Concept development, floating bridge
E39 Bjørnafjorden

Appendix N – Enclosure 1

10205546-13-NOT-185
Finite element analysis of locking joint

MEMO

PROJECT	Concept development, floating bridge E39 Bjørnafjorden	DOCUMENT CODE	10205546-13-NOT-185
CLIENT	Statens vegvesen	ACCESSIBILITY	Restricted
SUBJECT	Finite element analysis of locking joint	PROJECT MANAGER	Svein Erik Jakobsen
TO	Statens vegvesen	PREPARED BY	Espen Tuveng
COPY TO		RESPONSIBLE UNIT	AMC

SUMMARY

This memo summarizes the finite element analysis performed on a local model of a locking joint proposed to be used during the assembly of the bridge on Bjørnafjorden. The locking joint will fix two ends of the bridge girder close together so that the ends can be welded. During assembly there will be dynamic global forces going through the bridge girder. The locking joint is able to transfer the forces between the two ends and at the same time restrain the skin plate ends from displacing much over the small gap between the two girder ends. Observed stress and strain in the first weld beads that are applied are acceptable.

The locking joint can by making small geometrical changes be tuned so that the stress and strain for the weld between the two bridge girder ends is at a specified level for a given dynamic load.

0	15.08.2019	Final issue	E. Tuveng	P. N. Larsen	S. E. Jakobsen
REV.	DATE	DESCRIPTION	PREPARED BY	CHECKED BY	APPROVED BY

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1 Introduction

The purpose of this analysis is to check the locking joint to be used during the assembly of the bridge on Bjørnafjorden. During assembly there will be dynamic global forces going through the bridge girder. The locking joint must transfer the forces between the two ends and at the same time fix the skin plate ends with a set distance between them so that they can be welded.

2 FEM model

The modelled part has dimensions of the top plate of a S1 cross-section. The top plate location is chosen for this analysis since it is furthest away from the horizontal neutral axis of the bridge girder. This leads to the maximum stress transferred through the locking joint when applying a weak axis bending moment.

The local model of the locking joint consists of a 600 mm wide part of the outer skin with trapezoidal stiffener of the bridge girder. This is based on a center distance between trapezoidal stiffeners of 600 mm. Symmetry conditions are used to simulate that the locking joint detail has been added along the whole circumference of the bridge girder. To ensure an even stress distribution from the skin plate and trapezoidal stiffener to the locking joint, the total length of the FE model is 1500 mm. Only half of the locking joint is modelled. A symmetry plane in the middle between the two joining bridge girder sections have been used.

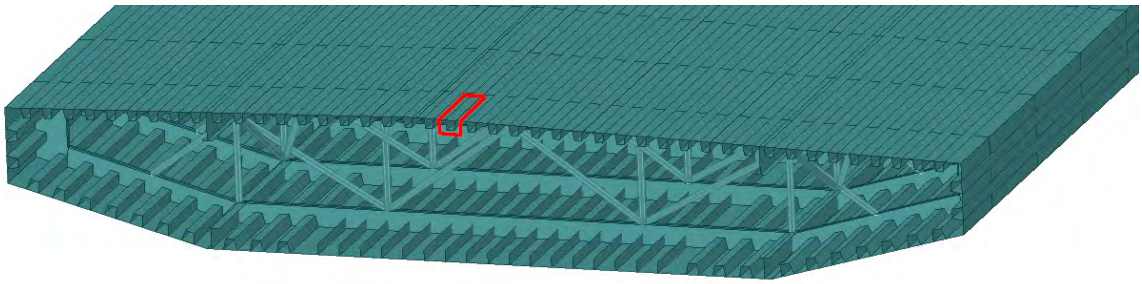


Figure 2-1 Part selected for local model

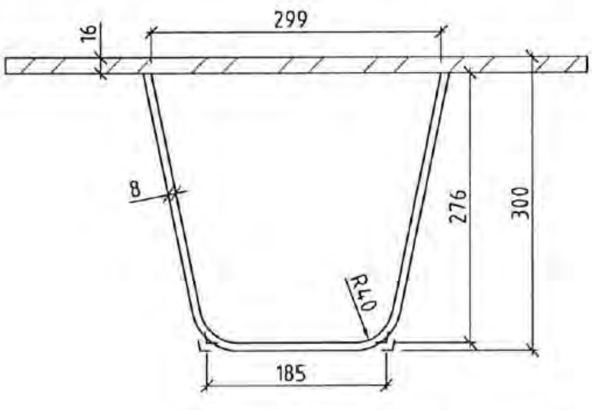


Figure 2-2 Local model dimensions

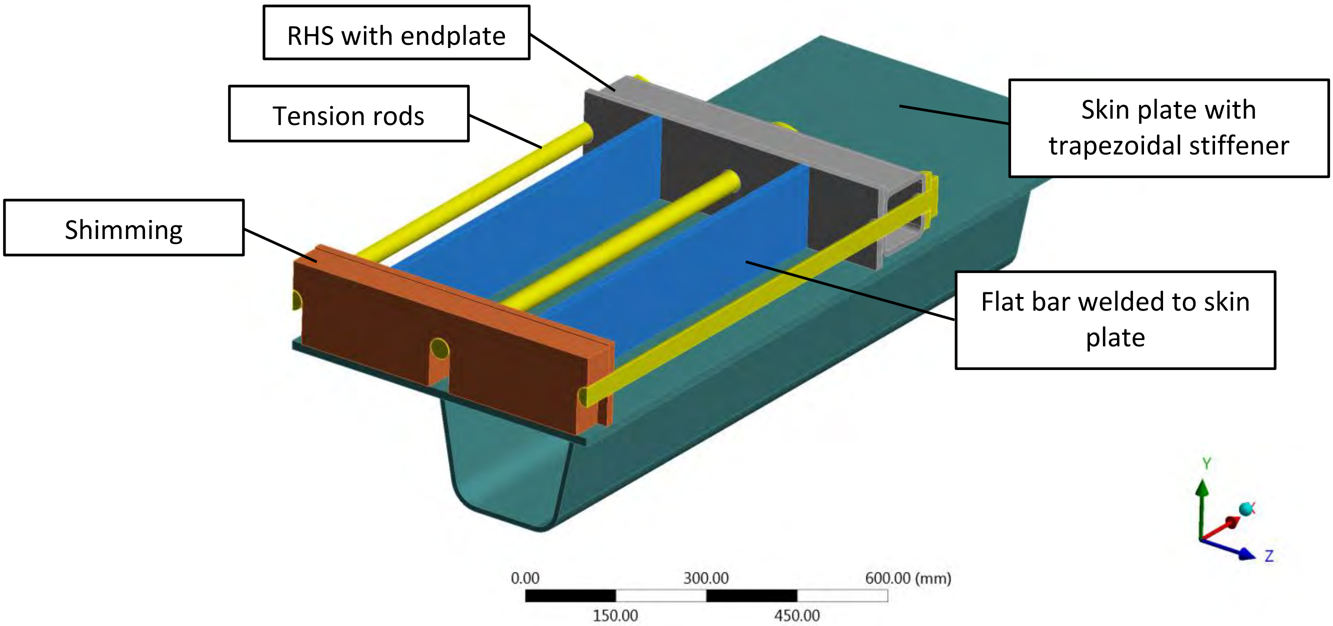


Figure 2-3 Local model, ISO view

The locking joint consists of shimming plates that are 150 mm thick and 150 mm high. For this symmetric FEM, the modelled shimming plates are 75 mm thick.
Flat bars are 750 mm long, 150 mm high and 15 mm thick. The flat bars are welded to the bridge girder skin plates with fillet welds.
Tension rods have a diameter of 36 mm.
The RHS has dimensions 120 x 120 x 10 mm.

A gap of 5 mm between the girder ends is assumed. Due to the symmetry in the local model, the modelled gap is 2.5 mm. See Figure 2-4.

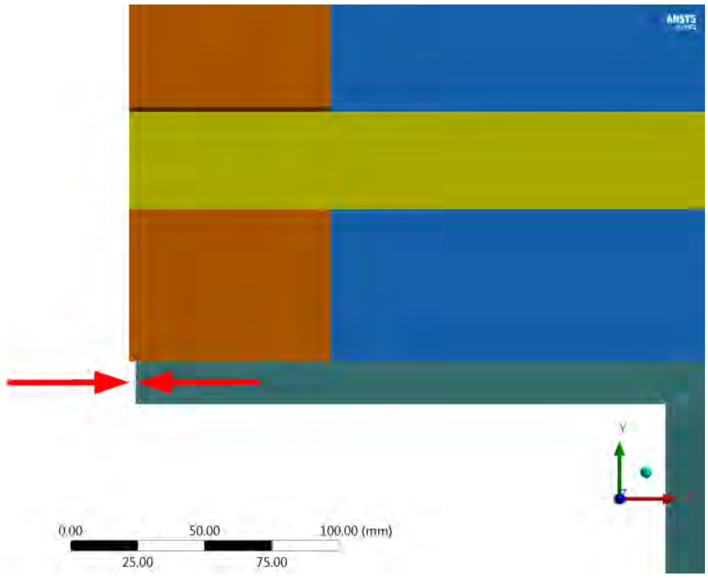


Figure 2-4 Modelled gap

2.1 Weld

A weld is introduced stepwise to evaluate how the behavior of a partially welded connection will be. For this analysis, the following steps are run:

- 3 mm throat thickness, 100 mm long weld. Results presented in section 4.2.
- 3 mm throat thickness, full width of weld. Results presented in section 4.3.
- 6 mm throat thickness, full width of weld. Results presented in section 4.4.

The purpose is to show that as the weld is built, the stress and strain in the weld is acceptable throughout the assembly. And also that the forces from dynamic weak axis bending moments are transferred more and more from the locking joint and to the weld.

An additional analysis with 3 mm throat thickness and 100 mm length is run with increased thickness of the flat bars. See section 4.5. This is done to show that small geometrical changes to the locking joint can increase the stiffness and reduce the stress and strain in the weld.

2.2 Symmetry

Symmetry conditions are shown on Figure 2-5 and Figure 2-6.

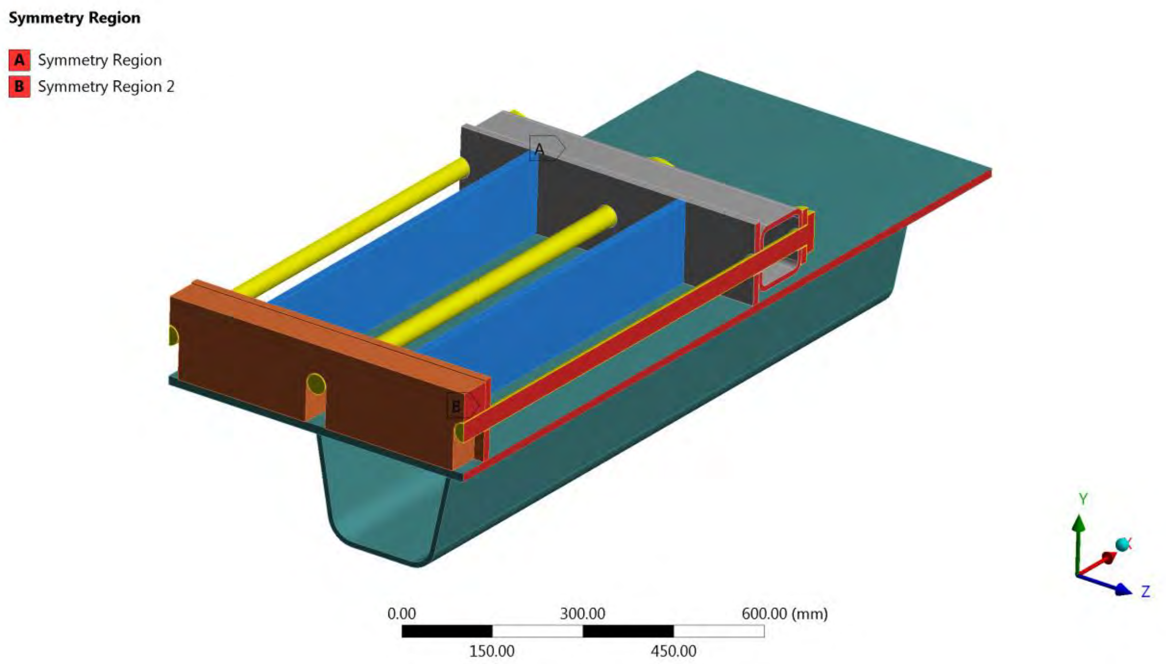


Figure 2-5 Symmetry along sides

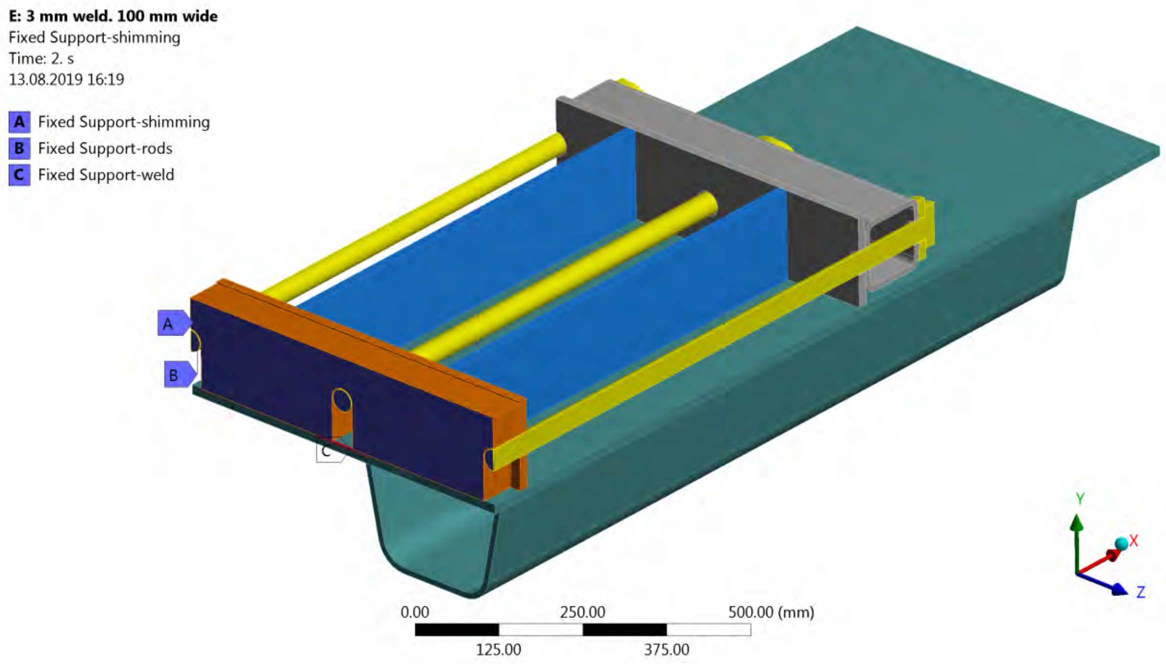


Figure 2-6 Symmetry at mid-plane between two joining beam girder sections

2.3 Mesh

The FE model is meshed with 3D solid elements with midside nodes (quadratic).The element mesh size is approximately 15 mm by 15 mm. Refinements have been made where the flatbars touch the shimming plates, and near the modelled weld. The mesh size here is approximately 3 mm by 3 mm. The mesh and refinements can be seen on the following figures.

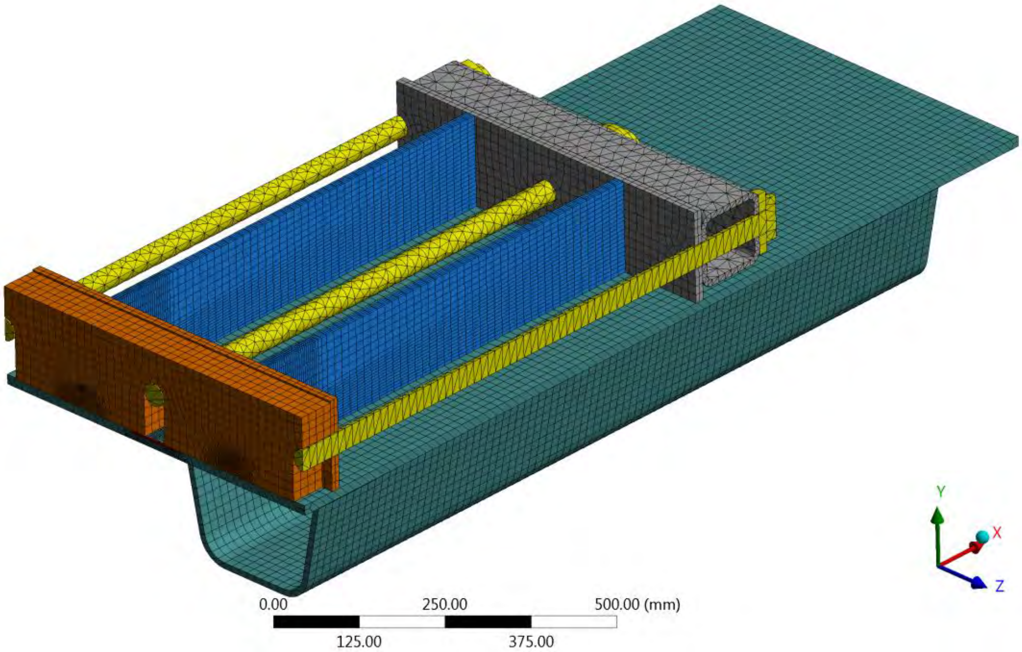


Figure 2-7 Element mesh

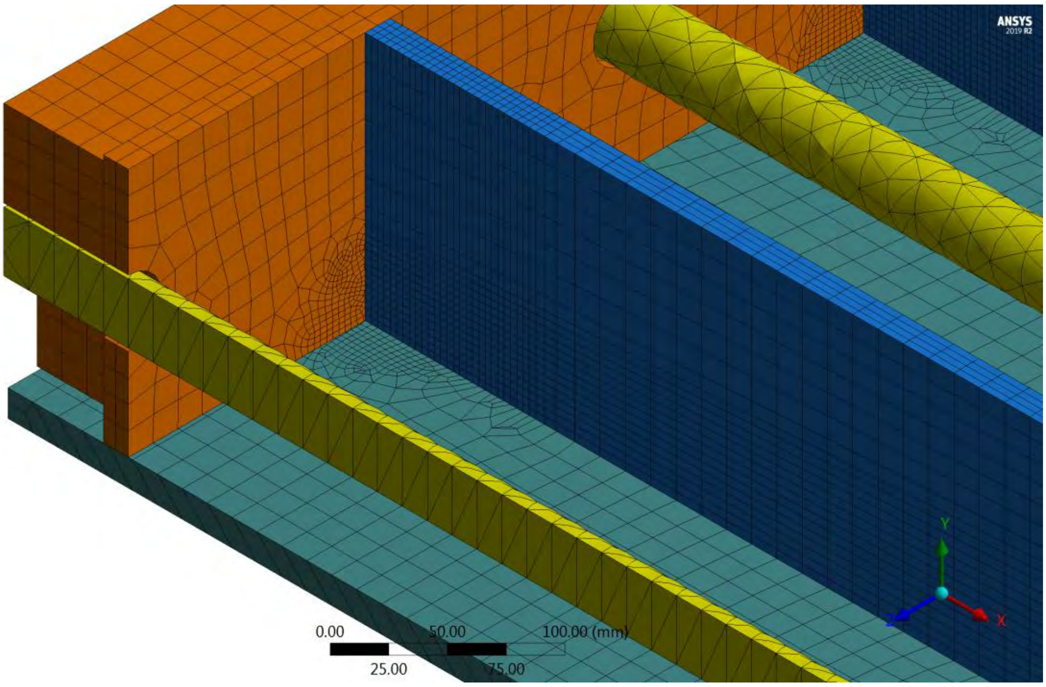


Figure 2-8 Mesh refinement near shim plates

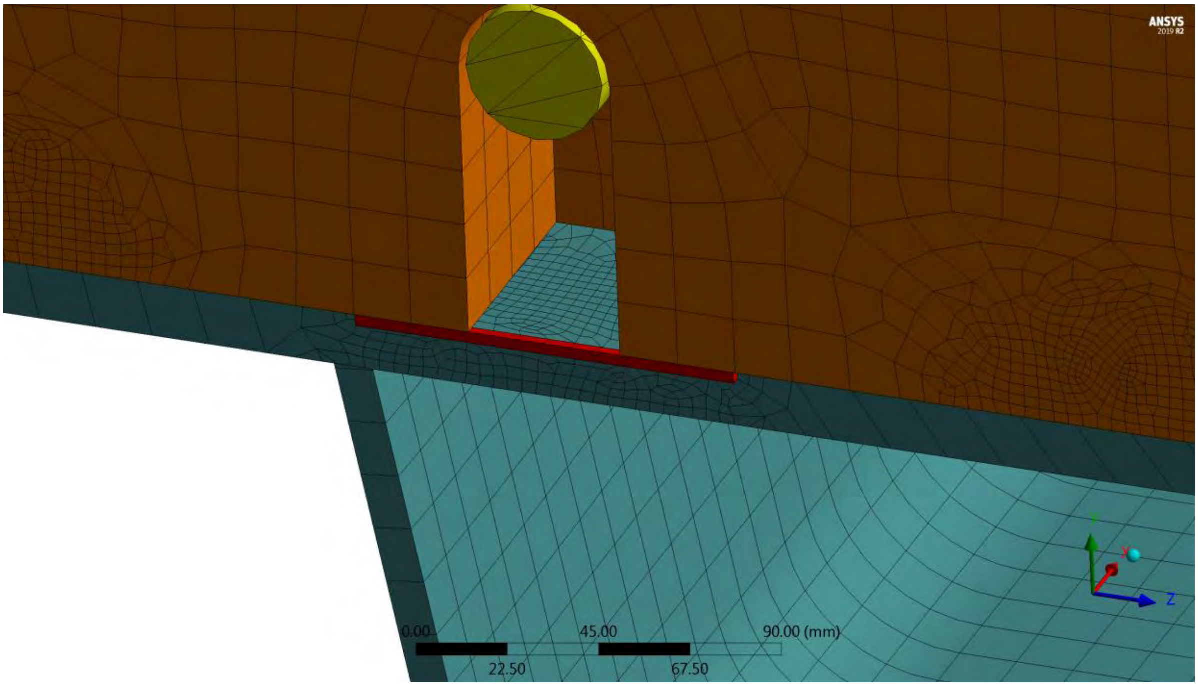


Figure 2-9 Mesh refinement near modelled weld

2.4 Material properties

Linear material has been utilized.

Table 2-1 Linear material properties

Property	Value
Modulus of elasticity	E = 210 000 MPa
Poison ratio	$\nu = 0.3$
Density	ρ= 7850 kg/m^3

2.5 Coordinate system

The global coordinate system is defined as follows:

Table 2-2 Coordinate system definition

Axis	Direction
X	North / South
Y	Up
Z	East / West

3 Loads and boundary conditions

3.1 Loads

Bridge girder weak axis dynamic moment creates the maximum stress for the local model. A weak axis moment of 14 MNm has been used as specified in Appendix N, table 10.3 (Analysis results for 0.5m Hs and 8m/s wind conditions).

Static model and section properties

<u>S1 section properties:</u>

Area moment of inertia:

$I_{y.S1} := 4.821\ m^4$

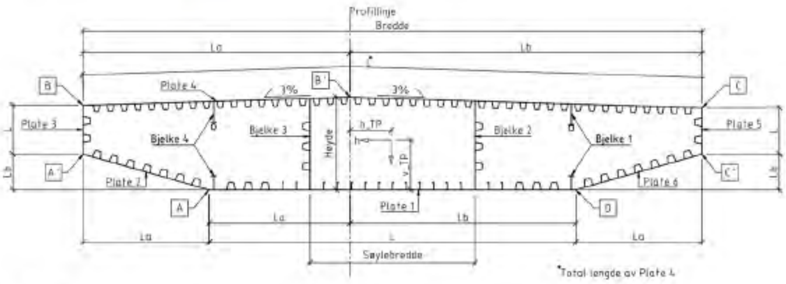
Neutral axis from UK bottom plate: $z_{0.S1} := 1.959\ m$

Distance from neutral axis:

$$\text{Point} \begin{bmatrix} A \\ B \\ B` \end{bmatrix} z_{S1} := \begin{bmatrix} 0 \\ 3.672 \\ 4.022 \end{bmatrix} m - z_{0.S1} = \begin{bmatrix} -1.959 \\ 1.713 \\ 2.063 \end{bmatrix} m$$

Calculated bending resistance (full section, no reductions):

$$W_{S1} := \frac{I_{y.S1}}{z_{S1}} = \begin{bmatrix} -2.461 \\ 2.814 \\ 2.337 \end{bmatrix} m^3$$



Calculated stress

Weak axis moment: $M_w := 14\ MNm$

Calculated stress at point A, B and B\`:

$$\text{Point} \begin{bmatrix} A \\ B \\ B` \end{bmatrix} \sigma := \frac{M_w}{W_{S1}} = \begin{bmatrix} -5.689 \\ 4.974 \\ 5.991 \end{bmatrix} MPa$$

Calculated force to apply to FEM

FEM section area: $A_{FEM} := 17306.4\ mm^2$

$$\text{Force: } F_{FEM} := \sigma \cdot A_{FEM} = \begin{bmatrix} -98454 \\ 86090 \\ 103680 \end{bmatrix} N$$

Point B' is furthest from the girder neutral axis and will experience highest stress from a weak axis bending. The force is applied in two steps:

1. Fx = 103.68 kN
2. Fx = - 103.68 kN

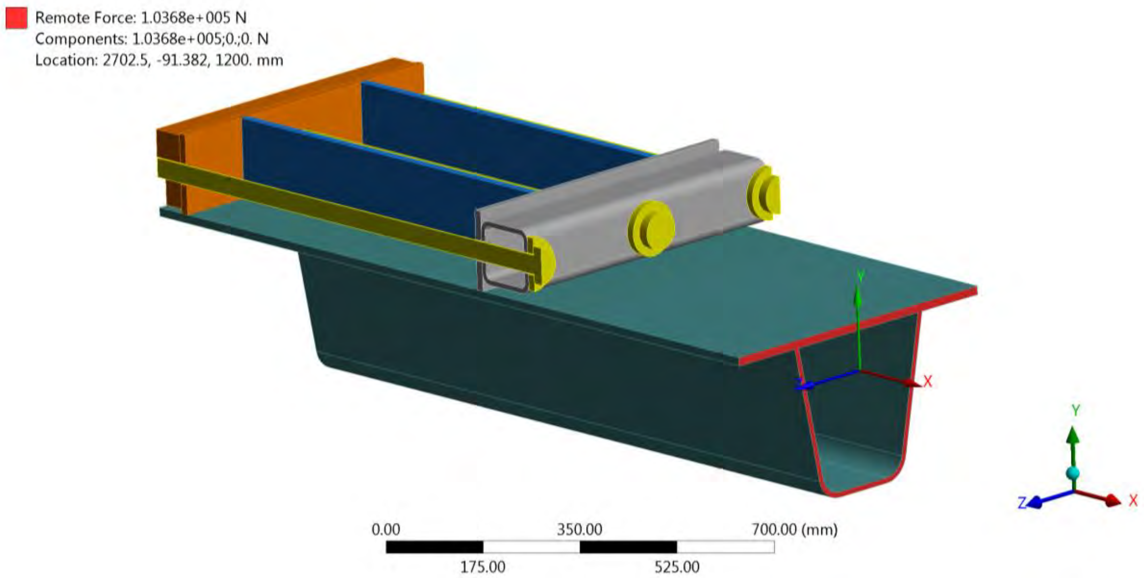


Figure 3-1 Force applied to top plate end

3.2 Boundary conditions

Boundary conditions and axis definitions are shown on Figure 3-2. Only half of the locking joint is modelled. There is a symmetry plane at the end of the shimming plates, thus fixed boundary conditions for shimming and rods are applied. In addition, the top plate end is restricted from translating in y-direction. This is done so that no artificial bending effects are introduced into the local model.

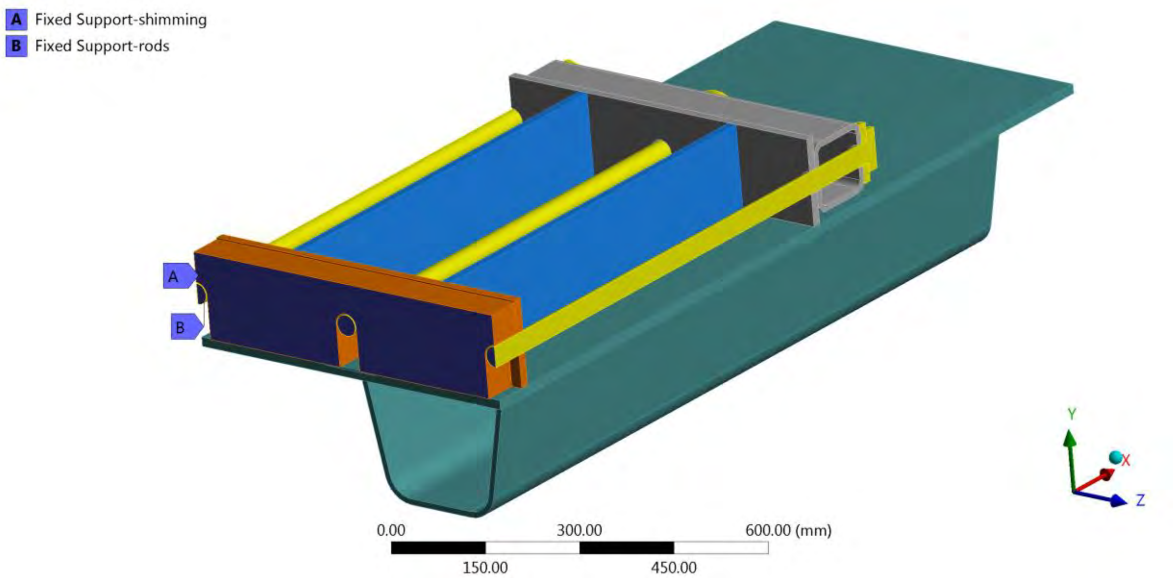


Figure 3-2 Boundary conditions

3.3 Bolt pretension

The bolts are pretensioned so that the shim plates will always be in compression. Since the pretensioning occurs before welding, and stress in the weld is only affected by the dynamic weak axis bending moment only, the pretension force is omitted in the analysis. This is valid when the analysis is linear.

3.4 Contacts

Contact is applied as listed in Table 3-1.

Table 3-1 Contact formulations

Part 1	Part 2	Contact type
Top plate	Flatbars	Bounded
Top plate	Shimming	Frictionless
Top plate	RHS with endplate	Frictionless
Flatbar	RHS with endplate	Bounded [1]
Flatbar	Shimming	Bounded [1]
Anchor rod and washer	RHS	Bounded [1]

[1] The pretensioning force will restrict the parts from separating. Since the bolt pretension forces are omitted, the contact is set to bounded.

4 Results

4.1 No weld

The analysis is first run without a weld to observe the behaviour of the skin plate end.

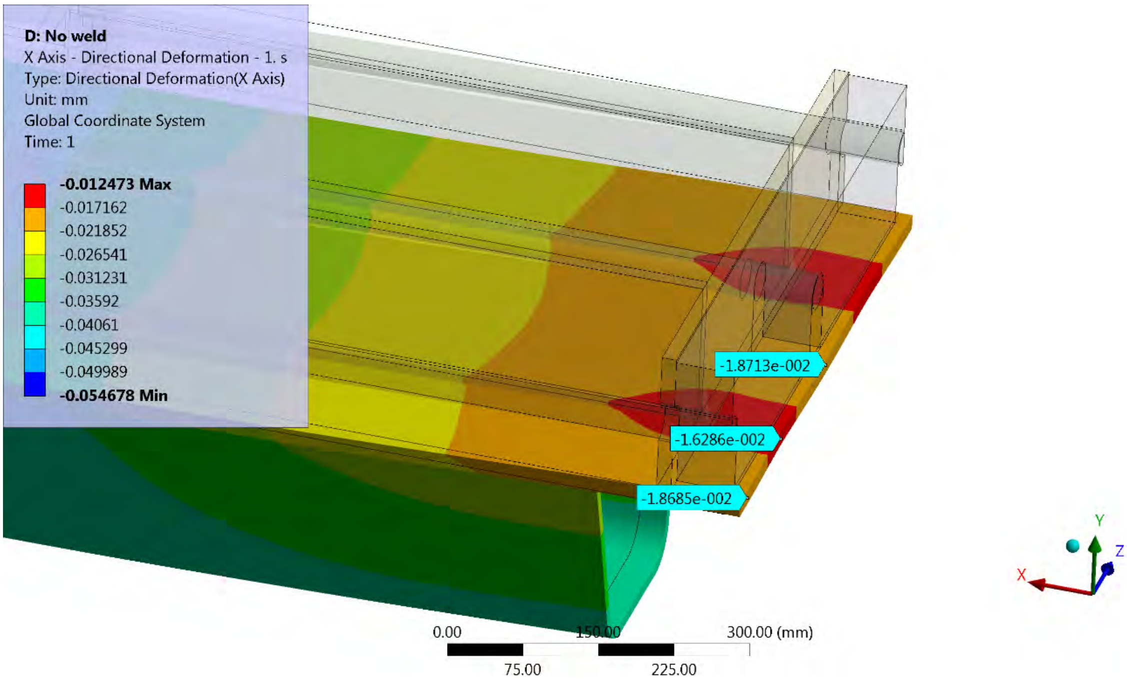


Figure 4-1 X-direction deformation of plate end. Deformations are greatly exaggerated

One can observe that the deformation is not equal over the width due to the flat bars and trapezoidal stiffener welded to the skin plate. An optimal behavior of the locking joint would be to restrain the the skin plate from any x-direction deformations.

As shown in table Table 4-1, the forces are transferred by the rods and shimming.

Table 4-1 Force resultants

	Resultant [kN]			
Global force	Rods	Shimming	Weld	SUM
-104	8	96	0	0
104	-8	-96	0	0

4.2 3 mm weld, 100 mm length

The beginning of a weld is simulated with a short weld, 100 mm long. The throat thickness is set to 3 mm.

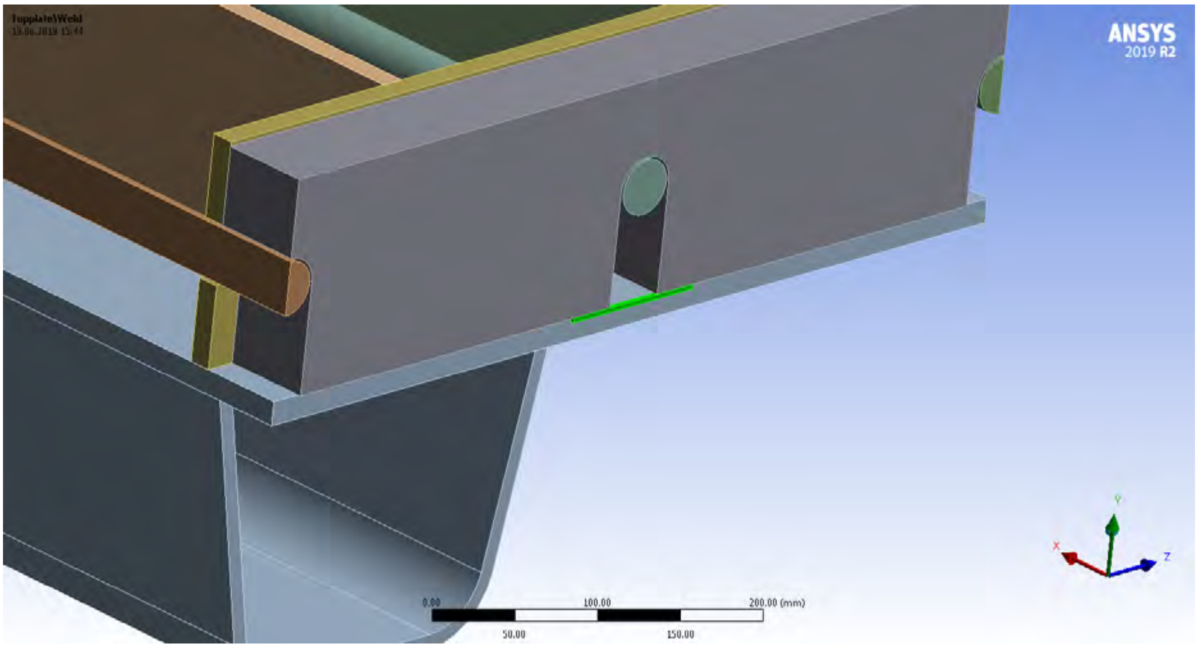


Figure 4-2 3 mm throat thickness, 100 mm long weld

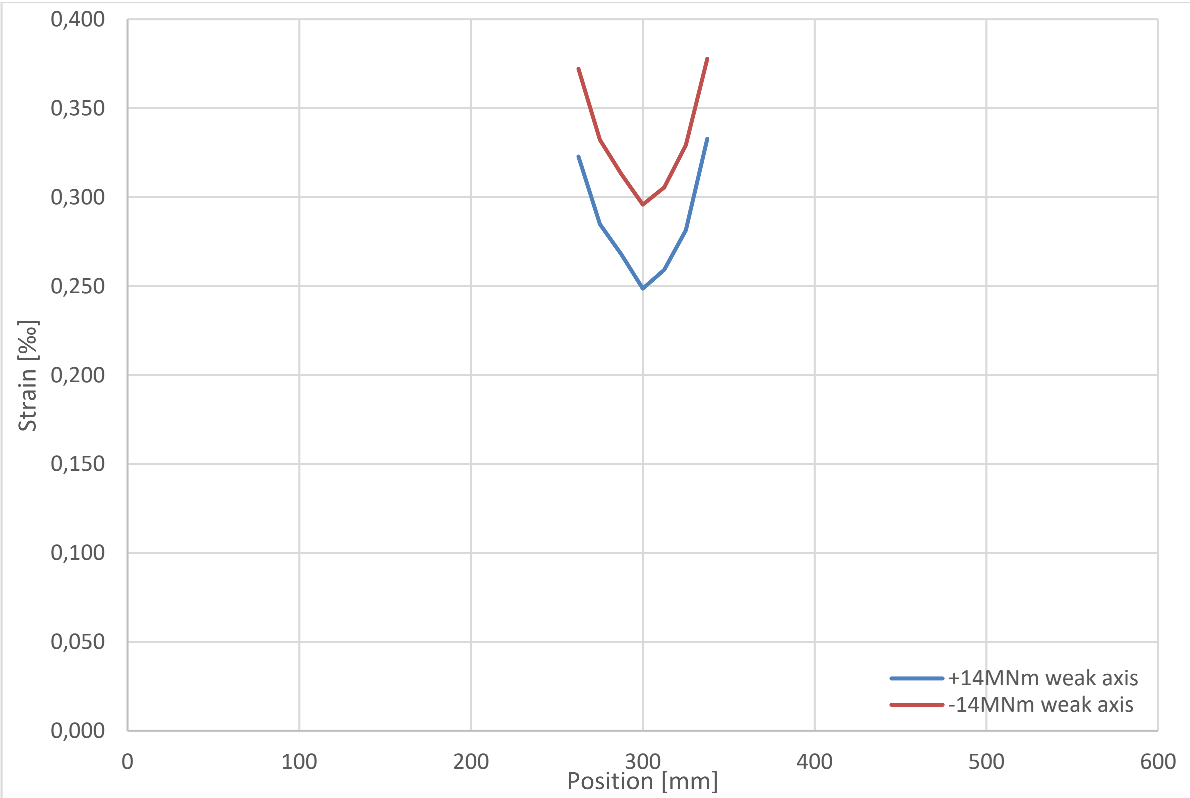


Figure 4-3 Strain over with of the weld

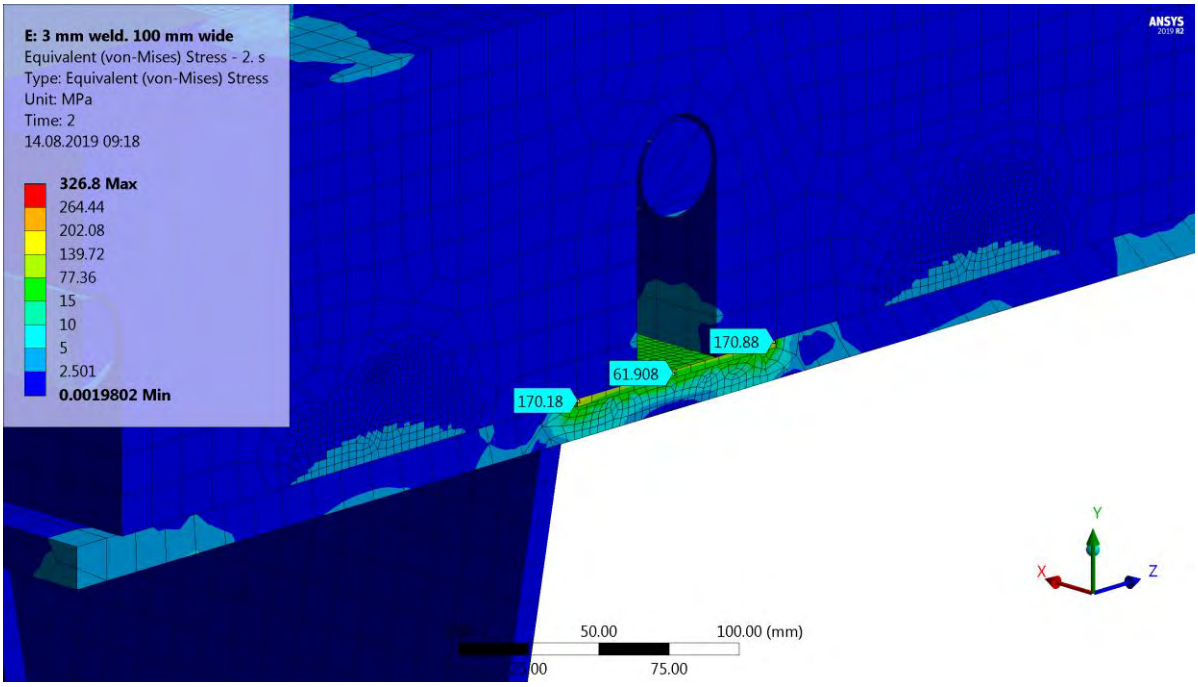


Figure 4-4 Stress in in 100 mm long weld with 3 mm throat thickness. Positive weak axis bending moment

Observed stress in the weld is below yield stress.

Resultants are presented in the table below. The weld carry some of the dynamic load, but the locking joint take the majority of the loads. The average stress in the weld is 81 MPa for a positive weak axis moment and 93 MPa for a negative weak axis moment.

Table 4-2 Force resultants

	Resultant [kN]			
Global force	Rods	Shimming	Weld	SUM
-104	7	73	24	0
104	-7	-69	-28	0

4.3 3 mm weld, full width

The first weld bead around the circumference of the bridge girder skin plate is simulated with a weld with 3 mm throat thickness.

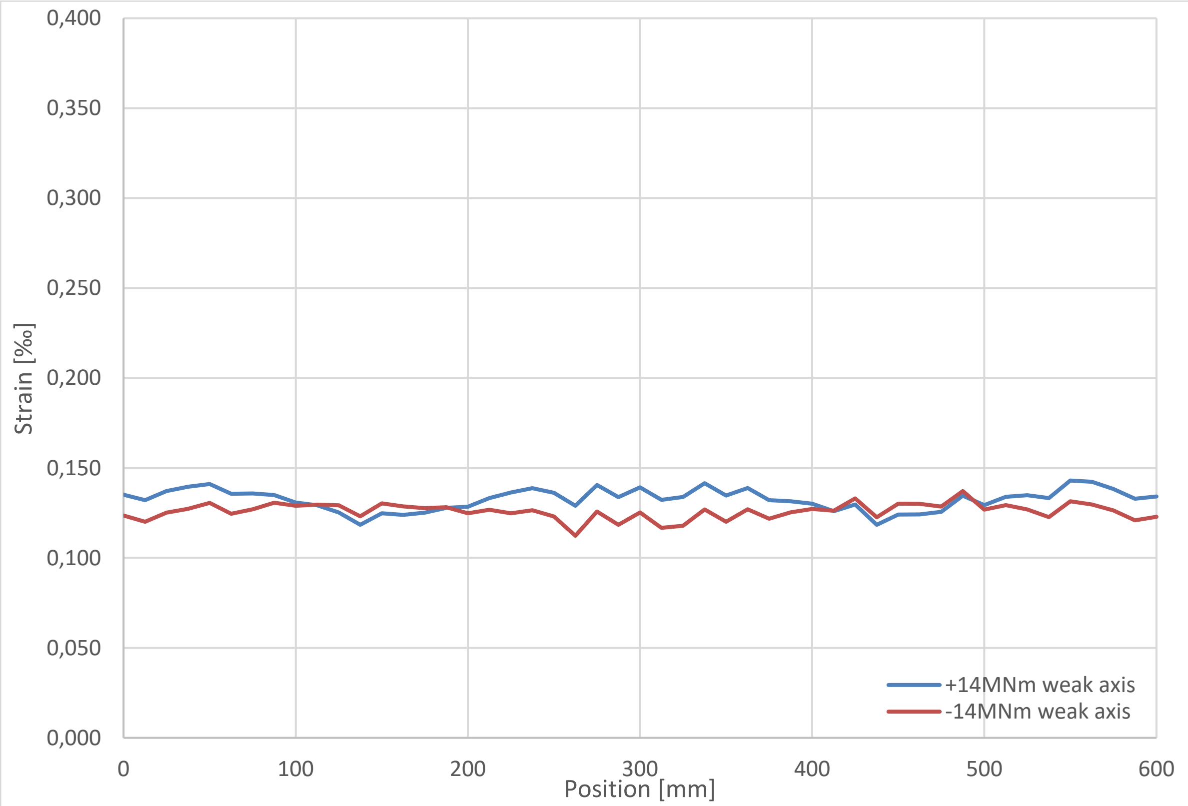


Figure 4-5 Strain along weld

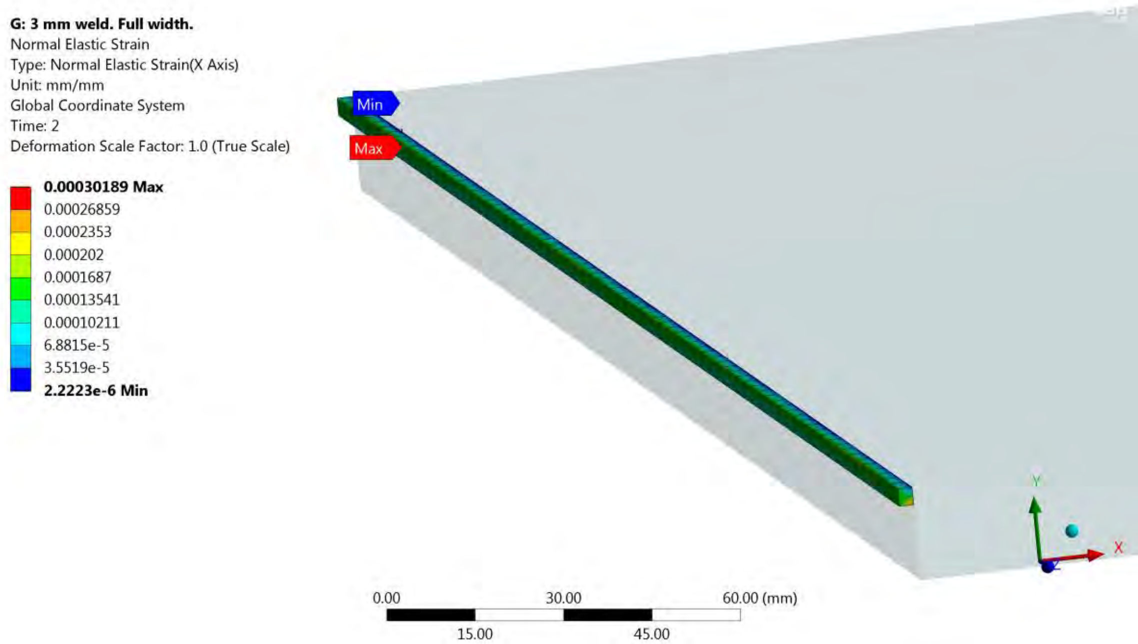


Figure 4-6 Strain for weld, contour plot. Positive weak axis bending moment

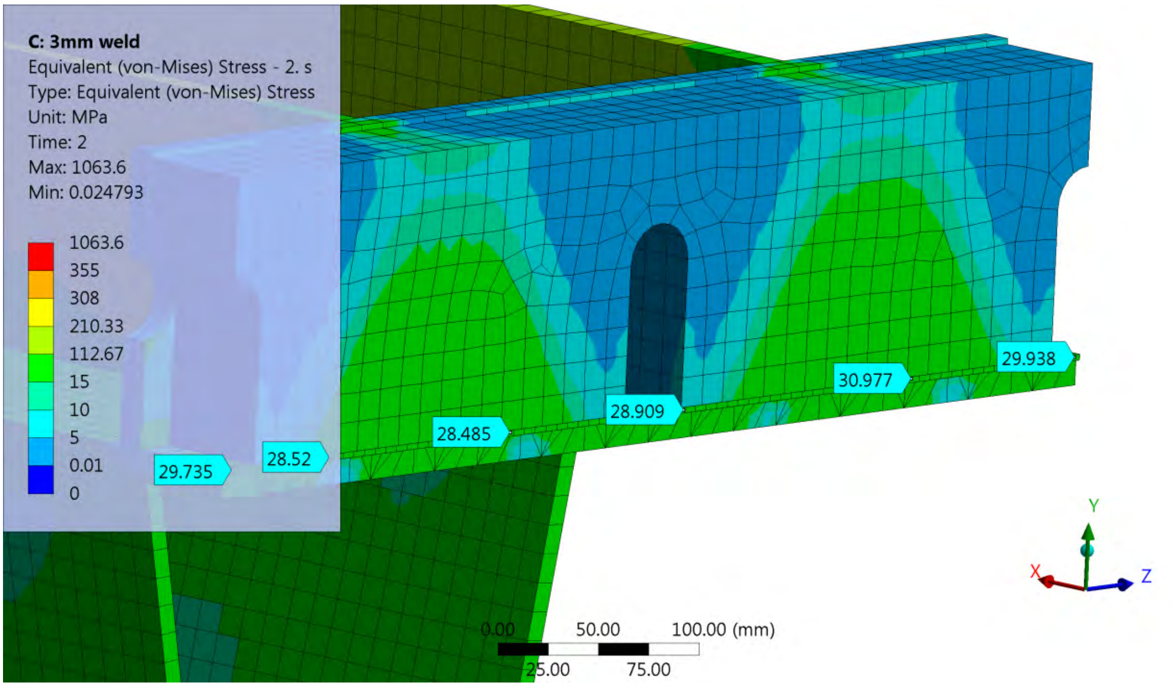


Figure 4-7 Stress in weld with 3 mm weld bead. Positive weak axis bending moment

Resultants are presented in Table 4-3. The weld now carry more than half of the dynamic load. The average stress in the weld is 31 MPa for a positive weak axis moment and -33 MPa for a negative weak axis moment.

Table 4-3 Force resultants

	Resultant [kN]			
Global force	**Rods**	**Shimming**	**Weld**	**SUM**
-104	5	42	56	0
104	-5	-39	-60	0

4.4 6 mm weld, full width

Further weld beads around the circumference of the bridge girder skin plate is simulated with a weld with 6 mm throat thickness.

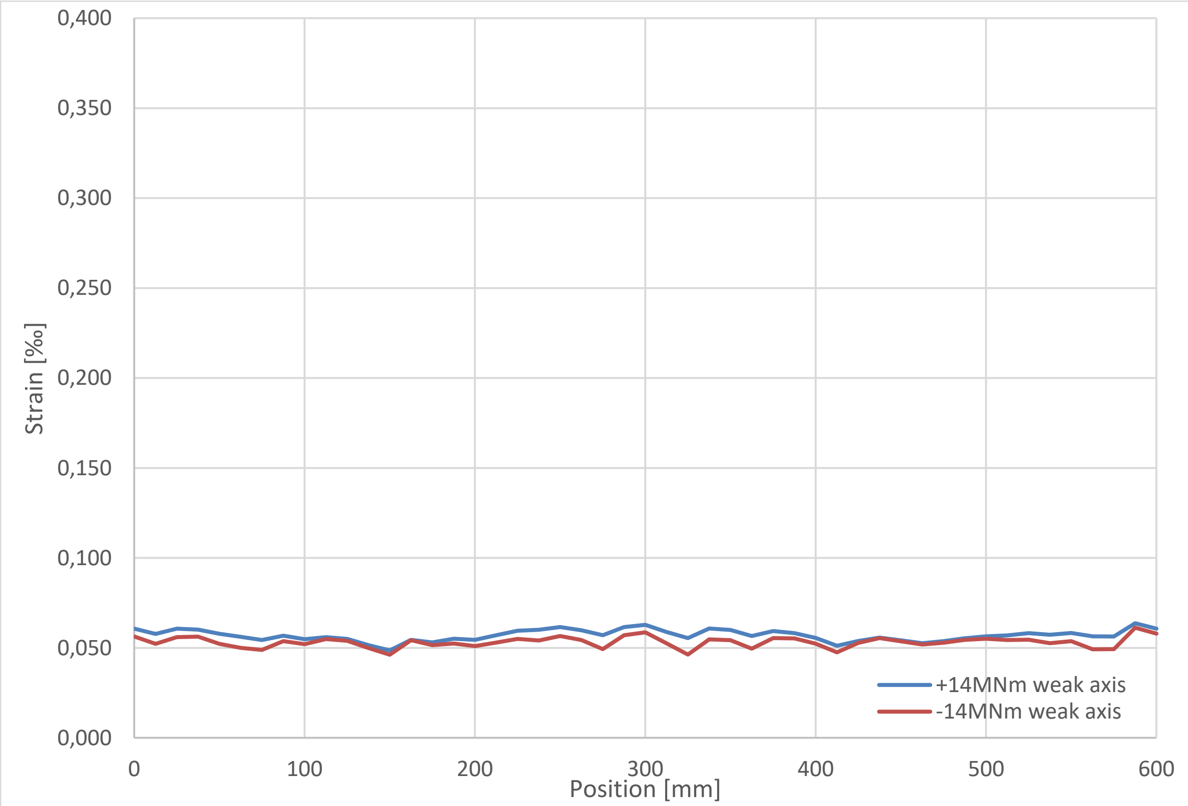


Figure 4-8 Strain along weld

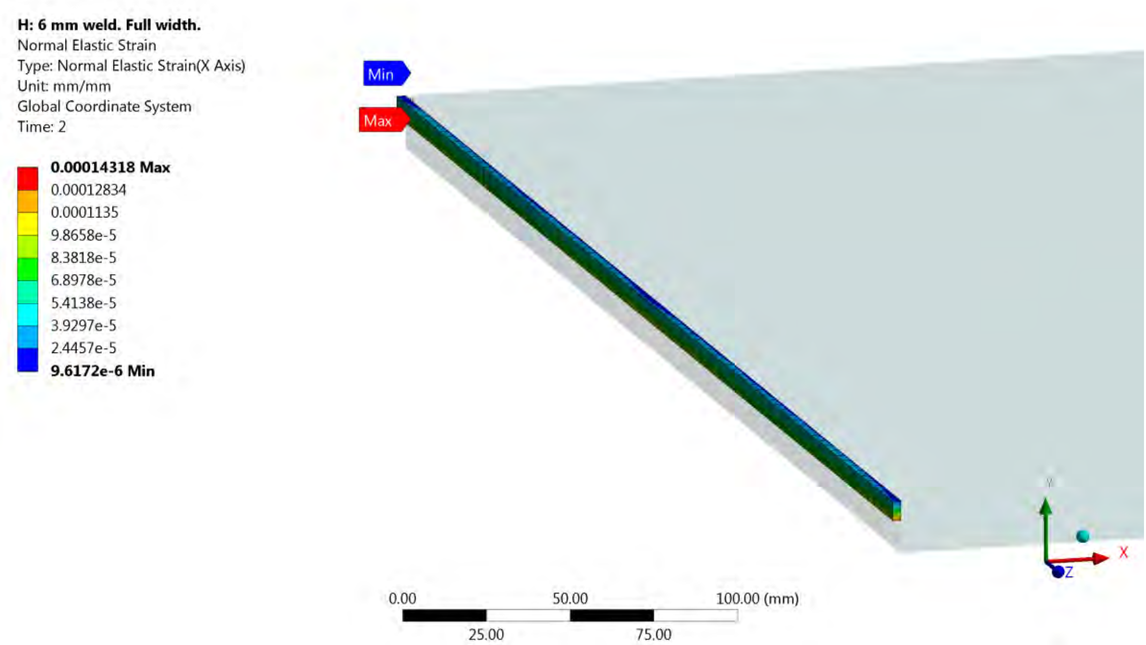


Figure 4-9 Strain for weld, contour plot. Positive weak axis bending moment

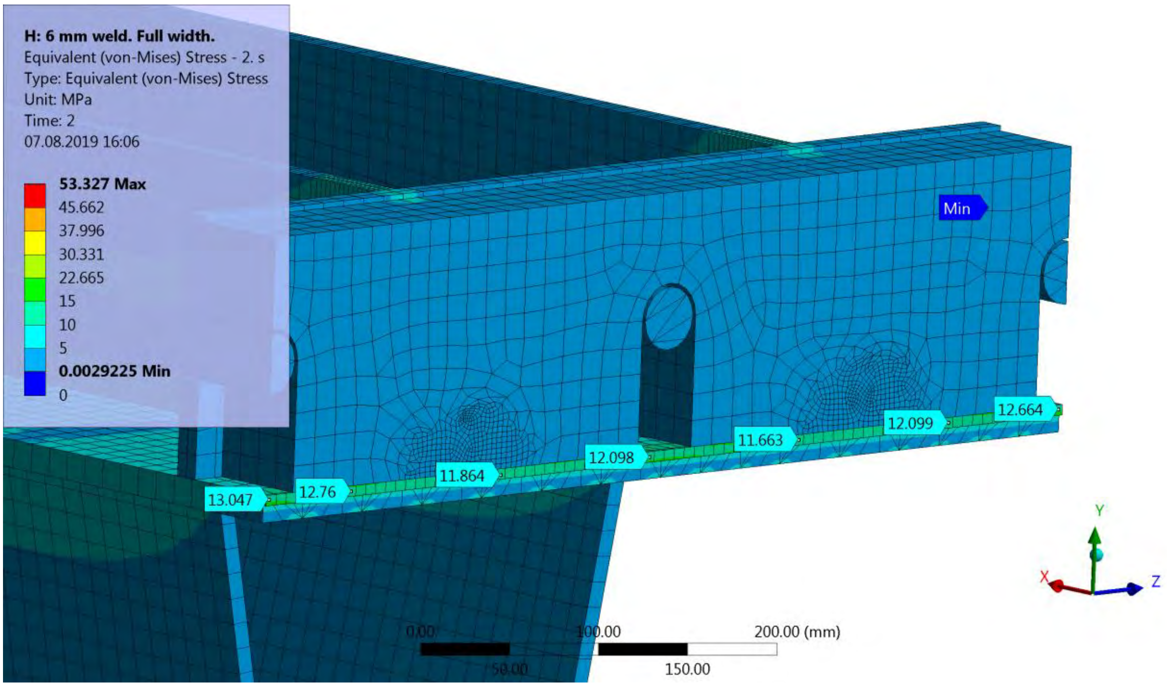


Figure 4-10 Stress in weld with 6 mm weld bead. Positive weak axis bending moment

Compared to a 3 mm weld, the strain and stress is reduced when increasing the weld size.

Resultants are presented in Table 4-4. The weld now carry even more of the load, but the increase from a 3 mm weld is moderate. This is due to the relationship between stiffness of the topplate/weld and locking joint. The average stress in the weld is 16.7 MPa for a positive weak axis moment and -17.1 MPa for a negative weak axis moment.

Table 4-4 Force resultants

Global force	Resultant [kN] Rods	Shimming	Weld	SUM
-104	5	39	60	0
104	-5	-37	-62	0

4.5 3 mm weld, 100 mm width. Extra thick flatbars

Due to small contact area between the flatbars welded to skin plate and shimming, high stress and deformations can be observed for local areas. The areas are encircled on the figure below. The behavior and stiffness of the locking joint can be improved with relatively small design changes.

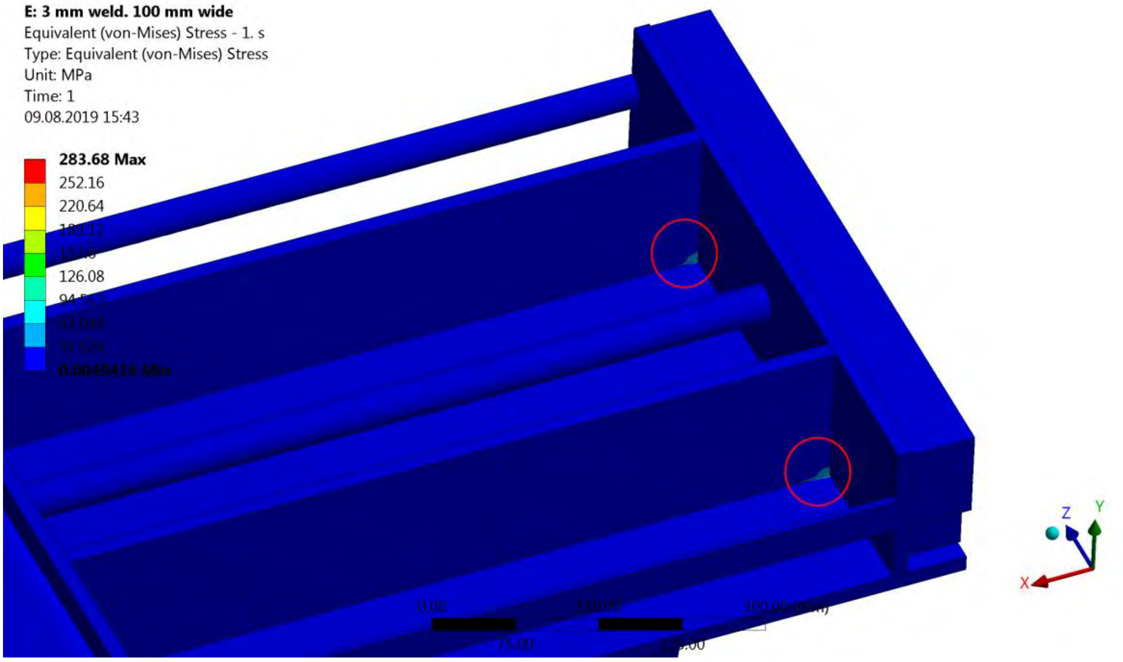


Figure 4-11 Local high stress and deformations between flatbars and shimming

One possibility is to increase the with of the flatbars near the shimming. An analysis where the flatbars are inceased to 45 mm width near the shimming have been run. The geometry is shown on Figure 4-12.

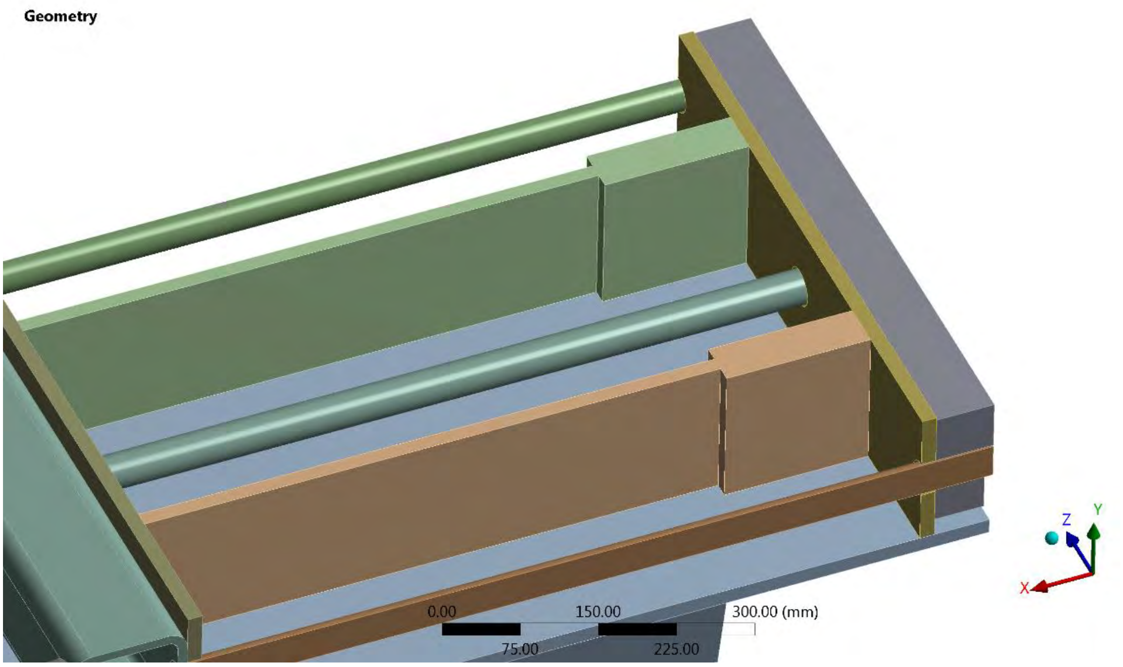


Figure 4-12 Extra wide flatbars near shimming

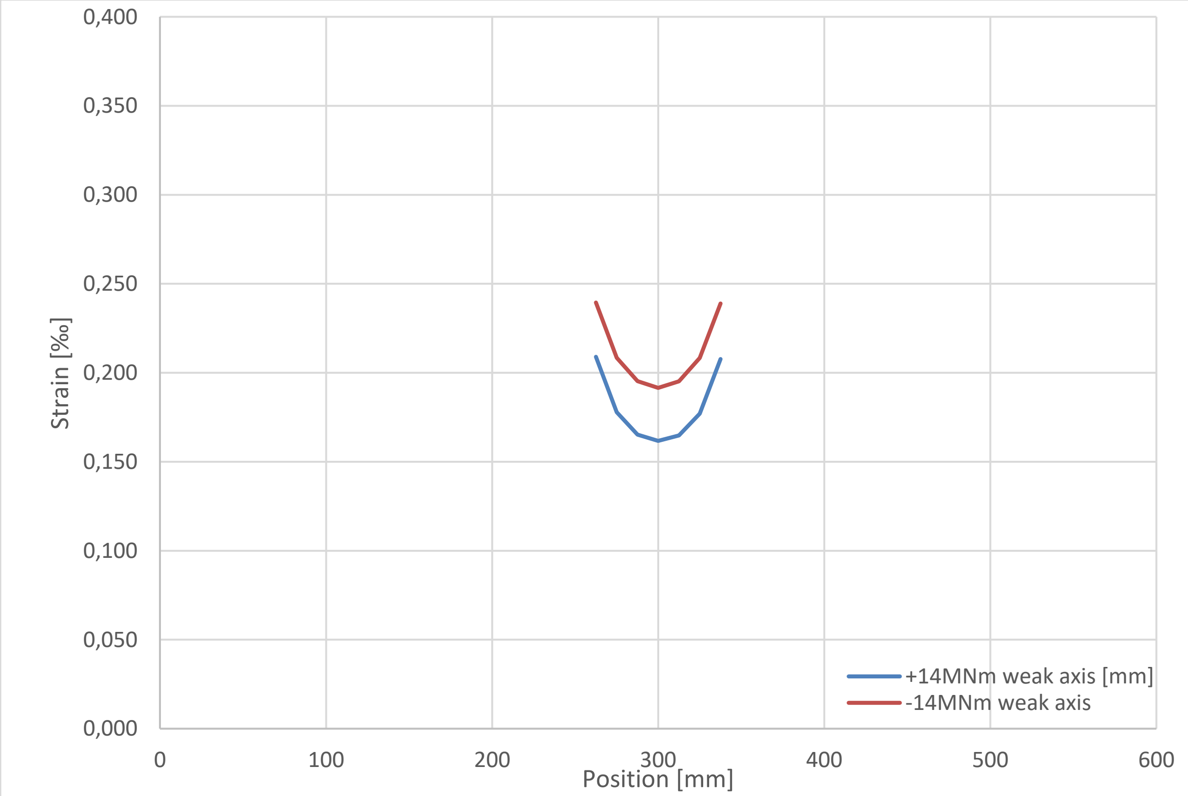


Figure 4-13

For a negative weak axis moment, the strain is reduced from ~0.35 ‰ to ~0.23 ‰ with extra plate width for the flatbars.

For a positive weak axis moment, the strain is reduced from ~0.30 ‰ to ~0.18 ‰.

Table 4-5 Force resultants

	Resultant [kN]			
Global force	**Rods**	**Shimming**	**Weld**	**SUM**
-104	6	83	15	0
104	-5	-81	-18	0

When comparing resultants for this analysis with those presented in section 4.2, one can observe that the shimming carries more of the load and that the weld is offloaded.

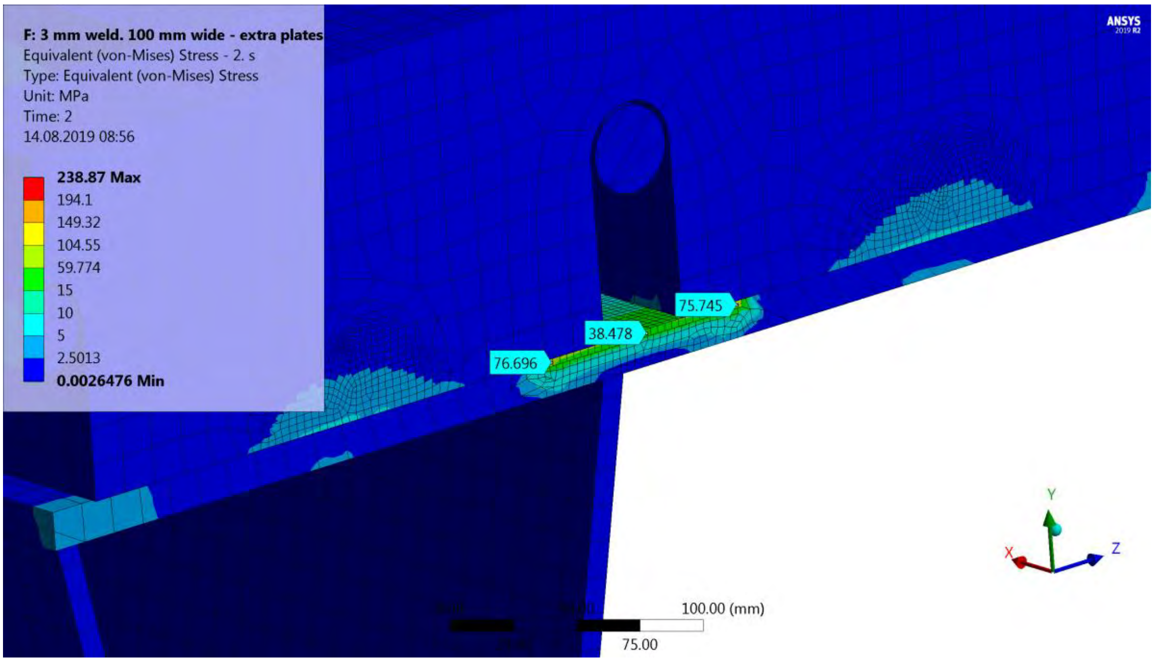


Figure 4-14

The stress is reduced to approximately 50 % by adding the extra plate width to the flatbars.

The locking joint can be tuned/optimized with small geometrical changes that will reduce the stress and strain in the weld during assembly.

Concept development, floating bridge
E39 Bjørnafjorden

Appendix N – Enclosure 2

CAL-AB016101-001
Feasibility Study for Jacking of Bridge Sections

Aker Solutions

FEASIBILITY STUDY

for

Jacking of Bridge Sections

for

Bjørnafjord Prosjektet, Norway

Title	Feasibility Study
Project	Bjørnafjord Prosjektet
Client	Aker Solutions
Document Number	CAL-AB016101-001

A	07/08/2019	Issued for Review	RM	KC	KC	
Revision	Date	Description	Prepared	Checked	Approved	Approved
ALE						Client

REVISIONS

Revision	Revision date	Description
A	07/08/2019	Issued for Review.

CONTENTS

1. INTRODUCTION

1.1. GENERAL

Aker Solutions is tasked with engineering study to design the bridge for the Fjord Crossing Project, along the coastal route E39. The Bjørnefjorden crossing will be 5000 m, located in 500 m deep water, with the possibility to bypass with 1300 m crossing.

Figure 1-1 The Coastal Route E39, Fjord Crossing Project

Due to environmental conditions, water depths and span of the water, traditional bridge designs need to be adapted to fit the local requirements. The concept of assembling and installing a Floating Bridge is generated.

The concept is concerned with the assembly of 10 Bridge spans at low level, after which each Bridge section is jacked up to allow installation of the vertical columns with floaters/pontoons and coupling to the main Bridge. To limit the area required, assembly and installation of the bridge sections will require one floating working platform, constructed of three North Sea type barges. The barges will be coupled by a steel grillage & skidding structure. During the assembly of each Bridge section, intermediate lifting and skidding of smaller pre-fabricated bridge sections is carried out.

ALE Heavylift is requested to provide an engineering study to investigate the feasibility and methodologies for assembly and installation of the bridge.

1.2. DETAILS OF TRANSPORT

Preliminary details of the items:

- Name/description of piece — Bridge Section (10 pcs to be assembled and installed)
- Dimensions: — 150m length / 32m width / 3.5m height
- Weight: — 2100t including support columns/pontoons
- Jacking height: — approx. 50m from water level

1.3. SCOPE OF CALCULATIONS

The scope of this document is to identify the engineering requirements for the jack-up and float-in of the Bridge Sections and identify potential issues and challenges of this methodology.

Following subjects are within this document:

- General specifications for engineering
- Basic Wind load calculations on bridge and jacking system
- Supply predicted jacking loads
- Basic barge stability checks

2. CONCLUSION AND RECOMMENDATIONS

Subject to the identified assumptions and starting points, the working methodology is considered as viable and realistic. Basic calculations show that loads are within equipment capacity and stability is sufficient.

Starting points and assumptions:

- Barges connection structure
  With the jacking of the bridge is on 4 separate positions, it is vital that these positions remain fixed relative to each other during the process. Also the inclination of the 'foundations' under the jacking towers needs to be identical. This is to prevent displacements and horizontal loads on top of the jacking towers.
  Difference in level between 'foundations' can be accommodated to a certain level, however this will result in different loads on the bridge deck and potential torsional deflections.
  In effect this means the barge spanning structure that is used to assemble the bridge needs to be designed for connecting the three barges fixed to each other in such a way it can be considered as one item. The conceptual 'Yokohama' fenders are considered not workable.
  As the operation is to take place in sheltered water (details not known) where wave loads are limited, it is considered realistic to design such a frame/structure.

- Environmental loads
  For the operational calculations, we have considered operational wind only and made some assumptions while calculating these. As we have no info on sea state conditions etc, we have not considered these at the moment.

Recommendations

- Overall stability
  Due to the relative low weight of the bridge structure, own stability of the jacking towers on full height is low on redundancy. To provide additional stability we have considered two stability mast, which provides guidance to the bridge and towers via a support/stability frame. The interactions with the towers (stiffness relation) and loads during out of service winds and barge motions is to be engineered further in detail, where a computer model needs to be created. This has not been included in this study.

- Positioning and connecting of the bridge legs (with/without pontoon) has not been included in this study. We recommend that attention is paid to the floating stability of these items.

- To prevent lateral movements of the barges, especially with jackup operation and with bridge deck at height, fixed mooring is recommended (hard fenders)

- More detailed engineering is required, a basic lookahead can be found in paragraph chapter 9.2.

3. DEFINITIONS AND ABBREVIATIONS

Term	Definition Of Term
+ve	Positive
-ve	Negative
AFT	After
ALE	Abnormal Load Engineering
COF	Centre of Floatation
COG	Center of Gravity
COW	Centre of Wind
DAF	Dynamic Amplification Factor
DNV	Det Norske Veritas
ER	Emergency Response
FP	Forward Perpendicular
FWD	Forward
GBP	Ground Bearing Pressure
GMt	Transversal Metacentric height
GZ	Righting arm
HAZID	Hazard identification
Hs	Significant wave height
HTV	Heavy Transport Vessel
HSQE	Health safety quality and environment
LCG	Longitudinal centre of gravity
ISO	International standards organization
ITP	Inspection and test plan
LAT	Lowest astronomical tide
LRFD	Load and resistance factor design
MOSES	Multi-Operational Structural Engineering Simulator
MS	Method statement
MWS	Marine Warranty Surveyor
NTE	Not to Exceed
ND	Noble Denton
PEP	Project execution plan
PPE	Personnel protective equipment
PTW	Permit to work
RA	Risk analysis
SI	International System of Units
SIMOP	Simultaneous operation
SOW	Scope of Work
SJA	Safe Job Analysis
STBD	Starboard
TBN	To be nominated
TBT	Toolbox talk
TCG	Transverse center of gravity
TRA	Task Risk Assessment
Tm	Mean period
Tp	Peak period
VCG	Vertical center of gravity
WCR	Weight Control Report
WLL	Work Load Limit (in metric tonnes)

4. UNITS

Quantity	Unity	Abbreviation
Accelerations	Meters per second squared	m/s^2
Angular	Degree	o deg
Area	Squared meter Squared millimetre	m^2 mm^2
Distance	Millimeter Centimeter Meter Inch Foot Nautical Mile	mm cm m in” *(1 inch = 25.4mm)* ft’ *(1 foot = 12 inches)* NM
Load	Kilo Newton	kN
Pressure	Bar	Bar
Speed	Meters per second	m/s
Time	Hours Minutes Seconds	hrs min s
Volume	Cubic meters Litres	m^3 L
Weight	Metric tonnes Kilograms	te kg

5. EXECUTION OF WORKS

In this section, a brief description of the equipment and corresponding sequences are presented.

5.1. SKIDDING

For positioning and assembling of the Bridge Sections, a hydraulic skid shoe arrangement may be used. The skidding system is designed and developed by ALE, in which hydraulic skid shoes with stainless steel bottom move over P.T.F.E. (Teflon) blocks which are laid into steel skid tracks.

The skid system is designed with a range of 150-800t skid shoes incorporating a corresponding vertical cylinder with a working stroke of 150-600 mm. On top of this cylinder, a pivot arrangement allows for movement in the longitudinal axis. The forward movement is intermittent, following an extend/retract sequence of cylinders. The motive force required for displacing the structure is generated by hydraulic push-pull cylinders, which are an integral part of the skid system. The units are directly coupled to the skid shoes by means of pin-construction. Centralised diesel-driven powerpacks will generate the hydraulic power required for operation of the hydraulic cylinders of the skid shoes and the push-pull units. The skid shoe stability is designed on a side-force up to a maximum of 10% of the vertical load on the skid shoe involved.

A combination of a number of skid shoes creates a flexible system to move complicated and heavy loads. Configurations of different types of skid shoes can be made up whereby the same hydraulic pressure in the system groups gives individual jacking forces.

A typical hydraulic skidding arrangement will provide a three-point suspension for each bridge section, allowing for relative height corrections of individual bridge sections during the assembly on top of the barge grillage. Ideally, after fitting of the sections, temporary supports + shimming are installed underneath the sections. This provides the opportunity to remove the load from the hydraulic skid shoes during the welding period.

5.2. JACKING

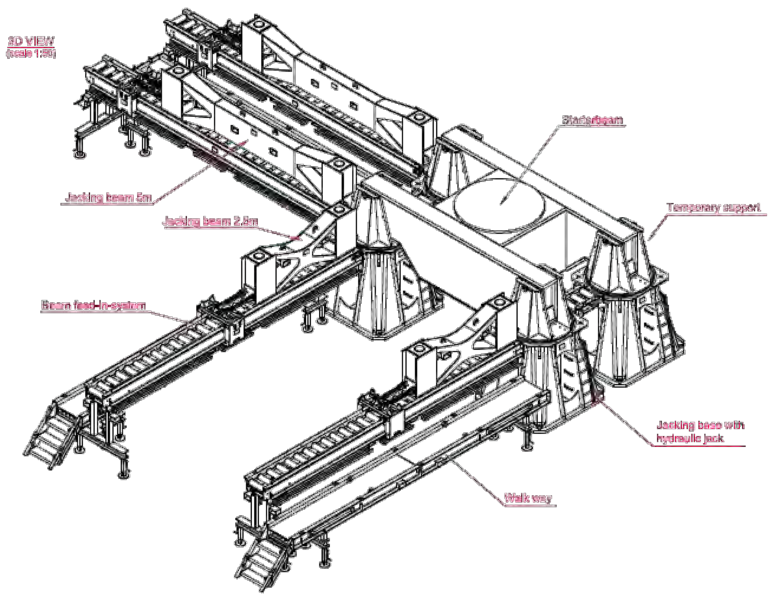
The parameters as displayed below will be used as basic parameters for the calculations. The start of the jacking operation will be the initial pick-up, whereby the bridge deck will be tilted. During this phase, one layer of beams will be inserted. Due to the possible foundation settlement, sliding pads can be installed prior initial pick-up. These sliding pads ensure that maximum 5% of horizontal load due to deflections will be locked within the MJS (max. 5% friction is achieved by using Teflon/Teclite).

5.2.1. MEGA JACK SYSTEM PARAMETERS

Parameter	Quantity	
Foundation points (number of jacking points)	4	
Distance between jacking points in x-direction	60,000	mm
Distance between jacking points in y-direction	8,000	mm
Number of jacks at a foundation point	4	
Foot structure height (jacking base)	2,085	mm
Misalignment factor for height* (maximum misalignment due to fabrication tolerances and clearances barge movement)	0.010	m/m
Misalignment factor for width* (maximum misalignment due to fabrication tolerances and clearances)	0.001	m/m
Stability base in x-direction (2,5 meter jacking beam)	2,500	mm
Stability base in y-direction (5 meter jacking beam)	5,000	mm
Amount of jacking layers total	35 /37	
Height of each layer (= height of jacking beam)	1,100	mm
Weight of jacking mast (Excl. starter beam)	175	t
Weight of jacking beams 2,5m (5m)	2.3 (2.57)	t
Weight of jacking bases (each)	15.5	t

*) These factors will be used for the determination of the maximum misalignment that needs to be considered in FEM calculations, procedures and dimension control during the installation of the equipment and jack-up.

Please note that picture is for information only:



5.2.2. WORKING LOAD LIMITS OF MAIN COMPONENTS

In the table below the working load limits are listed for the main components of the Mega Jack System. The in-service and out-of-service values show the values which can be applicable for this project. The extreme values are displayed to show the allowable load on the MJS without plastic deformations and maintaining a marginal safety factor. The extreme load conditions are determined to have usable values for extreme storm conditions.

Design loads	In service	Out of service	Extreme
WLL Jacking beams (each corner profile)			
Vertical	13,000 kN	15,000 kN	19,000 kN
Horizontal	650 kN	650 kN	650 kN
WLL Temporary (Rotation) support			
Vertical	13,000 kN	15,000 kN	19,000 * kN
Horizontal	650 kN	650 kN	650 kN
WLL Jacking base			
Vertical	13,000 kN	15,000 kN	19,000 kN
Horizontal	650 kN	650 kN	650 kN
WLL 13,000kN Jack (extended)			
Vertical	13,000 kN	13,000 kN	13,000 kN
Horizontal	650 kN	650 kN	650 kN

*) In these conditions, a total of 4,000kN of the vertical load is to be taken into account by the hydraulic jack. The remaining 15,000kN and horizontal load will be transferred via the rotation supports.

5.2.3. OPERATION BOUNDARIES FOR JACKING

In the next table the operational conditions are stated. It states the governing limiting factors for jacking; maximum load deviations and maximum height deviations of the different supports.

Operational Boundaries	Value
Operational maximum jack load (85%)	11,050 kN
Load tolerance between jacks at a jacking point	± 10 [%]
Maximum level deviation between jacking points compared to the as build situation	25 [mm]
Maximum foundation settlement: For nominal load conditions [SLSa – excl. safety factors] For worst case load conditions [SLSb – excl. safety factors]	 12 [mm] 25 [mm]

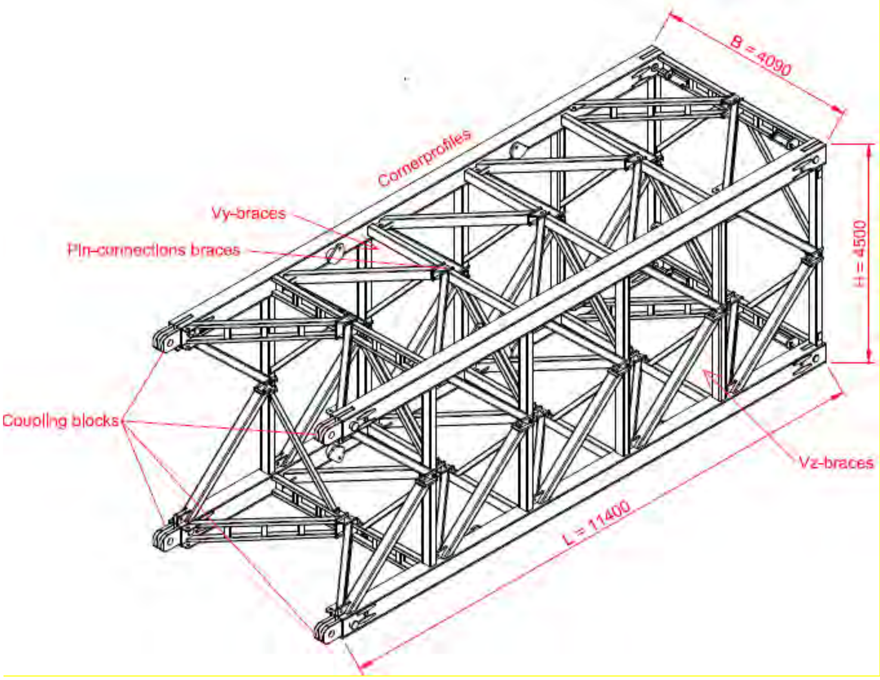
In case displacements/deformations between the barges/jacking points are to be expected, a shimming procedure can be set up to carry out correction during jack up, to stay within allowable limits of the system. Eg. barge displacements/deformations can be corrected up to a certain level. The operational limit of the Mega Jack System will be designed for 40mm of maximum settlement.

5.2.4. STABILITY MAST PROPERTIES

As per DRW-AB016101-001, stability mast sections are sketched for the jack up of the Bridge sections. Actuals loading of the stability mast is not checked in this document. To be considered in a later stage.

Basic mast properties can be found below:

Wide assembly LxBxH = 11.400*4.090*4.500 m (outer dimensions).
Cornerprofiles 400x280
Vy-brace system
Vz-braces system
Pin connections in braces with eyeplates
Coupling blocks



5.3. BALLASTING

At all times during the normal operations, the vessel is maintained with minimal heel, and minimal trim.
For each step in the skidding and jacking procedure, an analysis of the pumping requirements for the barge arrangement will be set up.

Ideally, ballasting will be carried out by an external ballast system providing full controls and monitoring over the ballast status, including real time reading of the tank content and barge trim and heel. Having submerged pumps in each barge tank will give optimum control over the ballast conditions.

5.4. FENDERING AND MOORING

The working platform is created by connecting three North Seay type barges. Due to the parameters and working boundaries of the skidding and jacking equipment, the barges are expected to be fixed with rigid connections. The spacings and possible movements between the barges are to be eliminated by hard fenders between the barges, and with rigid grillage frames connecting the three barges.

During the entire operation, station keeping of the barge is achieved by mooring. Pending on the availability of existing bollards in the surrounding, additional anchors can be opted. The mooring should be calculated for environmental conditions such as currents, waves and wind.

5.5. (WEIGHING)

Optionally to the above scopes, the ALE Mega Jack System can be utilised to provide accurate weight details of the Bridge Section assembly.

After the initial pick up, the Weighing operation will be executed. In the table below the operational conditions and parameters are stated.

Parameter	Quantity	
Maximum wind speed during operation[1]	5	m/s
Accuracy of load cell Weighing[2]	± 0.5	%
Max. capacity per load cell	750	t

Other weighing requirements:

- The choice of the cell and quantity shall be such that each cell works within a range of 10% to 90% of its rated (or calibrated) capacity.
- For weighing operation, the Bridge shall be raised 3 times. When in the raised position the Bridge shall be checked for level and the load cell readings taken, then the Bridge is lowered. When the load cell readings have returned to zero the process may be repeated. Should there be a difference of more than 0.5% between the readings, the reason shall be determined and if necessary faulty equipment replaced or repaired and the operation repeated until three readings are achieved to the satisfaction of the CONTRACTOR.

[1] The wind speed affects the accuracy of the Weighing. ALE uses a maximum wind speed of 5 m/s to maintain the guaranteed accuracy.
[2] Provided accuracy is common for ALE weighing on solid ground. Influence of barge movements/accelerations to be investigated in later stage.

6. GENERAL SPECIFICATIONS FOR CALCULATIONS

The objective of the calculations is to prove theoretically that the equipment, considering the service conditions agreed between the user, designer and/or manufacturer, as well as the states during erection, dismantling and transport, has been designed in conformance to the safety requirements to prevent mechanical hazards with a margin of safety.

6.1. GENERAL

The general starting points are:

- All values are in Metric system
- X = Longitudinal, perpendicular to Bridge
- Y = Transverse, parallel to bridge
- Z = Height from water level upwards

6.2. DESIGN CODES AND STANDARDS

Below standards will be applied during detailed engineering phases. For this feasibility study, a more basic approach can be applied.

6.2.1. STEEL STRUCTURES

The steel structure for the skidding and jacking will be checked and designed according the following standards. The wind load applicable on these structures is determined using the same standards.

No.	Title	European Standard
1	General rules and rules for buildings 1	NEN-EN 1993-1-1 (2007)
2	Design of steel structures for strength and stability 2	NEN-EN 1993-1-6 (2007)
3	Design of steel structures and design of joints 3	NEN-EN 1993-1-8 (2007)
4	Cranes – General design – Part 1	NEN-EN 13001-1 (2009)
5	Crane safety – General design – Part 2	NEN-EN 13001-2 (2011)

6.2.2. SKIDDING AND JACKING

Skidding, jacking and vessel handling operations will be prepared and executed according the provided standards.

Approved Codes of Practice		
No.	**Title**	**Standard**
1	DNV GL Marine Operation and Marine Warranty	DNVGL-ST-N001
2	DNV GL General Guidelines for Load-out Operations	0013/ND Rev 8
3	DNV GL General Guidelines for Moorings Operations	0032/ND Rev2.1
10	Load Transfer Operations.	DNV-OS-H201
11	Marine Operations, Design and Fabrication	DNV-OS-H102
12	Marine Operations General	DNV-OS-H101
13	Buckling Strength of Plated Structures	DNV-RP-C201

6.2.3. DETAILED DESIGN

Detailed design and calculations in later stage.

The following approach is used to determine the loads on the systems and for the detailed design of the equipment:

Global Calculations	
Ballast Calculations	Microsoft Office 365 Pro - Excel 64-bit
Mooring Calculations	OPTIMOOR
Strength and Stability Calculations	Bentley MOSES Rev.7

Detailed Calculations	
Pin-hole calculations	ALE in-house calculation according standards (European Standard)
Weld design	ALE in-house calculation according standards (European Standard)
Detailed local design	FEM-program “DLUBAL RFEM 5.18” or “SCIA ESA 2013”.
Bolted connections	ALE in-house calculation according standards.

Note: Validation of the spreadsheets is done according the ALE QA/ QC system.

6.3. MATERIAL

Table 6-1 Used materials for calculations

code :	EN 1993 & 10025-2 S235	
t_{max}	f_y	f_u
16,0	235,0	360,0
40,0	225,0	360,0
63,0	215,0	360,0
80,0	215,0	360,0
100,0	215,0	360,0
150,0	195,0	350,0
200,0	185,0	340,0
250,0	175,0	340,0

code :	EN 1993 & 10025-3 S355	
t_{max}	f_y	f_u
16,0	355,0	470,0
40,0	345,0	470,0
63,0	335,0	470,0
80,0	325,0	470,0
100,0	315,0	470,0
150,0	295,0	470,0
200,0	285,0	450,0
250,0	275,0	450,0

6.4. FRICTION

Standard practice friction coefficients, as used per ALE standard;

Steel-steel contact - 0.1
Steel-wood contact - 0.2
Steel-neoprene contact - 0.3 (high friction rubber)

Rubber-gravel contact - 0.3 (semi-wet, rolling resistance 8%)
Rubber-gravel contact - 0.4 (semi-dry, rolling resistance 8%)
Rubber-tarmac - 0.6 (normal conditions, rolling resistance 2%)

Skidding ALE system (Teflon – stainless steel interface, lubricated):
Break-out percentage - 0.07
Skidding percentage - 0.03-0.05 (upper bound to be incorporated)

Note: During barge movements, sea-fastening of the Bridge Section is required during towage, as the load is positioned onto a low friction skid system.

6.5. LOAD FACTORS AND COMBINATIONS

The standards as used by ALE will be applicable for steel design (support beams, lifting lugs, strength calculation, etc). This includes applying load factors as such. The load factors comply with the ALE internal standard, EN13001-2 (crane standard) and EN1993-1-1.

Table 6-2 Overview of load factors for steel design

Load combinations	Safety group	Loads	Load		ALE Heavylift: Load factors (γ_f) Unfavourable	ALE Heavylift: Load factors (γ_f) Favourable	ALE Heavylift: DAF-factor (φ) Unfavourable	ALE Heavylift: DAF-factor (φ) Favourable	Material factor (γ_m): Steel materials σ_y	Material factor (γ_m): Steel materials σ_u	Material factor (γ_m): Welds σ_u	Material factor (γ_m): Bolts σ_u
Load combinations	Safety group A (ULS)	Regular loads	Selfweight		1.35	0.90	1.15	0.90	1.1	1.25	1.25	1.25
			Payload				1.15	0.90				
			Horizontal load:	Oblique load			1.15	0.90				
	Safety group B (ULS)	Occassional loads	Selfweight		1.35	0.90	1.15	0.90	1.1	1.25	1.25	1.25
			Payload				1.15	0.90				
			Horizontal load:	Oblique load			1.15	0.90				
				Skidding accelleration (X) 3%			1.00	1.00				
				Wind in-service			1.00	1.00				
	Safety group C (ULS)	Exceptional loads (Out-of-service wind)	Selfweight		1.20	0.90	1.00	1.00	1.1	1.25	1.25	1.25
			Payload				1.00	1.00				
			Horizontal load:	Oblique load			1.00	1.00				
				Wind out-of-serv.			1.00	1.00				

Example 1:	Operational wind speed, resulting total safety factor in Unity Check (Fmax)	(Safety group B)	$\gamma_f * \gamma_m * \varphi$ =	1.35 * 1.1 * 1.15	=	1.71
Example 2:	Out-of-service wind speed, resulting total safety factor in Unity Check (Fmax):	(Safety group C)	$\gamma_f * \gamma_m * \varphi$ =	1.20 * 1.1 * 1.0	=	1.32

6.6. WEATHER FORECASTING AND MONITORING

Weather forecasting and monitoring will be applicable prior to, during, and after the jack-up operation. Client is to supply the weather forecasting. The environmental conditions and restrictions will be stated in the deliciated procedures.

Weather forecasting shall contain at least:

- Mean and gust wind speed for next 48/72 hours
- Mean and guest wind speed for next 24 hours
- Wind direction
- Sea State / Surge
- Potential lightning
- Precipitation

6.7. WEATHER CONDITIONS

Skidding, (weighing), and jacking operations will be executed in suitable weather window. The weather window shall contain wind speeds and environmental conditions according the 'in-service' conditions. As these conditions contain dynamic movements, an additional dynamic amplification factor is to be considered.

The weather window is determined using weather forecasting. These forecasts can be reliable up to 48-hours (experience based). Because the duration of the heavy lifting phases is longer than 48-hours, higher environmental conditions are to be taken into account into the calculations. To be determined in a later stage.

6.8. WIND LOAD DATA

For this study, the calculation of the wind loads is based on following assumptions:

1. The total surface will be determined by outlining the complete structure in a CAD-program. The CAD-program will determine the actual COW (= Center of Wind) of the complete area
2. The steel parts of the bridge will be taken into account as closed surfaces, Shape factor Cw = 2,0.
3. Truss like structures (Stability mast / Mega Jack Tower) will be taken into account as closed surfaces, Shape factor Cw = 2,0 to compensate for multiple towers & members in combination with open areas.
4. The steel parts of the grillage frame (longitudinal wind) will be taken into account as closed surface, Shape factor Cw = 1,0 to compensate for multiple members in combination with open areas.
5. The wind speed for the wind load calculation is based on an assumed wind speed of 16 m/s, independent from height.
6. Basic Wind pressure per area is calculated as follows:

$$F_w = 1/2 \cdot \rho \cdot v^2 \cdot C_w \cdot A$$

where

F_w = *wind force (N)*	
A = *surface area [m²]*	as per (2)
ρ = *density of air [kg/m³]*	= 1.25 kg/m³
v = *wind speed (m/s)*	= 16 m/s
C_w = shape factor	as per (2), (3), (4)

To be determined in later stage:

1. Height compensated wind speed (wind profile power law to be considered).
2. Actual shape factors to be determined according the applicable codes, in later stage.
3. Gust factor for in-service wind is factored for the maximum jacking height.
4. >48h / Out of service conditions are not taken into consideration within this study, to be determined in later stage.

Following wind speeds are taken into account for the installation operations:

	Mean wind speed (m/s)
In-service v(avg)	16.0 m/s
Out-of-service v(ref)	TBD, not considered

6.9. WIND LOAD – PHASE 01 – BRIDGE ASSEMBLY / INITIAL JACK UP

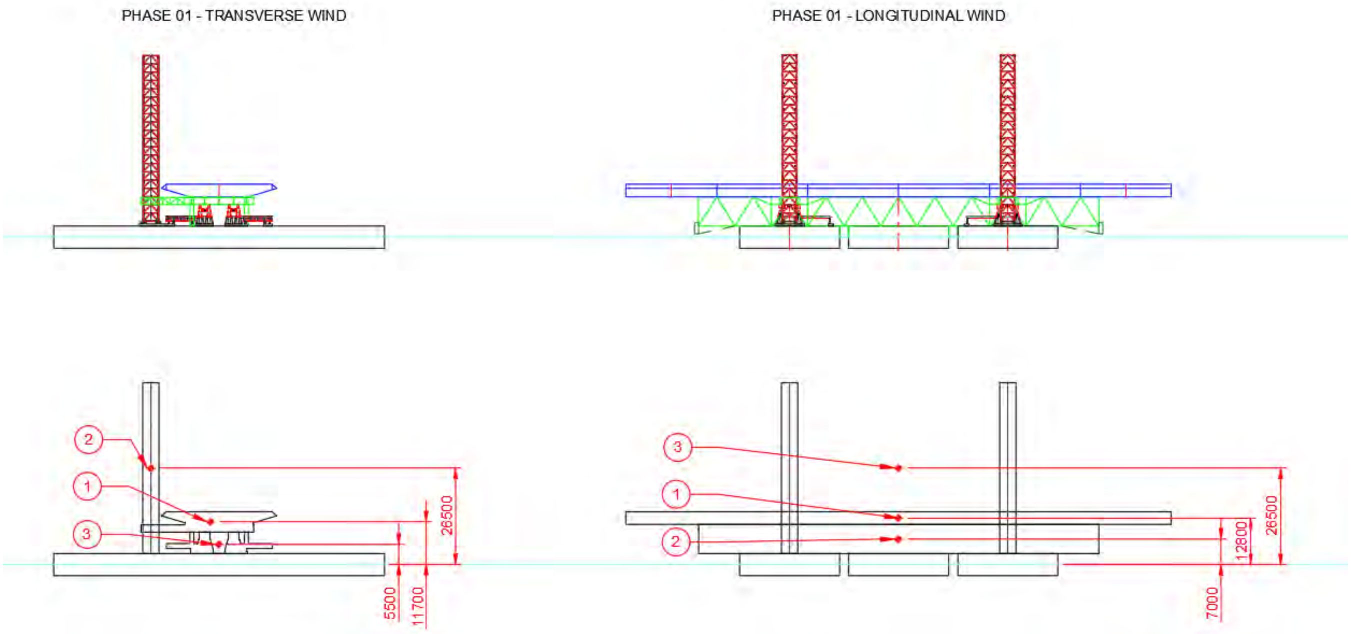


Figure 6-1 Determination of wind areas- phase 01

PHASE 01 - BRIDGE ASSEMBLY -TRANSVERSE WIND LOAD

	ITEM DESCRIPTION	DEFINED AREA [m2]	Cw [-]	H_{COW} [m]	WIND LOAD [t]	WINDMOMENT [t·m]
1	Bridge deck section + stability frame	150	2,0	11,7	4,9	57,2
2	Stability mast	210	2,0	26,5	6,9	181,5
3	MJS jacking tower + grillage frame	80	2,0	5,5	2,6	14,4
Intergrated wind load					**14,4**	**253,1**

PHASE 01 - BRIDGE ASSEMBLY - LONGIDINAL WIND LOAD

	ITEM DESCRIPTION	DEFINED AREA [m2]	Cw [-]	H_{COW} [m]	WIND LOAD [t]	WINDMOMENT [t·m]
1	Bridge deck section	525	2,0	12,8	17,1	219,2
2	Grillage frame	880	1,0	7	14,4	100,5
3	Stability mast +MJS jacking tower	420	2,0	26,5	13,7	363,1
Intergrated wind load					**45,2**	**682,7**

6.10. WIND LOAD – PHASE 01- BRIDGE AT FINAL HEIGHT

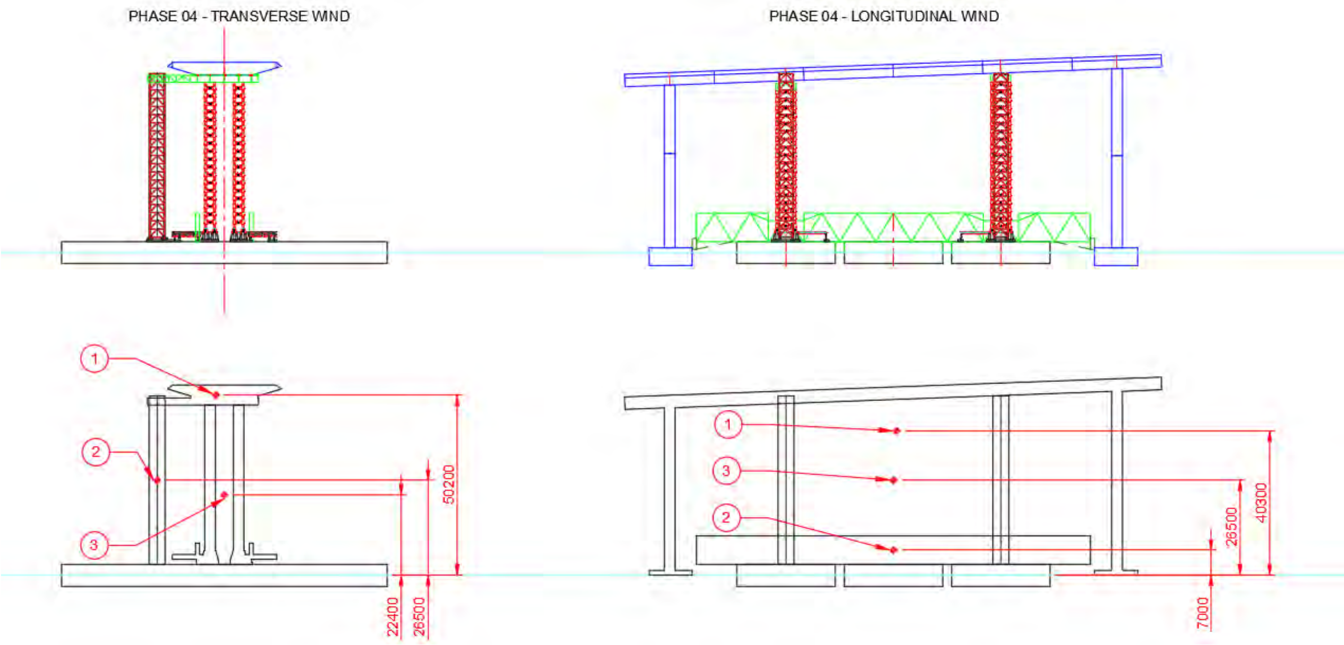


Figure 6-2 Determination of wind areas – phase 04

PHASE 04 - JACK-UP TO FULL HEIGHT - TRANSVERSE WIND LOAD

ITEM DESCRIPTION	DEFINED AREA [m2]	Cw [-]	H_{COW} [m]	WIND LOAD [t]	WINDMOMENT [t·m]
1 Bridge deck section + stability frame	150	2,0	50,2	4,9	245,6
2 Stability mast	210	2,0	26,5	6,9	181,5
3 MJS jacking tower + grillage frame	305	2,0	22,4	9,9	222,9
Intergrated wind load				**21,7**	**650,0**

PHASE 04 - JACK-UP TO FULL HEIGHT - LONGIDINAL WIND LOAD

ITEM DESCRIPTION	DEFINED AREA [m2]	Cw [-]	H_{COW} [m]	WIND LOAD [t]	WINDMOMENT [t·m]
1 Bridge deck section + columns	825	2,0	40,3	26,9	1084,5
2 Grillage frame	880	1,0	7	14,4	100,5
3 Stability mast + MJS jacking tower	420	2,0	26,5	13,7	363,1
Intergrated wind load				**55,0**	**1548,1**

6.11. OBLIQUE FACTOR

The horizontal load due to the imperfection of the foundation or other external factors is taken into account as maximum 1.0% of the total vertical load applied on the jacking system. These horizontal loads are considered to incorporate the assembly tolerances. The value is based on previous experiences.

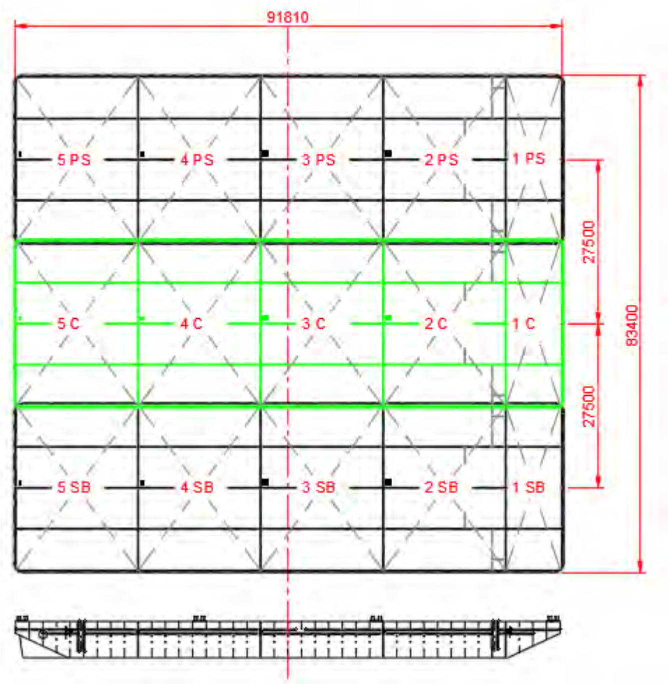
7. BARGE STABILITY

In this chapter, the assumed barge arrangement is checked for stability.

7.1. BARGE DATA

7.1.1. BARGE ARRANGEMENT

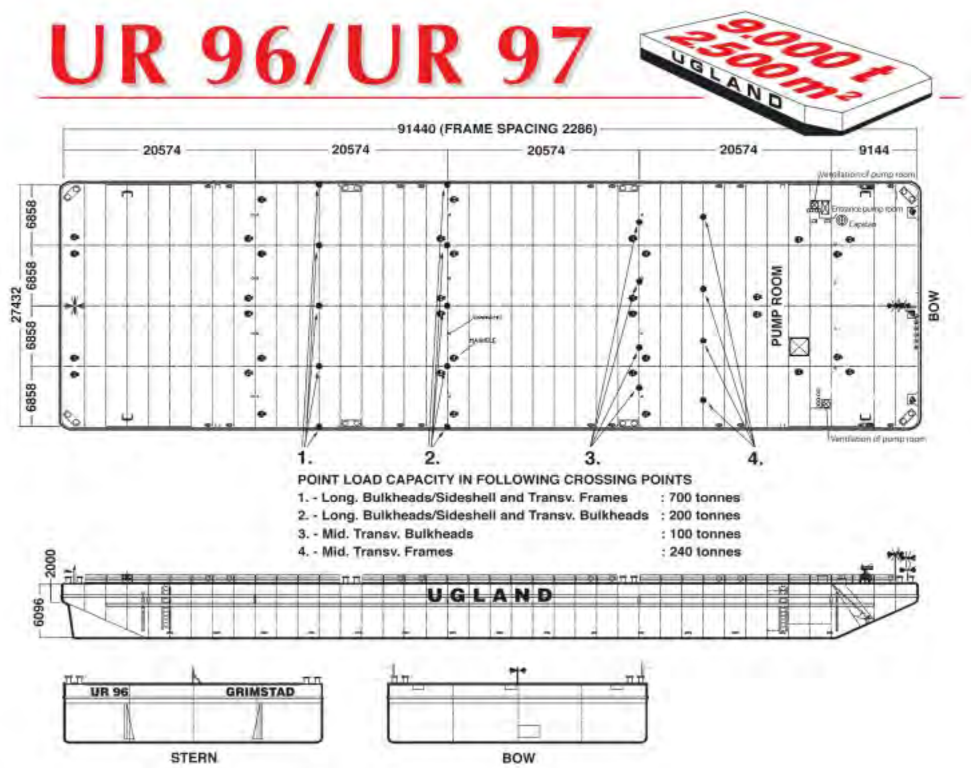
For calculation purposes, the following barge arrangement is applied:



Notes:
- *To ease initial calculations, spacing between barges is neglected.*
- *Adding spacing between barges in a later stage will provide an increased stability base.*
- *To ease initial calculations, multiple tanks are considered connected with each other.*

7.1.2. BARGE DETAILS

Ugland UR 96 / 97 Cargo Barge (single)



Built: 2008 by Dalian Shipyard
Class: Det Norske Veritas (DnV) + 1A1
Signal letters: UR96: LK9905 / UR 97: LK9904
Register tonnage: 4058 gross. / 1217 net.

DIMENSIONS:

Length overall:	300'	91,440 m
Breadth:	90'	27,432 m
Depth:	20'	6,096 m
Light Draft:	Fwd.:	1,308 m
	Aft.:	0,894 m
Loaded draft:		4,840 m

CAPASITIES:

Deadweight:	9094 tonnes
Lightship:	2334 tonnes
Deck area:	2508 sq.m
Deck unit load:	25 tonnes/sq.m

ARRANGEMENT AND FORM:

Bulkheads:	3 longitudinal, 4 transverse + pump room bulkhead.
Double bottom:	In pump room.
Ballast tanks:	20
Bow:	Raked.
Stern:	Raked with two skegs.

EQUIPMENT:

Auxiliaries:	Three water-cooled Iveco Motor Marine Diesel engines, Model NEF 150 Type N67MNAM15, 55kw at 1800 rpm.
Alternator:	One Cummins Generator Technologie, Type UCM224F1, 66kvA 86,6A 440v, 60 Hz at 1800 rpm.
Lightening:	El. light in pump room/Shore connection and battery charger Solar powered navigation lights.
Ballast pumps:	Two centrifugal pumps, 600 cub.m./hour, each.
Anchor winch:	Hydraulic mooring winch. Maker: Dalian Shipyard Tools Industry Co.

MOORING / TOWING:

Anchor:	1 anchor, Spek M-type, 4000 kg (FOR EMERGENCY ONLY)
Anchor wire:	610 m, dia. 38 mm.
Towing arr.:	Smit towing arrangement for main- and emergency towing, SWL 85 tonnes.
Towing bridle:	Chain /wire with triangel plate, SWL 85 tonnes.
Bollards:	Positioned on deck.
Fenders:	2 tiers of horizontal steel fenders on each side. 2 double tiers of vertical steel fenders on each side.

7.2. BARGE LOADS

7.2.1. VERTICAL LOADS

To calculated barge stability, the assumed arrangement is checked for the applied vertical loads (self-weight of (jacking) equipment and bridge section). Below item weights are considered:

Bridge assembly / initial jack up with MJS:

Item	ASSUMED WEIGHT (t)	ASSUMED COG POS. ON BARGE (X,Y)	ASSUMED COG HEIGHT ABOVE BARGE DECK (Z)
Bridge section (assembled)	2100,0	Centre, symmetrical	11.5 m
Grillage / skidding beam	1000,0	Centre, symmetrical	4.0 m
Mast / MJS load spreading	500,0	Centre, symmetrical	1.0 m
Stability mast (2 pcs, eccentric in Long.)	250,0	Longitud. shift -18.75m	25.0 m
Mega jack system (2 jacking beam layers)	400,0	Centre, symmetrical	3.5 m
Ballast equipment	50,0	Centre, symmetrical	1.0 m
Other equipment / etc.	250,0	Centre, symmetrical	1.0 m

Jacking to final height:

Item	ASSUMED WEIGHT (t)	ASSUMED COG POS. ON BARGE (X,Y)	ASSUMED COG HEIGHT ABOVE BARGE DECK (Z)
Bridge section (assembled)	2100,0	Centre, symmetrical	**50.0 m**
Grillage / skidding beam	1000,0	Centre, symmetrical	4.0 m
Mast / MJS load spreading	500,0	Centre, symmetrical	1.0 m
Stability mast (2 pcs, eccentric in Long.)	250,0	Longitud. shift -18.75m	25.0 m
Mega jack system **(36 jacking beam layers)**	**1150,0**	Centre, symmetrical	**25.0 m**
Ballast equipment	50,0	Centre, symmetrical	1.0 m
Other equipment / etc.	250,0	Centre, symmetrical	1.0 m

7.2.2. HORIZONTAL LOADS

Applied wind loads on the barge stability calculations as per section 5.9 and section 5.10.

7.3. BARGE LOAD CASES

In order to check the impact on the barge condition (resulting static list and trim) of wind loads, the barge stability calculation is conducted excluding and including horizontal wind loads for four conditions. Wind loads resulting in wind moments are considered in longitudinal and transverse direction, acting at the same instance (conservative consideration). Ballast tank contents are kept unchanged during the four load cases, to simulate the static reactions by the wind moments. The ballast calculation sheets can be found in the appendices A-D.

Before jack-up:

LC1 Phase 01 – assembly of bridge section, pre-ballast condition, no wind load [Appendix A]

LC2 Phase 01 – assembly of bridge section, pre-ballast condition, including wind load X/Y [Appendix B]

After jack-up:

LC3 Phase 04 – jack-up of bridge to final height, pre, pre-ballast condition, no wind load [Appendix C]

LC4 Phase 04 – jack-up of bridge to final height, pre-ballast condition, including wind load X/Y [Appendix D]

7.4. RESULTING STATIC LIST AND TRIM

Below results are extracts from the appendices (A-D).

LC1	LIST=	0,00	m SB	TRIM=	0,00	m FORWARDS	
	LIST in degrees=	0,00	degr SB	TRIM in degrees=	0,00	degr FORWARDS	
	MIN FREEBOARD IS :	2,0042	m	DRAUGHT FORE =	4,09 m	AFT =	4,09 m
	INCL LIST & TRIM			FREEBOARD FORE =	2,00 m	AFT =	2,00 m
LC2	LIST=	0,01	m SB	TRIM=	0,01	m FORWARDS	
	LIST in degrees=	0,00	degr SB	TRIM in degrees=	0,01	degr FORWARDS	
	MIN FREEBOARD IS :	1,9950	m	DRAUGHT FORE =	4,10 m	AFT =	4,09 m
	INCL LIST & TRIM			FREEBOARD FORE =	2,00 m	AFT =	2,01 m
LC3	LIST=	0,00	m SB	TRIM=	0,00	m FORWARDS	
	LIST in degrees=	0,00	degr SB	TRIM in degrees=	0,00	degr FORWARDS	
	MIN FREEBOARD IS :	1,9045	m	DRAUGHT FORE =	4,19 m	AFT =	4,19 m
	INCL LIST & TRIM			FREEBOARD FORE =	1,90 m	AFT =	1,90 m
LC4	LIST=	0,01	m SB	TRIM=	0,03	m FORWARDS	
	LIST in degrees=	0,01	degr SB	TRIM in degrees=	0,02	degr FORWARDS	
	MIN FREEBOARD IS :	1,8823	m	DRAUGHT FORE =	4,21 m	AFT =	4,18 m
	INCL LIST & TRIM			FREEBOARD FORE =	1,89 m	AFT =	1,92 m

Maximum static trim due to wind = 30mm = 0.02 degree

Maximum static list due to wind = 14 mm = 0.01 degree

7.5. RECOMMENDATIONS

The calculated static barge heel/trim due to wind loads is within the assumed 1% oblique limit as per section 6.11. Stability of the towers is checked in section 8.4. However, this does not consider additional displacement and accelerations induced by waves, dynamic (gust) winds, etc.

To get more accurate understanding of the motions induced by the environment, detailed calculations of are to be conducted (eg. MOSES). These calculate include:
-(dynamic) wind loads
-wave heights
-wave periods
-currents
-accelerations

8. MEGA JACK CALCULATION

8.1. JACKING CONFIGURATION

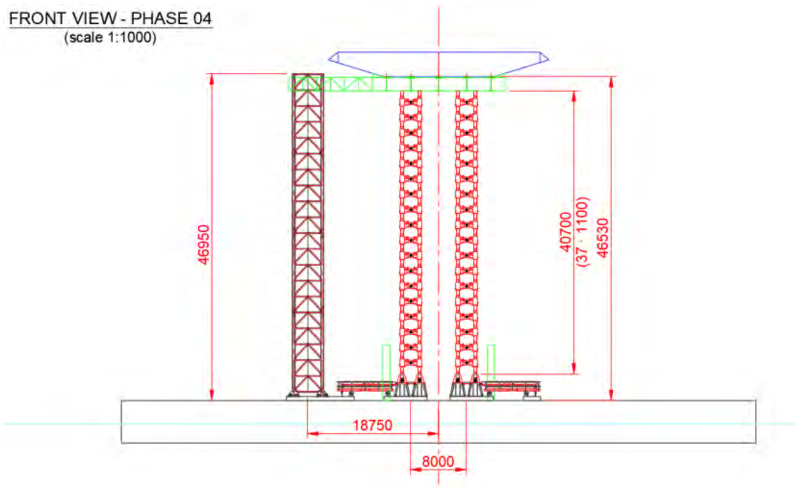
This calculation is concerned with the jack up operations of the Bridge Section by using ALE's Mega Jack System. The purpose of this calculation is to determine and check the following items:

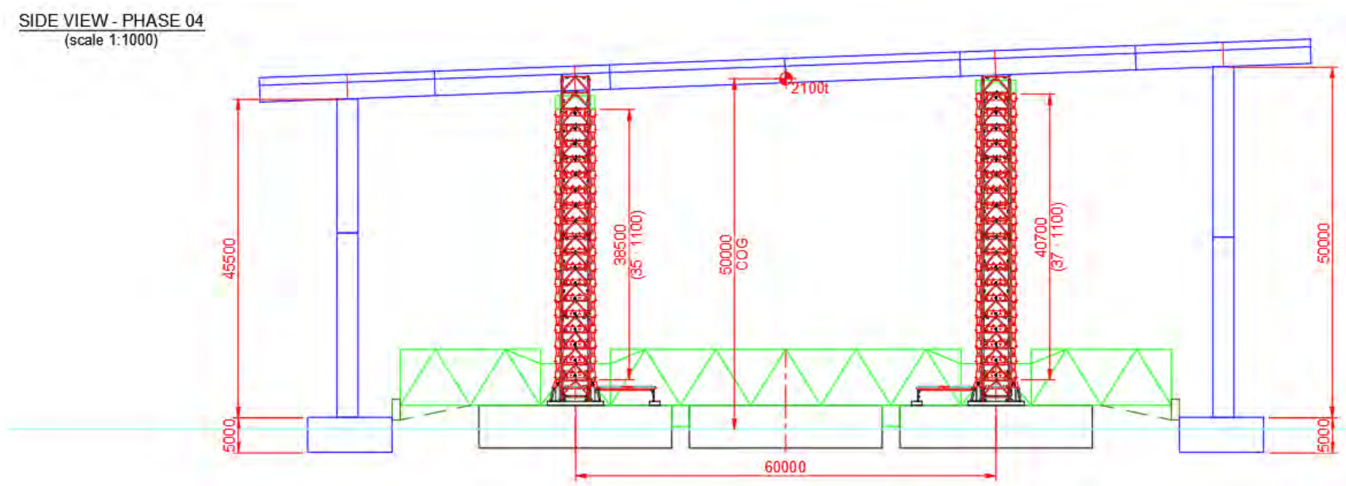
- Approximation of Mega Jack System (MJS) loadings
- Approximation of the occurring ground bearing pressure (G.B.P.) during jacking directly underneath the jacking bases. (loads will be spread by steel load spreading onto barge deck/grillage, t.b.d.).

The bridge is to be assembled on a skidding system to allow translation, correction and assembly of the Bridge Sections. The maximum required jacking height is determined by the installation height at its final supporting pillars (the final jacking heights). ALE will perform the jack-up operation using the ALE Mega Jack System (MJS) with a nominal capacity of 5.200t per jacking tower.

For the jack up ALE will use the following set-up:

4 No. single jacking tower in 5,0 x 2,5m configuration (4 x 4 pcs = 16 bases)





Dimensions based on DRW-AB016101-001 [Ref.B01]

8.3. LOADS

These calculations present the loads that may occur during the jack up operation, depending on the weight of the Bridge, position of COG, COG envelope and the horizontal forces, occurring during the jack up operation.

Gravity load
Load case : Bridge weight = 2100t (base case, provided weight)

Additional COG envelope (2000 x 1000 mm)
For additional contingency within this feasibility calculation, an COG envelope is introduced by ALE, dimensions: ±1000mm in X-direction and ±500mm in Y-direction
The envelope is considered for both load cases.

Horizontal loads
Wind loads as per §6.10.
Misalignment as per §6.11.

Vertical Strand Jack within jacking tower
Optionally, the vertical load on the jacking towers can be increased by installing strand jacks, one in each tower. The vertically installed strand jacks generate additional vertical load on the system, which leads to increased stability of the system.

The strand jacks that can be used by ALE have capacities of 70t, 200t, 500t and 850t.

Since operation of the MJS jacking system and strand jack are fully computerised, it is possible to obtain constant additional tension by the strand jack during jack up.

The strand jack is connected from a steel structure connected to the jacking bases of the MJS system to the starter beam (interface beam between jacking beams and bridge). It only generates internal loads in the jacking system. Therefore, no additional loads are generated on the barge deck.

8.4. RESULTS

Stability of the jacking system is calculated per:

Appendix E: MJS calculation - Load case 1 - 2100t (no strand jack)
Appendix F: MJS calculation - Load case 2 – 2100+ 800t (additional 200t strand jack per jacking tower)

For content of the MJS calculation sheet, see §7.6.

Jack loads
Each MJS tower comprises of 4 jacking bases.
The calculations that have been conducted check for minimum and maximum reaction corner loads.

Maximum loads:
Max. allowable corner stresses (jack loads)
In service: 1300 [t]
Out of service: 1900 [t]

Minimum loads:
Negative jack loads: Not allowed without additional technical measures
Indicate instability of the jacking system (=uplift of the jacking beams within the jacking towers).

A summary of the minimum and maximum jack loads within the jacking towers is provided below:

Load case 1

		P1	P2	P3	P4	
		Rv1 [t]	Rv2 [t]	Rv3 [t]	Rv4 [t]	
Operation	Maximum	229	229	229	299	<1300t
	Minimum	70	70	70	70	

Maximum utility of jack capacity:
Operational 0.18 OK

Load case 2

		P1	P2	P3	P4	
		Rv1 [t]	Rv2 [t]	Rv3 [t]	Rv [t]	
Operation	Maximum	297	297	297	297	<1300t
	Minimum	98	98	98	98	

Maximum utility of jack capacity:
Operational 0.25 OK

In the summary tables on the previous page, the minimum and maximum jack loads are listed.
These are the net. calculated loads, thus without safety or dynamic factors. Note that there is more capacity present in the system. If the weight is likely to in-/decrease, it is necessary to re-check MJS stability and foundation loads.

Load case 1
By calculation, the system has marginal own stability (16m/s wind speeds).

Load case 2
By calculation, the system has increased stability but this situation is not yet calculated for stand-by / out-of-service conditions, TBD.

8.5. RECOMMENDATIONS

Stability of the towers is checked in section 8.4, taking into account the stated max. oblique factor as per section 6.11. As proposed, additional vertical loads by strand jacks is preferred; minimum of 200t capacity strand jack for each MJS jacking tower.

To get more accurate understanding of the tower loads and reactions induced by the environment, detailed calculations of are to be conducted (eg. MOSES in combination with RFEM). These calculate include:
-accurate in- and out-of-service conditions.
-(dynamic) wind loads
-wave heights
-wave periods
-accelerations
-requirements for stability mast and vertical strand jack bracings (for in- and out-of service conditions)

8.6. MJS CALCULATION SHEET OVERVIEW

Regarding the MJS calculation sheet in the appendices (E-F), the following overview applies:

Page 1 of 6

- Deck geometries
- Jacking geometries
- COG envelope
- COW (center of wind)
- Wind loads
- General loads
- Summary of tower loads based on net. Weight

Page 2 of 6 – Loadings on P1

- Wind loadings
- Foundation loads
- Mega Jack system loads
- Mega Jack system corner loadings
- Mega Jack system dimensions/weights

Page 3 of 6 – Loadings on P2

- Wind loadings
- Foundation loads
- Mega Jack system loads
- Mega Jack system corner loadings
- Mega Jack system dimensions/weights

Page 4 of 6 – Loadings on P3

- Wind loadings
- Foundation loads
- Mega Jack system loads
- Mega Jack system corner loadings
- Mega Jack system dimensions/weights

Page 5 of 6 – Loadings on P4

- Wind loadings
- Foundation loads
- Mega Jack system loads
- Mega Jack system corner loadings
- Mega Jack system dimensions/weights

Page 6 of 6 – Loadings on P4

- Summary of single jack loads

9. CONCLUSION

Subject to the identified assumptions and starting points, the working methodology is considered as viable and realistic. Basic calculations show that loads are within equipment capacity and stability is sufficient.

Optimisation of the jacking and barge stability requirements are to be achieved during detailed engineering phase, considering the following:

-environmental conditions (eg. wind loads, sea state)
-combined COG of bridge and columns; potentially lower COG position
-approximation of item weights (eg. grillage)
-detailed stability check of jacking system in combination with stability mast system and vertical strand bracings

9.1. OVERALL RECOMMENDATIONS

- Stability
  Due to the relative low weight of the bridge structure, own stability of the jacking towers on full height is low on redundancy. To provide additional stability we have considered two stability mast, which provides guidance to the bridge and towers via a support/stability frame. The interactions with the towers (stiffness relation) and loads during out of service winds and barge motions is to be engineered further in detail, where a computer model needs to be created. This has not been included in this study.

- Positioning and connecting of the bridge legs (with/without pontoon) has not been included in this study. We recommend that attention is paid to the floating stability of these items.

- To prevent lateral movements of the barges, especially with jackup operation and with bridge deck at height, fixed mooring is recommended (hard fenders).

9.2. LOOKAHEAD DETAILED ENGINEERING

Below tables provide an overview of the expected scopes during the detailed engineering phases.

9.2.1. SKIDDING

No.	Description
1	To determine the required skid shoe arrangement for the handling and assembly of Bridge Sections
2	To calculate the predicted skid shoe loads during the skidding operation (GBP)
3	To calculate the required push pull capacity (propulsion system)
4	To determine skid track arrangement
5	To calculate reaction loads due to environmental conditions during the skidding operation

9.2.2. JACKING

No.	Description
1	Design and structural integrity check of Bridge Sections (local loading and global integrity).
2	Deflections / Displacements / Rotations of the Bridge section during various load cases (at support points)
3	To determine jacking arrangement, including stability masts / vertical strand jack requirements

4	Grillage design and integrity check based on skid shoe loads, barge loads, environmental loads, etc.
5	Structural integrity of provided vessels/barges during skidding and jacking
6	Determination and analysis of out of service conditions / stand by time during assembly of bridge sections / installation of vertical columns etc.
7	To determine maximum Trim / Heel of the barge during the operations
8	To determine maximum site environment conditions (in- and out-of-service)

9.2.3. BALLASTING

No.	Description
1	To calculate the required ballast for each stage of the skidding and jacking operations
2	To determine the requirement of temporary ballast system
3	To maintain minimal trim and heel throughout the skidding and jacking stages
4	To determine Quay Datum Levels and Water (Tide) Levels.
5	To investigate barge intact stability during the operation.
6	To calculate global bending moment and shear force checks of barge during the ballast stages
7	To determine required pump flow rate in every stage of operations

9.2.4. FENDERING AND MOORING

No.	Description
1	To perform quasi-static mooring analysis of the barge arrangement during the operations
2	To design mooring arrangement for each step of the operation
3	To determine requirements for mooring of floater (underneath vertical columns) and other related equipment
4	To calculate maximum line tensions and fender loads based provided environment forces
5	To determine Barge Fender Details (hard fender required).
6	To demine Mooring criteria and Bollard capacities

10. REFERENCE DOCUMENT LIST

10.1. ALE REFERENCE DOCUMENT LIST

REF.	CALCULATIONS	
A01	CAL-AB016101-002	Ballast Calculation
A02	CAL-AB016101-003	Mega Jack system Calculation – 2100t excl. vertical strand jack
A03	CAL-AB016101-004	Mega Jack system Calculation – 2100t incl. vertical strand jack
	DRAWINGS	
B01	DRW-AB016101-001	Jacking of bridge sections

11. APPENDICES

Documents attached for important references:

ALE Documents:

[Appendix A] Barge stability calculation – LC1
[Appendix B] Barge stability calculation – LC2
[Appendix C] Barge stability calculation – LC3
[Appendix D] Barge stability calculation – LC4
[Appendix E] MJS calculation - Load case 1 - 2100t (no strand jack)
[Appendix F] MJS calculation - Load case 2 – 2100+ 800t (additional 200t strand jack per jacking tower)

APPENDIX A - BARGE STABILITY CALCULATION – LC1

ALE SMARTER, SAFER, STRONGER

STABILITY OF PONTOONS		PROJECT NR.	: AB016101
DATE :	15/Aug/19	CLIENT	: Aker Solutions
TIME :	11:39:16	PROJECT	: Jacking of Bridge Sections

ALE Heavylift B.V.
Konijnenberg 68
4825 BD Breda
The Netherlands

Phone : + 31 (0) 76 57 15 240
Fax : + 31 (0) 76 58 75 084
E-mail : info@ale-heavylift.com
Internet : www.ale-heavylift.com

PARTICULARS OF THE PONTOON : **NAME OF PONTOON : UR98**

LENGTH	91,44	m
BEAM	82,30	m
DEPTH	6,10	m
EMPTY DRAUGHT	1,01	m
OWN WEIGHT	7002	ton
MAX.LOAD CAPACITY	27282	ton
NR.OF L.BULKHDS	4	nr
NR.OF TR.BULKHDS	6	nr

SITUATION: LC1 Pre ballast - phase 01 - low level (without wind loads)

TOTAL CARGO+R. WATER	23190	ton
COMB.C.O.G CARGO+R.WATER	-1,42	m BELOW DECK
COMB.C.O.G CARGO+R.WATER	0,00	m TO SB
COMB.C.O.G CARGO+R.WATER	0,00	m FORW..5 L
MEAN SUBMERSION	3,08	m
MEAN DRAUGHT	4,09	m
MEAN FREEBOARD	2,00	m
DISPLACEMENT	30192	m^3

INFO DISPLAY

STABILITY = OK !!

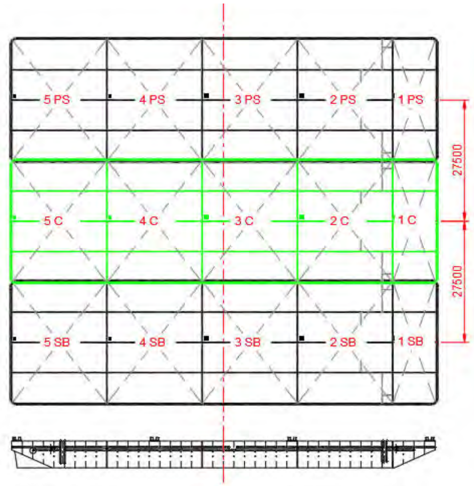
LIST = 0,00 m SB

TRIM = 0,00 m IN BOW

NAME CARGO	CARGO (TON)	C.O.G. (Trnsvr) +=SB in m -=PS in m	C.O.G.(Lngtdnl) +=forw.5L in m -=aft.5L in m	C.O.G. (H) +=ABOVE DECK -=BELOW DECK	C.O.G. (FULL) BALLAST TANKS BELOW DECK	% FILLED BALLAST TANKS	CAPACITY (T) BALLAST TANKS
Bridge section	2100,0	0,00	0,00	11,50			
Grillage / skidding beam (assumed)	1000,0	0,00	0,00	4,00			
Mast / MJS load spreading	500,0	0,00	0,00	1,00			
Stability mast (2 pcs, eccentric in Long.)	250,0	0,00	-18,75	25,00			
Mega jack system (assumed symmetrical)	400,0	0,00	0,00	3,50			
Ballast equipment (assumed symmetrical)	50,0	0,00	0,00	1,00			
Other equipment / etc.	250,0	0,00	0,00	1,00			
Tank No. 1 (PS)	1090,0	-27,50	40,17	-3,05	-2,92	100,00%	1090,0
Tank No. 1 (C)	1090,0	0,00	40,17	-3,05	-2,92	100,00%	1090,0
Tank No. 1 (SB)	1090,0	27,50	40,17	-3,05	-2,92	100,00%	1090,0
Tank No. 2 (PS)	2300,0	-27,50	26,25	-4,09	-3,05	65,94%	3488,0
Tank No. 2 (C)	0,0	0,00	26,25	-6,10	-3,05	0,00%	3488,0
Tank No. 2 (SB)	2300,0	27,50	26,25	-4,09	-3,05	65,94%	3488,0
Tank No. 3 (PS)	650,0	-27,50	5,70	-5,53	-3,05	18,64%	3488,0
Tank No. 3 (C)	0,0	0,00	5,70	-6,10	-3,05	0,00%	3488,0
Tank No. 3 (SB)	650,0	27,50	5,70	-5,53	-3,05	18,64%	3488,0
Tank No. 4 (PS)	650,0	-27,50	-14,86	-5,53	-3,05	18,64%	3488,0
Tank No. 4 (C)	0,0	0,00	-14,86	-6,10	-3,05	0,00%	3488,0
Tank No. 4 (SB)	650,0	27,50	-14,86	-5,53	-3,05	18,64%	3488,0
Tank No. 5 (PS)	2500,0	-27,50	-34,22	-3,51	-2,92	84,75%	2950,0
Tank No. 5 (C)	2525,0	0,00	-34,22	-3,49	-2,92	85,59%	2950,0
Tank No. 5 (SB)	2500,0	27,50	-34,22	-3,51	-2,92	84,75%	2950,0
Pump room	645,0	0,00	34,12				
TOTAL OF CARGO	23190,0						
RESTWATER IN TANKS	0,0	0,10					

MF=	133,64	m		MFlong=	164,98	m
FK=	2,17	m		FK	2,17	m
MK=	135,80	m		MKlong=	167,15	m
GK=	4,37	m		GK	4,37	m
MG=	131,43	m		MGlong=	162,78	m
MG red.free water	5,35	m		MGl red.free water	2,60	m
MG reduced	126,09	m		MG l reduced	160,18	m
EXCEN.CARGMOM.=	0	t*m		EXCEN.CARGMOM.=	12,3	t*m
WINDMOMENT=	0,00	t*m		WINDMOMENT=	0,00	t*m
TAN @=	0,00	rad		TAN ls=	0,00	rad
LIST=	0,00	m SB		TRIM=	0,00	m FORWARDS
LIST in degrees=	0,00	degr SB		TRIM in degrees=	0,00	degr FORWARDS

MIN FREEBOARD IS :	2,0042 m	DRAUGHT FORE =	4,09 m	AFT =	4,09 m
INCL LIST & TRIM		FREEBOARD FORE =	2,00 m	AFT =	2,00 m



WINDFORCE		Bf
WINDSPEED	16,00	m/sec
LENGTH OF CARGO	31,60	m
HEIGHT OF CARGO	3,50	m
BEAM OF CARGO	150,00	m
HEIGHT OF SUPPORT	50,00	m
SHAPE FACTOR	2,00	
WINDAREA CARGO TRANV	150,00	m^2
WINDF.ON CARGO TRANS		TON
WINDAREA CARGO LONG	525,00	m^2
WINDF.ON CARGO LONG		TON

	AFT		FWD	
Draught:	**4092**	**mm**	**4092**	**mm**
Freeboard:	**2004**	**mm**	**2004**	**mm**
Freeboard load-out:	**2030**	**mm**	**2030**	**mm**
Deviation:	**-26**	**mm**	**-26**	**mm**
	Phase			

APPENDIX B - BARGE STABILITY CALCULATION – LC2

SMARTER, SAFER, STRONGER

STABILITY OF PONTOONS		**PROJECT NR.**	**: AB016101**
DATE	: 15/Aug/19	**CLIENT**	**: Aker Solutions**
TIME	: 11:39:16	**PROJECT**	**: Jacking of Bridge Sections**

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4825 BD Breda
The Netherlands

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E-mail : info@ale-heavylift.com
Internet : www.ale-heavylift.com

PARTICULARS OF THE PONTOON : **NAME OF PONTOON : UR98**

LENGTH	91,44	m
BEAM	82,30	m
DEPTH	6,10	m
EMPTY DRAUGHT	1,01	m
OWN WEIGHT	7002	ton
MAX.LOAD CAPACITY	27282	ton
NR.OF L.BULKHDS	4	nr
NR.OF TR.BULKHDS	6	nr

SITUATION: LC2 Pre ballast - phase 01 - low level (without wind loads)

TOTAL CARGO+R. WATER	23190	ton
COMB.C.O.G CARGO+R.WATER	-1,42	m BELOW DECK
COMB.C.O.G CARGO+R.WATER	0,00	m TO SB
COMB.C.O.G CARGO+R.WATER	0,00	m FORW..5 L
MEAN SUBMERSION	3,08	m
MEAN DRAUGHT	4,09	m
MEAN FREEBOARD	2,00	m
DISPLACEMENT	30192	m^3

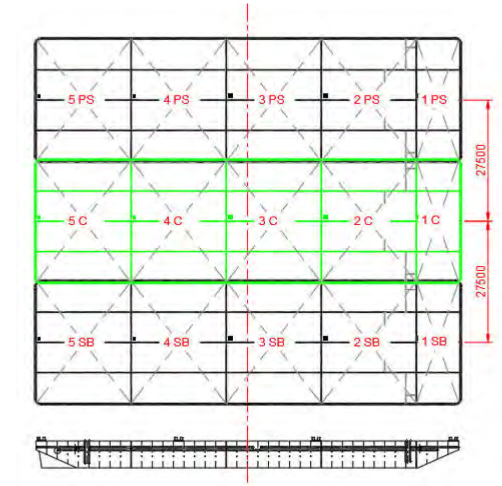
INFO DISPLAY		
STABILITY = OK !!		
LIST =	**0,01**	**m SB**
TRIM =	**0,01**	**m IN BOW**

NAME CARGO	**CARGO (TON)**	**C.O.G. (Trnsvr) +=SB in m -=PS in m**	**C.O.G.(Lngtdnl) +=forw.5L in m -=aft.5L in m**	**C.O.G. (H) +=ABOVE DECK -=BELOW DECK**	**C.O.G. (FULL) BALLAST TANKS BELOW DECK**	**% FILLED BALLAST TANKS**	**CAPACITY (T) BALLAST TANKS**
Bridge section	2100,0	0,00	0,00	11,50			
Grillage / skidding beam (assumed)	1000,0	0,00	0,00	4,00			
Mast / MJS load spreading	500,0	0,00	0,00	1,00			
Stability mast (2 pcs, eccentric in Long.)	250,0	0,00	-18,75	25,00			
Mega jack system (assumed symmetrical)	400,0	0,00	0,00	3,50			
Ballast equipment (assumed symmetrical)	50,0	0,00	0,00	1,00			
Other equipment / etc.	250,0	0,00	0,00	1,00			
Tank No. 1 (PS)	1090,0	-27,50	40,17	-3,05	-2,92	100,00%	1090,0
Tank No. 1 (C)	1090,0	0,00	40,17	-3,05	-2,92	100,00%	1090,0
Tank No. 1 (SB)	1090,0	27,50	40,17	-3,05	-2,92	100,00%	1090,0
Tank No. 2 (PS)	2300,0	-27,50	26,25	-4,09	-3,05	65,94%	3488,0
Tank No. 2 (C)	0,0	0,00	26,25	-6,10	-3,05	0,00%	3488,0
Tank No. 2 (SB)	2300,0	27,50	26,25	-4,09	-3,05	65,94%	3488,0
Tank No. 3 (PS)	650,0	-27,50	5,70	-5,53	-3,05	18,64%	3488,0
Tank No. 3 (C)	0,0	0,00	5,70	-6,10	-3,05	0,00%	3488,0
Tank No. 3 (SB)	650,0	27,50	5,70	-5,53	-3,05	18,64%	3488,0
Tank No. 4 (PS)	650,0	-27,50	-14,86	-5,53	-3,05	18,64%	3488,0
Tank No. 4 (C)	0,0	0,00	-14,86	-6,10	-3,05	0,00%	3488,0
Tank No. 4 (SB)	650,0	27,50	-14,86	-5,53	-3,05	18,64%	3488,0
Tank No. 5 (PS)	2500,0	-27,50	-34,22	-3,51	-2,92	84,75%	2950,0
Tank No. 5 (C)	2525,0	0,00	-34,22	-3,49	-2,92	85,59%	2950,0
Tank No. 5 (SB)	2500,0	27,50	-34,22	-3,51	-2,92	84,75%	2950,0
Pump room	645,0	0,00	34,12				
TOTAL OF CARGO	23190,0						
RESTWATER IN TANKS	0,0	0,10					

MF=	133,64	m
FK=	2,17	m
MK=	135,80	m
GK=	4,37	m
MG=	131,43	m
MG red.free water	5,35	m
MG reduced	**126,09**	m
EXCEN.CARGMOM.=	0	t*m
WINDMOMENT=	253,10	t*m
TAN @=	0,00	rad
LIST=	0,01	m SB
LIST in degrees=	0,00	degr SB
MIN FREEBOARD IS :	1,9950	m
INCL LIST & TRIM		

MFlong=	164,98	m
FK	2,17	m
MKlong=	167,15	m
GK	4,37	m
MGlong=	162,78	m
MGl red.free water	2,60	m
MG l reduced	**160,18**	m
EXCEN.CARGMOM.=	12,3	t*m
WINDMOMENT=	682,70	t*m
TAN Is=	0,00	rad
TRIM=	0,01	m FORWARDS
TRIM in degrees=	0,01	degr FORWARDS

DRAUGHT FORE =	4,10	m	AFT =	4,09	m
FREEBOARD FORE =	2,00	m	AFT =	2,01	m



WINDFORCE		Bf
WINDSPEED	16,00	m/sec
LENGTH OF CARGO	31,60	m
HEIGHT OF CARGO	3,50	m
BEAM OF CARGO	150,00	m
HEIGHT OF SUPPORT	50,00	m
SHAPE FACTOR	2,00	
WINDAREA CARGO TRANV	150,00	m^2
WINDF.ON CARGO TRANS		TON
WINDAREA CARGO LONG	525,00	m^2
WINDF.ON CARGO LONG		TON

	AFT		FWD	
Draught:	**4085**	**mm**	**4098**	**mm**
Freeboard:	**2011**	**mm**	**1998**	**mm**
Freeboard load-out:	**2030**	**mm**	**2030**	**mm**
Deviation:	**-19**	**mm**	**-32**	**mm**

Phase

APPENDIX C - BARGE STABILITY CALCULATION – LC3

ALE
SMARTER, SAFER, STRONGER

STABILITY OF PONTOONS		PROJECT NR.	: AB016101
DATE	: 15/Aug/19	CLIENT	: Aker Solutions
TIME	: 11:39:16	PROJECT	: Jacking of Bridge Sections

ALE Heavylift B.V.
Konijnenberg 68
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PARTICULARS OF THE PONTOON : **NAME OF PONTOON : UR98**

LENGTH	91,44	m
BEAM	82,30	m
DEPTH	6,10	m
EMPTY DRAUGHT	1,01	m
OWN WEIGHT	7002	ton
MAX.LOAD CAPACITY	27282	ton
NR.OF L.BULKHDS	4	nr
NR.OF TR.BULKHDS	6	nr

SITUATION: LC3 Jack up - excl. wind loads

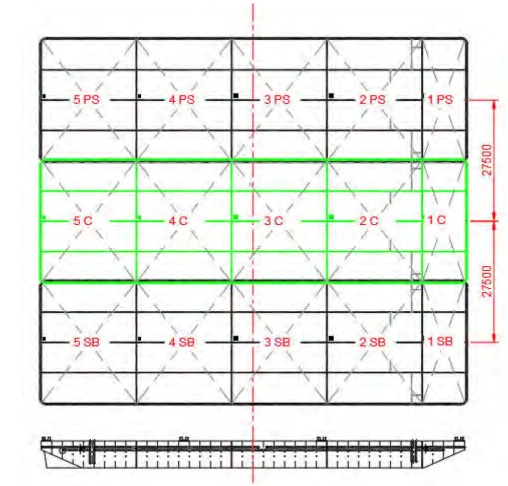
TOTAL CARGO+R. WATER	23940	ton
COMB.C.O.G CARGO+R.WATER	3,15	m ABOVE DECK
COMB.C.O.G CARGO+R.WATER	0,00	m TO SB
COMB.C.O.G CARGO+R.WATER	0,00	m FORW..5 L
MEAN SUBMERSION	3,18	m
MEAN DRAUGHT	4,19	m
MEAN FREEBOARD	1,90	m
DISPLACEMENT	30942	m^3

INFO DISPLAY			
STABILITY = OK !!			
LIST =	0,00	m	SB
TRIM =	0,00	m IN	BOW

NAME CARGO	CARGO (TON)	C.O.G. (Trnsvr) +=SB in m -=PS in m	C.O.G.(Lngtdnl) +=forw.5L in m -=aft.5L in m	C.O.G. (H) +=ABOVE DECK -=BELOW DECK	C.O.G. (FULL) BALLAST TANKS BELOW DECK	% FILLED BALLAST TANKS	CAPACITY (T) BALLAST TANKS
Bridge section	2100,0	0,00	0,00	50,00			
Grillage / skidding beam (assumed)	1000,0	0,00	0,00	4,00			
Mast / MJS load spreading	500,0	0,00	0,00	1,00			
Stability mast (2 pcs, eccentric in Long.)	250,0	0,00	-18,75	25,00			
Mega jack system (assumed symmetrical)	1150,0	0,00	0,00	25,00			
Ballast equipment (assumed symmetrical)	50,0	0,00	0,00	1,00			
Other equipment / etc.	250,0	0,00	0,00	1,00			
Tank No. 1 (PS)	1090,0	-27,50	40,17	-3,05	-2,92	100,00%	1090,0
Tank No. 1 (C)	1090,0	0,00	40,17	-3,05	-2,92	100,00%	1090,0
Tank No. 1 (SB)	1090,0	27,50	40,17	-3,05	-2,92	100,00%	1090,0
Tank No. 2 (PS)	2300,0	-27,50	26,25	-4,09	-3,05	65,94%	3488,0
Tank No. 2 (C)	0,0	0,00	26,25	-6,10	-3,05	0,00%	3488,0
Tank No. 2 (SB)	2300,0	27,50	26,25	-4,09	-3,05	65,94%	3488,0
Tank No. 3 (PS)	650,0	-27,50	5,70	-5,53	-3,05	18,64%	3488,0
Tank No. 3 (C)	0,0	0,00	5,70	-6,10	-3,05	0,00%	3488,0
Tank No. 3 (SB)	650,0	27,50	5,70	-5,53	-3,05	18,64%	3488,0
Tank No. 4 (PS)	650,0	-27,50	-14,86	-5,53	-3,05	18,64%	3488,0
Tank No. 4 (C)	0,0	0,00	-14,86	-6,10	-3,05	0,00%	3488,0
Tank No. 4 (SB)	650,0	27,50	-14,86	-5,53	-3,05	18,64%	3488,0
Tank No. 5 (PS)	2500,0	-27,50	-34,22	-3,51	-2,92	84,75%	2950,0
Tank No. 5 (C)	2525,0	0,00	-34,22	-3,49	-2,92	85,59%	2950,0
Tank No. 5 (SB)	2500,0	27,50	-34,22	-3,51	-2,92	84,75%	2950,0
Pump room	645,0	0,00	34,12				
TOTAL OF CARGO	23940,0						
RESTWATER IN TANKS	0,0	0,10					

MF=	130,40	m	MFlong=	160,98	m
FK=	2,22	m	FK	2,22	m
MK=	132,62	m	MKlong=	163,20	m
GK=	7,91	m	GK	7,91	m
MG=	124,71	m	MGlong=	155,30	m
MG red.free water	5,22	m	MGl red.free water	2,54	m
MG reduced	119,49	m	MG l reduced	152,75	m
EXCEN.CARGMOM.=	0	t*m	EXCEN.CARGMOM.=	12,3	t*m
WINDMOMENT=	0,00	t*m	WINDMOMENT=	0,00	t*m
TAN @=	0,00	rad	TAN Is=	0,00	rad
LIST=	0,00	m SB	TRIM=	0,00	m FORWARDS
LIST in degrees=	0,00	degr SB	TRIM in degrees=	0,00	degr FORWARDS

MIN FREEBOARD IS :	1,9045 m	DRAUGHT FORE =	4,19	m	AFT =	4,19 m
INCL LIST & TRIM		FREEBOARD FORE =	1,90	m	AFT =	1,90 m



WINDFORCE		Bf
WINDSPEED	16,00	m/sec
LENGTH OF CARGO	31,60	m
HEIGHT OF CARGO	3,50	m
BEAM OF CARGO	150,00	m
HEIGHT OF SUPPORT	50,00	m
SHAPE FACTOR	2,00	
WINDAREA CARGO TRANV	150,00	m^2
WINDF.ON CARGO TRANS		TON
WINDAREA CARGO LONG	525,00	m^2
WINDF.ON CARGO LONG		TON

	AFT		FWD	
Draught:	4191	mm	4191	mm
Freeboard:	1905	mm	1905	mm
Freeboard load-out:	2030	mm	2030	mm
Deviation:	-125	mm	-125	mm
	Phase			

APPENDIX D - BARGE STABILITY CALCULATION – LC4

ALE SMARTER, SAFER, STRONGER	**STABILITY OF PONTOONS** DATE : 15/Aug/19 TIME : 11:39:16	**PROJECT NR.** : **AB016101** **CLIENT** : **Aker Solutions** **PROJECT** : **Jacking of Bridge Sections**	

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PARTICULARS OF THE PONTOON : | **NAME OF PONTOON : UR98**

LENGTH	91,44	m
BEAM	82,30	m
DEPTH	6,10	m
EMPTY DRAUGHT	1,01	m
OWN WEIGHT	7002	ton
MAX.LOAD CAPACITY	27282	ton
NR.OF L.BULKHDS	4	nr
NR.OF TR.BULKHDS	6	nr

SITUATION: LC4 Jack up - excl. wind loads

TOTAL CARGO+R. WATER	23940	ton
COMB.C.O.G CARGO+R.WATER	3,15	m ABOVE DECK
COMB.C.O.G CARGO+R.WATER	0,00	m TO SB
COMB.C.O.G CARGO+R.WATER	0,00	m FORW..5 L
MEAN SUBMERSION	3,18	m
MEAN DRAUGHT	4,19	m
MEAN FREEBOARD	1,90	m
DISPLACEMENT	30942	m^3

INFO DISPLAY
STABILITY = OK !!

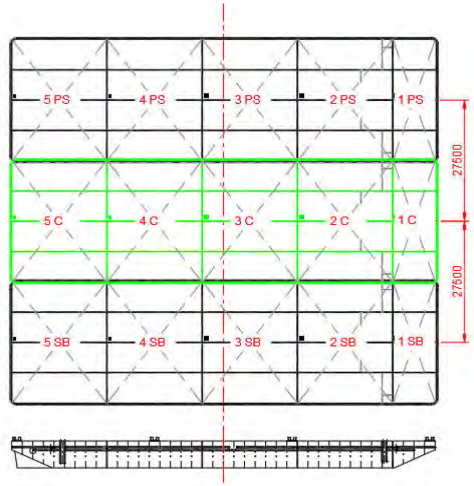
LIST =	**0,01**	**m SB**
TRIM =	**0,03**	**m IN BOW**

NAME CARGO	**CARGO (TON)**	**C.O.G. (Trnsvr)** +=SB in m -=PS in m	**C.O.G.(Lngtdnl)** +=forw.5L in m -=aft.5L in m	**C.O.G. (H)** +=ABOVE DECK -=BELOW DECK	**C.O.G. (FULL)** BALLAST TANKS BELOW DECK	**% FILLED** BALLAST TANKS	**CAPACITY (T)** BALLAST TANKS
Bridge section	2100,0	0,00	0,00	50,00			
Grillage / skidding beam (assumed)	1000,0	0,00	0,00	4,00			
Mast / MJS load spreading	500,0	0,00	0,00	1,00			
Stability mast (2 pcs, eccentric in Long.)	250,0	0,00	-18,75	25,00			
Mega jack system (assumed symmetrical)	1150,0	0,00	0,00	25,00			
Ballast equipment (assumed symmetrical)	50,0	0,00	0,00	1,00			
Other equipment / etc.	250,0	0,00	0,00	1,00			
Tank No. 1 (PS)	1090,0	-27,50	40,17	-3,05	-2,92	100,00%	1090,0
Tank No. 1 (C)	1090,0	0,00	40,17	-3,05	-2,92	100,00%	1090,0
Tank No. 1 (SB)	1090,0	27,50	40,17	-3,05	-2,92	100,00%	1090,0
Tank No. 2 (PS)	2300,0	-27,50	26,25	-4,09	-3,05	65,94%	3488,0
Tank No. 2 (C)	0,0	0,00	26,25	-6,10	-3,05	0,00%	3488,0
Tank No. 2 (SB)	2300,0	27,50	26,25	-4,09	-3,05	65,94%	3488,0
Tank No. 3 (PS)	650,0	-27,50	5,70	-5,53	-3,05	18,64%	3488,0
Tank No. 3 (C)	0,0	0,00	5,70	-6,10	-3,05	0,00%	3488,0
Tank No. 3 (SB)	650,0	27,50	5,70	-5,53	-3,05	18,64%	3488,0
Tank No. 4 (PS)	650,0	-27,50	-14,86	-5,53	-3,05	18,64%	3488,0
Tank No. 4 (C)	0,0	0,00	-14,86	-6,10	-3,05	0,00%	3488,0
Tank No. 4 (SB)	650,0	27,50	-14,86	-5,53	-3,05	18,64%	3488,0
Tank No. 5 (PS)	2500,0	-27,50	-34,22	-3,51	-2,92	84,75%	2950,0
Tank No. 5 (C)	2525,0	0,00	-34,22	-3,49	-2,92	85,59%	2950,0
Tank No. 5 (SB)	2500,0	27,50	-34,22	-3,51	-2,92	84,75%	2950,0
Pump room	645,0	0,00	34,12				
TOTAL OF CARGO	23940,0						
RESTWATER IN TANKS	0,0	0,10					

MF=	130,40	m
FK=	2,22	m
MK=	132,62	m
GK=	7,91	m
MG=	124,71	m
MG red.free water	5,22	m
MG reduced	**119,49**	m
EXCEN.CARGMOM.=	0	t*m
WINDMOMENT=	650,00	t*m
TAN @=	0,00	rad
LIST=	0,014	m SB
LIST in degrees=	0,01	degr SB
MIN FREEBOARD IS :	1,8823	m
INCL LIST & TRIM		

MFlong=	160,98	m
FK	2,22	m
MKlong=	163,20	m
GK	7,91	m
MGlong=	155,30	m
MGl red.free water	2,54	m
MG l reduced	**152,75**	m
EXCEN.CARGMOM.=	12,3	t*m
WINDMOMENT=	1548,10	t*m
TAN Is=	0,00	rad
TRIM=	0,03	m FORWARDS
TRIM in degrees=	0,02	degr FORWARDS

DRAUGHT FORE =	4,21	m	AFT =	4,18 m
FREEBOARD FORE =	1,89	m	AFT =	1,92 m



WINDFORCE		Bf
WINDSPEED	16,00	m/sec
LENGTH OF CARGO	31,60	m
HEIGHT OF CARGO	3,50	m
BEAM OF CARGO	150,00	m
HEIGHT OF SUPPORT	50,00	m
SHAPE FACTOR	2,00	
WINDAREA CARGO TRANV	150,00	m^2
WINDF.ON CARGO TRANS		TON
WINDAREA CARGO LONG	525,00	m^2
WINDF.ON CARGO LONG		TON

	AFT		FWD	
Draught:	**4176**	**mm**	**4206**	**mm**
Freeboard:	**1920**	**mm**	**1890**	**mm**
Freeboard load-out:	**2030**	**mm**	**2030**	**mm**
Deviation:	**-110**	**mm**	**-140**	**mm**
	Phase			

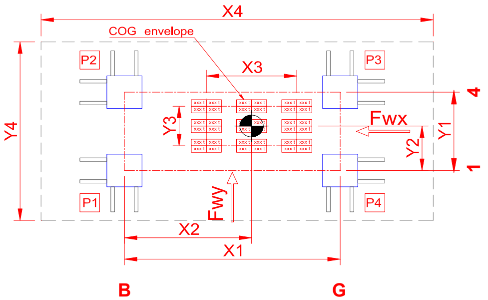
APPENDIX E – MEGA JACK STABILITY CALCULATION – LC1 WITHOUT STRAND JACKS

	Project :	Jacking of Bridge Sections	No:	AB016101	Dept :	ALE Heavylift		
ALE SMARTER, SAFER, STRONGER	Project Title :	Bjørnafjord Prosjektet			Initials :	RM		
		Mega Jack System General loadings - without vertical strand jacks			Date :	15/aug/19		
		Jacking to 46 mtrs.			Rev :	A		based on rev 2.4

Bridge geometries		
Bridge weight [t]		2100
Width		
x1 [mm]		60000
x2 [mm]	to CoG	30000
Length		
y1 [mm]		8000
y2 [mm]	to CoG	4000
Envelope		
x3 [mm]		2000
y3 [mm]		1000
Overal dimensions lxwxh		
x4 [mm]		150000
y4 [mm]		31600
z1 [mm]		3500
Dimensions to CoW		
x5 [mm]		30000
y5 [mm]		4000
z2 [mm]		1750
z3 [mm]		47750
Jacking geometries		
Footstructure height [mm]		3535
z4 [mm]	Jacking height	46000
Foundation points [#]		4
Tower type 1		
Weight starterbeam 1 [t]	**4 points**	25
Height starterbeam 1 [mm]		2050
z5 [mm]	Height jacking beams	22000
No. Layers		36
Weight tower type 1 [t]		192
Tower type 2		
Weight starterbeam 2 [t]	**4 points**	25
Height starterbeam 2 [mm]		2050
z5 [mm]	Height jacking beams	22000
No. Layers		36
Weight tower type 2 [t]		192
Missallignment		
misalignment factor height [m/m]		0,010
misalignment factor width [m/m]		0,001
Maximum Load per Jacking Point		
Max load operational [t]		1300
Max load out-of-service [t]		1500
Max load extreme [t]		1900

Vertical loads per jacking point [t]:

Deviation of the corner loads depending on the given envelope



	P1	P2	P3	P4	Extreme
	B1	B4	G4	G1	
	Fv1	Fv2	Fv3	Fv4	Fv
Maximum	610	610	610	610	610
Minimum	444	444	444	444	444

COG envelope with loading on top of each jacking point:

610	571	591	591	571	**610**
475	444	459	459	444	475
543	508	525	525	508	543
543	508	525	525	508	543
475	444	459	459	444	475
610	571	591	591	571	**610**

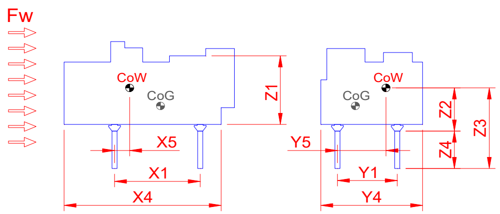
Numbering of corners

B4	G4
B1	G1

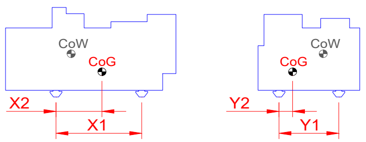
Weights / Loads are in metric tonnes [t]

Wind Loads		
Estimation of the surfaces		
Aside [m2]		111
Afront [m2]		525
cw [-]		1,00
weather condition		
q1 [N/m2]	operational	237
q2 [N/m2]	out of service	1352
q3 [N/m2]	extreme	1352
Corresponding windspeeds		
v1 [m/s]	operational	16
v2 [m/s]	out of service	na
v3 [m/s]	extreme	na
Wind forces*		
Fw1x [kN]	operational	48
Fw1y [kN]	operational	264
Fw2x [kN]	out of service	0
Fw2y [kN]	out of service	0
Fw3x [kN]	extreme	0
Fw3y [kN]	extreme	0
Gravity acceleration		
G		9,81

Boundary conditions:
Rigid structure, Towers absorb an equal amount of wind



0,2%
1,3%
0,0%
0,0%
0,0%
0,0%



input taken from wind calculation CAL-AB016101-001

only 16 m/s wind speed considered, in service

General loads **Per foundation**

Moment on foundation due to wind

		Operational	Out of service	Extreme	
Mw-x	(x-direction)	56	0	0	[tm]
Mw-y	(y-direction)	309	0	0	[tm]

Additional load effect due to wind

		Operational	Out of service	Extreme	
Rwx	(x-direction)	2	0	0	[t]
Rwy	(y-direction)	80	0	0	[t]

Horizontal load on foundation due to wind

		Operational	Out of service	Extreme	
Fx	(x-direction)	1	0	0	[t]
Fy	(y-direction)	7	0	0	[t]

Correction factor per line due to CoW

	for Fwx		for Fwy	
line	A	D	2	7
percentage	100%	100%	100%	100%

Jacking point P1 / B1

Jack point/foundation

Type of tower	1
Number of jacks	4
Stability base x-direction	5000
Stability base y-direction	2500
Min Jacks/stability point	2

Maxima per Jacking Point

Max. vertical load	303	[t]
Max. foundation pressure	63	[t/m²]
Max horizontal load in x-direction	0	[t]
Max horizontal load in y-direction	0	[t]

Interface to deck			Correction factors Jacking point P1 / B1		
				for Fwx	for Fwy
X	5000	**2,00**	line	A	2
Y	2500	**2,00**	percentage	100%	100%

Moments [tm] (corrected)

		Mm-x	Mm-y
Misalignment		252	258
Wind		Mw-x	Mw-y
	Operational	56	309
	Out of service	0	0
	Extreme	0	0

Maximum Vertical Load

Overall maximum jacking point foundation loads							
Wind	Loads [t]					Moment [tm]	
	Fv1	Fm	Rwx	Rwy	Max	Mx	My
Operational	610	192	2	80	883	280	413
Out of service	610	192	0	0	802	252	258
Extreme	610	192	0	0	802	252	258

Maximum single jackload			
(Wind X-direction)		(Wind Y-direction)	
Max	Min	Max	Min
229	173	303	138
226	175	252	149
226	175	252	149

	Mm-x	Mm-y
Misalignment	184	188

Minimum Vertical Load

Overall minimum jacking point foundation loads							
Wind	Loads [t]					Moment [tm]	
	Fv1	Fm	Rwx	Rwy	Min	Mx	My
Operational	444	192	2	80	556	212	342
Out of service	444	192	0	0	636	184	188
Extreme	444	192	0	0	636	184	188

Minimum single jackload			
(Wind X-direction)		(Wind Y-direction)	
Max	Min	Max	Min
180	137	207	70
177	141	197	121
177	141	197	121

Jacking point P1 / B1 Maximum single jackload (Wind X-direction)

Operation			173	173			804
			229	229			
Out of service			175	175			802
			226	226			
Extreme			175	175			802
			226	226			

Jacking point P1 / B1 Maximum single jackload (Wind Y-direction)

Operation			138	303			883
			138	303			
Out of service			149	252			802
			149	252			
Extreme			149	252			802
			149	252			

Jacking point P1 / B1 Minimum single jackload (Wind X-direction)

Operation			137	137			634
			180	180			
Out of service			141	141			636
			177	177			
Extreme			141	141			636
			177	177			

Jacking point P1 / B1 Minimum single jackload (Wind Y-direction)

Operation			70	207			556
			70	207			
Out of service			121	197			636
			121	197			
Extreme			121	197			636
			121	197			

Jacking point P2 / B4

Jack point/foundation

Type of tower	1
Number of jacks	4
Stability base x-direction	5000
Stability base y-direction	2500
Min Jacks/stability point	2

Maxima per Jacking Point

Max. vertical load	303 [t]
Max. foundation pressure	63 [t/m²]
Max horizontal load in x-direction	0 [t]
Max horizontal load in y-direction	0 [t]

Interface to deck		
X	5000	2,00
Y	2500	2,00

Correction factors Jacking point P2 / B4		
	for Fwx	for Fwy
line	D	2
percentage	100%	100%

Moments [tm] (corrected)

		Mm-x	Mm-y
Misalignment		252	258
Wind		Mw-x	Mw-y
	Operational	56	309
	Out of service	0	0
	Extreme	0	0

Maximum Vertical Load

Overall maximum jacking point foundation loads							
Wind	Loads [t]					Moment [tm]	
	Fv2	Fm	Rwx	Rwy	Max	Mx	My
Operational	610	192	2	80	883	280	413
Out of service	610	192	0	0	802	252	258
Extreme	610	192	0	0	802	252	258

Maximum single jackload			
(Wind X-direction)		(Wind Y-direction)	
Max	Min	Max	Min
229	173	303	138
226	175	252	149
226	175	252	149

	Mm-x	Mm-y
Misalignment	184	188

Minimum Vertical Load

Overall minimum jacking point foundation loads							
Wind	Loads [t]					Moment [tm]	
	Fv2	Fm	Rwx	Rwy	Min	Mx	My
Operational	444	192	2	80	556	212	342
Out of service	444	192	0	0	636	184	188
Extreme	444	192	0	0	636	184	188

Minimum single jackload			
(Wind X-direction)		(Wind Y-direction)	
Max	Min	Max	Min
180	137	207	70
177	141	197	121
177	141	197	121

Jacking point P2 / B4 Maximum single jackload (Wind X-direction)

Operation			173	173			804
			229	229			
Out of service			175	175			802
			226	226			
Extreme			175	175			802
			226	226			

Jacking point P2 / B4 Maximum single jackload (Wind Y-direction)

Operation			138	303			883
			138	303			
Out of service			149	252			802
			149	252			
Extreme			149	252			802
			149	252			

Jacking point P2 / B4 Minimum single jackload (Wind X-direction)

Operation			137	137			634
			180	180			
Out of service			141	141			636
			177	177			
Extreme			141	141			636
			177	177			

Jacking point P2 / B4 Minimum single jackload (Wind Y-direction)

Operation			70	207			556
			70	207			
Out of service			121	197			636
			121	197			
Extreme			121	197			636
			121	197			

Jacking point P3 / G4

Jack point/foundation

Type of tower	1
Number of jacks	4
Stability base x-direction	5000
Stability base y-direction	2500
Min Jacks/stability point	2

Maxima per Jacking Point

Max. vertical load	303 [t]
Max. foundation pressure	63 [t/m²]
Max horizontal load in x-direction	0 [t]
Max horizontal load in y-direction	0 [t]

Interface to deck		
X	5000	**2,00**
Y	2500	**2,00**

Correction factors Jacking point P3 / G4		
	for Fwx	for Fwy
line	D	7
percentage	100%	100%

Moments [tm] (corrected)

		Mm-x	Mm-y
Misalignment		252	258
Wind		Mw-x	Mw-y
	Operational	56	309
	Out of service	0	0
	Extreme	0	0

Maximum Vertical Load

Overall maximum jacking point foundation loads							
Wind	Loads [t]					Moment [tm]	
	Fv3	Fm	Rwx	Rwy	Max	Mx	My
Operational	610	192	2	80	883	280	413
Out of service	610	192	0	0	802	252	258
Extreme	610	192	0	0	802	252	258

Maximum single jackload			
(Wind X-direction)		(Wind Y-direction)	
Max	Min	Max	Min
229	173	303	138
226	175	252	149
226	175	252	149

	Mm-x	Mm-y
Misalignment	184	188

Minimum Vertical Load

Overall minimum jacking point foundation loads							
Wind	Loads [t]					Moment [tm]	
	Fv3	Fm	Rwx	Rwy	Min	Mx	My
Operational	444	192	2	80	556	212	342
Out of service	444	192	0	0	636	184	188
Extreme	444	192	0	0	636	184	188

Minimum single jackload			
(Wind X-direction)		(Wind Y-direction)	
Max	Min	Max	Min
180	137	207	70
177	141	197	121
177	141	197	121

Jacking point P3 / G4 Maximum single jackload (Wind X-direction)

Operation			173	173			804
			229	229			
Out of service			175	175			802
			226	226			
Extreme			175	175			802
			226	226			

Jacking point P3 / G4 Maximum single jackload (Wind Y-direction)

Operation			138	303			883
			138	303			
Out of service			149	252			802
			149	252			
Extreme			149	252			802
			149	252			

Jacking point P3 / G4 Minimum single jackload (Wind X-direction)

Operation			137	137			634
			180	180			
Out of service			141	141			636
			177	177			
Extreme			141	141			636
			177	177			

Jacking point P3 / G4 Minimum single jackload (Wind Y-direction)

Operation			70	207			556
			70	207			
Out of service			121	197			636
			121	197			
Extreme			121	197			636
			121	197			

Jacking point P4 / G1

Jack point/foundation

Type of tower	1
Number of jacks	4
Stability base x-direction	5000
Stability base y-direction	2500
Min Jacks/stability point	2

Maxima per Jacking Point

Max. vertical load	303	[t]
Max. foundation pressure	63	[t/m²]
Max horizontal load in x-direction	0	[t]
Max horizontal load in y-direction	0	[t]

Interface to deck			Correction factors Jacking point P4 / G1		
				for Fwx	for Fwy
X	5000	**2,00**	line	A	7
Y	2500	**2,00**	percentage	100%	100%

Moments [tm] (corrected)

		Mm-x	Mm-y
Misalignment		252	258
Wind		Mw-x	Mw-y
	Operational	56	309
	Out of service	0	0
	Extreme	0	0

Maximum Vertical Load

Overall maximum jacking point foundation loads							
Wind	Loads [t]					Moment [tm]	
	Fv4	Fm	Rwx	Rwy	Max	Mx	My
Operational	610	192	2	80	883	280	413
Out of service	610	192	0	0	802	252	258
Extreme	610	192	0	0	802	252	258

Maximum single jackload			
(Wind X-direction)		(Wind Y-direction)	
Max	Min	Max	Min
229	173	303	138
226	175	252	149
226	175	252	149

Misalignment	Mm-x	Mm-y
	184	188

Minimum Vertical Load

Overall minimum jacking point foundation loads							
Wind	Loads [t]					Moment [tm]	
	Fv4	Fm	Rwx	Rwy	Min	Mx	My
Operational	444	192	2	80	556	212	342
Out of service	444	192	0	0	636	184	188
Extreme	444	192	0	0	636	184	188

Minimum single jackload			
(Wind X-direction)		(Wind Y-direction)	
Max	Min	Max	Min
180	137	207	70
177	141	197	121
177	141	197	121

Jacking point P4 / G1 Maximum single jackload (Wind X-direction)

Operation			173	173			804
			229	229			
Out of service			175	175			802
			226	226			
Extreme			175	175			802
			226	226			

Jacking point P4 / G1 Maximum single jackload (Wind Y-direction)

Operation			138	303			883
			138	303			
Out of service			149	252			802
			149	252			
Extreme			149	252			802
			149	252			

Jacking point P4 / G1 Minimum single jackload (Wind X-direction)

Operation			137	137			634
			180	180			
Out of service			141	141			636
			177	177			
Extreme			141	141			636
			177	177			

Jacking point P4 / G1 Minimum single jackload (Wind Y-direction)

Operation			70	207			556
			70	207			
Out of service			121	197			636
			121	197			
Extreme			121	197			636
			121	197			

Summary

		P1	P2	P3	P4	Extreme
		Rv1	Rv2	Rv3	Rv4	Rv
Operation	Maximum	303	303	303	303	303
	Minimum	70	70	70	70	70
Out of service	Maximum	252	252	252	252	252
	Minimum	121	121	121	121	121
Extreme	Maximum	303	303	303	303	303
	Minimum	70	70	70	70	70

Load on foundation, COG in centre envelope, no wind

Point P2		Point P3	
4 jacks	179	4 jacks	179
total	717	total	717

Total load incl weight towers **2868**

Point P1		Point P4	
4 jacks	179	4 jacks	179
total	717	total	717

MAXIMUM SINGLE JACKLOADS

Jacking point P2 / B4		Jacking point P3 / G4	
Operation		Operation	
229	173	229	173
229	173	229	173
total	804	total	804

Operation Wind 16 m/s

WIND IN X-DIRECTION

Jacking point P1 / B1		Jacking point P4 / G1	
Operation		Operation	
229	173	229	173
229	173	229	173
total	804	total	804

Jacking point P2 / B4		Jacking point P3 / G4	
Out of service		Out of service	
226	175	226	175
226	175	226	175
total	802	total	802

Out of service Wind na

WIND IN X-DIRECTION

Jacking point P1 / B1		Jacking point P4 / G1	
Out of service		Out of service	
226	175	226	175
226	175	226	175
total	802	total	802

Jacking point P2 / B4		Jacking point P3 / G4	
Extreme		Extreme	
226	175	226	175
226	175	226	175
total	802	total	802

Extreme Wind na

WIND IN X-DIRECTION

Jacking point P1 / B1		Jacking point P4 / G1	
Extreme		Extreme	
226	175	226	175
226	175	226	175
total	802	total	802

Jacking point P2 / B4		Jacking point P3 / G4	
Operation		Operation	
138	138	138	138
303	303	303	303
	883		883

Operation Wind 16 m/s

WIND IN Y-DIRECTION

Jacking point P1 / B1		Jacking point P4 / G1	
Operation		Operation	
138	138	138	138
303	303	303	303
	883		883

Jacking point P2 / B4		Jacking point P3 / G4	
Out of service		Out of service	
149	149	149	149
252	252	252	252
	802		802

Out of service Wind na

WIND IN Y-DIRECTION

Jacking point P1 / B1		Jacking point P4 / G1	
Out of service		Out of service	
149	149	149	149
252	252	252	252
	802		802

Jacking point P2 / B4		Jacking point P3 / G4	
Extreme		Extreme	
149	149	149	149
252	252	252	252
	802		802

Extreme Wind na

WIND IN Y-DIRECTION

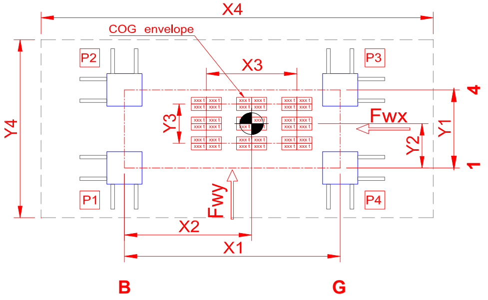
Jacking point P1 / B1		Jacking point P4 / G1	
Extreme		Extreme	
149	149	149	149
252	252	252	252
	802		802

APPENDIX F – MEGA JACK STABILITY CALCULATION – LC2 WITH 4X 200T STRAND JACK

	Project :	Jacking of Bridge Sections	No: AB016101	Dept :	ALE Heavylift		
ALE SMARTER, SAFER, STRONGER	Project Title :	Bjørnafjord Prosjektet		Initials :	RM		
		Mega Jack System General loadings - with vertical strand jacks (4x 200t)		Date :	15/aug/19		
		Jacking to 46 mtrs.		Rev :	A	based on rev 2.4	

Bridge geometries		
Bridge weight [t]		2900
Width		
x1 [mm]		60000
x2 [mm]	to CoG	30000
Length		
y1 [mm]		8000
y2 [mm]	to CoG	4000
Envelope		
x3 [mm]		2000
y3 [mm]		1000
Overal dimensions lxwxh		
x4 [mm]		150000
y4 [mm]		31600
z1 [mm]		3500
Dimensions to CoW		
x5 [mm]		30000
y5 [mm]		4000
z2 [mm]		1750
z3 [mm]		47750
Jacking geometries		
Footstructure height [mm]		3535
z4 [mm]	Jacking height	46000
Foundation points [#]		4
Tower type 1		
Weight starterbeam 1 [t]	**4 points**	25
Height starterbeam 1 [mm]		2050
z5 [mm]	Height jacking beams	22000
No. Layers		36
Weight tower type 1 [t]		192
Tower type 2		
Weight starterbeam 2 [t]	**4 points**	25
Height starterbeam 2 [mm]		2050
z5 [mm]	Height jacking beams	22000
No. Layers		36
Weight tower type 2 [t]		192
Missallignment		
misalignment factor height [m/m]		0,010
misalignment factor width [m/m]		0,001
Maximum Load per Jacking Point		
Max load operational [t]		1300
Max load out-of-service [t]		1500
Max load extreme [t]		1900

Vertical loads per jacking point [t]:
Deviation of the corner loads
depending on the given envelope



	P1	P2	P3	P4	Extreme
	B1	B4	G4	G1	
	Fv1	Fv2	Fv3	Fv4	Fv
Maximum	843	843	843	843	843
Minimum	613	613	613	613	613

COG envelope with loading on top of each jacking point:

843	788	816	816	788	**843**
656	613	634	634	613	656
749	701	725	725	701	749
749	701	725	725	701	749
656	613	634	634	613	656
843	788	816	816	788	**843**

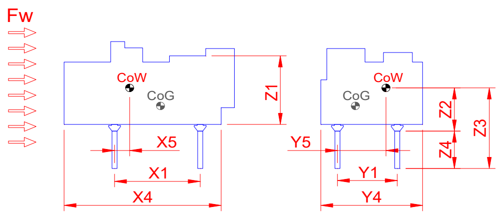
Numbering of corners

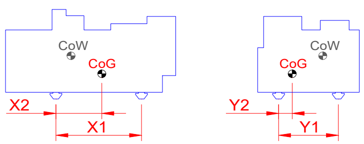
B4	G4
B1	G1

Weights / Loads are in metric tonnes [t]

Wind Loads			
Estimation of the surfaces			
Aside [m2]		111	
Afront [m2]		525	
cw [-]		1,00	
weather condition			
q1 [N/m2]	operational	237	
q2 [N/m2]	out of service	1352	
q3 [N/m2]	extreme	1352	
Corresponding windspeeds			
v1 [m/s]	operational	16	
v2 [m/s]	out of service	na	
v3 [m/s]	extreme	na	
Wind forces*			
Fw1x [kN]	operational	48	0,2%
Fw1y [kN]	operational	264	0,9%
Fw2x [kN]	out of service	0	0,0%
Fw2y [kN]	out of service	0	0,0%
Fw3x [kN]	extreme	0	0,0%
Fw3y [kN]	extreme	0	0,0%
Gravity acceleration			
G		9,81	

Boundary conditions:
Rigid structure, Towers absorb
an equal amount of wind





**input taken from wind calculation CAL-AB016101-001*
only 16 m/s wind speed considered, in service

General loads **Per foundation**

Moment on foundation due to wind

		Operational	Out of service	Extreme	
Mw-x	(x-direction)	56	0	0	[tm]
Mw-y	(y-direction)	309	0	0	[tm]

Additional load effect due to wind

		Operational	Out of service	Extreme	
Rwx	(x-direction)	2	0	0	[t]
Rwy	(y-direction)	80	0	0	[t]

Horizontal load on foundation due to wind

		Operational	Out of service	Extreme	
Fx	(x-direction)	1	0	0	[t]
Fy	(y-direction)	7	0	0	[t]

Correction factor per line due to CoW

	for Fwx		for Fwy	
line	A	D	2	7
percentage	100%	100%	100%	100%

Jacking point P1 / B1

Jack point/foundation

Type of tower	1
Number of jacks	4
Stability base x-direction	5000
Stability base y-direction	2500
Min Jacks/stability point	2

Maxima per Jacking Point

Max. vertical load	381	[t]
Max. foundation pressure	79	[t/m²]
Max horizontal load in x-direction	0	[t]
Max horizontal load in y-direction	0	[t]

Interface to deck			Correction factors Jacking point P1 / B1		
				for Fwx	for Fwy
X	5000	**2,00**	line	A	2
Y	2500	**2,00**	percentage	100%	100%

Moments [tm] (corrected)

		Mm-x	Mm-y
Misalignment		348	356
Wind		Mw-x	Mw-y
	Operational	56	309
	Out of service	0	0
	Extreme	0	0

Maximum Vertical Load

Overall maximum jacking point foundation loads							
Wind	Loads [t]					Moment [tm]	
	Fv1	Fm	Rwx	Rwy	Max	Mx	My
Operational	843	192	2	80	1115	377	511
Out of service	843	192	0	0	1035	348	356
Extreme	843	192	0	0	1035	348	356

Maximum single jackload			
(Wind X-direction)		(Wind Y-direction)	
Max	Min	Max	Min
297	222	381	177
294	224	330	187
294	224	330	187

Minimum Vertical Load

	Mm-x	Mm-y
Misalignment	253	259

Overall minimum jacking point foundation loads							
Wind	Loads [t]					Moment [tm]	
	Fv1	Fm	Rwx	Rwy	Min	Mx	My
Operational	613	192	2	80	725	282	414
Out of service	613	192	0	0	805	253	259
Extreme	613	192	0	0	805	253	259

Minimum single jackload			
(Wind X-direction)		(Wind Y-direction)	
Max	Min	Max	Min
229	173	264	98
227	176	253	149
227	176	253	149

Jacking point P1 / B1 Maximum single jackload (Wind X-direction)

Operation			222	222			1037
			297	297			
Out of service			224	224			1035
			294	294			
Extreme			224	224			1035
			294	294			

Jacking point P1 / B1 Maximum single jackload (Wind Y-direction)

Operation			177	381			1115
			177	381			
Out of service			187	330			1035
			187	330			
Extreme			187	330			1035
			187	330			

Jacking point P1 / B1 Minimum single jackload (Wind X-direction)

Operation			173	173			803
			229	229			
Out of service			176	176			805
			227	227			
Extreme			176	176			805
			227	227			

Jacking point P1 / B1 Minimum single jackload (Wind Y-direction)

Operation			98	264			725
			98	264			
Out of service			149	253			805
			149	253			
Extreme			149	253			805
			149	253			

Jacking point P2 / B4

Jack point/foundation

Type of tower	1
Number of jacks	4
Stability base x-direction	5000
Stability base y-direction	2500
Min Jacks/stability point	2

Maxima per Jacking Point

Max. vertical load	381	[t]
Max. foundation pressure	79	[t/m²]
Max horizontal load in x-direction	0	[t]
Max horizontal load in y-direction	0	[t]

Interface to deck			Correction factors Jacking point P2 / B4		
				for Fwx	for Fwy
X	5000	**2,00**	line	D	2
Y	2500	**2,00**	percentage	100%	100%

Moments [tm] (corrected)

Misalignment		Mm-x	Mm-y
		348	356
Wind		Mw-x	Mw-y
	Operational	56	309
	Out of service	0	0
	Extreme	0	0

Maximum Vertical Load

Overall maximum jacking point foundation loads							
Wind	Loads [t]					Moment [tm]	
	Fv2	Fm	Rwx	Rwy	Max	Mx	My
Operational	843	192	2	80	1115	377	511
Out of service	843	192	0	0	1035	348	356
Extreme	843	192	0	0	1035	348	356

Maximum single jackload			
(Wind X-direction)		(Wind Y-direction)	
Max	Min	Max	Min
297	222	381	177
294	224	330	187
294	224	330	187

Minimum Vertical Load

Misalignment	Mm-x	Mm-y
	253	259

Overall minimum jacking point foundation loads							
Wind	Loads [t]					Moment [tm]	
	Fv2	Fm	Rwx	Rwy	Min	Mx	My
Operational	613	192	2	80	725	282	414
Out of service	613	192	0	0	805	253	259
Extreme	613	192	0	0	805	253	259

Minimum single jackload			
(Wind X-direction)		(Wind Y-direction)	
Max	Min	Max	Min
229	173	264	98
227	176	253	149
227	176	253	149

Jacking point P2 / B4 Maximum single jackload (Wind X-direction)

Operation			222	222			1037
			297	297			
Out of service			224	224			1035
			294	294			
Extreme			224	224			1035
			294	294			

Jacking point P2 / B4 Maximum single jackload (Wind Y-direction)

Operation			177	381			1115
			177	381			
Out of service			187	330			1035
			187	330			
Extreme			187	330			1035
			187	330			

Jacking point P2 / B4 Minimum single jackload (Wind X-direction)

Operation			173	173			803
			229	229			
Out of service			176	176			805
			227	227			
Extreme			176	176			805
			227	227			

Jacking point P2 / B4 Minimum single jackload (Wind Y-direction)

Operation			98	264			725
			98	264			
Out of service			149	253			805
			149	253			
Extreme			149	253			805
			149	253			

Jacking point P3 / G4
Jack point/foundation

Type of tower	1
Number of jacks	4
Stability base x-direction	5000
Stability base y-direction	2500
Min Jacks/stability point	2

Maxima per Jacking Point

Max. vertical load	381	[t]
Max. foundation pressure	79	[t/m²]
Max horizontal load in x-direction	0	[t]
Max horizontal load in y-direction	0	[t]

Interface to deck			Correction factors Jacking point P3 / G4		
				for Fwx	for Fwy
X	5000	2,00	line	D	7
Y	2500	2,00	percentage	100%	100%

Moments [tm] (corrected)

		Mm-x	Mm-y
Misalignment		348	356
Wind		Mw-x	Mw-y
	Operational	56	309
	Out of service	0	0
	Extreme	0	0

Maximum Vertical Load

Overall maximum jacking point foundation loads							
Wind	Loads [t]					Moment [tm]	
	Fv3	Fm	Rwx	Rwy	Max	Mx	My
Operational	843	192	2	80	1115	377	511
Out of service	843	192	0	0	1035	348	356
Extreme	843	192	0	0	1035	348	356

Maximum single jackload			
(Wind X-direction)		(Wind Y-direction)	
Max	Min	Max	Min
297	222	381	177
294	224	330	187
294	224	330	187

Minimum Vertical Load

	Mm-x	Mm-y
Misalignment	253	259

Overall minimum jacking point foundation loads							
Wind	Loads [t]					Moment [tm]	
	Fv3	Fm	Rwx	Rwy	Min	Mx	My
Operational	613	192	2	80	725	282	414
Out of service	613	192	0	0	805	253	259
Extreme	613	192	0	0	805	253	259

Minimum single jackload			
(Wind X-direction)		(Wind Y-direction)	
Max	Min	Max	Min
229	173	264	98
227	176	253	149
227	176	253	149

Jacking point P3 / G4 Maximum single jackload (Wind X-direction)

Operation			222	222			1037
			297	297			
Out of service			224	224			1035
			294	294			
Extreme			224	224			1035
			294	294			

Jacking point P3 / G4 Maximum single jackload (Wind Y-direction)

Operation			177	381			1115
			177	381			
Out of service			187	330			1035
			187	330			
Extreme			187	330			1035
			187	330			

Jacking point P3 / G4 Minimum single jackload (Wind X-direction)

Operation			173	173			803
			229	229			
Out of service			176	176			805
			227	227			
Extreme			176	176			805
			227	227			

Jacking point P3 / G4 Minimum single jackload (Wind Y-direction)

Operation			98	264			725
			98	264			
Out of service			149	253			805
			149	253			
Extreme			149	253			805
			149	253			

Jacking point P4 / G1

Jack point/foundation

Type of tower	1
Number of jacks	4
Stability base x-direction	5000
Stability base y-direction	2500
Min Jacks/stability point	2

Maxima per Jacking Point

Max. vertical load	381 [t]
Max. foundation pressure	79 [t/m²]
Max horizontal load in x-direction	0 [t]
Max horizontal load in y-direction	0 [t]

Interface to deck			Correction factors Jacking point P4 / G1		
				for Fwx	for Fwy
X	5000	2,00	line	A	7
Y	2500	2,00	percentage	100%	100%

Moments [tm] (corrected)

		Mm-x	Mm-y
Misalignment		348	356
Wind		Mw-x	Mw-y
	Operational	56	309
	Out of service	0	0
	Extreme	0	0

Maximum Vertical Load

Overall maximum jacking point foundation loads							
Wind	Loads [t]					Moment [tm]	
	Fv4	Fm	Rwx	Rwy	Max	Mx	My
Operational	843	192	2	80	1115	377	511
Out of service	843	192	0	0	1035	348	356
Extreme	843	192	0	0	1035	348	356

Maximum single jackload			
(Wind X-direction)		(Wind Y-direction)	
Max	Min	Max	Min
297	222	381	177
294	224	330	187
294	224	330	187

Minimum Vertical Load

	Mm-x	Mm-y
Misalignment	253	259

Overall minimum jacking point foundation loads							
Wind	Loads [t]					Moment [tm]	
	Fv4	Fm	Rwx	Rwy	Min	Mx	My
Operational	613	192	2	80	725	282	414
Out of service	613	192	0	0	805	253	259
Extreme	613	192	0	0	805	253	259

Minimum single jackload			
(Wind X-direction)		(Wind Y-direction)	
Max	Min	Max	Min
229	173	264	98
227	176	253	149
227	176	253	149

Jacking point P4 / G1 Maximum single jackload (Wind X-direction)

Operation			222	222			1037
			297	297			
Out of service			224	224			1035
			294	294			
Extreme			224	224			1035
			294	294			

Jacking point P4 / G1 Maximum single jackload (Wind Y-direction)

Operation			177	381			1115
			177	381			
Out of service			187	330			1035
			187	330			
Extreme			187	330			1035
			187	330			

Jacking point P4 / G1 Minimum single jackload (Wind X-direction)

Operation			173	173			803
			229	229			
Out of service			176	176			805
			227	227			
Extreme			176	176			805
			227	227			

Jacking point P4 / G1 Minimum single jackload (Wind Y-direction)

Operation			98	264			725
			98	264			
Out of service			149	253			805
			149	253			
Extreme			149	253			805
			149	253			

Project :	Jacking of Bridge Sections	No:	AB016101
Project Title :	Bjørnafjord Prosjektet		
	Mega Jack System General loadings - with vertical strand jacks (4x 200t)		
	Jacking to 46 mtrs.		

Dept :	ALE Heavylift		
Initials :	RM		
Date :	15/aug/19		
Rev :	A		based on rev 2.4

SMARTER, SAFER, STRONGER

Summary

		P1	P2	P3	P4	Extreme
		Rv1	Rv2	Rv3	Rv4	Rv
Operation	Maximum	381	381	381	381	381
	Minimum	98	98	98	98	98
Out of service	Maximum	330	330	330	330	330
	Minimum	149	149	149	149	149
Extreme	Maximum	381	381	381	381	381
	Minimum	98	98	98	98	98

Load on foundation, COG in centre envelope, no wind

Point P2			Point P3	
4 jacks	229		4 jacks	229
total	917		total	917
Total load incl weight towers		3668		
Point P1			**Point P4**	
4 jacks	229		4 jacks	229
total	917		total	917

MAXIMUM SINGLE JACKLOADS

Jacking point P2 / B4		Jacking point P3 / G4	
Operation		Operation	
297	222	297	222
297	222	297	222
total	1037	total	1037

Operation Wind 16 m/s

WIND IN X-DIRECTION

Jacking point P1 / B1		Jacking point P4 / G1	
Operation		Operation	
297	222	297	222
297	222	297	222
total	1037	total	1037

Jacking point P2 / B4		Jacking point P3 / G4	
Out of service		Out of service	
294	224	294	224
294	224	294	224
total	1035	total	1035

Out of service Wind na

WIND IN X-DIRECTION

Jacking point P1 / B1		Jacking point P4 / G1	
Out of service		Out of service	
294	224	294	224
294	224	294	224
total	1035	total	1035

Jacking point P2 / B4		Jacking point P3 / G4	
Extreme		Extreme	
294	224	294	224
294	224	294	224
total	1035	total	1035

Extreme Wind na

WIND IN X-DIRECTION

Jacking point P1 / B1		Jacking point P4 / G1	
Extreme		Extreme	
294	224	294	224
294	224	294	224
total	1035	total	1035

Jacking point P2 / B4		Jacking point P3 / G4	
Operation		Operation	
177	177	177	177
381	381	381	381
	1115		1115

Operation Wind 16 m/s

WIND IN Y-DIRECTION

Jacking point P1 / B1		Jacking point P4 / G1	
Operation		Operation	
177	177	177	177
381	381	381	381
	1115		1115

Jacking point P2 / B4		Jacking point P3 / G4	
Out of service		Out of service	
187	187	187	187
330	330	330	330
	1035		1035

Out of service Wind na

WIND IN Y-DIRECTION

Jacking point P1 / B1		Jacking point P4 / G1	
Out of service		Out of service	
187	187	187	187
330	330	330	330
	1035		1035

Jacking point P2 / B4		Jacking point P3 / G4	
Extreme		Extreme	
187	187	187	187
330	330	330	330
	1035		1035

Extreme Wind na

WIND IN Y-DIRECTION

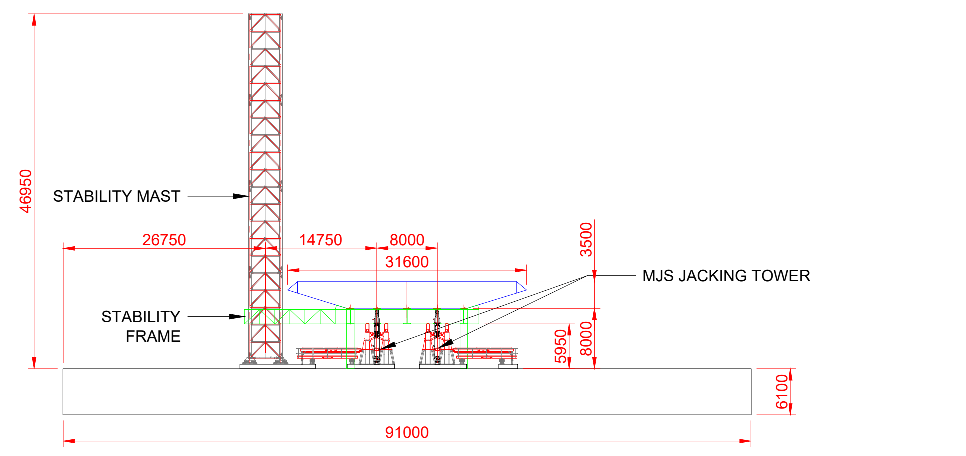
Jacking point P1 / B1		Jacking point P4 / G1	
Extreme		Extreme	
187	187	187	187
330	330	330	330
	1035		1035

Concept development, floating bridge
E39 Bjørnafjorden

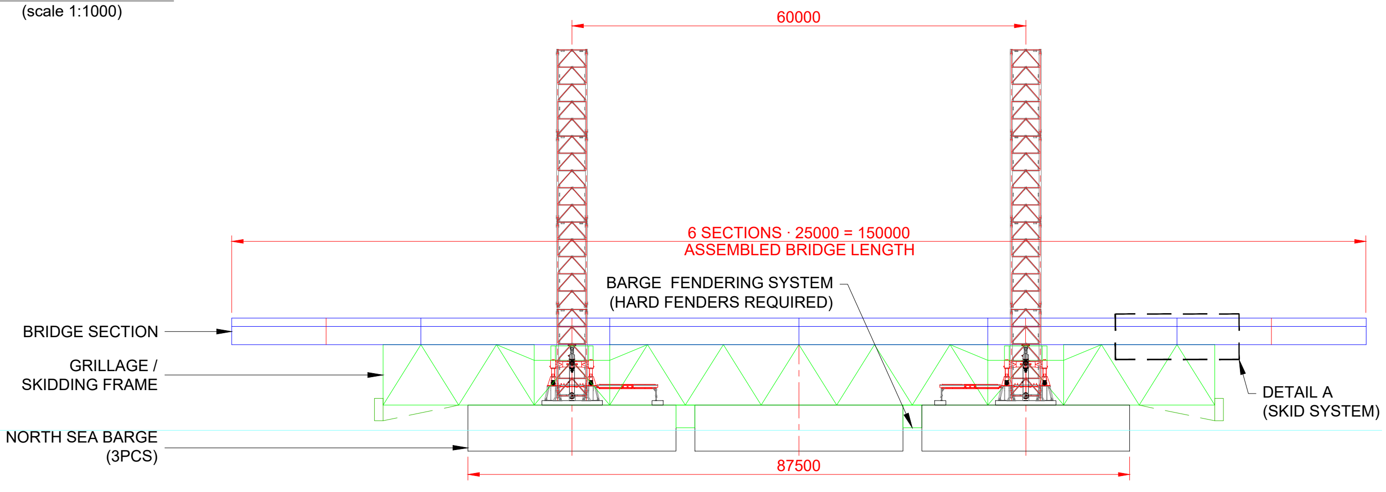
Appendix N – Enclosure 3

DRW-AB016101-001
Jacking of bridge sections

FRONT VIEW - PHASE 01
(scale 1:1000)

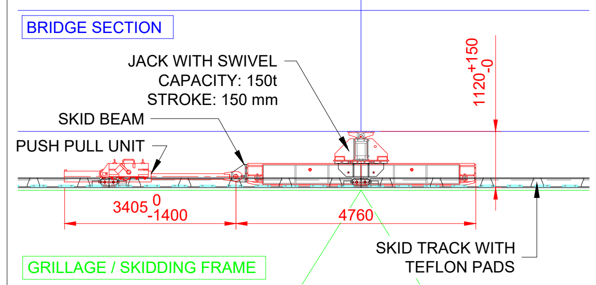


SIDE VIEW - PHASE 01
(scale 1:1000)

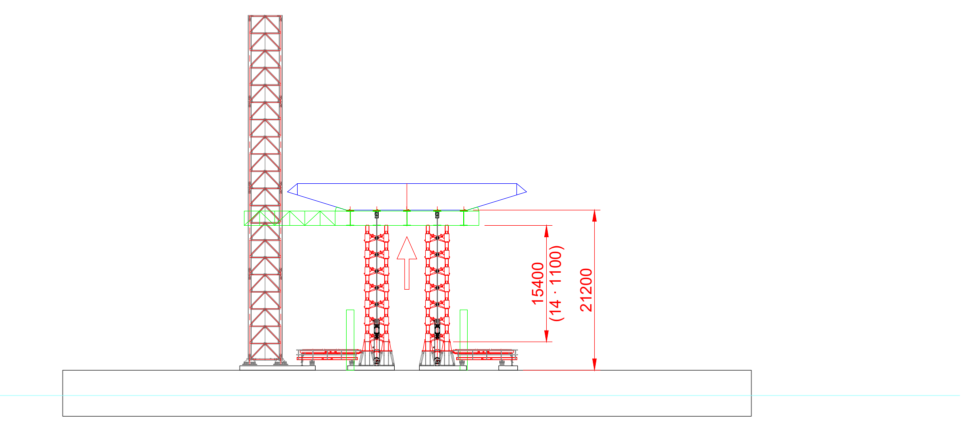


PHASE 01:
- LIFT NO. 6 BRIDGE GIRDERS ONTO BARGE GRILLAGE.
- USE SKIDDING SYSTEM ON BARGE GRILLAGE TO CORRECT BRIDGE GIRDERS / SECTIONS.
- WELDING OF BRIDGE SECTIONS

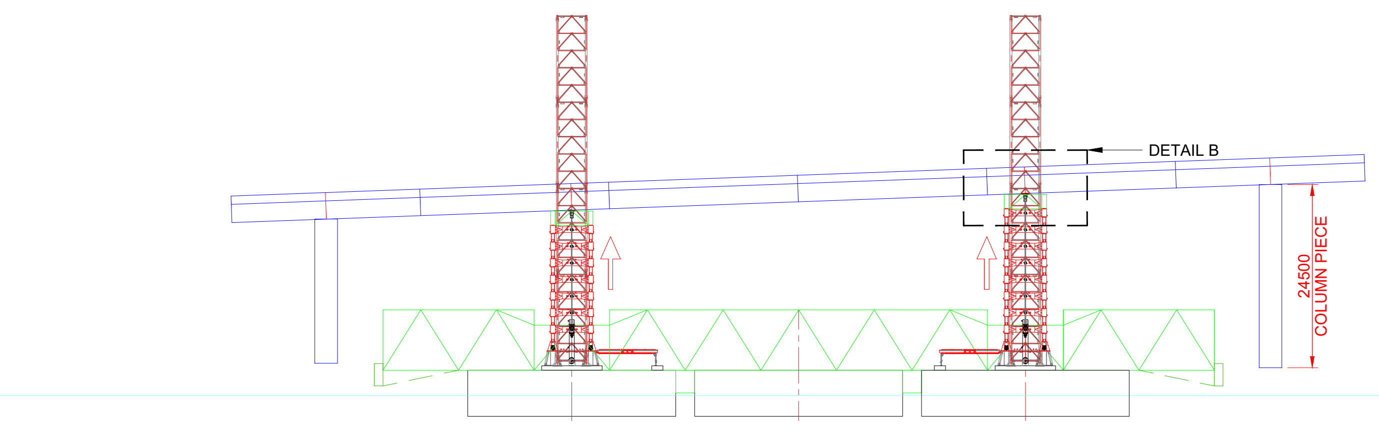
DETAIL A
(SKID SYSTEM)
(scale 1:150)



FRONT VIEW - PHASE 02
(scale 1:1000)

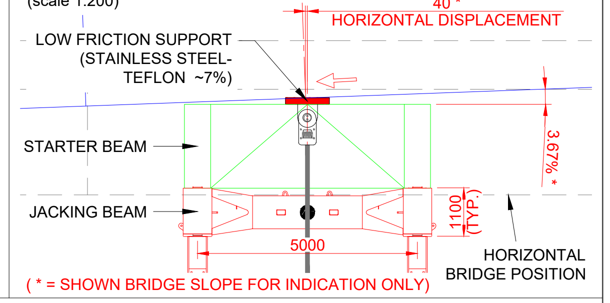


SIDE VIEW - PHASE 02
(scale 1:1000)

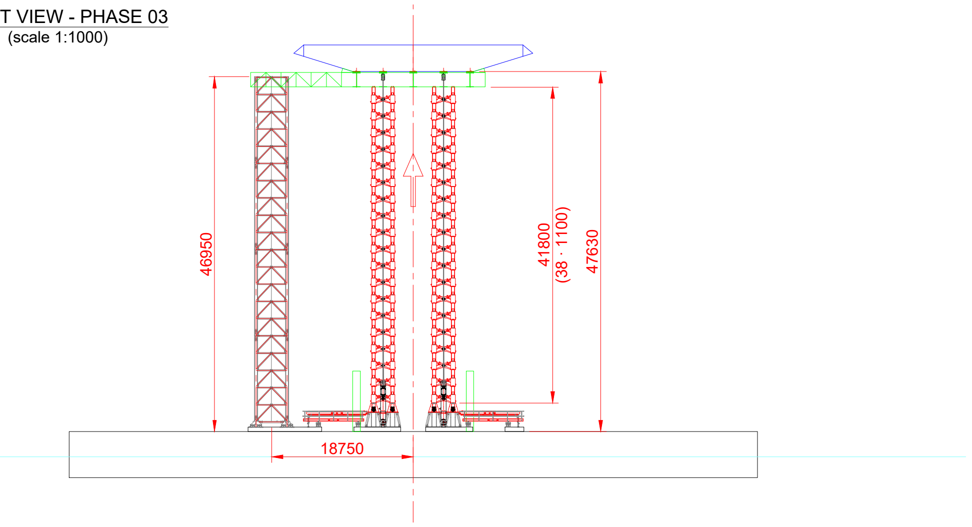


PHASE 02:
- JACK-UP JACKING TOWERS BY INSERTING JACKING BEAMS.
- MATE JACKING TOWERS WITH BRIDGE SECTION.
- ACHIEVE DEFINED BRIDGE SLOPE BY ASYMMETRIC JACKING HEIGHTS.
- JACK THE ASSEMBLED BRIDGE SECTIONS TO AN HEIGHT OF APPROXIMATELY 25m.
- INSTALL 25m COLUMN PIECES UNDERNEATH BRIDGE GIRDER COLUMN PUPS.

DETAIL B
(scale 1:200)

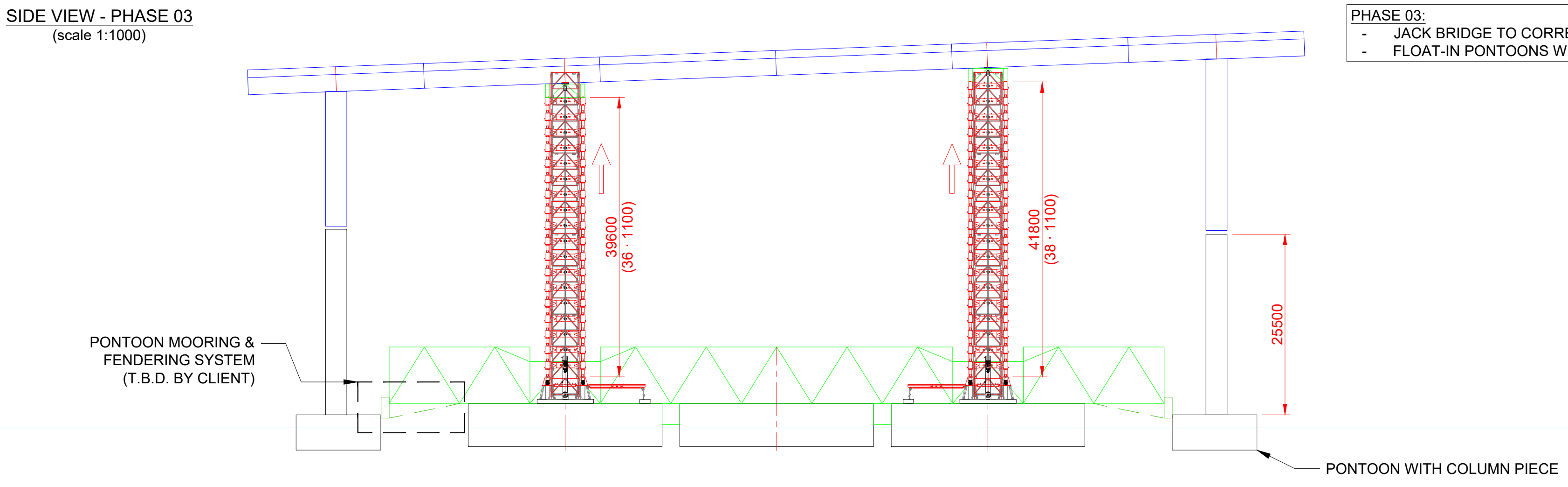


FRONT VIEW - PHASE 03
(scale 1:1000)



SIDE VIEW - PHASE 03
(scale 1:1000)

PHASE 03:
- JACK BRIDGE TO CORRECT HEIGHT.
- FLOAT-IN PONTOONS WITH LOWER COLUMN PIECES.



DRAWING NOTES:

- ALL DIMENSIONS ARE IN mm UNLESS OTHERWISE STATED.
- ALL WEIGHTS ARE IN t (METRIC TONNES) UNLESS OTHERWISE STATED.
- ALL DETAILS ARE PROVISIONAL AND ARE SUBJECT TO CONFIRMATION.

TECHNICAL NOTES:

-WEIGHT GIVEN BY CLIENT FOR ONE ASSEMBLED BRIDGE SECTION INCLUDING SUPPORTING COLUMNS IS 2100t.
-CENTER OF GRAVITY (C.O.G.) IS ESTIMATED BY CLIENT, EXACT DIMENSIONS TO BE PROVIDED BY CLIENT IN LATER STAGE.
-CENTER OF WIND (C.O.W.) IS UNKNOWN, TO BE PROVIDED BY CLIENT.
-PROJECT LOCATION:
-PROJECT EXECUTION PERIOD:
-AVAILABLE WORKSPACES TO BE DISCUSSED AT A LATER STAGE.
-STRUCTURAL INTEGRITY OF BRIDGE, BARGE & GRILLAGE TO BE CHECKED BY CLIENT
-NO BENDING / DEFLECTION OF BRIDGE TAKEN INTO ACCOUNT
-ADDITIONAL FOUNDATIONS, REINFORCEMENTS, LOAD SPREADING TO BE PROVIDED BY CLIENT
-EXACT BARGE SUBJECT TO DETAILED ENGINEERING
-BARGE FENDERING SYSTEM AND MOORING PLAN SUBJECT TO DETAILED ENGINEERING

Rev.	Date	DRAW	CHK	APP	Description
C					
B					
A					
0	05-08-2019	RM	KC	KC	First Issue

ALE-IMS-01-ENG-TEM-002 Rev.1

ALE Heavylift B.V.
Breda, The Netherlands
Tel: +31 (0) 76 571 52 40
Web: www.ale-heavylift.com

Client: AkerSolutions

Project Title: Bjørnafjord Prosjektet

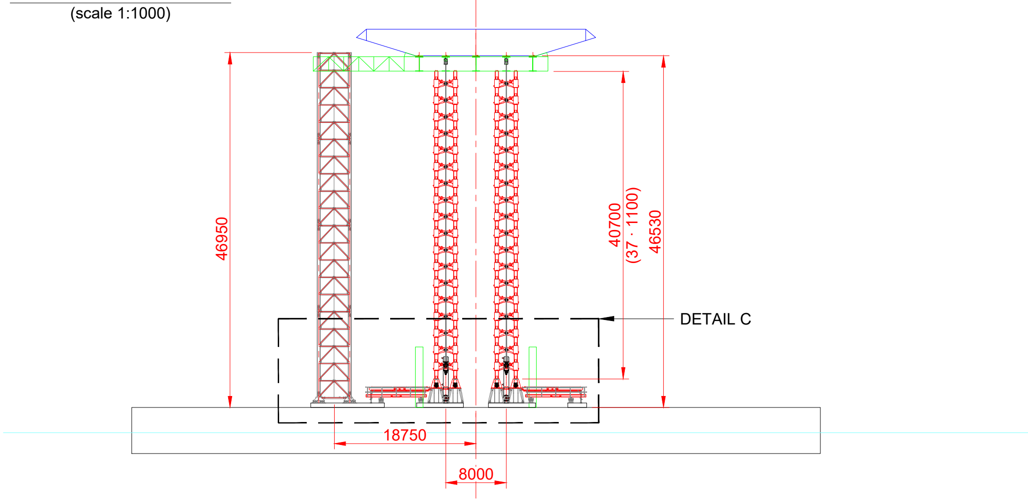
Drawing Title: Jacking of bridge sections

Date	Drawn	Checked	Approved	Scale (A3)	Sheet
05-08-2019	RM	KC	KC	See views	1 of 2

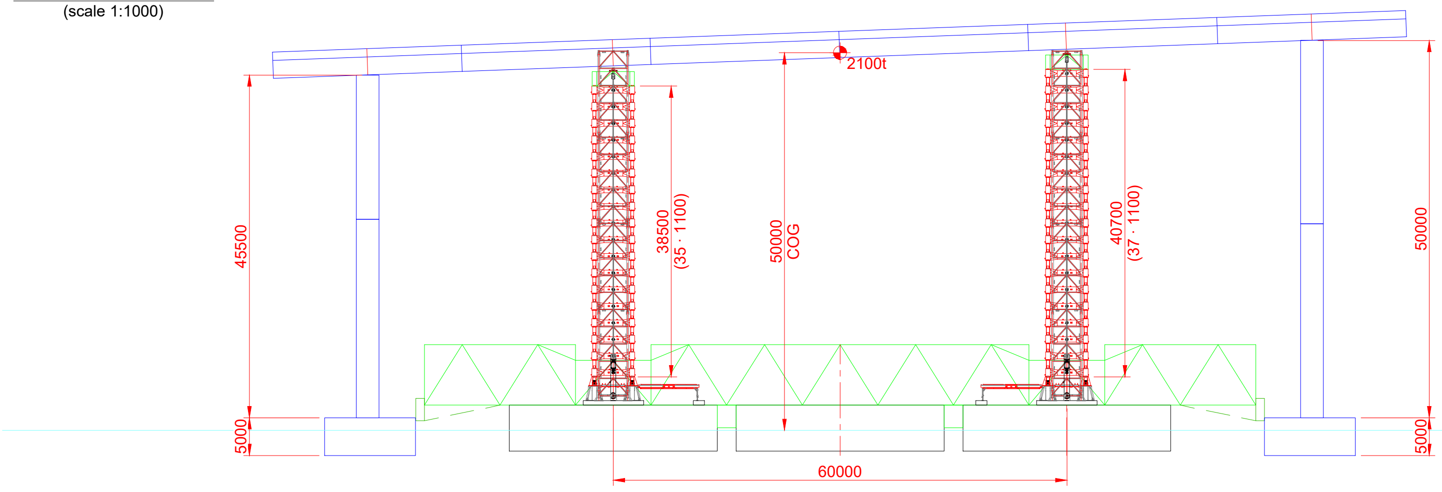
Project No.	Drawing No.	Rev.
AB016101	DRW-AB016101-001	0

File location: Z:\Projects\Projects AB\AB01xxxx\AB016101-Aker Solutions-Bjørnafjordprosjektet\Drawings ALE\MDL-AB016101-001-A (RM).dwg

FRONT VIEW - PHASE 04
(scale 1:1000)

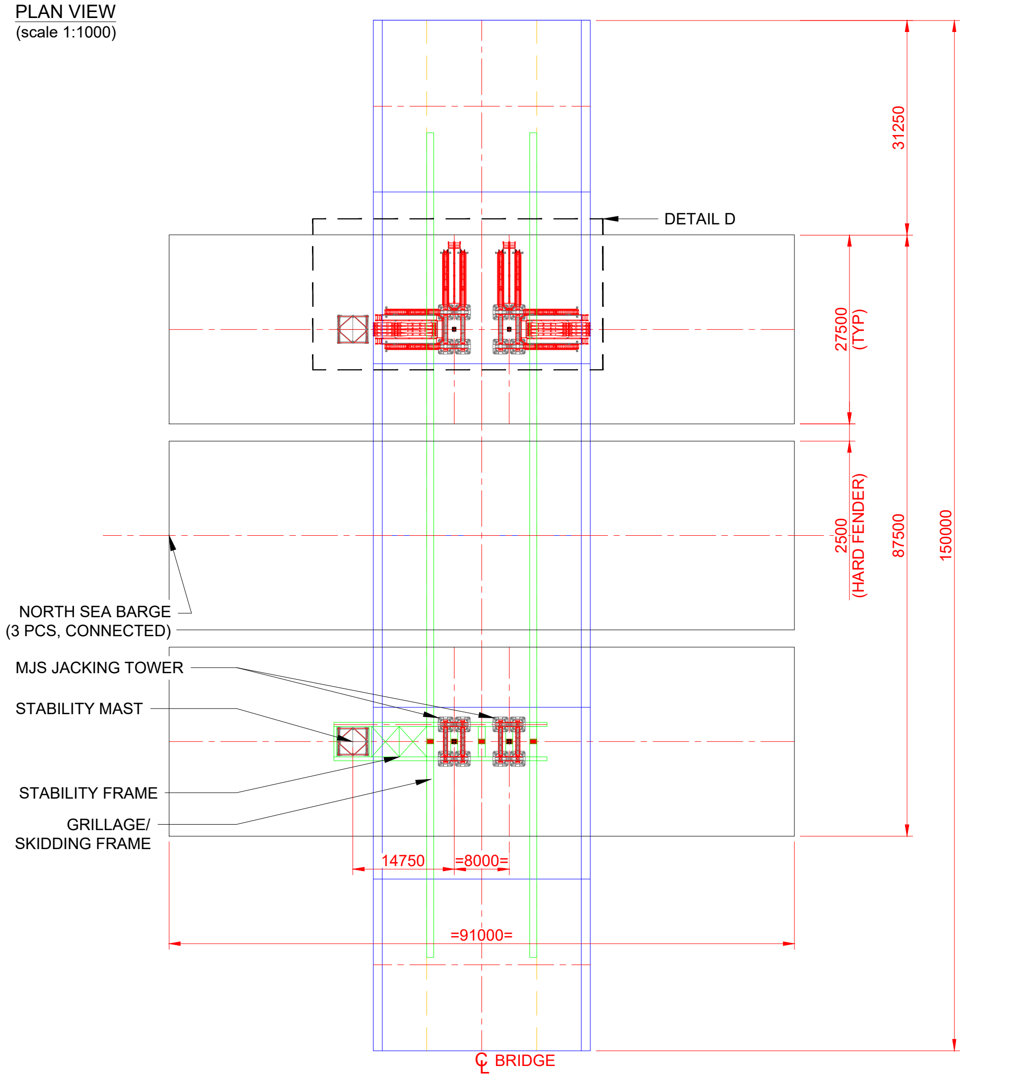


SIDE VIEW - PHASE 04
(scale 1:1000)

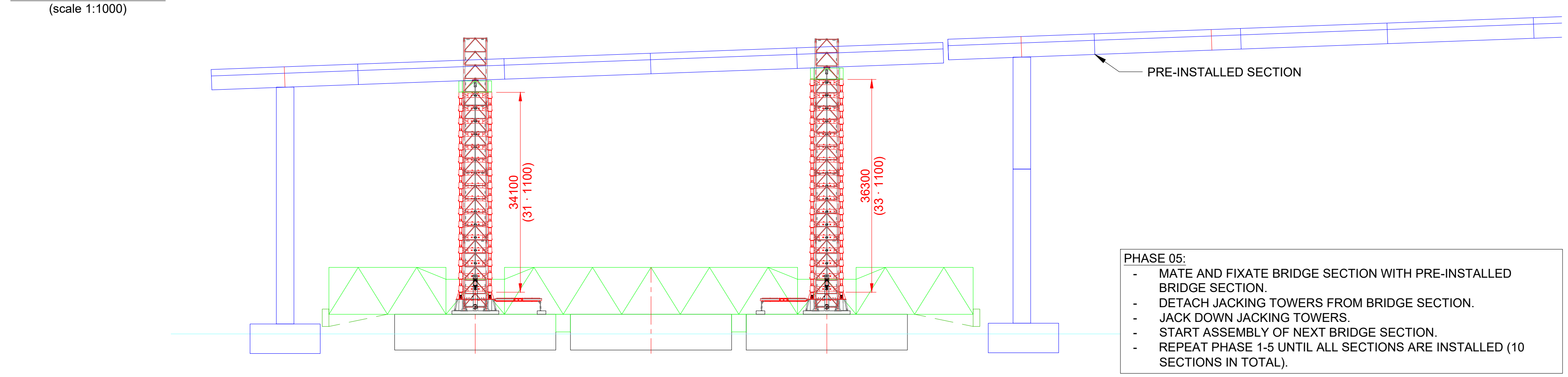


PHASE 04:
- DEBALLAST PONTOONS TO MATE THE TWO COLUMN PARTS.
- FIXATE COLUMN PARTS BY WELDING.

PLAN VIEW
(scale 1:1000)

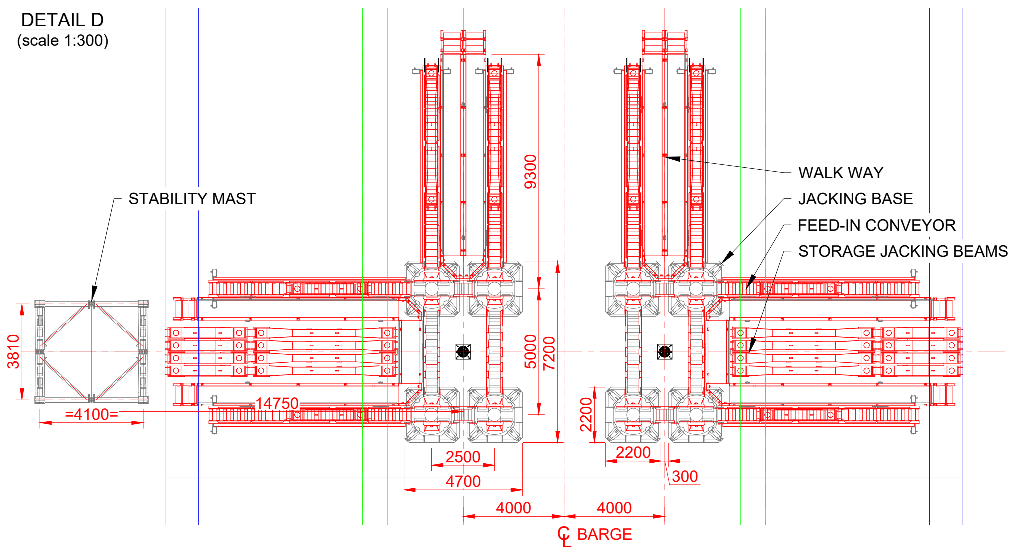


SIDE VIEW - PHASE 05
(scale 1:1000)

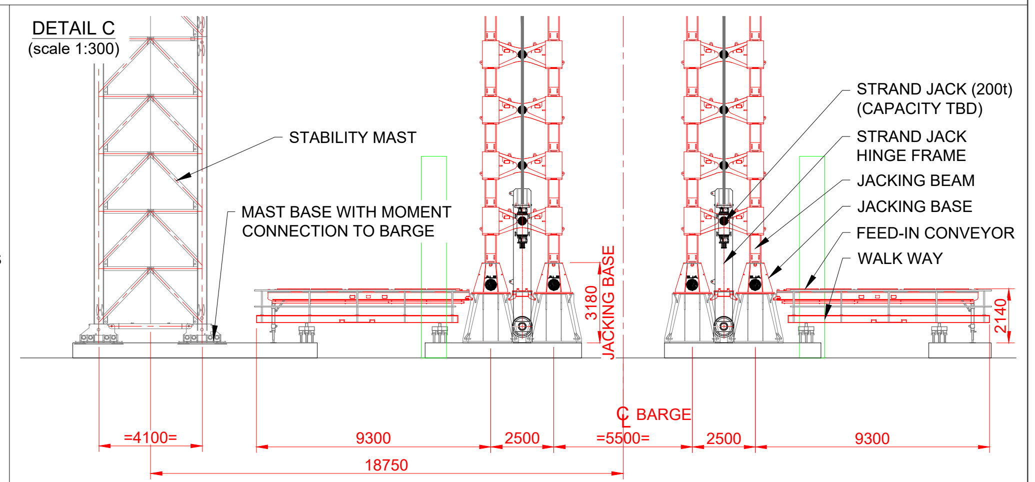


PHASE 05:
- MATE AND FIXATE BRIDGE SECTION WITH PRE-INSTALLED BRIDGE SECTION.
- DETACH JACKING TOWERS FROM BRIDGE SECTION.
- JACK DOWN JACKING TOWERS.
- START ASSEMBLY OF NEXT BRIDGE SECTION.
- REPEAT PHASE 1-5 UNTIL ALL SECTIONS ARE INSTALLED (10 SECTIONS IN TOTAL).

DETAIL D
(scale 1:300)



DETAIL C
(scale 1:300)



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Rev.	Date	DRAW	CHK	APP	Description
C					
B					
A					
0	05-08-2019	RM	KC	KC	First Issue

ALE-IMS-01-ENG-TEM-002 Rev.1

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Tel: +31 (0) 76 571 52 40
Web: www.ale-heavylift.com

ALE

Client: AkerSolutions

Project Title: Bjørnafjord Prosjektet

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Date	Drawn	Checked	Approved	Scale (A3)	Sheet
05-08-2019	RM	KC	KC	See Views	2 of 2

Project No.	Drawing No.	Rev.
AB016101	DRW-AB016101-001	0

File location: Z:\Projects\Projects AB\AB01xxxx\AB016101-Aker Solutions-Bjørnafjordprosjektet\Drawings ALE\MDL-AB016101-001-A (RM).dwg