	BX101070	OK	0.27	uf6_57	Geom OK	Norsok joint	Cc3.run(2)	100% K
J506060	LC101	BY506060	OK	0.26	uf6_57	Geom OK	Norsok joint	Cc3.run(2)	86% X, 14% YT
J504060	LC101	BY503860	OK	0.26	uf6_57	Geom OK	Norsok joint	Cc3.run(2)	83% X, 17% YT
J604060	LC101	BX504060	OK	0.25	uf6_57	Geom OK	Norsok joint	Cc3.run(2)	100% K
J109070	LC101	BX109070	OK	0.24	uf6_57	Geom OK	Norsok joint	Cc3.run(2)	100% K
J603060	LC101	BX503060	OK	0.23	uf6_57	Geom OK	Norsok joint	Cc3.run(2)	71% K, 29% YT
J607070	LC101	BX507070	OK	0.23	uf6_57	Geom OK	Norsok joint	Cc3.run(2)	52% YT, 48% K
J603070	LC101	BX503070	OK	0.23	uf6_57	Geom OK	Norsok joint	Cc3.run(2)	51% YT, 49% K
J506090	LC101	BY504090	OK	0.22	uf6_57	Geom OK	Norsok joint	Cc3.run(2)	88% X, 12% KTT
J607060	LC101	BX507060	OK	0.22	uf6_57	Geom OK	Norsok joint	Cc3.run(2)	67% K, 33% YT
J301060	LC101	BY301060	OK	0.22	uf6_57	Geom OK	Norsok joint	Cc3.run(2)	100% K
J606060	LC101	BX506060	OK	0.22	uf6_57	Geom OK	Norsok joint	Cc3.run(2)	100% K
J901070	LC101	BX801070	OK	0.21	uf6_57	Geom OK	Norsok joint	Cc3.run(2)	100% K
J309060	LC101	BY307060	OK	0.20	uf6_57	Geom OK	Norsok joint	Cc3.run(2)	100% K
J909070	LC101	BX809070	OK	0.19	uf6_57	Geom OK	Norsok joint	Cc3.run(2)	100% K
J606090	LC101	BX506090	OK	0.19	uf6_57	Geom OK	Norsok joint	Cc3.run(2)	100% YT
J106890	LC101	BB106890	OK	0.19	uf6_57	Geom OK	Norsok joint	Cc3.run(2)	100% YT
J304070	LC101	BY304070	OK	0.19	uf6_57	Geom OK	Norsok joint	Cc3.run(2)	98% X, 2% K
J101090	LC101	BX101090	OK	0.19	uf6_57	Geom OK	Norsok joint	Cc3.run(2)	100% YT
J905090	LC101	BA801090	OK	0.18	uf6_57	Geom OK	Norsok joint	Cc3.run(2)	100% KTK
J306060	LC101	BY306060	OK	0.18	uf6_57	Geom OK	Norsok joint	Cc3.run(2)	100% X
J103290	LC101	BA103290	OK	0.18	uf6_57	Geom OK	Norsok joint	Cc3.run(2)	100% YT
J109090	LC101	BX109090	OK	0.18	uf6_57	Geom OK	Norsok joint	Cc3.run(2)	100% YT
J604090	LC101	BX504090	OK	0.16	uf6_57	Geom OK	Norsok joint	Cc3.run(2)	100% K
J901090	LC101	BX801090	OK	0.16	uf6_57	Geom OK	Norsok joint	Cc3.run(2)	100% YT
J805090	LC101	BX605090	OK	0.16	uf6_57	Geom OK	Norsok joint	Cc3.run(2)	100% X
J105070	LC101	BZ105070	OK	0.15	uf6_57	Geom OK	Norsok joint	Cc3.run(2)	100% YT
J105090	LC101	BZ105070	OK	0.15	uf6_57mod	Geom OK	Norsok joint	Cc3.run(2)	100% KTK
J605070	LC101	BX605070	OK	0.15	uf6_57	Geom OK	Norsok joint	Cc3.run(2)	82% X, 18% YT
J909090	LC101	BX809090	OK	0.15	uf6_57	Geom OK	Norsok joint	Cc3.run(2)	100% YT
J905070	LC101	BZ905070	OK	0.14	uf6_57	Geom OK	Norsok joint	Cc3.run(2)	100% YT
J905060	LC101	BA801060	OK	0.14	uf6_57	Geom OK	Norsok joint	Cc3.run(2)	100% KTK
J503860	LC101	BA503860	OK	0.14	uf6_57	Geom OK	Norsok joint	Cc3.run(2)	100% K
J607090	LC101	BX507090	OK	0.13	uf6_57	Geom OK	Norsok joint	Cc3.run(2)	100% YT
J601070	LC101	BX501070	OK	0.12	uf6_57	Geom OK	Norsok joint	Cc3.run(2)	100% K
J603090	LC101	BB553490	OK	0.12	uf6_57	Geom OK	Norsok joint	Cc3.run(2)	100% YT
J333090	LC101	BY331090	OK	0.12	uf6_57	Geom OK	Norsok joint	Cc3.run(2)	100% YT
J503870	LC101	BA503870	OK	0.12	uf6_57	Geom OK	Norsok joint	Cc3.run(2)	99% K, 1% YT

Joint	Load Case	Member	Status	UfTot	Formula	GeomCheck	SubCheck	Run	JointType
J809070	LC101	BD809070	OK	0.12	uf6_57	Geom OK	Norsok joint	Cc3.run(2)	91% K, 9% X
J306070	LC101	BY304070	OK	0.11	uf6_57	Geom OK	Norsok joint	Cc3.run(2)	96% X, 4% KTT
J609070	LC101	BX509070	OK	0.11	uf6_57	Geom OK	Norsok joint	Cc3.run(2)	100% K
J506570	LC101	BB506570	OK	0.10	uf6_57	Geom OK	Norsok joint	Cc3.run(2)	99% K, 1% YT
J805070	LC101	BX605070	OK	0.10	uf6_57	Geom OK	Norsok joint	Cc3.run(2)	62% KTT, 32% X, 6% YT
J457090	LC101	BB339090	OK	0.10	uf6_57	Geom OK	Norsok joint	Cc3.run(2)	51% K, 49% YT
J506560	LC101	BB506560	OK	0.10	uf6_57	Geom OK	Norsok joint	Cc3.run(2)	100% K
J605090	LC101	BX605090	OK	0.10	uf6_57	Geom OK	Norsok joint	Cc3.run(2)	100% YT
J709060	LC101	BB709060	OK	0.10	uf6_57	Geom OK	Norsok joint	Cc3.run(2)	86% K, 14% YT
J805060	LC101	BX605060	Failed(geo)	0.09	uf6_57	gamma	Norsok joint	Cc3.run(2)	75% X, 17% KTT, 8% YT
J354090	LC101	BY354090	OK	0.09	uf6_57	Geom OK	Norsok joint	Cc3.run(2)	100% YT
J701070	LC101	BA701070	OK	0.08	uf6_57	Geom OK	Norsok joint	Cc3.run(2)	61% K, 39% YT
J303860	LC101	BB104060	OK	0.08	uf6_57	Geom OK	Norsok joint	Cc3.run(2)	100% K
J701090	LC101	BA701090	OK	0.08	uf6_57	Geom OK	Norsok joint	Cc3.run(2)	70% YT, 30% K
J709070	LC101	BB709070	OK	0.08	uf6_57	Geom OK	Norsok joint	Cc3.run(2)	64% K, 36% YT
J701060	LC101	BA701060	OK	0.08	uf6_57	Geom OK	Norsok joint	Cc3.run(2)	100% K
J605060	LC101	BX605060	Failed(geo)	0.08	uf6_57	gamma	Norsok joint	Cc3.run(2)	100% YT
J337090	LC101	BY337090	OK	0.08	uf6_57	Geom OK	Norsok joint	Cc3.run(2)	100% YT
J503890	LC101	BA503890	OK	0.07	uf6_57	Geom OK	Norsok joint	Cc3.run(2)	100% K
J306570	LC101	BA106070	OK	0.07	uf6_57	Geom OK	Norsok joint	Cc3.run(2)	100% K
J303870	LC101	BB104070	OK	0.07	uf6_57	Geom OK	Norsok joint	Cc3.run(2)	100% K
J355090	LC101	BY354090	OK	0.07	uf6_57	Geom OK	Norsok joint	Cc3.run(2)	100% YT
J453090	LC101	BB331090	OK	0.07	uf6_57	Geom OK	Norsok joint	Cc3.run(2)	74% YT, 26% K
J709090	LC101	BB709090	OK	0.07	uf6_57	Geom OK	Norsok joint	Cc3.run(2)	63% YT, 37% K
J306560	LC101	BA106060	OK	0.06	uf6_57	Geom OK	Norsok joint	Cc3.run(2)	99% K, 1% YT
J105060	LC101	BF101070	OK	0.06	uf6_57	Geom OK	Norsok joint	Cc3.run(2)	100% K
J415090	LC101	BA415090	OK	0.06	uf6_57	Geom OK	Norsok joint	Cc3.run(2)	100% X
J901040	LC101	BD801060	OK	0.05	uf6_57	Geom OK	Norsok joint	Cc3.run(2)	100% YT
J909040	LC101	BD809060	OK	0.05	uf6_57	Geom OK	Norsok joint	Cc3.run(2)	100% YT
J101040	LC101	BC101040	OK	0.05	uf6_57	Geom OK	Norsok joint	Cc3.run(2)	100% YT
J601065	LC101	BY601065	OK	0.05	uf6_57	Geom OK	Norsok joint	Cc3.run(2)	100% YT
J801065	LC101	BY801065	OK	0.05	uf6_57	Geom OK	Norsok joint	Cc3.run(2)	100% YT
J109040	LC101	BC109040	OK	0.05	uf6_57	Geom OK	Norsok joint	Cc3.run(2)	100% YT
J506590	LC101	BB506590	OK	0.05	uf6_57	Geom OK	Norsok joint	Cc3.run(2)	100% K
J305090	LC101	BX305090	OK	0.04	uf6_57	Geom OK	Norsok joint	Cc3.run(2)	100% YT
J306590	LC101	BB106890	OK	0.04	uf6_57	Geom OK	Norsok joint	Cc3.run(2)	53% YT, 47% K
J601050	LC101	BY601050	OK	0.03	uf6_57	Geom OK	Norsok joint	Cc3.run(2)	68% YT, 32% K

Joint	Load Case	Member	Status	UfTot	Formula	GeomCheck	SubCheck	Run	JointType
J801945	LC101	BF801050	OK	0.03	uf6_57	Geom OK	Norsok joint	Cc3.run(2)	95% YT, 5% K
J801050	LC101	BY801050	OK	0.02	uf6_57	Geom OK	Norsok joint	Cc3.run(2)	55% YT, 45% K
J303890	LC101	BA103290	OK	0.02	uf6_57	Geom OK	Norsok joint	Cc3.run(2)	100% YT
J105040	LC101	BF101060	OK	0.02	uf6_57	Geom OK	Norsok joint	Cc3.run(2)	100% YT
J553990	LC101	BY553490	OK	0.02	uf6_57	Geom OK	Norsok joint	Cc3.run(2)	100% YT
J905040	LC101	BF901060	OK	0.02	uf6_57	Geom OK	Norsok joint	Cc3.run(2)	100% YT
J603765	LC101	BY601065	OK	0.02	uf6_57	Geom OK	Norsok joint	Cc3.run(2)	63% YT, 37% K
J603550	LC101	BY601050	OK	0.02	uf6_57	Geom OK	Norsok joint	Cc3.run(2)	64% K, 36% YT
J803550	LC101	BY801050	OK	0.02	uf6_57	Geom OK	Norsok joint	Cc3.run(2)	51% YT, 49% K
J809040	LC101	BD609060	OK	0.02	uf6_57	Geom OK	Norsok joint	Cc3.run(2)	100% YT
J801040	LC101	BD601060	OK	0.01	uf6_57	Geom OK	Norsok joint	Cc3.run(2)	100% YT
J601945	LC101	BF601050	OK	0.01	uf6_57	Geom OK	Norsok joint	Cc3.run(2)	100% YT
J803765	LC101	BY801065	OK	0.01	uf6_57	Geom OK	Norsok joint	Cc3.run(2)	73% YT, 27% K
J805040	LC101	BF803550	Failed(geo)	0.01	uf6_57	gamma	Norsok joint	Cc3.run(2)	100% YT
J605040	LC101	BF603550	Failed(geo)	0.01	uf6_57	gamma	Norsok joint	Cc3.run(2)	100% YT
J601045	LC101	BY601045	OK	0.01	uf6_57	Geom OK	Norsok joint	Cc3.run(2)	100% YT
J801045	LC101	BY801045	OK	0.00	uf6_57	Geom OK	Norsok joint	Cc3.run(2)	100% YT
J601040	LC101	BE601040	OK	0.00	uf6_57	Geom OK	Norsok joint	Cc3.run(2)	100% YT
J553490	LC101	BY553490	OK	0.00	uf6_57	Geom OK	Norsok joint	Cc3.run(2)	100% YT

D.2.2 Analysis of vertical split removal method, results from Usfos

```
          --- U S F O S   A N A L Y S I S   S T A T U S ---

                     Version 8-4 / Release 08-04-01
                             U s f o s  A/S

          Vertical split of jacket,short side, with 4 BTA's  Buoyancy Case
                Usfos Simulation
                AkerSolutions 2011

                           Input files:
                                         P:\Shared\Analysegruppe\Master
oppgaver\Master_SA_ UIS_2011\Usfos\Input filer til rapport\Vertical Split\Vertical
split\4SJ_removedSleeves.dyn.head.fem
                                         P:\Shared\Analysegruppe\Master
oppgaver\Master_SA_ UIS_2011\Usfos\Input filer til rapport\Vertical Split\Vertical
split\res_removedSleeves_ufo.fem
                                         P:\Shared\Analysegruppe\Master
oppgaver\Master_SA_ UIS_2011\Usfos\Input filer til rapport\Vertical Split\Vertical
split\4SJ_removedSleeves_opt.fem


    Number of nodal points               :                      1849
    Number of elements                   :                      2135

                                                                     Time
    First yield, (elasto-plastic hinge) at:                         346.000
    First fully developed plastic hinge at:                         345.000
    First buckling at                    :                          349.500
    Ecceeding utilization threshold of   :     1.10 at :            351.000
    No negative pivot element detected
    Max number of new hinges in one step  :       10 at :           347.500
    Analysis terminated at               :                          400.000

                --    Yielding Status (hinge introduced)   --


    Elem ID  Position   Cross sect.                                  Time
                        utilization
     1681     node 2       0.73                                     346.000
     1536      mid         0.79                                     346.500
      744      mid         0.60                                     347.000
     1847     node 1       0.91                                     349.000
     1181     node 1       1.01                                     349.500
     1476     node 2       0.78                                     349.500
     1165     node 1       1.02                                     350.000
      476      mid         0.83                                     350.500
     1202     node 2       1.05                                     350.500
     1047      mid         0.88                                     351.500

                --    Plastic hinge Status (fully developed) --


    Elem ID  Position   Cross sect.                                  Time
                        utilization
     1836     node 1       1.00                                     345.000
      167     node 1       1.00                                     349.500
     1181     node 2       1.00                                     349.500
     1202     node 1       1.00                                     349.500
     1165     node 1       1.08                                     351.000
     1661     node 1       1.00                                     352.000
       89     node 1       1.00                                     352.500
     1681      mid         1.07                                     353.000
      596     node 2       1.00                                     355.000
```

```
   743     node 1       1.00                                        355.000

                 --    Buckling Status    --


  Elem ID   Member     Buckling  P/P_eul  N/    My/   Mz/            Time
            Length     k_factor           Np    Myp   Mzp
   1511      19.675      2.23      20%  0.21  0.91  0.02            349.500
    701      10.186      1.41      50%  0.64  0.44  0.03            351.000
   1564      28.162      2.88      12%  0.24  0.06  0.65            352.000
   1879      28.642      3.19      10%  0.24  0.06  0.60            356.000
   1881      28.642      4.54       5%  0.12  0.08  0.57            356.000

                 -- Elements Ecceeding utilization of   1.10  --


  Elem ID  Position   Cross sect.                                    Time
                      utilization
   1381     node 1      1.15                                        351.000
   1165     node 2      1.11                                        351.500
   1181     node 1      1.10                                        351.500
   1202      mid        1.11                                        351.500
   1646     node 2      1.12                                        354.000
   1661     node 1      1.12                                        354.000
   1681     node 2      1.12                                        354.000
   1628     node 2      1.10                                        357.500


        ----- E N D   A N A L Y S I S   S T A T U S -----
```

A check has been performed to control how USFOS software program calculate buoyancy forces

D.2.3 Analysis of reversed launching removal method, results from Usfos

```
         --- U S F O S   A N A L Y S I S   S T A T U S ---

                     Version 8-4 / Release 08-04-01
                             U s f o s  A/S

           Reversed launching with 2 BTA's  Buoyancy Case
                  Usfos Simulation
                 AkerSolutions 2011

                         Input files:
                                        P:\Shared\Analysegruppe\Master
oppgaver\Master_SA_ UIS_2011\Usfos\Reversed
launching\BTAandPMBbelow58deg_PMB36.24m\RL_bargeBuo_head_dyn.fem
                                        P:\Shared\Analysegruppe\Master
oppgaver\Master_SA_ UIS_2011\Usfos\Reversed
launching\BTAandPMBbelow58deg_PMB36.24m\res58deg_PMB36.24x22x6_ufo.fem
                                        P:\Shared\Analysegruppe\Master
oppgaver\Master_SA_ UIS_2011\Usfos\Reversed
launching\BTAandPMBbelow58deg_PMB36.24m\RL_bargeBuo_opt.fem


    Number of nodal points              :                      1653
    Number of elements                  :                      2040

                                                                   Time
    First yield, (elasto-plastic hinge) at:                          2.500
    First fully developed plastic hinge at:                          4.500
    No buckling detected
    Utilization threshold of :  1.10 not ecceded
    No negative pivot element detected
    Max number of new hinges in one step  :       5 at :             3.000
    Analysis terminated at              :                          400.000

                --    Yielding Status (hinge introduced)   --


    Elem ID  Position   Cross sect.                                Time
                        utilization
     1477     node 2       0.75                                      2.500
     1514     node 2       0.77                                      2.500
     1378     node 1       0.80                                      3.500
     1499     node 2       0.84                                      3.500
     1365     node 1       0.87                                      4.500
     1401     node 1       0.87                                      4.500
     1416     node 2       0.76                                      4.500
     1462     node 1       0.74                                      4.500
     1500     node 1       0.95                                      4.500
     1300     node 1       0.78                                      5.500

                --    Plastic hinge Status (fully developed) --


    Elem ID  Position   Cross sect.                                Time
                        utilization
     1378     node 2       1.00                                      4.500
     1499     node 1       1.00                                      4.500


         ----- E N D   A N A L Y S I S   S T A T U S -----
```