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## PREFACE

This thesis concludes my master's degree in Mechanical and Structural Engineering with specialization in Offshore Construction at the University of Stavanger. The thesis was proposed by the Structural Department of Aker Solutions in collaboration with the University of Stavanger. By drawing on topics learned during my study at the university, this thesis represents a natural closure to my degree.

I would like to thank Aker Solutions for offering me this challenge and providing me with office space, a computer and additional software that was necessary to finalize this thesis. Thanks to my supervisors, Ragnhild O. Steigen and Mikael K. Seierstad, for the helpful feedback and giving me confidence to write this thesis. Thanks also to my professor and supervisor Sudath Siriwardane for guidance and support throughout the writing of this thesis. Thanks finally to my fellow student, Ingve Nilsen, for discussions and advice in regard to this thesis.

Stavanger, June 2014.

Bjarte Malmin

## Summary

This thesis consists of two main objectives: Learning to use NORSOK-R002 and comparing it with Aker Solutions former work instruction manual A237; and conducting a case study on the main frame of the C05 east balcony for the Gina Krog project.

The main task in the case study was to maintain proper weight structure with sufficient capacity and strength in respect to transportation, installation and operation. Apart from that, the design analysis and optimization of this structure were undertaken to create a structure that has a high element of safety with respect to life, environment and economic risk. NORSOK R-002 was used for hand calculations of lifting accessories used in the case study.

During modeling, design analysis and optimization of the C05 balcony the following software tools were learned and used:

- STAAD.pro.
- Mathcad.

In addition, the following topics were considered:

- Evaluation and use of relevant rules and standards for offshore construction.
- Optimizing the main frame and selection of steel profiles to achieve optimum design with respect to weight, strength and costs for transport, lifting, installation and operation.
- Using the load and resistance factor design (LRFD) method for checks and control.
- Local calculation of joints, beams, lifting lug, slings, master links, forerunners, bolts, welds and other lifting accessories.

The structural design and analysis was performed considering the lifting operation as basic. However, other stages had to be considered in order to create an optimal structure. During the case study, NORSOK R-002 and Aker work instruction manual A237 were both used for full comprehension and comparison. In an issues chapter below, factors are evaluated and compared.

## Terms, definitions and abbreviations

### **Breaking load (breaking force)**

The maximum load reached during a static tensile test to destruction of a lifting component or lifting accessories. Destruction is understood as actual breakage or failure to sustain a load due to parts disconnecting as result of deformation.

### **Crane**

Lifting appliance whereby the load can be moved horizontally in one or more directions, in addition to vertical movement.

### **Lay down area**

Deck area for temporary storage of loads and equipment.

### **Lifting accessories**

Components or equipment used between the lifting appliance and the load or on the load to grip it which is not an integrated part of the lifting appliance.

### **Lifting appliance**

Machine or device used for vertical movement of a load, with or without horizontal movement.

### **Lifting components**

Components used as integral parts of lifting appliances and/or as part of lifting accessories.

### **Lifting equipment**

Common term for all equipment covered by the scope of NORSOK R-002.

### **Lifting operation**

All administrative and operational activities before, during and after a load is moved and until the lifting equipment is ready for a new load.

### **Lifting point load (PLP)**

Heaviest loaded lifting point which is normally the point closest to center of gravity (CoG). This point has a maximum vertical reaction for design.

### **Lifting zone**

Space between the working area and the maximum lifting height.

### **Offboard lift**

Lifting operation between the offshore installation and a floating unit or the sea.

### **Risk**

Combination of the probability of occurrence of harm and the severity of that harm.

### **Safe working load**

(SWL)

Maximum working load that the lifting equipment is designed to lift under specific conditions.

### **Working load limit**

(WLL)

Maximum load that a lifting accessory is designed to lift using a specific configuration.

ALS	Accidental limit state
CoG	Centre of gravity
DAF	Dynamic amplification factor
DC	Design class
DF	Design factor
DOP	Dropped object protection
FLS	Fatigue limit state
HAZ	Heat affected zone
Hs	Significant wave height for the operational limitation in meters (m)
HSE	Health, safety and environment
LRFD	Load and resistance factor design
LSD	Limit state design
MBL	Minimum breaking load
PSA	Petroleum Safety Authority (Norway)
SDoF	Single degree of freedom
SKL	Skew load factor
SLS	Serviceability limit state
SMYS	Specified minimum yield strength
SWL	Safe work load
ULS	Ultimate limit state
$W_{CF}$	Weight contingency factor
$W_{\cdot cog}$	Center of gravity envelope factor
WSD	Working stress design
$Y_{\cdot M1.ULS}$	General material factor
$Y_{\cdot M2.ULS}$	Material factor for bolted and welded connections
$Y_{\cdot RM}$	Resistance factor

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# Chapter 1

## Introduction

Offshore activities in the Norwegian continental shelf include numerous smaller modification structures which are lifted from sea to platform using a platform crane. Objects vary in shape, size and weight. Many of the objects weigh below 50 metric tons and it would be of great advantage if calculations regarding such lifting operations could be standardized.

In 2012, NORSOK issued a new standard, R-002 “Lifting equipment” , to ensure that adequate safety requirements are complied with in connection to lifting operations on the Norwegian continental shelf.

In this thesis, a framework lifting analysis is considered. The work is an important part of the connection of the Gudrun platform to the Sleipner platforms. Oil and gas is supplied to Sleipner A via two pipelines from the Gudrun platform.

A comparison of the R-002 standard and Aker Solutions work manual A237 will also be considered during this thesis.

### 1.1 Thesis background

An offshore structure can be defined as a structure that has no fixed access to dry land and is required to withstand weather conditions. Offshore structures support the exploration and production of oil and gas from the Norwegian continental shelf.

The design, analysis and construction of these structures can be one of the most demanding tasks met by the engineering profession.

Due to the environment and financial aspects of offshore structures, it is necessary that as much as possible is prefabricated onshore so that offshore work is kept to a minimum.

Aker Solutions, on behalf of Statoil, is performing modification work on the Sleipner A and T platforms and a bridge between the two platforms. The work is an important part of the connection of the Gudrun platform to the Sleipner platforms. Oil and gas will be supplied to Sleipner A via two pipelines from the Gudrun platform, including one gas pipeline and one oil pipeline for further processing and export from Sleipner.

This thesis covers the calculations for the installation of the main frame of the C05 east balcony as a part of building block D04. The balcony is divided into three sub-structures: Main frame, south deck and north deck. It's located on the east side of Sleipner A, below the M22 main deck and M22/M23 infill area, as shown in Fig. 1. The strength verification covers the sub-structures themselves, temporary lifting beams and lugs, rigging equipment and other lifting accessories.

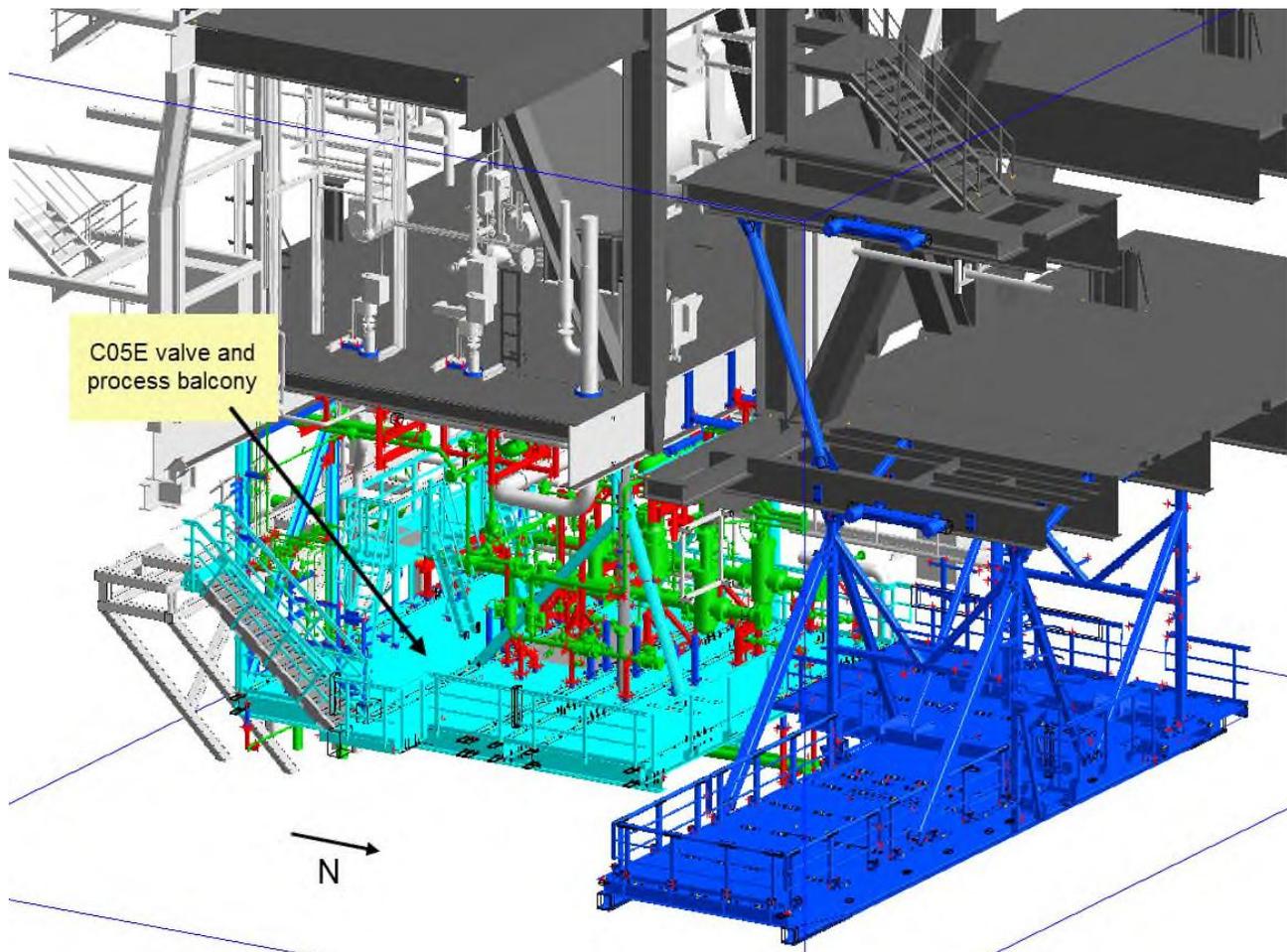


Figure 1. Main frame of the C05 east balcony. Dark blue is the new C05 balcony (source: Aker Solutions).

## 1.2 Goal and scope of thesis

This thesis will focus on the design rules in the new version of the lifting guidelines in NORSOK R-002, highlighting the consequences of their use for the design of lifting accessories, lifting components, lifting lugs and other lifting accessories. Developing templates for lifting equipment will be a part of this thesis.

All calculations comply with requirements set forth by prevailing rules and standards. Specific tasks undertaken in regard to NORSOK R-002 (edition 2) were:

- Gaining detailed knowledge and understanding of the standards set out in the document.
- Reading through the standard with a critical eye and pointing out mistakes and errors.
- Suggest improvements to the design rules for lifting accessories and lifting points.
- Comparing the standard against the standard previously used, Aker work instruction manual A237 (Lifting Design) and discussing advantages and pointing out any disadvantages.
- Developing templates based on the standard to make calculations based on typically used lifting equipment for lifting operations below 50 metric tons.
- Illustrating the design rules in the standard through use of a case study.
- Learning to use relevant software and applying it to topics discussed in the thesis.

## Chapter 2

### Theory

#### 2.1 Dynamic amplification factor

To understand the NORSOK R-002 it's important to understand the factors used. Dynamic amplification factor (DAF) is one of the factors that is found to be different in Aker Solutions' own work instruction manual A237 (Lifting Design) when compared with NORSOK R-002; the difference has a major effect on results. This difference will be discussed more in Chapter 4. Hence am I going to solve the equation starting with the general equation of motion:

$$M\ddot{z}+B\dot{z}+Cz=F_z(t) \quad \text{Eq. (2.1)}$$

##### 2.1.1 Solutions of equation

To solve this equation one must consider it as a differential equation. This means that two solutions should be considered (Rao, 2011): The particular solution  $Z_p(t)$  and the homogeneous solution  $Z_h(t)$ . Then we get a total solution:  $Z(t)=Z_h(t)+Z_p(t)$

The homogeneous and particular solutions are given in Eq. 2.2 and Eq. 2.3:

$$M\ddot{z}+B\dot{z}+Cz=F_z(t) \quad \text{Eq. (2.2)}$$

$$M\ddot{z}+B\dot{z}+Cz=0 \quad \text{Eq. (2.3)}$$

##### Particular solution

Eq. 2.2 is a general differential equation, and the harmonic force is equalized by the frequency  $\omega$ . Then:  $F_z(t)=F_0\sin(\omega t)$  where  $M$  is system mass,  $B$  is damping, and  $C$  is stiffness. To solve the equation of a damped system under harmonic force we can use the solution demonstrated in (Rao 2011).

$$M \cdot \frac{d^2 Z_p}{dt^2} + B \cdot \frac{dZ_p}{dt} + CZ := F_0 \cdot \sin(\omega t) \quad \text{Eq. (2.4)}$$

The force is harmonic, hence the solution of Eq. 2.2 can also be assumed to be harmonic with difference in phase,  $\varepsilon_z$ , between the force and the motion (Rao, 2011).

$$Z \cdot \omega \cdot \cos(\omega t + \varepsilon_z), \frac{d^2 Z_p}{dt^2} := -Z \cdot \omega^2 \sin(\omega t + \varepsilon_z) = \quad Z_p := \left( Z \cdot \sin(\omega t + \varepsilon_z), \frac{dZ_p}{dt} \right) \quad \text{Eq. (2.5)}$$

When substituting Eq. 2.5 with Eq. 2.2 you get Eq. 2.6:

$$Z \left[ \left( C - M \cdot \omega_e^2 \right) \sin(\omega t + \varepsilon_z) + B \omega \cos(\omega t + \varepsilon_z) \right] := F_0 \cdot \sin(\omega t) \quad \text{Eq. (2.6)}$$

By using trigonometric relations (Eq. 2.7, Eq. 2.8) one gets Eq. 2.9:

$$\cos(\omega t + \varepsilon) := \cos \omega t \cdot \cos \varepsilon + \sin \omega t \cdot \sin \varepsilon \quad \text{Eq. (2.7)}$$

$$\sin(\omega t + \varepsilon) := \sin \omega t \cdot \cos \varepsilon + \cos \omega t \cdot \sin \varepsilon \quad \text{Eq. (2.8)}$$

$$Z \left[ \left( C - M \cdot \omega_e^2 \right) \cos(\varepsilon_z) + B \omega_e \cdot \sin(\varepsilon_z) \right] \sin(\omega t) := F_0 \cdot \sin(\omega t) \quad \text{Eq. (2.9)}$$

Hence Z is given as:

$$Z := \frac{F_0}{\sqrt{\left( c - M\omega^2 \right)^2 + (B\omega)^2}} \quad \text{Eq. (2.10)}$$

## 2.1.2 Dynamic amplification factor

If we multiply the displacement and the combined structural stiffness we get the total load acting on an object:

$$F_{\text{total}} := Z \cdot C \quad \text{Eq. (2.11)}$$

To achieve this relation, we divide Eq. 2.10 by stiffness coefficient, C:

$$Z := \frac{\frac{F_0}{C}}{\sqrt{\frac{(C - M\omega^2)^2}{C^2} + \frac{(B\omega)^2}{C^2}}} \quad \text{Eq. (2.12)}$$

Eq. 2.13 gives us the relations for  $\omega_n$ ,  $\lambda$ , and  $r$ , where  $\omega_n$  is natural frequency,  $\lambda$  is frequency ratio, and  $r$  is the relation:

$$\omega_n := \sqrt{\frac{C}{M}} \quad \lambda := \frac{B}{2M\omega_n} \quad r := \frac{\omega}{\omega_n} \quad \text{Eq. (2.13)}$$

By substituting Eq. 2.13 in Eq. 2.12 we get Eq. 2.14:

$$\text{DAF} := \frac{ZC}{F_0} = \frac{1}{\sqrt{(1 - r^2)^2 + (2\lambda r)^2}} \quad \text{Eq. (2.14)}$$

For every system with one single degree of freedom (SDoF) in harmonic motion, this relation will be the same. To obtain Eq. 2.15 we combine Eq. 2.12 and Eq. 2.14:

$$F_{\text{tot}} := F_0 \cdot \text{DAF} \quad \text{Eq. (2.15)}$$

Equation 2.15 gives us the total force ( $F_{\text{tot}}$ ) in the system by multiplying the static force ( $F_0$ ) with the DAF. This serves to prove that we can obtain the total load in a system ( $F_0 \cdot \text{DAF}$ ) by using the equation of motion.

## 2.2 Rules and regulations

All work conducted in the Norwegian continental shelf needs to fulfill the requirements of Norwegian law. Fig. 2 illustrates the hierarchy of the legal system in Norway.

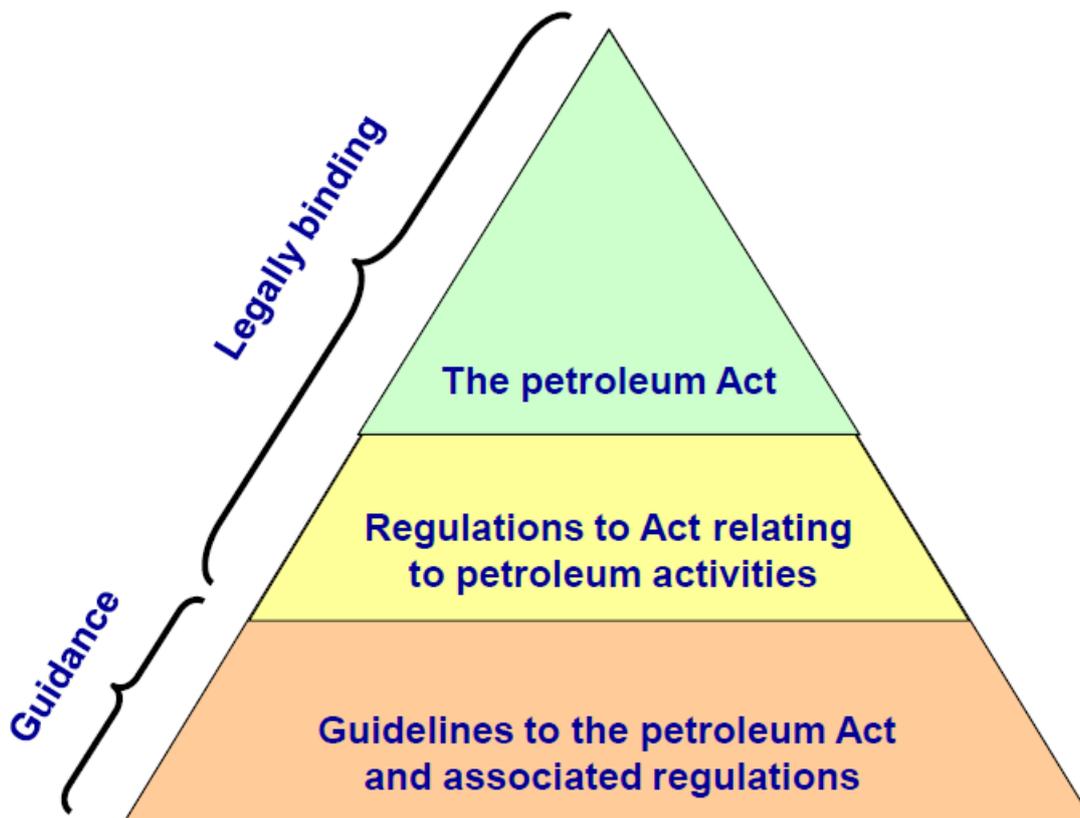


Figure 2. Hierarchy of the legal system in Norway (source: Odland, 2013).

The organization of the Norwegian petroleum sector is illustrated in Fig. 3. Stortinget (parliament) is the legislative body in Norway which prepares the framework for petroleum activities. The government has executive power and is therefore responsible for petroleum policy (via the Norwegian parliament). The different ministries have the responsibility to execute various roles in regard to petroleum policy (Odland, 2013).

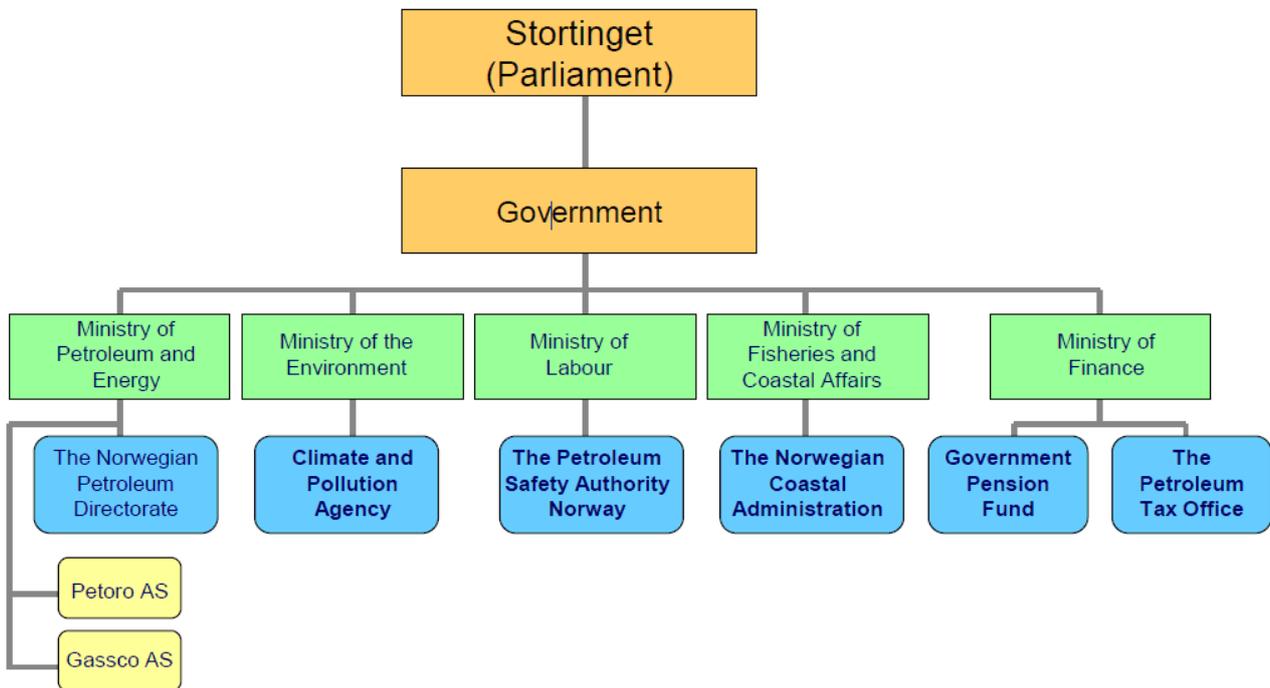


Figure 3. National organization of the petroleum sector in Norway (source: Odland, 2013).

## 2.2.1 Level of standards

According to EN 45020 (ISO/IEC Directives, 2011):

A standard is a document which is established by consensus and approved by a recognized body, that provides, for common and repeated use, rules, guidelines or characteristics for activities or their results, aimed at the achievement of the optimum degree of order in a given context.

Standards should be based on science, technology and experience and be aimed at the promotion of optimum community benefits. We divide petroleum standards into four categories:

- Industry and association standards.
- National standards.
- Regional standards (European).
- International standards.

## 2.2.2 Industry and association standards

Standards that deliver technical contributions to the industry are often called industry and association standards. The NORSOK standard is a guideline for activity on the Norwegian continental shelf developed by the Norwegian petroleum industry. Standard Norway develops the NORSOK standard for the Norwegian petroleum industry, but they depend on input from the industry to develop the product.

The industry and association standards are developed to ensure safe and economical design and processes. Norwegian safety frameworks and climate conditions may require their own standards, or additions to the international and European standards. NORSOK was established to fulfill this need and as far as possible replace oil companies' own specifications. (Standard Norway, 2014)

## 2.2.3 National standards

Norway is a part of CEN, the European committee of standardization. Hence every standard issued by CEN becomes a national standard.

CEN is an association that brings together the national standardization bodies of 33 European countries. CEN is one of three European standardization organizations (together with CENELEC the European Committee for Electrotechnical Standardization and ETSI the European Telecommunications Standards Institute) that have been officially recognized by the European Union and by the European Free Trade Association (EFTA) as being responsible for developing and defining voluntary standards at a European level.

CEN provides a platform for the development of European standards and other technical documents in relation to various kinds of products, materials, services and processes.

CEN supports standardization activities in relation to a wide range of fields and sectors including: air and space, chemicals, construction, consumer products, defense and security, energy, the environment, food and feed, health and safety, healthcare, ICT, machinery, materials, pressure equipment, services, smart living, transport and packaging ([www.cen.eu](http://www.cen.eu), 2014).

## 2.2.4 International standards

The International Organization for Standardization, the International Telecommunication Union and the International Electro-Technical Commission has the international responsibility to issue international standards to the public.

## 2.2.5 NORSOK

The NORSOK standards are developed by the Norwegian petroleum industry to ensure adequate safety, value adding and cost effectiveness for petroleum industry developments and operations. NORSOK is short for **NOR**sk **SO**kkel **K**onkurransesposisjon (Norwegian shelf competitive position) and specifies general principles and guidelines for design, assessment and verification of load bearing structures on the Norwegian continental shelf. NORSOK standards are normally based on recognized international standards, adding the provisions deemed necessary to fulfill the broad needs of the Norwegian petroleum industry.

The NORSOK standards are divided into material areas , with N representing the structural standards and R those containing technical requirements concerning lifting and lowering facilities of launching and recovery appliances for life saving equipment.

The NORSOK standard was created in 1993, to replace internal company specifications and provide input for the Norwegian petroleum industry when possible. (Standards Norway)

Some of the NORSOK standards used for offshore steel constructions and lifting equipment are:

- NORSOK N-001: “Integrity of offshore structures.”
- NORSOK N-003: “Actions and actions effect.”
- NORSOK N-004: “Design of steel structures.”
- NORSOK R-002: “Lifting Equipment.”

## 2.3 Lifting condition

Lifting operations with offshore cranes is divided in two groups: inboard and offboard lifts (see Fig. 4). Inboard lifts are used when an object being lifted is placed inside a platform and offboard lifts are used when an object being lifted is placed outside a platform. Factors and calculations for lifting accessories may be different for each situation.



Figure 4. Illustration of offboard lifts ([www.looking-glass-animations.co.uk](http://www.looking-glass-animations.co.uk), 2014).

## 2.4 Lifting of C05 balcony

For the Sleipner connection project the offshore crane has a lifting capacity of 50 metric tons. Due to unpredictable weather conditions it is recommended that objects weigh less than 36 metric tons when possible. When a lifted object weighs less than 36 metric tons waves will not cause a problem when lifting in normal weather.

The offshore crane on Sleipner A is operated by Statoil and the crane operator has authority to determine when it's safe to lift. There are many factors that come into play such as object shape, wind, waves, etc. Since the crane operator conducts a professional assessment for each lift, there is no scientific logic for weight and lifting. However experience indicates that objects weighing less than 36 metric tons can tolerate twice as high waves as objects weighing 50 metric tons.

There are several different lifting methods used which impact the design considerations. In the case study a four part sling arrangement is used, but single hook, multiple hook, spreader bar, lifting frame, and three part sling arrangements were also considered.

The four part sling arrangement shown in Fig. 5 proved to be the best suited because of the small size of the area and the change in hook up point.

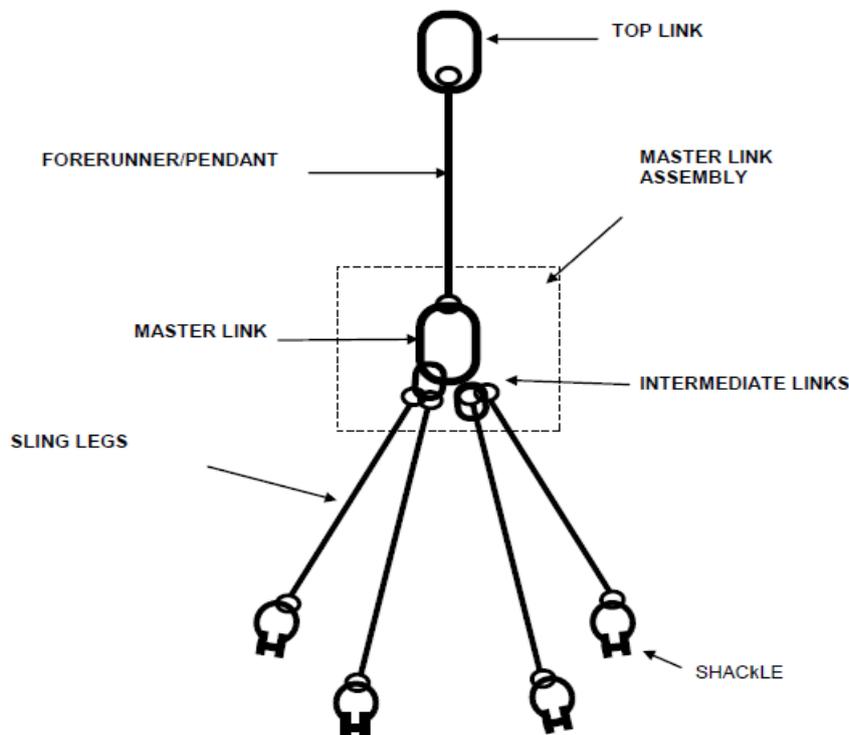


Figure 5. Four part sling arrangement (source: NORSOK R-002).

# Chapter 3

## Design of balcony

### 3.1 Design basis

The design of the C05 balcony is based on the given standards and regulations as well as the given technical specification given by the developer (Statoil). This chapter will include a basic description of the work being done, as well as a description of the design loads and the limitations of the balcony (see Fig. 6).

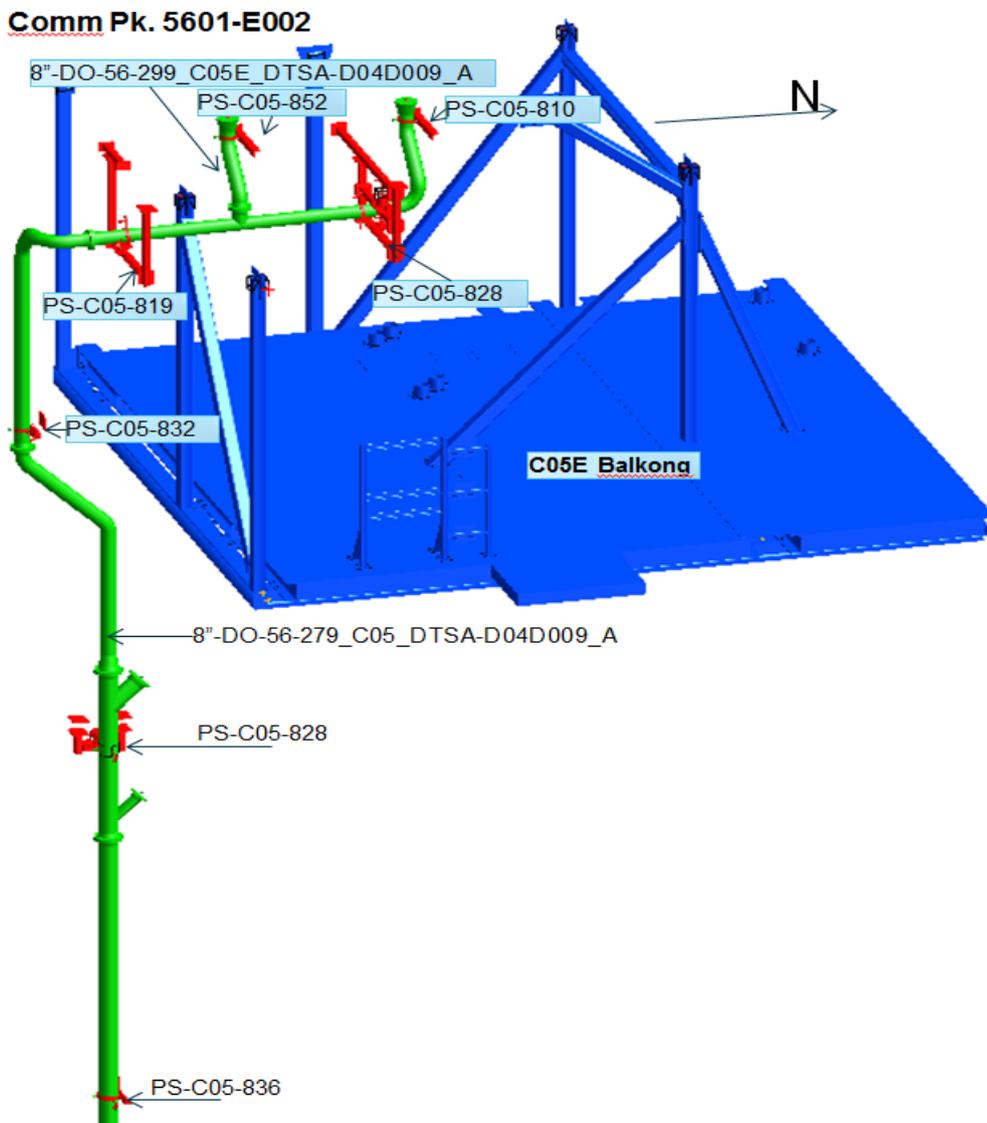


Figure 6. C05E Balcony (Aker Solutions, 2014).

### 3.1.1 Field description

Aker Solutions, on behalf of Statoil, is performing modification work on the Sleipner A and T platforms. This work is an important part of the connection of the Gudrun platform to Sleipner. Oil and gas will be supplied to Sleipner A in two pipelines from the Gudrun platform. One part of this installation is the balcony (C05 east), used as an access point to the Sleipner platform and holding safety valves for the oil and gases pipes.

The Sleipner field is located in the southern (Norwegian) part of the North Sea. The field is developed with a wellhead facility, Sleipner B, which is remotely operated from the drilling and processing platform Sleipner A. A processing facility, Sleipner T, and a separate riser facility, Sleipner R, are connected to Sleipner A by bridge. Subsea templates are connected to Sleipner A and R.

The Gina Krog platform is located north of the Sleipner field and will be connected to Sleipner A through a gas pipeline. The pipeline is split into two pipelines at Sleipner A (see Fig. 7).

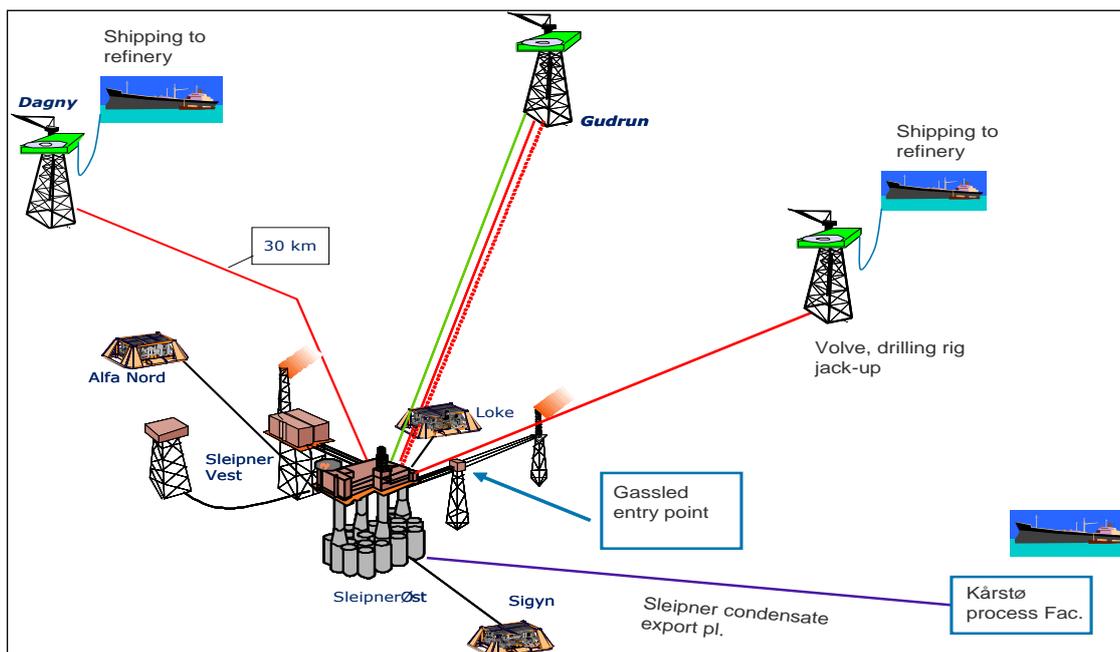


Figure 7. Field layout (source: Statoil 2012 ).

### **3.1.2 Design life**

The service life of the Sleipner topside is 25 years from the start of production. The service lifetime for the equipment and system is 20 years.

### **3.1.3 Existing load and bearing structure**

To refine this report I will not go through all existing bearing structures. I will only make calculations for the structure that comes in direct contact with the C05 balcony.

The existing structure is already approved for the planned loads; this was conducted during a previous study. After the modifications are executed there should only be small changes to the initial study.

## **3.2 Design premise**

References used as a design premise were obtained from Statoil and Aker Solutions.

### **3.2.1 Limit states**

For the last 20 years, developments in structural design have been moving from working stress design (WSD) toward limit state design (LSD).

LSD is based on considerations of the various situations that may make a structure cease to fulfill its purpose. For these situations, the strength is calculated using different factors in design. As for the WSD, there is one safety factor used based on previous experience and working load, instead of design load.

LSD refers to a design method used in structural engineering. A limit state is the condition of a structure when it no longer fulfils the relevant design criteria. For each case of use a limit state is applied that will ensure that the structure sustains all actions that are likely to occur during its design life. There are several different limit state design codes that may be used in the same design; use of the one that has the most conservative outcome is preferred. The different limit states provide safety factors that are based on standards and regulations as shown in the chapter on design premise. This changes depending on the area, task being done and materials used.

In limit state design there are four different limit states (ULS, SLS, ALS and FLS), described below. (Paik and Thayamballi, 2003)

## **ULS**

Ultimate limit state: Limit states that generally correspond to the resistance to maximum applied actions.

- Loss of structural resistance (yield or buckling).
- Failure due to brittle fractures.
- Loss of static equilibrium in the entire structure or parts of it.
- Failure of critical components caused by exceeding the ultimate resistance.
- Instability in part or of the entire structure resulting from buckling or plastic collapse.

## **SLS**

Serviceability limit state: Limit states that correspond to the criteria governing normal functional use. If more stringent functional requirements are not otherwise specified, the following requirements for vertical deflection apply:

- Local damage which reduces the durability or affects the efficiency of structure.
- Deformations which change the distribution of loads between the supporting rigid object and the supporting structure.

## **FLS**

Fatigue limit state: Limit states that correspond to the accumulated effect of repetitive actions. Fatigue design life of relevant details should be considered where appropriate based on a S-N (stress life testing) approach:

- Cumulative damage due to cyclic dynamic loads.

## **ALS**

Accident limit state: Limit states that correspond to situations of accidental or abnormal events. The check may be omitted if an overall evaluation shows that a collapse of structure will not entail:

- Structural damage caused by accidental loads.
- Change in resistance and structural integrity of damaged structures.

In ALS design, it is necessary to achieve a design such that the main safety functions of the structure are not impaired during and after an accident event (Paik and Thayamballi, 2003).

The standards and regulations are the applicable design criteria. When using a specified set of limit states, a situation where the structure no longer satisfies the design requirements may occur (see Table 1).

Table 1. Limit states (source: NORSOK N-001, “Integrity of offshore structures”).

Condition	Limit for $\delta_{\max}$	Limit for $\delta_2$
Deck beams	L/200	L/300
Beams supporting plaster or other brittle finish	L/250	L/350

In Table 1, L represents the span of the beam. For cantilever beams L is twice the projecting length of the cantilever.

The maximum vertical deflection is:

$$\delta_{\max} = \delta_1 + \delta_2 - \delta_0$$

Where:

$\delta_0$  = The pre-camber.

$\delta_1$  = The variation of the deflection of the beam due to the permanent loads immediately after loading.

$\delta_2$  = The variation of the deflection of the beam due to the variable loading plus any time dependent deformations due to the permanent load (NORSOK N-001, “Integrity of offshore structures”).

### 3.3 Technical data

#### 3.3.1 Design classes

The C05 balcony is in Design Class 2 according to the Norsok standard N-004. It has high failure consequences and low complexity (see Table 2). Minimum material quality and weld inspection categories of the structural components are determined according to the given design class (see Table 3).

Table 2: Classification of structural joints and components (source: Norsok N-004).

Design Class <sup>1)</sup>	Joint complexity <sup>2)</sup>	Consequences of failure
DC1	High	Applicable for joints and members where failure will have substantial consequences <sup>3)</sup> and the structure possesses limited residual strength. <sup>4)</sup>
DC2	Low	
DC3	High	Applicable for joints and members where failure will be without substantial consequences <sup>3)</sup> due to residual strength. <sup>4)</sup>
DC4	Low	
DC5	Any	Applicable for joints and members where failure will be without substantial consequences. <sup>3)</sup>

Table 3: Correlation between design classes and steel quality level (source: Norsok N-004).

Design Class	Steel Quality Level			
	I	II	III	IV
DC1	X			
DC2	(X)	X		
DC3	(X)	X		
DC4	(X)		X	
DC5				X

### 3.3.2 Material qualities and weld inspections

The following steel qualities will be used for the Gina Krog connection to the Sleipner modification:

Plates:	Y30 (420MPa) Y05 for $t \leq 8\text{mm}$
Sections:	Y05
Tubulars:	Y06/Y07

As can be seen from Table 3, Design Class 2 should have steel quality of II or better. In Table 4 below we see that Rectangular Hollow Section (RHS) profiles have a steel quality of III. This can be a problem as RHS profiles are very desirable to use because of their ability to take torsion. The reason RHS has a steel quality of III is due to lamination flaws. So if there is a risk of lamination flaws and it's very desirable to use RHS profiles, it's possible to use a non-destructive testing method like ultrasonic waves to make sure that it will hold.

Use of a lower steel quality than recommended in the standards must be justified by solid arguments.

#### Arguments for using RHS for lifting beams

RHS beams supporting lifting lugs can be regarded as belonging to Design Class 4 according to NORSOK (N-004, section 5.1), based on:

- Low geometrical joint complexity.
- Simple static system.
- Clear load transfer.
- Residual rest capacity due to special design factor for lifting beams and use of elastic yield criterion or conservative linear summation of utilization ratios for each stress resultant; see EN-NS 1993-1-1 section 6.2.1(5) and (7).
- Through thickness testing will be performed in production if relevant.

Hence, MDS Y07 steel quality III can be used for RHS beams supporting lifting lugs.

Table 4. Aker Solutions/Statoil steel guidelines (Aker Solutions, 2014).

MDS No.	Standard	Steel grade	Product type	Steel quality level
Y04	EN 10025	S355J0/J0h/J2H	Plates, sections, tubulars	IV
Y05	EN 10025	S355J2, S355 K2	Plates and sections	III
Y06	EN 10225	S355G1+N	Hot finished seamless tubulars	III
Y07	EN 10210	S355NH/S355K2H	Hot finished tubulars	III
Y26	EN 10225	S355G11+N/G11+M	Rolled sections	II
Y27	EN 10225	S355G14+Q/G14+N	Seamless tubulars	II
Y28	EN 10225	S355G13+N	Welded tubulars	II
Y30	EN 10225	S420G2+Q/G2+M	Plates	I

### Aluminium:

Extruded profiles	AA 6082	T6
Plates used for main structures	AA 5383	0/H116
Plates used for secondary structures	AA 5052	0/H24
Weld material	AA 5183	

All aluminium structures to be isolated from carbon steel by minimum 1mm stainless steel shims – type 316L. In bolt connections stainless steel bolts should be used.

### Bolts:

Bolts and nuts	Metric Gr. 8.8 hot dip galvanized. For particular connections Gr. 10.9 may be used.
Bolts and nuts stainless steel	Metric Gr. A4 – 80 (Type 316)

### Pretension of bolts:

The threads of the bolts and the side of the nut facing the washer should be coated with MolyKote G-Rapid Plus before pretension.

Bolts in joints that are primary transferring tension should be pretensioned with a torque according to Table 5 From Table 3.2 in NS-EN 1993-1-8 we can see that bolts in joints that are primary transferring shear are in category A and they shall be pretensioned with max 30% of the torque in Table 5.

When checking the bolt capacity for combined shear and tension, the pretension load can be ignored. According to Aker Solutions and Statoil's guidelines (see Table 5 below) bolts should be secured with an extra nut pretensioned with 50% of the torque from Table 5

Table 5. Aker Solutions/Statoil guidelines on bolt pretension (Aker Solutions, 2014)

BOLT DIA. (MM)	GR. 8.8 HDG	GR 10.9 HDG	GR 4A-80
12	60 Nm	82 Nm	55 Nm
16	147 Nm	196 Nm	133 Nm
20	286 Nm	382 Nm	258 Nm
24	495 Nm	660 Nm	
27	719 Nm	958 Nm	
30	987 Nm	1310 Nm	
33	1322 Nm	1757 Nm	
36	1713 Nm	2274 Nm	
39	2104 Nm	2791 Nm	

### 3.3.3 Inspections of category of welds

Inspections of category B-D, as specified by Table 5.3 in NORSOK N-004, will be used for most of the welding.

### 3.3.4 Material properties

The balcony C05 is designed with Y26 MDS which is the normal steel for rolled sections. Table 6 and Table 7 below present figures for 20 degrees Celsius which is acceptable for the North Sea. The NORSOK R-002 is valid for temperatures down to -20 degrees Celsius.

Table 6. Aker Solutions/Statoil design guidelines.(Aker Solutions)

MDS	Nominal thickness of the element t [mm]			
	t < 40 mm		40 mm < t < 60 mm	
	f <sub>y</sub>	f <sub>u</sub>	f <sub>y</sub>	f <sub>u</sub>
Y05	355 MPa	510 MPa	335 MPa	470 MPa
Y06	355 MPa t ≤ 16 mm 345 MPa 16 mm < t	470 MPa	-	-
Y07	355 MPa	490 MPa	355 MPa	470 MPa
Y26	355 MPa t ≤ 16 mm 345 MPa 16 mm < t	460 MPa	335 MPa	460 MPa
Y27	355 MPa t ≤ 20 mm 345 MPa 20 mm < t	460 MPa	-	-
Y30	420 MPa	500 MPa	420 MPa	500 MPa

Table 7. Aker Solutions/Statoil design guidelines. (Aker Solutions)

Alloy	Temper	Min. yield strength $f_y$ , N/mm <sup>2</sup>	Min. tensile strength $f_u$ , N/mm <sup>2</sup>	Elongation %	Reduction factor for heat affected zones	Yield strength in HAZ
AA6082	T6	255	295	8	0.50	127
AA5052	H24/H34	150	230	10	0.44	80
AA5083	H24/H34	280	340	14	0.55	155
AA5083	0	125	275	15	1.00	125
AA5183		220	275	17	1.00	220

### 3.3.5 Material factors

The calculations require materials factors for design. This is to account for uncertainty in the material capacity. Using STAAD.pro we chose Eurocode for executive regulations since NORSOK is not an option. Therefore it can be useful to see the factors for both standards, as in Table 8.

Table 8. Aker Solutions/Statoil design guidelines. (Aker Solutions, 2014)

Description	Eurocode 3 1993-1-1-2005		Norsok N-004
	EC3 6.1	EC3 NA 6.1	Chapter 6.3
$\gamma_0$ Capacity for all cross section classes	1.00	1.05	1.15
$\gamma_1$ Capacity for instability in trusses	1.00	1.05	1.15
$\gamma_2$ Axial tensile capacity	1.25	1.25	1.30

### Eurocode3 versus Norsok N-004

Both design standards give formulas for loads alone and in combinations but it's very important not to use them in combination with each other.

Eurocode and Norsok give identical formulas for axial tension; the only difference is the material factor. Hence we can say that Norsok is the most conservative (a rate of 1.15/1.05 gives a difference of approximately 9.5% in favor of Norsok).

Eurocode gives formulas for biaxial bending for cross sections in classes 1 and 2, but for cross section 3, a conservative approximation of linear summation is given where utilization ratios for each section are used.

Norsok does not give design guidance on tubular members subjected to biaxial bending. However, formulas used for combined bending and axial compression force can be used assuming that there is no axial force.

Different formulas are used for uniform members subjected to both bending and axial compression in Eurocode and Norsok.

### 3.4 Inaccuracy factors

The structural elements are calculated using LRFD according to Norsok. By multiplying the design loads with relevant factors we get the minimum resistance of the structure.

$$\text{DesignWeight} := \text{Weight}_{\text{balcony}} \cdot \text{WCF} \quad \text{Eq. (3.1)}$$

$$\text{Slingload} = \frac{\text{DesignWeight} \cdot a_1 \cdot b_1 \cdot W_{\text{cog}} \cdot \text{SKL} \cdot \text{DAF}}{a_{\text{tot}} \cdot b_{\text{tot}}} \quad \text{Eq. (3.2)}$$

From Appendix (A)

### 3.4.1 Center of gravity, $W_{\text{cog}}$

When completing a lift of a structure it is desirable to have the lifting hook placed above the object's CoG to ensure that the vertical force is below the hook to prevent the object from tilting when it's lifted into the air. Because of uncertainties in weight and center of gravity estimates, a factor ( $W_{\text{cog}}$ ) is multiplied with the estimated weight to obtain a design weight as given in Eq. 3.1. From NORSOK R-002 (F.7.2.3.3) we see that this is due to different factors. For weighted objects or objects with a simple weight pattern the  $W_{\text{cog}}$  is 1.0 and for unweighted objects or objects with a complex weight pattern the  $W_{\text{cog}}$  is 1.1.

According to Det Norske Veritas DNV (DNV, 1996 – pt.1, ch.3, section 3.5.3) the CoG safety factor should be 1.05 if there is a linear relation between shifts in CoG and resulting load effects while the structure shows little sensitivity to changes. Every structure produced by Aker Solutions MMO Stavanger is test lifted before use. This is to ensure that it doesn't tilt in any direction and to determine the real weight. If the structure doesn't tilt the real CoG is approximately the same as in the design.

### 3.4.2 Skew load factor, SKL

The skew load factor (SKL) is used as a safety factor to secure extra loads which are encountered because of mismatches in sling length. This may arise as a consequence of human failure or fabrication failure. In a four point lift with slings without spreader bars the SKL factor is 1.25 according to NORSOK R-002 (Table F.3). This is the same as a 20% ( $1/1.25=0.8$ ) mismatch in sling length which is quite a lot considering that most slings are at least 1m.

The SKL should reflect the object's ability to adjust itself to the designed load and CoG. The safety factor should prevent human failure and/or fabrication failure causing an unwanted situation.

### 3.4.3 Dynamic amplification factor, DAF

As shown in Chapter 2 (Eq. 2.15) the DAF multiplied with the static load is the total force in a system. By using this method it's possible to show the loadings caused by dynamic forces on the structure using only one factor.

The NORSOK R-002 uses different DAF factors for offshore and onshore lifts. Offshore means the lift from the boat and on to the platform; every lift inside the platform is classified as onshore. From section F.7.2.3.5 in NORSOK R-002 we can see that onshore lifts under 50 metric tons should use 1.5 as DAF. For offshore lifts under 50 metric tons Eq. 3.3 should be used.

Lifts under 2 metric tons are normally not calculated and the crane operator can, through expertise and experience, use the right equipment for the job.

$$DAF_{\text{offshore}} := 1.09 + 0.41 \cdot \sqrt{\frac{50}{\text{DesignWeight}}} \quad \text{Eq. (3.3)}$$

### 3.4.4 Material resistance factor, $\gamma R_m$

$$MBL_{\text{shackle}} := \frac{\text{Slingload} \cdot \gamma R_m \cdot DF}{\cos(\alpha_B)} \quad \text{Eq. (3.4)}$$

Material resistance factor is used to secure the resistance in equipment due to fabrication and/or material error.

In NORSOK R-002,  $\gamma R_m$  for lifting lugs and structural parts are 1.15 and 1.3 for bolts and welds.

### 3.4.5 Design factor, DF

Design factor is a combination of the consequence factor ( $\gamma_c$ ) and partial load factor ( $\gamma_p$ ). The partial load factor is 1.34 in all cases from the NORSOK R-002, but the consequence factor varies from 1.0 to 1.25. In the present case and most other cases when the lifting lugs are attached directly to the object, the consequence factor will be 1.25 making the design factor 1.68.

$$DF := \gamma_c \cdot \gamma_p \quad \text{Eq. (3.5)}$$

### 3.4.6 End termination factor, $\gamma_e$

End termination factor is a safety factor used on slings to secure the load resistance. When a wire sling is produced a termination is made in the end as shown in Fig. 8 below. The end termination is often seen as a weaker link than the wire, therefore NORSOK R-002 proposes 0.8 or 0.9 depending on the type of end termination.

$$MBL_{\text{sling}} = \frac{\text{Slingload} \cdot R_m \cdot DF}{\cos(\alpha_B) \gamma_e} \quad \text{Eq. (3.6)}$$

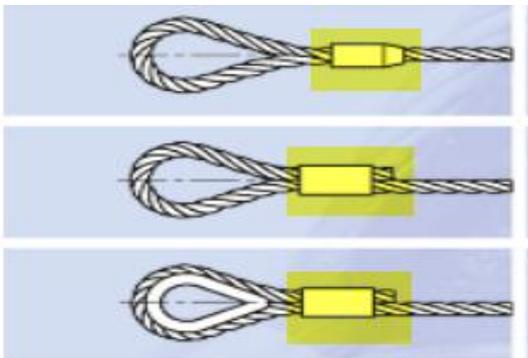


Figure 8. Wire rope technology (source: <http://www.pfeifer.de/en/wire-rope-technology/rope-terminations/common-used-rope-end-terminations>).

### 3.4.7 Design factors for lifting equipment

Lifting equipment is designed with more conservative factors than structure; this is because of the consequences of failure in lifting equipment as discussed above.

Most of the equipment is classified by the supplier: They are given the maximum sling load and will deliver according to the required standards and regulations. The safety factor used varies from supplier to supplier and for the sling load. Often the smaller sling loads have a greater safety factor than the larger sling loads. This is because large objects and structures often involve more calculations and more accurate weight estimates.

From the DNV we see that the minimum safety factor for slings is 3 (see Table 9 below). This means that the smallest safety factor the suppliers can use is 3; normally they use 4 or more.

Table 9. Safety factors for offshore lifts (source: DNV, 1996, pt.2, ch.5, section 3.1)

Load factor:	1.30
Consequence factor:	1.30
Reduction factor:	1.33
Bending factor:	1.00 (hard eyes on both ends)
Wear factor:	1.00 (single application purpose)
Material factor:	1.35 (certified new steel wire rope sling)
Total safety factor:	3.03

### 3.5 Design concept

The balcony C05 must be designed to withstand all the forces that the structure is subjected to during its lifetime. This includes forces that occur during installation; during the lifting operation in particular, these may be the largest forces the structure is subjected to.

Because of the large amount of force involved during the lifting operation, the structure must be rigid enough to prevent any permanent deformation to the structure. This was solved by using two square hollow sections (SHS) 300x10 beams to connect the lifting lugs. This makes it easier to lift using CoG and makes the structure more rigid to prevent deformation. To make the installation of pipes and other equipment on the balcony possible it will be covered with gridding plates. To maintain safety there will also be railings installed. Railings and gridding plates are not included in the STAAD model; only member force will be used to ensure that the loadings are right. The dimensions of the balcony are provided by Statoil and have to be very accurate since installation will occur in an existing structure.

The balcony must be designed in a way that makes it possible to perform maintenance and to check bolts, welding and beams for corrosion and/or fatigue damage.

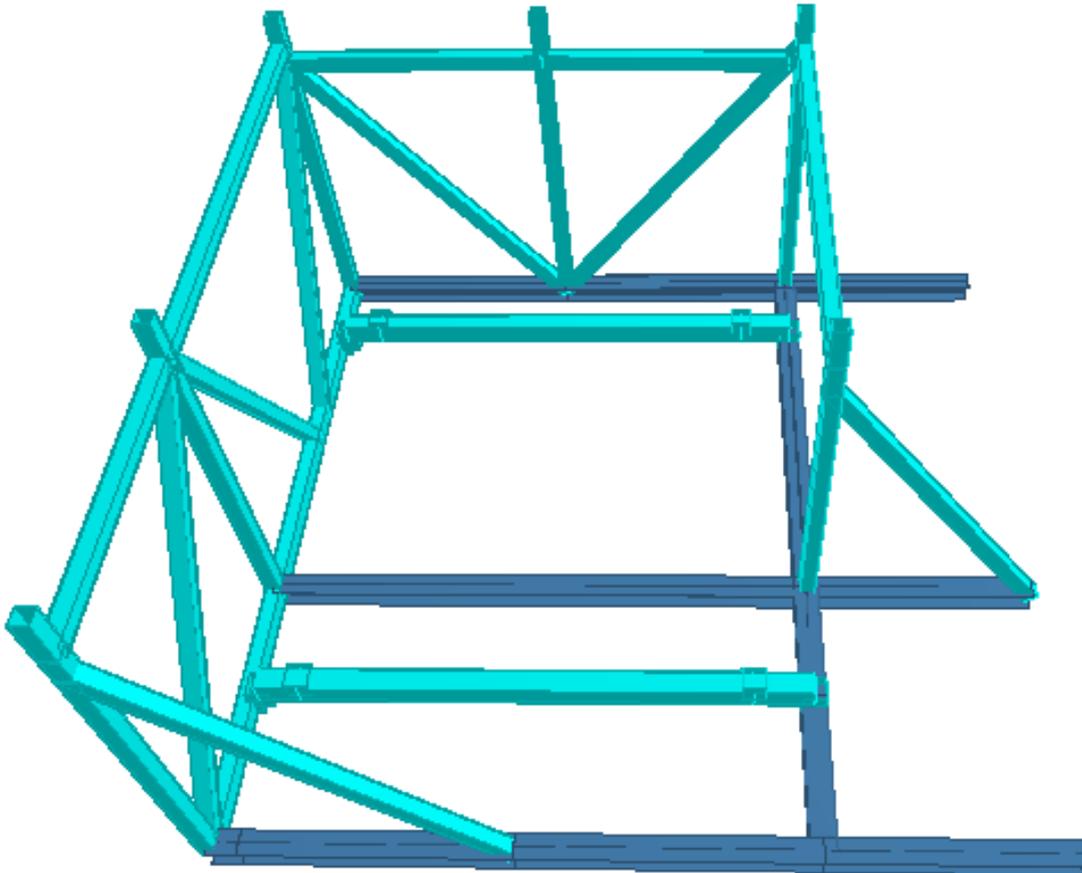


Figure 9. C05 balcony from Staad.pro design (Appendix B).

## CHAPTER 4

### AOP vs NORSOK R-002

#### 4.1 NORSOK R-002

The NORSOK R-002 standard is valid for technical requirements regarding lifting appliances and lifting accessories on all fixed and floating installations, mobile offshore units, barges and vessels, as well as on land-based plants where petroleum activities are performed. This standard is also valid for material handling and the following equipment (NORSOK R-002):

- Launching and recovery appliances for life saving equipment, with and without lifting functions.
- Means of connection and release systems that are integrated parts of life saving equipment, as well as their anchorage in the life saving equipment.
- Portable units.
- Foundations and suspensions for lifting appliances.
- Lifts.

In this thesis I will look at annexes C, F, H and J from NORSOK R-002. These annexes are applicable for my case study and comprise:

- Annex C: *“The requirements given in this annex are applicable only for lifting accessories intended for onshore and onboard lifting, unless offboard lifting is explicitly stated for particular groups or sub groups of this annex. Lifting accessories for offboard lifting shall in addition comply with applicable requirements in Annex F.”*
- Annex F: *“For portable units the requirements of this annex is applied in addition to the requirements stated in Clause 1 to Clause 5.”*
- Annex H: *“The requirements of this annex apply in addition to the requirements stated in Clause 1 to Clause 5. Foundations and suspensions are not regarded as lifting appliances. They are structural components/elements used for supporting or suspending the lifting appliance and is considered as the interface between a lifting appliance and general structure.”*
- Annex J: *“Design of lifting lugs and mating shackles is highlighted in this annex. This annex applies together with: Annex F for lifting lugs on equipment or units to be used for transportations, installation and decommissioning; Annex H for lifting lugs suspension of permanent or temporary lifting equipment; and Annex C for lifting lugs integrated in lifting accessories.”*

## 4.2 Aker work instruction manual A237

In the absence of reliable standards regarding lifting operations Aker Solutions created a work instruction for lifting equipment A237.

This was made to ensure safety and efficiency in calculation of lifting operations offboard and onboard. The work instruction manual A237 was based on DNV 2.7-3 (for portable units offshore) and was used as an executive document for lifting operations at Aker Solutions from 2009 until NORSOK R-002 was published in September 2011.

When NORSOK R-002 was released, Aker work instruction manual A237 was sent in as a proposal for the new standard, hence the similarities in inaccuracy factors and calculation methods.

## 4.3 Dynamic amplification factor in NORSOK and A237

### 4.3.1 Dynamic amplification factor

As shown in Chapter 2 DAF can be determined using the general equation of motion. In a structure exposed to dynamic loads, for example wave loadings, acceleration forces (also called mass forces or inertia forces) will arise and energy will be lost because of damping. This will lead to a dynamic effect that we have to account for when determining the loadings and making calculations regarding lifting accessories and structural components (Dynamics1 Marine Operations, Ove Tobias Gudmestad 2013; see Fig. 10).

Dynamics 1 Marine Operations (2013) define dynamics of structures in the sea in the following manner:

- “Structures as a system are dynamic which means they can be set in motion. In a system there are mass and stiffness such that motion can be sustained. Likewise, there will be some sort of damping in all systems to dampen the motion. Damping can be caused by friction in the structure or externally (in the water).”
- “In addition, waves are a driving force. Regular waves have definite periods. These can cause resonance between the loading and the structural system.”
- “A real state is actually composed of several waves (Fourier decomposition) and wave climate (sum of the waves) could find resonance between structural systems and some of the waves.”

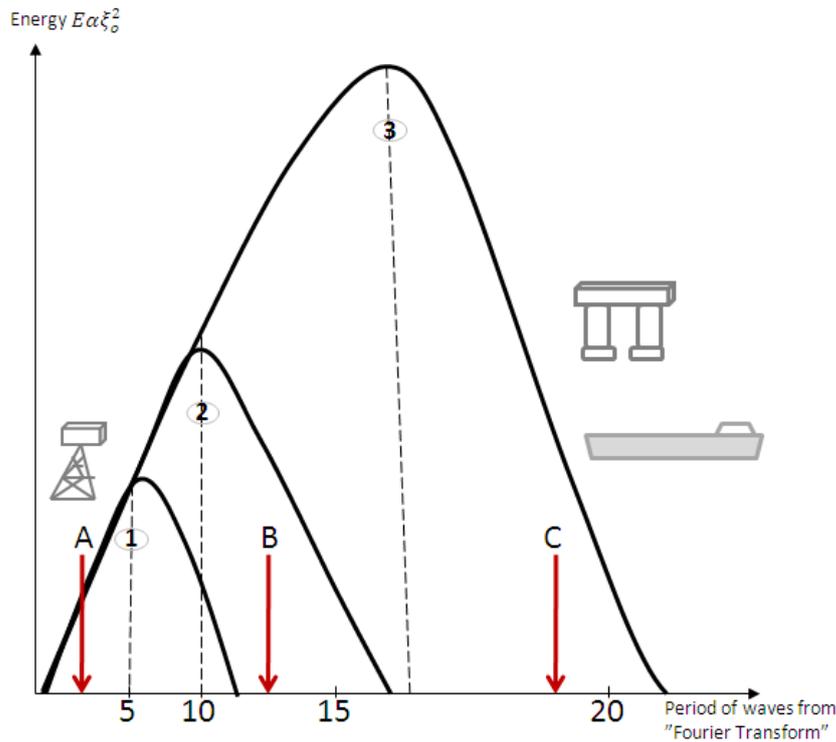


Figure 10. Waves energy in the Norwegian shelf.

Where: 1, Calm day in the North Sea; 2, Normal situation; and 3, Storm situation (source: Dynamics 1 Marine Operations, Ove Tobias Gudmestad 2013).

Dynamics of structure is a very important aspect for objects being lifted from the sea. Since the loading is dynamic the movement will also be dynamic.

In this chapter I will define the effect and importance of the DAF. I will only study systems with one degree of freedom since most systems can be described as one degree of freedom systems.

DAF is used to calculate the real loading and incorporates forces caused by movement in involved components. When lifting with an offshore crane, waves and wind will cause movements in the crane, object and the vessel transporting the object.

This affects the following aspects of DAF when lifting offshore:

- Skip motion.
- Crane motion.
- Object motion.

### 4.3.2 Vessel motion

Fig. 11 below shows six different vessel motions. Waves are the most common source of vessel motion.

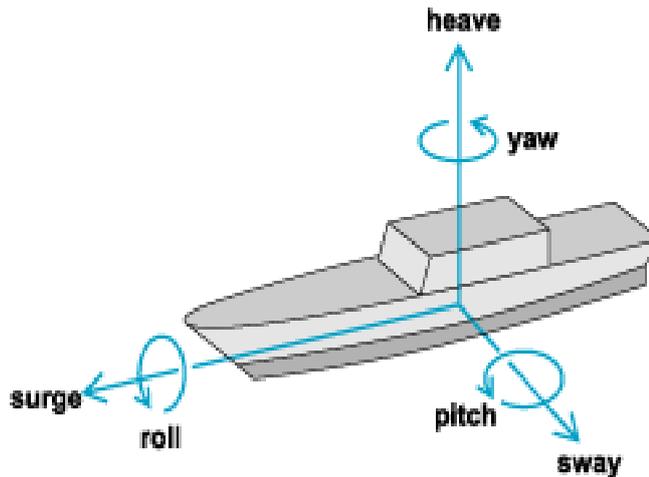


Figure 11.(source: Vessel Motion Marine Operations , (Ove Tobias Gudmestad 2013).

Eq. 4.1 and 4.2 show how the eigen frequency and eigen period of a vessel/platform can be obtained:

$$\omega_0 = \sqrt{\frac{k}{m}} \quad , \quad T_0 = \frac{2\pi}{\omega_0} = 2\pi\sqrt{\frac{m}{k}} \quad \text{Eq. (4.1, 4.2)}$$

Where:

- $\omega_0$  = Eigen frequency.
- $T_0$  = Eigen period.
- $k$  = Stiffness.
- $m$  = Mass.

When choosing a vessel for transporting offshore, it is very important to avoid similar eigen periods and wave periods, which in the worst case can cause resonance.

Eq. 4.3 and 4.4 (Marine Operation, Ove Tobias Gudmestad 2013) show simple formulas for calculation of heave and pitch motion.

$$\delta_{\text{heave}} := \frac{H_{\text{max}}}{2} \cdot \sin(\omega \cdot t) \quad \text{Eq. (4.3)}$$

$$\delta_{\text{pitch}} := R \cdot \sin(\phi \cdot \sin(\omega \cdot t)) \quad \text{Eq. (4.4)}$$

Where:

- H max = Highest wave in period.
- $\omega$  = Eigen frequency of vessel/platform.
- t = Time.
- R = Radius of the crane.

Vertical velocity and acceleration in waves (Marine Operation, Ove Tobias Gudmestad 2013) is given by:

$$\dot{z}_p(t) = \frac{F_0}{k} \cdot \text{DAF} \cdot \omega \cdot \cos(\omega t - \theta) \quad \text{Eq. (4.5)}$$

$$\ddot{z}_p(t) = -\frac{F_0}{k} \cdot \text{DAF} \cdot \omega^2 \cdot \sin(\omega t - \theta) \quad \text{Eq. (4.6)}$$

Vessel motion is a topic that is too broad to explain in this thesis. From the equations above we can see that DAF and motion of the vessel is affected by the vessel characteristic. Hence there will be a difference in DAF for each vessel depending on cargo, size and weight.

### 4.3.3 Crane motion

Motion in the crane can be a challenge when lifting and installing new equipment on platforms. This motion can be caused by several different factors where wind, waves and snap load are the most common.

Wind can cause some motion in the crane, but in cases of strong wind, the lifting operation will be postponed; hence we can neglect the effect of wind on the crane for this case study. Waves will not cause motion in the crane, but can affect motion of the platform. This may lead to motion in the crane. Hence waves can cause motion in the crane. Eq. 4.3 and 4.4 shows how heave and pitch motion are applicable for the platform. From Eq. 4.3 and 4.4 we see that eigen frequency has a significant influence on the motion, and the frequency varies with mass and stiffness (as shown in Eq. 4.1). Hence we see that the motion caused by waves will vary depending on the platform characteristics.

In normal weather conditions snap load causes most of the crane motion. When an object is lifted either inboard or offboard it will cause a snap load; this will cause motion in the object, wire and crane.

$$F_{\text{snap}} := v_{\text{snap}} \cdot \sqrt{K \cdot (M + A_{33})} \quad \text{Eq. (4.7)}$$

Where:

- $v_{\text{snap}}$  = Characteristic snap velocity [m/s].
- $K$  = Stiffness of hoisting system [N/m].
- $M$  = Mass of object in air [kg].
- $A_{33}$  = Heave added mass of object [kg].

From Eq. 4.1 and 4.7 (DNV-RP-H103) we see that the mass of the object along with stiffness of the crane and hoisting system will have an influence on the snap load and hence the motion of the crane.

### 4.3.4 Object motion

The motion of the object can be caused by the same factors as motion in the crane. Wind will cause movement of the object depending on the design and area of the object. For the C05 balcony there are no large surfaces hence the motion caused by wind can be neglected. Waves will not cause motion of the object directly but on the crane and/or vessel. The snap load and elasticity of the hoisting system will cause motion of the object.

From Eq. 4.2 we see the correlation between eigen frequency and eigen period hence Eq. 4.8 shows the relation between motion and stiffness in the wire.

Eq. 4.8 shows the period of the objects hanging in an offshore crane.

$$T_{\text{object}} := 2\pi \cdot \sqrt{\frac{m_{\text{object}} + m_{\text{wire}}}{k_{\text{wire}}}} \quad \text{Eq. (4.8)}$$

Where:

- $m_{\text{object}}$  = Mass of the object in metric tons.
- $m_{\text{wire}}$  = Mass of the wire in metric tons.
- $k_{\text{wire}}$  = Stiffness of the wire.

### 4.3.5 Dynamic amplification factor in NORSOK R-002

According to NORSOK R-002, Appendix F, all onboard lifts less than 50 metric tons shall use a DAF of 1.5 or more and use a linear reduction from 1.5 to 1.3 for lift between 50 and 100 metric tons as shown in Fig. 12. For offboard lifts NORSOK uses equation 4.9 for lifts under 50 metric tons and equation 4.10 for lift between 50 and 100 metric tons.

The greatest error in the NORSOK R-002 is that the DAF is given without an applicable significant wave height ( $H_s$ ). Hence the DAF from Fig. 12 can be used for any  $H_s$ .

According to NORSOK R-002:

As an alternative to the requirements given in the subsequent clauses, design and manufacturing according to DNV 2.7.3 may also be acceptable for types B, C, D and E

defined in DNV 2.7.3. Only units designed for operational class R60 is acceptable for use on the Norwegian continental shelf, even if their use is intended for less severe sea states.

In DNV 2.7.3 the significant wave height is 6m therefore it can be assumed that Hs in NORSOK R-002 should be the same.

$$DAF := 1.09 + 0.41 \cdot \sqrt{\frac{50}{WLL}} \quad \text{Eq. (4.9)}$$

$$DAF := 1.7 - 0.004 \cdot WLL \quad \text{Eq. (4.10)}$$

Where:

- WLL = Working load limit.

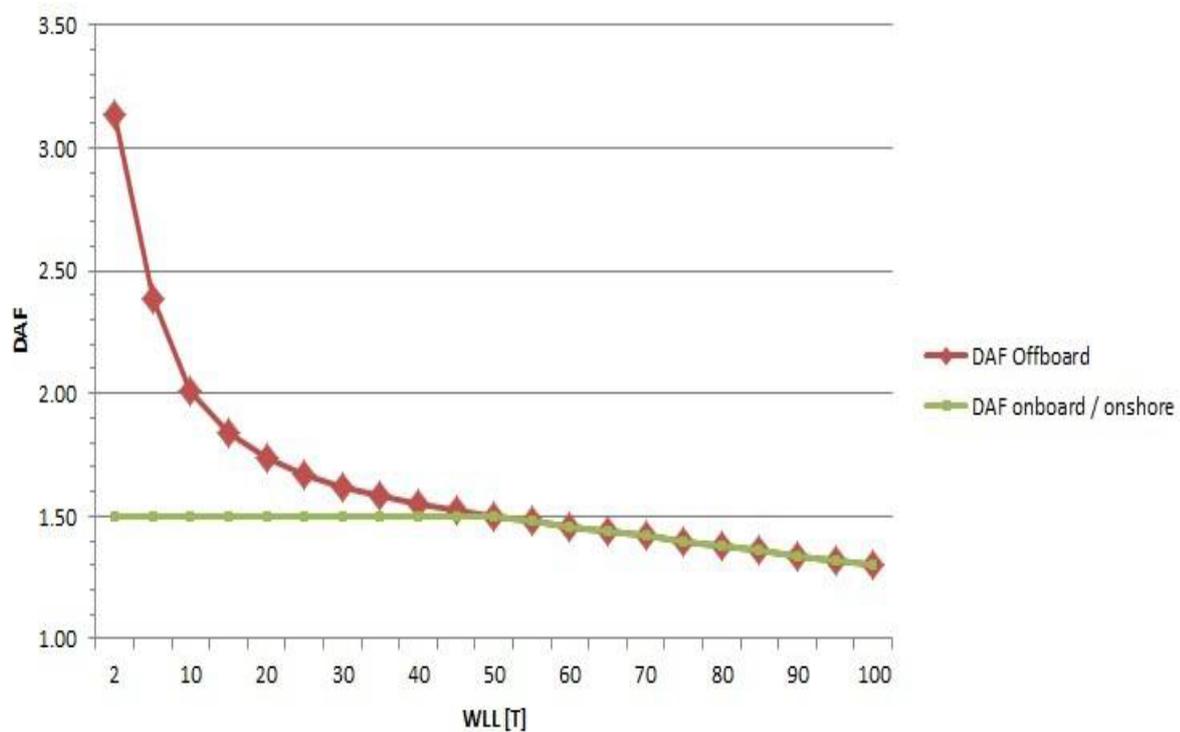


Figure 12. DAF offboard and onboard (source: NORSOK R-002).

### 4.3.6 Dynamic amplification factor in A237

Aker work instruction manual is only applicable for lifts less than 50 metric tons and uses different categories to separate the lifts as illustrated in Table 10 below.

Table 10. Lift separation categories (source: Aker work instruction manual A237).

Category	Description	Comment	Design rules Primary references	Covered by this work instructio n
A	Heavy lifts > 50T	Lifted by heavy lift vessel	DNV Rules ref. /12/	No
B	Special offshore lifts < 50T	Lifts between platform and vessel, without use of standard container/ baskets	NORSOK ref. /8/ & /9/ DNV SFC 2.7-3 ref./15/ <sup>1)</sup>	Yes
C	Standard offshore lifts < 25T	Lift between platform and vessel with standard containers/baskets	NORSOK ref. /8/ & /9/ DNV SFC 2.7-1 ref./14/	No
D <sup>2)</sup>	Platform internal lifts < 50T	Lift onboard fixed platform	NORSOK ref. /8/ & /9/ DNV SFC 2.7-3 ref./15/ <sup>1)</sup>	Yes
E	At shore/inshore lifts < 50 T	Lift by vessel or harbor crane in harbor or sheltered waters	NORSOK ref. /8/ & /9/ DNV SFC 2.7-3 ref./15/ <sup>1)</sup>	Yes
F	Onshore lifts	Yard lifts, etc.	“Machinery Regulations” ref. /2/ & /3/	No

Note 1)

*On occasion a project or client choose to define DNV SFC 2.7-1 as the Design Rule Reference for their activity, or parts thereof, related to this type of lifting. Requirements of those rules must then be added to present references.*

Note 2)

*“Non-critical” platform lifts may be performed as field-run by qualified riggers, based on the Safe Job Analysis and without formal documentation from the engineering organisation.*

Eq. 4.11 shows how the results in Fig. 13 are calculated.

$$DAF := a \cdot W + b$$

Eq. (4.11)

Table 11. Input for DAF calculations according to A237(Aker work instruction manual A237).

	<b>DAF = aW + b</b> where W = weight in tonnes					
	W: 2 - 10 T		W: 10 - 20 T		W: 20 - 50 T	
	a	b	a	b	a	b
<b>Cat. B</b>	-0.10	2.70	-0.02	1.90	-0.0067	1.6333
<b>Cat. E</b>	-0.05	1.85	-0.01	1.45	-0.0033	1.3167
<b>Cat. D &amp; F</b>	-0.0375	1.625	-0.005	1.30	-0.0033	1.2667

Fig. 13 shows DAF as a result of Eq. 4.11.

Note that Fig. 13 is not applicable for subsea lifts or other unconventional lifts; the assumed Hs is 3m (additional Hs should be considered in rougher weather conditions according to Aker work instruction manual A237).

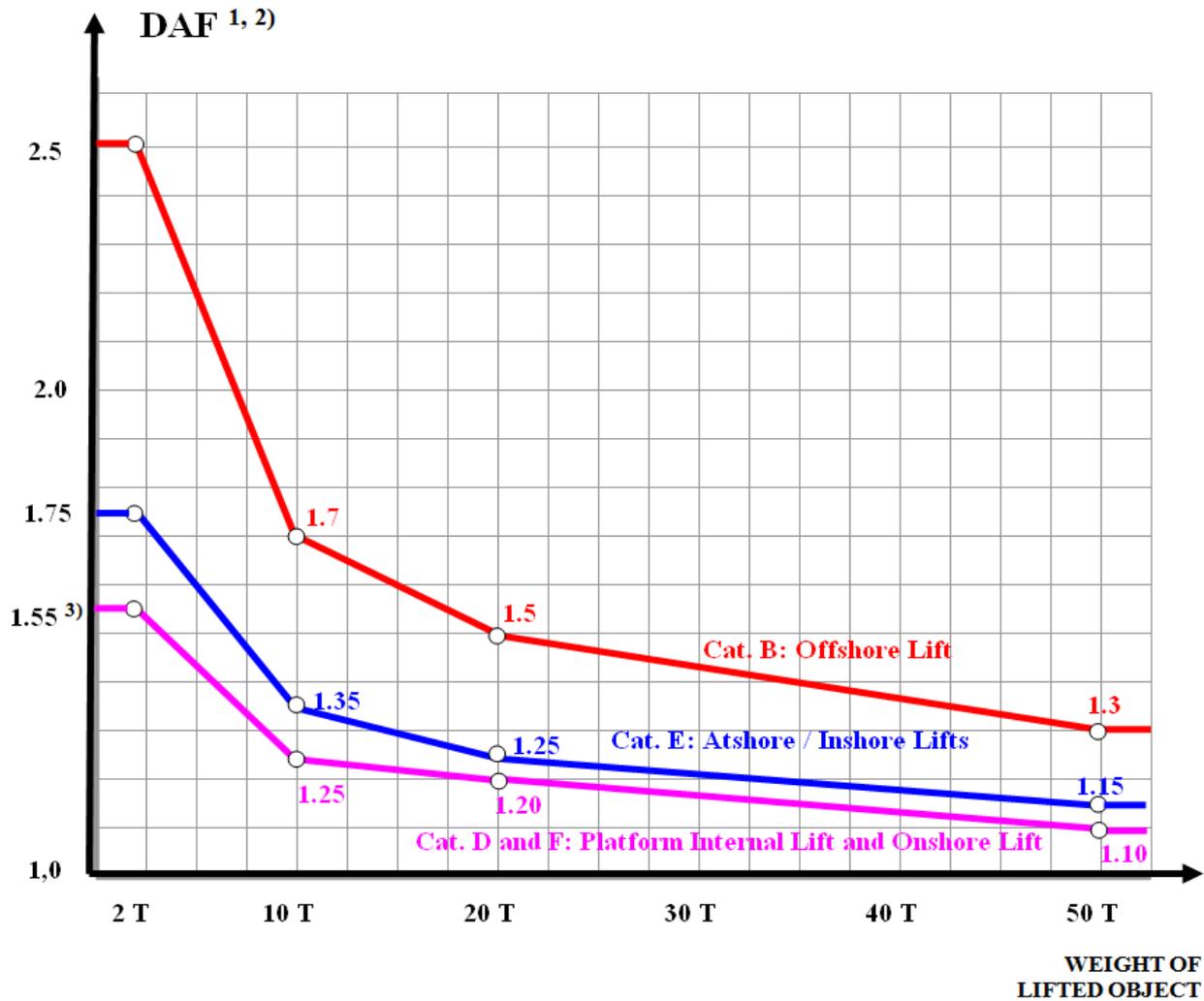


Figure 13. DAF for category B,D,E and F according to A237 (Aker work instruction manual A237).

Note 1) Figure 2-1 is not applicable for sub-sea lifts or other unconventional lifts. DAF for such lifts shall be established by more detailed calculations such as dynamic analyses or by references to similar lifts where effects of dynamics are quantified and documented.

Note 2) Is derived assuming a Hs = 3m. Additional amplification shall be considered if a rougher seastate prevails.

Note 3) This limit is derived by assuming equality of DAF· DF with NORSOK ref. /8/ on material handling lug, i.e.  $DAF_{Cat\ D/F} \cdot DF_{Cat\ D/F} = DAF_{lug} \cdot DF_{lug} \Rightarrow DAF_{Cat\ D/F} = 2.0 \times 1.3 / 1.7 = 1.55$

### 4.3.7 Discussion

From Figs. 14 and 15 we can see the differences in DAF between NORSOK R-002 and A237.

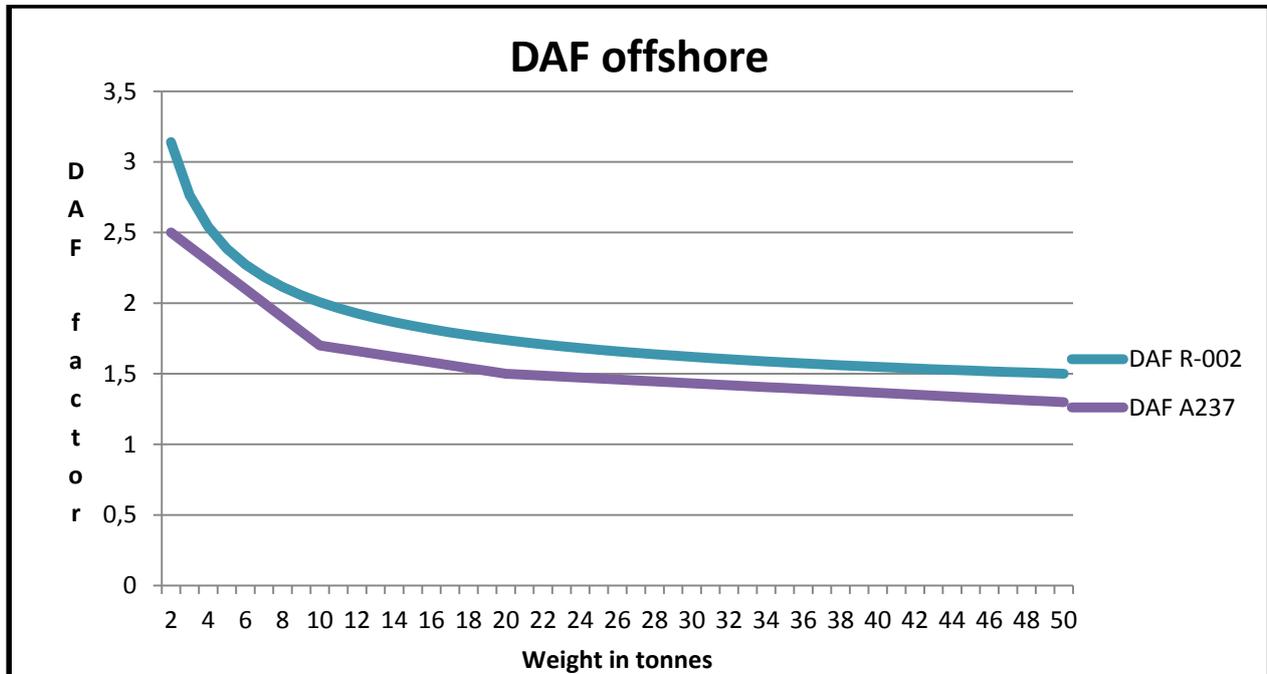


Figure 14 Difference in DAF offshore in R-002 and A237 (Appendix C)

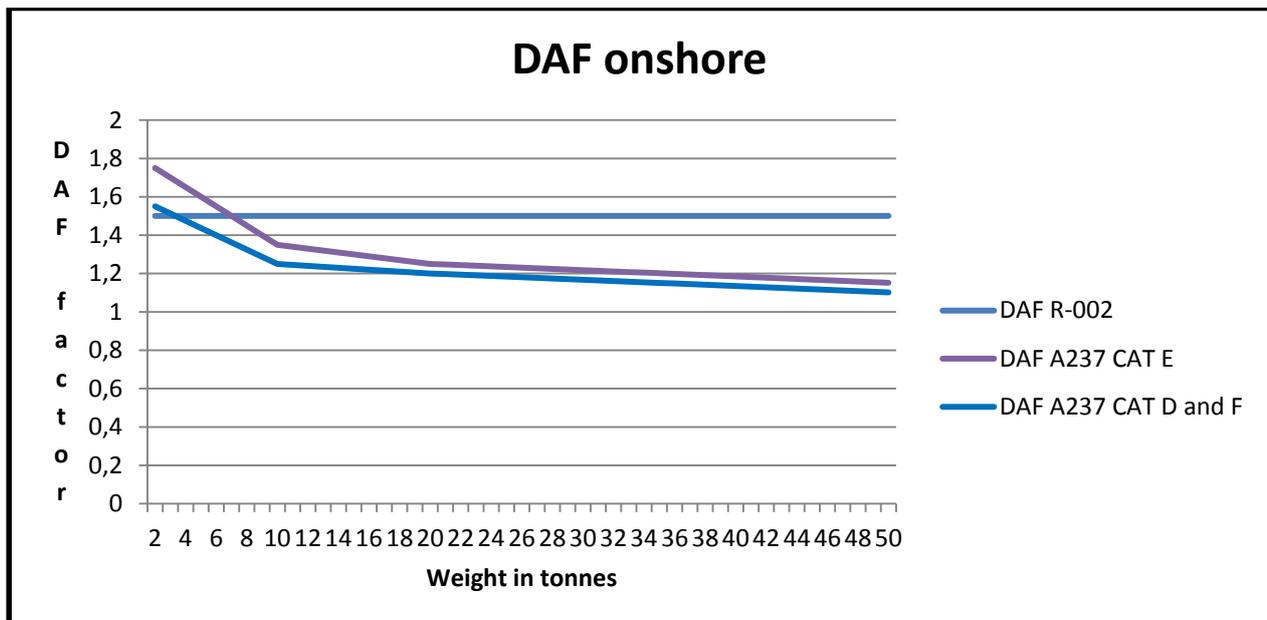


Figure 15 Difference in DAF onshore in R-002 and A237 (Appendix C)

In Chapter 4 (4.3.1) I tried to include the most important contributory factors to motion and thereby DAF. From the text above we can see that DAF for a lifting operation offshore mainly depends on weather conditions, vessel characteristics, platform characteristics, weight of object and stiffness of the crane and hosting system. Hence the DAF will in reality not be the same for two given lifting operations.

From Fig. 14 we see that NOROSK R-002 is a little more conservative than A237; it would be a reasonable conclusion that NOROSK uses a higher  $H_s$  than A237 but this is only speculation.

Fig. 15 shows that NOROSK R-002 is more conservative for the lifts above 3 metric tons in category D, another indication for higher  $H_s$ .

To ensure the safety of people and equipment, we can assume that DAF is conservative and calculated for a worst case scenario.

We know that in the North Sea there are offshore cranes lifting approximately 40 metric tons to 200 metric tons: The size and stiffness in those cranes will be significantly different, hence the DAF will be different. An ideal situation is a 50 metric ton crane lifting 50 metric tons as this will cause minimum DAF. Therefore it is very conservative when NOROSK R-002 uses 1.5 as DAF for all internal lifts. The same argument can be used regarding the transport vessel. A vessel weighing 9,000 metric tons will probably cause less motion than a vessel weighing 3,000 metric tons. Hence we can assume that DAF must be very conservative to ensure safety.

### 4.3.8 Conclusion

The consequence of the conservative approach in NOROSK R-002 is that lifting accessories can be significantly oversized and the costs higher than necessary. Oversized equipment can also cause challenges in design. The benefits can be less engineering hours and less chance of error due to wrong DAF.

Since NOROSK R-002 doesn't use a significant wave height for the DAF there will be significant uncertainty when using it.

From Figs. 16 and 17 below we can see the difference in lifting point load in NOROSK R-002 versus Aker solutions work instructions manual A237. In my opinion it would be accurate if we used several significant wave heights, as waves vary with season and there is no point in using the same  $H_s$  in winter and summer. This could save equipment costs and minimize the engineering hours.

The topic of cost and benefits when using a set factor instead of varying factor should be elaborated on more; as I don't have time to do it in this thesis, it's a task for the future.

In Figs. 16 and 17 we can see the difference in lifting point load (PLP) when using NOROSK R-002 and A237.

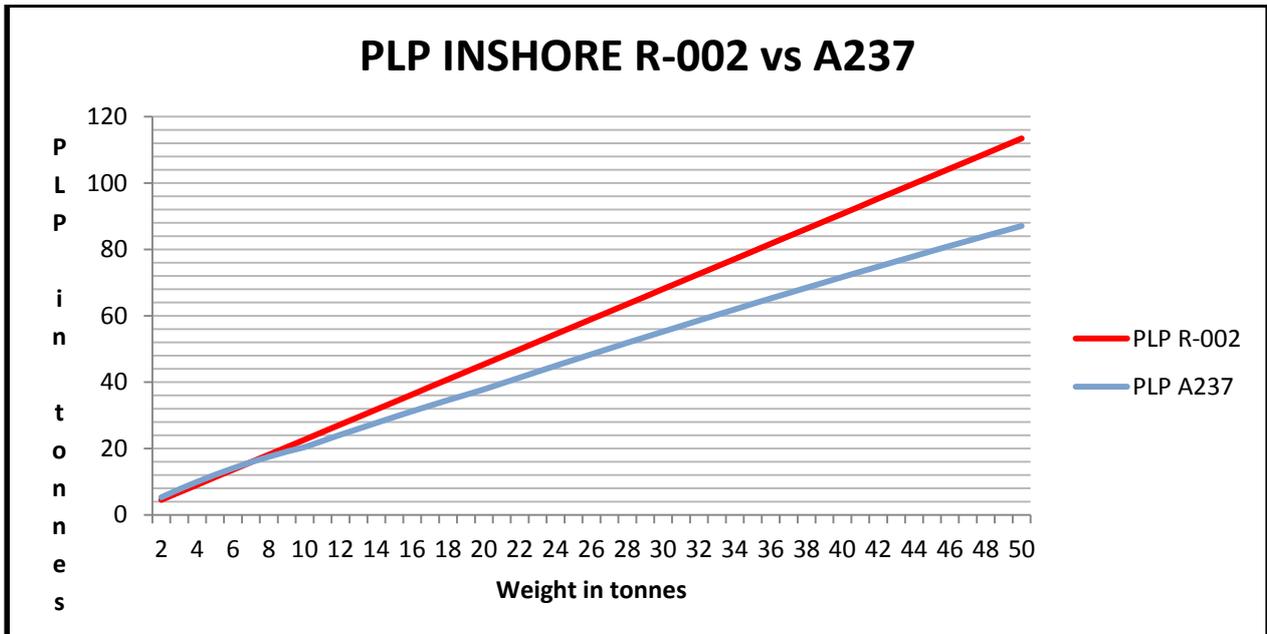


Figure 16. Difference in lifting point load for inshore lift when using R-002 and A237 (Appendix C)

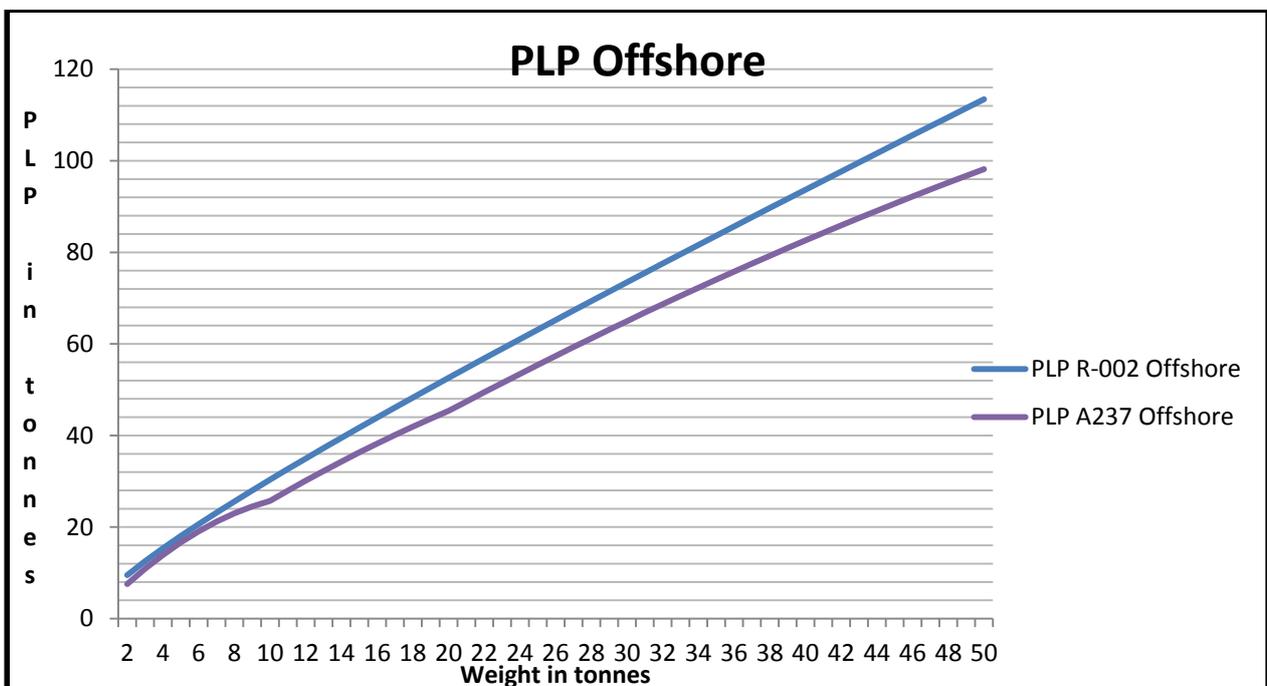


Figure 17. Difference in lifting point load for offshore lift when using R-002 and A237 (Appendix C)

## 4.4 Center of gravity, $W_{cog}$ , in R-002 and A237

The  $W_{cog}$ , as explained in section 3.4.1, is a factor used to obtain the uncertainties around the weight and CoG. Both R-002 and A237 use 1.1 as a factor for unweighted objects with a complex weight pattern.

Using software to calculate the CoG will be very accurate and it is therefore mainly human mistakes that can cause deviation. If any equipment or other items are forgotten in the software or items/equipment are loosened or moved from intended places it can cause significant deviation in CoG. Therefore, proper routines and communication are very important.

### 4.4.1 Discussion

From Fig. 18 we can see that the CoG must move over 40% before the change in sling force will be 10%. This is because the slings are elastic and will divide the force even when CoG is moved. Therefore this may seem a very conservative factor, which it is for a four part sling arrangement. But the same factor is used for a two part sling arrangement where the effect of moving the CoG has a significant effect.

Fig. 18 was obtained by moving the node representing the lifting hook in a STAAD.pro file 1% at a time and showing change in sling force in percentage for the sling with maximum force.

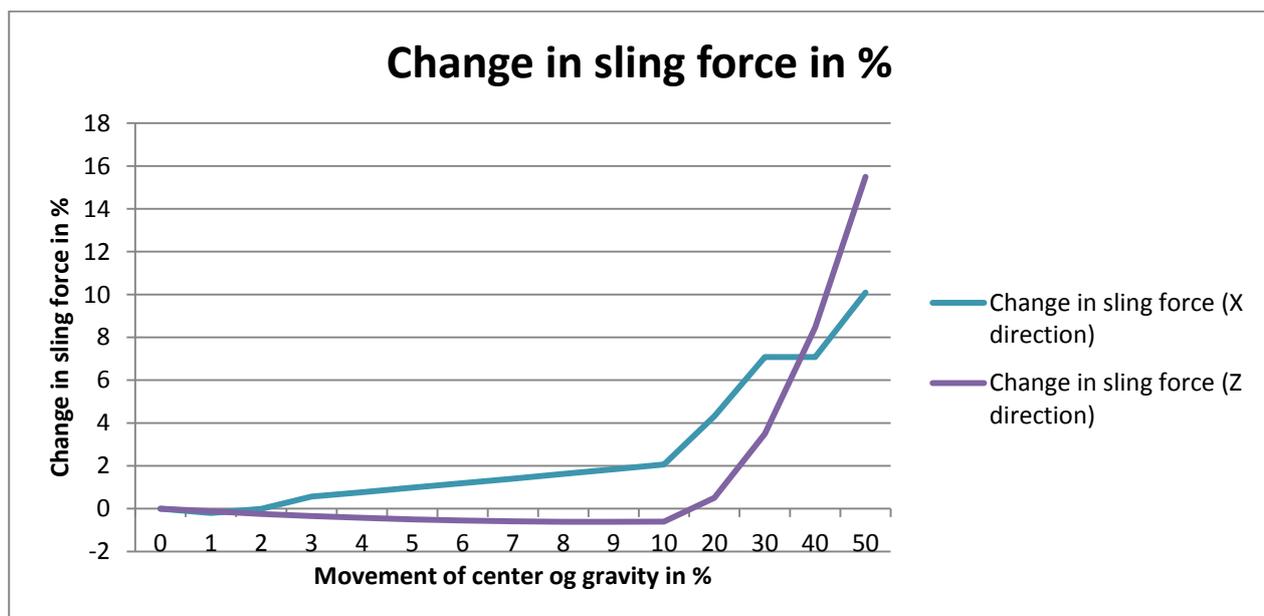


Figure 18. Change in sling force (Appendix C).

## 4.4.2 Conclusion

We can see that for a four part sling arrangement the  $W_{cog}$  factor is too conservative and will increase costs and amount of equipment slightly. But since the same factor is used for a two part sling arrangement the factor is not conservative. Hence the factor should be different for two and four point lifts.

I don't know if reducing the  $W_{cog}$  for four point lift will have a significant effect on costs, and therefore consider that there would be more disadvantages than advantages. Hence my conclusion is that it should stay as it is.

## 4.5 Skew Load factor in R-002 and A237

The SKL is used as a safety factor to secure extra loads appearing because of mismatches in sling lengths, as explained in Chapter 3 (3.4.2).

The SKL is 1.25 in both NORSOK R-002 and A237.

From NORSOK R-002:

Skew loads are additional loads from redistribution due to equipment and fabrication tolerances and other uncertainties with respect to force distribution in the rigging arrangement. The following SKL values should be used when the rigging fulfils the following criteria:

- Sling lengths within fabrication tolerances.
- Approximately symmetrical sling configuration with a working angle not more than 45 degrees from the vertical.

Table 12 shows the SKL for the different lifting configurations; it is the same in both NORSOK R-002 and A237.

Table 12. Lifting configurations (source: Aker work instruction manual A237).

LIFTING CONFIGURATION	SKL
Single hook 4 point lift without spreader bar (statically indeterminate)	1.25
Single hook 4 point lift with 1 or 2 floating spreader bars	1.10
Tandem hook 4 point lifts (statically determinate)	1.00
3 point lift (statically determinate)	1.00

### 4.5.1 Analysis of SKL factor

The skew load for the design in the case study is 1.25 according to NORSOK. This is applicable for a four point statically indeterminate lift where tolerance for sling lengths is less than 0.15%. The SKL should account for uncertainties in sling lengths. An analysis in STAAD.pro, using the C05 balcony as structure, and changing the sling lengths by moving the hook node in different directions is illustrated in Fig. 19.

The hook is moved to various points as illustrated in Fig. 19 where point 0 is the CoG. The box is 2x2x2m hence the hook will at maximum be moved 1m in each direction. Table 13 shows the results for utilization and sling force when moving the node in the different positions. Fig. 19 shows the C05 balcony and the hook node highlighted in the box. 0 is CoG and the box is 2x2x2m.

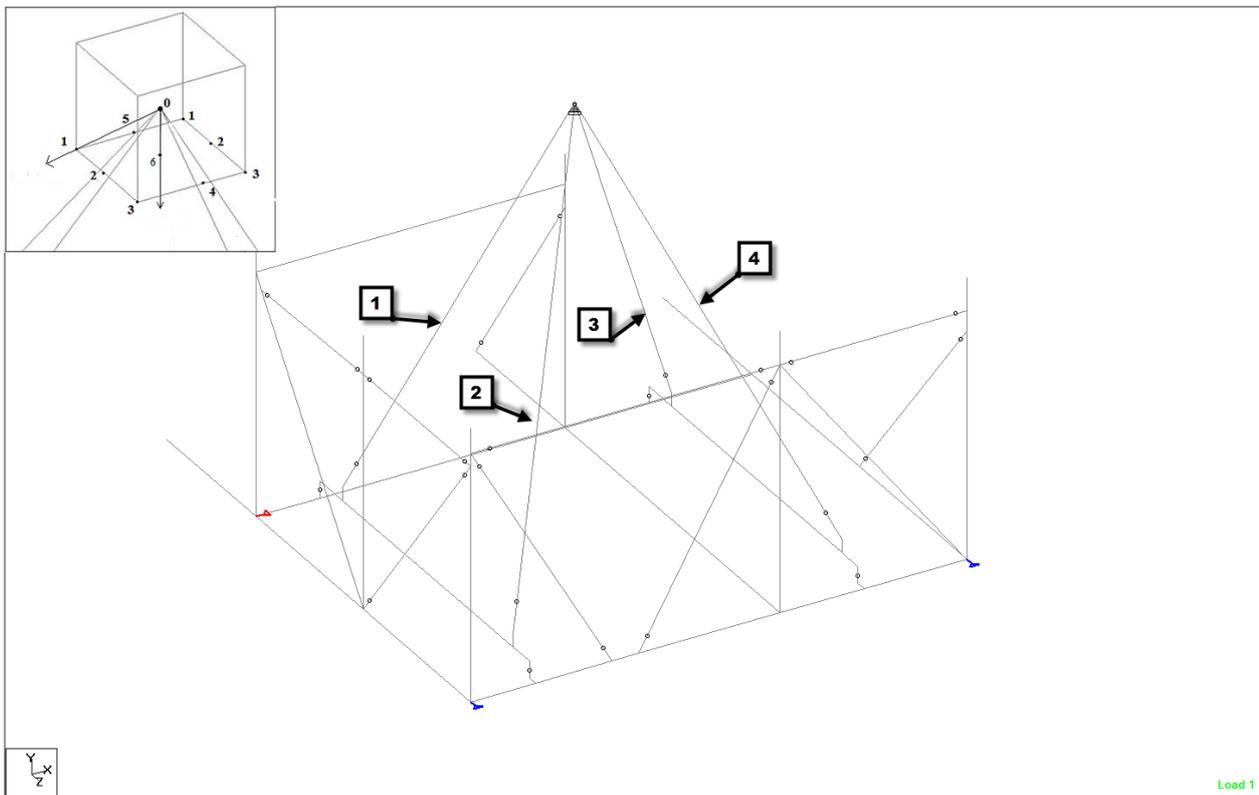


Figure 19. C05 balcony 1,2,3 and 4 is the slings used when simulating the lift (Appendix B).

By moving the nodes in the six different positions (illustrated in Fig. 19) the load distribution will change and cause changes in utilization ratio and sling force. The scope of this analysis is to check the impact that change in sling lengths will cause on the structure. This is done by checking changes in the four most utilized beams when moving the hook node. The deviation in the beams is illustrated as a percentage from position 0. Self-weight in air is used as load in this analysis.

Table 13 shows the deviation in utilization ratio and sling force for the four most utilized beams in structure C05 when moving the hook node as illustrated in Fig. 19. The deviation is calculated based on position 0.

Table 13. Deviation in utilization ratio and sling force for the four most utilized beams in structure C05

Position	Coordinate (Δx, Δz, Δy) [m]	Member number (utilization factor )					Sling number (kN)			
		18 232	41 501	34 509	28 515	1	2	3	4	
0	(0, 0, 0)	0.489	0.467	0.429	0.362	256	152	219	183	
1	(-1, -1, -1)	0.661	<b>0.568</b>	<b>0.545</b>	0.364	253	<b>163</b>	236	<b>197</b>	
2	(-1, 0, -1)	0.494	0.534	0.492	0.318	256	159	236	194	
3	(-1, 1, -1)	0.419	0.500	0.439	0.345	262	158	<b>240</b>	192	
4	(0, 1, -1)	0.443	0.462	0.410	0.349	<b>267</b>	158	229	189	
5	(0, -1, -1)	<b>0.685</b>	0.517	0.493	<b>0.414</b>	261	162	226	194	
6	(0, 0, -1)	0.514	0.480	0.438	0.370	264	159	227	191	
Max utilization and sling force		0.685	0.568	0.545	0.414	262	156	228	189	
Max deviation		40%	22%	27%	14%	2.3%	0.7%	1%	0.8%	

The intention of the analysis is to see how the structure reacts to changes in sling lengths. Member 18 has both the highest deviation and utilization ratio and is therefore the most critical element of this analysis. Beam 18 is illustrated in Fig. 20.

$$\text{Max}_{\text{deviation}} = \frac{U_{ij} - U_{0j}}{U_{0j}} \% \quad \text{Eq. (4.12)}$$

Where:

- $U_{ij}$  = the utilization ratio for member  $j$  and position  $i$ .
- $U_{0j}$  = the utilization ratio for position 0 and member  $j$ .

Fig. 20 shows the members used in Table 13.

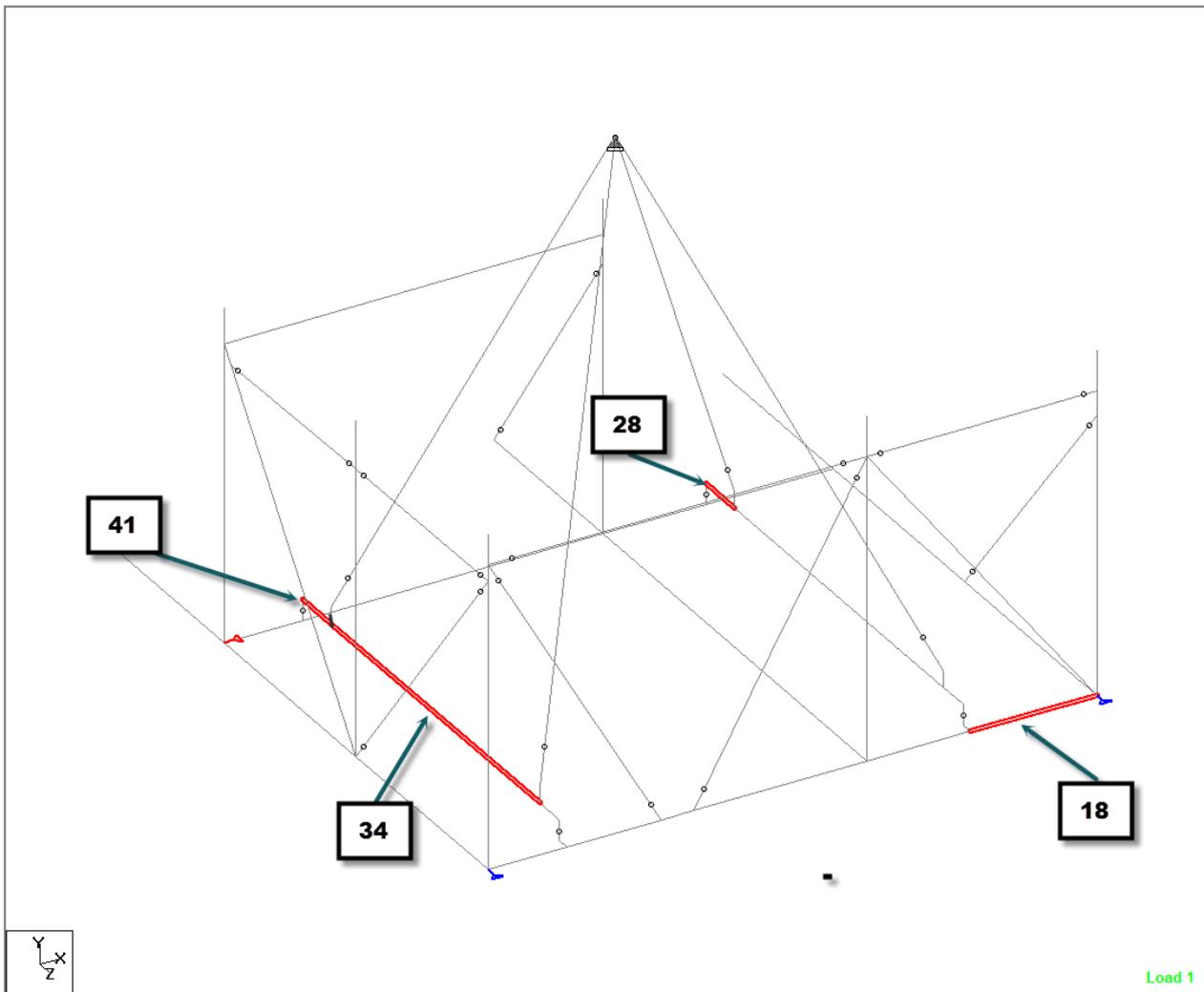


Figure 20. The four most utilized beams from table 13 (Appendix B).

### 4.5.2 Discussion

In this chapter (4.5) we have seen that SKL is 1.25 for a four part sling arrangement and that max deviation in Table 13 is 40%. Hence the SKL is not sufficient for my case study when the node is moved to position 1 and 5. In Fig. 21 we see that the deviation will exceed the 25% the SKL provides when the movement is above 0.6 meters. This shows that it is possible to exceed the 25% provided by the SKL

The probability of exceeding will depend on the shape, length and weight of the structure. Therefore it would be more accurate with a SKL dependent on the shape and size of the structure. For a quadratic structure that is 2x2m; it will be conservative with 1.25 as the SKL. But for a structure with indeterminate shape with 40m length and 15m width, it may not be enough to have 1.25 as the SKL.

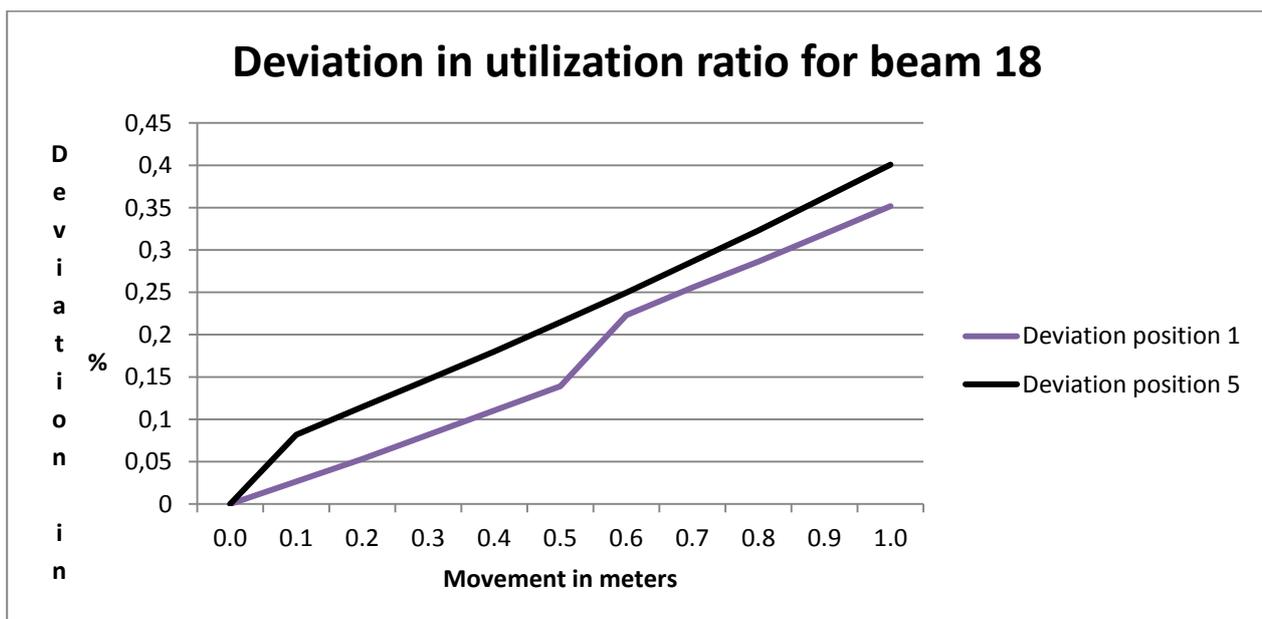


Figure 21 Deviation in utilization ratio for beam 18 (Appendix C).

### 4.5.3 Conclusion

The SKL of 1.25 may in some cases be conservative and sometimes be liberal. In the future it would be desirable to check the pros and cons when using one factor for all cases with the pros and cons when dividing up into more groups.

## 4.6 Weight contingency factor, WCF in R-002 and A237

NORSOK and A237 use the same table for weight contingency factor. Table 14 shows how the  $W_{CF}$  is defined.

Table 14. Weight contingency factor in R-002 (source: Norsork R-002).

METHOD TO DETERMINE THE WEIGHT	$W_{CF}$	COMMENT
Weighing	1,03	Incl. weighing by platform crane with calibrated loadcell within $\pm 3$ % accuracy.
Detailed calculation, based on up-to-date drawings	1,1	NOTE Possibility of significant weight development during construction and fabrication.
Detailed calculation, based on less updated drawings/info	$\geq 1,2$	$W_{CF}$ to be assessed specifically. A factor of 1,5 or more should be considered for demolition lift.

From Table 14 we see that the  $W_{CF}$  increases depending on the uncertainties in the weight of the structure. For most of the structures there will be a high uncertainty in the early stages which will decrease during the project. Factors that can cause uncertainty are fire protection, equipment, etc.  $W_{CF}$  factors that should be 1.2 or more will be determined based on experience and expertise.

Since most of the  $W_{CF}$  is based on experience and expertise there will always be a chance of error. Most of the structures delivered by Aker Solutions are test lifted at the yard before transport, hence any error will only cause loss of resources and not cause failure.

## Chapter 5

# STATIC LIFTING ANALYSIS

This chapter shows how to obtain a STAAD.pro model and gives a guide on model making.

As a part of this thesis I will verify the structural integrity of the CO5 balcony during the lift. In order to secure that the design is reliable according to Eurocode 3 in STAAD.Pro the utilization factors for the members and connection in the model must be checked.

To make a qualified global analysis it's important that all the relevant design loads are considered. The first global analysis is with all loads included as a worst case scenario at ULS design; if this holds there is no point in reducing the loads. In case the worst scenarios don't hold, some loads may be reduced in order to keep costs down. Only loads where we can argue that safety and integrity are maintained will be removed.

STAAD.pro (Structural Analysis and Design for Professionals) is a finite element software developed by Bentley. The program is capable of analyzing advanced structures in almost every kind of material. It calculates stress, deformation and internal force. Different codes can be used to check the structure.

### 5.1 Pre-processing

To avoid errors when performing a global analysis in STAAD.pro it's very important to define and check the input file to ensure that the output will be correct. The first part is pre-processing and the second part is post-processing. In the pre-processing stage the following steps should be taken:

- Define the geometry:
  - Create the nodes and put members between them.
- Define section properties:
  - Select the most suitable section for use.
- Define material properties:
  - Set the damping coefficient, alpha factor, density, Poisson's ratio and the elastic module.
- Define supports:

Set the right support for the structure (fixed, fixed but, pinned, enforced and enforced but).

➤ Define member releases:

In some cases the members and joints are not able to absorb moment and forces 100%; here it is important to set releases to get the right result.

➤ Define loads:

Define loads on nodes and members and set load cases with factor for ULS, SLS, etc.

➤ Find the CoG:

To find the right sling loads it's important to set the right CoG node.

➤ Define input:

Set the codes that STAAD.pro should use to check the structure. There are several different calculations to find the utilization factor and it's very important to set the one you desire. A utilization factor at one can be full plastic collapse or merely full elastic capacity depending on the codes in your input file.

When using Eurocode 3 material factors, yield stress, buckling lengths and buckling factors must be defined manually.

### 5.1.1 Structure geometry

Before the structure is modeled in STAAD.pro it's important to clarify the requirements and limitations. The most important topics and considerations when modeling the C05 balcony in STAAD.pro are the following:

- The C05 balcony must fit in the existing structure with the requirements set by Aker Solutions in collaboration with Statoil. It must have the strength and size to fulfill its purpose as a platform for oil and gas pipes. The design must also make it possible to fit and fasten the bolts that hold it together onto the existing structure.
- The structure must be rigid enough to withstand plastic deformation during the lifting process.
- The structure must sustain fatigue collapse during its lifetime.
- The structure cannot have a deformation larger than  $L/200$ .
- All joint and braces should be designed with an angle higher than 30 degrees to ensure high capacity welds.
- All structural corners should have a maximum angle of 58 degrees (NORSOK U-001, 2002).
- Structure must be designed with the purpose of retrofitting the hand railing.

After taking consideration of these criteria the structure can be modeled in STAAD.pro. The structure is modeled in STAAD.pro using the general user interface. First we set all the nodes by giving them coordinates in x, y and z directions. The coordinate system is built according to terrace orientation where X is pointing east, Y is pointing upwards and Z is pointing south. When the nodes are set we create members between the nodes.

### 5.1.2 Define material and section properties

#### Material properties

Materials properties must be defined for all members. Elasticity module, Poisson's ratios and density must be defined. For the balcony C05 there will only be 'normal' steel used and the material will be chosen according to Tables 12 and 13. Lifting equipment is considered individually and should be suitable (according to NORSOK R-002, R-003 and R-005) for the forces obtained using STAAD.pro. All the elements considered in the STAAD.pro model have the same properties hence there will only be one group. Bolts and welds are not included in the STAAD.pro model.

## Section properties

Section properties should be chosen based on price, strength, accessibility, size and weight. Material properties for all members must be defined.

Choosing section properties for a STAAD.pro model is normally done based on a qualified guess and experience. After the sections are selected, the structure is analyzed checking the utilization ratio for the chosen sections. Thereafter the section properties can be adjusted to obtain the wanted result.

STAAD.pro delivers a section database where the most regular European section is included. If there is use for sections that not are included in the database, it is possible to define one's own sections, yet these will often be more expensive and less accessible. The section database is illustrated in the Appendix (B).

### 5.1.3 Support and member release

#### Support

In the lifting operation there is only one support: The lifting hook at the CoG as shown in Fig.22. To make the structure stable I had to put in some dummy supports to take forces in X and Z directions. When installed on the platform there will be more supports as shown in Appendix (A). The different types of support are:

- Fixed: Restraint in FX, FY, FZ, MX, MY and MZ.
- Fixed but: Restraint in all directions but possible to choose release in every direction. It's also possible to define a spring force in every direction.
- Pinned: Restraint in FX, FY and FZ.
- Enforced: Restraint in FX, FY, FZ, MX, MY and MZ.
- Enforced but: Restraint in all directions but possible to choose release in every direction.

#### Member release

If no specific member release is set STAAD.pro will think of all connections as fixed. That means that if nothing is specified all joints will take forces and moments in every directions. Since all members don't take moments and forces in every direction we must go in and manually set the releases for each member. The joints that are not considered rigid must be defined with a member release in the direction it is incapable of sustaining.

For the C05 balcony there are releases in:

- Slings: Slings have no ability to take moments and are therefore released for all moments.
- Temporary beams: Some of the transverse beams are only temporary in place to make the structure stable during the lifting operation. This will only have a weak bolt connection and will therefore not be able to transfer moments.
- SHS: Two SHS beams are connected to a RHS around its weak axis and there is therefore a release for the moment around Y axis.

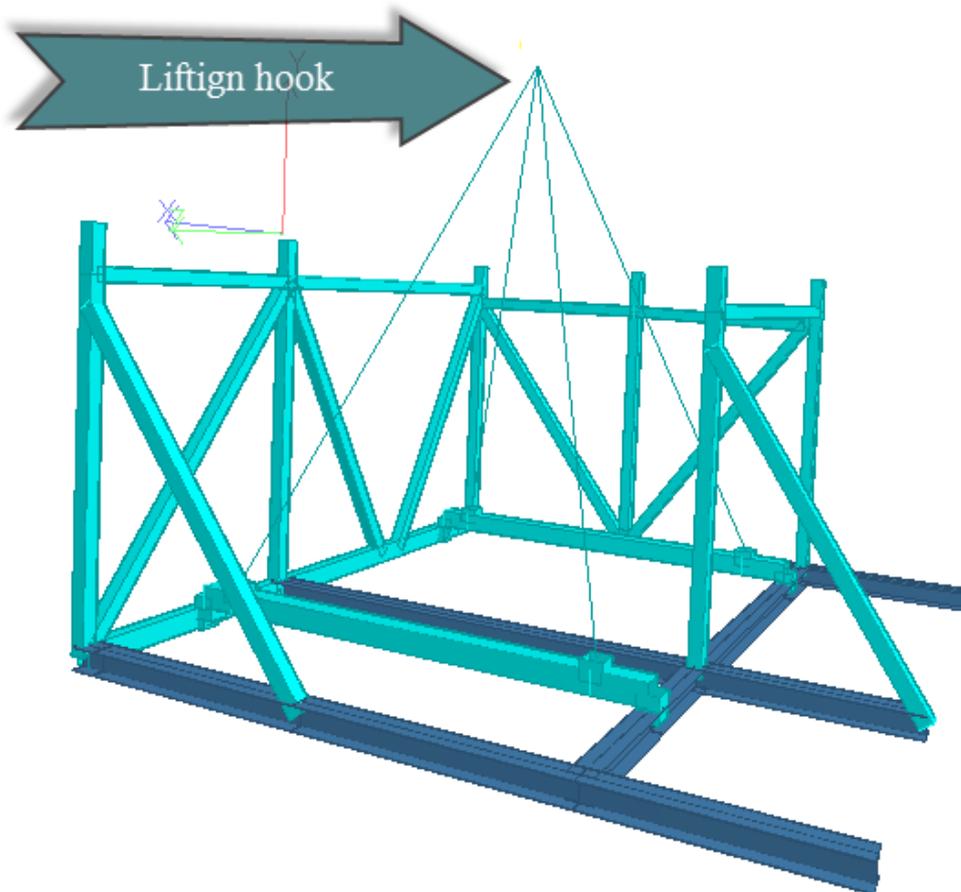


Figure 22 Lifting hook C05 balcony (Appendix B).

## 5.2 Actions and Action Effects

### General

This section focuses on design loads relevant for the designing of the connection of the C05 balcony and is obtained from Aker Solutions' internal design premise for the Sleipner project. More detailed information about design loads is available in NORSOK N-003 "Action and action effects."

#### 5.2.1 Dead Loads

The permanent loads shall be defined as the dead weight of permanent items, e.g. structure, piping, valves and equipment.

Dead load or permanent load can often be determined with a high precision. The dead load is therefore often taken as the expected average based on actual data of material density and volume of materials. A contingency factor of 1.1 should be applied to all permanent loads.

#### Structural weight

The weight of the structure shall comprise:

- Weight of modeled structural steel work.
- Secondary and outfitting structures not included in the model.
- Passive fire protection.
- Corrosion protection.

The STAAD.pro model should be adjusted for the non-modeled steel, fire protection and corrosion protection.

#### Equipment and bulk dry weight

The weight of equipment and bulk (other than steel) will consist of the following:

- Equipment.
- Electrical bulk.
- Fire and safety bulk.
- Instrument and telecommunications bulk.
- Architectural bulk.

- Piping bulk.
- Miscellaneous bulk.

Finding all the relevant bulk weight inputs from the other engineering disciplines is necessary. The forces will be added as uniform forces divided over the whole structure if nothing else is specified.

### 5.2.2 Live loads

The variable loads will be defined as loads from equipment, bulk weights and from general deck area actions, as specified below.

#### Equipment and bulk weight

The following aspect should be taken into consideration in relation to the equipment and bulk weight loads:

- Loads arising through exceptional operational requirements and/or through inspection or maintenance requirements, e.g. hydrostatic pressure tests of piping.

Items of the above having an operating weight of 3 metric tons or more will be applied in accordance with equipment arrangement drawings/plot plans. Other items will be grouped under area load and applied as uniformly distributed load (UDL).

#### Variable deck area actions

During the platform life cycle, generally all floor and roof areas can be expected to support loads in addition to the known permanent equipment, piping, structural loads, etc. Variable deck area actions should be applied in the structural check to account for loose items like supply stores, miscellaneous portable equipment, tools, personnel, etc. Deck area actions should be in accordance with NORSOK N-003.

Table 15. Variable deck area actions (source: Aker Solutions, 2014).

Deck area	Local design		Primary design	Global design
	Distributed action (kN/m <sup>2</sup> )	Point action (kN)	Distributed action (kN/m <sup>2</sup> )	Distributed action (kN/m <sup>2</sup> )
Lay down areas	15	25	15 x f	15 x f
Area between equipment	5	5	5 x f	0
Walkways, staircases and	4	4	4 x f	0

platforms				
Walkways, staircases and platforms for inspection and maintenance only	3	3	3 x f	0
Roofs accessible for inspection and repair only	1	2	1	0
Offices, electronic and instrument rooms	2	2	2 x f	0

### 5.2.3 Environmental loads

#### Wind loads

Wind loading should be applied to new structures as recommended by standard and regulations. For the C05 balcony we can use static wind pressure for design because this structure is not sensitive to wind-induced vibrations. The 3 second duration gust should be used for structures with all dimensions less than 50m.

Structures between sea level and cellar deck, and structures above weather deck modules should use the wind profile as given in section 6.3 of NORSOK N-003.

$$u(z, t) = U(z) \cdot [1 - 0.41 \cdot I_u(z) \cdot \ln(t/t_0)] \quad \text{Eq. (5.1)}$$

Where:

- $t$  = Gust duration in seconds.
- $t_0$  = 3,600 seconds (reference time in seconds).

$$U(z) = U_0 [1 + C \cdot \ln(z/10)] \quad \text{Eq. (5.2)}$$

(for 1hour mean wind speed)

$$C = 5.73 \cdot 10^{-2} \cdot \sqrt{1 + 0.15 \cdot U_0} \quad \text{Eq. (5.3)}$$

Where:

- $U_0$  = 1 hour mean wind speed at 10m above sea level.
- $Z$  = Meters above mean sea level.

$$I_u(z) = 0.06 \cdot (1 + 0.043U_0) \cdot (z/10)^{-0.22} \quad \text{Eq. (5.4)}$$

Where:

- $I_u$  = Turbulence intensity factor.

Where appropriate, wind-induced vibrations should be checked according to section 6.3.5 of NORSOK N-003.

The reference wind velocities are selected from Sleipner Field Metocean Design Basis RE2010-006.

Table 16. 1 hour mean wind velocity at 10m above SWL. (Aker Solutions, 2014)

Annual probability of exceedance	$U_0$ [m/s] 10m, 1hour
$10^{-2}$	34.0
$10^{-4}$	43.1

The static wind action should be calculated in accordance with NORSOK N-003.

The wind loads should be calculated using the following formula:

$$F = \frac{1}{2} \rho C_s A U_m^2 \cdot \sin \alpha \quad \text{Eq. (5.5)}$$

Where:

- $\rho$  = Mass density of air = 1.225 kg/m<sup>3</sup>.
- $C_s$  = Shape coefficient.
- $A$  = Area of the member or surface area normal to the direction of the force.
- $\alpha$  = Angle between the direction of the wind and the exposed member or surface.
- $U_m$  = Wind speed.

$$q := \frac{1}{2} \cdot \rho_a \cdot U_{TZ}^2 \quad \text{Eq. (5.6)}$$

Where:

- $\rho_a$  = The mass density of air to be taken as 1.226 kg/m<sup>3</sup> for dry air at 15 degrees Celsius.
- $q$  = The basic wind pressure or suction.
- $U_{TZ}$  = The wind velocity averaged over a time interval (T) at a height (Z meters) above the mean water level or onshore ground.

For a 100 year return period static wind pressure without shape coefficient:

- Main deck (46.45 m above SWL).
- Weather deck (66.75 m above SWL).

$$q_{100 \text{ main deck}} = 1.79 \text{ kN/m}^2$$

$$q_{100 \text{ weather deck}} = 1.88 \text{ kN/m}^2$$

For a 10,000 year return period static wind pressure without shape coefficient:

- Main deck (46.45 m above SWL).
- Weather deck (66.75 m above SWL).

$$q_{10,000 \text{ main deck}} = 3,21 \text{ kN/m}^2$$

$$q_{10,000 \text{ weather deck}} = 3,38 \text{ kN/m}^2$$

The shape coefficients and formulas were obtained from DNV-RP-C205

## Wave Loads

Wave loads are not relevant in the balcony C05 project. According to C007-C-N-SS-600 “Design premises structural steel detail engineering, rev. 8” (Aker Engineering, 1990), the maximum wave crest elevation is 25.1 meters above mean water level for a 100 year wave. The 25.1 meters includes tidal amplitude (0.8 meters), storm surge (0.9 meters), platform settlement (0.7 meters), reservoir subsidence (1.0 meters), uncertainties (0.5 meters), wave crest (16 meters) and caisson effect (5.2 meters).

Even though this design premise is from 1990, it’s still applicable.

## Ice and snow loads

Ice from sea spray is not relevant for structures located higher than 25m above sea level. All topside structures are above 25m. Thus, sea spray ice is not considered in the calculations for the C05 balcony.

Ice from rain/snow causes 10mm icing with a density of  $900\text{kg/m}^3$ , according to Norsok N-003. The resulting load of  $90\text{ N/m}^2$  is small compared to typical deck and equipment loads. So for the C05 balcony, ice from rain/snow is neglected and shall not be included in this analysis.

Snow load can be considered to cause  $0.5\text{ kN/m}^2$ , according to NORSOK N-003. The load is relatively small compared with the deck area loads on open areas (typical  $4\text{ kN/m}^2$ ). So this will be considered included in the deck area load.

It is expected that governing load condition for new structures will be the ULS combination of a 100 year wind. According to NORSOK N-003 (section 6.7), 100 year ice loading is only combined with a 10 year return period wind, wave and current loading, while 100 year snow loading should not be combined with any other environmental loadings at all. Therefore excluding the ice and snow loads will not affect the analysis.

## Earthquake Actions

The C05 balcony should be checked in regard to both ULS and ALS for earthquake actions. The seismic accelerations can be obtained from the original design premises:

- C007-C-N-SS-600 “Design premises structural steel detail engineering, rev. 8” (Aker Engineering, 1990).
- C007-C-N-RD-225 “Seismic accelerations for module analysis.”

Earthquakes will be evaluated based on linear static analyses. Additional manual checks will be performed if necessary to verify the structural strength based on plastic section capacity. Local buckling will be checked if necessary.

## Deformation loads

In general deformation, actions are those caused by deformations of the support points of the structure. These can be caused by temperature, like heat radiation from top of the flare boom, or action effects on other parts of the structure, like waves, wind, movement of derrick, etc.

The support displacements will have little or no influence on the C05 balcony structure and will hence be neglected in the analysis.

## 5.3 Accidental loads

### Blast loads

Blast loads are specified in C007-C-S-SD-115 “Accidental load specification.”

The design pressure is defined for each structure where a simplified quasi-static approach will be used, including effects of components dynamic responses with maximum SDOF dynamic system DAF applied.

Dynamic pressure load on items, where the fluid is allowed to pass the obstacles, is often dominated by drag forces. The pressure will often in these cases be significantly lower than the overpressure considered above.

In order to simplify the calculations, the peak overpressure (including dynamic effects) will be conservatively applied to all components. Therefore I will not include any shape factor in addition to the conservative action applied. However, if this approach leads to reinforcement of the C05 balcony or significantly increases the size, it may be beneficial to use drag forces. Drag forces will be provided for safety discipline.

Blast load shall be applied as described below:

For the overall design of the balconies vertical blast load is to be applied on the entire deck area of the structure (platform/balcony) together with horizontal blast load on blast walls and substantial obstructions exposed for horizontal blast (with material coefficients according to NORSOK N-001 for ULS and ALS). Note that for the overall design of the balconies the blast loads from pipe supports will not be considered.

### Dropped object

The new dropped object protection (DOP) structures will be designed according to ALS limit states to absorb the same impact energy as given in the design accidental loads specification.

The design of the DOP will be based on simplified methods suitable for hand calculations of plastic deformations, strain and energy absorption. Maximum allowable ultimate strain shall be based on the minimum guaranteed strain for the specific steel quality. If the strain is assumed constant in the plastic zone the maximum allowable ultimate strain will be 15%.

Energy absorption of beams can be calculated according to the following practice, specified in DNV Technical Report 82-0959:

- Length of plastic zone for each plastic hinge is to be found.
- Maximum allowable rotation angle per unit length (rad/mm) is based on maximum allowable strain and profile height. The average rotation angle per unit length (rad/mm) in the plastic zone shall be taken as 70% of the maximum allowable rotation angle per unit length.
- The average rotation angle in the plastic zone to be based on the length of the plastic zone and the average rotation angle per unit length (rad/mm).
- The maximum absorptive plastic energy to be based on average rotation angle for each plastic hinge and the plastic moment capacity of the sections using the minimum specified yield stress.
- The total absorptive plastic energy must be higher than the impact energy.

According to DNV Technical Report 82-0959, strain varies linearly from a maximum to zero; therefore using 50% of the maximum allowable rotation angle in the plastic zone per unit length will be considered as conservative. This is conservative because strain hardening will lead to larger stress as strain is increasing. If necessary it is possible to use 70% of the maximum allowable rotation angle per unit length; the fastening/hardening deformation effect is then considered. The C05 balcony is not intended to be a dropped object protector. But since dropped objects are a significant challenge when calculating structures offshore it can be useful to understand the when defining actions and action effects.

## Swinging objects

To prevent swinging objects crashing into new piping and valves a protection barrier should be provided where necessary. The design of the barrier will be based on frequently handled items that often are 7 metric ton containers crashing into the barrier with a velocity corresponding to the maximum crane rotation speed.

The maximum crane rotation is 0.8 rotations per minute in SLA.

- $t = 75$  seconds/round.

The impact energy depends on the crane radius.

Impact speed will be:

$$V_c := 2 \cdot \pi \cdot \frac{r}{t} \quad \text{Eq. (5.7)}$$

Where:

- r = Crane radius.
- w = Weight.

Kinetic energy will be:

$$E_k := \frac{w \cdot V_c^2}{2} \quad \text{Eq. (5.8)}$$

The impact energy will be calculated individually for each structure depending on the crane radius. For impact energy ALS design criteria will be applied.

When designing protection structures the calculations will be in the plastic zone. The only consideration is that the deflection shouldn't hit the pipes. Maximum allowable ultimate strain should be based on the minimum guaranteed strain for the specific steel quality. If the strain is assumed to be constant in the plastic zone the maximum allowable ultimate strain is 15%. For the C05 balcony we can argue that it is placed so far down on the platform that there is no danger of it being hit by swinging objects. Hence we don't need to include this in the calculations.

### 5.4.1 Primary load cases

Before defining load combination the primary load cases must be established. The considered structure is a balcony made to receive oil and gas risers on an existing platform. When designing the balcony in STAAD.pro the primary load cases are necessary to get the right design load output. It makes it easy to have control and to do weight summaries of individual structural parts. Table 17 below shows the primary load cases.

Table 17. Primary load cases.

Primary load case	Definition	Description
1	Self-weight of the structure in air	Self-weight of the structure modeled in STAAD.pro: Equipment and accessories are <u>not</u> included
2	Weight of equipment and accessories	An additional load added to the whole structure to compensate for the equipment and accessories which are not modeled in STAAD.pro
3	Loadings from wind	Loadings from wind on the balcony
4	Load from gas and oil pipe	Loads coming from the oil and gas risers
5	Area load	A load distributed to the whole deck area used as a safety load for loads that may appear like snow load, live load from people during maintenance, etc

Load combinations are defined depending on which loads the structure is subjected to during a certain time. All loads are divided into two groups during the lifting operation and when installed. Note that the loadings for the lifting equipment will be calculated in a separate Mathcad sheet based on the maximum loadings from these load combinations.

For design checks, the following limit states are to be assessed:

- ULS(a) and ULS(b).
- Deformations shall be checked in the SLS state as appropriate.
- FLS: To be checked where applicable.
- ALS: To be checked where applicable.

The design factors applied to different actions for limit state checks are given in Table 18:

Table 18. Design factors applied to different action for limit state checks.

Load combination	Limit state	Load condition	Primary load cases	P	L	E	A	Material coefficient
100 101	ULS A			1.3	1.3	0.7	-	1.15 / 1.3
200 201	ULS B			1.0	1.0	1.3	-	1.15 / 1.3
300 301	SLS			1.0	1.0	1.0	-	1.00
400 401	FLS			1.0	1.0	1.0	-	1.00
500 501	ALS	Accidental Abnormal env. Damaged		1.0 1.0 1.0	1.0 1.0 1.0	- 1.0 1.0	1.0 - -	1.00 / 1.1 1.00 / 1.1 1.00 / 1.1

Where:

- P = Permanent load.
- L = Live load.
- E = Environmental load.
- A = Accidental load.
- x00 = Lifting operation.
- x01 = When installed .

## CHAPTER 6

### CASE STUDY

#### 6.1 Introduction

Aker Solutions is performing modification work on Sleipner A and T on behalf of Statoil. This work is a part of the Sleipner connection project. Oil and gas will be supplied to Sleipner A via two pipelines from the Gudrun platform: One gas pipeline and one oil pipeline for further processing and export from Sleipner.

All calculations and design is in Appendix A and B, the summary of utilizations factors is shown in table 21 in chapter 7.

This case study covers the calculations for the lift and installation of the C05 east balcony. The balcony is divided into three sub-structures: The main frame, south deck and north deck. It's located on the east side of Sleipner A, below M22 main deck and M22/M23 infill area, as shown in Fig. 27. The strength verification in this case study covers the main frame, temporary lifting beams, lugs and other lifting accessories during the lift and installation. The dark blue coloring focuses the C05 east balcony.

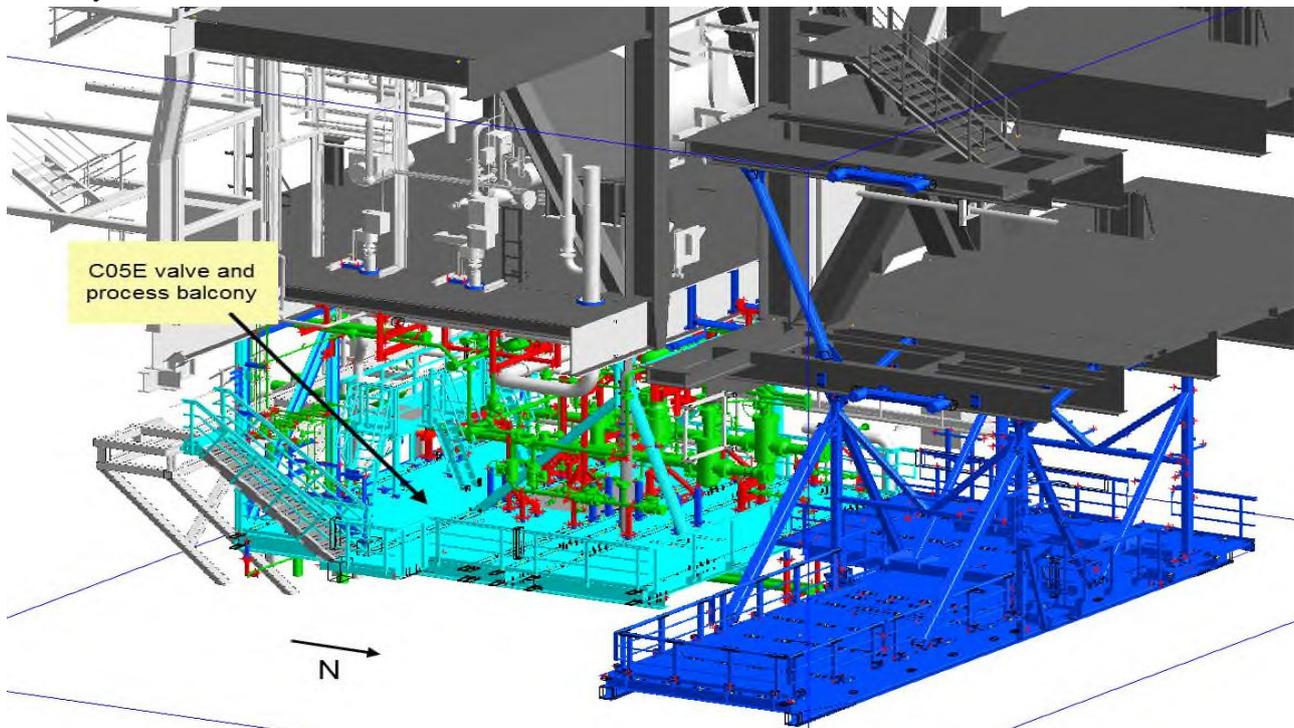


Figure 27. C05 east (source: Aker Solutions/Statoil, 2013).

The interaction between main members and temporary beams reduces the distance between zero moments at the top and bottom, reducing the effective buckling length as well as distributing the force and hence increasing the maximum load that the structure can withstand. The temporary beams were therefore necessary for the design, to provide structural stability during lifting and installation. Fig. 28 shows the temporary beams used in the main frame of the C05 balcony.

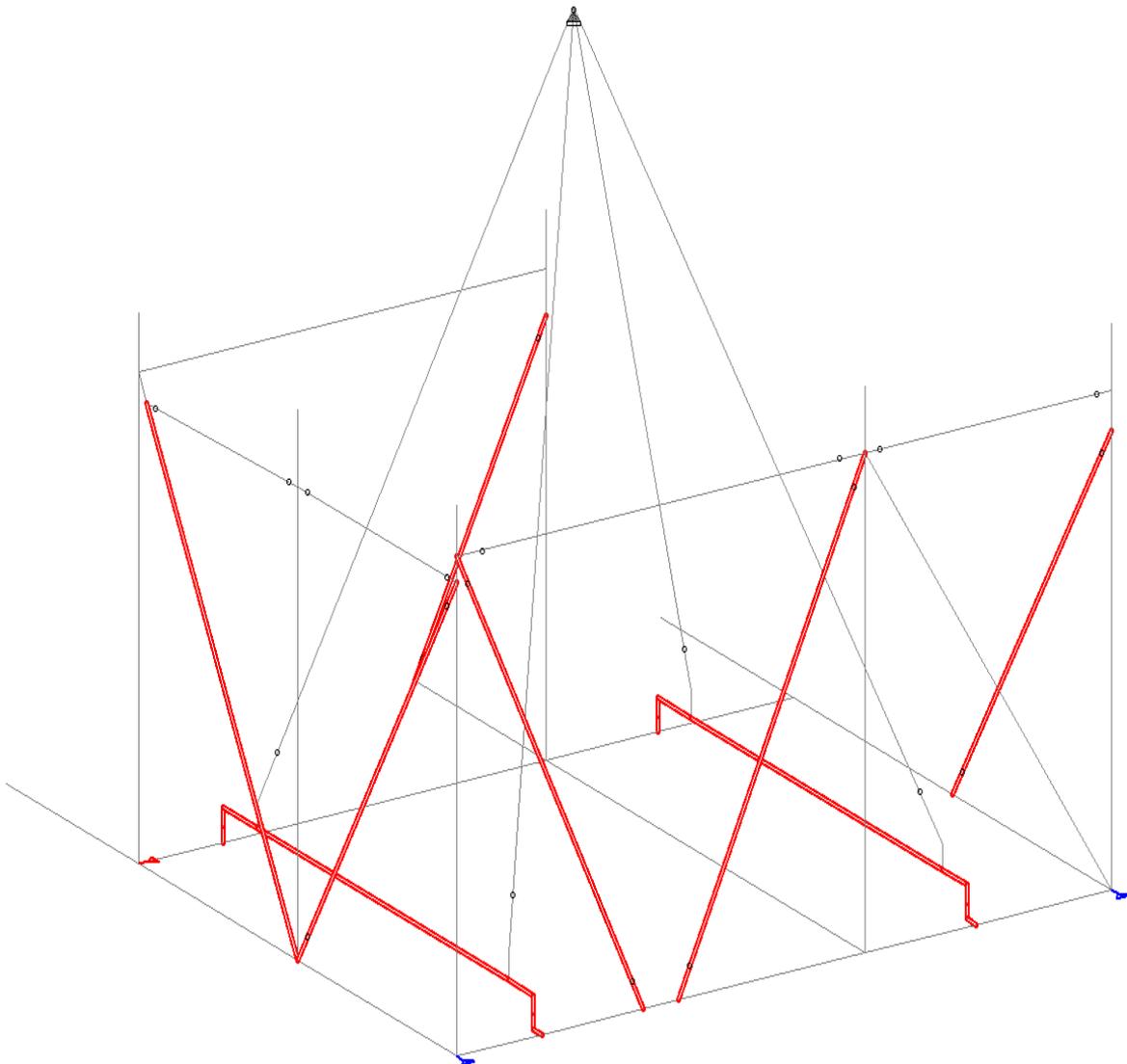


Figure 28. Temporary beams on C05 east balcony (Appendix B)

## 6.2 Lifting method

For the C05 balcony there will be four phases in the lifting operation:

1. Lifted from production yard to supply vessel. Lifted with a four point sling arrangement.
2. Lifted from the supply vessel to the platform using the platform crane. Using the same sling arrangement as before.
3. Load is transferred from the platform crane to chain hoists in existing structure as illustrated in Figs. 29–33.
4. Load is transferred from chain hoists to final destination where it's fastened with bolts.

Figs. 29–33 show the installation sequence for the C05 balcony.

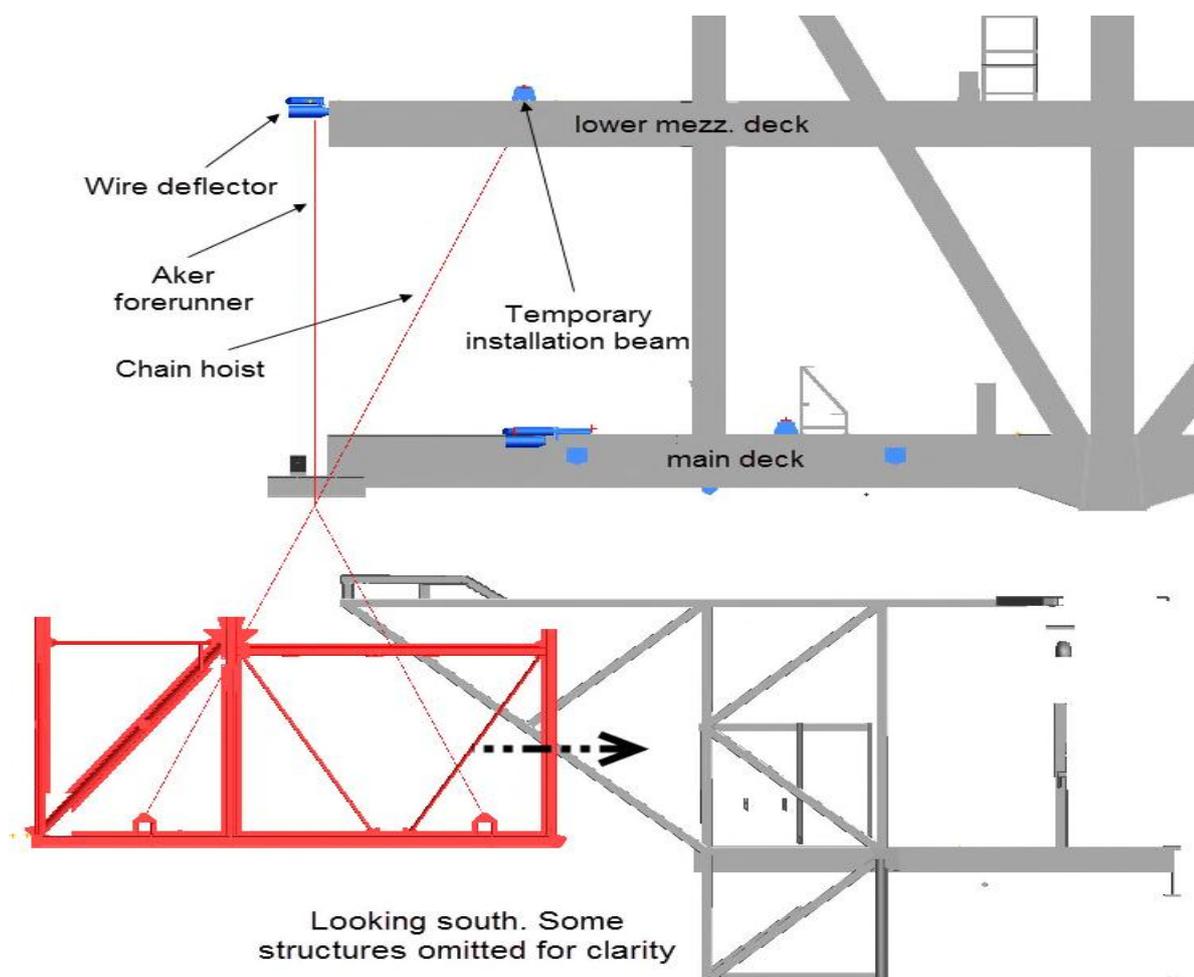


Figure 29. Installation of C05 main frame (source: Aker Solutions, 2014).

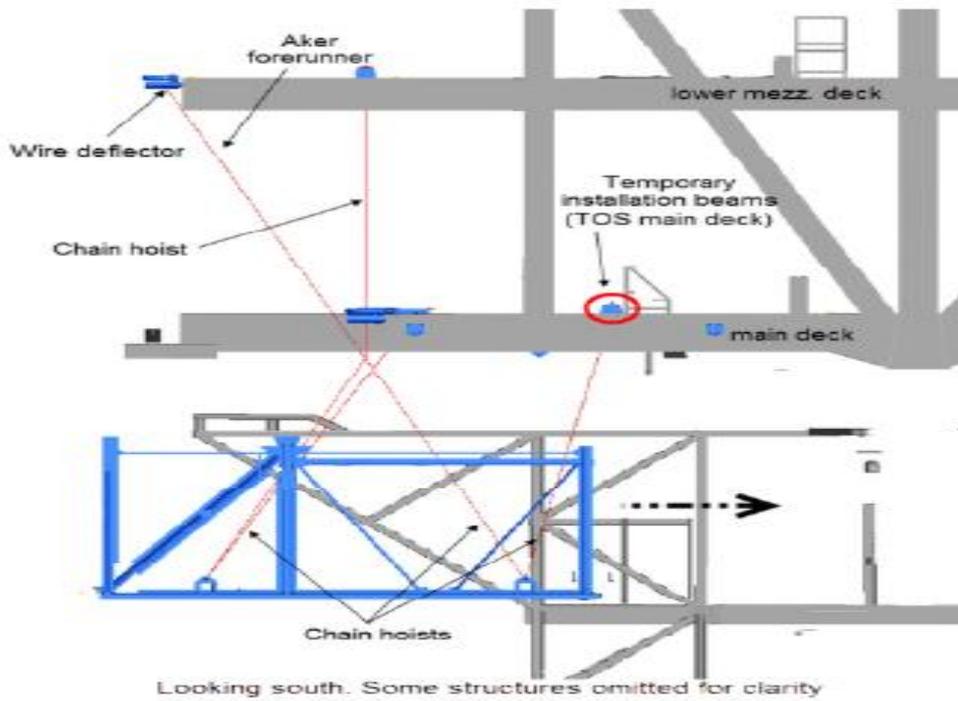


Figure 30. Installation of C05 main frame (source: Aker Solutions, 2014).

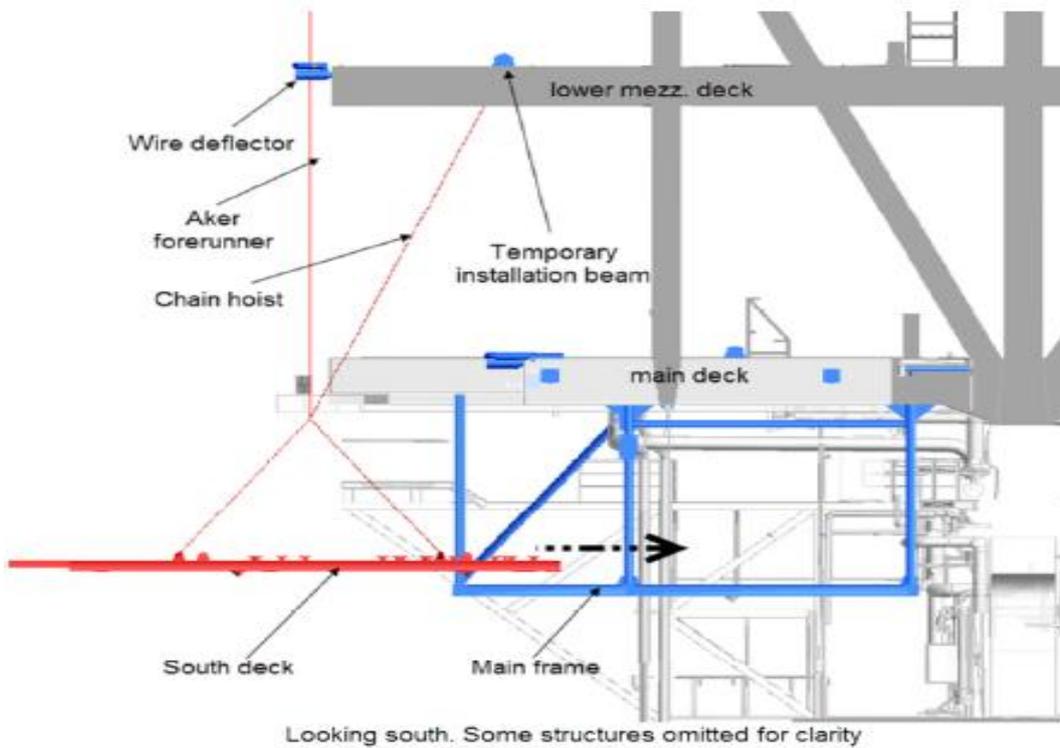


Figure 31. Installation of C05 south deck (source: Aker Solutions, 2014).

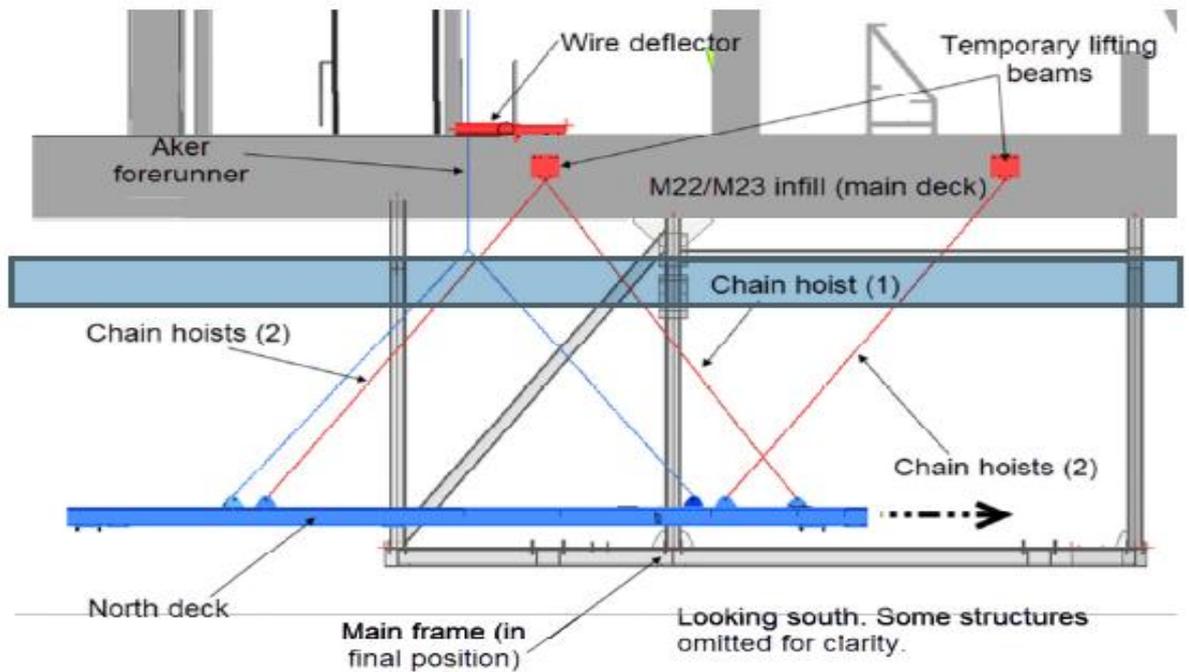


Figure 32. Installation of C05 north deck (source: Aker Solutions, 2014).

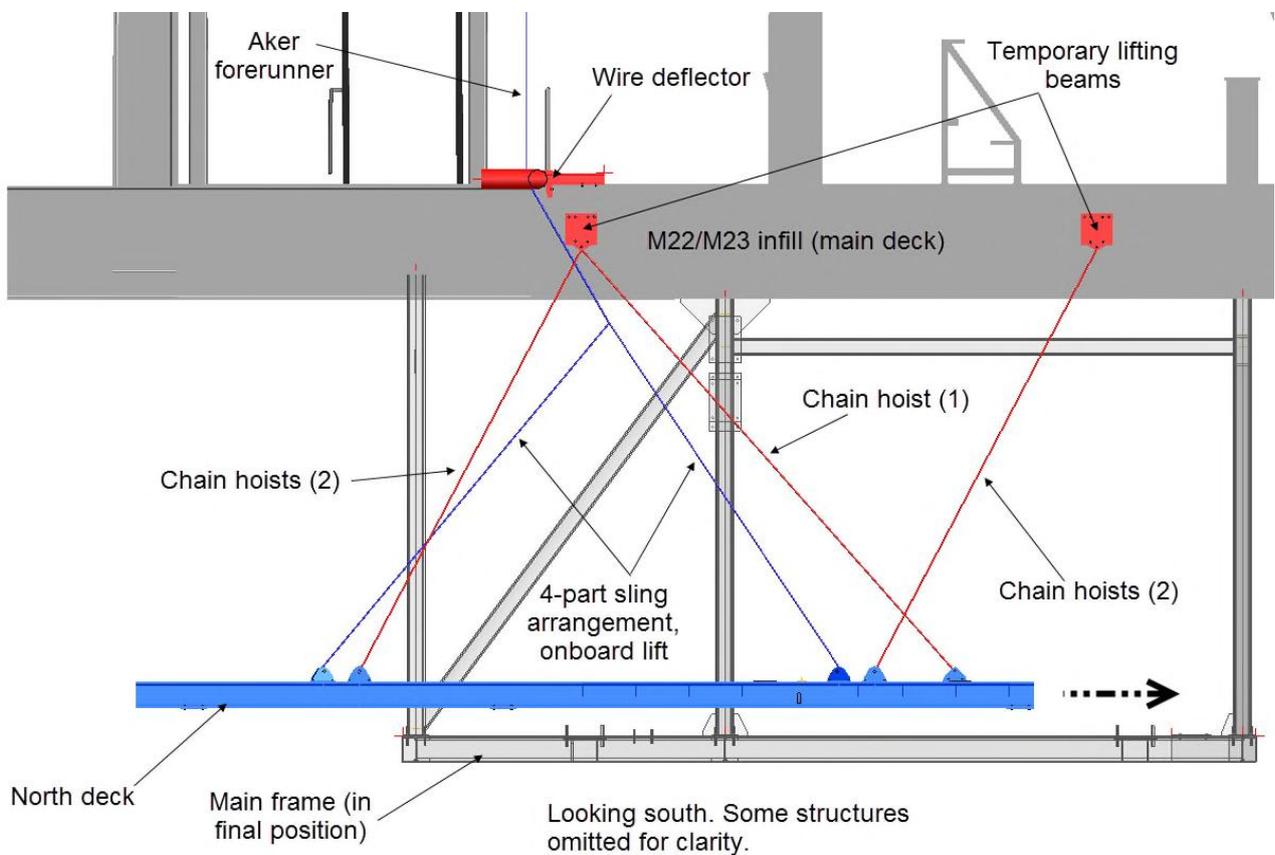


Figure 33. Installation of C05 north deck (source: Aker Solutions, 2014).

## 6.3 Loadings and factors

### 6.3.1 Weight of structures

Table 19 shows the installation weight of the structures.

Table 19. Installation weights.

Structure	Weight (metric tons)	PFP weight (metric tons)	WCF	Gross weight (metric tons)
Main frame	12	1.5	1.3	17.5
South deck	12.2	1	1.25	16.5
North deck	5.8	1	1.25	8.5

PFP = Passive fire protection.

WCF = Weight contingency factor.

From the pictures in the Appendix E we can see that the weight of the main frame during test lift was almost 14 metric tons. Hence the weight estimate was adequate and the gross weight was greater than actual weight.

Load combinations are defined by which loads the structure is subjected to during a certain time. All loads are divided in two groups during the lifting operation and when installed. Note that the loadings for the lifting equipment will be calculated in a separate Mathcad sheet based on the maximum loadings from these load combinations.

For design checks, the following limit states are to be assessed:

- ULS(a) and ULS(b).
- Deformations shall be checked in the SLS as appropriate.
- FLS: To be checked where applicable.
- ALS: To be checked where applicable.

In order to simplify the STAAD.pro output I have used one factor that I multiplied with the self-weight to get the most conservative output. The calculation of the factors is shown in Appendix A.

Self-weight multiplied with -6.5 in y direction is used to achieve offshore design weight. This is a conservative factor used based on the calculations in Appendix A.

### 6.3.2 Factors

Table 20 shows the factors used as design basic for the calculations in Appendix A

Table 20. Offshore and onshore factors.

<b>Factors</b>	<b>Onshore</b>	<b>Offshore</b>
WCF	1.30	1.30
DAF	1.50	1.78
DF	1.68	1.68
SKL	1.25	1.25
$W_{\cdot cog}$	1.10	1.10
$Y_{\cdot Rm}$	2.0	2.0
$Y_{\cdot M1.ULS}$	1.15	1.15
$Y_{\cdot M2.ULS}$	1.30	1.30

WCF = Weight contingency factor.

DAF = Dynamic amplification factor.

DF = Design factor.

SKL = Skew load factor.

$W_{\cdot cog}$  = CoG envelope factor.

$Y_{\cdot RM}$  = Resistance factor.

$Y_{\cdot M1.ULS}$  = General material factor.

$Y_{\cdot M2.ULS}$  = Material factor for bolted and welded connections.

Load combinations are defined by which loads the structure is subjected to during a certain time.

All loads are divided into two groups during the lifting operation and when installed.

Note that the loadings for the lifting equipment will be calculated in a separate Mathcad sheet based on the maximum loadings from these load combinations.

## Chapter 7

# Conclusion and Future recommendations

### 7.1 Conclusion

The main objective of this thesis was to learn to use NORSOK-R002 and compare it with Aker Solutions work instruction manual A237 and conduct a case study of the main frame of the C05 east balcony on the Gina Krog project.

The main frame in the case study should be designed to be a proper weighed structure that has sufficient capacity and strength with respect to transportation, installation and operation. Apart from these factors the goal of design analysis and optimization of this structure is to achieve a structure that has high safety with respect to life, environment and economic risk.

A static analysis was performed using STAAD.pro to verify the structural integrity and local calculations were performed according to NORSOK R-002. An evaluation of the most significant factors used in the NORSOK R-002 and A237 was necessary to determine the similarities and potential for improvements.

The STAAD.pro analysis reported a maximum utilization ratio of 49% where buckling of member 18 was the most critical failure mode for the most utilized member. The frame structure consists of main members and temporary beams to support the structure during lifting and installation. The interaction between main members and temporary beams reduces the distance between zero moments at top and bottom, reducing the effective buckling length and distributing the force, hence increasing the maximum load that the structure can withstand. The temporary beams were therefore necessary for the design, providing structural stability during lifting and installation. The structure was checked using a LRFD approach, where design loads were obtained by multiplying self-weight with relevant load factors.

From the STAAD.pro analysis sling forces and hook load were obtained and used in local calculation to determine the lifting accessories. According to the calculations in Appendix A all usage and stress level for the lifting accessories are within the acceptable criteria.

The existing structure was checked and proven to be capable to withstand the installation loads. A summary of the maximum usages from Appendix A and B is shown below in table 21.

Table 21 Utilizations factors from Appendix A and B.

Item	UF	Comment
Lug base	0.84	
Lug welds	0.7	
Bolts	0.8	
Lug bearing/tear out	0.5	
Shackles	0.89	
Slings	0.9	
Master link	0.8	
Forerunner	0.8	
Temp. installation beam	0.9	Conservative calculations
C05E Main frame globally	0.49	
C05E Main frame locally	0.75	

During the case study NORSOK R-002 was used and compared with the Aker work instruction manual A237 (discussed in Chapter 4).

The results from the comparison show that NORSOK R-002 is probably based on A237 and the similarities are therefore obvious. Dynamic amplification factor is the only change that makes a significant impact on the results. From Figs. 16 and 17 we can see that a structure weighing 50 metric tons will have almost 20 metric tons higher PLP when using the NORSOK R-002 DAF. This can indicate that NORSOK R-002 uses a higher significant wave height, but since there is no significant wave height given in the NORSOK R-002 it can only be considered as an assumption. The missing wave height must be considered as an error in the NORSOK R-002 documentation which makes it impossible to issue a design statement based on the NORSOK R-002.

This thesis can be used as a guideline for lifting operation internal in Aker Solutions and can also be sent to Standard Norway as input for the new revision of NORSOK R-002. Appendix A can be seen as a template for calculation of lifting accessories according to the new NORSOK R-002 and it will be published for internal use in Aker Solutions.

## 7.2 Future recommendations

As discussed in Chapter 4, many of the factors used in NORSOK R-002 and A237 are very conservative. To study what the best use of resources is, it would be useful to determine if a conservative approach with simple calculations is more effective than a more liberal approach with more calculations.

It would also be desirable to get a significant wave height related to the dynamic amplification factor in NORSOK R-002, and a request should be sent to Standards Norway to include this when they issue a new revision.

## REFERENCES

Rao, S. S. (2011). *Mechanical Vibrations*. Singapore: Pearson Education South Asia.

NORSOK R-002, edition 2, September 2012.

[http://en.wikipedia.org/wiki/Limit\\_state\\_design](http://en.wikipedia.org/wiki/Limit_state_design)

NORSOK N-001, “Integrity of offshore structures,” rev. 8, September 2012.

NORSOK N-004, rev. 2, October 2004.

NS-EN 1993-1-8 Eurocode 3: Design of steel structures - Part 1–8: Design of joints.

NORSOK N-004, “Design of steel structures,” rev. 2, October 2004.

NORSOK N-004, “Design of steel structures,” draft edition 3, November 2012.

NS1993-1-1-2005 NA.6.1.

NORSOK M-120, “Material data sheets for structural steel,” rev. 5, November 2008.

Ultimate Limit State Design of Steel-Plated Structures, Paik and Thayamballi, 2003

<http://www.pfeifer.de/en/wire-rope-technology/rope-terminations/common-used-rope-end-terminations/>

NORSOK N-003, “Actions and action effects,” rev. 2, September 2007.

Sleipner Field Metocean Design Basis RE2010-006.

DNV-RP-C205.

C007-C-N-SS-600. “Design premises structural steel detail engineering, rev. 8,” Aker Engineering, 1990.

C007-C-N-RD-225. “Seismic accelerations for module analysis.”

C007-C-S-SD-115. “Accidental load specification.”

DNV Technical Report 82-0959.

NORSOK S-001.

Offshore field development Odland 2013.

EN 45020 2007. Standardization and related activities. *General vocabulary*. British Standards Institution.

<http://www.standard.no/en/sectors/energi-og-klima/petroleum/>

<http://www.cen.eu>

EN 45020 (ISO/IEC Directives, 2011)

Dynamics1 Marine Operations, Ove Tobias Gudmestad 2013

Vessel Motion Marine Operations, Ove Tobias Gudmestad 2013

DNV-RP-H103

NORSOK U-001

Aker work instructions A237

# APPENDIX A

Local calculations of C05E  
main frame and lifting  
equipment for onboard and  
offboard lifts.

## Appendix A.1

### Offboard lift C05E balcony main frame

#### ***SUMMARY AND CONCLUSIONS***

All parts fulfil the requirements to acceptable stress and deformation levels. Maximum utilizations are follows:

Lug base UR=0.6  
Lug welds UR=0.2  
Lug bearing/tear out UR=0.5  
Shackles UR=0.8  
Slings UR=0.9  
Masterlink / Top link UR=0.8  
Forerunner UR=0.8  
Temporary installation RHS UR=0.47  
C05 main frame UR=0.49

# Design Basic

## Material data

### Material factors

ULS

General

$$\gamma_{M1,ULS} := 1.15$$

Bolted and welded connection

$$\gamma_{M2,ULS} := 1.3$$

### Structural steel

#### Y05

Yield strength

$$f_{y,355} := 355 \text{ MPa}$$

Tensile strength

$$f_{u,355} := 470 \text{ MPa}$$

Allowable stress

$$\sigma_{355,d} := \frac{f_{y,355}}{\gamma_{M1,ULS}} = 308.7 \text{ MPa}$$

#### Y30

Yield strength of plate material

$$f_{y,420} := 420 \text{ MPa}$$

Tensile strength

$$f_{u,420} := 500 \text{ MPa}$$

Allowable stress in plates

$$\sigma_{420,d} := \frac{f_{y,420}}{\gamma_{M1,ULS}} = 365.2 \text{ MPa}$$

### Welds

Correlation for weld calculation, EC3 BS EN 1993-1-8 2005, pt. 4.5.3.2 table 4.1:

$$S355: \beta_{w,355} := 0.9$$

$$S420: \beta_{w,420} := 1.0$$

Design weld stress, EC3 BS EN 1993-1-8 2005, pt. 4.5.3.2 (6):

$$S355: \sigma_{355,w} := \frac{f_{u,355}}{\gamma_{M2,ULS} \cdot \beta_{w,355}} = 401.7 \text{ MPa}$$

$$\sigma_{n,355,w} := \frac{0.9 \cdot f_{u,355}}{\gamma_{M2,ULS}} = 325.4 \text{ MPa}$$

$$S420: \sigma_{420,w} := \frac{f_{u,420}}{\gamma_{M2,ULS} \cdot \beta_{w,420}} = 384.6 \text{ MPa}$$

$$\sigma_{n,420,w} := \frac{0.9 \cdot f_{u,420}}{\gamma_{M2,ULS}} = 346.2 \text{ MPa}$$

## BOLTS

Values for Yield and Ultimate tensile strength (GR 8.8):

Yield strength of bolt material 8.8

$$f_{yb\_8.8} := 640\text{MPa}$$

Ultimate Tensile strength of bolts

$$f_{ub\_8.8} := 800\text{MPa}$$

### M20

Area of bolt

$$A_{20} := 245\text{mm}^2$$

Tensile capacity per bolt

$$F_{t.Rd.M20} := \frac{0.9f_{ub\_8.8}}{\gamma_{M2.ULS}} \cdot A_{20} = 135.7 \cdot \text{kN}$$

Shear capacity per bolt

$$F_{v.Rd.M20} := \frac{0.6f_{ub\_8.8}}{\gamma_{M2.ULS}} \cdot A_{20} = 90.5 \cdot \text{kN}$$

### M24

Area of bolt

$$A_{24} := 353\text{mm}^2$$

Tensile capacity per bolt

$$F_{t.Rd.M24} := \frac{0.9f_{ub\_8.8}}{\gamma_{M2.ULS}} \cdot A_{24} = 195.5 \cdot \text{kN}$$

Shear capacity per bolt

$$F_{v.Rd.M24} := \frac{0.6f_{ub\_8.8}}{\gamma_{M2.ULS}} \cdot A_{24} = 130.3 \cdot \text{kN}$$

### M30

Area of bolt

$$A_{30} := 561\text{mm}^2$$

Tensile capacity per bolt

$$F_{t.Rd.M30} := \frac{0.9f_{ub\_8.8}}{\gamma_{M2.ULS}} \cdot A_{30} = 310.7 \cdot \text{kN}$$

Shear capacity per bolt

$$F_{v.Rd.M30} := \frac{0.6f_{ub\_8.8}}{\gamma_{M2.ULS}} \cdot A_{30} = 207.1 \cdot \text{kN}$$

## LIFTING DESIGN BASIS

### Weight, WCF and $W_{\text{COG}}$

The weight of C05 east balcony main frame is about 12t, according to Aker Solutions drawings. A weight contingency factor (WCF) of 1.3 is added in order to allow some weight growth. In addition, a factor for uncertainties ( $W_{\text{COG}}$ ) in the location of the COG is included. All factors are taken from Norsk Standard R-002, Annex F

Mass of frame	$\text{Mass} := 12\text{tonne}$
Mass of fire protection	$M_{\text{fp}} := 1.5\text{tonne}$
Weight contingency factor	$\text{WCF} := 1.3$
Uncertainty in Cog	$W_{\text{cog}} := 1.1$
Gross Weight	$W_{\text{gross}} := (\text{Mass} + M_{\text{fp}}) \cdot \text{WCF} = 1.8 \times 10^4 \text{ kg}$

### DAF and SKL

Offshore lift	$\text{DAF}_{\text{off}} := 1.09 + 0.41 \cdot \sqrt{\frac{50\text{tonne}}{W_{\text{gross}}}} = 1.8$
Platform internal lift (onshore)	$\text{DAF}_{\text{on}} := 1.5$
Four part sling arrangement	$\text{SKL} := 1.25$

### Load and consequence factors

Consider the load factor 1.34 and the consequence factor 1.25 for both lifting lug design and main structural elements supporting the lifting point.

$$\gamma_{\text{F}} := 1.34 \qquad \gamma_{\text{C}} := 1.25 \qquad \text{DF} := \gamma_{\text{F}} \cdot \gamma_{\text{C}} = 1.7$$

$$\gamma_{\text{t}} := 0.0785$$

### Total load factors

Total applied load factor for offshore lift

$$\gamma_{\text{d.off}} := W_{\text{cog}} \cdot \text{DAF}_{\text{off}} \cdot \text{SKL} \cdot \text{DF} = 4.1$$

Total applied load factor for onshore lift

$$\gamma_{\text{d.on}} := W_{\text{cog}} \cdot \text{DAF}_{\text{on}} \cdot \text{SKL} \cdot \text{DF} = 3.5$$

## CALCULATIONS FOR OFFBOARD LIFT

This math cad sheet covers the strength verification of the lifting accessories including the lifting lugs for offshore installation.

### Geometry and forces

$$W_{d.off} := W_{gross} \cdot g \cdot \gamma_{d.off} = 7.1 \times 10^5 \cdot N$$

$$\text{Length } a_1 \quad a_1 := 3115 \text{ mm}$$

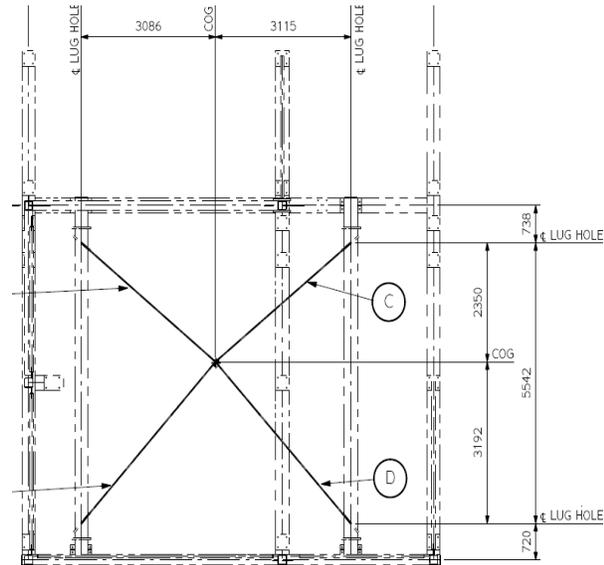
$$\text{Length } a_2 \quad a_2 := 3086 \text{ mm}$$

$$\text{Length } b_1 \quad b_1 := 3192 \text{ mm}$$

$$\text{Length } b_2 \quad b_2 := 2350 \text{ mm}$$

$$\text{Length A-B} \quad L_{AB} := a_1 + a_2 = 6201 \cdot \text{mm}$$

$$\text{Length B-C} \quad L_{BC} := b_1 + b_2 = 5542 \cdot \text{mm}$$



PLAN ON DECK

### Horizontal distances to COG

$$R_{nw} := \sqrt{a_1^2 + b_2^2} = 3902 \cdot \text{mm}$$

$$R_{sw} := \sqrt{a_1^2 + b_1^2} = 4460.1 \cdot \text{mm}$$

$$R_{ne} := \sqrt{a_2^2 + b_2^2} = 3878.9 \cdot \text{mm}$$

$$R_{se} := \sqrt{a_2^2 + b_1^2} = 4439.8 \cdot \text{mm}$$

### Angles with horizontal

$$h := 7.94 \text{ m} - 0.42 \text{ m} = 7520 \cdot \text{mm}$$

$$\theta_{nw} := \text{atan}\left(\frac{h}{R_{nw}}\right) = 62.6 \cdot \text{deg}$$

$$\theta_{ne} := \text{atan}\left(\frac{h}{R_{ne}}\right) = 62.7 \cdot \text{deg}$$

$$\theta_{sw} := \text{atan}\left(\frac{h}{R_{sw}}\right) = 59.3 \cdot \text{deg}$$

$$\theta_{se} := \text{atan}\left(\frac{h}{R_{se}}\right) = 59.4 \cdot \text{deg}$$

### Sling dimensions

$$l_{sling.nw} := \sqrt{h^2 + R_{nw}^2} = 8472.1 \cdot \text{mm}$$

$$l_{sling.ne} := \sqrt{h^2 + R_{ne}^2} = 8461.5 \cdot \text{mm}$$

$$l_{sling.sw} := \sqrt{h^2 + R_{sw}^2} = 8743.1 \cdot \text{mm}$$

$$l_{sling.se} := \sqrt{h^2 + R_{se}^2} = 8732.8 \cdot \text{mm}$$

Maximum vertical reaction in NW lug

Sling force in NW sling

$$F_{v.nw} := \frac{W_{d.off} \cdot a_1 \cdot b_1}{L_{AB} \cdot L_{BC}} = 204.4 \cdot \text{kN}$$

$$F_{s.nw} := \frac{F_{v.nw}}{\sin(\theta_{nw})} = 230.2 \cdot \text{kN}$$

The global capacity of the frame is documented by modeling the structure in Staad.Pro. The slings are included in the analysis and their loads calculated.

A load factor of 6.5 is used to achieve the offshore design weight. There is some deviation between Staad.Pro calculated sling loads and the ones calculated in this section. This can be justified by the fact that in the hand calculations the model is considered absolutely rigid, which is not the case. Therefore Staad.Pro forces are used for designing, as they reflect better the structure's behavior.

32	1 SELF WEIG	29	-257.852	-0.001	-0.000	0.000	0.000	0.000
		28	257.852	0.001	0.000	0.000	0.001	-0.004
	2 WEIGHT OF	29	-97.832	2.730	0.119	0.000	0.000	0.000
		28	112.872	4.847	-0.119	0.000	-1.003	-8.913
	3 WIND LOA	29	-26.321	-0.000	-0.000	0.000	0.000	0.000
		28	26.321	0.000	0.000	0.000	0.000	-0.001
	4 LOAD FRO	29	-0.343	0.154	2.108	0.000	0.000	0.000
		28	0.343	-0.154	-2.108	7.520	-13.960	1.293
	5 AREA LOA	29	-195.664	5.459	0.238	0.000	0.000	0.000
		28	225.744	9.694	-0.238	0.000	-2.005	-17.826

Maximum sling reaction from Staad.pro model

$$F_{nw} := 258 \text{ kN}$$

Vertical force NW lug

$$F_{v.nw} := F_{s.nw} \cdot \sin(\theta_{nw}) = 204.4 \cdot \text{kN}$$

Transverse force NW lug

$$F_{t.nw} := \gamma_t \cdot F_{s.nw} = 18.1 \cdot \text{kN}$$

Horizontal force NW lug

$$F_{h.nw} := F_{s.nw} \cdot \cos(\theta_{nw}) = 106 \cdot \text{kN}$$

## Lifting accessories for offboard lift

### Shackles

Safety factor for shackle	$SF_{sh} := 6$
Design factor	$DF_{sh} := 1.68$
Material resistance factor	$\gamma RM_{sh} := 1.8$
Minimum breaking load	$MBL_{shackle} := \frac{F_{nw} \cdot DF_{sh} \cdot \gamma RM_{sh}}{g \cdot DF} = 47.5 \cdot \text{tonne}$
WLL	$WLL_{min.shackle} := \frac{MBL_{shackle}}{SF_{sh}} = 7.9 \cdot \text{tonne}$

Based on this calculations I choose a shackle with WLL 9,5tonne

$$WLL_{use.shackle} := 9.5 \text{ tonne}$$
$$UR_{shackle} := \frac{WLL_{min.shackle}}{WLL_{use.shackle}} = 0.8$$

### Master link

Safety factor for master link	$SF_{link} := 4$
Design factor	$DF_{ml} := 1.68$
Material resistance factor	$\gamma RM_{ml} := 1.8$
End termination factor	$\gamma e_{ml} := 1$
Minimum breaking load	$MBL_{link} := W_{gross} \cdot DAF_{off} \cdot DF_{ml} \cdot \frac{1}{\gamma e_{ml}} \cdot \gamma RM_{ml} = 94.6 \cdot \text{tonne}$
WLL	$WLL_{link} := \frac{MBL_{link}}{SF_{link}} = 23.6 \cdot \text{tonne}$

Based on this calculations I choose  $\varnothing 38\text{mm}$  master link

$$WLL_{link.use} := 28.1 \text{ tonne}$$
$$UF_{link} := \frac{WLL_{link}}{WLL_{link.use}} = 0.8$$

## Slings

Design factor  $DF_{sl} := 1.68$

Material resistance factor  $\gamma_{RM_{sl}} := 2.0$

End termination factor  $\gamma_{e_{sl}} := 0.8$

Minimum breaking load  $MBL_{sling} := F_{nw} \cdot \frac{DF_{sl}}{DF} \cdot \frac{1}{\gamma_{e_{sl}}} \cdot \gamma_{RM_{sl}} = 646.9 \cdot \text{kN}$

Based on this calculations i choose 6x36 IWRC Ø32 1960MPa

$MBL_{sling.use} := 715 \text{kN}$

$$UF_{sling} := \frac{MBL_{sling}}{MBL_{sling.use}} = 0.9$$

## Forerunner

Design factor  $DF_{fr} := 1.68$

Material resistance factor  $\gamma_{RM_{fr}} := 2.0$

End termination factor  $\gamma_{e_{fr}} := 0.8$

Minimum breaking load  $MBL_{fr} := W_{gross} \cdot g \cdot DAF_{off} \cdot DF_{fr} \cdot \frac{1}{\gamma_{e_{fr}}} \cdot \gamma_{RM_{fr}} = 1.3 \times 10^6 \text{ N}$

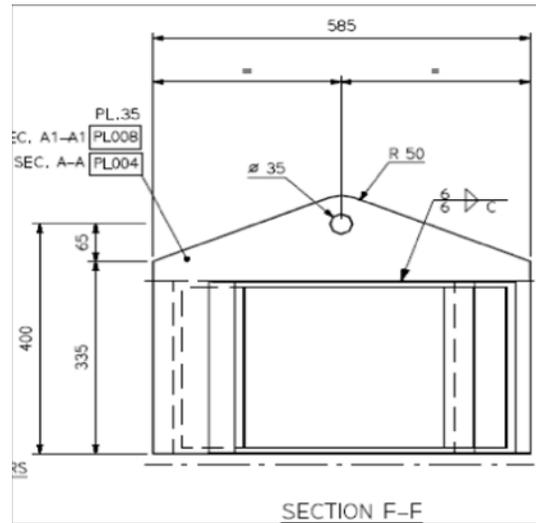
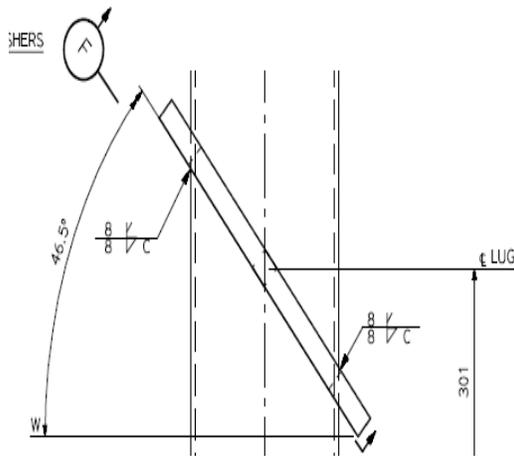
Based on this calculations i choose 6x36 IWRC Ø48 1960MPa

$MBL_{fr.use} := 1608 \text{kN}$

$$UF_{fr} := \frac{MBL_{fr}}{MBL_{fr.use}} = 0.8$$

## Lifting lugs

The lugs have the same geometry, therefore it will be sufficient to only check the one with the highest slin load.



### Shackle data

$$d_1 := 32\text{mm}$$

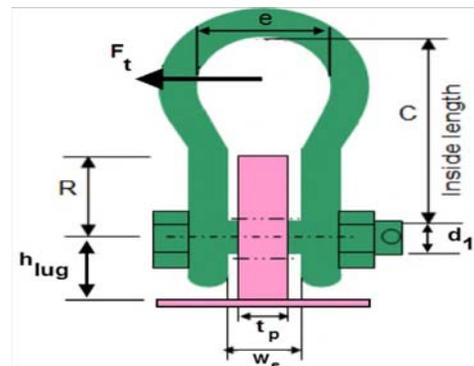
$$W_s := 46\text{mm}$$

$$c := 108\text{mm}$$

$$e := 74\text{mm}$$

Distasense to center of shackle bow

$$C_C := \frac{d_1}{2} + c - \frac{e}{2} = 87\text{mm}$$



### Lug data

$$d_{lug} := 35\text{mm}$$

$$t_{lug} := 35\text{mm}$$

$$R_{lug} := 50\text{mm}$$

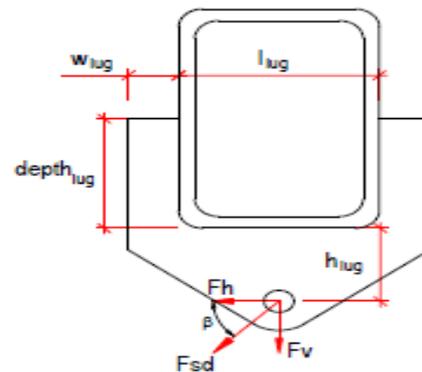
$$l_{lug} := 375\text{mm}$$

$$h_{lug} := 100\text{mm}$$

$$\text{depth}_{lug} := 300\text{mm}$$

$$w_{lug} := 60\text{mm}$$

$$l_{tot} := l_{lug} + 2 \cdot w_{lug} = 495\text{mm}$$



## Loads

Design load	$F_{sd} := F_{nw} = 258 \cdot \text{kN}$
Angle with horizontal	$\beta := \theta_{nw} = 62.6 \cdot \text{deg}$
Vertical component	$F_v := F_{sd} \cdot \sin(\beta) = 229 \cdot \text{kN}$
Horizontal component	$F_h := F_{sd} \cdot \cos(\beta) = 118.8 \cdot \text{kN}$
Transversal component	$F_t := F_{sd} \cdot \gamma_t = 20.3 \cdot \text{kN}$

$$M_{\text{strong}} := h_{\text{lug}} \cdot F_h = 11.9 \cdot \text{kN} \cdot \text{m}$$

$$M_{\text{weak}} := F_t \cdot (h_{\text{lug}} + C_C \cdot \sin(\beta)) = 3.6 \cdot \text{kN} \cdot \text{m}$$

$$T := F_t \cdot C_C \cdot \cos(\beta) = 0.8 \cdot \text{kN} \cdot \text{m}$$

## Stresses

$$\sigma := \frac{F_v}{2 \cdot w_{\text{lug}} \cdot t_{\text{lug}}} + \frac{M_{\text{strong}}}{(w_{\text{lug}} + l_{\text{lug}}) \cdot t_{\text{lug}} \cdot w_{\text{lug}}} + \frac{M_{\text{weak}} \cdot 6}{2 \cdot w_{\text{lug}} \cdot t_{\text{lug}}^2} = 214 \cdot \text{MPa}$$

$$\tau_1 := \frac{F_h}{l_{\text{tot}} \cdot t_{\text{lug}}} + \frac{3 \cdot T}{l_{\text{tot}} \cdot t_{\text{lug}}^2} = 10.9 \cdot \text{MPa}$$

$$\tau_2 := \frac{F_t}{l_{\text{tot}} \cdot t_{\text{lug}}} + \frac{3 \cdot T}{l_{\text{tot}} \cdot t_{\text{lug}}^2} = 5.2 \cdot \text{MPa}$$

$$\sigma_j := \sqrt{\sigma^2 + 3(\tau_1^2 + \tau_2^2)} = 215 \cdot \text{MPa}$$

$$\text{UF} := \frac{\sigma_j}{\sigma_{420.d}} = 0.6$$

## Welds

### Horizontal weld

Filled weld throat  $a_w := 6 \text{mm}$

$$\tau_{\parallel} := \frac{F_h}{2 \cdot l_{\text{lug}} \cdot a_w} + \frac{T}{t_{\text{lug}} \cdot a_w \cdot l_{\text{lug}}} = 36.7 \cdot \text{MPa} \quad \sigma_{\perp} := \frac{F_t}{2 \cdot a_w \cdot l_{\text{lug}} \cdot \sqrt{2}} = 3.2 \cdot \text{MPa}$$

$$\tau_{\perp} := \sigma_{\perp} = 3.2 \cdot \text{MPa}$$

$$UF_h := \frac{\sqrt{\sigma_{\perp}^2 + 3(\tau_{\parallel}^2 + \tau_{\perp}^2)}}{\sigma_{420.w}^2} = 0.2$$

### Vertical weld

Filled weld throat

$$a_{v.w} := 8 \text{ mm}$$

$$\tau_{\parallel.Fv} := \frac{F_v}{4 \cdot a_{v.w} \cdot \text{depth}_{lug}} = 23.9 \cdot \text{MPa} \quad \tau_{\parallel.MS} := \frac{M_{strong}}{l_{lug}} \cdot \frac{1}{2 \cdot a_{v.w} \cdot \text{depth}_{lug}} = 6.6 \cdot \text{MPa}$$

$$\tau_{\parallel.Mw} := \frac{M_{weak}}{l_{lug}} \cdot \frac{1}{2 \cdot a_{v.w} \cdot \text{depth}_{lug}} = 21.4 \cdot \text{MPa} \quad \tau_{\parallel.Fv} = 23.9 \cdot \text{MPa}$$

$$UF_v := \frac{\sqrt{3 \cdot (\tau_{\parallel.Fv} + \tau_{\parallel.MS} + \tau_{\parallel.Mw})^2}}{\sigma_{420.w}^2} = 0.2$$

### **Lug details**

#### **Tear out**

Shear stresses

$$\tau := \frac{F_{sd}}{2 \cdot \left( R_{lug} - \frac{d_{lug}}{2} \right) t_{lug}} = 113.4 \cdot \text{MPa}$$

Shear stress resistance

$$\tau_D := \frac{f_{y.420}}{\sqrt{3} \cdot \gamma_{M1.ULS}} = 210.9 \cdot \text{MPa}$$

Usage factor

$$UF_{Lug} := \frac{\tau}{\tau_D} = 0.5$$

## Bearing

Bearing stress

$$\sigma_H := \frac{F_{sd}}{t_{lug} \cdot d_1} = 230.4 \cdot \text{MPa}$$

Bearing stress resistance

$$f_{d,b} := 1.5 \cdot \frac{f_{y,420}}{\gamma_{M1,ULS}} = 547.8 \cdot \text{MPa}$$

Usage factor

$$UF_{bearing} := \frac{\sigma_H}{f_{d,b}} = 0.4$$

## Appendix A.2

### Onboard lift C05E balcony main frame

#### ***SUMMARY AND CONCLUSIONS***

This appendix covers the strength verification of the temporary lifting lugs and equipment used for installation of the new C05 east balcony main frame below the main deck on the east side of M22. The frame will be lifted into a position east and below the final position and the weight transferred from the platform crane to hoists connected to Sleipner A existing structures. The frame has four lugs for connection of air driven chain hoists for final installation

All parts fulfil the requirements to acceptable stress and deformation levels. Maximum utilizations are as follows:

Lug base UR=0.84  
Lug welds UR=0.6  
Lug bearing/tear out UR=0.5  
Shackles UR=0.89  
Masterlink UR=0.7  
Forerunner UR=0.8  
Temporary installation beams UR=0.9  
Bolts UR=0.8

# Design Basic

## Material data

### Material factors

ULS

General

$$\gamma_{M1.ULS} := 1.15$$

Bolted and welded connection

$$\gamma_{M2.ULS} := 1.3$$

### Structural steel

#### Y05

Yield strength

$$f_{y.355} := 355 \text{ MPa}$$

Tensile strength

$$f_{u.355} := 470 \text{ MPa}$$

Allowable stress

$$\sigma_{355.d} := \frac{f_{y.355}}{\gamma_{M1.ULS}} = 308.7 \cdot \text{MPa}$$

#### Y30

Yield strength of plate material

$$f_{y.420} := 420 \text{ MPa}$$

Tensile strength

$$f_{u.420} := 500 \text{ MPa}$$

Allowable stress in plates

$$\sigma_{420.d} := \frac{f_{y.420}}{\gamma_{M1.ULS}} = 365.2 \cdot \text{MPa}$$

### Welds

Correlation for weld calculation, EC3 BS EN 1993-1-8 2005, pt. 4.5.3.2 table 4.1:

$$S355: \beta_{w.355} := 0.9$$

$$S420: \beta_{w.420} := 1.0$$

Design weld stress, EC3 BS EN 1993-1-8 2005, pt. 4.5.3.2 (6):

$$S355: \sigma_{355.w} := \frac{f_{u.355}}{\gamma_{M2.ULS} \cdot \beta_{w.355}} = 401.7 \cdot \text{MPa} \quad \sigma_{n.355.w} := \frac{0.9 \cdot f_{u.355}}{\gamma_{M2.ULS}} = 325.4 \cdot \text{MPa}$$

$$S420: \sigma_{420.w} := \frac{f_{u.420}}{\gamma_{M2.ULS} \cdot \beta_{w.420}} = 384.6 \cdot \text{MPa} \quad \sigma_{n.420.w} := \frac{0.9 \cdot f_{u.420}}{\gamma_{M2.ULS}} = 346.2 \cdot \text{MPa}$$

## BOLTS

Values for Yield and Ultimate tensile strength (GR 8.8):

Yield strength of bolt material 8.8  $f_{yb\_8.8} := 640\text{MPa}$

Ultimate Tensile strength of bolts  $f_{ub\_8.8} := 800\text{MPa}$

### M20

Area of bolt  $A_{20} := 245\text{mm}^2$

Tensile capacity per bolt  $F_{t.Rd.M20} := \frac{0.9f_{ub\_8.8}}{\gamma_{M2.ULS}} \cdot A_{20} = 135.7 \cdot \text{kN}$

Shear capacity per bolt  $F_{v.Rd.M20} := \frac{0.6f_{ub\_8.8}}{\gamma_{M2.ULS}} \cdot A_{20} = 90.5 \cdot \text{kN}$

### M24

Area of bolt  $A_{24} := 353\text{mm}^2$

Tensile capacity per bolt  $F_{t.Rd.M24} := \frac{0.9f_{ub\_8.8}}{\gamma_{M2.ULS}} \cdot A_{24} = 195.5 \cdot \text{kN}$

Shear capacity per bolt  $F_{v.Rd.M24} := \frac{0.6f_{ub\_8.8}}{\gamma_{M2.ULS}} \cdot A_{24} = 130.3 \cdot \text{kN}$

### M30

Area of bolt  $A_{30} := 561\text{mm}^2$

Tensile capacity per bolt  $F_{t.Rd.M30} := \frac{0.9f_{ub\_8.8}}{\gamma_{M2.ULS}} \cdot A_{30} = 310.7 \cdot \text{kN}$

Shear capacity per bolt  $F_{v.Rd.M30} := \frac{0.6f_{ub\_8.8}}{\gamma_{M2.ULS}} \cdot A_{30} = 207.1 \cdot \text{kN}$

## **LIFTING DESIGN BASIS**

### **Weight, WCF and $W_{\text{COG}}$**

The weight of C05 east balcony main frame is about 12t, according to Aker Solutions drawings. A weight contingency factor (WCF) of 1.3 is added in order to allow some weight growth. In addition, a factor for uncertainties (WCOG) in the location of the COG is included. All factors are taken from Norsk Standard R-002, Annex F

Mass of frame	Mass := 12tonne
Mass of fire protection	$M_{\text{fp}} := 1.5\text{tonne}$
Weight contingency factor	WCF := 1.3
Uncertainty in Cog	$W_{\text{cog}} := 1.1$
Gross Weight	$W_{\text{gross}} := (\text{Mass} + M_{\text{fp}}) \cdot \text{WCF} = 1.8 \times 10^4 \text{ kg}$

### **DAF and SKL**

Offshore lift	$\text{DAF}_{\text{off}} := 1.09 + 0.41 \cdot \sqrt{\frac{50\text{tonne}}{W_{\text{gross}}}} = 1.8$
Platform internal lift (onshore)	$\text{DAF}_{\text{on}} := 1.5$
Four part sling arrangement	SKL := 1.25

### **Load and consequence factors**

Consider the load factor 1.34 and the consequence factor 1.25 for both lifting lug design and main structural elements supporting the lifting point.

$$\gamma_{\text{F}} := 1.34 \qquad \gamma_{\text{C}} := 1.25 \qquad \text{DF} := \gamma_{\text{F}} \cdot \gamma_{\text{C}} = 1.7$$

$$\gamma_{\text{t}} := 0.0785$$

### **Total load factors**

Total applied load factor for offshore lift

$$\gamma_{\text{d.off}} := W_{\text{cog}} \cdot \text{DAF}_{\text{off}} \cdot \text{SKL} \cdot \text{DF} = 4.1$$

Total applied load factor for onshore lift

$$\gamma_{\text{d.on}} := W_{\text{cog}} \cdot \text{DAF}_{\text{on}} \cdot \text{SKL} \cdot \text{DF} = 3.5$$

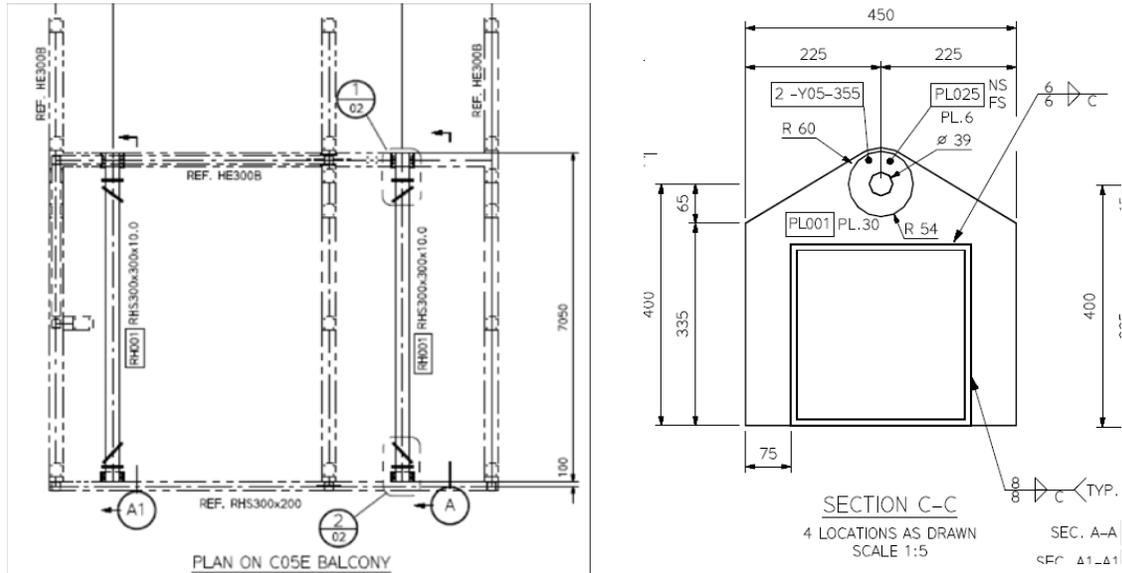
## ***CALCULATIONS FOR ONBOARD LIFT***

The design weight for onboard lift using a four part sling arrangement is less than the offboard lift design weight. Therefore lifting lugs, rigging equipments and temporary installation beams are OK by inspection. The same sling arrangement shall be used for both scenarios.

$$W_{d.on} := W_{gross} \cdot g \cdot \gamma_{d.on} = 594.6 \cdot kN$$

$$W_{d.off} := W_{gross} \cdot g \cdot \gamma_{d.off} = 706.4 \cdot kN$$

## CALCULATIONS FOR ONBOARD LIFT - TRANSIT INTO FINAL POSITION



It is assumed that due to difficulties operating hoists accurately, each lug might be subjected to half the platform weight

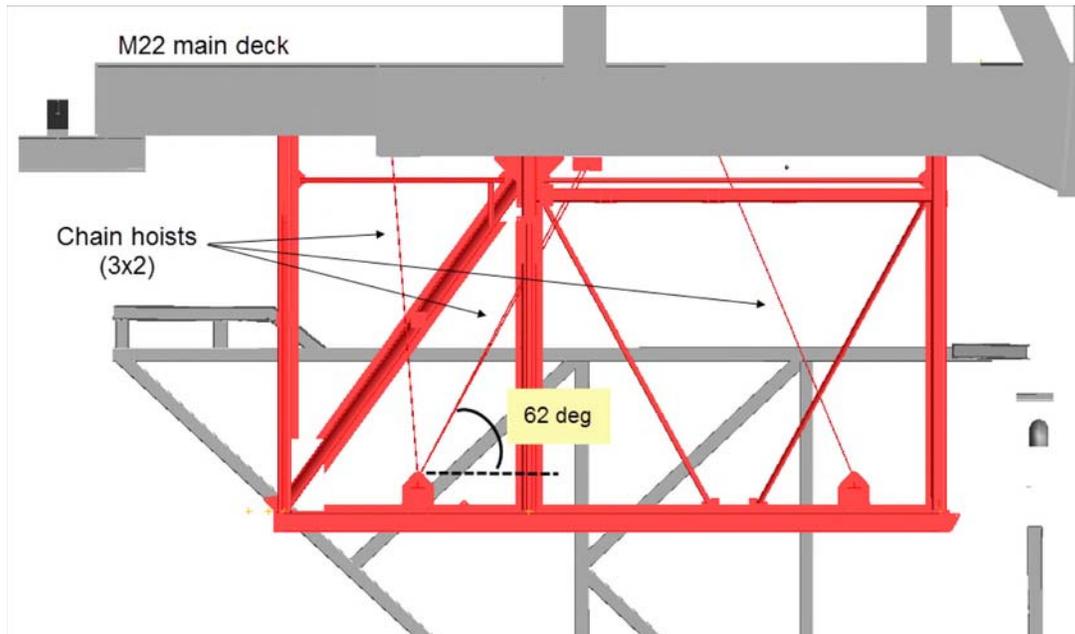
$$W_{d.on} = 594.6 \cdot \text{kN}$$

$$W_d := \frac{W_{gross}}{2} \cdot g \cdot DF \cdot DAF_{on} = 216.2 \cdot \text{kN}$$

If 12t air driven chain hoists are used for installation, the design load shall be equal to the hoist capacity. This is due to pulling the frame while it is in contact with the existing structures. Nevertheless, this load is conservative as this situation happens only at the final position, and no DAF should be needed to account for.

$$W_{d.hoist} := 12 \text{ tonne} \cdot g \cdot DF \cdot DAF_{on} = 295.7 \cdot \text{kN}$$

The design forces when the frame is in transit using chain hoists are shown in the next figure. Conservative the maximum horizontal component is applied with the maximum vertical component. The maximum horizontal component is found for the minimum angle with horizontal, which is around 62 deg.



Maximum sling force

$$F_{sd} := W_{d,hoist} = 295.7 \cdot \text{kN}$$

Design vertical load

$$F_v := W_{d,hoist} = 295.7 \cdot \text{kN}$$

Design horizontal load

$$F_h := F_{sd} \cdot \cos(61\text{deg}) = 143.3 \cdot \text{kN}$$

### Shackles

Safety factor for shackle

$$SF_{sh} := 6$$

Design factor

$$DF_{sh} := 1.68$$

Material resistance factor

$$\gamma RM_{sh} := 1.8$$

Minimum breaking load

$$MBL_{shackle} := \frac{F_{sd} \cdot DF_{sh} \cdot \gamma RM_{sh}}{g \cdot DF} = 54.4 \cdot \text{tonne}$$

WLL

$$WLL_{min.shackle} := \frac{MBL_{shackle}}{SF_{sh}} = 9.1 \cdot \text{tonne}$$

Based on this calculations I choose a shackle with WLL 12tonne

$WLL_{use.shackle} := 12\text{tonne}$

$$UR_{shackle} := \frac{WLL_{min.shackle}}{WLL_{use.shackle}} = 0.8$$

## Lug type 2

### Shackle data

$$d_1 := 35\text{mm}$$

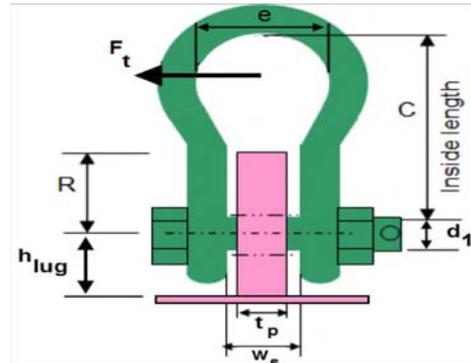
$$W_s := 52\text{mm}$$

$$c_w := 119\text{mm}$$

$$e_w := 83\text{mm}$$

Distasense to center of shackle bow

$$C_C := \frac{d_1}{2} + c - \frac{e}{2} = 95\cdot\text{mm}$$



### Lug data

$$d_{lug} := 39\text{mm}$$

$$t_{lug} := 30\text{mm}$$

$$R_{lug} := 60\text{mm}$$

$$l_{lug} := 300\text{mm}$$

$$h_{lug} := 100\text{mm}$$

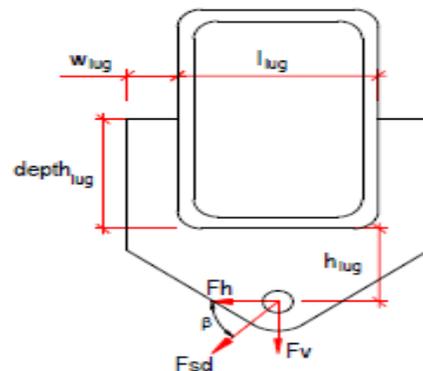
$$\text{depth}_{lug} := 300\text{mm}$$

$$w_{lug} := 75\text{mm}$$

$$R_b := 54\text{mm}$$

$$t_c := 6\text{mm}$$

$$l_{tot} := l_{lug} + 2 \cdot w_{lug} = 450\cdot\text{mm}$$



### Loads

Design load

$$F_{sd} := 295.7\text{kN}$$

Angle with horizontal

$$\beta := 61\text{deg}$$

Vertical component

$$F_{v} := W_{d.\text{hoist}} = 295.7\cdot\text{kN}$$

Horizontal component

$$F_{h} := F_{sd} \cdot \cos(\beta) = 143.3\cdot\text{kN}$$

Transversal component

$$F_t := F_{sd} \cdot \gamma_t = 23.2\cdot\text{kN}$$

$$M_{\text{strong}} := h_{lug} \cdot F_h = 14.3\cdot\text{kN}\cdot\text{m}$$

$$M_{\text{weak}} := F_t \cdot (h_{lug} + C_C \cdot \sin(\beta)) = 4.2\cdot\text{kN}\cdot\text{m}$$

$$T := F_t \cdot C_C \cdot \cos(\beta) = 1.1\cdot\text{kN}\cdot\text{m}$$

## Stresses

$$\sigma := \frac{F_v}{2 \cdot w_{lug} \cdot t_{lug}} + \frac{M_{strong}}{(w_{lug} + l_{lug}) \cdot t_{lug} \cdot w_{lug}} + \frac{M_{weak} \cdot 6}{2 \cdot w_{lug} \cdot t_{lug}^2} = 271.6 \cdot \text{MPa}$$

$$\tau_1 := \frac{F_h}{l_{tot} \cdot t_{lug}} + \frac{3 \cdot T}{l_{tot} \cdot t_{lug}^2} = 18.5 \cdot \text{MPa}$$

$$\tau_2 := \frac{F_t}{l_{tot} \cdot t_{lug}} + \frac{3 \cdot T}{l_{tot} \cdot t_{lug}^2} = 9.6 \cdot \text{MPa}$$

$$\sigma_j := \sqrt{\sigma^2 + 3(\tau_1^2 + \tau_2^2)} = 274 \cdot \text{MPa}$$

$$UF := \frac{\sigma_j}{\sigma_{420.d}} = 0.8$$

## Welds

### Horizontal weld

Filled weld throat

$$a_w := 6 \text{ mm}$$

$$\tau_{||} := \frac{F_h}{2 \cdot l_{lug} \cdot a_w} + \frac{T}{t_{lug} \cdot a_w \cdot l_{lug}} = 59.6 \cdot \text{MPa} \quad \sigma_{\perp} := \frac{F_t}{2 \cdot a_w \cdot l_{lug} \cdot \sqrt{2}} = 4.6 \cdot \text{MPa}$$

$$\tau_{\perp} := \sigma_{\perp} = 4.6 \cdot \text{MPa}$$

$$UF_h := \frac{\sqrt{\sigma_{\perp}^2 + 3(\tau_{||}^2 + \tau_{\perp}^2)}}{\sigma_{420.w}} = 0.3$$

### Vertical weld

Filled weld throat

$$a_{v.w} := 8 \text{ mm}$$

$$\tau_{||.Fv} := \frac{F_v}{4 \cdot a_{v.w} \cdot \text{depth}_{lug}} = 30.8 \cdot \text{MPa} \quad \tau_{||.MS} := \frac{M_{strong}}{l_{lug}} \cdot \frac{1}{2 \cdot a_{v.w} \cdot \text{depth}_{lug}} = 10 \cdot \text{MPa}$$

$$\tau_{||.Mw} := \frac{M_{weak}}{t_{lug}} \cdot \frac{1}{2 \cdot a_{v.w} \cdot depth_{lug}} = 29.5 \cdot \text{MPa} \quad \tau_{||.Fv} = 30.8 \cdot \text{MPa}$$

$$UF_V := \sqrt{3 \cdot \frac{(\tau_{||.Fv} + \tau_{||.MS} + \tau_{||.Mw})^2}{\sigma_{420.w}^2}} = 0.3$$

## Lug details

### Tear out

Shear stresses

$$\tau := \frac{F_{sd}}{2 \cdot \left[ \left( R_{lug} - \frac{d_{lug}}{2} \right) t_{lug} + 2 \cdot \left( R_b - \frac{d_{lug}}{2} \right) \cdot t_c \right]} = 90.8 \cdot \text{MPa}$$

Shear stress resistance

$$\tau_D := \frac{f_y \cdot 420}{\sqrt{3} \cdot \gamma_{M1.ULS}} = 210.9 \cdot \text{MPa}$$

Usage factor

$$UF_{Lug} := \frac{\tau}{\tau_D} = 0.4$$

## Bearing

Bearing stress

$$\sigma_H := \frac{F_{sd}}{(t_{lug} + 2 \cdot t_c) \cdot d_1} = 201.1 \cdot \text{MPa}$$

Bearing stress resistance

$$f_{d.b} := 1.5 \cdot \frac{f_y \cdot 420}{\gamma_{M1.ULS}} = 547.8 \cdot \text{MPa}$$

Usage factor

$$UF_{bearing} := \frac{\sigma_H}{f_{d.b}} = 0.4$$

## Fillet weld cheek plates

Fillet weld throat

$$a_w := 4\text{mm}$$

Effective weld length

$$l_{w,\text{eff}} := \frac{2}{3} \cdot 2 \cdot \pi \cdot R_b = 226.2 \cdot \text{mm}$$

Force on each weld

$$F_w := \frac{F_{sd} \cdot t_c}{t_{\text{lug}} + 2 \cdot t_c} = 42.2 \cdot \text{kN}$$

Weld stress

$$\tau_{Ed} := \frac{F_w}{l_{w,\text{eff}} \cdot a_w} = 46.7 \cdot \text{MPa}$$

Weld usage

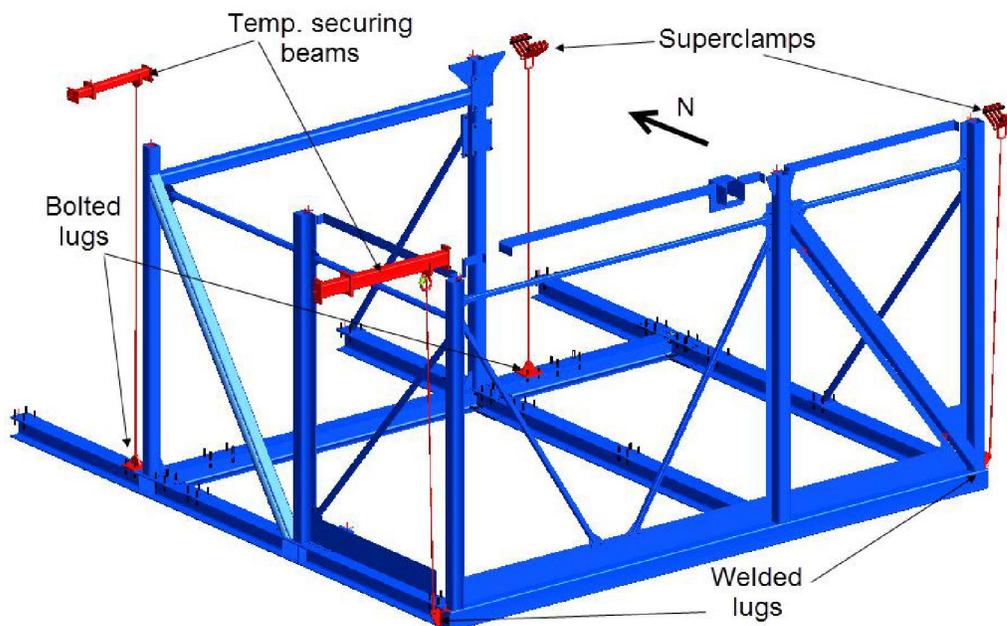
$$UF_w := \frac{\tau_{Ed} \cdot \sqrt{3}}{\sigma_{420.w}} = 0.2$$

## Appendix A.3

### Temp. securing beams/lugs for C05 balcony

#### **SUMMARY**

This appendix covers the strength verification of the temporary securing beams and lugs used to maintain C05 main frame in the correct final position until it's welded. The frame is secured in four points using chains and turnbuckles, ref. dwgs. C007-C-C05E-NK-004-01, C007-C-M22-NK-566-01. On the east side two superclamps are used to secure against existing girders, whereas on the west side two temp. RHS beams are bolted to the existing structures.



## Conclusions

All parts fulfil the requirements to acceptable stress and deformation levels. Maximum utilizations are as follows:

Lug base UR=0.44  
Lug welds UR=0.7  
Lug bearing/tear out UR=0.3  
Shackles UR=0.53  
Turnbuckles UR=0.6  
Chains UR=0.6  
Temporary securing RHS UR=0.67  
Bolts UR=0.5  
Existing structures UR=0.97\*

Utilization for existing structures are calculated by Aker Solutions and are OK.

# Design Basic

## Material data

### Material factors

ULS

General

$$\gamma_{M1,ULS} := 1.15$$

Bolted and welded connection

$$\gamma_{M2,ULS} := 1.3$$

### Structural steel

#### Y05

Yield strength

$$f_{y,355} := 355 \text{ MPa}$$

Tensile strength

$$f_{u,355} := 470 \text{ MPa}$$

Allowable stress

$$\sigma_{355,d} := \frac{f_{y,355}}{\gamma_{M1,ULS}} = 308.7 \text{ MPa}$$

#### Y30

Yield strength of plate material

$$f_{y,420} := 420 \text{ MPa}$$

Tensile strength

$$f_{u,420} := 500 \text{ MPa}$$

Allowable stress in plates

$$\sigma_{420,d} := \frac{f_{y,420}}{\gamma_{M1,ULS}} = 365.22 \text{ MPa}$$

### Welds

Correlation for weld calculation, EC3 BS EN 1993-1-8 2005, pt. 4.5.3.2 table 4.1:

$$\text{S355: } \beta_{w,355} := 0.9$$

$$\text{S420: } \beta_{w,420} := 1.0$$

Design weld stress, EC3 BS EN 1993-1-8 2005, pt. 4.5.3.2 (6):

$$\text{S355: } \sigma_{355,w} := \frac{f_{u,355}}{\gamma_{M2,ULS} \cdot \beta_{w,355}} = 401.71 \text{ MPa} \quad \sigma_{n,355,w} := \frac{0.9 \cdot f_{u,355}}{\gamma_{M2,ULS}} = 325.38 \text{ MPa}$$

$$\text{S420: } \sigma_{420,w} := \frac{f_{u,420}}{\gamma_{M2,ULS} \cdot \beta_{w,420}} = 384.62 \text{ MPa} \quad \sigma_{n,420,w} := \frac{0.9 \cdot f_{u,420}}{\gamma_{M2,ULS}} = 346.15 \text{ MPa}$$

## BOLTS

Values for Yield and Ultimate tensile strength (GR 8.8):

Yield strength of bolt material 8.8

$$f_{yb\_8.8} := 640\text{MPa}$$

Ultimate Tensile strength of bolts

$$f_{ub\_8.8} := 800\text{MPa}$$

### M20

Area of bolt

$$A_{20} := 245\text{mm}^2$$

Tensile capacity per bolt

$$F_{t.Rd.M20} := \frac{0.9f_{ub\_8.8}}{\gamma_{M2.ULS}} \cdot A_{20} = 135.69 \cdot \text{kN}$$

Shear capacity per bolt

$$F_{v.Rd.M20} := \frac{0.6f_{ub\_8.8}}{\gamma_{M2.ULS}} \cdot A_{20} = 90.46 \cdot \text{kN}$$

### M24

Area of bolt

$$A_{24} := 353\text{mm}^2$$

Tensile capacity per bolt

$$F_{t.Rd.M24} := \frac{0.9f_{ub\_8.8}}{\gamma_{M2.ULS}} \cdot A_{24} = 195.51 \cdot \text{kN}$$

Shear capacity per bolt

$$F_{v.Rd.M24} := \frac{0.6f_{ub\_8.8}}{\gamma_{M2.ULS}} \cdot A_{24} = 130.34 \cdot \text{kN}$$

### M30

Area of bolt

$$A_{30} := 561\text{mm}^2$$

Tensile capacity per bolt

$$F_{t.Rd.M30} := \frac{0.9f_{ub\_8.8}}{\gamma_{M2.ULS}} \cdot A_{30} = 310.71 \cdot \text{kN}$$

Shear capacity per bolt

$$F_{v.Rd.M30} := \frac{0.6f_{ub\_8.8}}{\gamma_{M2.ULS}} \cdot A_{30} = 207.14 \cdot \text{kN}$$

## LIFTING DESIGN BASIS

### Weight, WCF and $W_{\text{COG}}$

The weight of C05 east balcony main frame is about 12t, according to Aker Solutions drawings. A weight contingency factor (WCF) of 1.3 is added in order to allow some weight growth. In addition, a factor for uncertainties ( $W_{\text{COG}}$ ) in the location of the COG is included. All factors are taken from Norsk Standard R-002, Annex F

Mass of frame	$\text{Mass} := 12\text{tonne}$
Mass of fire protection	$M_{\text{fp}} := 1.5\text{tonne}$
Weight contingency factor	$\text{WCF} := 1.3$
Uncertainty in Cog	$W_{\text{cog}} := 1.1$
Gross Weight	$W_{\text{gross}} := (\text{Mass} + M_{\text{fp}}) \cdot \text{WCF} = 1.75 \times 10^4 \text{ kg}$

### DAF and SKL

Offshore lift	$\text{DAF}_{\text{off}} := 1.09 + 0.41 \cdot \sqrt{\frac{50\text{tonne}}{W_{\text{gross}}}} = 1.78$
Platform internal lift (onshore)	$\text{DAF}_{\text{on}} := 1.5$
Four part sling arrangement	$\text{SKL} := 1.25$

### Load and consequence factors

Consider the load factor 1.34 and the consequence factor 1.25 for both lifting lug design and main structural elements supporting the lifting point.

$$\gamma_{\text{F}} := 1.34 \qquad \gamma_{\text{c}} := 1.25 \qquad \text{DF} := \gamma_{\text{F}} \cdot \gamma_{\text{c}} = 1.68$$

$$\gamma_{\text{t}} := 0.0785$$

### Total load factors

Total applied load factor for offshore lift

$$\gamma_{\text{d.off}} := W_{\text{cog}} \cdot \text{DAF}_{\text{off}} \cdot \text{SKL} \cdot \text{DF} = 4.1$$

Total applied load factor for onshore lift

$$\gamma_{\text{d.on}} := W_{\text{cog}} \cdot \text{DAF}_{\text{on}} \cdot \text{SKL} \cdot \text{DF} = 3.45$$

## Design load

$$W_{\text{gross}} := 17550\text{kg}$$

$$DF = 1.68$$

$$DAF_{\text{on}} = 1.5$$

Design transverse load accounts for 4.5deg. shift with vertical (recommended is 5%)

Consider that during the securing process one lug might be subjected to half the design weight.

$$\frac{W_{\text{gross}}}{2} = 8775\text{kg}$$

When tightening the frame against existing structures, the load at each lug is calculated without DAF as:

$$F_{\text{chain}} := 10\text{tonne} \cdot DF \cdot g = 164.26\text{kN}$$

## Securing equipment

### Shackles

Safety factor for shackle

$$SF_{\text{sh}} := 6$$

Design factor

$$DF_{\text{sh}} := 1.68$$

Material resistance factor

$$\gamma RM_{\text{sh}} := 1.8$$

Minimum breaking load

$$MBL_{\text{shackle}} := \frac{F_{\text{chain}} \cdot DF_{\text{sh}} \cdot \gamma RM_{\text{sh}}}{g \cdot DF} = 30.24 \cdot \text{tonne}$$

WLL

$$WLL_{\text{min.shackle}} := \frac{MBL_{\text{shackle}}}{SF_{\text{sh}}} = 5.04 \cdot \text{tonne}$$

Based on this calculations I choose a shackle with WLL 9,5 tonne

$$WLL_{\text{use.shackle}} := 9.5\text{tonne}$$

$$UR_{\text{shackle}} := \frac{WLL_{\text{min.shackle}}}{WLL_{\text{use.shackle}}} = 0.53$$

## Turnbuckles

Safety factor for turnbuckle

$$SF_{tb} := 5$$

Design factor

$$DF_{tb} := 1.68$$

Material resistance factor

$$\gamma RM_{tb} := 1.8$$

Minimum breaking load

$$MBL_{tb} := \frac{F_{chain} \cdot DF_{sh} \cdot \gamma RM_{sh}}{g \cdot DF} = 30.24 \cdot \text{tonne}$$

WLL

$$WLL_{min.tb} := \frac{MBL_{tb}}{SF_{tb}} = 6.05 \cdot \text{tonne}$$

Based on this calculations I choose a turnbuckle with WLL 10 tonne

$$WLL_{use.tb} := 9.5 \text{ tonne}$$

$$UR_{tb} := \frac{WLL_{min.tb}}{WLL_{use.tb}} = 0.64$$

## Chain

Safety factor for chain

$$SF_{ch} := 4$$

Design factor

$$DF_{ch} := 1.68$$

Material resistance factor

$$\gamma RM_{ch} := 1.8$$

Minimum breaking load

$$MBL_{ch} := \frac{F_{chain} \cdot DF_{ch} \cdot \gamma RM_{ch}}{g \cdot DF} = 30.24 \cdot \text{tonne}$$

WLL

$$WLL_{min.ch} := \frac{MBL_{ch}}{SF_{ch}} = 7.56 \cdot \text{tonne}$$

Based on this calculations I choose a chain with WLL 12.5 tonne

$$WLL_{use.ch} := 12.5 \text{ tonne}$$

$$UR_{ch} := \frac{WLL_{min.ch}}{WLL_{use.ch}} = 0.6$$

### Lugs bolted to C05 main frame (north side)

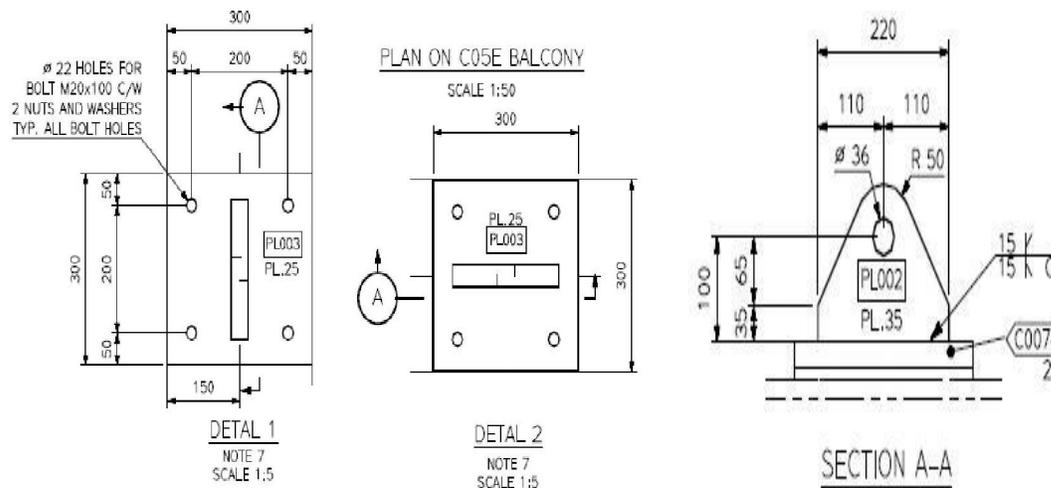
Maximum sling force  $F_{sd} := F_{chain} = 164.26 \text{ kN}$

Angle with horizontal  $\beta := 85 \text{ deg}$

Design vertical load  $F_v := F_{sd} = 164.26 \text{ kN}$

Design horizontal load  $F_h := F_{sd} \cdot \cos(\beta) = 14.32 \text{ kN}$

Design transversal load  $F_t := F_{sd} \cdot \gamma_t = 12.89 \text{ kN}$



### Lug type 1

#### Shackle data

$d_1 := 32 \text{ mm}$

$W_s := 46 \text{ mm}$

$c := 108 \text{ mm}$

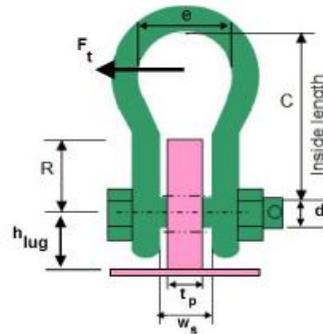
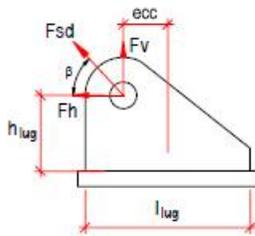
$e := 74 \text{ mm}$

Distasense to center of shackle bow

$$C_C := \frac{d_1}{2} + c - \frac{e}{2} = 87 \cdot \text{mm}$$

### Lug data

$$\begin{aligned}d_{\text{lug}} &:= 36\text{mm} \\t_{\text{lug}} &:= 35\text{mm} \\R_{\text{lug}} &:= 50\text{mm} \\l_{\text{lug}} &:= 220\text{mm} \\h_{\text{lug}} &:= 125\text{mm} \\ecc &:= 0\text{mm}\end{aligned}$$



### Loads

$$M_{\text{strong}} := h_{\text{lug}} \cdot F_h - ecc \cdot F_v = 1.79 \cdot \text{kN} \cdot \text{m}$$

$$M_{\text{weak}} := F_t \cdot (h_{\text{lug}} + C \cdot \sin(\beta)) = 2.73 \cdot \text{kN} \cdot \text{m}$$

$$T := F_t \cdot C \cdot \cos(\beta) = 0.1 \cdot \text{kN} \cdot \text{m}$$

### Stresses

$$\sigma := \frac{F_v}{l_{\text{lug}} \cdot t_{\text{lug}}} + \frac{M_{\text{strong}} \cdot 6}{l_{\text{lug}}^2 \cdot t_{\text{lug}}} + \frac{M_{\text{weak}} \cdot 6}{l_{\text{lug}} \cdot t_{\text{lug}}^2} = 88.44 \cdot \text{MPa}$$

$$\tau_1 := \frac{F_h}{l_{\text{lug}} \cdot t_{\text{lug}}} + \frac{3 \cdot T}{l_{\text{lug}} \cdot t_{\text{lug}}^2} = 2.95 \cdot \text{MPa}$$

$$\tau_2 := \frac{F_t}{l_{\text{lug}} \cdot t_{\text{lug}}} + \frac{3 \cdot T}{l_{\text{lug}} \cdot t_{\text{lug}}^2} = 2.76 \cdot \text{MPa}$$

$$\sigma_j := \sqrt{\sigma^2 + 3(\tau_1^2 + \tau_2^2)} = 88.71 \cdot \text{MPa}$$

$$UF := \frac{\sigma_j}{\sigma_{420.d}} = 0.24$$

## Welds

### Horizontal weld

Weld throat  $a_w := 15 \text{ mm}$

Weld length  $l_w := l_{lug} = 220 \text{ mm}$

$$d := t_{lug} - 2 \cdot a_w = 5 \text{ mm}$$

$$I_{\text{weak.w}} := 2 \left[ a_w \cdot l_w \cdot \left( \frac{d + a_w}{2} \right)^2 + \frac{a_w^3 \cdot l_w}{12} \right] = 783750 \text{ mm}^4$$

$$W_{\text{weak.w}} := \frac{I_{\text{weak.w}}}{\frac{d}{2} + a_w} = 44785.71 \text{ mm}^3$$

$$\tau_{Fh} := \frac{F_h}{2 \cdot l_w \cdot a_w} = 2.17 \text{ MPa}$$

$$\sigma_{Fv} := \frac{F_v}{2 \cdot a_w \cdot l_{lug}} = 24.89 \text{ MPa}$$

$$\sigma_{Ms} := \frac{M_{\text{strong}} \cdot 6}{2 \cdot l_w^2 \cdot a_w} = 7.39 \text{ MPa}$$

$$\sigma_{Mw} := \frac{M_{\text{weak}}}{W_{\text{weak.w}}} = 60.94 \text{ MPa}$$

$$\tau_{Ft} := \frac{F_t}{2 \cdot l_w \cdot a_w} = 1.95 \text{ MPa}$$

$$\tau_T := \frac{T}{t_{lug} - a_w} \cdot \frac{1}{a_w \cdot l_w} = 1.48 \text{ MPa}$$

$$\sigma_j := \sqrt{(\sigma_{Fv} + \sigma_{Ms} + \sigma_{Mw})^2 + 3 \cdot (\tau_{Fh} + \tau_{Ft} + \tau_T)^2} = 93.73 \text{ MPa}$$

$$UF := \frac{\sigma_j}{\sigma_{420.d}} = 0.26$$

## Lug details

### Tear out

Shear stresses

$$\tau := \frac{F_{sd}}{2 \cdot \left( R_{lug} - \frac{d_{lug}}{2} \right) t_{lug}} = 73.33 \cdot \text{MPa}$$

Shear stress resistance

$$\tau_D := \frac{f_y \cdot 420}{\sqrt{3} \cdot \gamma_{M1} \cdot ULS} = 210.86 \cdot \text{MPa}$$

Usage factor

$$UF_{Lug} := \frac{\tau}{\tau_D} = 0.35$$

### Bearing

Bearing stress

$$\sigma_H := \frac{F_{sd}}{t_{lug} \cdot d_1} = 146.66 \cdot \text{MPa}$$

Bearing stress resistance

$$f_{d,b} := 1.5 \cdot \frac{f_y \cdot 420}{\gamma_{M1} \cdot ULS} = 547.83 \cdot \text{MPa}$$

Usage factor

$$UF_{bearing} := \frac{\sigma_H}{f_{d,b}} = 0.27$$

## **Bolts**

$$p_1 := 200\text{mm}$$

$$p_2 := 200\text{mm}$$

$$\theta := \text{atan}\left(\frac{p_1}{p_2}\right) = 0.79$$

## **Shear force per bolt**

$$F_{v.Fh} := \frac{F_h}{4} = 3.58\text{ kN}$$

$$F_{v.Ft} := \frac{F_t}{4} = 3.22\text{ kN}$$

$$F_{v.T} := \frac{T}{4 \cdot \sqrt{\left(\frac{p_1}{2}\right)^2 + \left(\frac{p_2}{2}\right)^2}} = 0.17\text{ kN}$$

$$F_{v.\text{tot}} := \sqrt{\left(F_{v.Fh} + F_{v.T} \cdot \cos(\theta)\right)^2 + \left(F_{v.Ft} + F_{v.T} \cdot \sin(\theta)\right)^2} = 4.99\text{ kN}$$

## **Axial force per bolt**

$$F_{t.\text{tot}} := \frac{F_v}{4} + \frac{M_{\text{strong}}}{p_1 \cdot 2} + \frac{M_{\text{weak}}}{p_2 \cdot 2} = 52.36\text{ kN}$$

## **Utilization factors**

$$UF_t := \frac{F_{t.\text{tot}}}{F_{t.Rd.M20}} = 0.39$$

$$UF_{F.v} := \frac{F_{v.\text{tot}}}{F_{v.Rd.M20}} = 0.06$$

$$UF_b := \frac{F_{v.\text{tot}}}{F_{v.Rd.M20}} + \frac{F_{t.\text{tot}}}{1.4 \cdot F_{t.Rd.M20}} = 0.33$$

## **Base plate in bending**

$$\text{arm} := 83\text{mm}$$

$$l_{\text{eff}} := 300\text{mm}$$

$$t_p := 25\text{mm}$$

$$\sigma_{\text{max}} := 2 \cdot \frac{F_{t.\text{tot}} \cdot \text{arm}}{\frac{1}{6} \cdot l_{\text{eff}} \cdot t_p^2} = 278.15\text{ MPa}$$

Stress level OK, conservative check

## HEB300 flange in bending

$$\begin{aligned} \text{Distance from bolt to web} & L_1 := \frac{200\text{mm} - 11\text{mm}}{2} = 94.5\text{ mm} \\ \text{Distance from bolt to edge of T-stub} & e := 50\text{mm} \\ \text{Spacing between bolts} & p := 200\text{mm} \\ \text{T-Stub plate thickness} & t_f := 19\text{mm} \\ m_{ts} & := L_1 - 0.8 \cdot 27\text{mm} = 72.9\text{ mm} \\ n & := \min(e, 1.25 \cdot m_{ts}) = 50\text{ mm} \end{aligned}$$

### Effective length

$$\begin{aligned} \text{circular patterns} & \Delta l_{\text{eff.cp}} := \min(2 \cdot \pi \cdot m_{ts}, \pi \cdot m_{ts} + p) = 429.02\text{ mm} \\ \text{non-circular patterns} & \Delta l_{\text{eff.nc}} := \min(4 \cdot m_{ts} + 1.25 \cdot e, 2 \cdot m_{ts} + 0.625 \cdot e + 0.5 \cdot p) = 277.05\text{ mm} \\ \text{Effective length} & l_{\text{eff}} := \min(\Delta l_{\text{eff.cp}}, \Delta l_{\text{eff.nc}}) = 277.05\text{ mm} \end{aligned}$$

$$\text{Design tension resistance of the T-Stub} \quad F_{t,\text{Rd.tot}} := 2 \cdot F_{t,\text{Rd.M20}} = 271.38\text{ kN}$$

### Method 1

$$M_{\text{pl.1.Rd}} := 0.25 \cdot l_{\text{eff}} \cdot t_f^2 \cdot \frac{f_y \cdot 355}{\gamma_{\text{M1.ULS}}} = 7.72\text{ kN}\cdot\text{m}$$

$$M_{\text{pl.2.Rd}} := M_{\text{pl.1.Rd}} = 7.72\text{ kN}\cdot\text{m}$$

$$\text{Mode 1} \quad F_{\text{T.1.Rd}} := \frac{4 \cdot M_{\text{pl.1.Rd}}}{m_{ts}} = 423.51\text{ kN}$$

$$\text{Mode 2} \quad F_{\text{T.2.Rd}} := \frac{2 \cdot M_{\text{pl.2.Rd}} + n \cdot F_{t,\text{Rd.tot}}}{m_{ts} + n} = 236.02\text{ kN}$$

$$\text{Mode 3} \quad F_{\text{T.3.Rd}} := F_{t,\text{Rd.tot}} = 271.38\text{ kN}$$

$$\text{Tensile resistance of the T-Stub} \quad F_{\text{T.Rd}} := \min(F_{\text{T.1.Rd}}, F_{\text{T.2.Rd}}, F_{\text{T.3.Rd}}) = 236.02\text{ kN}$$

$$\text{Total tensile force on the T-Stub} \quad F_{\text{T.Ed}} := 2 \cdot F_{t,\text{tot}} = 104.73\text{ kN}$$

$$\text{Utilization Factor} \quad \text{UF} := \frac{F_{\text{T.Ed}}}{F_{\text{T.Rd}}} = 0.44$$



## Loads

Design load

$$F_{sd} := F_{chain} = 164.26 \cdot \text{kN}$$

Angle with horizontal

$$\beta := 85 \text{deg}$$

Vertical component

$$F_v := F_{sd} = 164.26 \cdot \text{kN}$$

Horizontal component

$$F_h := F_{sd} \cdot \cos(\beta) = 14.32 \cdot \text{kN}$$

Transversal component

$$F_t := F_{sd} \cdot \gamma_t = 12.89 \cdot \text{kN}$$

$$M_{strong} := h_{lug} \cdot F_h = 1.15 \cdot \text{kN} \cdot \text{m}$$

$$M_{weak} := F_t \cdot (h_{lug} + C_C \cdot \sin(\beta)) = 2.15 \cdot \text{kN} \cdot \text{m}$$

$$T := F_t \cdot C_C \cdot \cos(\beta) = 0.1 \cdot \text{kN} \cdot \text{m}$$

## Stresses

$$\sigma := \frac{F_v}{2 \cdot w_{lug} \cdot t_{lug}} + \frac{M_{strong}}{(w_{lug} + l_{lug}) \cdot t_{lug} \cdot w_{lug}} + \frac{M_{weak} \cdot 6}{2 \cdot w_{lug} \cdot t_{lug}^2} = 129.86 \cdot \text{MPa}$$

$$\tau_1 := \frac{F_h}{l_{tot} \cdot t_{lug}} + \frac{3 \cdot T}{l_{tot} \cdot t_{lug}^2} = 2.7 \cdot \text{MPa}$$

$$\tau_2 := \frac{F_t}{l_{tot} \cdot t_{lug}} + \frac{3 \cdot T}{l_{tot} \cdot t_{lug}^2} = 2.53 \cdot \text{MPa}$$

$$\sigma_j := \sqrt{\sigma^2 + 3(\tau_1^2 + \tau_2^2)} = 130.02 \cdot \text{MPa}$$

$$UF := \frac{\sigma_j}{\sigma_{420.d}} = 0.36$$

## Welds

### Horizontal weld

Filled weld throat

$$a_w := 5 \text{mm}$$

$$\tau_{||} := \frac{F_h}{2 \cdot l_{lug} \cdot a_w} + \frac{T}{t_{lug} \cdot a_w \cdot l_{lug}} = 16.59 \cdot \text{MPa} \quad \sigma_{\perp} := \frac{F_t}{2 \cdot a_w \cdot l_{lug} \cdot \sqrt{2}} = 7.6 \cdot \text{MPa}$$

$$\tau_{\perp} := \sigma_{\perp} = 7.6 \cdot \text{MPa}$$

$$UF_h := \sqrt{\frac{\sigma_{\perp}^2 + 3(\tau_{\parallel}^2 + \tau_{\perp}^2)}{\sigma_{420.w}^2}} = 0.08$$

### Vertical weld

Filled weld throat

$$a_{v.w} := 8\text{mm}$$

$$\tau_{\parallel.Fv} := \frac{F_v}{4 \cdot a_{v.w} \cdot \text{depth}_{lug}} = 51.33 \cdot \text{MPa} \quad \tau_{\parallel.MS} := \frac{M_{strong.}}{l_{lug.}} \cdot \frac{1}{2 \cdot a_{v.w} \cdot \text{depth}_{lug}} = 5.97 \cdot \text{MPa}$$

$$\tau_{\parallel.Mw} := \frac{M_{weak.}}{l_{lug.}} \cdot \frac{1}{2 \cdot a_{v.w} \cdot \text{depth}_{lug}} = 38.38 \cdot \text{MPa} \quad \tau_{\parallel.Fv} = 51.33 \cdot \text{MPa}$$

$$UF_v := \sqrt{3 \cdot \frac{(\tau_{\parallel.Fv} + \tau_{\parallel.MS} + \tau_{\parallel.Mw})^2}{\sigma_{420.w}^2}} = 0.43$$

### **Lug details**

Ok by inspection, see G.3.3, same plate thickness and radius

### **Check temp. RHS120x10**

$$F_{v.RHS} := 164.3\text{kN}$$

$$F_{h.RHS} := 14.3\text{kN}$$

$$F_{t.RHS} := 12.9\text{kN}$$

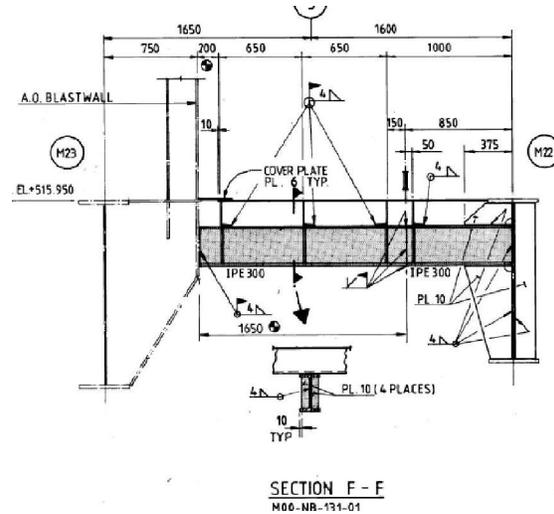
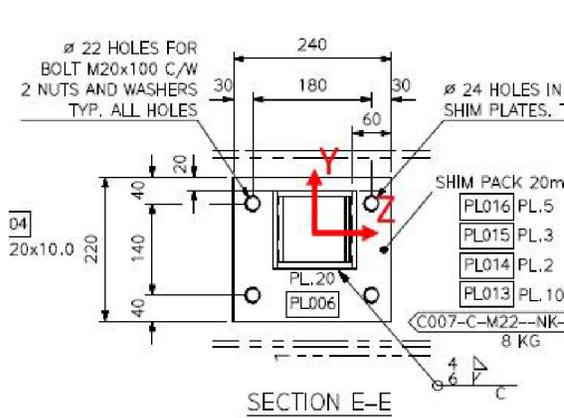
$$M_{strong.RHS} := F_{t.RHS} \cdot (h_{lug.} + 60\text{mm} + C_C) = 2.93 \text{ kN} \cdot \text{m}$$

$$T_{RHS} := F_{h.RHS} \cdot (h_{lug.} + 60\text{mm}) = 2 \text{ kN} \cdot \text{m}$$

$$\tau_{tors} := \frac{T_{RHS}}{2 \cdot (200\text{mm} - 10\text{mm})^2 \cdot 10\text{mm}} = 2.77 \text{ MPa}$$

OK!

## Bolts - IPE side



$$p_1 := 140\text{mm}$$

$$t_{sh} := 20\text{mm}$$

$$p_2 := 180\text{mm}$$

$$d_{20} := 20\text{mm}$$

$$F_y := 140\text{kN}$$

$$M_x := T_{RHS} = 2\text{kN}\cdot\text{m} \quad (\text{all taken at IPE side})$$

$$F_x := F_t = 12.89\text{kN} \quad (\text{all taken at IPE side})$$

$$F_z := 13\text{kN}$$

### Shear force per bolt

$$F_{v,Fy} := \frac{F_y}{4} = 35\text{kN}$$

$$F_{v,Fz} := \frac{F_z}{4} = 3.25\text{kN}$$

$$F_{v,Mx} := \frac{M_x}{4 \cdot \sqrt{\left(\frac{p_1}{2}\right)^2 + \left(\frac{p_2}{2}\right)^2}} = 4.39\text{kN}$$

$$F_{v,tot.} := \sqrt{\left(F_{v,Fy} + F_{v,Mx} \cdot \cos(\theta)\right)^2 + \left(F_{v,Fz} + F_{v,Mx} \cdot \sin(\theta)\right)^2} = 38.63\text{kN}$$

### Axial force per bolt

$$F_{t,tot.} := \frac{F_x}{2} = 6.45\text{kN}$$

## Utilization factors

Design shear resistance reduction factor (due to shim plates);

$$\beta_p := \text{if} \left( t_{\text{sh}} \geq \frac{d_{20}}{3}, \frac{9 \cdot d_{20}}{8 \cdot d_{20} + 3 \cdot t_{\text{sh}}}, 1 \right) = 0.82$$

$$UF_{V.} := \frac{F_{v.\text{tot.}}}{\beta_p \cdot F_{v.\text{Rd.M20}}} = 0.52$$

## **Welds**

Weld length

$$l_w := 120 \text{ mm}$$

Weld throat thickness

$$a_w := 6 \text{ mm} \cdot \sqrt{2} = 8.49 \text{ mm}$$

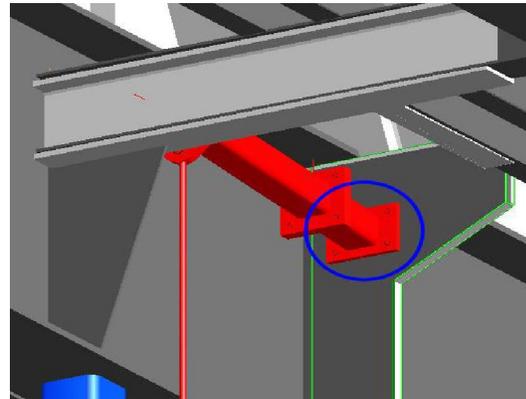
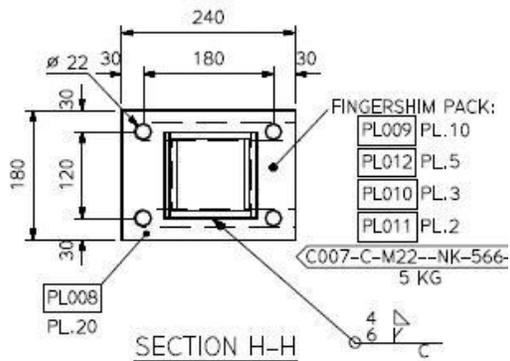
Check vertical welds only (most loaded)

$$\tau_{\parallel,1} := \frac{F_y}{2 \cdot a_w \cdot l_w} = 68.75 \cdot \text{MPa}$$

$$\tau_{\parallel,2} := \frac{M_x}{2 \cdot (120 \text{ mm} + a_w)^2 \cdot a_w} = 7.15 \cdot \text{MPa}$$

$$UF_{\text{weld}} := \frac{\sqrt{3} \cdot (\tau_{\parallel,1} + \tau_{\parallel,2})}{\sigma_{420.w}} = 0.34$$

## Bearing IPE web



$$\sigma := \frac{F_{v,tot.}}{20\text{mm} \cdot 7.1\text{mm}} = 272.04 \text{ MPa} \quad \text{high stress but ok, conservative check}$$

Connection details are OK by inspection as the design loads are smaller.

## Beam split

$$F_x := 2 \text{ kN}$$

$$F_y := 30 \text{ kN}$$

$$F_z := 3 \text{ kN}$$

$$M_x := 0.5 \text{ kN} \cdot \text{m}$$

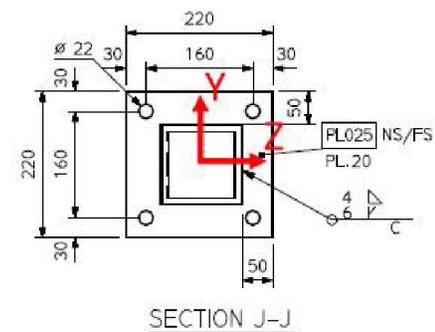
$$M_y := 320 \text{ mm} \cdot F_z = 0.96 \text{ kN} \cdot \text{m}$$

$$M_z := 320 \text{ mm} \cdot F_y = 44.8 \text{ kN} \cdot \text{m}$$

$$p_{1..} := 160 \text{ mm}$$

$$p_{2..} := 160 \text{ mm}$$

$$\theta := \text{atan} \left( \frac{p_{1..}}{p_{2..}} \right) = 0.79$$



## Shear force per bolt

$$F_{v,Fy} := \frac{F_y}{4} = 7.5 \text{ kN}$$

$$F_{v,Fz} := \frac{F_z}{4} = 0.75 \text{ kN}$$

$$F_{v,Mx} := \frac{M_x}{4 \cdot \sqrt{\left(\frac{p_{1..}}{2}\right)^2 + \left(\frac{p_{2..}}{2}\right)^2}} = 1.1 \text{ kN}$$

$$F_{v,tot..} := \sqrt{\left(F_{v,Fy} + F_{v,Mx} \cdot \cos(\theta)\right)^2 + \left(F_{v,Fz} + F_{v,Mx} \cdot \sin(\theta)\right)^2} = 8.41 \text{ kN}$$

Axial force per bolt

$$F_{t,tot..} := \frac{F_x}{2} + \frac{M_{strong}}{2 \cdot p_{1..}} + \frac{M_{weak}}{p_{2..} \cdot 2} = 15.12 \text{ kN}$$

## Utilization factors

$$UF_b := \frac{F_{v,tot..}}{F_{v,Rd.M20}} + \frac{F_{t,tot..}}{1.4 \cdot F_{t,Rd.M20}} = 0.17$$

Welds and 20mm plates are OK by inspection.

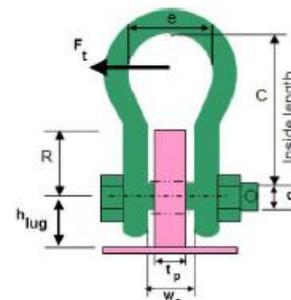
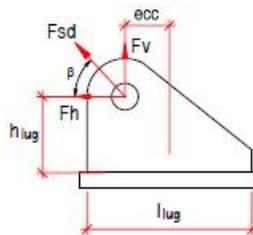
## **Existing I1300x400x12x25 GR.I girder (north east securing point)**

Report is produced by Aker Solutions and it is OK.

## **South east lug welded to C05 main frame**

### Lug data

- $d_{lug} := 36 \text{ mm}$
- $t_{lug} := 35 \text{ mm}$
- $R_{lug} := 50 \text{ mm}$
- $l_{lug} := 200 \text{ mm}$
- $h_{lug} := 130 \text{ mm}$
- $e_{cc} := 50 \text{ mm}$



### Loads

Design load

$$F_{.sd} := F_{chain} = 164.26 \text{ kN}$$

Angle with horizontal

$$\beta := 0 \text{ deg}$$

Vertical component

$$F_{.v} := F_{.sd} \cdot \sin(\beta) = 0 \text{ kN}$$

Horizontal component

$$F_{.h} := F_{.sd} \cdot \cos(\beta) = 164.26 \text{ kN}$$

Transversal component

$$F_{.t} := F_{.sd} \cdot \gamma_t = 12.89 \text{ kN}$$

$$M_{.strong} := h_{.lug} \cdot F_{.h} = 21.35 \cdot \text{kN} \cdot \text{m}$$

$$M_{.weak} := F_{.t} \cdot (h_{.lug} + e_{cc} \cdot \sin(\beta)) = 1.68 \cdot \text{kN} \cdot \text{m}$$

$$T_{.} := F_{.t} \cdot (C_C \cdot \cos(\beta) + e_{cc}) = 1.77 \cdot \text{kN} \cdot \text{m}$$

## Stresses

$$\sigma_{..} := \frac{F_{.v}}{l_{.lug} \cdot t_{.lug}} + \frac{M_{.strong} \cdot 6}{t_{.lug} \cdot l_{.lug}^2} + \frac{M_{.weak} \cdot 6}{l_{.lug} \cdot t_{.lug}^2} = 132.57 \cdot \text{MPa}$$

$$\tau_{.1} := \frac{F_{.h}}{l_{.lug} \cdot t_{.lug}} + \frac{3 \cdot T}{l_{.lug} \cdot t_{.lug}^2} = 24.66 \cdot \text{MPa}$$

$$\tau_{.2} := \frac{F_{.t}}{l_{.lug} \cdot t_{.lug}} + \frac{3 \cdot T}{l_{.lug} \cdot t_{.lug}^2} = 3.04 \cdot \text{MPa}$$

$$\sigma_{.j.} := \sqrt{\sigma_{..}^2 + 3(\tau_{.1}^2 + \tau_{.2}^2)} = 275.43 \cdot \text{MPa}$$

$$U_F := \frac{\sigma_{.j.}}{\sigma_{420.d}} = 0.75$$

## Welds

$$F_{.w} := \frac{M_{.strong}}{l_{.lug}} = 106.77 \text{ kN}$$

$$F_{.weak} := \frac{M_{.weak}}{t_{.lug}} = 47.89 \text{ kN}$$

$$\tau_{||.s} := \frac{F_{.w}}{2 \cdot 10 \text{ mm} \cdot 50 \text{ mm}} = 106.77 \text{ MPa}$$

horizontal welds (50 minimum at bottom)

$$\tau_{||.w} := \frac{F_{.weak}}{2 \cdot 10 \text{ mm} \cdot 50 \text{ mm}} = 47.89 \text{ MPa}$$

$$U_F := \frac{\sqrt{3} \cdot (\tau_{||.s} + \tau_{||.w})}{\sigma_{420.w}} = 0.7$$

$$\tau_{.||} := \frac{F_{.sd}}{2 \cdot 6 \text{ mm} \cdot 200 \text{ mm}} = 68.44 \text{ MPa}$$

$$U_{.F.} := \frac{\sqrt{3} \cdot \tau_{.||}}{\sigma_{420.w}} = 0.31$$

### Load transfer to column

The plate will take the load as bending avoiding the RHS to deform. Considering a simply supported model

$$M_{.sd} := \frac{F_{.w} \cdot (200\text{mm} - 12.5\text{mm})}{4} = 5 \text{ kN} \cdot \text{m}$$

$$\sigma_c := \frac{M_{.sd}}{\frac{1}{6} \cdot (90\text{mm})^2 \cdot 20\text{mm}} = 185.36 \text{ MPa} \quad \tau_c := \frac{0.5 \cdot F_{.w}}{90\text{mm} \cdot 20\text{mm}} = 29.66 \text{ MPa}$$

$$UF_c := \frac{\sqrt{\sigma_c^2 + 3 \cdot \tau_c^2}}{\sigma_{420.d}} = 0.53$$

### Welds on plate

$$l_{.w.eff} := 40\text{mm}$$

$$a_{.w.} := 10\text{mm}$$

$$\sigma_p := \frac{0.5 \cdot F_{.w}}{l_{.w.eff} \cdot 10\text{mm}} = 133.46 \text{ MPa} \quad \text{OK, low stress}$$

### Existing I1000x400x12x25 GR.I girder (south east securing point)

Report is produced by Aker Solutions and it is OK.

## South west lug welded to C05 main frame

### Lug data

$$d_{lug.sw} := 36\text{mm}$$

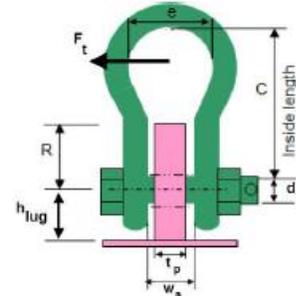
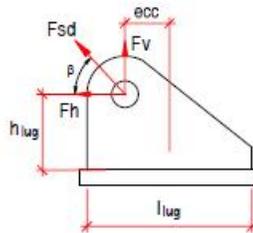
$$t_{lug.sw} := 35\text{mm}$$

$$R_{lug.sw} := 50\text{mm}$$

$$l_{lug.sw} := 262\text{mm}$$

$$h_{lug.sw} := 100\text{mm}$$

$$e_{cc.sw} := 86.5\text{mm}$$



### Loads

Design load

$$F_{sd.sw} := F_{chain} = 164.26\text{ kN}$$

Angle with horizontal

$$\beta_{sw} := 0\text{deg}$$

Vertical component

$$F_{v.sw} := F_{sd.sw} \cdot \sin(\beta_{sw}) = 0\text{ kN}$$

Horizontal component

$$F_{h.sw} := F_{sd.sw} \cdot \cos(\beta_{sw}) = 164.26\text{ kN}$$

Transversal component

$$F_{t.sw} := F_{sd.sw} \cdot \gamma_t = 12.89\text{ kN}$$

$$M_{strong.sw} := h_{lug.sw} \cdot F_{h.sw} = 16.43\text{ kN}\cdot\text{m}$$

$$M_{weak.sw} := F_{t.sw} \cdot (h_{lug.sw} + e_{cc.sw} \cdot \sin(\beta_{sw})) = 1.29\text{ kN}\cdot\text{m}$$

$$T_{sw} := F_{t.sw} \cdot (C_C \cdot \cos(\beta_{sw}) + e_{cc.sw}) = 2.24\text{ kN}\cdot\text{m}$$

## Stresses

$$\sigma_{sw} := \frac{F_{v,sw}}{l_{lug,sw} \cdot t_{lug,sw}} + \frac{M_{strong,sw} \cdot 6}{t_{lug,sw} \cdot l_{lug,sw}^2} + \frac{M_{weak,sw} \cdot 6}{l_{lug,sw} \cdot t_{lug,sw}^2} = 65.13 \cdot \text{MPa}$$

$$\tau_{1,sw} := \frac{F_{h,sw}}{l_{lug,sw} \cdot t_{lug,sw}} + \frac{3 \cdot T_{sw}}{l_{lug,sw} \cdot t_{lug,sw}^2} = 38.82 \cdot \text{MPa}$$

$$\tau_{2,sw} := \frac{F_{t,sw}}{l_{lug,sw} \cdot t_{lug,sw}} + \frac{3 \cdot T_{sw}}{l_{lug,sw} \cdot t_{lug,sw}^2} = 22.32 \cdot \text{MPa}$$

$$\sigma_{j,sw} := \sqrt{\sigma_{sw}^2 + 3(\tau_{1,sw}^2 + \tau_{2,sw}^2)} = 101.28 \cdot \text{MPa}$$

$$UF_{sw} := \frac{\sigma_{j,sw}}{\sigma_{420.d}} = 0.28$$

## Welds

$$l_{w,1,sw} := 120 \text{ mm}$$

$$l_{w,2,sw} := 262 \text{ mm}$$

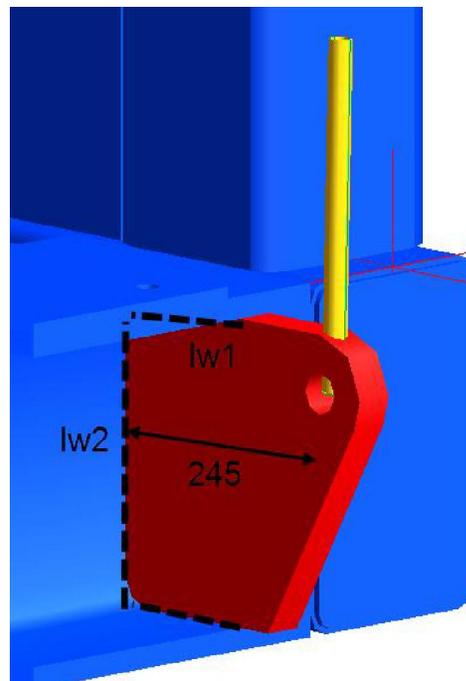
$$a_{w,sw} := 20 \text{ mm}$$

$$M_{w,sw} := F_{sd,sw} \cdot 245 \text{ mm} = 40.24 \text{ kN} \cdot \text{m}$$

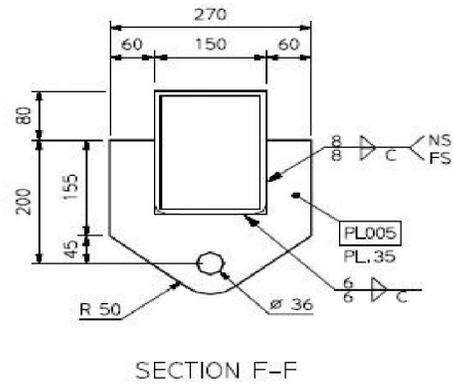
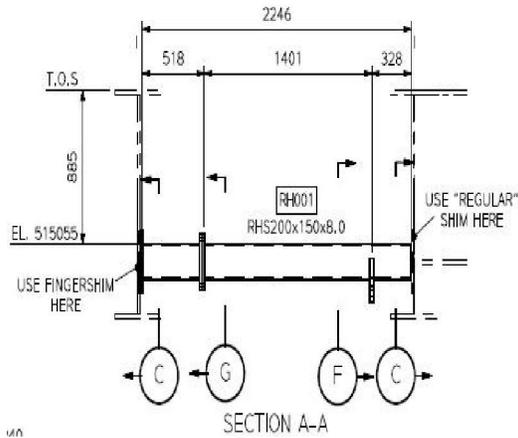
$$\tau_{1,sw} := \frac{M_{w,sw}}{262 \text{ mm} \cdot l_{w,1,sw} \cdot a_{w,sw}} = 64 \text{ MPa}$$

$$\tau_{2,sw} := \frac{F_{sd,sw}}{l_{w,2,sw} \cdot a_{w,sw}} = 31.35 \text{ MPa}$$

Stresses are low, OK



## Bolted south west temp. securing beam on existing structure



## Lug type 2

### Shackle data

$$d_{1.tsw} := 32\text{mm}$$

$$W_{s.tsw} := 46\text{mm}$$

$$c_{tsw} := 108\text{mm}$$

$$e_{tsw} := 74\text{mm}$$

Distasense to center of shackle bow

$$C_{C.tsw} := \frac{d_{1.tsw}}{2} + c_{tsw} - \frac{e_{tsw}}{2} = 87\text{mm}$$

### Lug data

$$d_{lug.tsw} := 36\text{mm}$$

$$t_{lug.tsw} := 35\text{mm}$$

$$R_{lug.tsw} := 50\text{mm}$$

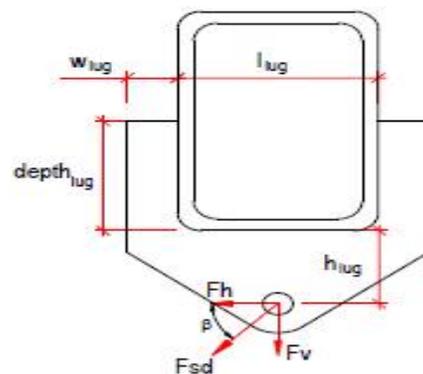
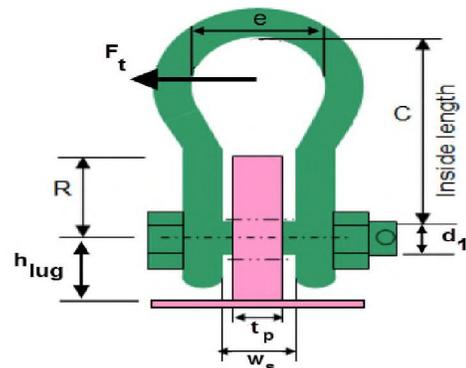
$$l_{lug.tsw} := 150\text{mm}$$

$$h_{lug.tsw} := 80\text{mm}$$

$$\text{depth}_{lug.tsw} := 120\text{mm}$$

$$w_{lug.tsw} := 60\text{mm}$$

$$l_{tot.tsw} := l_{lug.tsw} + 2 \cdot w_{lug.tsw} = 270\text{mm}$$



## Loads

Design load	$F_{sd.tsw} := F_{chain} = 164.26 \text{ kN}$
Angle with horizontal	$\beta_{tsw} := 85 \text{ deg}$
Vertical component	$F_{v.tsw} := F_{sd.tsw} = 164.26 \cdot \text{kN}$
Horizontal component	$F_{h.tsw} := F_{sd.tsw} \cdot \cos(\beta_{tsw}) = 14.32 \cdot \text{kN}$
Transversal component	$F_{t.tsw} := F_{sd.tsw} \cdot \gamma_t = 12.89 \cdot \text{kN}$

$$M_{strong.tsw} := h_{lug.tsw} \cdot F_{h.tsw} = 1.15 \cdot \text{kN} \cdot \text{m}$$

$$M_{weak.tsw} := F_{t.tsw} \cdot (h_{lug.tsw} + C_{C.tsw} \cdot \sin(\beta_{tsw})) = 2.15 \cdot \text{kN} \cdot \text{m}$$

$$T_{tsw} := F_{t.tsw} \cdot C_{C.tsw} \cdot \cos(\beta_{tsw}) = 0.1 \cdot \text{kN} \cdot \text{m}$$

## Stresses

$$\sigma_{tsw} := \frac{F_{v.tsw}}{2 \cdot w_{lug.tsw} \cdot l_{lug.tsw}} + \frac{M_{strong.tsw}}{(w_{lug.tsw} + l_{lug.tsw}) \cdot l_{lug.tsw} \cdot w_{lug.tsw}} + \frac{M_{weak.tsw} \cdot 6}{2 \cdot w_{lug.tsw} \cdot l_{lug.tsw}^2} = 129.43 \cdot \text{MPa}$$

$$\tau_{1.tsw} := \frac{F_{h.tsw}}{l_{tot.tsw} \cdot l_{lug.tsw}} + \frac{3 \cdot T_{tsw}}{l_{tot.tsw} \cdot l_{lug.tsw}^2} = 2.4 \cdot \text{MPa}$$

$$\tau_{2.tsw} := \frac{F_{t.tsw}}{l_{tot.tsw} \cdot l_{lug.tsw}} + \frac{3 \cdot T_{tsw}}{l_{tot.tsw} \cdot l_{lug.tsw}^2} = 2.25 \cdot \text{MPa}$$

$$\sigma_{j.tsw} := \sqrt{\sigma_{tsw}^2 + 3(\tau_{1.tsw}^2 + \tau_{2.tsw}^2)} = 129.55 \cdot \text{MPa}$$

$$UF_{tsw} := \frac{\sigma_{j.tsw}}{\sigma_{420.d}} = 0.35$$

## Welds

### Horizontal weld

Filled weld throat  $a_{w.tsw} := 6\text{mm}$

$$\tau_{||.tsw} := \frac{F_{h.tsw}}{2 \cdot l_{lug.tsw} \cdot a_{w.tsw}} + \frac{T_{tsw}}{t_{lug.tsw} \cdot a_{w.tsw} \cdot l_{lug.tsw}} = 11.06 \cdot \text{MPa}$$

$$\sigma_{\perp.tsw} := \frac{F_{t.tsw}}{2 \cdot a_{w.tsw} \cdot l_{lug.tsw} \cdot \sqrt{2}} = 5.07 \cdot \text{MPa}$$

$$\tau_{\perp.tsw} := \sigma_{\perp.tsw} = 5.07 \cdot \text{MPa}$$

$$UF_{h.tsw} := \sqrt{\frac{\sigma_{\perp.tsw}^2 + 3(\tau_{||.tsw}^2 + \tau_{\perp.tsw}^2)}{\sigma_{420.w}^2}} = 0.06$$

### Vertical weld

Filled weld throat  $a_{v.w.tsw} := 8\text{mm}$

$$\tau_{||.Fv.tsw} := \frac{F_{v.tsw}}{4 \cdot a_{v.w.tsw} \cdot \text{depth}_{lug.tsw}} = 42.78 \cdot \text{MPa}$$

$$\tau_{||.MS.tsw} := \frac{M_{strong.tsw}}{l_{lug.tsw}} \cdot \frac{1}{2 \cdot a_{v.w.tsw} \cdot \text{depth}_{lug.tsw}} = 3.98 \cdot \text{MPa}$$

$$\tau_{||.Mw.tsw} := \frac{M_{weak.tsw}}{t_{lug.tsw}} \cdot \frac{1}{2 \cdot a_{v.w.tsw} \cdot \text{depth}_{lug.tsw}} = 31.98 \cdot \text{MPa}$$

$$UF_{v.tsw} := \sqrt{3 \cdot \frac{(\tau_{||.Fv.tsw} + \tau_{||.MS.tsw} + \tau_{||.Mw.tsw})^2}{\sigma_{420.w}^2}} = 0.35$$

### **Lug details**

Ok, see A.3 for lug with same plate thickness and radius.

### Check temp. RHS200x150x8

$$M_{\text{strong,temp}} := F_{\text{t.tsw}} \cdot \left( h_{\text{lug.tsw}} + C_{\text{C.tsw}} + 200 \frac{\text{mm}}{2} \right) = 3.44 \text{ m kN}$$

$$F_{\text{v.tsw}} = 164.26 \text{ kN}$$

$$F_{\text{h.tsw}} = 14.32 \text{ kN}$$

$$F_{\text{t.tsw}} = 12.89 \text{ kN}$$

Torsion

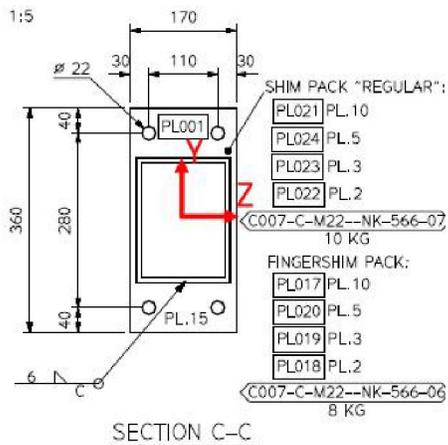
$$M_{\text{x.tsw}} := F_{\text{h.tsw}} \cdot \left( 200 \frac{\text{mm}}{2} + h_{\text{lug.tsw}} \right) = 2.58 \text{ m kN}$$

Shear due to torsion

$$\tau_{\text{T.tsw}} := \frac{M_{\text{x.tsw}}}{2 \cdot (200\text{mm} - 8\text{mm}) \cdot (150\text{mm} - 8\text{mm}) \cdot 8\text{mm}} = 5.91 \text{ MPa}$$

Extra usage due to torsion is neglectable

## Bolts



$$P1.bolt := 280\text{mm}$$

$$P2.bolt := 110\text{mm}$$

$$\theta_{bolt} := \text{atan}\left(\frac{P1.bolt}{P2.bolt}\right) = 68.55 \text{ deg}$$

$$t_{sh.bolt} := 20\text{mm}$$

$$d_{20} = 20\text{mm}$$

$$F_{x.bolt} := F_t = 12.89\text{ kN}$$

$$F_{y.bolt} := 140\text{ kN}$$

$$F_{z.bolt} := 13\text{ kN}$$

$$M_{x.bolt} := 2.6\text{ kN}\cdot\text{m}$$

### Shear force per bolt

$$F_{v.fy.bolt} := \frac{F_{y.bolt}}{4} = 35\text{ kN}$$

$$F_{v.fz.bolt} := \frac{F_{z.bolt}}{4} = 3.25\text{ kN}$$

$$F_{v.Mx.bolt} := \frac{M_{x.bolt}}{4 \cdot \sqrt{\left(\frac{P1.bolt}{2}\right)^2 + \left(\frac{P2.bolt}{2}\right)^2}} = 4.32\text{ kN}$$

$$F_{v.tot.bolt} := \sqrt{\left(F_{v.fy.bolt} + F_{v.Mx.bolt} \cdot \cos(\theta_{bolt})\right)^2 + \left(F_{v.fz} + F_{v.Mx} \cdot \sin(\theta_{bolt})\right)^2} = 37.31\text{ kN}$$

### Axial force per bolt

$$F_{t.tot.bolt} := \frac{F_{x.bolt}}{4} = 3.22\text{ kN}$$

## Utilization factors

Design shear resistance reduction factor (due to shim plates);

$$\beta_{p.bolt} := \text{if} \left( t_{sh.bolt} \geq \frac{d_{20}}{3}, \frac{9 \cdot d_{20}}{8 \cdot d_{20} + 3 \cdot t_{sh.bolt}}, 1 \right) = 0.82$$

$$UF_{v.bolt} := \frac{F_{v.tot.bolt}}{\beta_{p.bolt} \cdot F_{v.Rd.M20}} = 0.5$$

### **Bearing girder web**

$$\sigma_{bolt} := \frac{F_{v.tot.bolt}}{d_{20} \cdot 12\text{mm}} = 155.45 \text{ MPa} \quad \text{Low stress, OK, conservative check}$$

### **Welds**

$$l_{w.tsw} := 200\text{mm}$$

$$a_{w..tsw} := 6\text{mm}$$

Check vertical welds only (most loaded)

$$\tau_{||.1.tsw} := \frac{F_{y.bolt}}{2 \cdot a_{w.tsw} \cdot l_{w.tsw}} = 58.33 \text{ MPa}$$

$$\tau_{||.2.tsw} := \frac{M_{x.bolt}}{2 \cdot (200\text{mm} \cdot 150\text{mm}) \cdot a_{w..tsw}} = 7.22 \text{ MPa}$$

$$UF_{.tsw} := \frac{\sqrt{3}(\tau_{||.2.tsw} + \tau_{||.1.tsw})}{\sigma_{420.w}} = 0.3$$

## Beam split

$$L_{bs} := 2315\text{mm}$$

$$L_{split} := 520\text{mm}$$

$$F_{y.bs} := 27\text{kN}$$

$$F_{z.bs} := 2.5\text{kN}$$

$$M_{strong.bs} := F_{y.bs} \cdot L_{split} = 14.04\text{kN}\cdot\text{m}$$

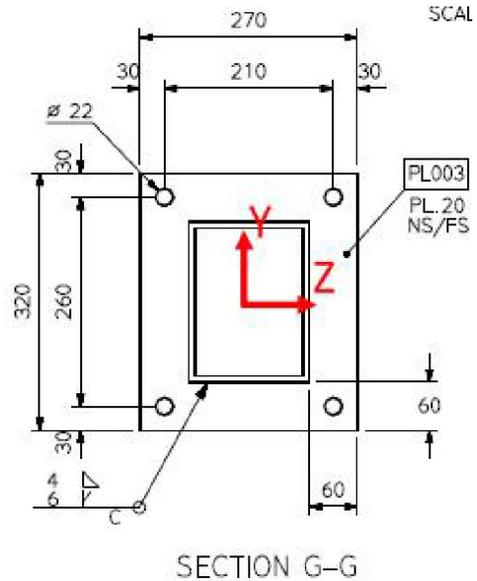
$$M_{weak.bs} := F_{z.bs} \cdot L_{split} = 1.3\text{kN}\cdot\text{m}$$

$$p_{1.bs} := 260\text{mm}$$

$$p_{2.bs} := 210\text{mm}$$

$$d_{20} = 20\text{mm}$$

$$\theta_{bs} := \text{atan}\left(\frac{p_{1.bs}}{p_{2.bs}}\right) = 51.07\text{ deg}$$



## Shear force per bolt

$$F_{v.Fy.bs} := \frac{F_{y.bs}}{4} = 6.75\text{ kN}$$

$$F_{v.Fz.bs} := \frac{F_{z.bs}}{4} = 0.63\text{ kN}$$

$$F_{v.Mx.bs} := \frac{M_{x.bolt}}{4 \cdot \sqrt{\left(\frac{p_{1.bs}}{2}\right)^2 + \left(\frac{p_{2.bs}}{2}\right)^2}} = 3.89\text{ kN}$$

$$F_{v.tot.bs} := \sqrt{\left(F_{v.Fy.bs} + F_{v.Mx.bs} \cdot \cos(\theta_{bs})\right)^2 + \left(F_{v.Fz.bs} + F_{v.Mx.bs} \cdot \sin(\theta_{bs})\right)^2} = 10.04\text{ kN}$$

## Axial force per bolt

$$F_{t.tot.bs} := \frac{M_{strong.bs}}{2 \cdot p_{1.bs}} + \frac{M_{weak.bs}}{p_{2.bs} \cdot 2} = 30.1\text{ kN}$$

## Utilization factors

$$UF_{bs} := \frac{F_{v,tot.bs}}{F_{v,Rd.M20}} + \frac{F_{t,tot.bs}}{1.4 \cdot F_{t,Rd.M20}} = 0.27$$

## **Welds**

Fillet weld equivalent throat

$$a_{w.bs} := 6\text{mm} \cdot \sqrt{2} = 8.49\text{ mm}$$

Minimum weld length to take tension in one bolt

$$l_{w.bs} := \sqrt{2} \cdot \frac{F_{t,tot.bs} \cdot \beta_{w.420} \cdot \gamma_{M2.ULS}}{f_{u.420} \cdot a_{w.bs}} = 13.04\text{ mm}$$

From above can be stated that welds are OK by inspection.

Plates (20mm) in bending are also OK by inspection.

# APPENDIX B

# STAAD.PRO ANALYSIS

## B.1 STAAD.PRO INPUT FILE

```
STAAD SPACE
START JOB INFORMATION
ENGINEER DATE 04-Feb-14
JOB NAME Master 2014
JOB CLIENT UiS
JOB NO 1
JOB REV 1
JOB PART 1
ENGINEER NAME Bjarte M
END JOB INFORMATION
INPUT WIDTH 79
UNIT METER KN
JOINT COORDINATES
1 2.315 -5.495 -10.84; 2 8.12 -1.34 -7.34; 3 8.12 -1.205 -14.34;
4 11.632 -0.5 -7.34; 5 8.12 -0.5 -7.34; 6 2.315 -0.65 -7.34;
7 2.315 -0.65 -10.84; 8 2.315 -0.65 -14.34; 9 8.12 -0.65 -14.34;
10 2.315 -5.815 -17.24; 11 2.315 -5.815 -14.34; 12 2.315 -5.815 -10.84;
13 2.315 -5.815 -7.34; 14 8.12 -5.815 -17.24; 15 8.12 -5.815 -14.34;
16 8.12 -5.815 -7.34; 17 11.632 -5.815 -14.34; 18 11.632 -5.815 -7.34;
19 11.632 -5.815 -17.24; 20 11.632 -5.815 -7.69; 21 11.632 -5.815 -10.84;
22 2.315 -1.2 -14.34; 23 8.12 -1.121 -7.34; 24 8.12 -1.645 -14.34;
25 2.315 -5.655 -10.84; 26 9.701 -5.815 -14.34; 27 3.525 -5.245 -8.07;
28 6.58 2.275 -11.36; 29 3.525 -5.245 -13.6; 30 9.701 -5.245 -13.6;
31 9.701 -5.245 -8.07; 32 3.525 -5.815 -14.34; 33 3.525 -5.665 -14.34;
34 9.701 -5.665 -14.34; 35 3.525 -5.495 -14.34; 36 3.525 -5.495 -13.6;
38 9.701 -5.495 -13.6; 39 3.525 -5.815 -7.54; 40 3.525 -5.665 -7.54;
41 9.701 -5.815 -7.54; 42 9.701 -5.665 -7.54; 43 3.525 -5.815 -7.34;
44 9.701 -5.815 -7.34; 45 9.701 -5.495 -8.07; 46 3.525 -5.495 -8.07;
47 3.525 -5.495 -7.54; 48 9.701 -5.495 -7.54; 49 4.965 -5.815 -7.34;
50 5.47 -5.815 -7.34; 51 2.315 -1.121 -7.34; 52 11.632 -1.121 -7.34;
53 2.315 -1.375 -10.84; 54 11.632 -1.501 -7.34; 55 2.315 -1.375 -7.34;
56 2.315 -1.446 -14.153; 57 9.701 -5.495 -14.34;
MEMBER INCIDENCES
1 24 3; 2 23 5; 3 3 22; 4 22 8; 5 11 12; 6 21 17; 7 20 21; 8 17 19; 9 18 20;
10 16 15; 11 11 32; 14 14 15; 15 11 10; 16 13 12; 17 16 50; 18 18 44; 19 2 23;
20 3 9; 21 45 48; 22 34 57; 23 42 48; 24 45 31; 25 41 44; 26 41 42; 27 38 30;
28 57 38; 29 26 34; 30 31 28; 31 30 28; 32 29 28; 33 27 28; 34 36 46; 35 46 47;
36 33 35; 37 40 47; 38 46 27; 39 39 43; 40 36 29; 41 35 36; 42 32 33; 43 44 16;
44 43 13; 45 32 15; 46 26 17; 47 25 1; 48 1 53; 49 12 56; 50 11 22; 51 18 54;
52 18 23; 53 16 2; 54 15 24; 55 13 55; 56 12 25; 57 38 45; 58 49 43; 59 50 49;
60 51 6; 61 50 23; 62 49 51; 63 52 4; 64 23 52; 65 12 55; 66 53 7; 67 53 55;
68 14 24; 69 21 54; 70 56 53; 71 51 23; 72 54 52; 73 55 51; 74 56 22; 75 40 39;
76 15 26;
DEFINE MATERIAL START
ISOTROPIC STEEL
E 6.83e+007
POISSON 0.3
DENSITY 77
ALPHA 1.2e-005
DAMP 0.03
* SLINGS
ISOTROPIC SLING
E 5.886e+007
POISSON 0.3
DENSITY 0.001
ALPHA 1.2e-005
DAMP 0.03
TYPE STEEL
```

STRENGTH FY 253200 FU 407800 RY 1.5 RT 1.2  
\*  
END DEFINE MATERIAL  
\*  
MEMBER PROPERTY EUROPEAN  
21 TO 29 34 TO 42 57 75 TABLE ST 300X10SHS  
2 4 19 47 TO 49 51 TO 53 55 56 60 63 66 72 TO 74 TABLE ST 200X12.5SHS  
5 TO 11 14 TO 16 45 46 76 TABLE ST HE300B  
17 18 43 44 58 59 TABLE ST 300X200X10RHS  
1 3 20 50 54 TABLE ST 200X16SHS  
61 62 64 65 67 TO 71 TABLE ST 80X6.3SHS  
30 TO 33 TABLE ST PIPE OD 0.032 ID 0  
CONSTANTS  
MATERIAL STEEL MEMB 1 TO 11 14 TO 29 34 TO 76  
MATERIAL SLING MEMB 30 TO 33  
SUPPORTS  
11 FIXED BUT FY FZ MX MY MZ  
13 18 FIXED BUT FX FY MX MY MZ  
28 PINNED  
MEMBER RELEASE  
30 TO 33 64 67 71 START MX MY MZ  
61 62 64 65 67 TO 71 END MX MY MZ  
75 START MY  
26 29 42 END MY  
61 62 65 68 TO 70 START MY MZ  
LOAD 1 LOADTYPE Dead TITLE SELF WEIGHT  
SELFWEIGHT Y -6.5  
LOAD 2 LOADTYPE Dead TITLE WEIGHT OF EQUIPMENT AND ACCESSORIES  
MEMBER LOAD  
1 TO 11 14 TO 76 UNI GY -2  
LOAD 3 LOADTYPE Wind TITLE WIND LOAD  
MEMBER LOAD  
17 18 43 44 46 51 53 55 58 59 61 62 64 71 UNI GZ -3.38  
LOAD 4 LOADTYPE Fluids TITLE LOAD FROM GAS AND OIL PIPE  
MEMBER LOAD  
1 TO 11 14 TO 76 UMOM GY -1  
LOAD 5 LOADTYPE Live TITLE AREA LOAD  
MEMBER LOAD  
1 TO 11 14 TO 76 UNI GY -4  
LOAD COMB 6 COMBINATION LOAD CASE 6  
1 1.0 2 1.0 5 1.0  
LOAD COMB 7 COMBINATION LOAD CASE 7  
1 1.0 2 1.0 4 1.0 3 1.0 5 1.0  
PERFORM ANALYSIS PRINT STATICS CHECK  
LOAD LIST 1  
PARAMETER 1  
CODE EN 1993-1-1:2005  
BEAM 3 ALL  
GM0 1.15 ALL  
BETA 1 ALL  
ELB 1 ALL  
TRACK 2 ALL  
SGR 2 ALL  
TORSION 1 ALL  
CHECK CODE ALL  
FINISH

## B.2 STAAD.PRO OUTPUT FILE

```

*****
*
*          *
*   STAAD.Pro V8i SELECTseries4   *
*   Version 20.07.09.31           *
*   Proprietary Program of       *
*   Bentley Systems, Inc.        *
*   Date= APR 24, 2014           *
*   Time= 14:41:37               *
*
*          *
*   USER ID: Aker Solutions ASA   *
*****
    
```

```

1. STAAD SPACE
INPUT FILE: MMM7.STD
2. START JOB INFORMATION
3. ENGINEER DATE 04-FEB-14
4. JOB NAME MASTER 2014
5. JOB CLIENT UIS
6. JOB NO 1
7. JOB REV 1
8. JOB PART 1
9. ENGINEER NAME BJARTE M
10. END JOB INFORMATION
11. INPUT WIDTH 79
12. UNIT METER KN
13. JOINT COORDINATES
14. 1 2.315 -5.495 -10.84; 2 8.12 -1.34 -7.34; 3 8.12 -1.205 -14.34
15. 4 11.632 -0.5 -7.34; 5 8.12 -0.5 -7.34; 6 2.315 -0.65 -7.34
16. 7 2.315 -0.65 -10.84; 8 2.315 -0.65 -14.34; 9 8.12 -0.65 -14.34
17. 10 2.315 -5.815 -17.24; 11 2.315 -5.815 -14.34; 12 2.315 -5.815 -10.84
18. 13 2.315 -5.815 -7.34; 14 8.12 -5.815 -17.24; 15 8.12 -5.815 -14.34
19. 16 8.12 -5.815 -7.34; 17 11.632 -5.815 -14.34; 18 11.632 -5.815 -7.34
20. 19 11.632 -5.815 -17.24; 20 11.632 -5.815 -7.69; 21 11.632 -5.815 -10.84
21. 22 2.315 -1.2 -14.34; 23 8.12 -1.121 -7.34; 24 8.12 -1.645 -14.34
22. 25 2.315 -5.655 -10.84; 26 9.701 -5.815 -14.34; 27 3.525 -5.245 -8.07
23. 28 6.58 2.275 -11.36; 29 3.525 -5.245 -13.6; 30 9.701 -5.245 -13.6
24. 31 9.701 -5.245 -8.07; 32 3.525 -5.815 -14.34; 33 3.525 -5.665 -14.34
25. 34 9.701 -5.665 -14.34; 35 3.525 -5.495 -14.34; 36 3.525 -5.495 -13.6
26. 38 9.701 -5.495 -13.6; 39 3.525 -5.815 -7.54; 40 3.525 -5.665 -7.54
27. 41 9.701 -5.815 -7.54; 42 9.701 -5.665 -7.54; 43 3.525 -5.815 -7.34
28. 44 9.701 -5.815 -7.34; 45 9.701 -5.495 -8.07; 46 3.525 -5.495 -8.07
29. 47 3.525 -5.495 -7.54; 48 9.701 -5.495 -7.54; 49 4.965 -5.815 -7.34
30. 50 5.47 -5.815 -7.34; 51 2.315 -1.121 -7.34; 52 11.632 -1.121 -7.34
31. 53 2.315 -1.375 -10.84; 54 11.632 -1.501 -7.34; 55 2.315 -1.375 -7.34
32. 56 2.315 -1.446 -14.153; 57 9.701 -5.495 -14.34
33. MEMBER INCIDENCES
34. 1 24 3; 2 23 5; 3 3 22; 4 22 8; 5 11 12; 6 21 17; 7 20 21; 8 17 19; 9 18 20
35. 10 16 15; 11 11 32; 14 14 15; 15 11 10; 16 13 12; 17 16 50; 18 18 44; 19 2 23
36. 20 3 9; 21 45 48; 22 34 57; 23 42 48; 24 45 31; 25 41 44; 26 41 42; 27 38 30
37. 28 57 38; 29 26 34; 30 31 28; 31 30 28; 32 29 28; 33 27 28; 34 36 46; 35 46 47
38. 36 33 35; 37 40 47; 38 46 27; 39 39 43; 40 36 29; 41 35 36; 42 32 33; 43 44 16
STAAD SPACE -- PAGE NO. 2

39. 44 43 13; 45 32 15; 46 26 17; 47 25 1; 48 1 53; 49 12 56; 50 11 22; 51 18 54
40. 52 18 23; 53 16 2; 54 15 24; 55 13 55; 56 12 25; 57 38 45; 58 49 43; 59 50 49
41. 60 51 6; 61 50 23; 62 49 51; 63 52 4; 64 23 52; 65 12 55; 66 53 7; 67 53 55
    
```

42. 68 14 24; 69 21 54; 70 56 53; 71 51 23; 72 54 52; 73 55 51; 74 56 22; 75 40 39  
43. 76 15 26  
44. DEFINE MATERIAL START  
45. ISOTROPIC STEEL  
46. E 6.83E+007  
47. POISSON 0.3  
48. DENSITY 77  
49. ALPHA 1.2E-005  
50. DAMP 0.03  
51. \* SLINGS  
52. ISOTROPIC SLING  
53. E 5.886E+007  
54. POISSON 0.3  
55. DENSITY 0.001  
56. ALPHA 1.2E-005  
57. DAMP 0.03  
58. TYPE STEEL  
59. STRENGTH FY 253200 FU 407800 RY 1.5 RT 1.2  
60. \*  
61. END DEFINE MATERIAL  
62. \*  
63. MEMBER PROPERTY EUROPEAN  
64. 21 TO 29 34 TO 42 57 75 TABLE ST 300X10SHS  
65. 2 4 19 47 TO 49 51 TO 53 55 56 60 63 66 72 TO 74 TABLE ST 200X12.5SHS  
66. 5 TO 11 14 TO 16 45 46 76 TABLE ST HE300B  
67. 17 18 43 44 58 59 TABLE ST 300X200X10RHS  
68. 1 3 20 50 54 TABLE ST 200X16SHS  
69. 61 62 64 65 67 TO 71 TABLE ST 80X6.3SHS  
70. 30 TO 33 TABLE ST PIPE OD 0.032 ID 0  
71. CONSTANTS  
72. MATERIAL STEEL MEMB 1 TO 11 14 TO 29 34 TO 76  
73. MATERIAL SLING MEMB 30 TO 33  
74. SUPPORTS  
75. 11 FIXED BUT FY FZ MX MY MZ  
76. 13 18 FIXED BUT FX FY MX MY MZ  
77. 28 PINNED  
78. MEMBER RELEASE  
79. 30 TO 33 64 67 71 START MX MY MZ  
80. 61 62 64 65 67 TO 71 END MX MY MZ  
81. 75 START MY  
82. 26 29 42 END MY  
83. 61 62 65 68 TO 70 START MY MZ  
84. LOAD 1 LOADTYPE DEAD TITLE SELF WEIGHT  
85. SELFWEIGHT Y -6.5  
86. LOAD 2 LOADTYPE DEAD TITLE WEIGHT OF EQUIPMENT AND ACCESSORIES  
87. MEMBER LOAD  
88. 1 TO 11 14 TO 76 UNI GY -2  
89. LOAD 3 LOADTYPE WIND TITLE WIND LOAD  
90. MEMBER LOAD  
91. 17 18 43 44 46 51 53 55 58 59 61 62 64 71 UNI GZ -3.38  
92. LOAD 4 LOADTYPE FLUIDS TITLE LOAD FROM GAS AND OIL PIPE  
93. MEMBER LOAD  
94. 1 TO 11 14 TO 76 UMOM GY -1.  
STAAD SPACE -- PAGE NO. 3

95. LOAD 5 LOADTYPE LIVE TITLE AREA LOAD  
96. MEMBER LOAD  
97. 1 TO 11 14 TO 76 UNI GY -4  
98. LOAD COMB 6 COMBINATION LOAD CASE 6  
99. 1 1.0 2 1.0 5 1.0  
100. LOAD COMB 7 COMBINATION LOAD CASE 7  
101. 1 1.0 2 1.0 4 1.0 3 1.0 5 1.0

## 102. PERFORM ANALYSIS PRINT STATICS CHECK

## PROBLEM STATISTICS

```

-----
NUMBER OF JOINTS      56 NUMBER OF MEMBERS   74
NUMBER OF PLATES     0 NUMBER OF SOLIDS    0
NUMBER OF SURFACES   0 NUMBER OF SUPPORTS   4
    
```

SOLVER USED IS THE OUT-OF-CORE BASIC SOLVER

```

ORIGINAL/FINAL BAND-WIDTH= 51/ 10/ 65 DOF
TOTAL PRIMARY LOAD CASES = 5, TOTAL DEGREES OF FREEDOM = 330
SIZE OF STIFFNESS MATRIX = 22 DOUBLE KILO-WORDS
REQRD/AVAIL. DISK SPACE = 12.4/ 0.0 MB
    
```

STAAD SPACE -- PAGE NO. 4

STATIC LOAD/REACTION/EQUILIBRIUM SUMMARY FOR CASE NO. 1  
LOADTYPE DEAD TITLE SELF WEIGHT

CENTER OF FORCE BASED ON X FORCES ONLY (METE).  
(FORCES IN NON-GLOBAL DIRECTIONS WILL INVALIDATE RESULTS)

```

X = 0.976353770E+01
Y = -0.335765352E+01
Z = -0.710883557E+01
    
```

CENTER OF FORCE BASED ON Y FORCES ONLY (METE).  
(FORCES IN NON-GLOBAL DIRECTIONS WILL INVALIDATE RESULTS)

```

X = 0.658530401E+01
Y = -0.464245998E+01
Z = -0.113620813E+02
    
```

CENTER OF FORCE BASED ON Z FORCES ONLY (METE).  
(FORCES IN NON-GLOBAL DIRECTIONS WILL INVALIDATE RESULTS)

```

X = 0.392626648E+01
Y = -0.326479631E+01
Z = -0.993436649E+01
    
```

\*\*\*TOTAL APPLIED LOAD ( KN METE ) SUMMARY (LOADING 1 )

```

SUMMATION FORCE-X = 0.00
SUMMATION FORCE-Y = -710.64
SUMMATION FORCE-Z = 0.00
    
```

SUMMATION OF MOMENTS AROUND THE ORIGIN-  
MX= -8074.32 MY= 0.00 MZ= -4679.77

\*\*\*TOTAL REACTION LOAD( KN METE ) SUMMARY (LOADING 1 )

```

SUMMATION FORCE-X = 0.00
SUMMATION FORCE-Y = 710.64
    
```

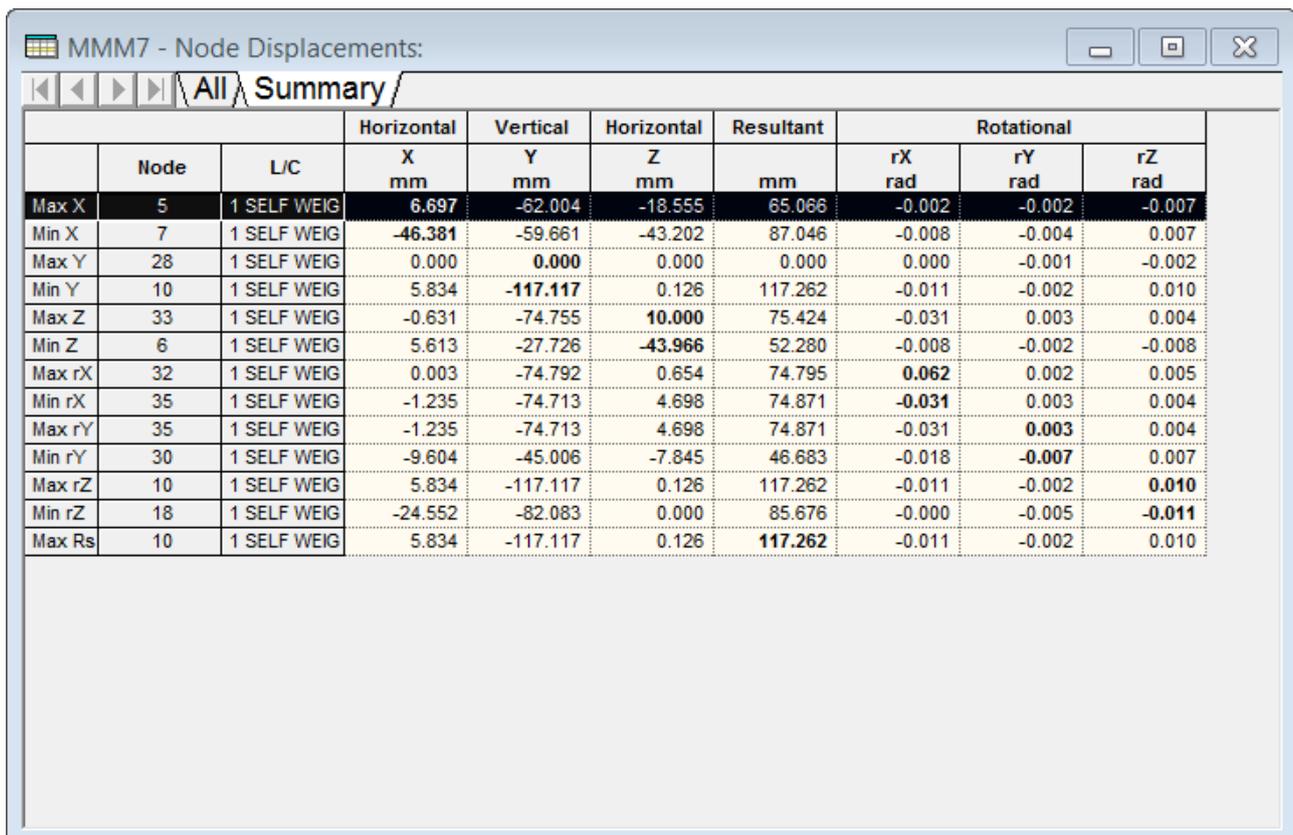
SUMMATION FORCE-Z = 0.00

SUMMATION OF MOMENTS AROUND THE ORIGIN-  
 MX= 8074.32 MY= 0.00 MZ= 4679.76

MAXIMUM DISPLACEMENTS ( CM /RADIANS) (LOADING 1)

MAXIMUMS AT NODE  
 X = -4.63812E+00 7  
 Y = -1.17117E+01 10  
 Z = -4.39656E+00 6  
 RX= 6.21413E-02 32  
 RY= -7.41220E-03 30  
 RZ= -1.10774E-02 18

## B.3 Postprocessing



	Node	L/C	Horizontal	Vertical	Horizontal	Resultant	Rotational		
			X mm	Y mm	Z mm		rX rad	rY rad	rZ rad
Max X	5	1 SELF WEIG	6.697	-62.004	-18.555	65.066	-0.002	-0.002	-0.007
Min X	7	1 SELF WEIG	-46.381	-59.661	-43.202	87.046	-0.008	-0.004	0.007
Max Y	28	1 SELF WEIG	0.000	0.000	0.000	0.000	0.000	-0.001	-0.002
Min Y	10	1 SELF WEIG	5.834	-117.117	0.126	117.262	-0.011	-0.002	0.010
Max Z	33	1 SELF WEIG	-0.631	-74.755	10.000	75.424	-0.031	0.003	0.004
Min Z	6	1 SELF WEIG	5.613	-27.726	-43.966	52.280	-0.008	-0.002	-0.008
Max rX	32	1 SELF WEIG	0.003	-74.792	0.654	74.795	0.062	0.002	0.005
Min rX	35	1 SELF WEIG	-1.235	-74.713	4.698	74.871	-0.031	0.003	0.004
Max rY	35	1 SELF WEIG	-1.235	-74.713	4.698	74.871	-0.031	0.003	0.004
Min rY	30	1 SELF WEIG	-9.604	-45.006	-7.845	46.683	-0.018	-0.007	0.007
Max rZ	10	1 SELF WEIG	5.834	-117.117	0.126	117.262	-0.011	-0.002	0.010
Min rZ	18	1 SELF WEIG	-24.552	-82.083	0.000	85.676	-0.000	-0.005	-0.011
Max Rs	10	1 SELF WEIG	5.834	-117.117	0.126	117.262	-0.011	-0.002	0.010

Table 1 Maximum node displacement for load case self-weight

MMM7 - Beam Relative Displacement Detail:

Navigation: All Relative Displacement | Max Relative Displacements

Beam	L/C	Length m	Max x mm	Dist m	Max y mm	Dist m	Max z mm	Dist m	Max mm
53	1 SELF WEIG	4.475	-0.000	1.865	3.481	1.865	-0.303	0.583	3.492
54	1 SELF WEIG	4.170	0.000	2.085	-1.296	2.433	1.392	0.417	1.859
55	1 SELF WEIG	4.440	0.000	4.070	4.117	1.850	-0.053	0.417	4.117
56	1 SELF WEIG	0.160	0.000	0.013	-0.000	0.053	-0.001	0.333	0.001
57	1 SELF WEIG	5.530	0.001	0.461	22.369	2.765	6.117	0.500	23.191
58	1 SELF WEIG	1.440	0.000	1.200	0.806	0.840	-1.076	0.500	1.336
59	1 SELF WEIG	0.505	-0.000	0.463	-0.035	0.210	-0.069	0.500	0.078
60	1 SELF WEIG	0.471	-0.000	0.432	-0.000	0.236	-0.001	0.917	0.001
61	1 SELF WEIG	5.390	0.000	4.043	-44.002	2.695	0.001	0.667	44.002
62	1 SELF WEIG	5.390	0.000	2.695	-44.002	2.695	-0.000	0.083	44.002
63	1 SELF WEIG	0.621	-0.000	0.569	0.000	0.000	-0.001	0.333	0.001
64	1 SELF WEIG	3.512	0.000	0.878	-16.128	1.756	-0.001	0.833	16.128
65	1 SELF WEIG	5.654	0.000	2.827	-67.053	2.827	-0.000	0.917	67.053
66	1 SELF WEIG	0.725	0.000	0.544	-0.000	0.665	-0.001	0.667	0.001
67	1 SELF WEIG	3.500	-0.000	1.750	-15.909	1.750	-0.000	0.500	15.909
68	1 SELF WEIG	5.079	-0.001	3.386	-40.287	2.540	0.001	0.667	40.287
69	1 SELF WEIG	5.555	0.000	4.166	-63.612	2.778	0.000	0.167	63.612
70	1 SELF WEIG	3.314	-0.001	0.828	-12.781	1.657	-0.000	0.583	12.781
71	1 SELF WEIG	5.805	0.001	5.321	-120.386	2.902	0.001	0.917	120.386
72	1 SELF WEIG	0.380	0.000	0.348	-0.003	0.190	-0.000	0.250	0.003
73	1 SELF WEIG	0.254	-0.000	0.190	0.001	0.106	0.001	0.750	0.001
74	1 SELF WEIG	0.309	-0.000	0.258	0.013	0.180	-0.020	0.500	0.023
75	1 SELF WEIG	0.150	0.000	0.088	-0.005	0.075	0.001	0.833	0.005

Table 2 Maximum relative displacement for load case self-weight

MMM7 - Beam End Forces:

Navigation: All | Summary | Envelope

	Beam	L/C	Node	Fx kN	Fy kN	Fz kN	Mx kNm	My kNm	Mz kNm
Max Fx	50	1 SELF WEIG	11	84.867	-0.054	2.123	-0.131	-1.835	9.212
Min Fx	32	1 SELF WEIG	29	-257.852	-0.001	-0.000	0.000	0.000	0.000
Max Fy	21	1 SELF WEIG	45	-19.253	150.653	65.221	22.836	-20.033	75.765
Min Fy	41	1 SELF WEIG	36	-23.517	-199.287	86.882	31.828	37.812	141.898
Max Fz	41	1 SELF WEIG	35	-23.517	-195.027	86.882	31.828	-26.480	-3.998
Min Fz	28	1 SELF WEIG	57	-6.956	-162.469	-80.905	-13.695	44.862	-1.183
Max Mx	22	1 SELF WEIG	34	-161.491	-80.905	-6.956	44.862	0.000	-27.449
Min Mx	36	1 SELF WEIG	33	-194.049	86.882	-23.517	-26.480	0.000	46.598
Max My	28	1 SELF WEIG	57	-6.956	-162.469	-80.905	-13.695	44.862	-1.183
Min My	39	1 SELF WEIG	43	-11.038	118.511	-58.778	-23.395	-41.983	-22.162
Max Mz	11	1 SELF WEIG	32	-2.715	-141.103	-19.192	-2.852	-31.646	156.012
Min Mz	76	1 SELF WEIG	15	81.489	-82.394	10.218	-0.659	1.491	-64.711

Table 3 Maximum beam end force for load case self-weight

MMM7 - Design Results:-

All / Failed Members

Beam	Analysis Property	Design Property	Actual Ratio	Allowable Ratio	Normalized Ratio (Actual/Allowable)	Clause	L/C	Ax cm2	
49	200X12.5SH	200X12.5SH	0.063	1.000	0.063	EC-6.2.1(7)	1	92.100	53
16	HE300B	HE300B	0.064	1.000	0.064	EC-6.3.3-662	1	149.000	25
53	200X12.5SH	200X12.5SH	0.070	1.000	0.070	EC-6.2.1(7)	1	92.100	53
14	HE300B	HE300B	0.071	1.000	0.071	EC-6.3.3-662	1	149.000	25
37	300X10SHS	300X10SHS	0.072	1.000	0.072	EC-6.2.1(7)	1	115.000	16
3	200X16SHS	200X16SHS	0.074	1.000	0.074	EC-6.2.1(7)	1	115.000	63
55	200X12.5SH	200X12.5SH	0.075	1.000	0.075	EC-6.2.1(7)	1	92.100	53
7	HE300B	HE300B	0.077	1.000	0.077	EC-6.3.3-662	1	149.000	25
74	200X12.5SH	200X12.5SH	0.079	1.000	0.079	EC-6.2.1(7)	1	92.100	53
51	200X12.5SH	200X12.5SH	0.084	1.000	0.084	EC-6.2.1(7)	1	92.100	53
5	HE300B	HE300B	0.086	1.000	0.086	EC-6.3.3-662	1	149.000	25
50	200X16SHS	200X16SHS	0.088	1.000	0.088	EC-6.2.1(7)	1	115.000	63
6	HE300B	HE300B	0.090	1.000	0.090	EC-6.3.3-662	1	149.000	25
64	80X6.3SHS	80X6.3SHS	0.096	1.000	0.096	EC-6.2.1(7)	1	18.100	16
75	300X10SHS	300X10SHS	0.099	1.000	0.099	EC-6.2.1(7)	1	115.000	16
59	300X200X10	300X200X10	0.104	1.000	0.104	EC-6.2.1(7)	1	94.900	11
38	300X10SHS	300X10SHS	0.106	1.000	0.106	EC-6.2.1(7)	1	115.000	16
68	80X6.3SHS	80X6.3SHS	0.110	1.000	0.110	EC-6.2.1(7)	1	18.100	16
22	300X10SHS	300X10SHS	0.117	1.000	0.117	EC-6.2.1(7)	1	115.000	16
52	200X12.5SH	200X12.5SH	0.123	1.000	0.123	EC-6.2.1(7)	1	92.100	53
23	300X10SHS	300X10SHS	0.129	1.000	0.129	EC-6.2.1(7)	1	115.000	16
24	300X10SHS	300X10SHS	0.133	1.000	0.133	EC-6.2.1(7)	1	115.000	16
27	300X10SHS	300X10SHS	0.143	1.000	0.143	EC-6.2.1(7)	1	115.000	16
25	300X10SHS	300X10SHS	0.145	1.000	0.145	EC-6.2.1(7)	1	115.000	16
69	80X6.3SHS	80X6.3SHS	0.145	1.000	0.145	EC-6.2.1(7)	1	18.100	16
29	300X10SHS	300X10SHS	0.151	1.000	0.151	EC-6.2.1(7)	1	115.000	16
70	80X6.3SHS	80X6.3SHS	0.154	1.000	0.154	EC-6.3.3-661	1	18.100	16
10	HE300B	HE300B	0.158	1.000	0.158	EC-6.3.2 LTB	1	149.000	25
26	300X10SHS	300X10SHS	0.162	1.000	0.162	EC-6.2.1(7)	1	115.000	16
35	300X10SHS	300X10SHS	0.170	1.000	0.170	EC-6.2.1(7)	1	115.000	16
39	300X10SHS	300X10SHS	0.170	1.000	0.170	EC-6.2.1(7)	1	115.000	16
40	300X10SHS	300X10SHS	0.170	1.000	0.170	EC-6.2.1(7)	1	115.000	16
61	80X6.3SHS	80X6.3SHS	0.170	1.000	0.170	EC-6.3.3-661	1	18.100	16
67	80X6.3SHS	80X6.3SHS	0.170	1.000	0.170	EC-6.3.3-661	1	18.100	16
36	300X10SHS	300X10SHS	0.176	1.000	0.176	EC-6.2.1(7)	1	115.000	16
76	HE300B	HE300B	0.188	1.000	0.188	EC-6.2.1(7)	1	149.000	25
17	300X200X10	300X200X10	0.190	1.000	0.190	EC-6.2.1(7)	1	94.900	11
62	80X6.3SHS	80X6.3SHS	0.203	1.000	0.203	EC-6.3.3-661	1	18.100	16
65	80X6.3SHS	80X6.3SHS	0.206	1.000	0.206	EC-6.2.1(7)	1	18.100	16
42	300X10SHS	300X10SHS	0.219	1.000	0.219	EC-6.2.1(7)	1	115.000	16
43	300X200X10	300X200X10	0.239	1.000	0.239	EC-6.2.1(7)	1	94.900	11
21	300X10SHS	300X10SHS	0.254	1.000	0.254	EC-6.2.1(7)	1	115.000	16
46	HE300B	HE300B	0.261	1.000	0.261	EC-6.2.1(7)	1	149.000	25
71	80X6.3SHS	80X6.3SHS	0.263	1.000	0.263	EC-6.2.1(7)	1	18.100	16
45	HE300B	HE300B	0.299	1.000	0.299	EC-6.3.3-662	1	149.000	25
58	300X200X10	300X200X10	0.311	1.000	0.311	EC-6.2.1(7)	1	94.900	11
57	300X10SHS	300X10SHS	0.330	1.000	0.330	EC-6.2.1(7)	1	115.000	16
11	HE300B	HE300B	0.338	1.000	0.338	EC-6.2.1(7)	1	149.000	25
44	300X200X10	300X200X10	0.343	1.000	0.343	EC-6.2.1(7)	1	94.900	11
28	300X10SHS	300X10SHS	0.355	1.000	0.355	EC-6.2.1(7)	1	115.000	16
34	300X10SHS	300X10SHS	0.435	1.000	0.435	EC-6.2.1(7)	1	115.000	16
41	300X10SHS	300X10SHS	0.474	1.000	0.474	EC-6.2.1(7)	1	115.000	16
18	300X200X10	300X200X10	0.489	1.000	0.489	EC-6.2.1(7)	1	94.900	11

Table 4 Maximum utilization ratio for members in load case self-weight

## B.4 Figures from STAAD.PRO

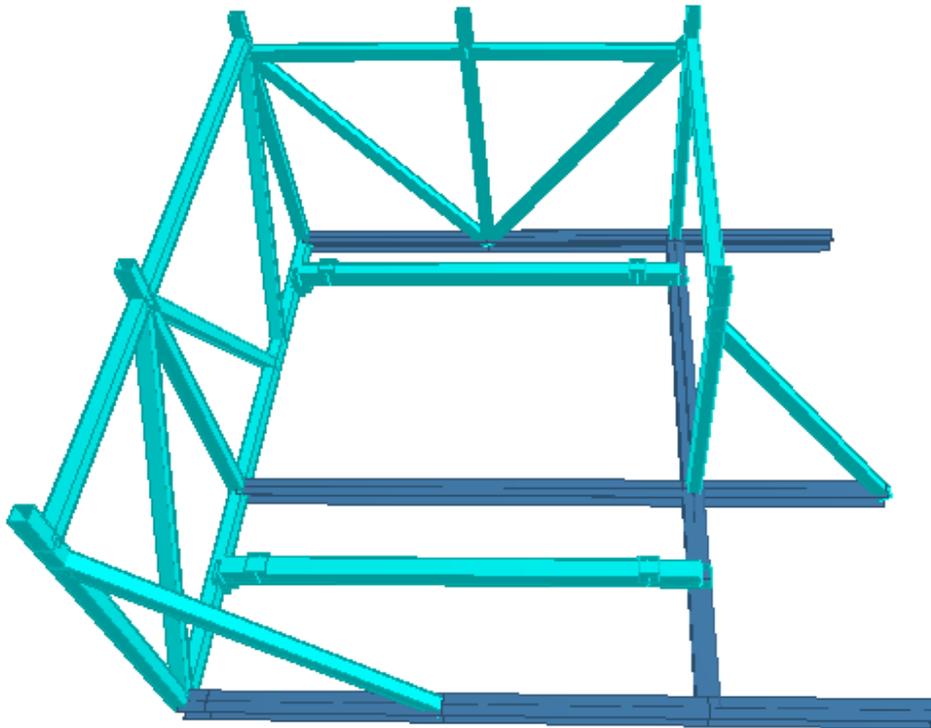


Figure 1. C05 balcony from Staad.pro design

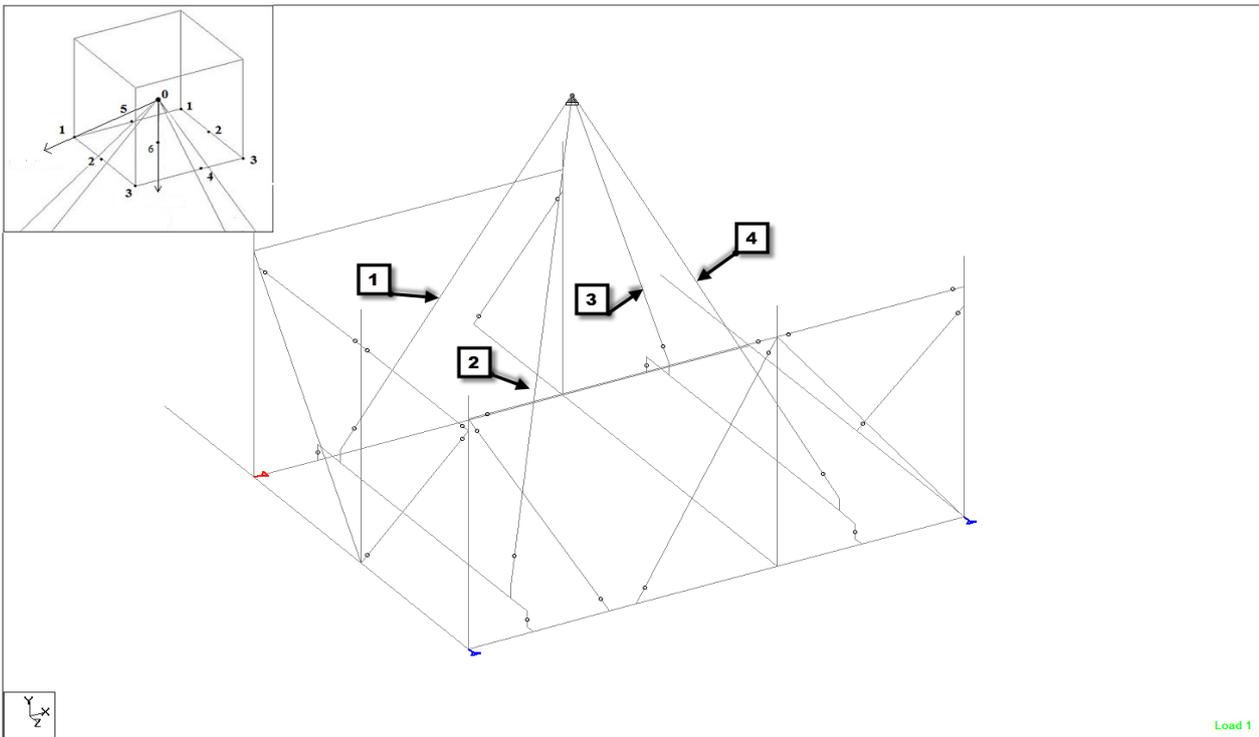


Figure 2. C05E balcony 1,2,3 and 4 is the slings used when simulating the lift.

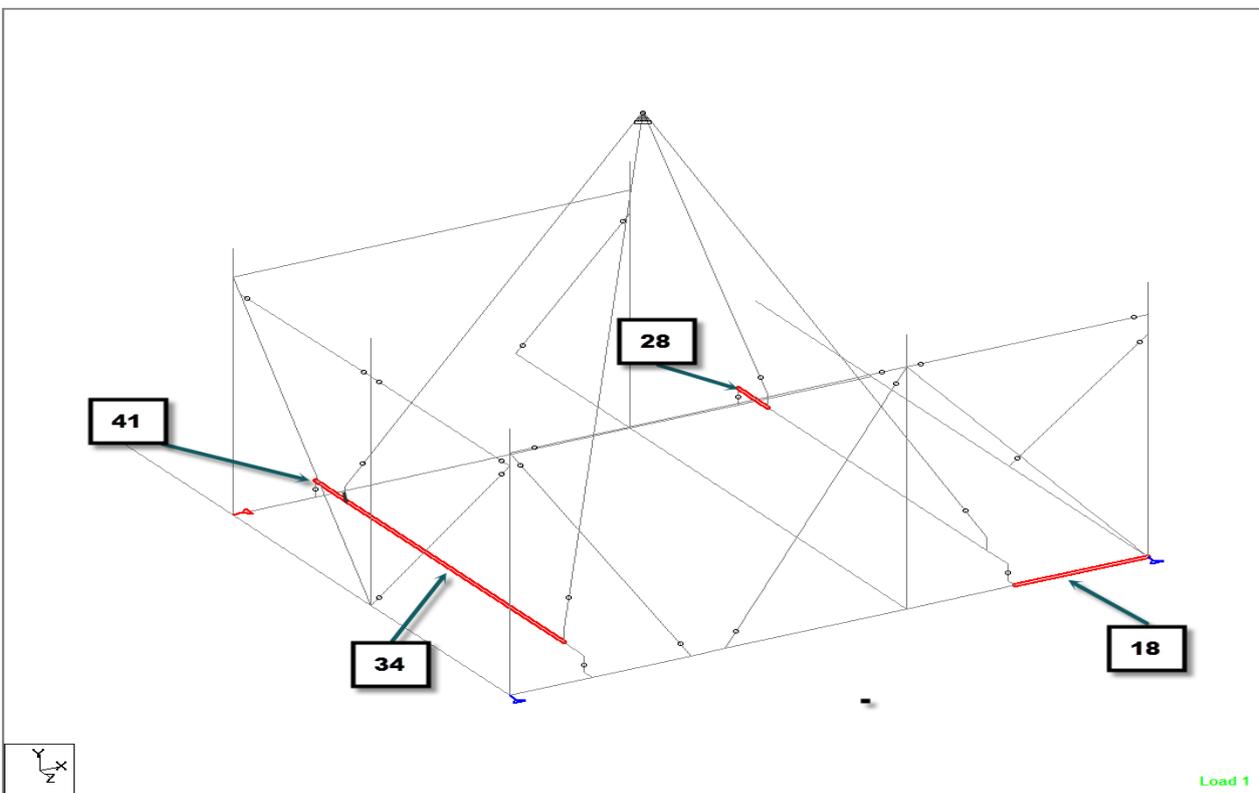


Figure 3. The four most utilized beams 41, 34, 28 and 18.

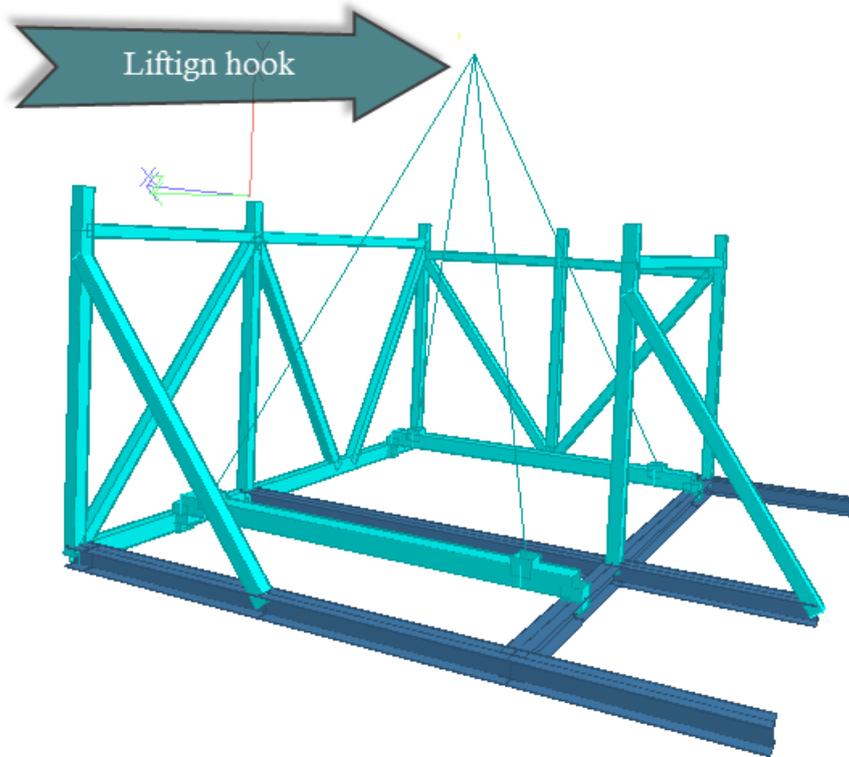


Figure 4. Lifting hook C05 balcony

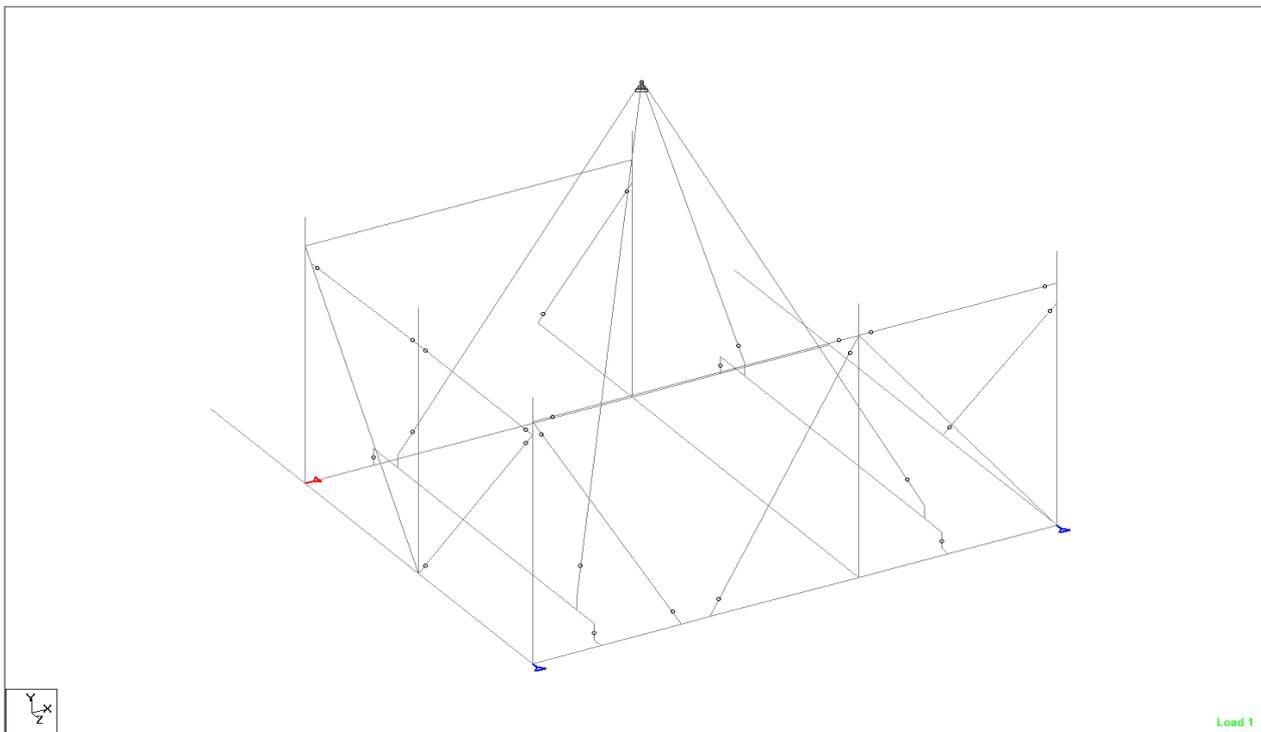


Figure 5 C05E balcony

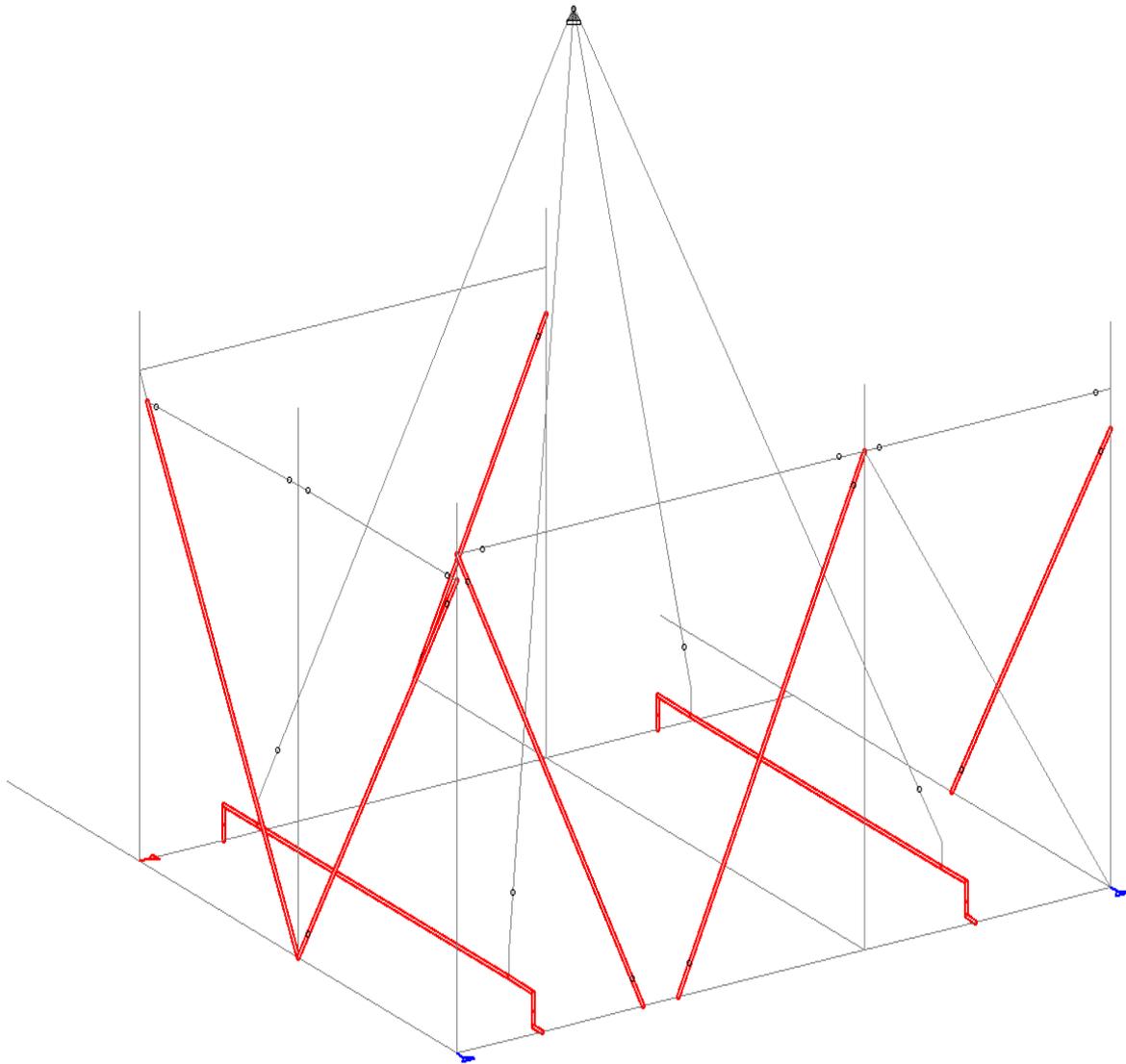


Figure 6. Temporary beams on C05 east balcony

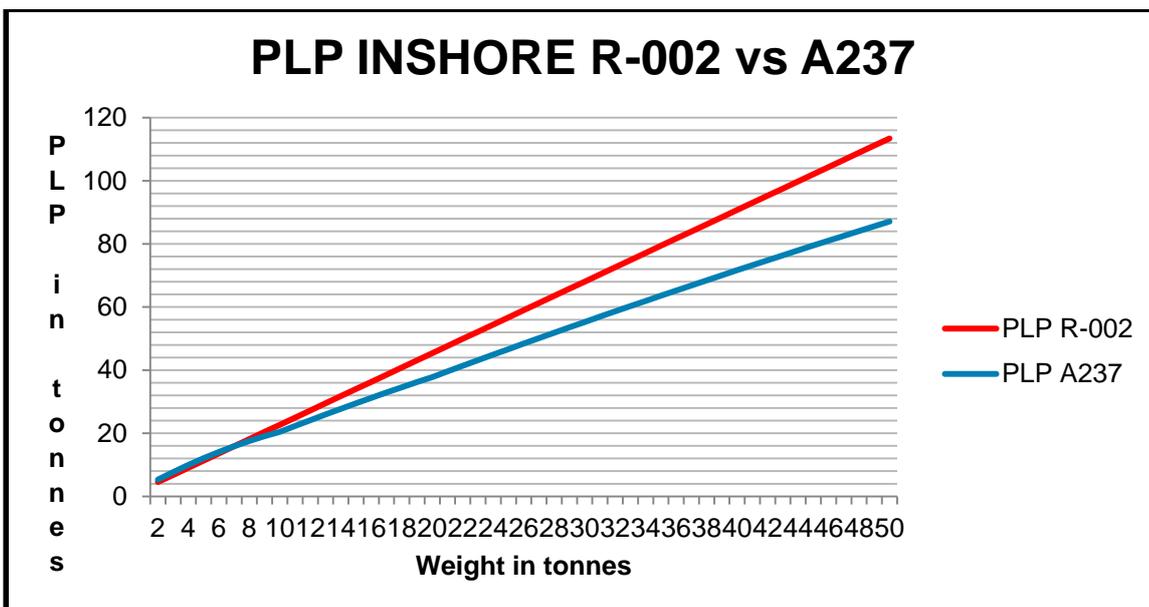
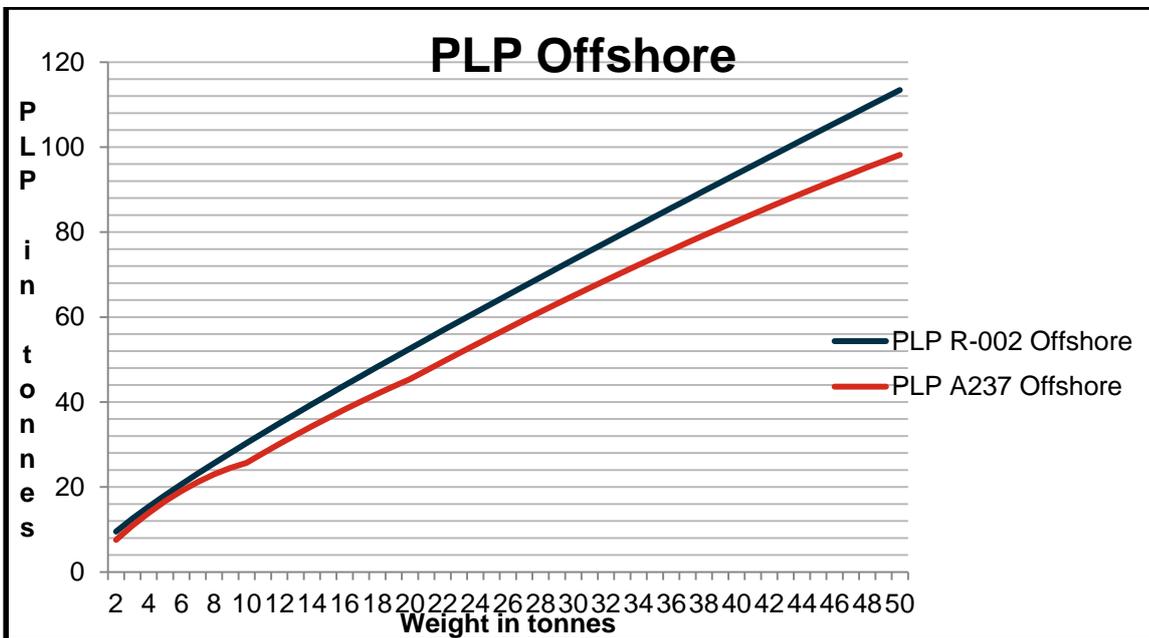
# APPENDIX C

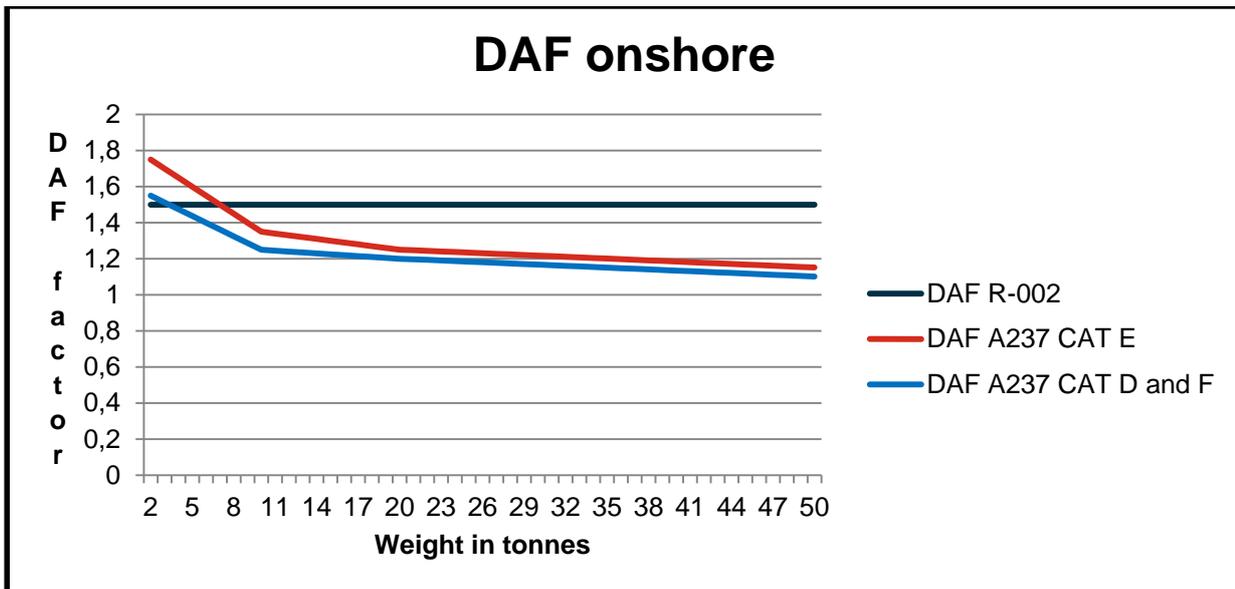
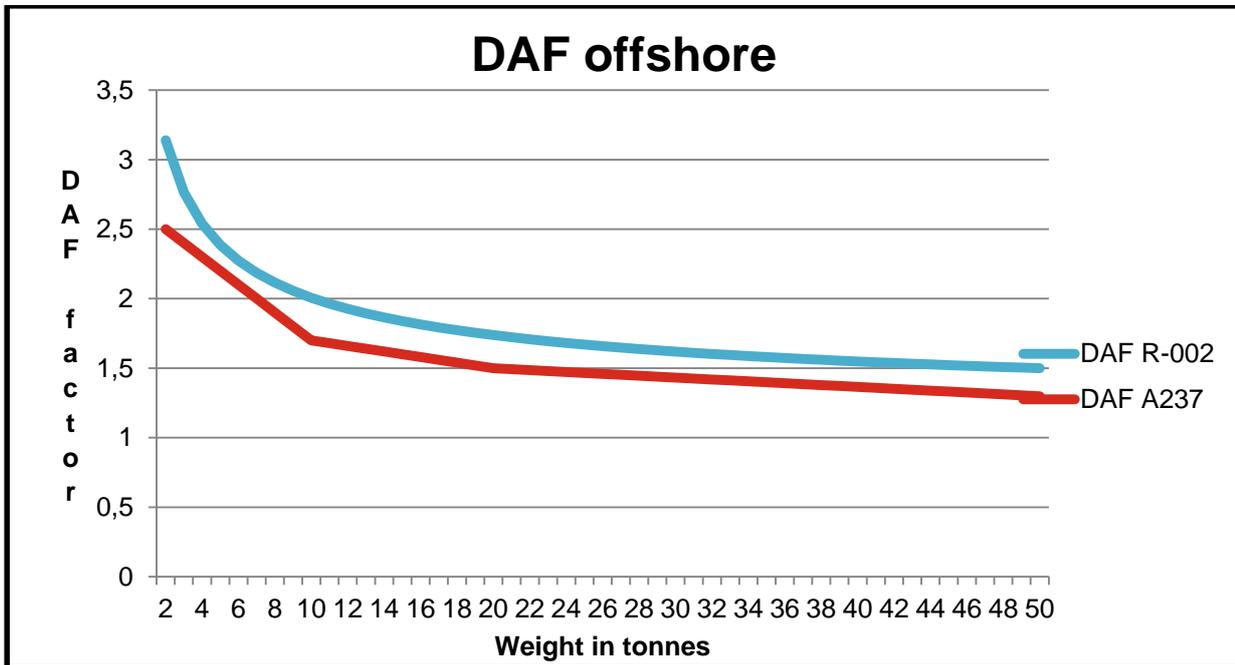
## Excel spread sheets

# C.1 PLP OFFSHORE, PLP INSHORE, DAF OFFSHORE and DAF ONSHORE



Microsoft Excel Worksheet

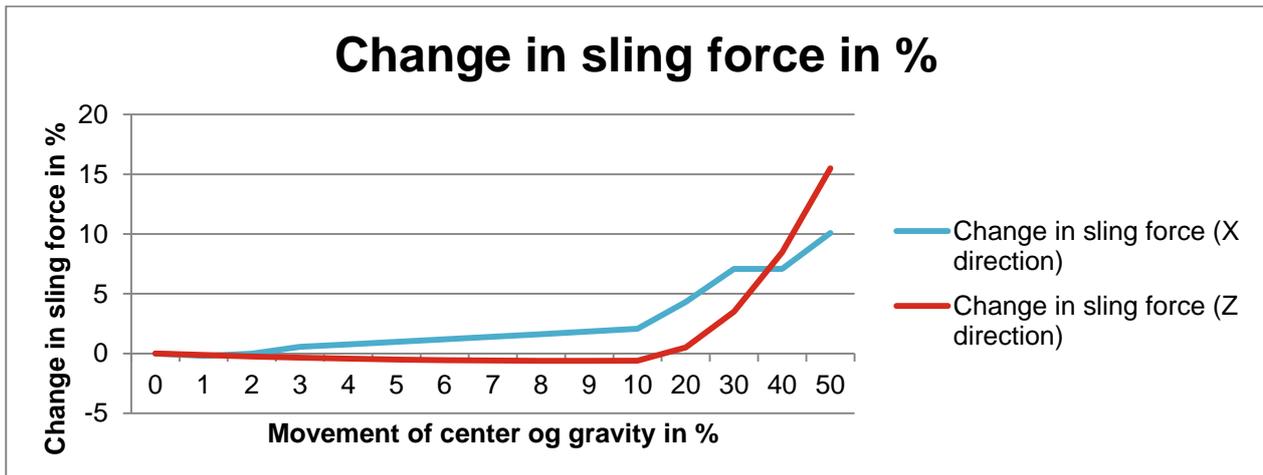




## C.2 CHANGE IN SLING FORCE



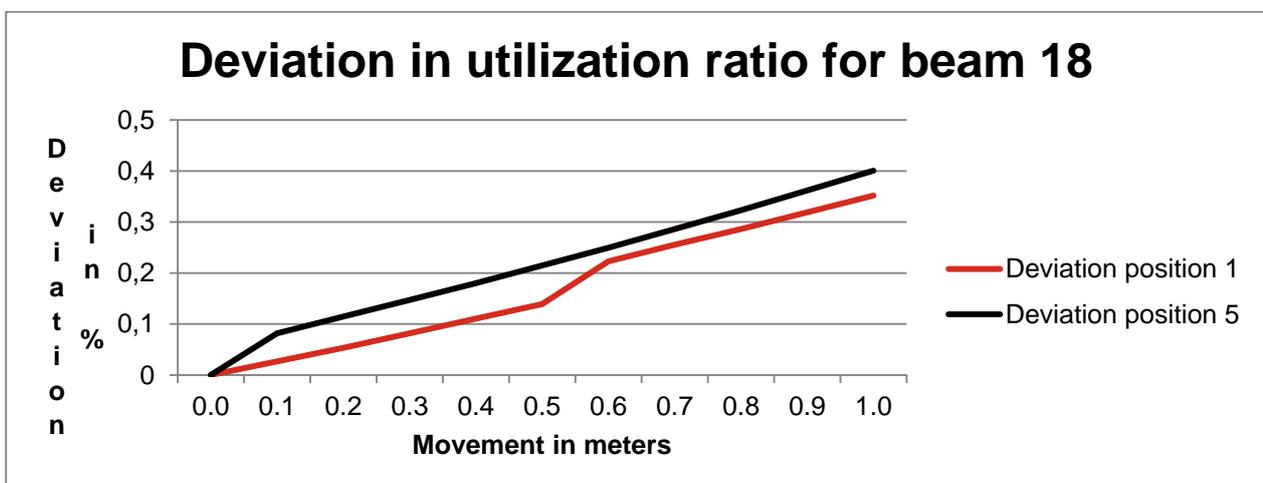
Microsoft Excel  
Worksheet



## C.3 DEVIATION IN UTILIZATION RATIO FOR BEAM 18



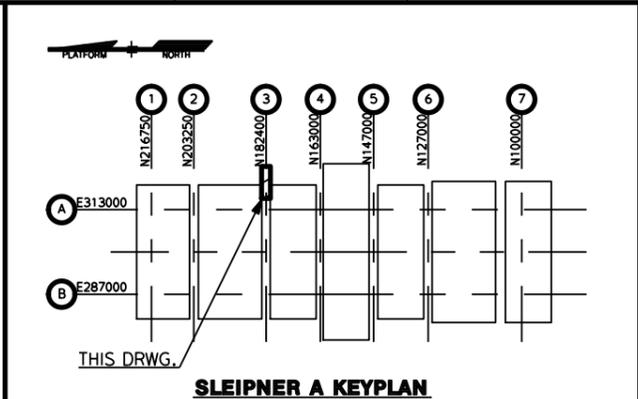
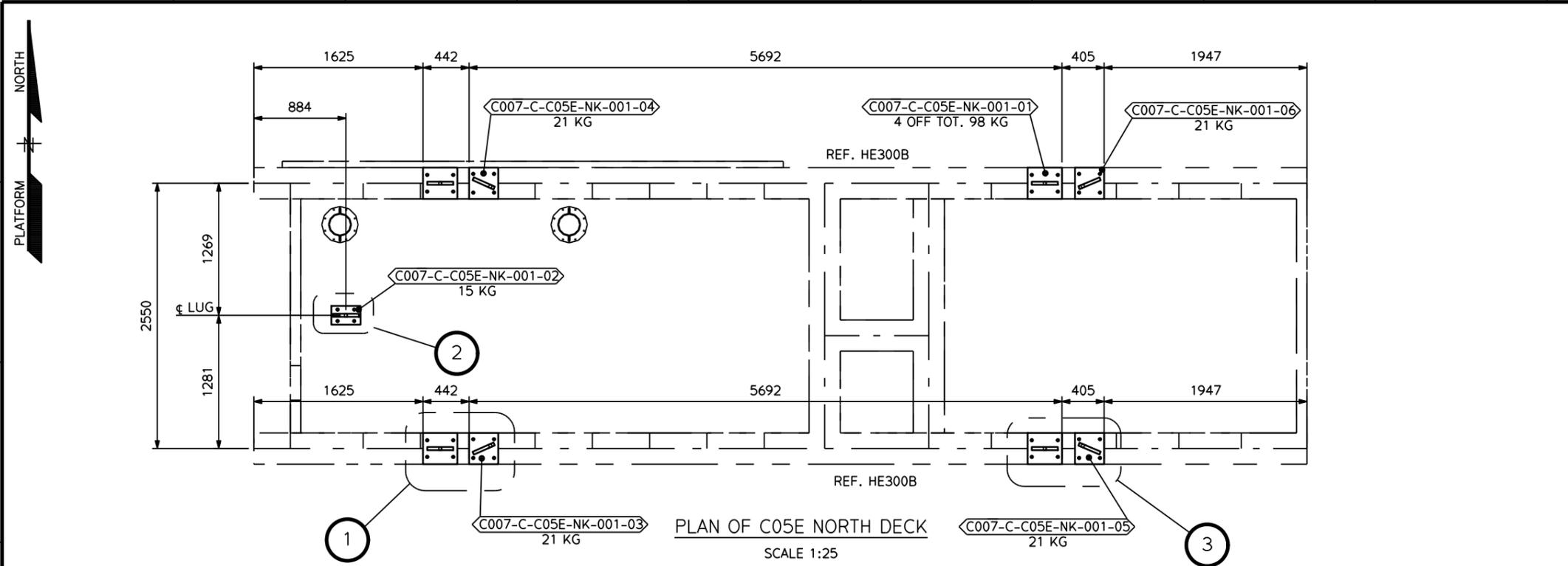
Microsoft Excel  
Worksheet



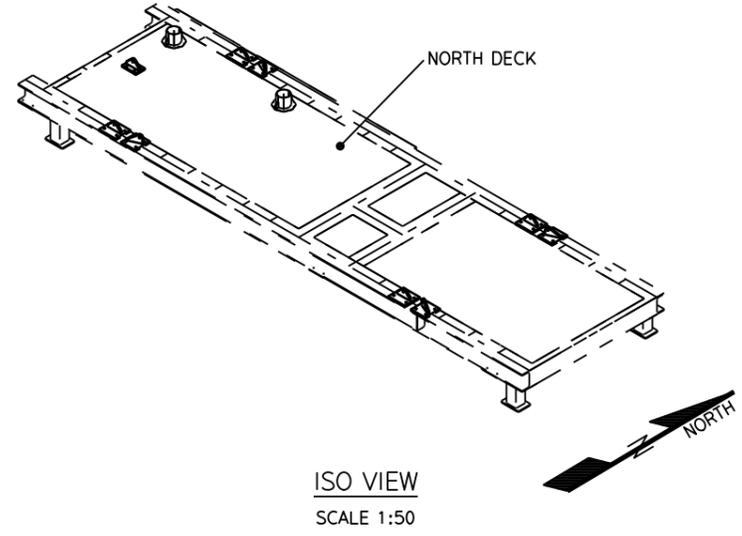
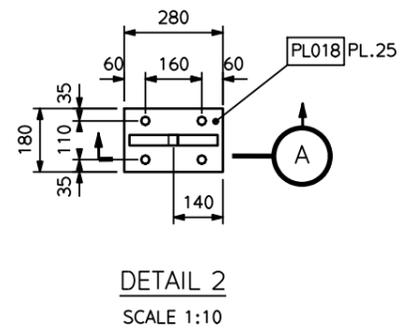
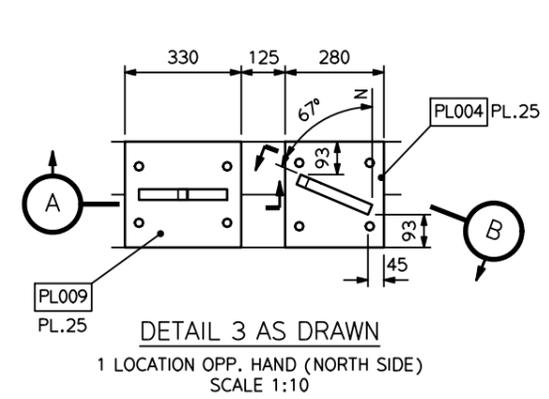
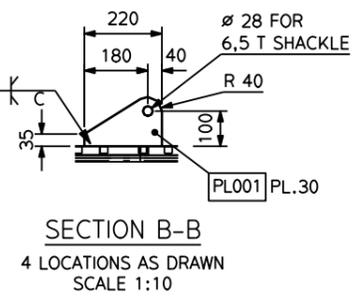
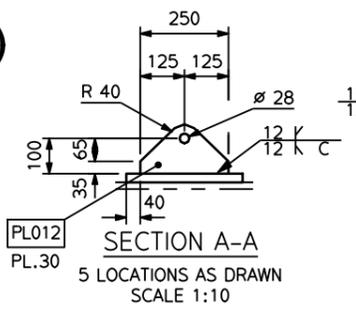
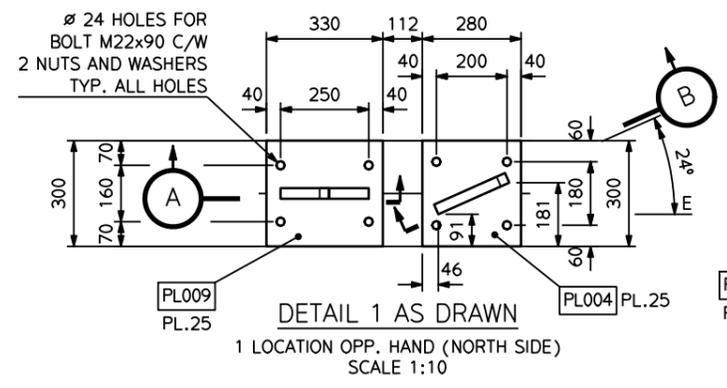
# APPENDIX D

# DRAWINGS

Note: The drawings are collected from Aker Solutions.



- NOTES:**
- FOR GENERAL NOTES AND SPECIFICATIONS SEE DRAWING NO.: C007-C-000--NT-202-01
  - ALL DIMENSIONS ARE THEORETICAL. SHOP DETERMINE OVERLENGTH / CUT OFF.
  - DESIGN CLASS - MATERIAL :  
 PLATES 2-Y30-420  
 BOLTS & NUTS 8.8 GR. 3.1 CERTIFICATE
  - APPLIED TORQUE ON NUT : 390Nm FOR BOLT M22  
 HALF TORQUE ON SECOND NUT  
 BOLT TO BE GREASED WITH MOLYCOAT G-RAPID PLUS BEFORE TIGHTENING
  - THE LIFTING LUG TO BE MARKED WITH HOOK-UP NO.
  - LIFTING CHECK OF OBJECT WITHOUT OVERLOAD.
  - LIFTING LUGS TO BE REMOVED AFTER USE.



REF.DRAWING NO.:		
C007-C-C05E-NK-003-01		
C007-C-C05E--NJ-001-01		
POS.NO.PLATES:	PL001, PL004, PL009, PL012, PL018	
POS.NO.PROFILES:		
HOOK-UP NO.:	C007-C-C05E--NK-001-	01-06
WELD NO.:	380	
WELD INSP.CATEGORY:	C	WELD INSTRUCTION:
PAINT SYSTEM:	COLOUR PINK, RAL 3015, SYSTEM 1T	
TOTAL WEIGHT:	197 KG	SHORT CODE:
		C05ETSLU02

**AkerSolutions**

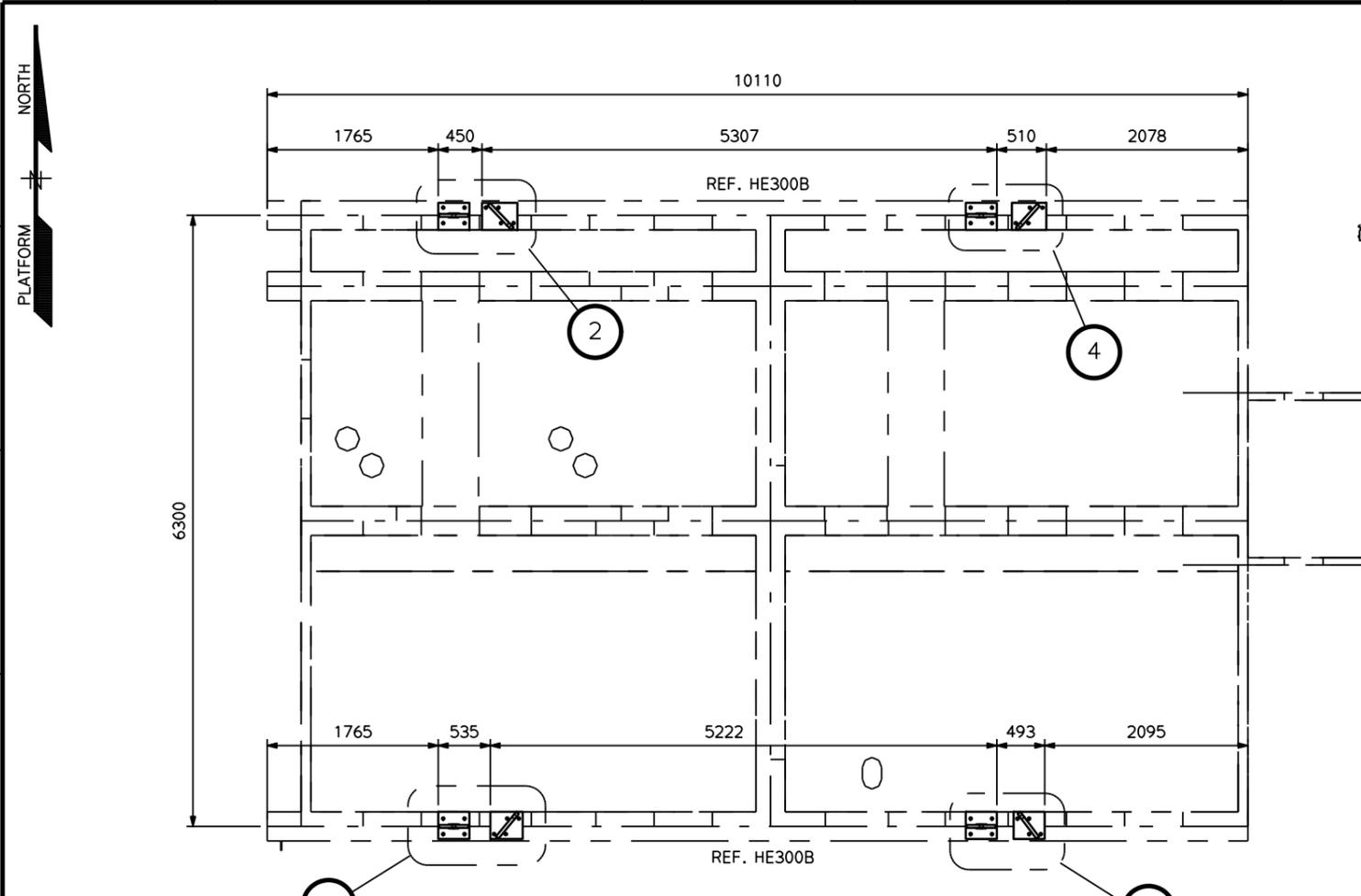
**Statoll**

INSTALLATION: SLEIPNER A

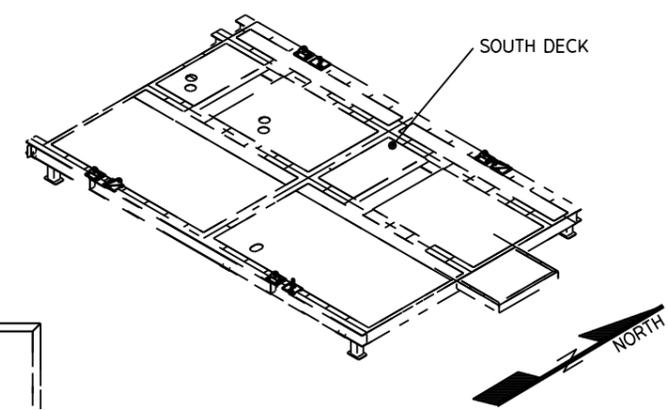
DRAWING TITLE: C05E BALCONY. TEMPORARY LIFTING LUGS FOR INSTALLATION. NORTH DECK.

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SCALE	SIZE	AREA	NETWORK

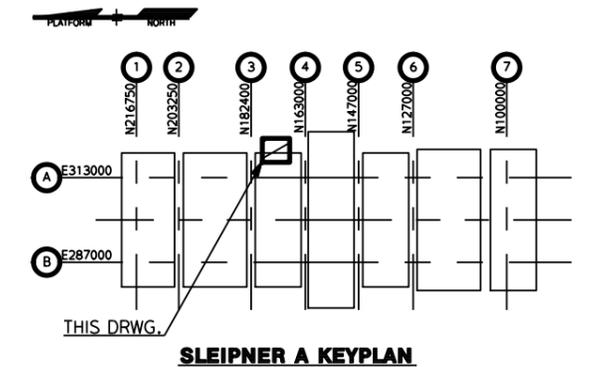
C007-C-C05E-NK-001-01	01
DRAWING NUMBER	
REV.	



PLAN OF C05E SOUTH DECK  
SCALE 1:33

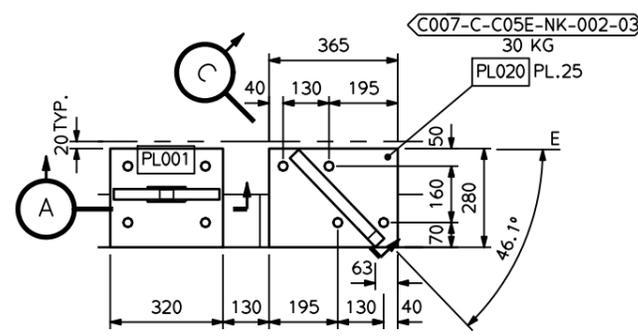


ISO VIEW  
SCALE 1:75

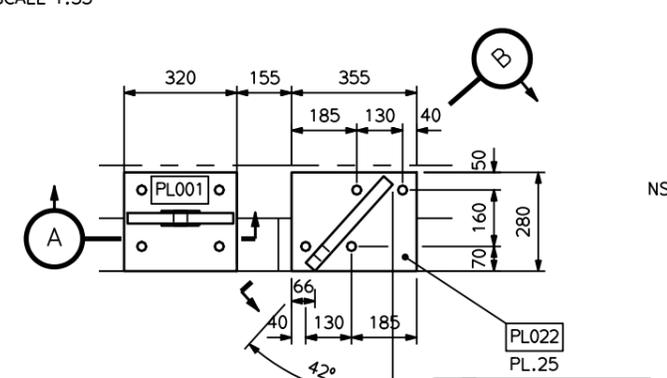


SLEIPNER A KEYPLAN

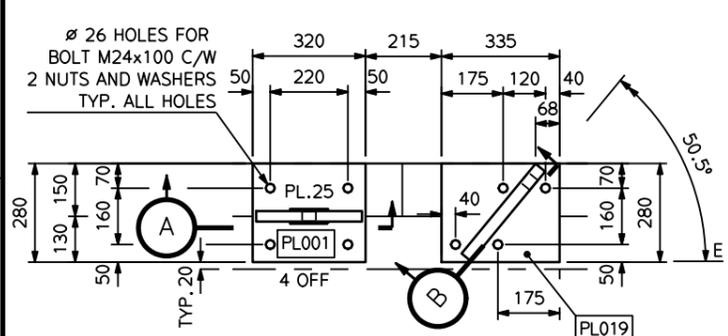
- NOTES:**
- FOR GENERAL NOTES AND SPECIFICATIONS SEE DRAWING NO.: C007-C-000--NT-202-01
  - ALL DIMENSIONS ARE THEORETICAL. SHOP DETERMINE OVERLENGTH / CUT OFF.
  - DESIGN CLASS - MATERIAL :  
PLATES 2-Y30-420 U.N.O  
BOLTS & NUTS 8.8 GR. 3.1 CERTIFICATE
  - APPLIED TORQUE ON NUT : 495Nm FOR BOLT M24  
HALF TORQUE ON SECOND NUT  
BOLT TO BE GREASED WITH MOLYCOAT G-RAPID PLUS BEFORE TIGHTENING
  - THE LIFTING LUG TO BE MARKED WITH HOOK-UP NO.
  - LIFTING CHECK OF OBJECT WITHOUT OVERLOAD.
  - LIFTING LUGS TO BE REMOVED AFTER USE.



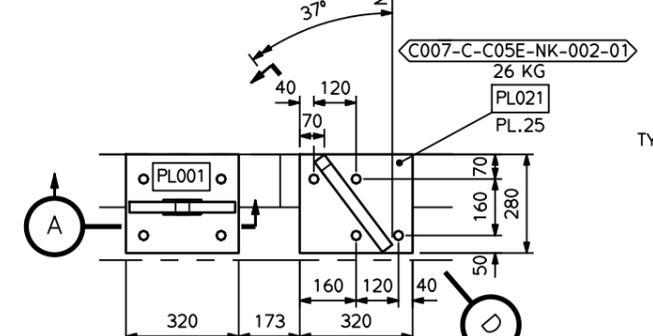
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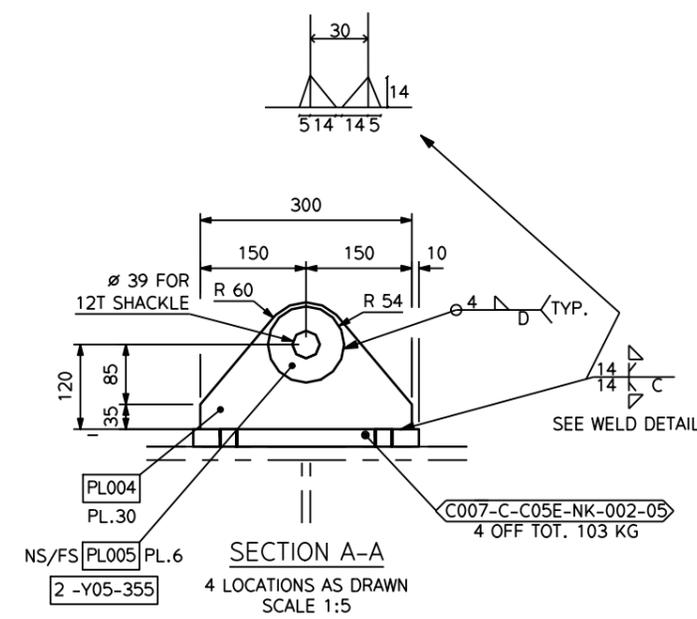
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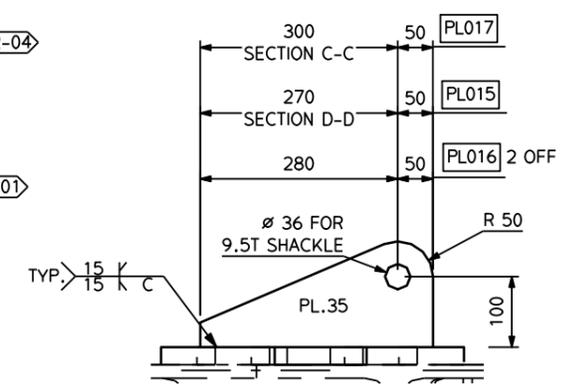
DETAIL 1  
SCALE 1:10



DETAIL 3  
SCALE 1:10



SECTION A-A  
4 LOCATIONS AS DRAWN  
SCALE 1:5



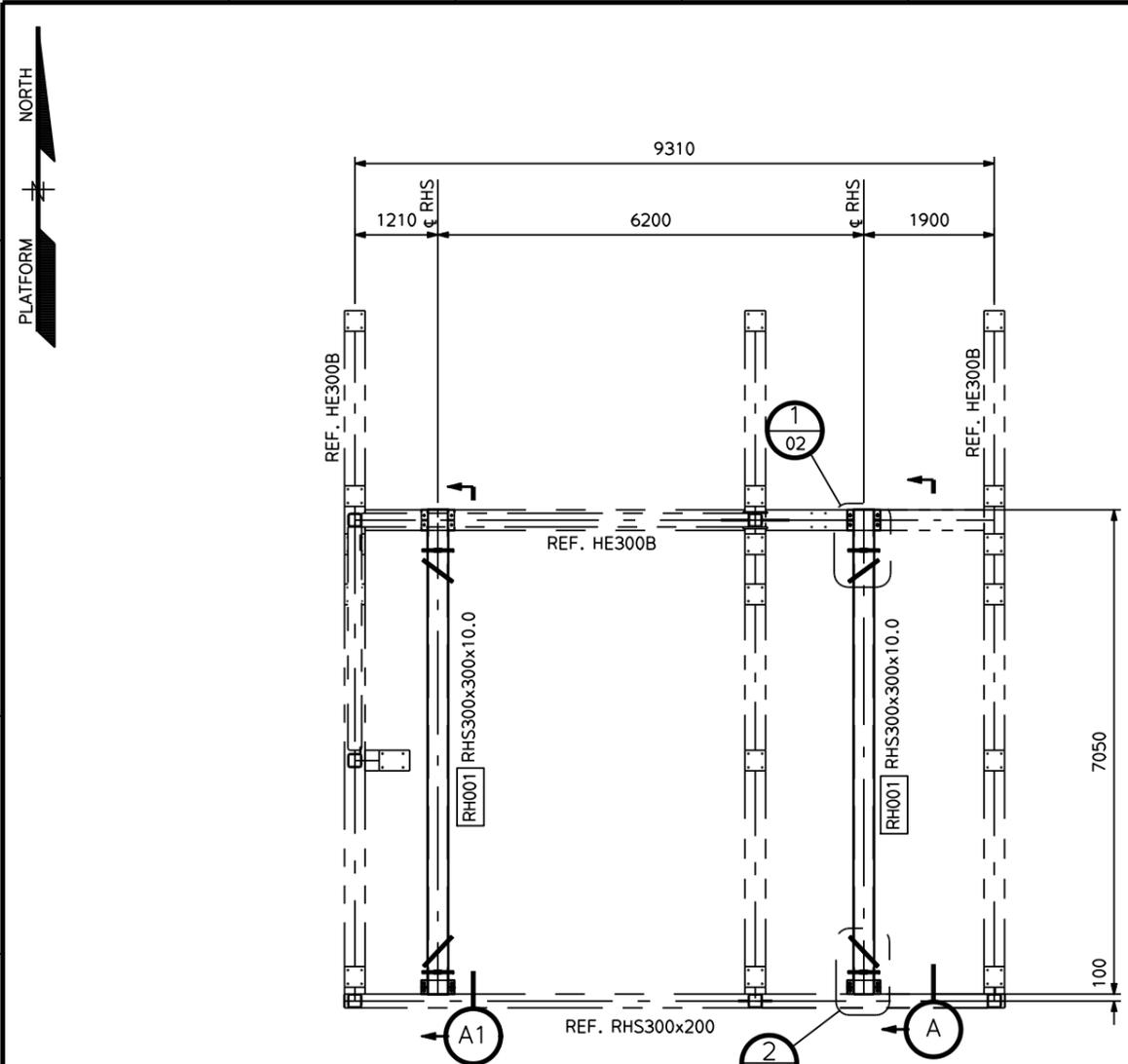
SECTION B-B 2 LOC  
SECTION C-C 1 LOC  
SECTION D-D 1 LOC  
SCALE 1:5

REF. DRAWING NO.:	
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C007-C-C05E-NJ-004-01	
POS. NO. PLATES:	PL001, PL004, PL005, PL015-PL017, PL019-PL022
POS. NO. PROFILES:	
HOOK-UP NO.:	C007-C-C05E--NK-002- 01-05
WELD NO.:	385, 400
WELD INSP. CATEGORY:	C, D WELD INSTRUCTION:
PAINT SYSTEM:	COLOUR PINK, RAL 3015, SYSTEM 1T
TOTAL WEIGHT:	215 KG SHORT CODE: C05ETSLU01

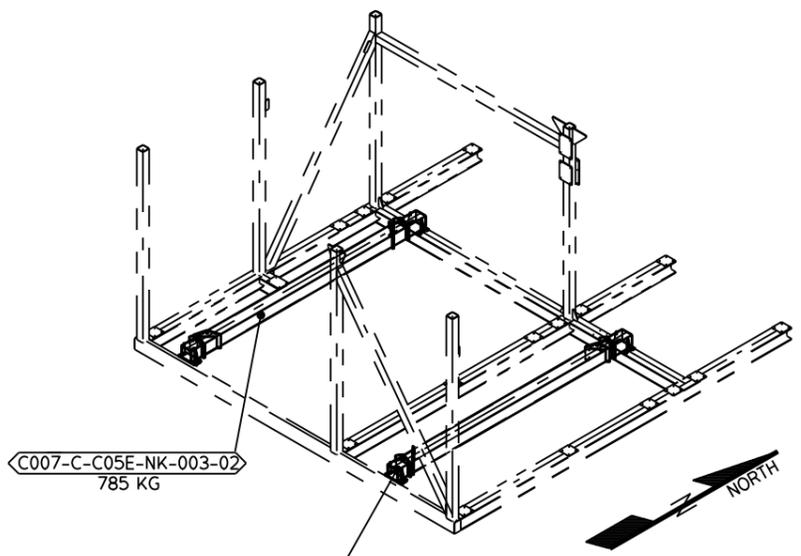


INSTALLATION: SLEIPNER A  
DRAWING TITLE: C05E BALCONY. TEMPORARY LIFTING LUGS FOR INSTALLATION. SOUTH DECK.

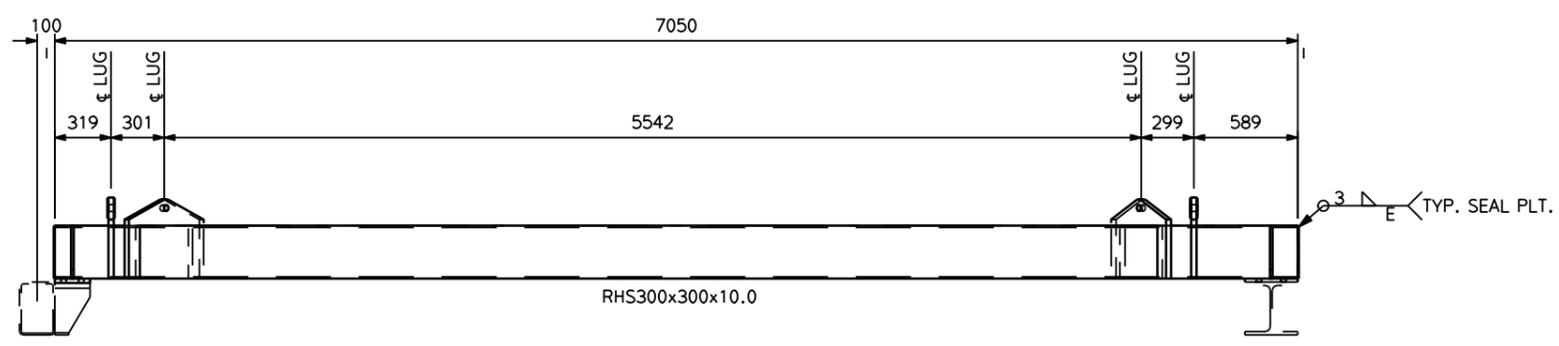
CONTR. NO.	104493
AS NOTED	AT A1 C05E D04
SCALE	SIZE AREA NETWORK
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DRAWING NUMBER	REV.



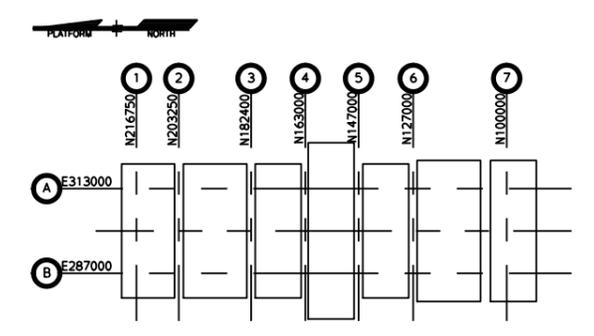
PLAN ON C05E BALCONY  
SCALE 1:50



ISO VIEW  
SCALE 1:75



SECTION A-A  
SECTION A1-A1 OPP.HAND  
SCALE 1:20



SLEIPNER A KEYPLAN

- NOTES:
- FOR GENERAL NOTES AND SPECIFICATIONS SEE DRAWING NO.: C007-C-000--NT-202-01
  - ALL DIMENSIONS ARE THEORETICAL. SHOP DETERMINE OVERLENGTH / CUT OFF.
  - DESIGN CLASS - MATERIAL :  
 PLATES 2-Y30-420 U.N.O  
 PROFILES 4-Y07-355  
 BOLTS & NUTS 8.8 GR. 3.1 CERTIFICATE
  - APPLIED TORQUE ON NUT : 719Nm FOR BOLT M27  
 HALF TORQUE ON SECOND NUT  
 BOLT TO BE GREASED WITH MOLYCOAT G-RAPID PLUS BEFORE TIGHTENING
  - LIFTING CHECK OF OBJECT WITHOUT OVERLOAD TO BE PERFORMED.

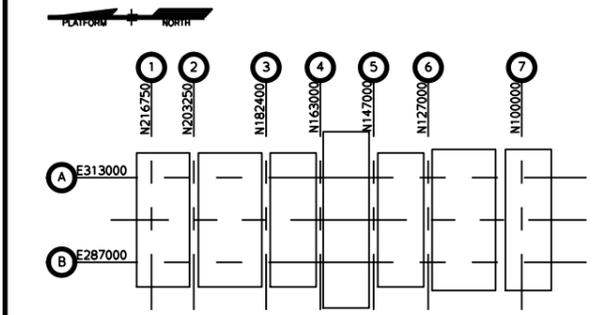
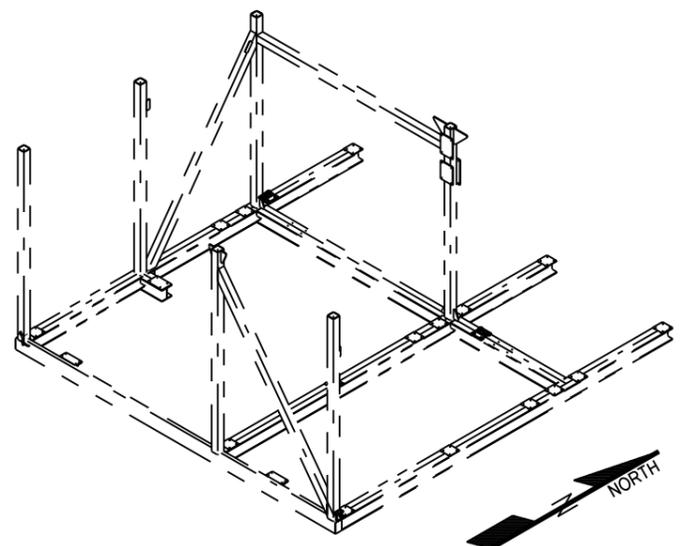
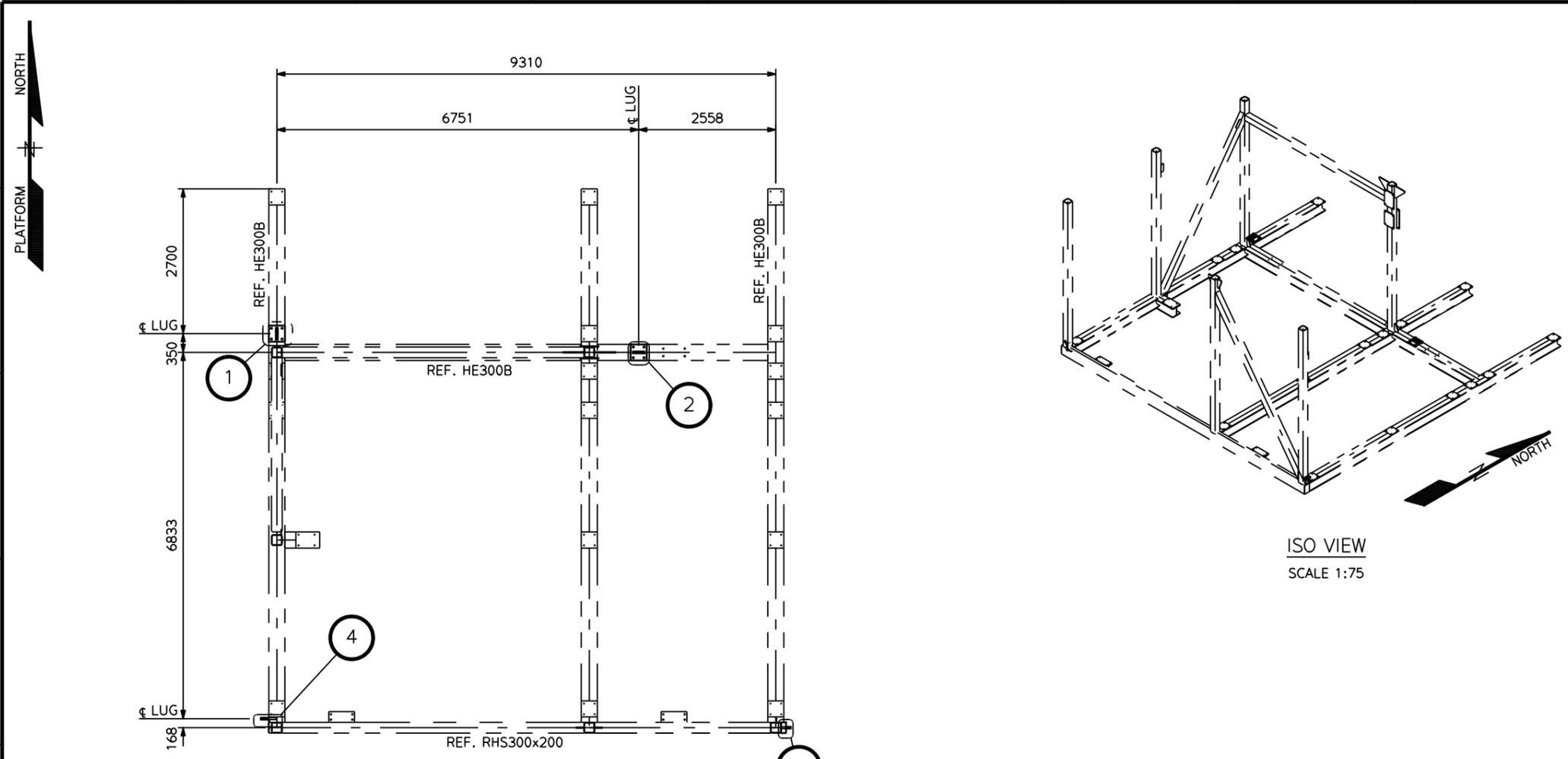
REF.DRAWING NO.:		
C007-C-000--NT-203-01		
C007-C-05E-NJ-002-01		
POS.NO.PLATES:	PL001-PL002, PL004, PL006, PL008-PL009, PL011-PL013	
	PL025	
POS.NO.PROFILES:	RH001	
HOOK-UP NO.:	C007-C-M22--NK-003-	01-02
WELD NO.:		350, 380, 500
WELD INSP.CATEGORY:	C, E	WELD INSTRUCTION:
PAINT SYSTEM:		COLOR PINK, SYSTEM 1T, RAL 3015
TOTAL WEIGHT:	1570 KG	SHORT CODE: C05ETSLB01



01	31.10.2013	FABR. & COMM. INFO S5	ST	PG/RIA	L0/BE
REV.	DATE	REASON FOR ISSUE	PREP.	CHECK.	APPR.

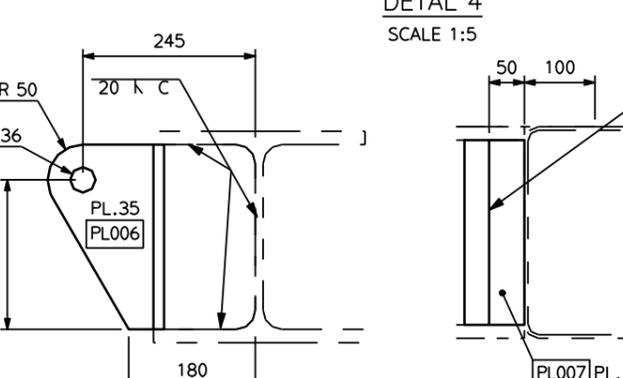
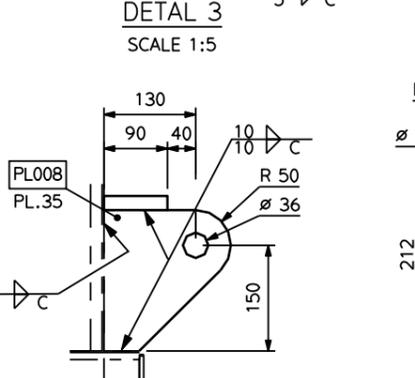
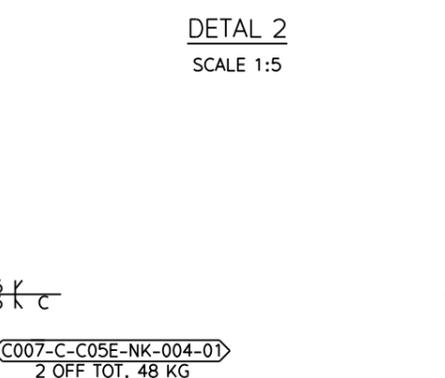
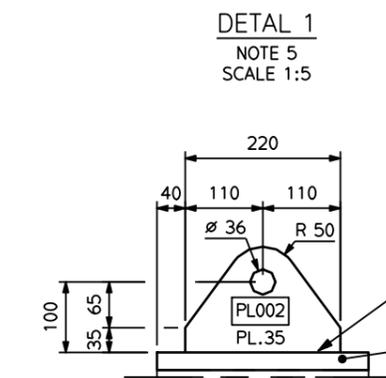
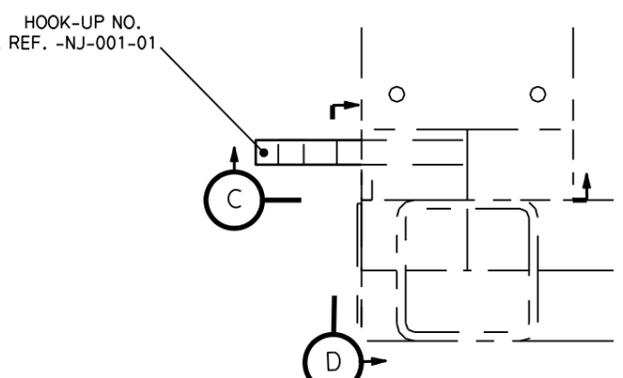
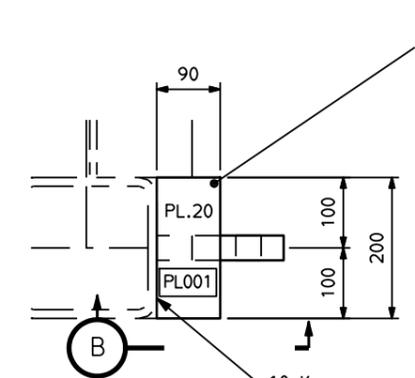
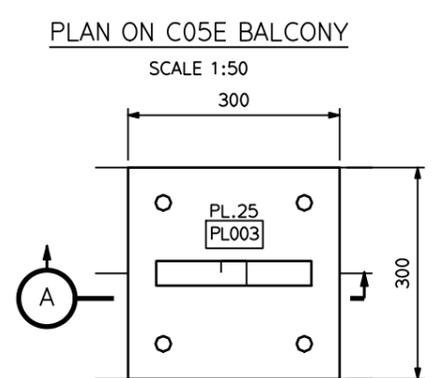
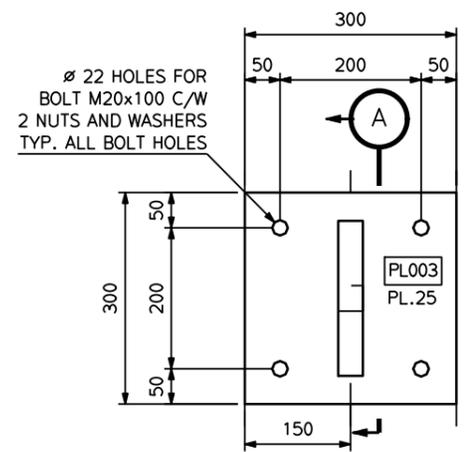
	INSTALLATION: SLEIPNER A	
	DRAWING TITLE: C05E BALCONY. TEMPORARY INSTALLATION BEAMS FOR MAIN FRAME.	
CONTR. NO. 104493	AS NOTED AT A1	C05E D04
SCALE	SIZE	AREA NETWORK
C007-C-C05E-NK-003-01		01
DRAWING NUMBER		REV.





**SLEIPNER A KEYPLAN**

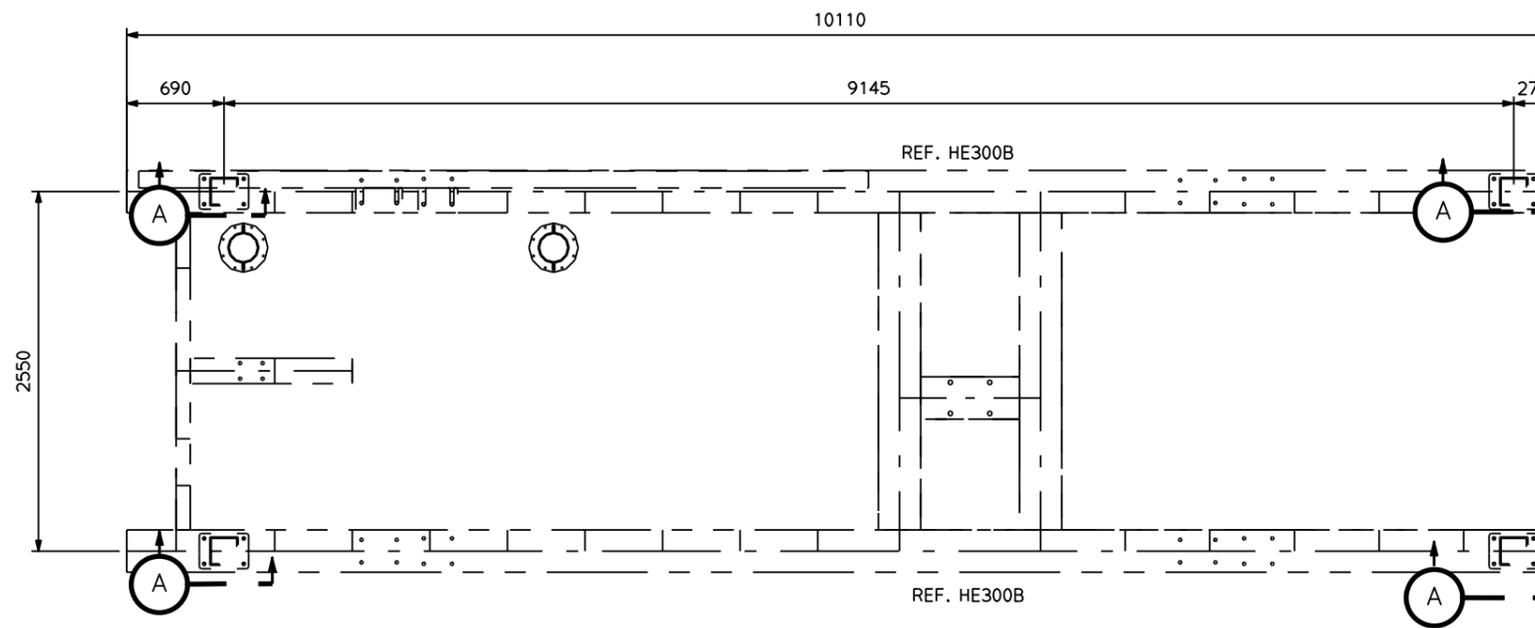
- NOTES:**
1. FOR GENERAL NOTES AND SPECIFICATIONS SEE DRAWING NO.: C007-C-000--NT-202-01
  2. ALL DIMENSIONS ARE THEORETICAL. SHOP DETERMINE OVERLENGTH / CUT OFF.
  3. DESIGN CLASS - MATERIAL :  
 PLATES 2-Y30-420  
 BOLTS & NUTS 8.8 GR. 3.1 CERTIFICATE
  4. APPLIED TORQUE ON NUT : 286Nm FOR BOLT M20  
 HALF TORQUE ON SECOND NUT  
 BOLT TO BE GREASED WITH MOLYCOAT G-RAPID PLUS BEFORE TIGHTENING
  5. LIFTING LUGS TO BE BOLTED TO TOP OF FOUNDATION PLATES, REF. DRWG: C007-C-C05E--NJ-002-01
  6. THE LIFTING LUG TO BE MARKED WITH A TYPICAL "CE SIGN" WITH HOOK-UP NO. AND FABRICATION SUPPLIER
  7. BOLTED LIFTING LUGS TO BE REMOVED, AND WELDED LIFTING LUGS HOLES TO BE SEALED OF BY BOLT AND NUT AFTER USE



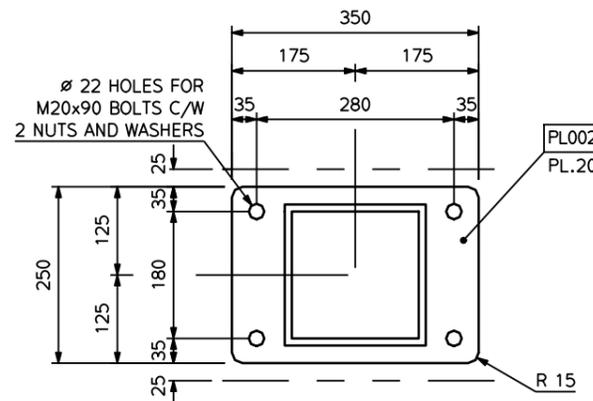
REF.DRAWING NO.:	
C007-C-000--NT-203-01	
C007-C-C05E--NJ-001-01	
POS.NO.PLATES:	PL001-PL003, PL006-PL008
POS.NO.PROFILES:	
HOOK-UP NO.:	C007-C-M22--NK-004-01
WELD NO.:	350, 380, 385
WELD INSP.CATEGORY:	C   WELD INSTRUCTION:
PAIN SYSTEM:	BOLTED LUGS: COLOUR PINK, SYSTEM 1T, RAL 3015 WELDED LUGS: COLOUR BLUE, SYSTEM 2B, RAL 5015
TOTAL WEIGHT:	76 KG   SHORT CODE: C05ETSSE01

<b>AkerSolutions</b>				
01	21.11.2013	FABR. & COMM. INFO S5	ST	PG/RIA L0/BE
REV.	DATE	REASON FOR ISSUE	PREP.	CHECK. APPR.

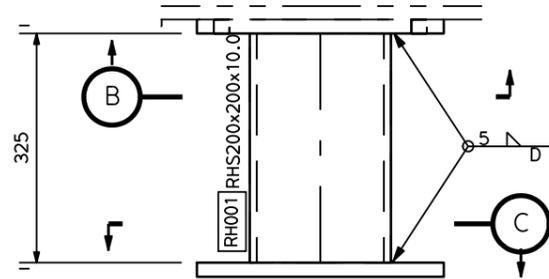
<b>Statoll</b>		INSTALLATION: SLEIPNER A	
DRAWING TITLE: C05E BALCONY. LUGS FOR SECURING ARRANGEMENT ON BALCONY.			
CONTR. NO. 104493	AS NOTED AT A1 C05E D04	C007-C-C05E-NK-004-01	01
SCALE	SIZE AREA NETWORK	DRAWING NUMBER	REV.



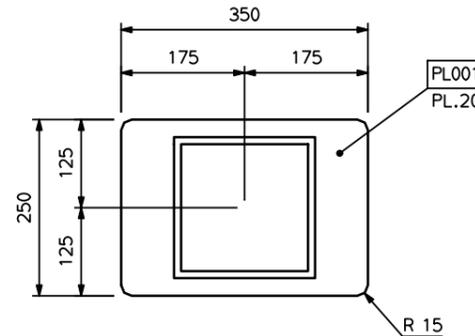
PLAN OF C05E NORTH DECK  
SCALE 1:25



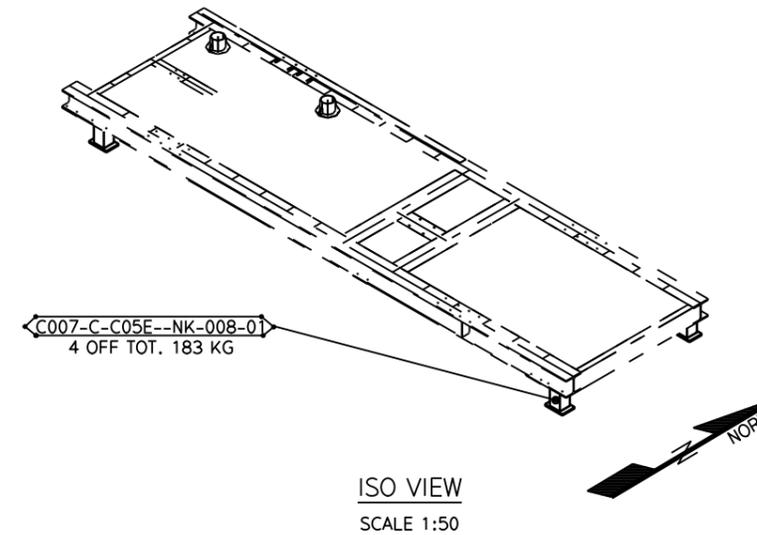
SECTION B-B  
SCALE 1:5



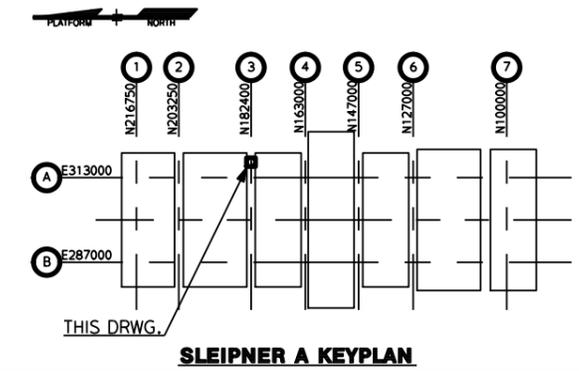
SECTION A-A  
4 LOCATIONS AS DRAWN  
SCALE 1:5



SECTION C-C  
SCALE 1:5



ISO VIEW  
SCALE 1:50



SLEIPNER A KEYPLAN

NOTES:

- FOR GENERAL NOTES AND SPECIFICATIONS SEE DRAWING NO.: C007-C-000--NT-202-01
- ALL DIMENSIONS ARE THEORETICAL. SHOP DETERMINE OVERLENGTH / CUT OFF.
- DESIGN CLASS - MATERIAL :  

PLATES	4-Y30-420
PROFILES	4-Y07-355
BOLTS & NUTS	8.8 GR. 3.1 CERTIFICATE
- APPLIED TORQUE ON NUT : 286Nm FOR BOLT M20  
 HALF TORQUE ON SECOND NUT  
 BOLT TO BE GREASED WITH MOLYCOAT G-RAPID PLUS BEFORE TIGHTENING

REF.DRAWING NO.:	
C007-C-C05E-NK-003-01	

POS.NO.PLATES:	PL001-PL002
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POS.NO.PROFILES:	RH001
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HOOK-UP NO.:	C007-C-C05E--NK-008-01
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WELD NO.:	400
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WELD INSP. CATEGORY:	D	WELD INSTRUCTION:	
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PAINT SYSTEM:	COLOUR PINK, RAL 3015, SYSTEM 1T
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TOTAL WEIGHT:	183 KG	SHORT CODE:	C05ETSD02L
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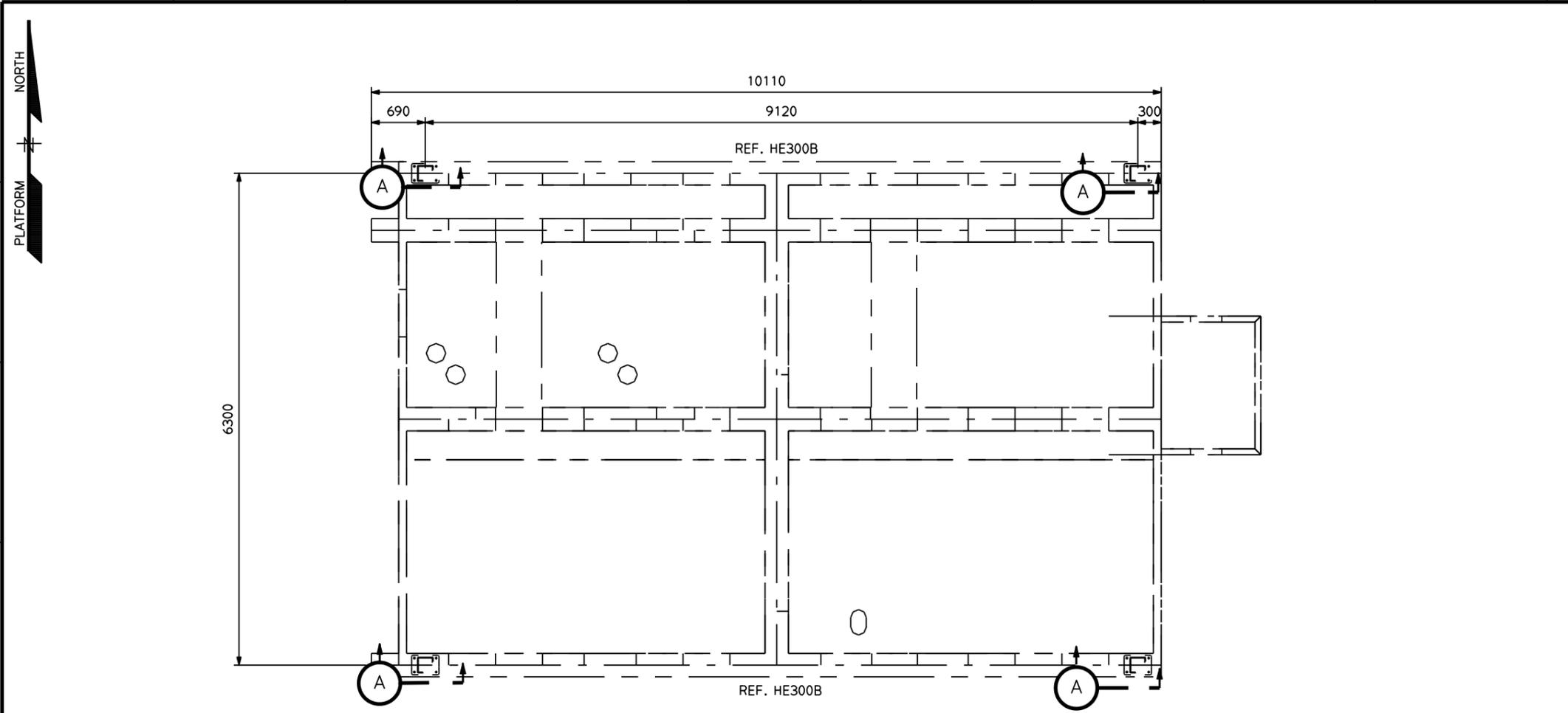


01	07.11.2013	FABR. & COMM. INFO S5	ST	RIA/PG	L0/BE
REV.	DATE	REASON FOR ISSUE	PREP.	CHECK.	APPR.

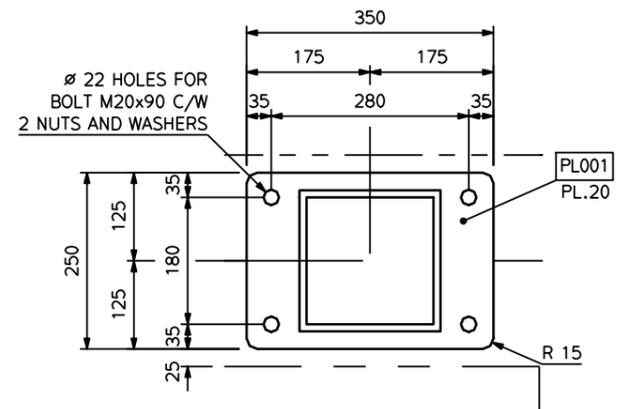


INSTALLATION: SLEIPNER A  
 DRAWING TITLE: C05E BALCONY. TRANSPORT LEGS FOR DECK NORTH

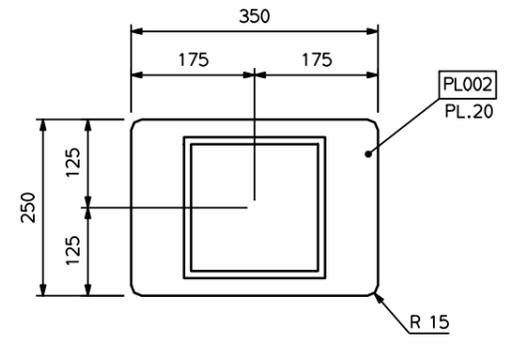
CONTR. NO.	104493				
AS NOTED	AT A1	C05E	D04	C007-C-C05E-NK-008-01	01
SCALE	SIZE	AREA	NETWORK	DRAWING NUMBER	REV.



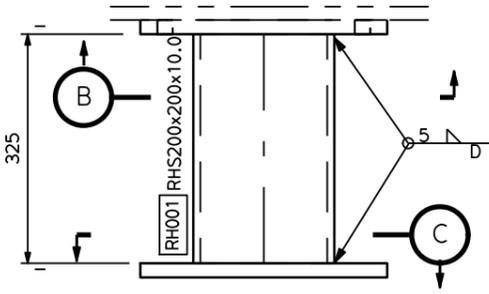
PLAN OF C05E SOUTH DECK  
SCALE 1:33



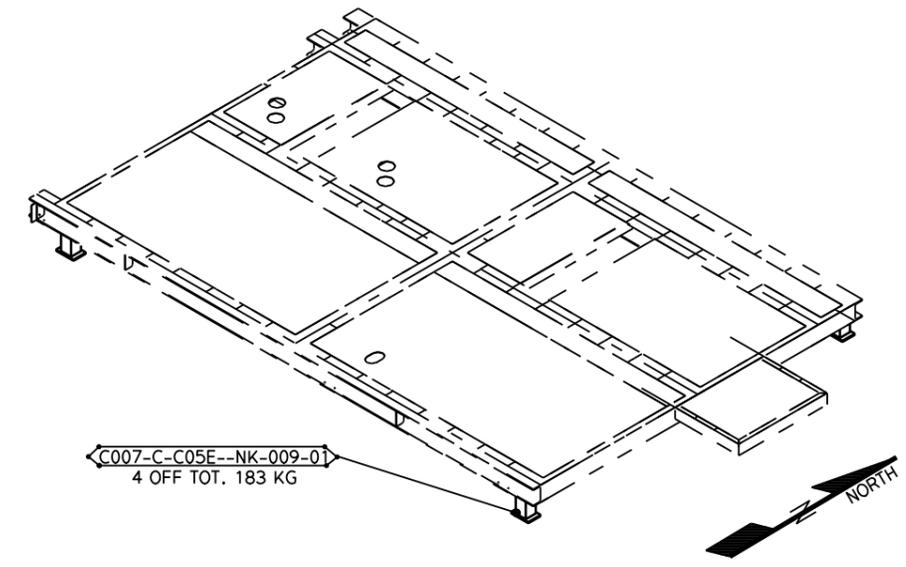
SECTION B-B  
SCALE 1:5



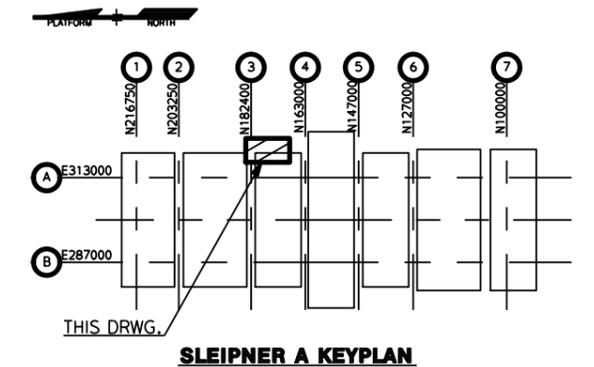
SECTION C-C  
SCALE 1:5



SECTION A-A  
4 LOCATIONS AS DRAWN  
SCALE 1:5



ISO VIEW  
SCALE 1:50



SLEIPNER A KEYPLAN

- NOTES:
- FOR GENERAL NOTES AND SPECIFICATIONS SEE DRAWING NO.: C007-C-000--NT-202-01
  - ALL DIMENSIONS ARE THEORETICAL. SHOP DETERMINE OVERLENGTH / CUT OFF.
  - DESIGN CLASS - MATERIAL :  

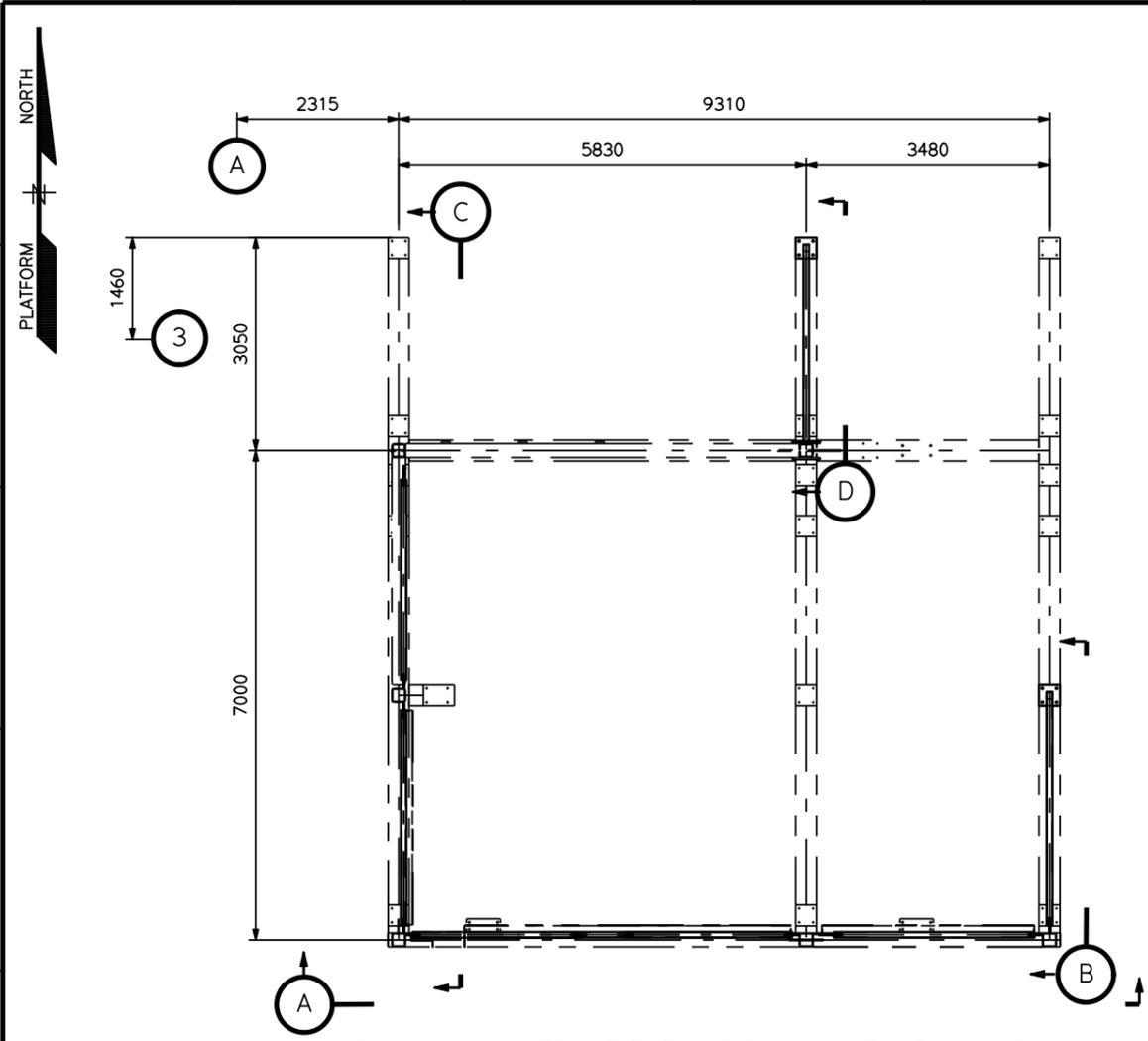
PLATES	4-Y30-420
PROFILES	4-Y07-355
BOLTS & NUTS	8.8 GR. 3.1 CERTIFICATE
  - APPLIED TORQUE ON NUT : 286Nm FOR BOLT M20  
 HALF TORQUE ON SECOND NUT  
 BOLT TO BE GREASED WITH MOLYCOAT G-RAPID PLUS BEFORE TIGHTENING

REF.DRAWING NO.:	
C007-C-C05E-NK-004-01	
POS.NO.PLATES:	PL001-PL002
POS.NO.PROFILES:	RH001
HOOK-UP NO.:	C007-C-C05E--NK-009-01
WELD NO.:	400
WELD INSP.CATEGORY:	D WELD INSTRUCTION:
PAINT SYSTEM:	COLOUR PINK, RAL 3015, SYSTEM 1T
TOTAL WEIGHT:	183 KG
SHORT CODE:	C05ETSD1LE

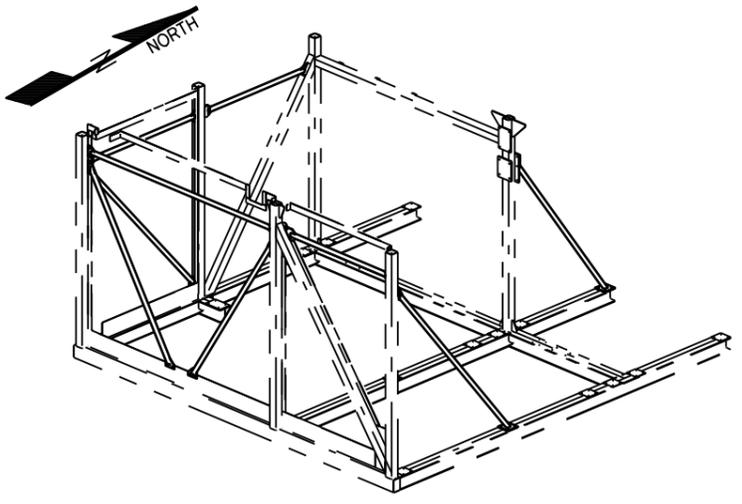


INSTALLATION: SLEIPNER A  
 DRAWING TITLE: C05E BALCONY. TRANSPORT LEGS FOR DECK SOUTH.

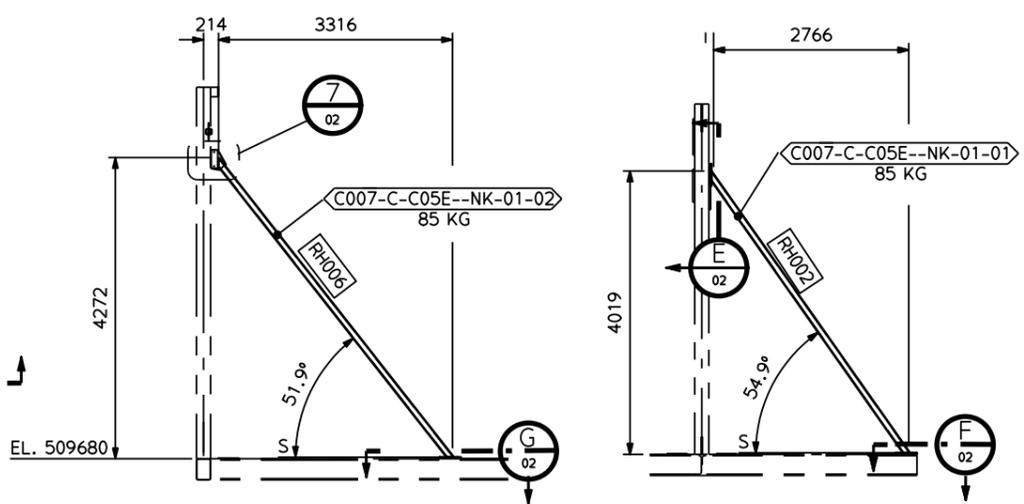
CONTR. NO.	104493				
AS NOTED	AT A1				
SCALE	SIZE	AREA	NETWORK	C007-C-C05E-NK-009-01	01
DRAWING NUMBER					REV.



PLAN ON MAIN FRAME FOR C05 BALCONY EL. 509680 T.O.S  
 ALL PROFILES TO BE RHS 80x80x6.3  
 SCALE 1:50

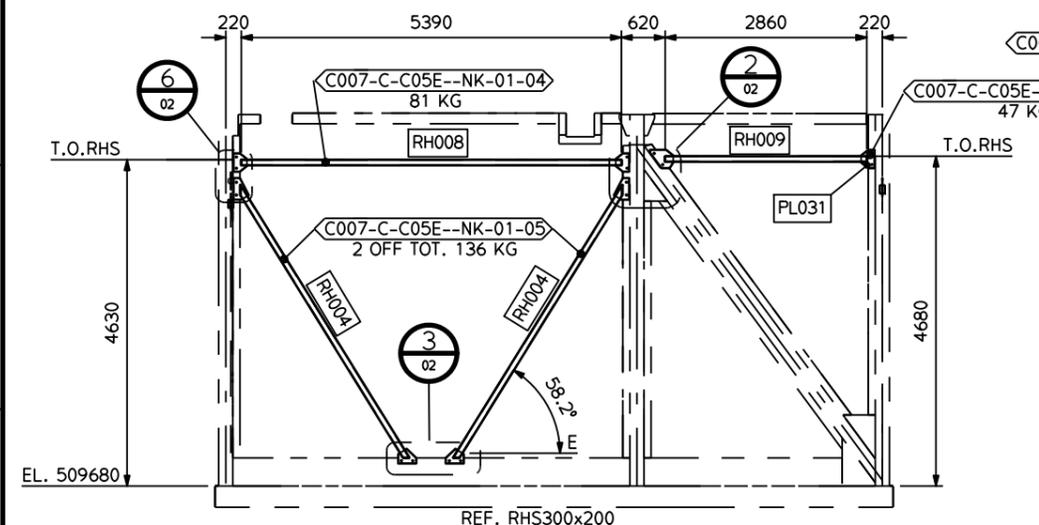


ISO VIEW  
 SCALE 1:75

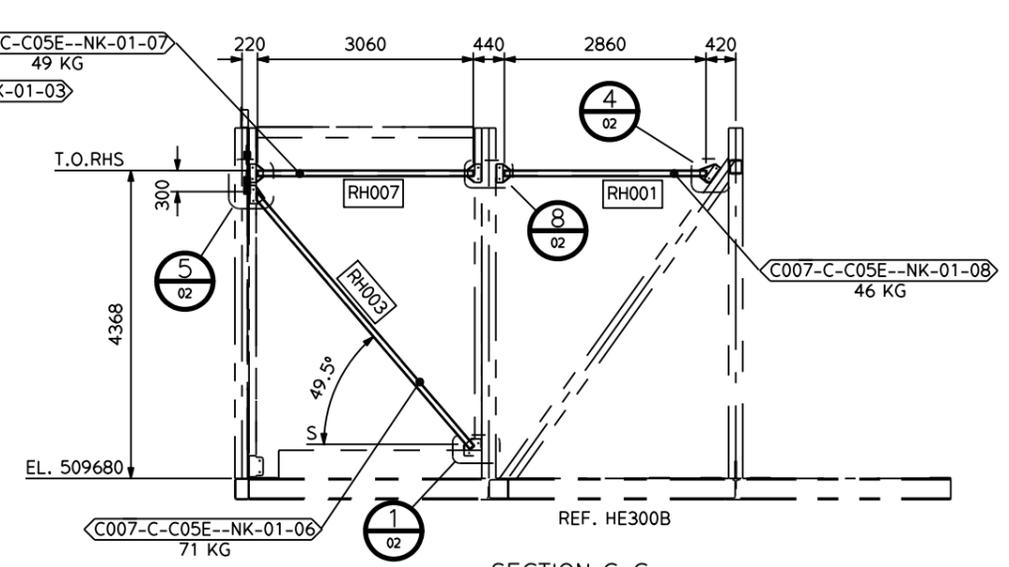


SECTION B-B  
 SCALE 1:50

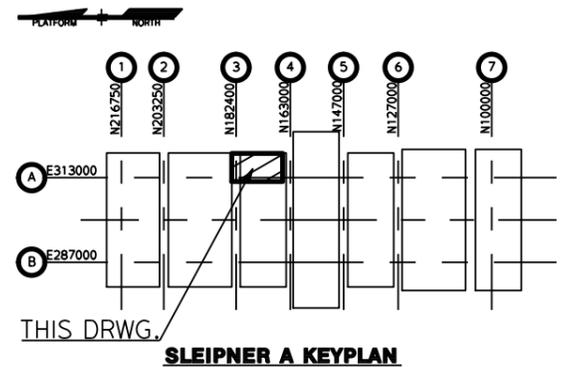
SECTION D-D  
 SCALE 1:50



SECTION A-A  
 SCALE 1:50



SECTION C-C  
 SCALE 1:50



SLEIPNER A KEYPLAN

- NOTES:
1. FOR GENERAL NOTES AND SPECIFICATIONS SEE DRAWING NO.: C007-C-000--NT-202-01
  2. ALL DIMENSIONS ARE THEORETICAL. SHOP DETERMINE OVERLENGTH / CUT OFF.
  3. DESIGN CLASS - MATERIAL :
 

PLATES > 10mm	2-Y30-420
PROFILES	4-Y07-355
BOLTS	8.8 GR. 3.1 CERTIFICATE
PLATES < 10mm	2-Y05-355
  4. BRACES TO BE FIXED WITH TWO M12 BOLT ON EACH SIDE WHEN POSSIBLE USE SAME HOLES ALREADY DRILLED FOR BLASTWALL. IF NECESSARY DRILL EXTRA ø13 HOLES. BOLTED ON THE OUTSIDE OF WALL SUPPORT.
  5. BRACINGS ONLY TO BE REMOVED AFTER MAIN FRAME HAS BEEN WELDED IN FINAL POSITION.

REF.DRAWING NO.:	C007-C-C05E--NJ-005-01
C007-C-C05E--NJ-001-01	C007-C-C05E--NJ-008-01
C007-C-C05E--NJ-002-01	
POS.NO.PLATES:	PL001, PL004, PL006, PL016, PL028, PL031-PL032, PL034-PL037, PL042-PL043, PL045-PL047
POS.NO.PROFILES:	RH001-RH004, RH006-RH009
HOOK-UP NO.:	C007-C-C05E--NK-011-01-08
WELD NO.:	350, 380, 500
WELD INSP.CATEGORY:	C, E   WELD INSTRUCTION:
PAINT SYSTEM:	COLOUR PINK, SYSTEM 1T, RAL 3015
TOTAL WEIGHT:	603 KG   SHORT CODE: C05ETSBRSU

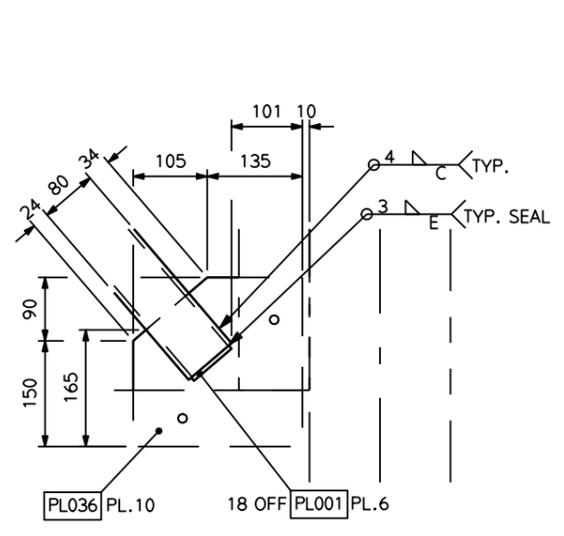


01	26.11.2013	FABR. & COMM. INFO S5	ST	PG/RIA	L0/BE
REV.	DATE	REASON FOR ISSUE	PREP.	CHECK.	APPR.

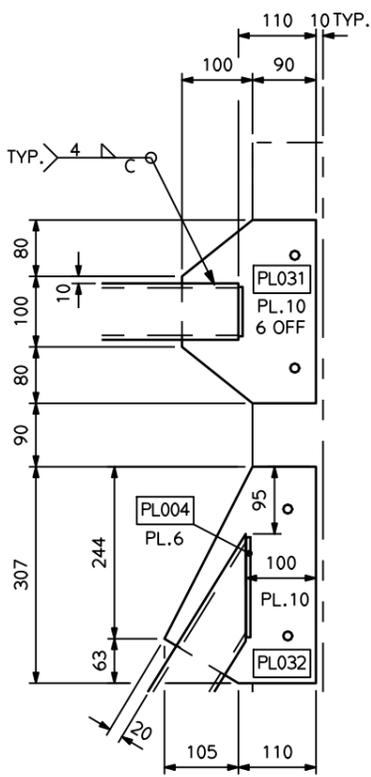
INSTALLATION: SLEIPNER A

DRAWING TITLE: C05E BALCONY. TEMPORARY BRACINGS FOR SECURING.

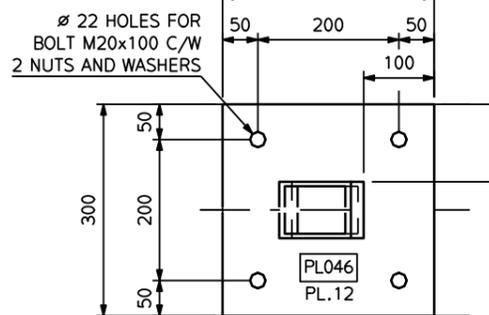
CONTR. NO.	104493
AS NOTED	AT A1   C05E   D04
SCALE	SIZE   AREA   NETWORK
C007-C-C05E-NK-011-01	01
DRAWING NUMBER	
REV.	



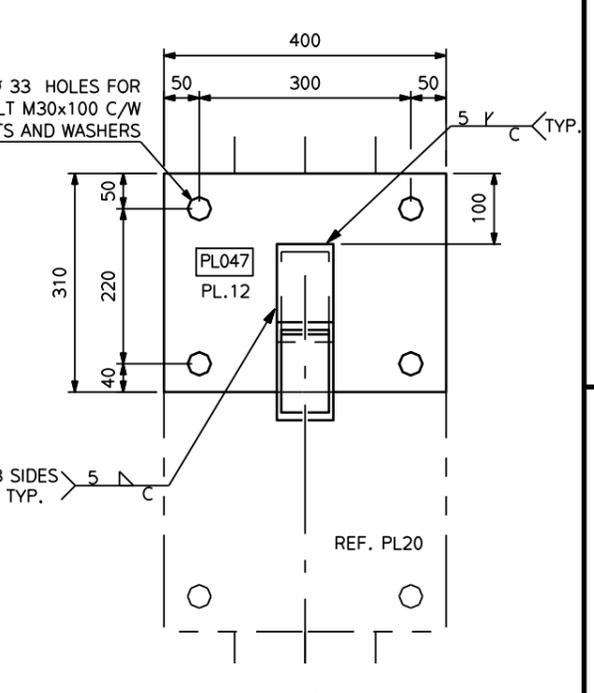
**DETAIL 1**  
REF. SHEET 01  
NOTE 4  
SCALE 1:5



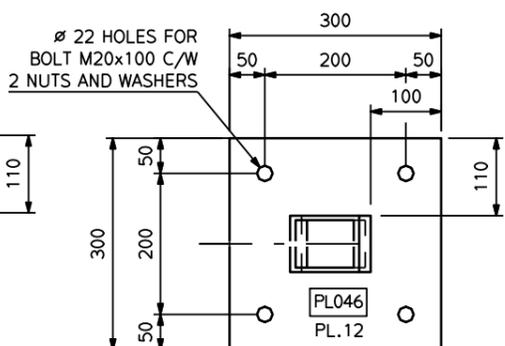
**DETAIL 2**  
REF. SHEET 01  
NOTE 4  
SCALE 1:5



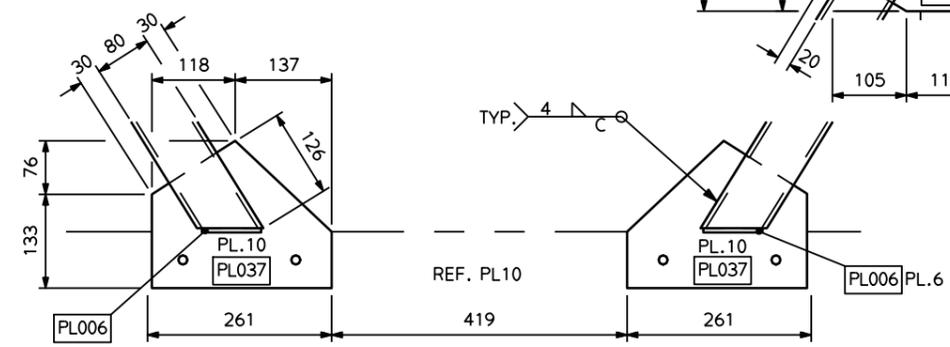
**SECTION G-G**  
REF. SHEET 01  
NOTE 6  
SCALE 1:5



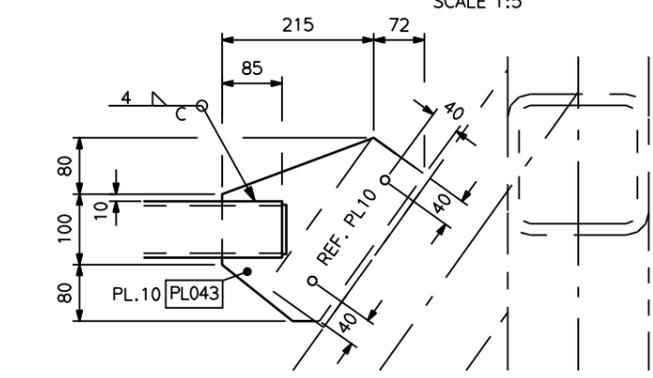
**SECTION E-E**  
REF. SHEET 01  
NOTE 7  
SCALE 1:5



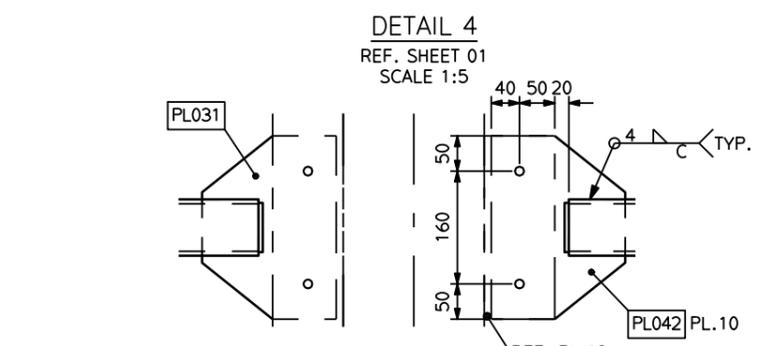
**SECTION F-F**  
REF. SHEET 01  
NOTE 6  
SCALE 1:5



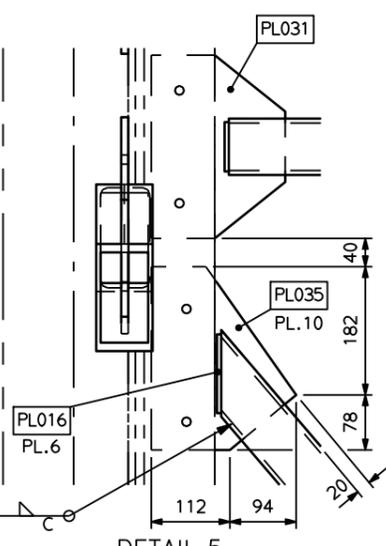
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REF. SHEET 01  
NOTE 4  
SCALE 1:5



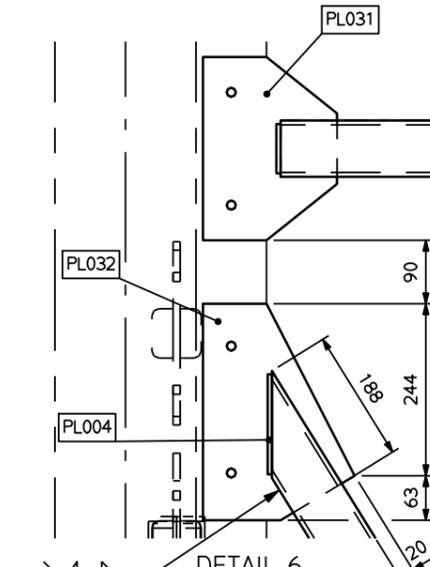
**DETAIL 4**  
REF. SHEET 01  
SCALE 1:5



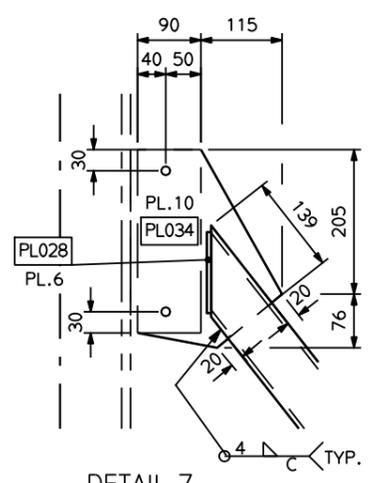
**DETAIL 8**  
REF. SHEET 01  
SCALE 1:5



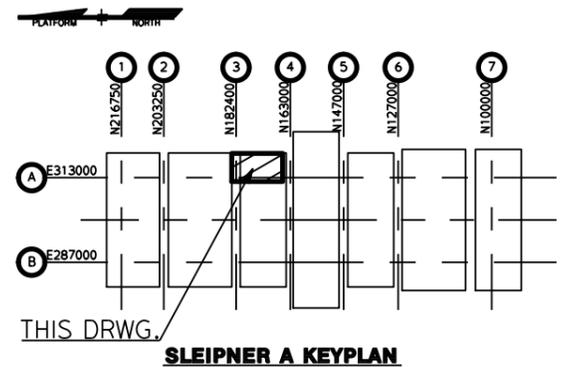
**DETAIL 5**  
REF. SHEET 01  
NOTE 4  
SCALE 1:5



**DETAIL 6**  
REF. SHEET 01  
NOTE 4  
SCALE 1:5



**DETAIL 7**  
REF. SHEET 01  
SCALE 1:5



- NOTES:**
1. FOR GENERAL NOTES AND SPECIFICATIONS SEE DRAWING NO.: C007-C-000--NT-202-01
  2. ALL DIMENSIONS ARE THEORETICAL. SHOP DETERMINE OVERLENGTH / CUT OFF.
  3. DESIGN CLASS - MATERIAL :  
 PLATES 2-Y30-420 U.N.O  
 PROFILES 4-Y07-355  
 BOLTS 8,8 GR 3.1 CERTIFICATE
  4. BRACES TO BE FIXED WITH TWO M12 BOLT ON EACH SIDE WHEN POSSIBLE USE SAME HOLES ALREADY DRILLED FOR BLASTWALL. IF NECESSARY DRILL EXTRA Ø13 HOLES.
  5. APPLIED TORQUE ON NUT : 987Nm FOR BOLT M30, 286Nm FOR BOLT M20, 20Nm FOR BOLT M12. HALF TORQUE ON SECOND NUT. BOLT TO BE GREASED WITH MOLYCOAT G-RAPID PLUS BEFORE TIGHTENING
  6. BRACES TO BE BOLTED TO TOP OF FOUNDATION PLATES, REF. DRWG: C007-C-C05E--NJ-002-01
  7. BOLTED TO EXISTING PLATE ON C05E COLUMN

REF. DRAWING NO.:	C007-C-C05E--NJ-005-01
C007-C-C05E--NJ-001-01	
C007-C-C05E--NJ-002-01	
POS. NO. PLATES:	SEE SHEET 01
POS. NO. PROFILES:	SEE SHEET 01
HOOK-UP NO.:	SEE SHEET 01
WELD NO.:	SEE SHEET 01
WELD INSP. CATEGORY:	SEE SHEET 01
WELD INSTRUCTION:	
PAINT SYSTEM:	SEE SHEET 01
TOTAL WEIGHT:	602 KG
SHORT CODE:	C05ETSBR5U

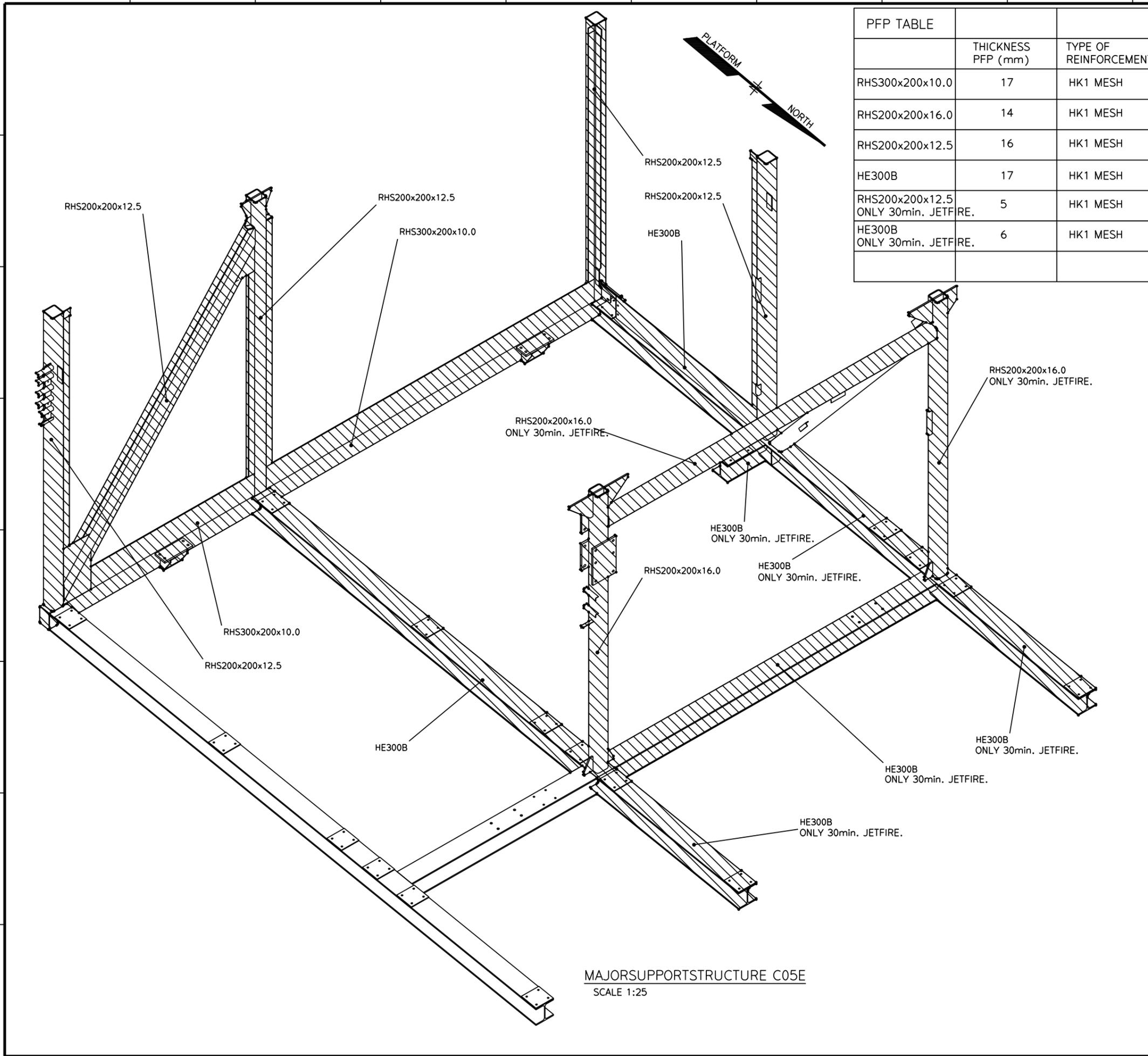


01	26.11.2013	FABR. & COMM. INFO S5	ST	PG/RIA	L0/BE
REV.	DATE	REASON FOR ISSUE	PREP.	CHECK.	APPR.

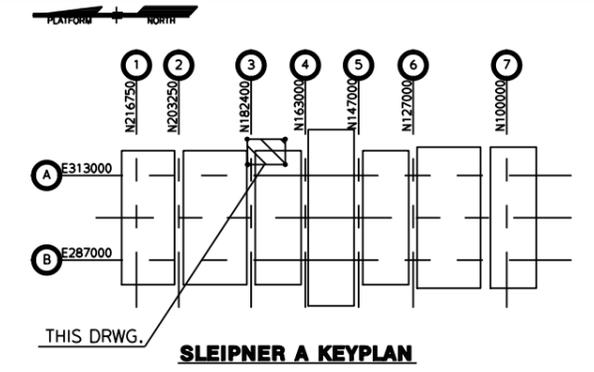


INSTALLATION: SLEIPNER A  
 DRAWING TITLE: C05E BALCONY. TEMPORARY BRACINGS FOR SECURING. SECTIONS AND DETAILS.

CONTR. NO.	104493
AS NOTED	AT A1
SCALE	SIZE
AREA	NETWORK
C05E	D04
C007-C-C05E-NK-011-02	
DRAWING NUMBER	
01	REV.



PFP TABLE		
	THICKNESS PFP (mm)	TYPE OF REINFORCEMENT
RHS300x200x10.0	17	HK1 MESH
RHS200x200x16.0	14	HK1 MESH
RHS200x200x12.5	16	HK1 MESH
HE300B	17	HK1 MESH
RHS200x200x12.5 ONLY 30min. JETFIRE.	5	HK1 MESH
HE300B ONLY 30min. JETFIRE.	6	HK1 MESH



- GENERAL NOTES:**
- CHARTEK 7 EPOXY SPRAY-ON MATERIAL SHALL BE USED.
  - WELDING AND PRE-HEATING WILL DAMAGE THE FIRE PROOFING MATERIAL. FOR WELD CUTBACK DISTANCES SEE APPLICATION MANUAL, NORSOK M-501 rev5 & TR0042.
  - MODULE FABRICATORS ARE RESPONSIBLE FOR PREPARING FABRICATION DRAWING FOR FIREPROOFING APPLICATION DETAILS.
  - APPLICATION OF FIREPROOFING MATERIAL SHALL STRICTLY FOLLOW THE FIREPROOFING APPLICATION MANUAL, NORSOK M-501 rev5 & TR0042.
  - SURFACE PREPARATION AND TOP COATING SHALL STRICTLY FOLLOW THE DOCUMENT "SURFACE PROTECTION REQUIREMENTS FOR PROCUREMENT PACKAGES", NORSOK M-501 rev5 & TR0042.
  - ALL APPLICATORS MUST ENDEAVOUR TO GIVE THE MATERIAL THICKNESS SHOWN. HOWEVER THE FOLLOWING TOLERANCE WILL BE ACCEPTED WITHOUT FORMAL ACCEPTANCE.
- | AVERAGE THICKNESS    | 5   | 6   | 7 | 8 | 10  | 12   | 14   | 16 | 17 |
|----------------------|-----|-----|---|---|-----|------|------|----|----|
| MIN. POINT THICKNESS | 4.5 | 5.5 | 6 | 7 | 8.5 | 10.5 | 12.5 | 14 | 15 |
- SUITABLE ANGLES TO BE PROVIDED FOR WATER DRAINAGE FROM COATING. NO POOLING ALLOWED.

- NOTES:**
- STRUCTURAL MEMBERS PROTECTED ON ALL SIDES.
  - 300mm COATBACK REQUIRED FOR ALL INCOMING MEMBERS OVER 1000mm<sup>2</sup> CROSS-SECTIONAL AREA.
  - CRITICAL STEEL TEMP. 400 deg. C
- FIRE SCENARIO**  
JETFIRE 30 min, 250kW/m<sup>2</sup>,  
WITH ADDITIONAL 90 min HC-FIRE, 200kW/m<sup>2</sup>
- PFP SURFACE AREA AND WEIGHT**
- NET PFP SURFACE AREA 78,0 m<sup>2</sup>.
  - TOTAL PFP SURFACE AREA 97,0 m<sup>2</sup>.
  - NET PFP WEIGHT 890 kg.
  - TOTAL PFP WEIGHT 1111 kg.

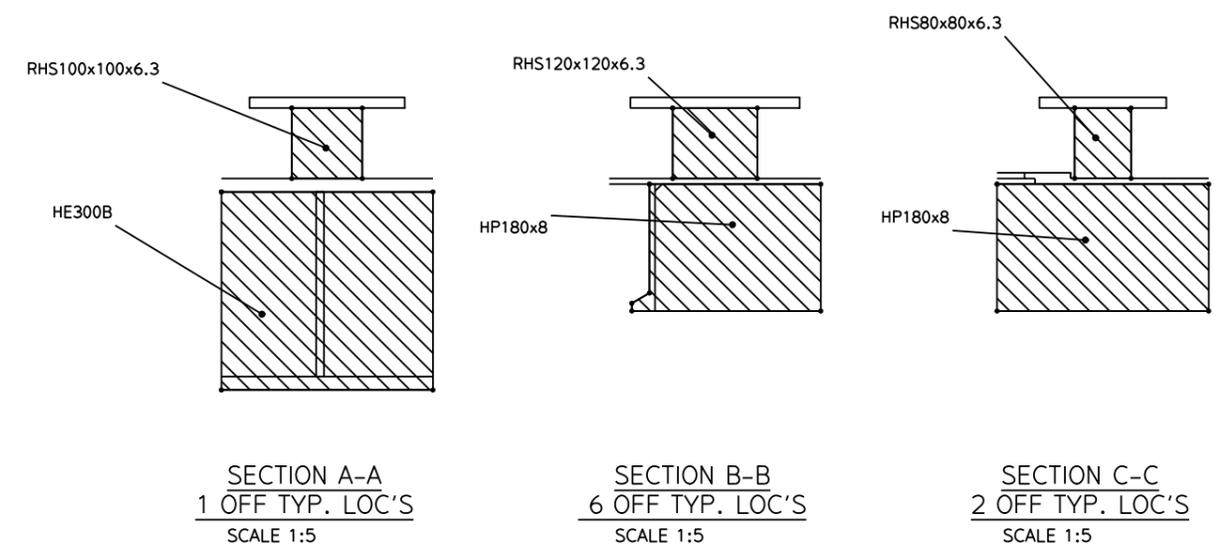
NOTES:	DESCRIPTION
	FIRE PROOFING MATERIAL

01	20.12.2013	RELEASED FOR IDC/VERIFICA	NTP	OF	FB
REV.	DATE	REASON FOR ISSUE	Made by	Checked by	Disc. Appr. Proj. Appr.

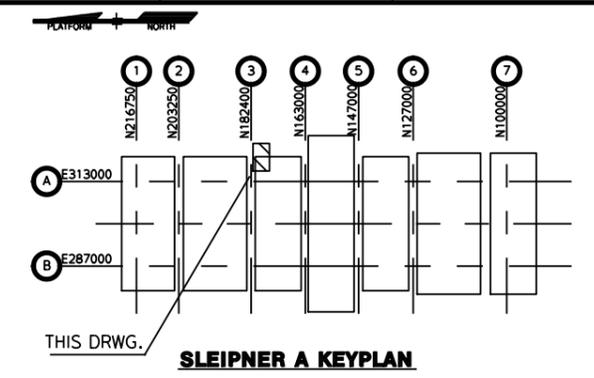
**AkerSolutions** PROJECT NAME: GINA KROG TIE-IN TO SLEIPNER

**Statoil** DRAWING TITLE: PASSIVE FIRE PROTECTION DRAWING - C05E BALCONY - MAIN STRUCTURE

NA	A1	104493	SLA	D04	C007-C-C05E-SL-200-01	01
Scale	Size	Proj.No.	Fac	Netw.	Proj.No.   Orig.Code	Area   Drg.Code   Seq.No.   Sht.No.   Rev.



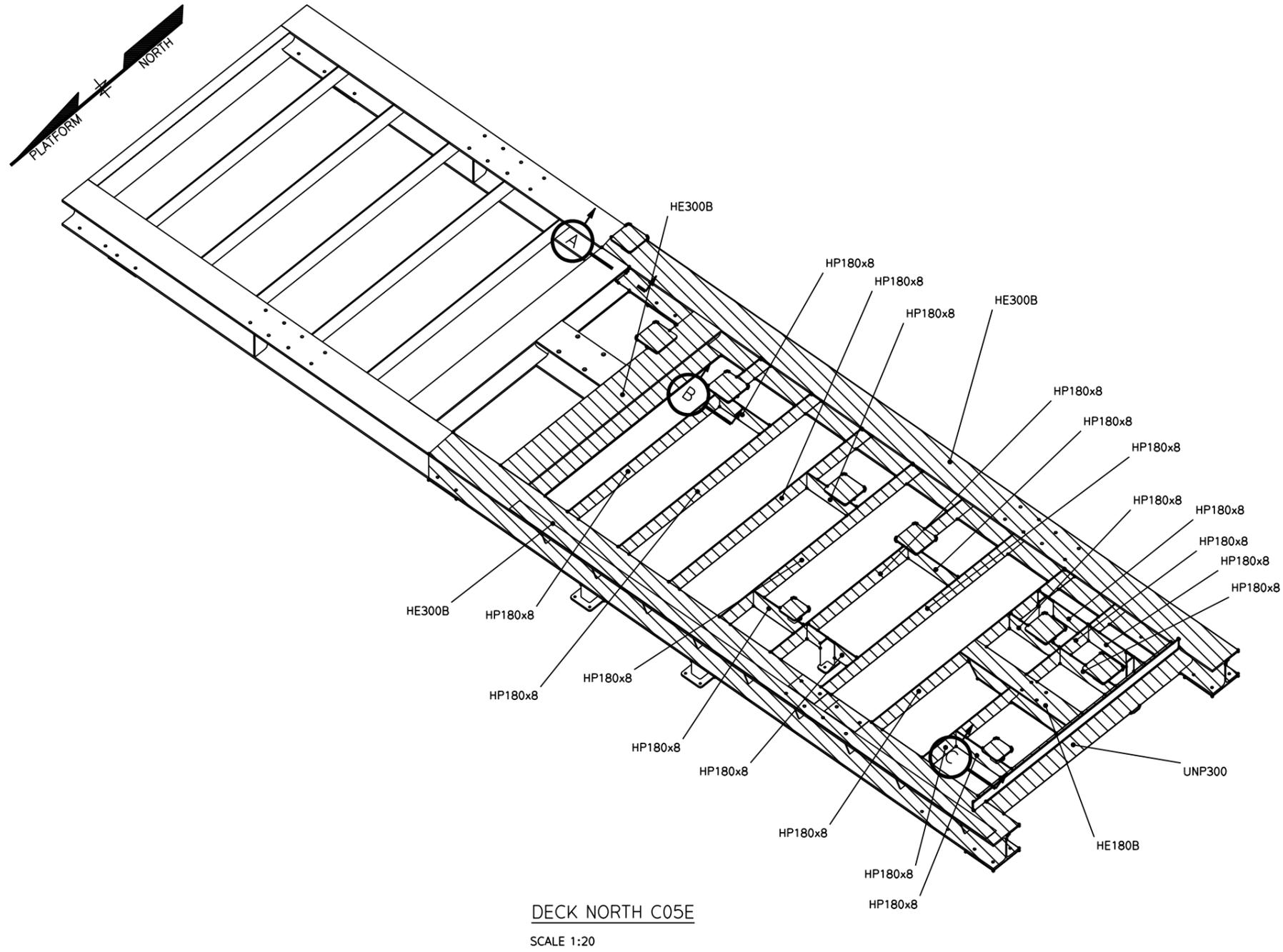
PFP TABLE		
	THICKNESS PFP (mm)	TYPE OF REINFORCEMENT
HE300B	6	HK1 MESH
HE180B	6	HK1 MESH
UNP300	6	HK1 MESH
HP180x8	6	HK1 MESH
RHS120x120x6.3	5	HK1 MESH
RHS100x100x6.3	5	HK1 MESH
RHS100x100x6.3	5	HK1 MESH



- GENERAL NOTES:**
- A. CHARTEK 7 EPOXY SPRAY-ON MATERIAL SHALL BE USED.
  - B. WELDING AND PRE-HEATING WILL DAMAGE THE FIRE PROOFING MATERIAL. FOR WELD CUTBACK DISTANCES SEE APPLICATION MANUAL, NORSOK M-501 rev5 & TR0042.
  - C. MODULE FABRICATORS ARE RESPONSIBLE FOR PREPARING FABRICATION DRAWING FOR FIREPROOFING APPLICATION DETAILS.
  - D. APPLICATION OF FIREPROOFING MATERIAL SHALL STRICTLY FOLLOW THE FIREPROOFING APPLICATION MANUAL, NORSOK M-501 rev5 & TR0042.
  - E. SURFACE PREPARATION AND TOP COATING SHALL STRICTLY FOLLOW THE DOCUMENT "SURFACE PROTECTION REQUIREMENTS FOR PROCUREMENT PACKAGES", NORSOK M-501 rev5 & TR0042.
  - F. ALL APPLICATORS MUST ENDEAVOUR TO GIVE THE MATERIAL THICKNESS SHOWN. HOWEVER THE FOLLOWING TOLERANCE WILL BE ACCEPTED WITHOUT FORMAL ACCEPTANCE.
- | AVERAGE THICKNESS    | 5   | 6   | 7 | 8 | 9 | 10  | 11  | 12   |
|----------------------|-----|-----|---|---|---|-----|-----|------|
| MIN. POINT THICKNESS | 4.5 | 5.5 | 6 | 7 | 8 | 8.5 | 9.5 | 10.5 |
- G. SUITABLE ANGLES TO BE PROVIDED FOR WATER DRAINAGE FROM COATING. NO POOLING ALLOWED.

- NOTES:**
1. MEMBERS PROTECTED UNDERNEATH DECK PLATES. NO PFP ON TOP OF TOP FLANGES AND DECK PLATES
  2. 300mm COATBACK REQUIRED FOR ALL INCOMING MEMBERS OVER 1000mm<sup>2</sup> CROSS-SECTIONAL AREA.
  3. CRITICAL STEEL TEMP. 400 deg. C
- FIRE SCENARIO**  
JETFIRE 30 min, 250kW/m<sup>2</sup>
- PFP SURFACE AREA AND WEIGHT**
1. NET PFP SURFACE AREA 38,9 m<sup>2</sup>.
  2. TOTAL PFP SURFACE AREA 56,4 m<sup>2</sup>.
  3. NET PFP WEIGHT 235 kg.
  4. TOTAL PFP WEIGHT 340 kg.

NOTES:	DESCRIPTION
	FIRE PROOFING MATERIAL

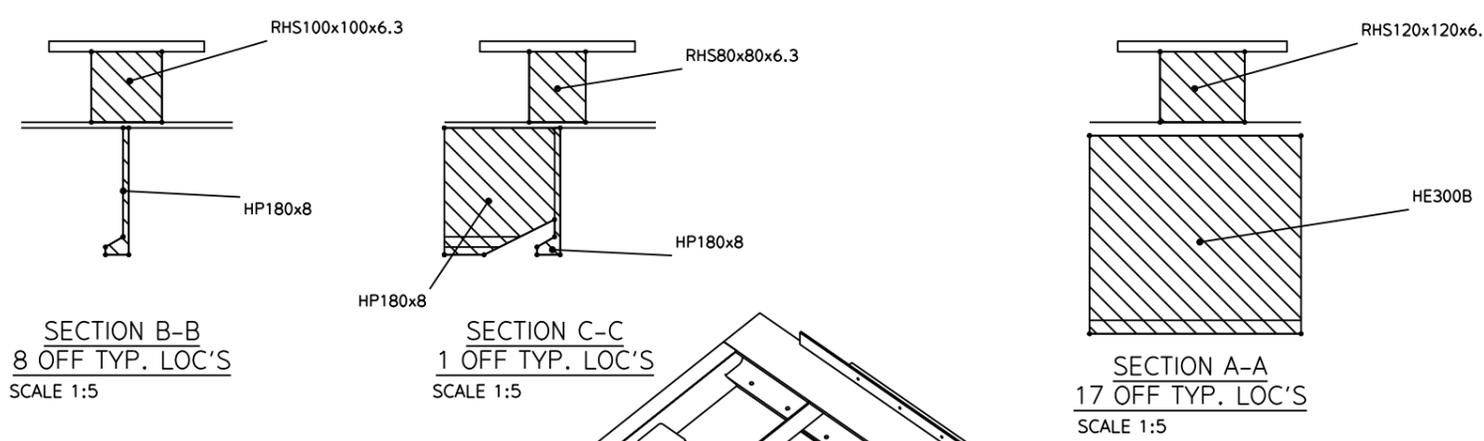


01	20.12.2013	RELEASED FOR IDC/VERIFICA	NTP	OF	FB
REV.	DATE	REASON FOR ISSUE	Made by	Checked by	Disc. Appr. Proj. Appr.

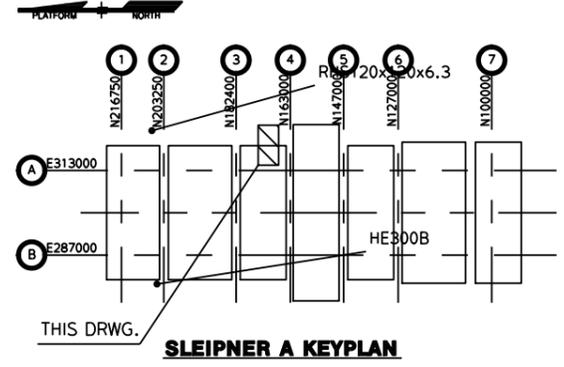
**AkerSolutions** PROJECT NAME: GINA KROG TIE-IN TO SLEIPNER

**Statoil** DRAWING TITLE: PASSIVE FIRE PROTECTION DRAWING - C05E BALCONY - DECK NORTH

NA	A1	104493	SLA	D04	C007-C-C05E-SL-202-01	01
Scale	Size	Proj.No.	Fac	Netw.	Proj.No.   Orig.Code Area	Seq.No.   Sht.No. Rev.



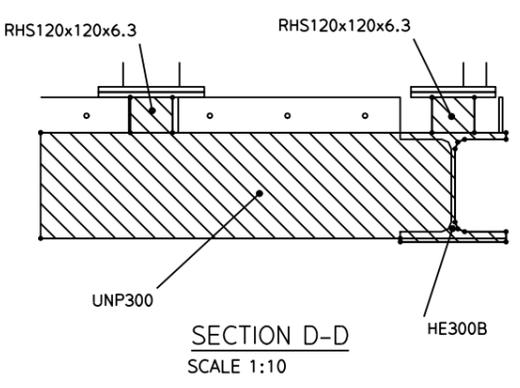
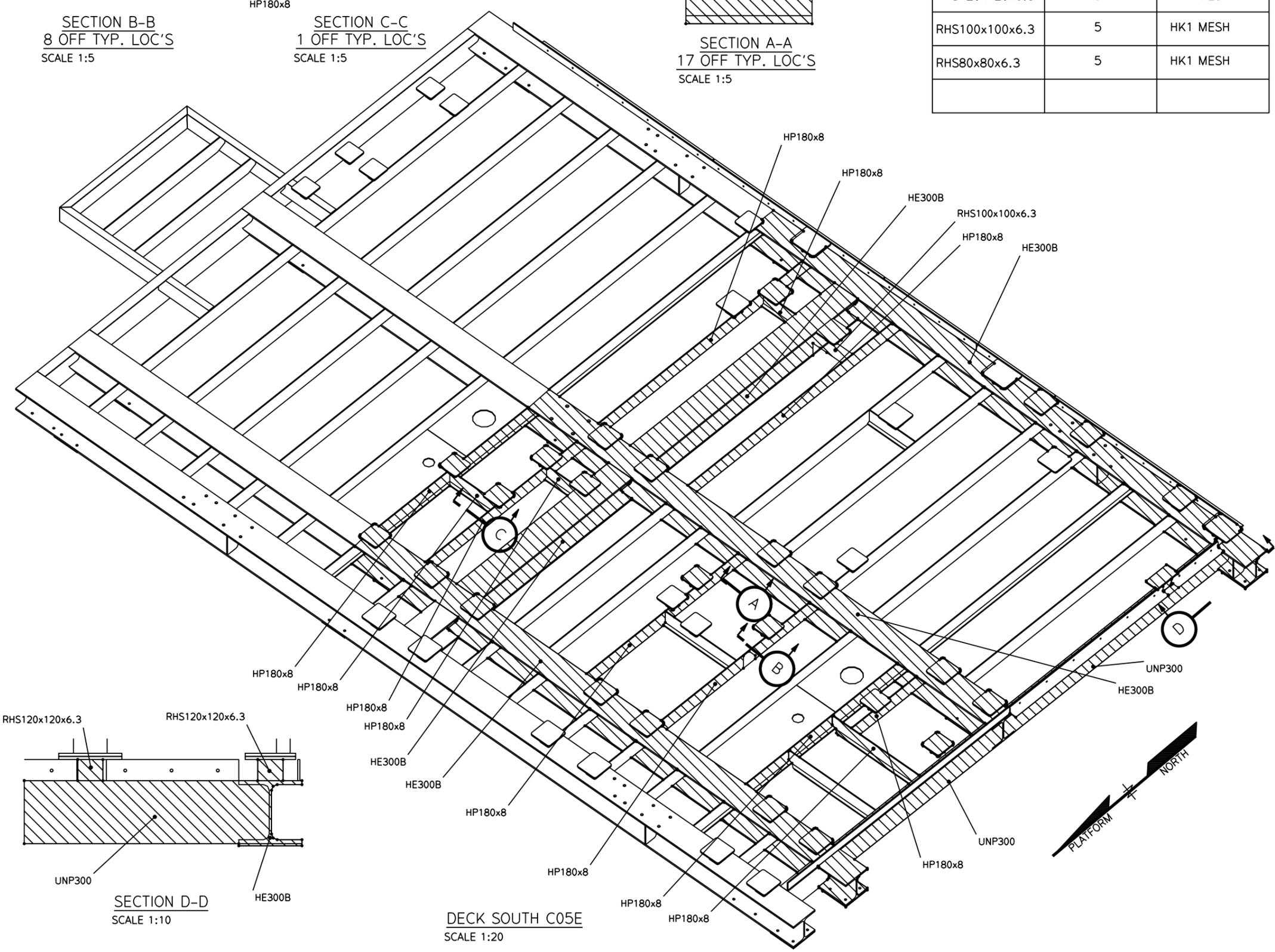
PFP TABLE		
	THICKNESS PFP (mm)	TYPE OF REINFORCEMENT
HE300B	6	HK1 MESH
UNP300	6	HK1 MESH
HP180x8	6	HK1 MESH
RHS120x120x6.3	5	HK1 MESH
RHS100x100x6.3	5	HK1 MESH
RHS80x80x6.3	5	HK1 MESH



- GENERAL NOTES:**
- CHARTEK 7 EPOXY SPRAY-ON MATERIAL SHALL BE USED.
  - WELDING AND PRE-HEATING WILL DAMAGE THE FIRE PROOFING MATERIAL. FOR WELD CUTBACK DISTANCES SEE APPLICATION MANUAL, NORSOK M-501 rev5 & TR0042.
  - MODULE FABRICATORS ARE RESPONSIBLE FOR PREPARING FABRICATION DRAWING FOR FIREPROOFING APPLICATION DETAILS.
  - APPLICATION OF FIREPROOFING MATERIAL SHALL STRICTLY FOLLOW THE FIREPROOFING APPLICATION MANUAL, NORSOK M-501 rev5 & TR0042.
  - SURFACE PREPARATION AND TOP COATING SHALL STRICTLY FOLLOW THE DOCUMENT "SURFACE PROTECTION REQUIREMENTS FOR PROCUREMENT PACKAGES", NORSOK M-501 rev5 & TR0042.
  - ALL APPLICATORS MUST ENDEAVOUR TO GIVE THE MATERIAL THICKNESS SHOWN. HOWEVER THE FOLLOWING TOLERANCE WILL BE ACCEPTED WITHOUT FORMAL ACCEPTANCE.
- |                      |     |     |   |   |   |     |     |      |
|----------------------|-----|-----|---|---|---|-----|-----|------|
| AVERAGE THICKNESS    | 5   | 6   | 7 | 8 | 9 | 10  | 11  | 12   |
| MIN. POINT THICKNESS | 4.5 | 5.5 | 6 | 7 | 8 | 8.5 | 9.5 | 10.5 |
- SUITABLE ANGLES TO BE PROVIDED FOR WATER DRAINAGE FROM COATING. NO POOLING ALLOWED.

- NOTES:**
- MEMBERS PROTECTED UNDERNEATH DECK PLATES. NO PFP ON TOP OF TOP FLANGES AND DECK PLATES
  - 300mm COATBACK REQUIRED FOR ALL INCOMING MEMBERS OVER 1000mm<sup>2</sup> CROSS-SECTIONAL AREA.
  - CRITICAL STEEL TEMP. 400 deg. C
- FIRE SCENARIO**  
JETFIRE 30 min, 250kW/m<sup>2</sup>
- PFP SURFACE AREA AND WEIGHT**
- NET PFP SURFACE AREA 34,8 m<sup>2</sup>.
  - TOTAL PFP SURFACE AREA 50,4 m<sup>2</sup>.
  - NET PFP WEIGHT 210 kg.
  - TOTAL PFP WEIGHT 304 kg.

NOTES:	DESCRIPTION
	FIRE PROOFING MATERIAL



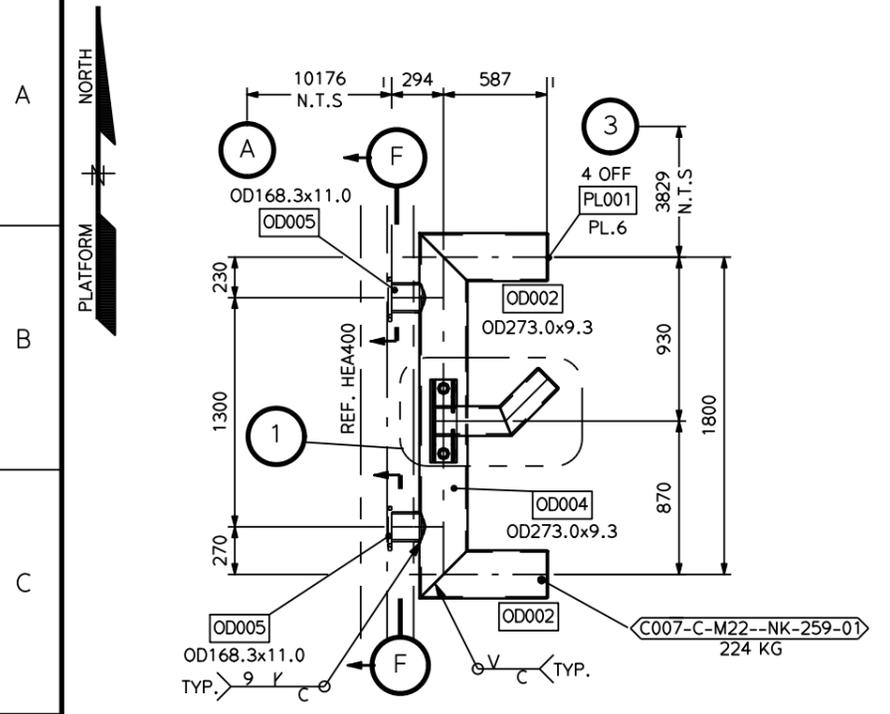
DECK SOUTH C05E  
SCALE 1:20

REV.	DATE	REASON FOR ISSUE	NTP Made by	OF Checked by	FB Disc. Appr.	Proj. Appr.
01	20.12.2013	RELEASED FOR IDC/VERIFICA				

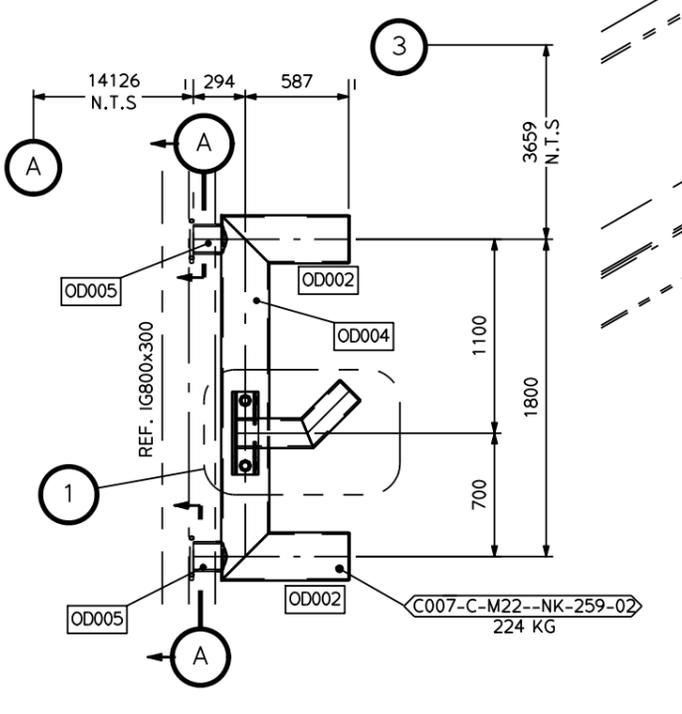
**AkerSolutions** PROJECT NAME: GINA KROG TIE-IN TO SLEIPNER

**Statoil** DRAWING TITLE: PASSIVE FIRE PROTECTION DRAWING - C05E BALCONY - DECK SOUTH

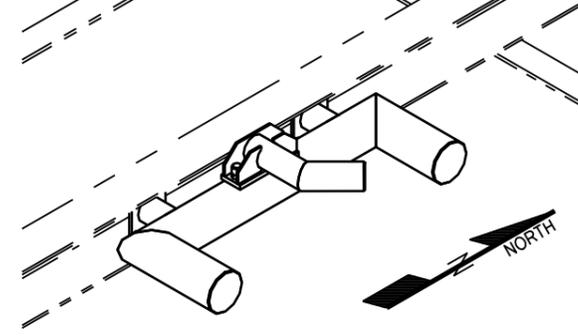
NA	A1	104493	SLA	D04	C007-C-C05E-SL-203-01	01
Scale	Size	Proj.No.	Fac	Netw.	Proj.No.   Orig.Code   Area   Drg.Code   Seq.No.   Sht.No.	Rev.



PLAN OF TEMPORARY WIRE PROTECTION ON MAIN DECK  
EL.515.950 T.O.S  
SCALE 1:20

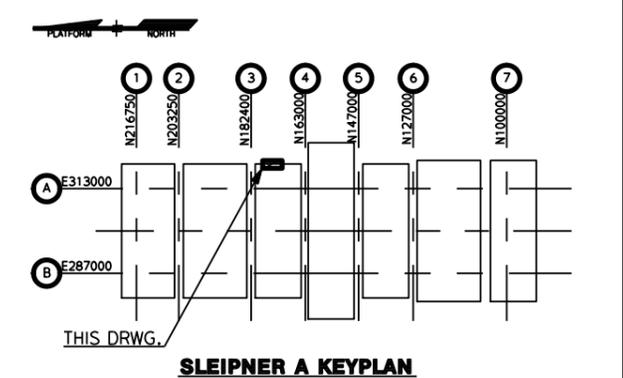


PLAN OF TEMPORARY WIRE PROTECTION ON LOWER MEZZ DECK  
EL. 523.950 T.O.S  
SCALE 1:20



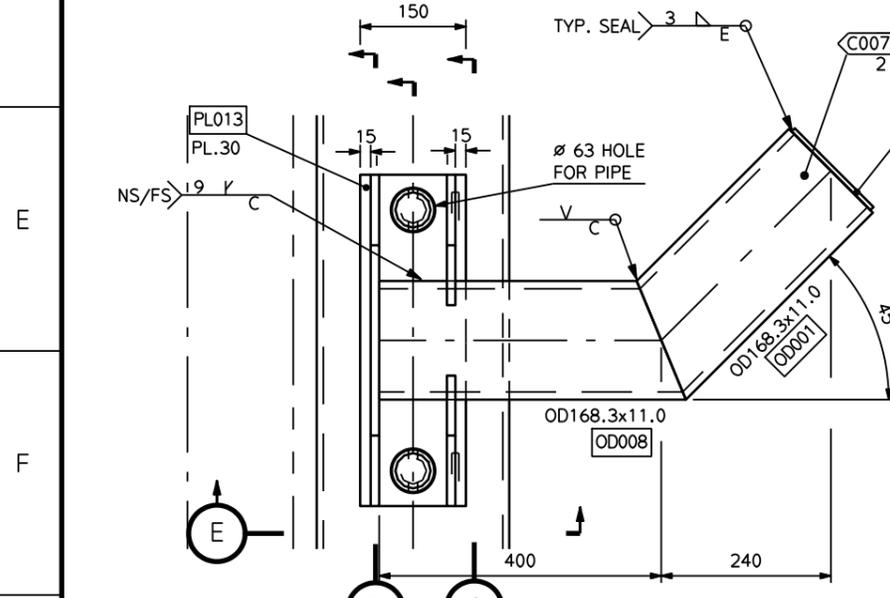
ISO VIEW  
SCALE 1:20

ELEVATIONS OF WIRE PROTECTION ON:  
MAIN DECK: EL.515892 T.O.OD004  
LOWER MEZZ DECK: EL.523837 T.O.OD004

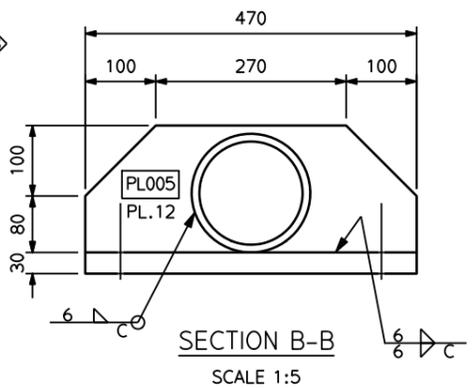


SLEIPNER A KEYPLAN

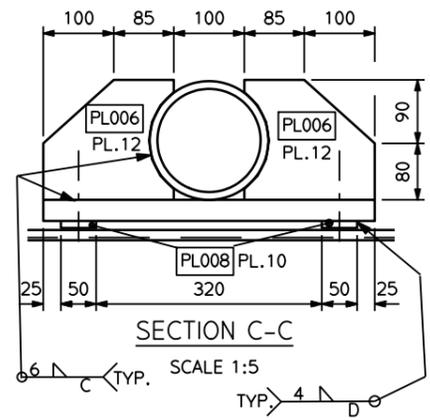
- NOTES:**
- FOR GENERAL NOTES AND SPECIFICATIONS SEE DRAWING NO.: C007-C-000--NT-202-01
  - ALL DIMENSIONS ARE THEORETICAL. SHOP DETERMINE OVERLENGTH / CUT OFF.
  - DESIGN CLASS - MATERIAL :  
PLATES 2-Y30-420 U.N.O  
PIPES AP1 5L X52  
BOLTS & NUTS 8.8 GR. 3.1 CERTIFICATE
  - APPLIED TORQUE ON NUT : 147Nm FOR BOLT M16, HALF TORQUE ON SECOND NUT  
BOLT TO BE GREASED WITH MOLYCOAT G-RAPID PLUS BEFORE TIGHTENING
  - GUIDES ONLY TO BE INSTALLED OFFSHORE BEFORE INSTALLING C05E SOUTH DECK. DO NOT USE GUIDES WHEN INSTALLING MAIN FRAME.
  - LOCKING BOLTS TO BE FINGERTIGHT



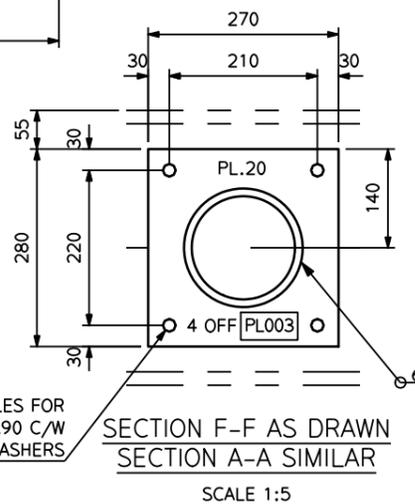
DETAIL 1  
2 LOCATIONS AS DRAWN  
NOTE 5  
SCALE 1:5



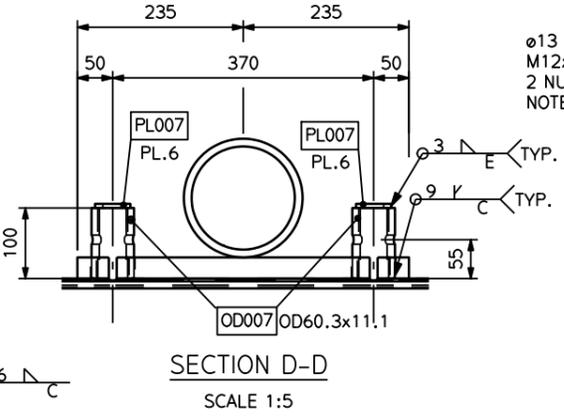
SECTION B-B  
SCALE 1:5



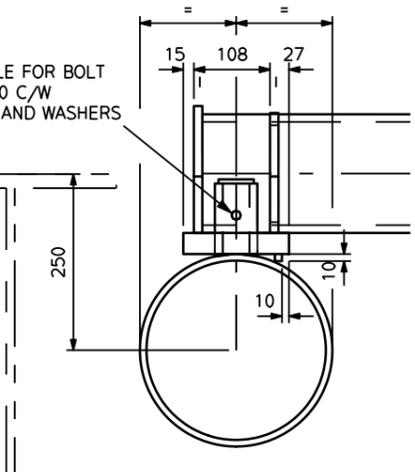
SECTION C-C  
SCALE 1:5



SECTION F-F AS DRAWN  
SECTION A-A SIMILAR  
SCALE 1:5



SECTION D-D  
SCALE 1:5



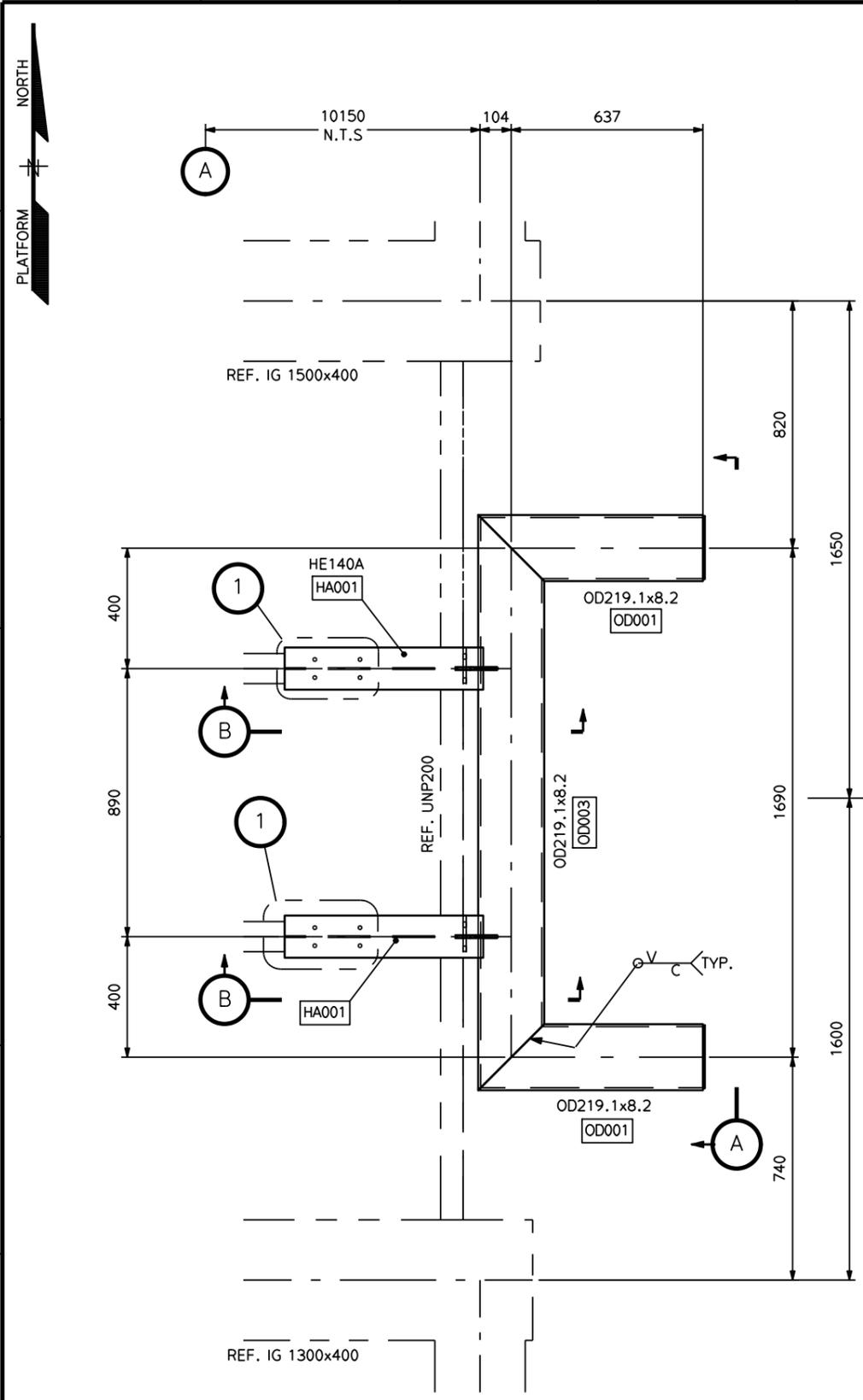
SECTION E-E  
SCALE 1:5

REF.DRAWING NO.:	C007-C-M23--NB-111-01
C007-C-000--NT-203-02	
C007-C-M22--NB-111-01	
POS.NO.PLATES:	PL001, PL003, PL005-PL008, PL010, PL013
POS.NO.PROFILES:	OD001-OD002, OD004-OD005, OD007-OD008
HOOK-UP NO.:	C007-C-M22--NK-259-01-03
WELD NO.:	350, 360, 365, 380, 500
WELD INSP.CATEGORY:	C, E WELD INSTRUCTION:
PAINT SYSTEM:	COLOUR PINK, RAL 3015, SYSTEM 1T
TOTAL WEIGHT:	568 KG SHORT CODE: M22TSWP02

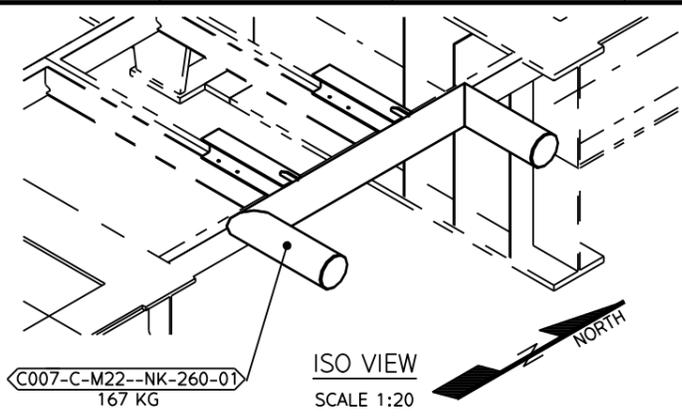


INSTALLATION: SLEIPNER A  
DRAWING TITLE: C05E BALCONY. WIRE PROTECTION ON LOWER MEZZ.DECK EL.523.950 & MAIN DECK EL.515.960 T.O.S.

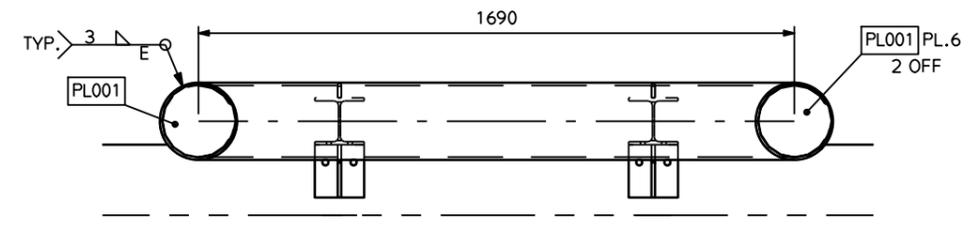
CONTR. NO.	104493
AS NOTED	AT A1 M22 D04
SCALE	SIZE AREA NETWORK
C007-C-M22--NK-259-01	01
DRAWING NUMBER	REV.



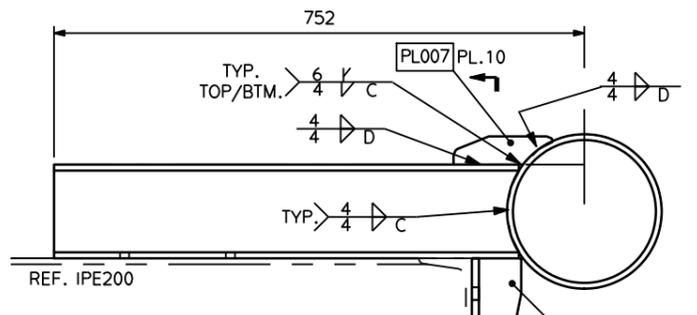
PLAN OF TEMPORARY WIRE PROTECTION IN INFILL AREA M22/M23  
DECKPLATE OMITTED FOR CLARITY  
SCALE 1:10



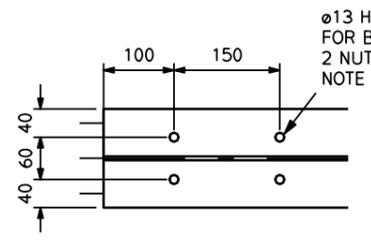
ISO VIEW  
SCALE 1:20



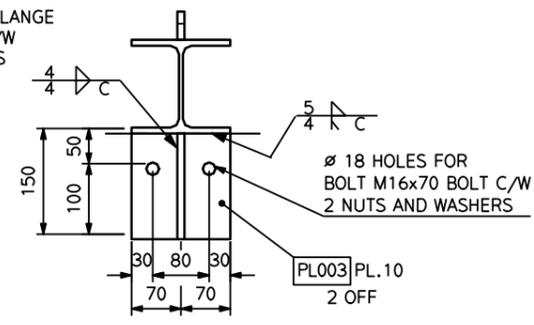
SECTION A-A  
SCALE 1:10



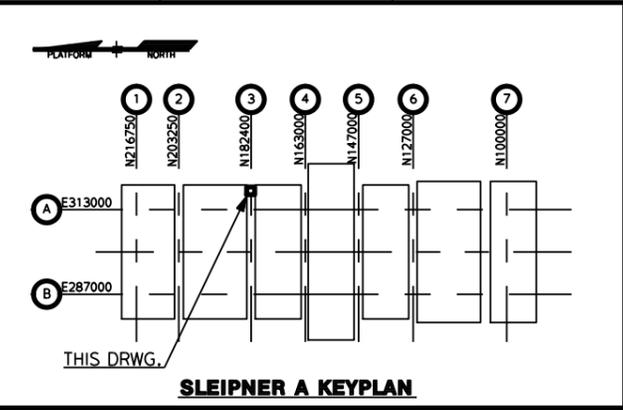
SECTION B-B  
2 LOCATIONS AS DRAWN  
SCALE 1:5



DETAIL 1  
SCALE 1:5



SECTION C-C  
SCALE 1:5



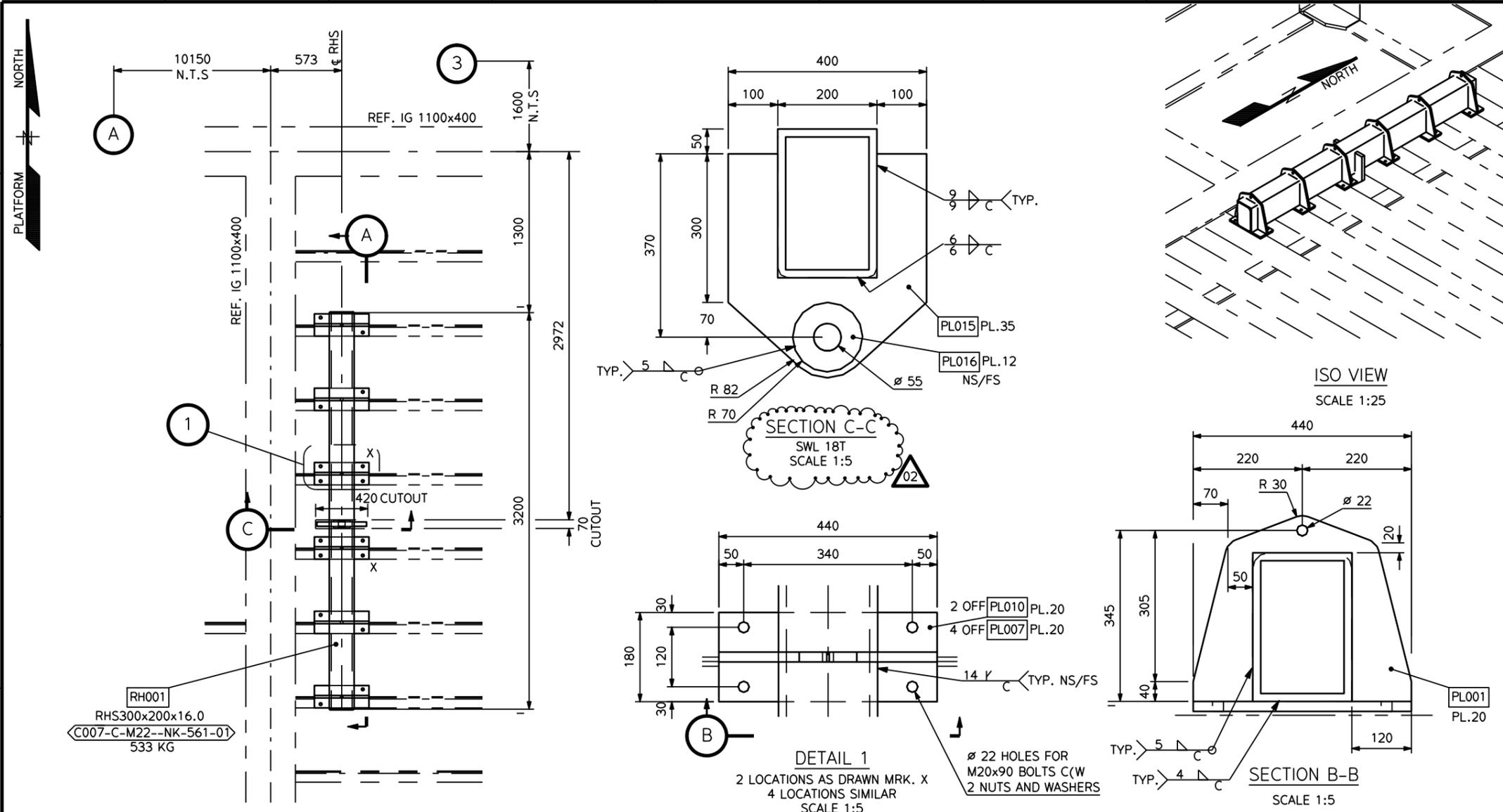
SLEIPNER A KEYPLAN

- NOTES:
1. FOR GENERAL NOTES AND SPECIFICATIONS SEE DRAWING NO.: C007-C-000--NT-202-01
  2. ALL DIMENSIONS ARE THEORETICAL. SHOP DETERMINE OVERLENGTH / CUT OFF.
  3. DESIGN CLASS - MATERIAL :  
 PLATES 2-Y30-420 U.N.O  
 PROFILES 4-Y26-355  
 BOLTS & NUTS 8.8 GR. 3.1 CERTIFICATE  
 PIPES API SL X52
  4. APPLIED TORQUE ON NUT : 60Nm FOR BOLT M12, 147Nm ON BOLT M16, HALF TORQUE ON SECOND NUT BOLT TO BE GREASED WITH MOLYCOAT G-RAPID PLUS BEFORE TIGHTENING
  5. DRILL BOLTHOLES OFFSHORE TO FIT EXISTING IPE BEAM
  6. TEMPORARY REMOVAL OF LDPH PLATES IS REQUIRED BEFORE INSTALLATION OF WIRE PROTECTION

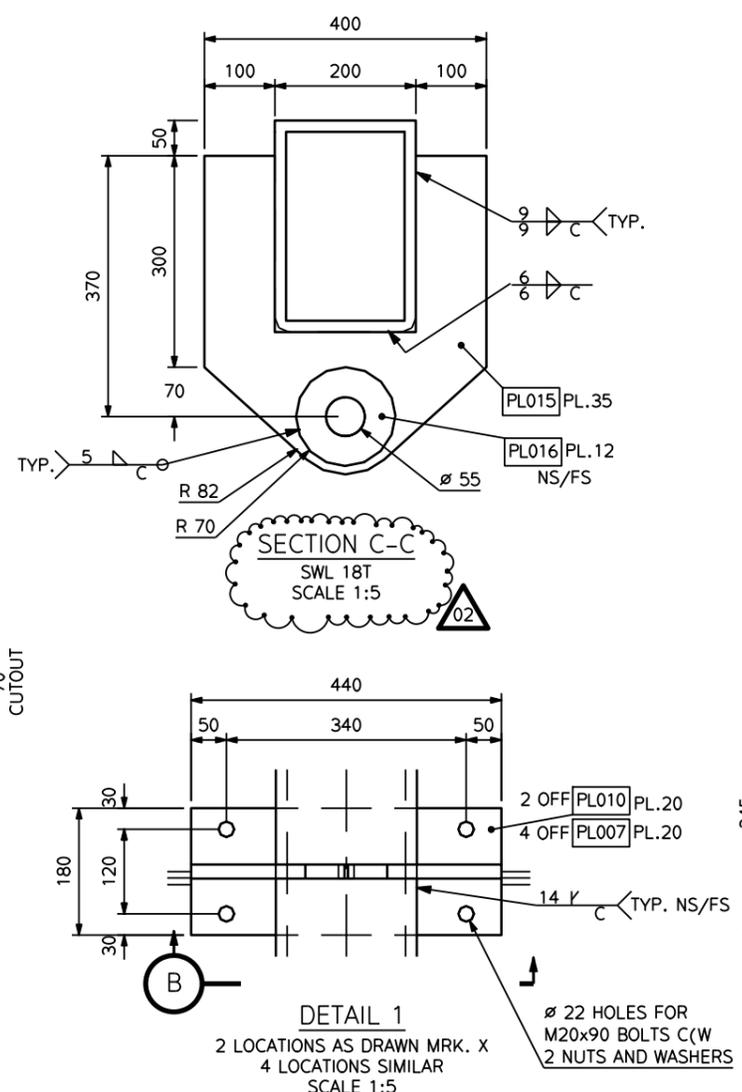
REF. DRAWING NO.:	C007-C-M23--NB-111-01
C007-C-000--NT-203-02	
C007-C-M22--NB-111-01	
POS. NO. PLATES:	PL001, PL003, PL005, PL007
POS. NO. PROFILES:	OD001, OD003, HA001
HOOK-UP NO.:	01
WELD NO.:	350, 360, 380, 500
WELD INSP. CATEGORY:	C, E WELD INSTRUCTION:
PAINT SYSTEM:	
	COLOUR PINK, RAL 3015, SYSTEM 1T
TOTAL WEIGHT:	167 KG
SHORT CODE:	M22TSPR01

<b>AkerSolutions</b>					
01	15.10.2013	FABR. & COMM. INFO S5	ST	RIA/PG	L0/BE
REV.	DATE	REASON FOR ISSUE	PREP.	CHECK.	APPR.

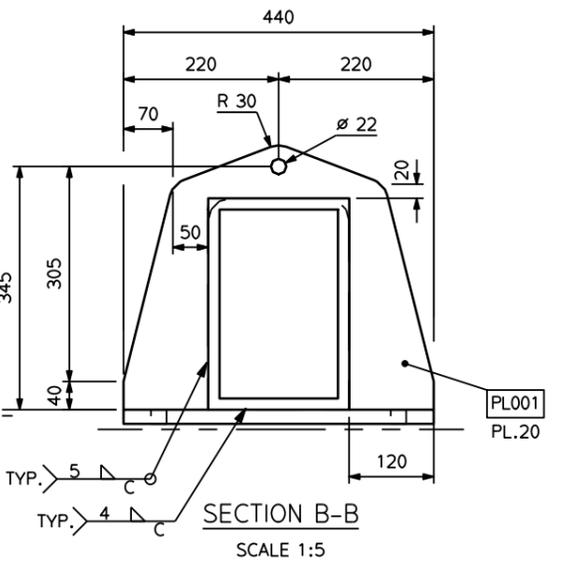
<b>Statoll</b>		INSTALLATION: SLEIPNER A	
		DRAWING TITLE: C05E BALCONY. WIRE PROTECTION ON MAIN DECK EL 515.950 T.O.S.	
CONTR. NO.	104493		
AS NOTED	AT A1	M22	D04
SCALE	SIZE	AREA	NETWORK
		C007-C-M22--NK-260-01	
		DRAWING NUMBER	
		01	
		REV.	



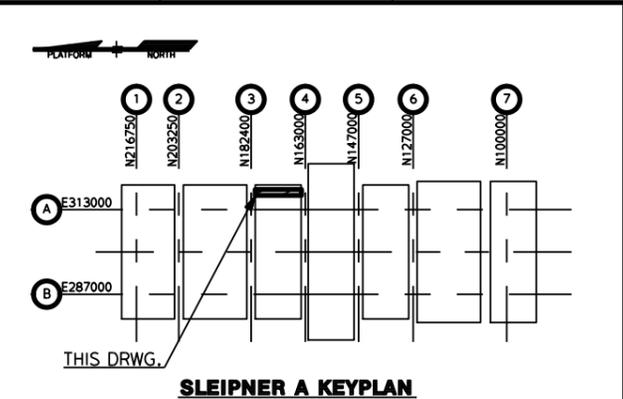
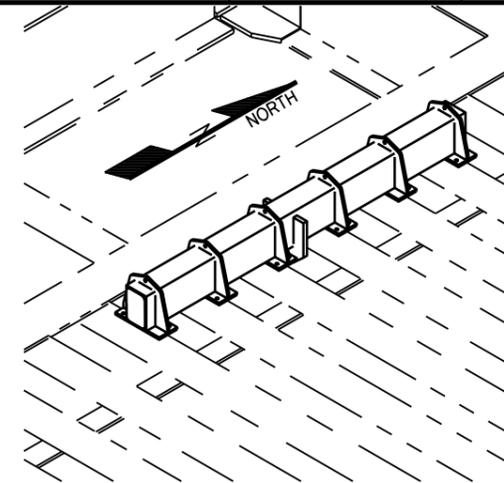
PLAN OF LIFTING BEAM ON LOWER MEZZ DECK EL. 523.950  
SCALE 1:20



DETAIL 1  
2 LOCATIONS AS DRAWN MRK. X  
4 LOCATIONS SIMILAR  
SCALE 1:5



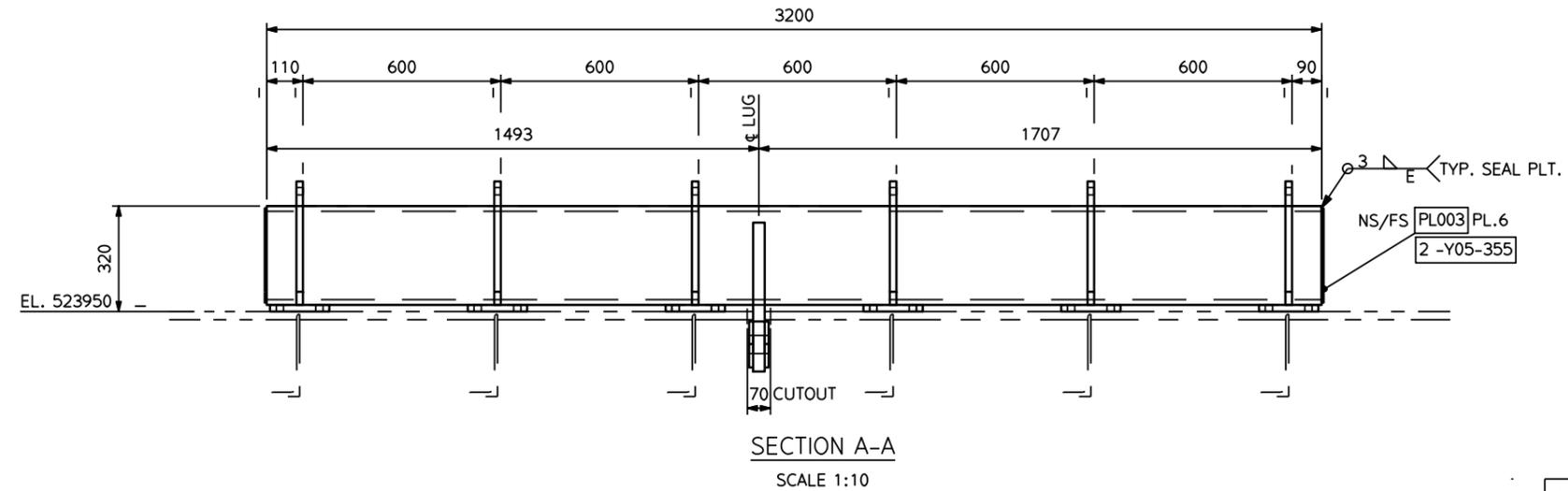
ISO VIEW  
SCALE 1:25



SLEIPNER A KEYPLAN

- NOTES:
1. FOR GENERAL NOTES AND SPECIFICATIONS SEE DRAWING NO.: C007-C-000--NT-202-01
  2. ALL DIMENSIONS ARE THEORETICAL. SHOP DETERMINE OVERLENGTH / CUT OFF.
  3. DESIGN CLASS - MATERIAL :  
PLATES 2-Y30-420 U.N.O  
PROFILES 4-Y07-355  
BOLTS & NUTS 8.8 GR. 3.1 CERTIFICATE
  4. APPLIED TORQUE ON NUT : 100Nm FOR BOLT M20  
HALF TORQUE ON SECOND NUT  
BOLT TO BE GREASED WITH MOLYCOAT G-RAPID PLUS BEFORE TIGHTENING
  5. THIS DRAWING CONTAINS DEMOLITION WORK (CUTOUT FOR LUG)
  6. SAFE WORKING LOAD LIMIT (SWL) AND HOOK-UP NO. TO BE PAINTED WITH 50mm HIGH LETTERS IN BLACK ON PINK BACKGROUND LOCAL TO LIFTING LUG/LIFTING BEAM.
  7. LIFTING LUG TO BE CERTIFIED BY ENTERPRISE OF COMPETENCE.

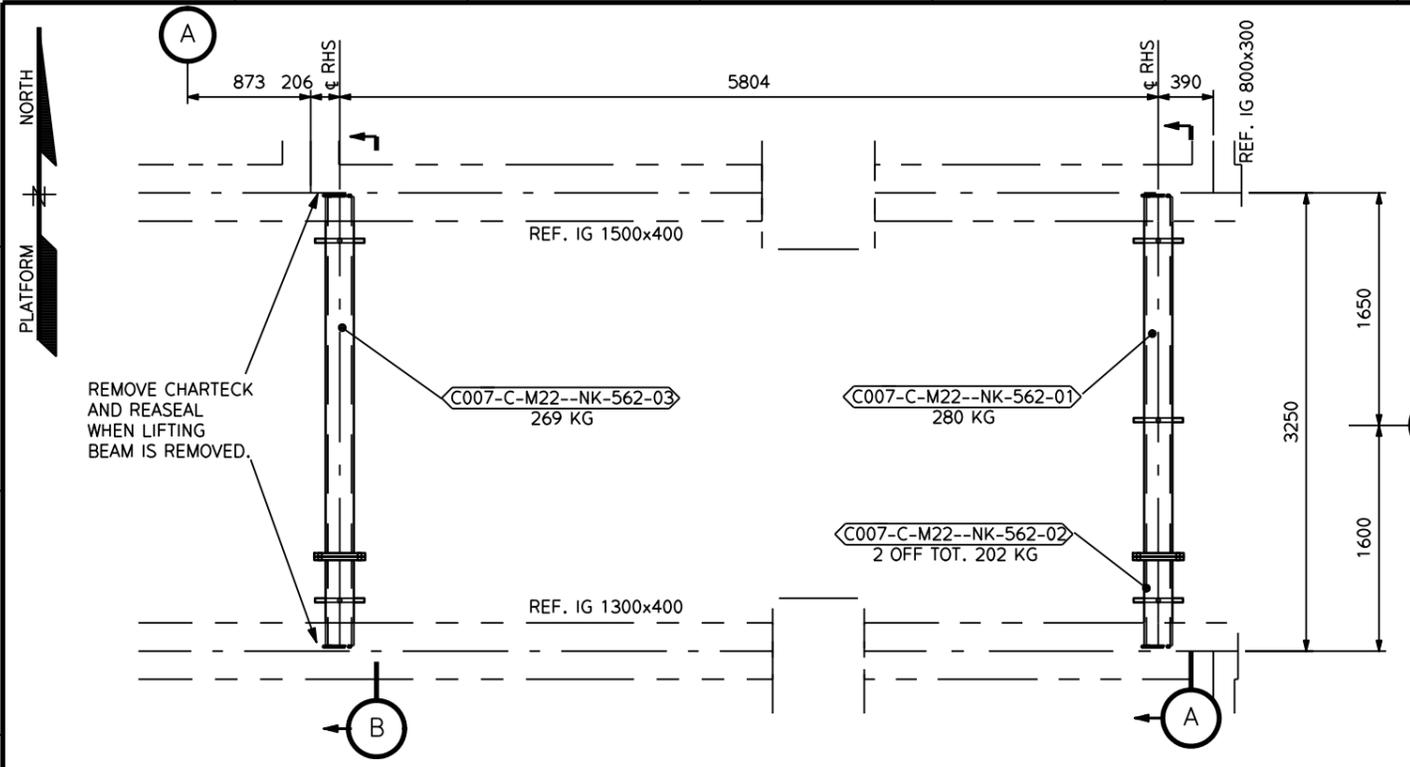
REF.DRAWING NO.:	C007-C-000--NT-203-01
POS.NO.PLATES:	PL001, PL003, PL007, PL010, PL015-PL016
POS.NO.PROFILES:	RH001
HOOK-UP NO.:	C007-C-M22--NK-561-01
WELD NO.:	350, 385, 500
WELD INSP.CATEGORY:	C, E WELD INSTRUCTION:
PAINT SYSTEM:	COLOUR PINK, RAL 3015, SYSTEM 1T
TOTAL WEIGHT:	533 KG SHORT CODE: M22TSLI02



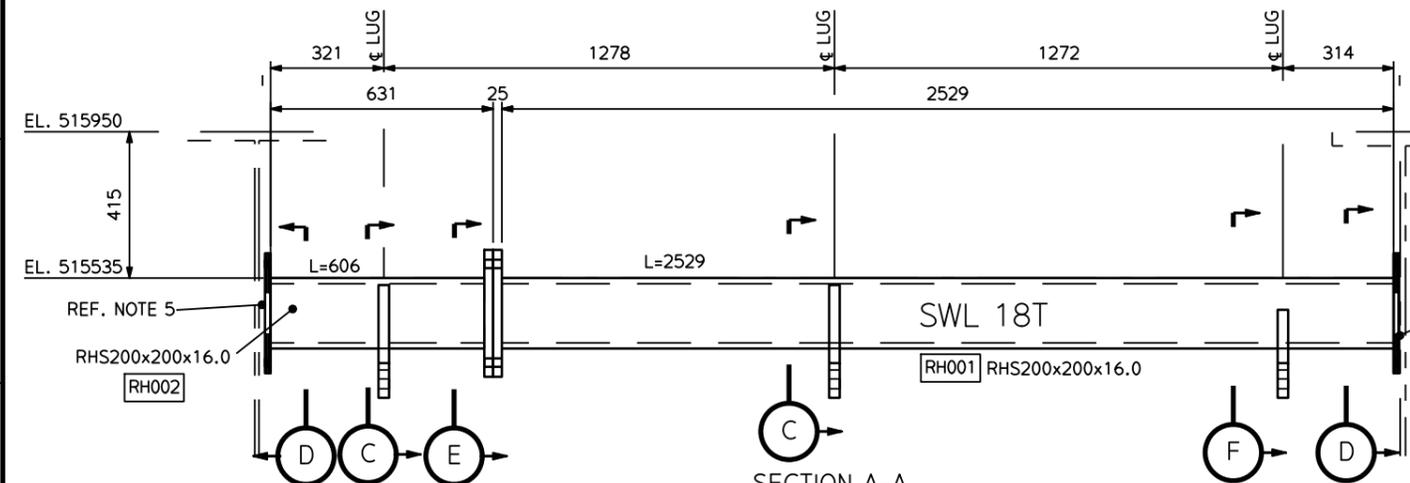
SECTION A-A  
SCALE 1:10

WEIGHT TO BE REMOVED  
CUTOUT IN DECK: 1 KG

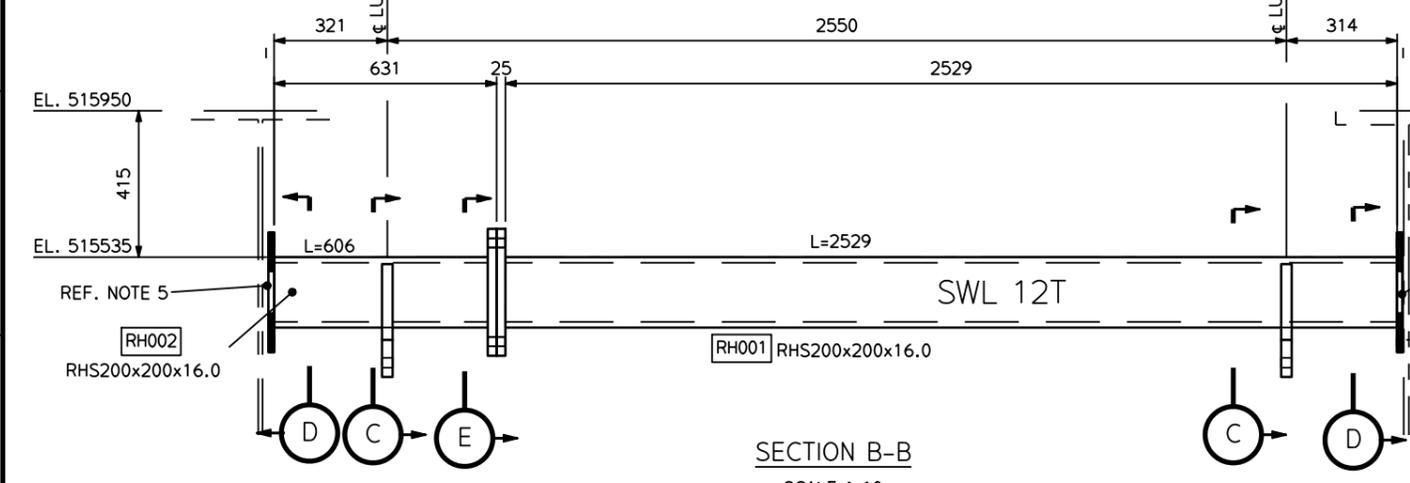
CONTR. NO. 104493		INSTALLATION: SLEIPNER A	
DRAWING TITLE: C05E BALCONY. TEMPORARY LIFTING BEAM ON LOWER MEZZ-DECK EL. 523.950 T.O.S.		AS NOTED AT A1 M22 D04 C007-C-M22--NK-561-01 02	
SCALE	SIZE	AREA	NETWORK
			DRAWING NUMBER
			REV.



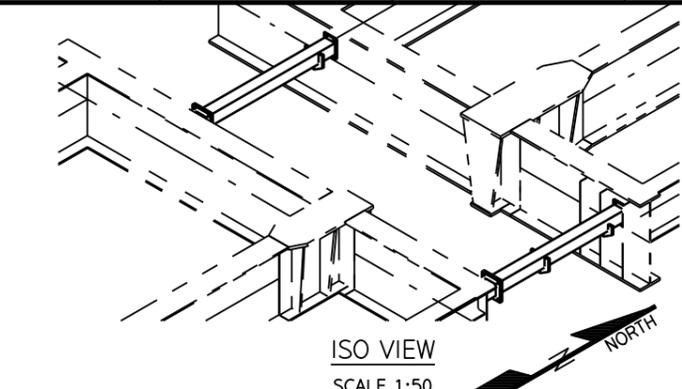
PLAN OF LIFTING BEAMS ABOVE C05E NORTH DECK  
SCALE 1:25



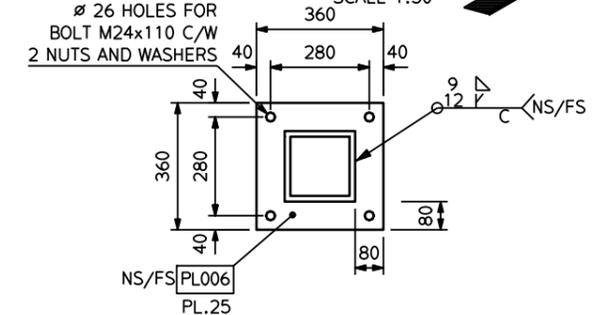
SECTION A-A  
SCALE 1:10



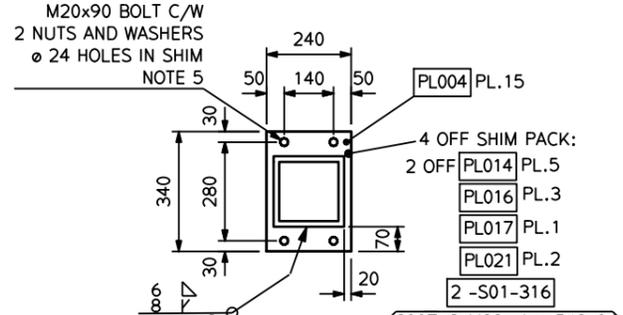
SECTION B-B  
SCALE 1:10



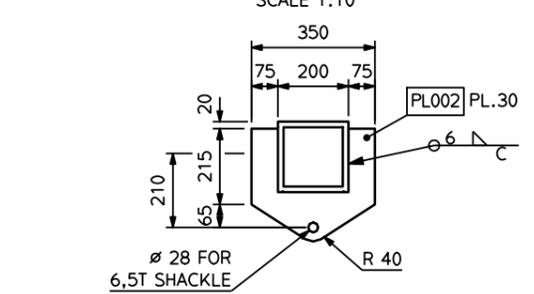
ISO VIEW  
SCALE 1:50



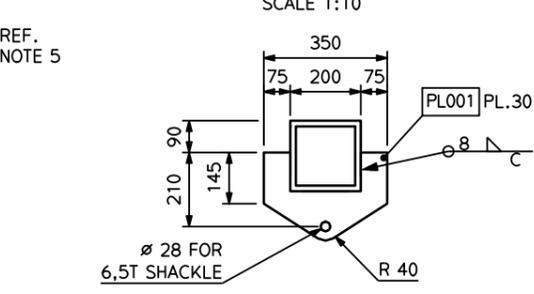
SECTION E-E  
2 LOCATIONS AS DRAWN  
SCALE 1:10



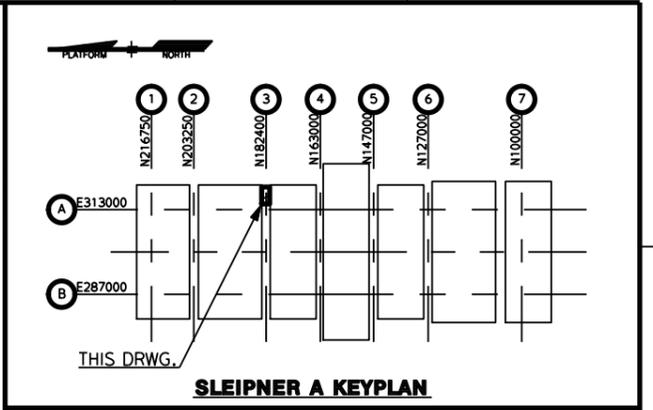
SECTION D-D  
4 LOCATIONS AS DRAWN  
SCALE 1:10



SECTION C-C  
4 LOCATIONS AS DRAWN  
SWL 6 T  
SCALE 1:10



SECTION F-F  
SWL 6 T  
SCALE 1:10



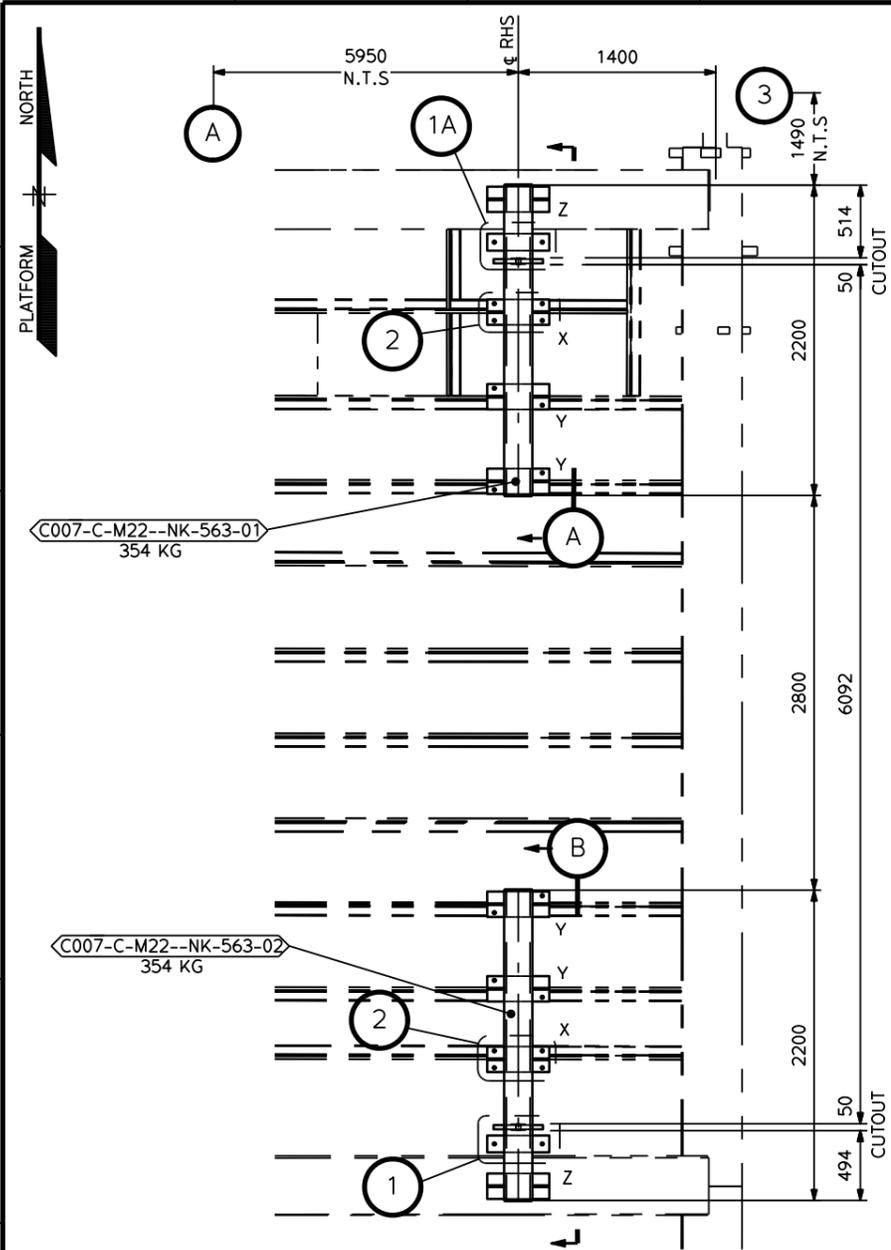
SLEIPNER A KEYPLAN

- NOTES:
- FOR GENERAL NOTES AND SPECIFICATIONS SEE DRAWING NO.: C007-C-000--NT-202-01
  - ALL DIMENSIONS ARE THEORETICAL. SHOP DETERMINE OVERLENGTH / CUT OFF.
  - DESIGN CLASS - MATERIAL :  
 PLATES: 2-Y30-420 U.N.O  
 PROFILES: 4-Y07-355  
 BOLTS & NUTS: 8.8 GR. 3.1 CERTIFICATE
  - APPLIED TORQUE ON NUT : 95Nm FOR BOLT M20, 495Nm FOR BOLT M24, HALF TORQUE ON SECOND NUT BOLT TO BE GREASED WITH MOLYCOAT G-RAPID PLUS BEFORE TIGHTENING
  - USE THE SAME AMOUNT OF SHIM ON BOTH SIDES OF RHS
  - SAFE WORKING LOAD LIMIT (SWL) AND HOOK-UP NO. TO BE PAINTED WITH 50mm HIGH LETTERS IN BLACK ON PINK BACKGROUND LOCAL TO LIFTING LUG/LIFTING BEAM.
  - LIFTING LUG TO BE CERTIFIED BY ENTERPRISE OF COMPETENCE.

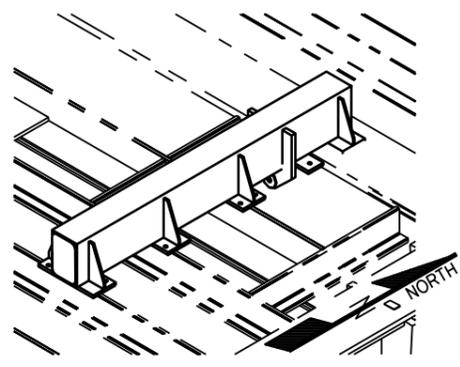
REF.DRAWING NO.:	C007-C-M23--NB-111-01
C007-C-000--NT-203-01	
C007-C-M22--NB-111-01	
POS.NO.PLATES:	PL001-PL002, PL004, PL006, PL014, PL016, PL017, PL021
POS.NO.PROFILES:	RH001, RH002
HOOK-UP NO.:	C007-C-M22--NK-562- 01-04
WELD NO.:	350, 380
WELD INSP.CATEGORY:	C   WELD INSTRUCTION:
PAIN SYSTEM:	COLOUR PINK, RAL 3015, SYSTEM 1T
TOTAL WEIGHT:	792 KG   SHORT CODE: M22TSLI03

<b>AkerSolutions</b>			
01	20.11.2013	FABR. & COMM. INFO S5	ST
REV.	DATE	REASON FOR ISSUE	PREP. CHECK. APPR.

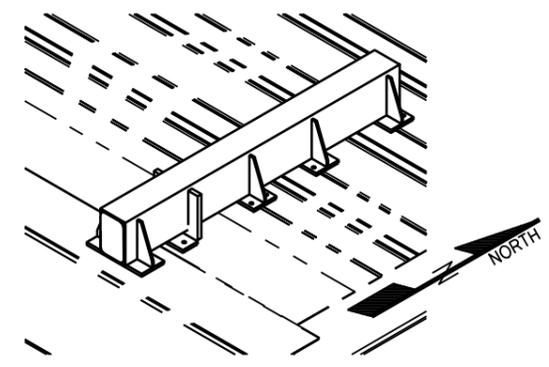
<b>Statoll</b>		INSTALLATION: SLEIPNER A	
DRAWING TITLE:		C05E BALCONY. TEMPORARY LIFTING BEAMS IN MAIN DECK INFILL EL. 515.485 T.O.S	
CONTR. NO.	104493	AS NOTED	AT A1 M22 D04
SCALE	SIZE	AREA	NETWORK
		C007-C-M22--NK-562-01 01	
		DRAWING NUMBER	
		REV.	



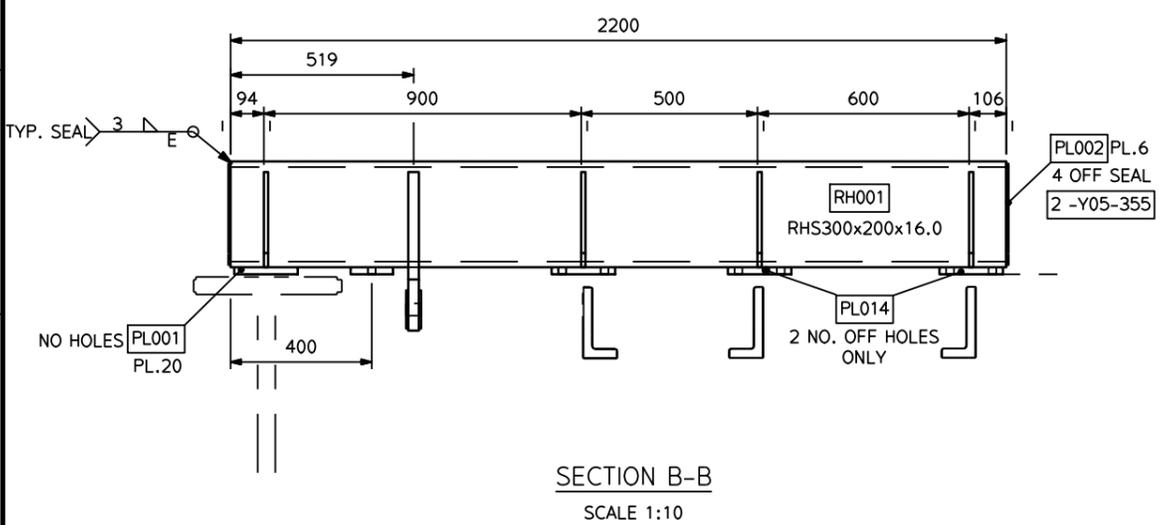
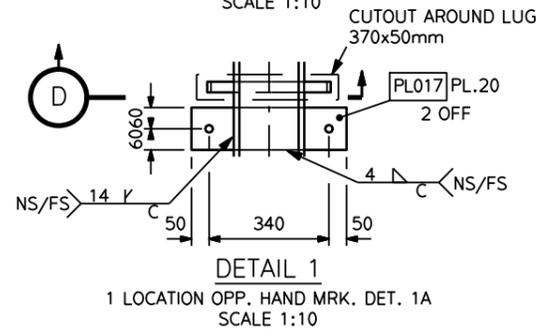
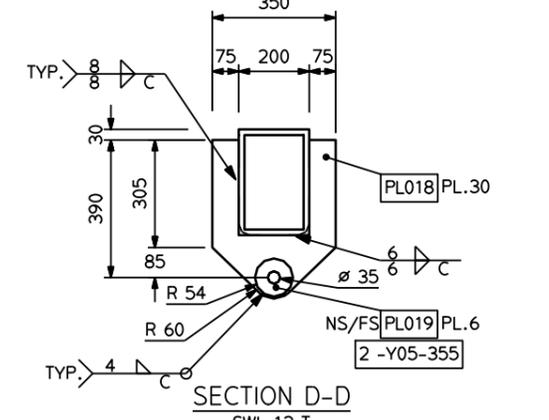
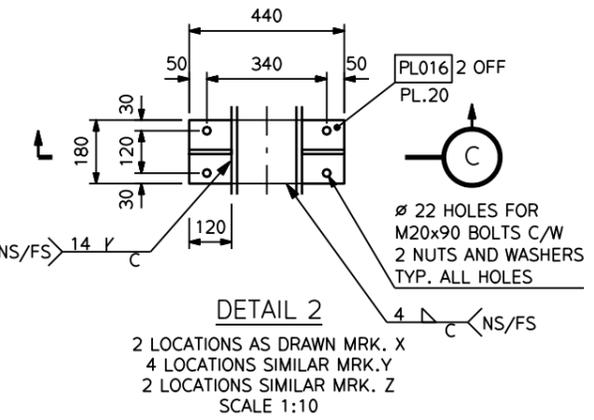
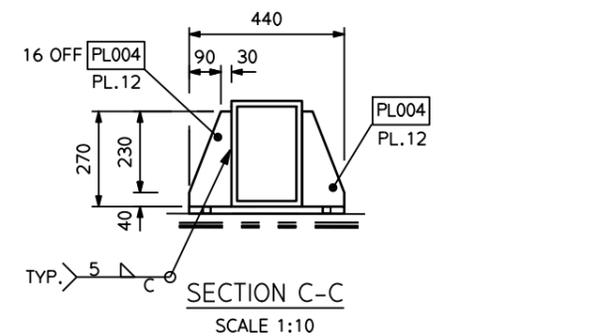
PLAN OF LIFTING BEAMS ON MAIN DECK EL.515.950  
SCALE 1:25



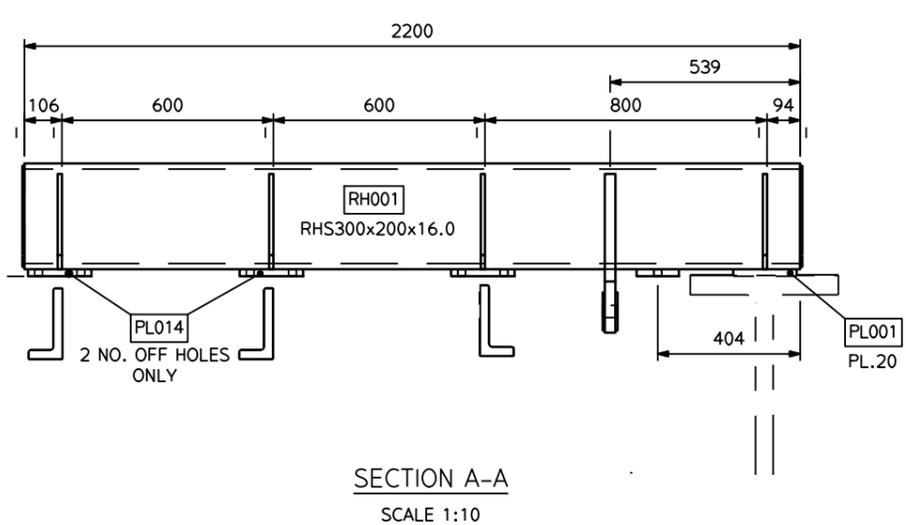
ISO VIEW OF SECTION A-A  
SCALE 1:20



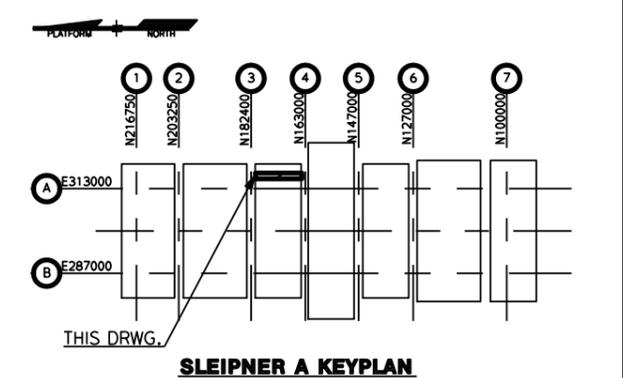
ISO VIEW OF SECTION B-B  
SCALE 1:20



SECTION B-B  
SCALE 1:10



SECTION A-A  
SCALE 1:10



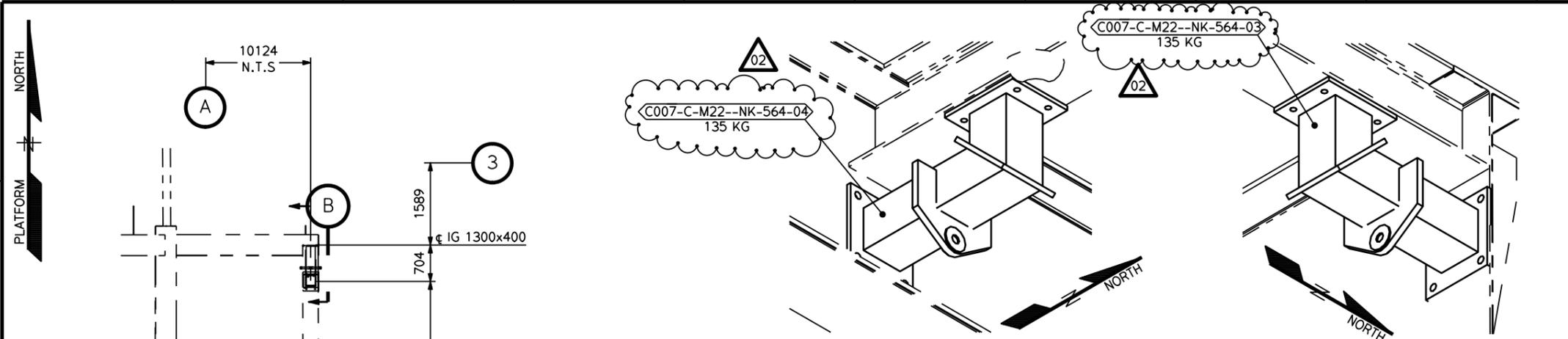
- NOTES:
- FOR GENERAL NOTES AND SPECIFICATIONS SEE DRAWING NO.: C007-C-000--NT-202-01
  - ALL DIMENSIONS ARE THEORETICAL. SHOP DETERMINE OVERLENGTH / CUT OFF.
  - DESIGN CLASS - MATERIAL :  
PLATES 2-Y30-420 U.N.O  
PROFILES 4-Y07-355  
BOLTS & NUTS 8.8 GR. 3.1 CERTIFICATE
  - APPLIED TORQUE ON NUT : 100Nm FOR BOLT M20  
HALF TORQUE ON SECOND NUT  
BOLT TO BE GREASED WITH MOLYCOAT G-RAPID PLUS BEFORE TIGHTENING
  - THIS DRAWING CONTAINS DEMOLITION WORK (CUTOUT FOR LUGS)
  - SAFE WORKING LOAD LIMIT (SWL) AND HOOK-UP NO. TO BE PAINTED WITH 50mm HIGH LETTERS IN BLACK ON PINK BACKGROUND LOCAL TO LIFTING LUG/LIFTING BEAM.
  - LIFTING LUG TO BE CERTIFIED BY ENTERPRISE OF COMPETENCE.

WEIGHT TO BE REMOVED  
CUTOUT IN DECK: 2 KG

REF. DRAWING NO.:	
C007-C-000--NT-203-01	
C007-C-M22--NB-111-01	
POS.NO.PLATES:	PL001, PL002, PL004, PL014, PL016-PL019
POS.NO.PROFILES:	RH001
HOOK-UP NO.:	C007-C-M22--NK-563-01-02
WELD NO.:	350, 385, 500
WELD INSP. CATEGORY:	C, E WELD INSTRUCTION:
PAINT SYSTEM:	COLOUR PINK, RAL 3015, SYSTEM 1T
TOTAL WEIGHT:	708 KG SHORT CODE: M22TSLI01

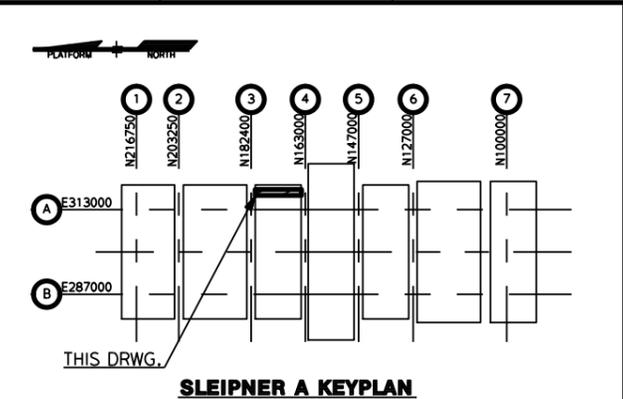
<b>AkerSolutions</b>			
01	28.10.2013	FABR. & COMM. INFO S5	ST
REV.	DATE	REASON FOR ISSUE	PREP. CHECK. APPR.

<b>Statoll</b>		INSTALLATION: SLEIPNER A	
DRAWING TITLE: C05E BALCONY. TEMPORARY LIFTING BEAMS ON MAIN DECK EL. 515.950 T.O.S			
CONTR. NO.	104493		
AS NOTED	AT A1	M22	D04
SCALE	SIZE	AREA	NETWORK
		C007-C-M22--NK-563-01 01	
		DRAWING NUMBER	
		REV.	



ISO VIEW OF SECTION A-A  
SCALE 1:10

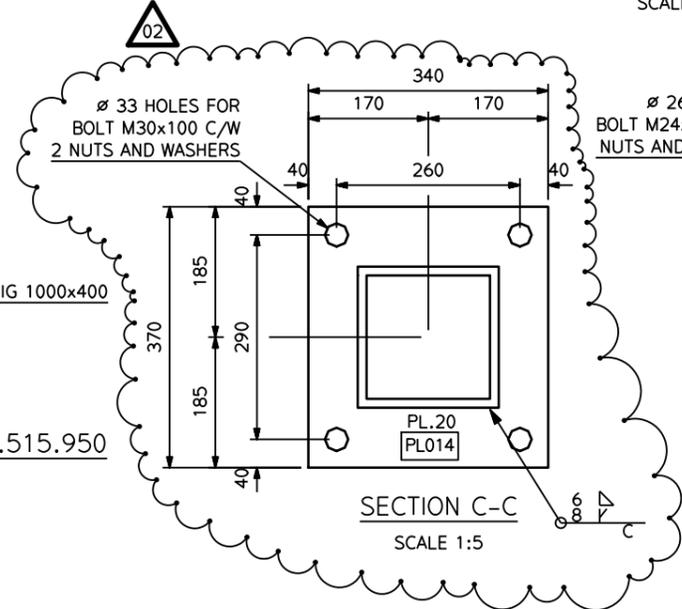
ISO VIEW OF SECTION B-B  
SCALE 1:10



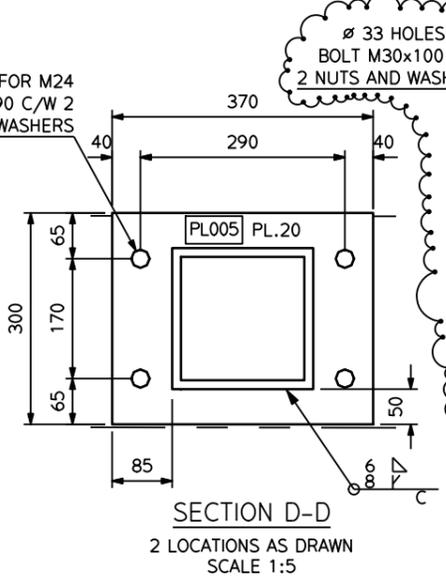
SLEIPNER A KEYPLAN

- NOTES:**
1. FOR GENERAL NOTES AND SPECIFICATIONS SEE DRAWING NO.: C007-C-000--NT-202-01
  2. ALL DIMENSIONS ARE THEORETICAL. SHOP DETERMINE OVERLENGTH / CUT OFF.
  3. DESIGN CLASS - MATERIAL :  
 PLATES 2-Y30-420 U.N.O  
 PROFILES 4-Y07-355  
 BOLTS & NUTS 8.8 GR. 3.1 CERTIFICATE
  4. APPLIED TORQUE ON NUT : 495Nm FOR BOLT M24, 295Nm FOR BOLT M30, HALF TORQUE ON SECOND NUT BOLT TO BE GREASED WITH MOLYCOAT G-RAPID PLUS BEFORE TIGHTENING
  5. SAFE WORKING LOAD LIMIT (SWL) AND HOOK-UP NO. TO BE PAINTED WITH 50mm HIGH LETTERS IN BLACK ON PINK BACKGROUND LOCAL TO LIFTING LUG/LIFTING BEAM.
  6. LIFTING LUG TO BE CERTIFIED BY ENTERPRISE OF COMPETENCE.

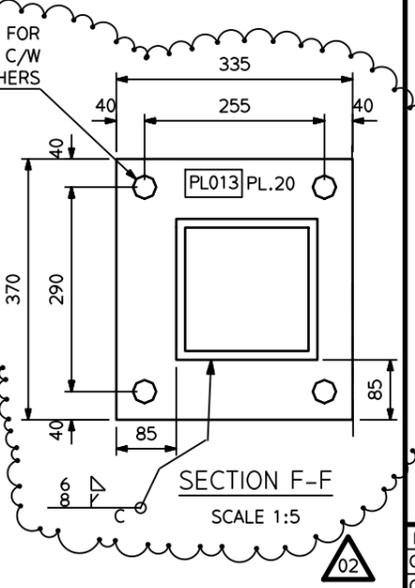
PLAN OF LIFTING BEAMS UNDER MAIN DECK EL.515.950  
SCALE 1:50



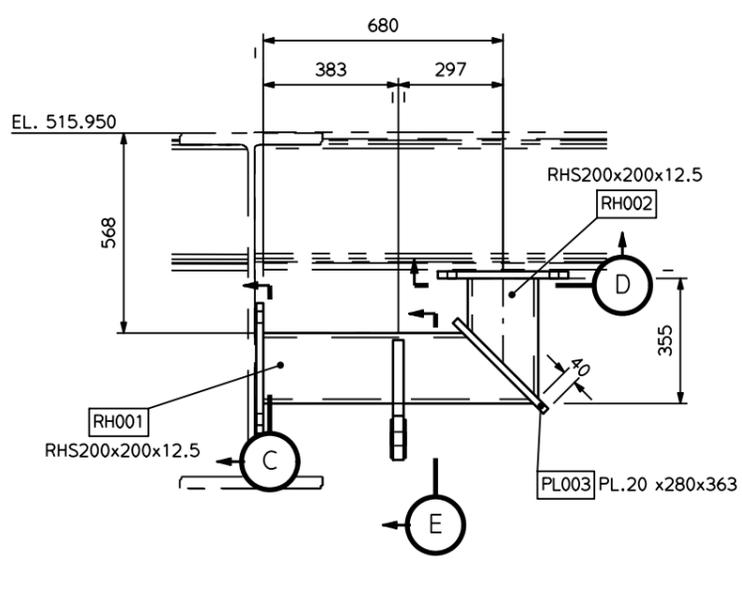
SECTION C-C  
SCALE 1:5



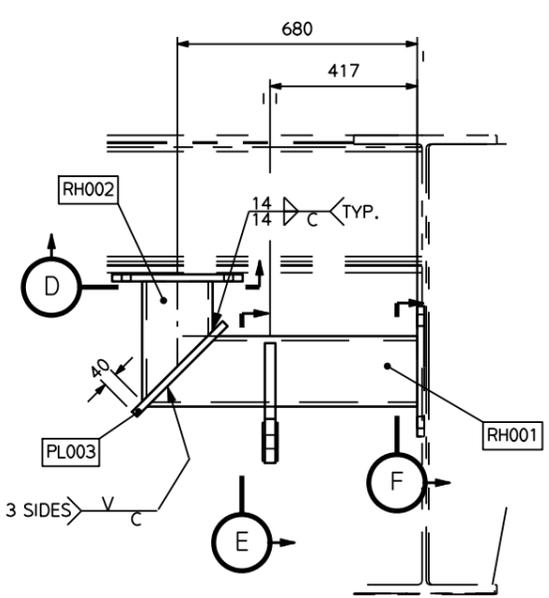
SECTION D-D  
2 LOCATIONS AS DRAWN  
SCALE 1:5



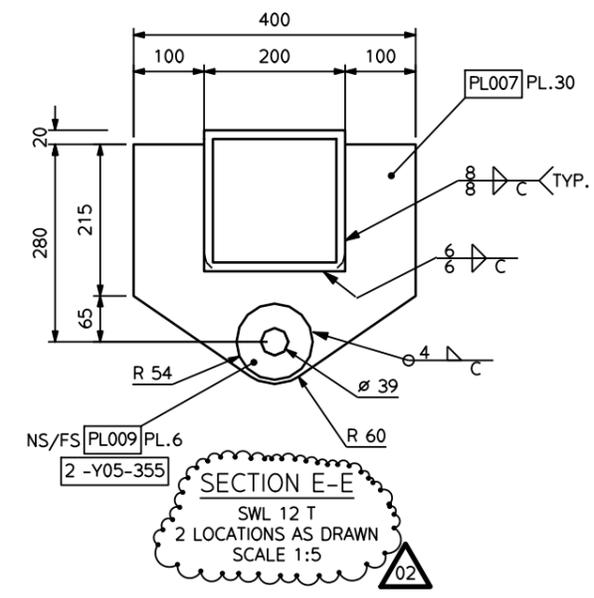
SECTION F-F  
SCALE 1:5



SECTION A-A  
SCALE 1:10



SECTION B-B  
SCALE 1:10



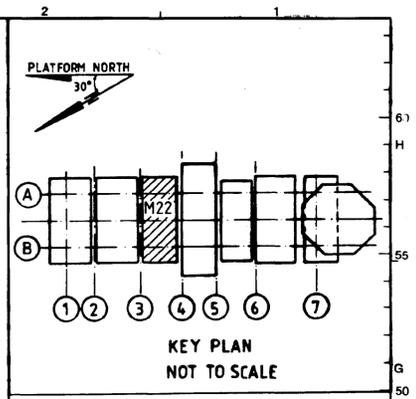
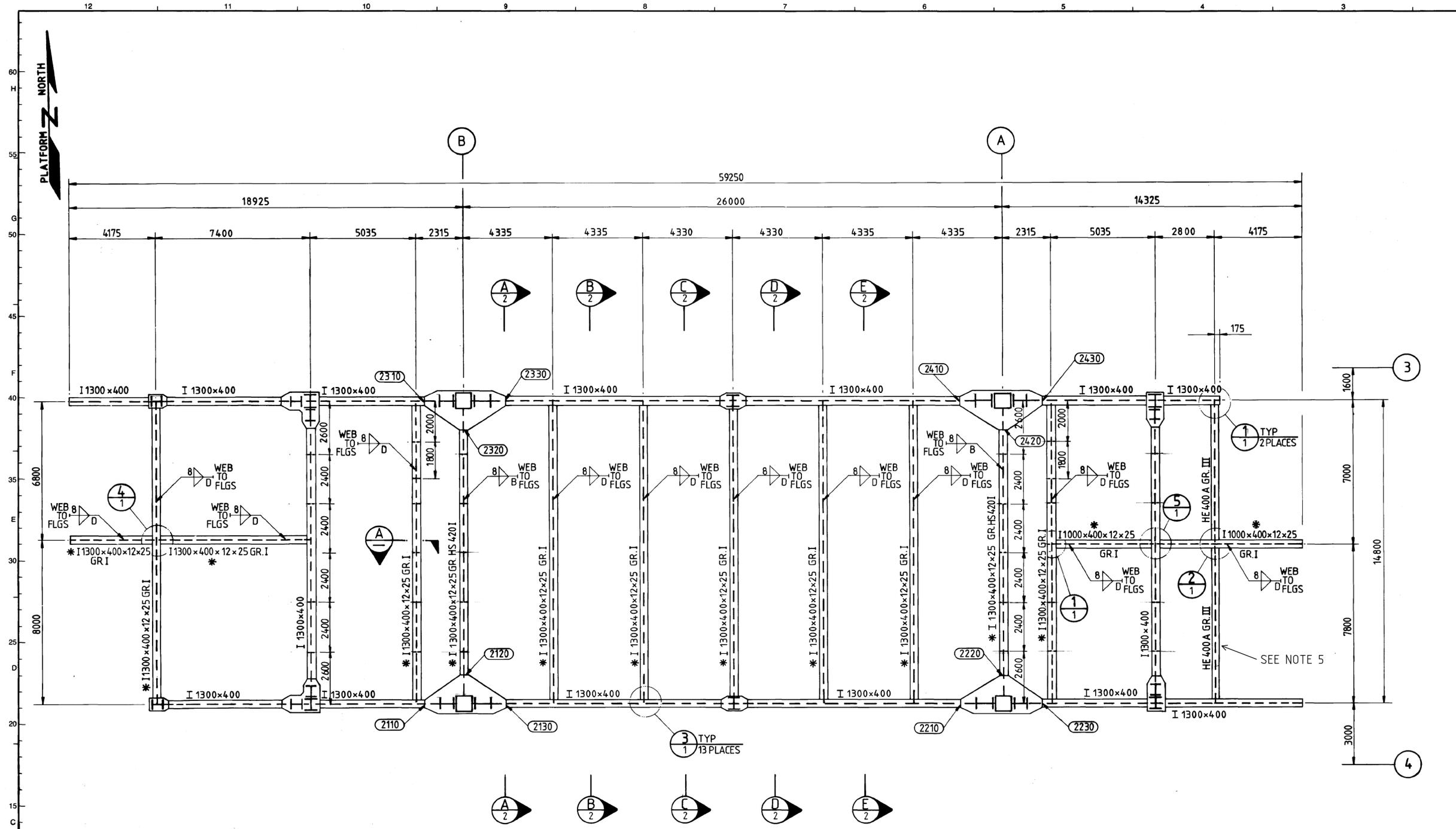
SECTION E-E  
SWL 12 T  
2 LOCATIONS AS DRAWN  
SCALE 1:5

REF. DRAWING NO.:	
C007-C-000--NT-203-01	
C007-C-M22--NB-111-01	
POS. NO. PLATES:	PL003, PL005, PL007, PL009, PL013, PL014
POS. NO. PROFILES:	RH001-RH002
HOOK-UP NO.:	C007-C-M22--NK-564-03-04
WELD NO.:	350, 365, 380
WELD INSP. CATEGORY:	C   WELD INSTRUCTION:
PAINT SYSTEM:	COLOUR PINK, RAL 3015, SYSTEM 1T
TOTAL WEIGHT:	270 KG   SHORT CODE: M22TSLI04

<b>AkerSolutions</b>			
02	05.11.2013	FABR. & COMM. INFO S5	ST PG/RIA L0/BE
01	28.10.2013	FABR. & COMM. INFO S5	ST RIA/PG L0/BE
REV.	DATE	REASON FOR ISSUE	PREP. CHECK. APPR.

<b>Statoll</b>		INSTALLATION: SLEIPNER A	
CONTR. NO. 104493		DRAWING TITLE: C05E BALCONY. TEMPORARY LIFTING BEAMS UNDER STRINGERS IN MAIN DECK EL. 515.950 T.O.S	
AS NOTED	AT A1	M22	D04
SCALE	SIZE	AREA	NETWORK
			C007-C-M22--NK-564-01 02
			DRAWING NUMBER
			REV.

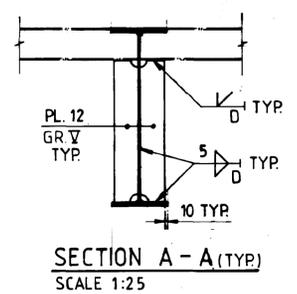




- NOTES:**
- FOR GENERAL INFORMATION SEE DRG. No. C007-C-000-NT-100-01
  - LEVELS DATUM:- EL.+500.000 (ARBITRARY) T.O.S. BOTTOM CHORD - MODULE SUPPORT FRAME
  - FOR AS BUILT DECK DIMS. SEE DRG. NO C007-C-M22-NA-111-01.
  - FOR DETAIL WELD NUMBERING, MATERIAL IDENTIFICATION AND REFERENCES TO N.D.T. DOCUMENTATION SEE FABRICATION DRG. NO.  
C007-P-M22-NB-5100-01  
NB-5101-01  
NB-5102-01  
NJ-7102-03  
NJ-7110-07
  - GUDRUN TIE-IN MODIFICATIONS: PIPE SUPPORTS INSTALLED REF. Drw. No. C007-C-M22-NJ-505-01

**LEGEND**  
\* INDICATES PREFABRICATED STRUCTURAL ITEMS SUPPLIED BY COMPANY

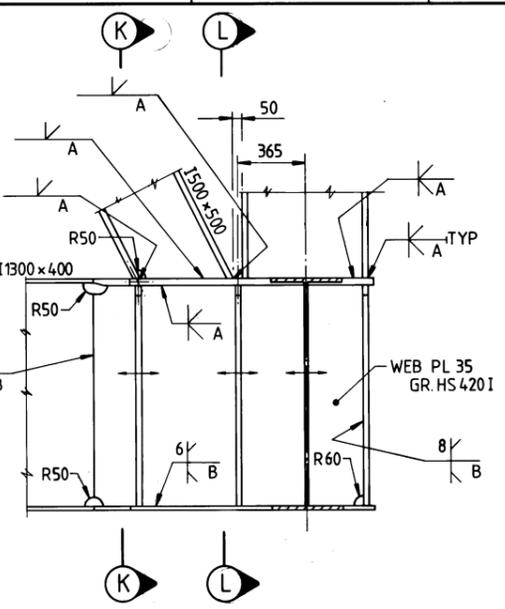
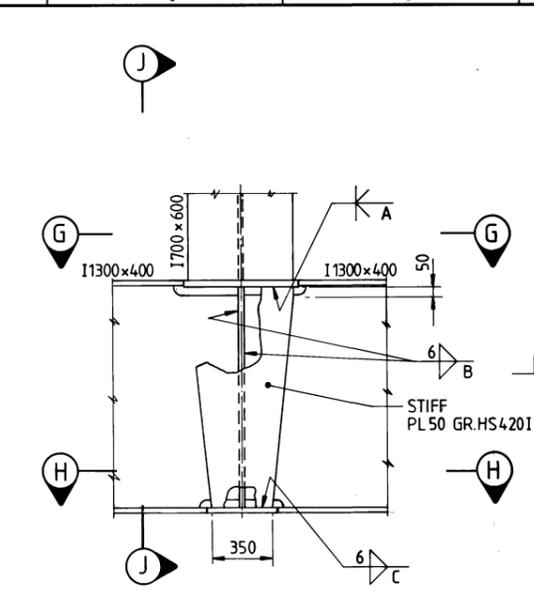
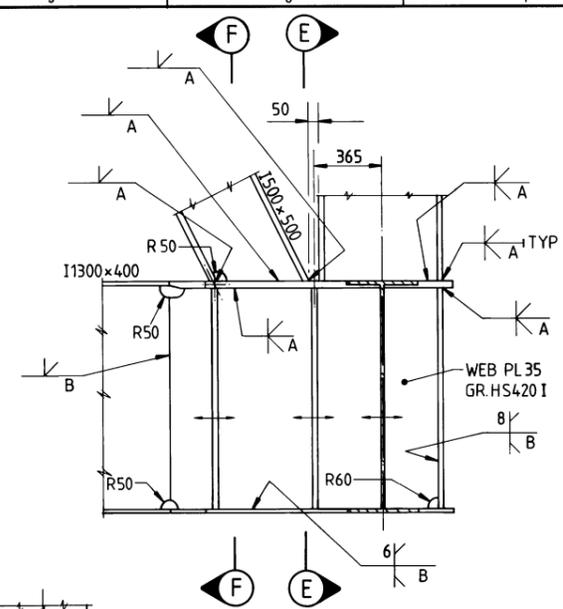
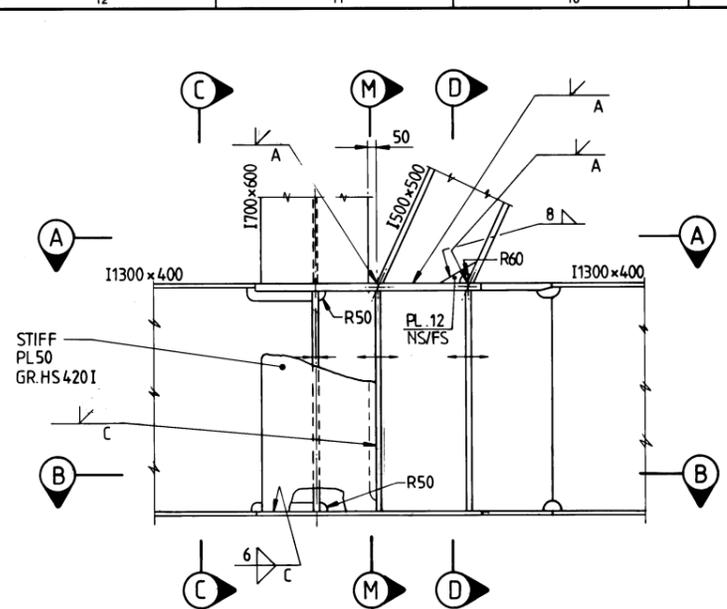
2	M22 -NB -112 -01
1	M22 -NB -150 -01
REF. N°	REF. DRG. N°



**PLAN MAIN DECK**  
EL.+515.950 T.O.S.

A C007-C-M22-NJ-505-01		PIPE SUPPORTS		A1		AS BUILT GDR TIE-IN. G07		24.04.13		KE		RIA		BE		28-10-88		DA		M.P.		N/A		STATOIL		SLEIPNER A PROJECT																							
M22 - NB - 137 - 01		MAIN STEEL - EAST & WEST ELEVATIONS														15.07.91		FC CONTRACT "AS-BUILT"		M.I.		N/A		Aker Engineering a.s.		M22 - GAS SEPARATION MODULE																							
M22 - NB - 134 - 01		MAIN STEEL - SOUTH ELEVATION														1-2-90		ISSUED FOR CONSTRUCTION		M.I.		N/A		MAIN STEEL																									
M22 - NB - 131 - 01		MAIN STEEL - NORTH ELEVATION														22-1-90		RE-ISSUED FOR TENDER		M.I.		N/A		MAIN DECK																									
																29-9-89		ISSUED FOR TENDER		M.I.		N/A																											
																7-7-89		ISSUED FOR I.D.C.		M.I.		N/A																											
																28-10-88		ISSUED FOR INFORMATION		M.I.		N/A																											
DRAWING NO		REFERENCE DRAWINGS		REV.		REASON FOR ISSUE		DATE		ORIGIN		CHECK		MICRO F.		DISC SUP.		PT		REV.		REASON FOR ISSUE		DATE		ORIGIN		CHECK		MICRO F.		DISC SUP.		PT		SCALE		SYSTEM NO.		WORK PACK NO.		DRAWING NO.							
12		11		10		9		8		7		6		5		4		3		2		1		A1		1:100		92		EC		C007-C-M22-NB-111-01		A1		PROJECT NO.		CONT.		AREA		CODE		NUMBER		SHT. NO.		REV.	





DETAIL 1 - AS DRAWN  
M22-NB-131-01

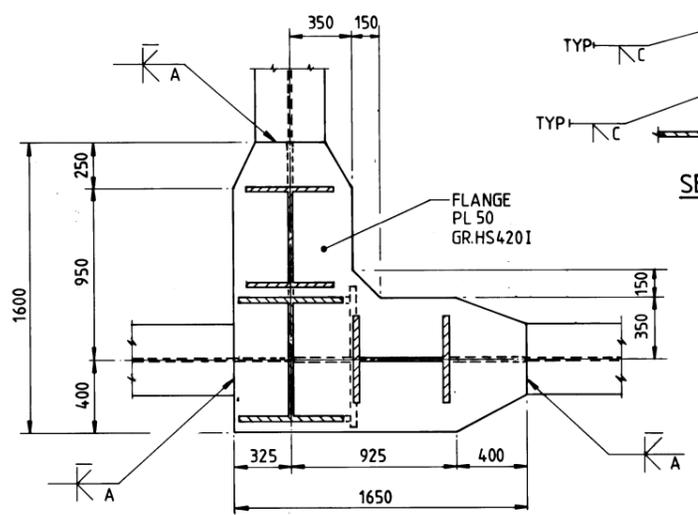
DETAIL 2 - OPP HAND  
M22-NB-134-01

SECTION C-C

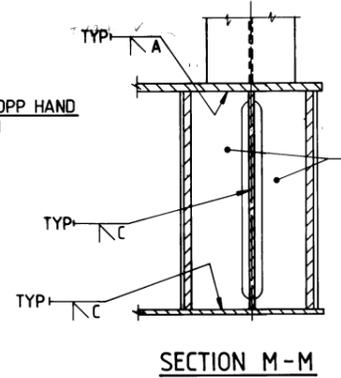
DETAIL 3  
M22-NB-131-01

DETAIL 4  
M22-NB-134-01

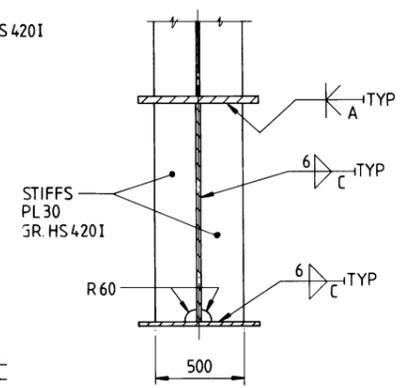
SECTION J-J



PLAN ON A-A

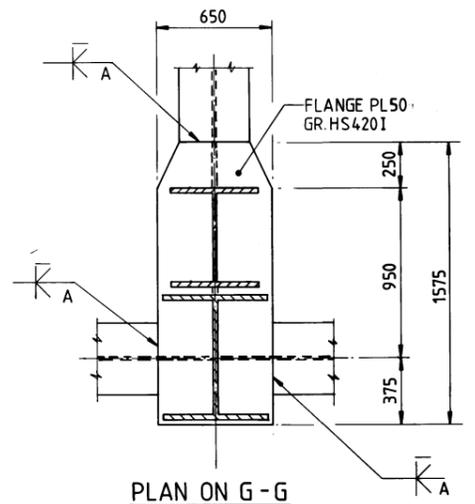


SECTION M-M

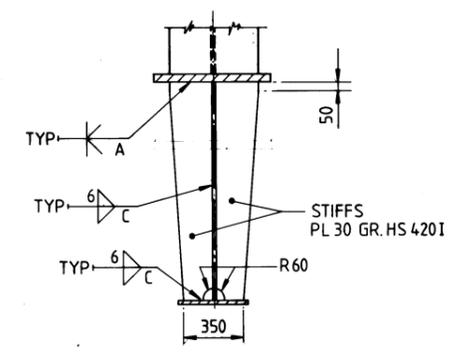


SECTION D-D  
SECTION F-F - SIMILAR

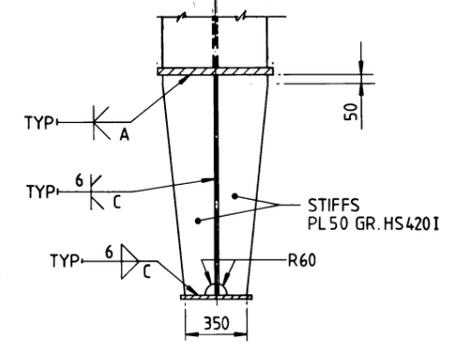
DETAIL 'X'  
(TYP. 4 PLACES)



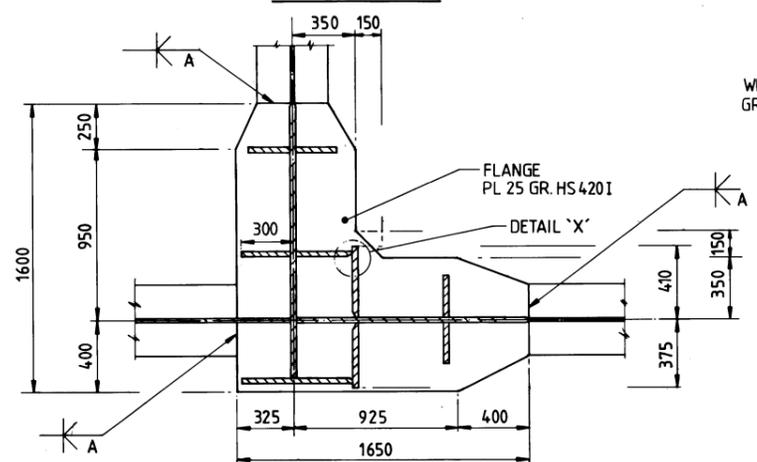
PLAN ON G-G



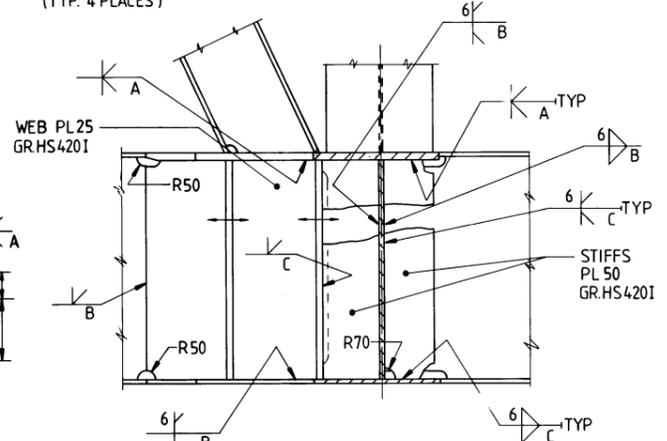
SECTION K-K  
STIFFENER DETAIL



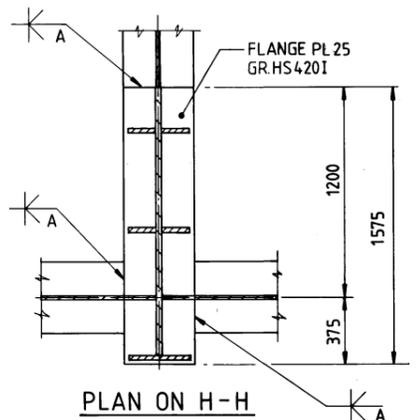
SECTION L-L  
STIFFENER DETAIL



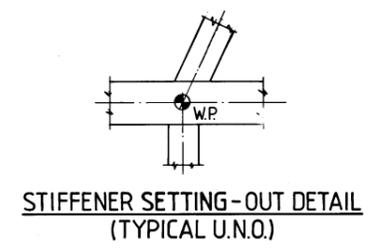
PLAN ON B-B



SECTION E-E



PLAN ON H-H



STIFFENER SETTING-OUT DETAIL  
(TYPICAL U.N.O.)

- NOTES.**
- FOR GENERAL INFORMATION SEE DRG N° C007-C-000-NT-100-01.
  - LEVELS DATUM.  
EL+500.000 (ARBITRARY) T.O.S. BOTTOM CHORD - MODULE SUPPORT FRAME
  - ALL RATHOLES AND NOTCHES SHOWN TO BE R40 U.N.O.  
ONLY RATHOLES SHOWN TO BE PERMITTED. SHOULD FURTHER RATHOLES BE NECESSARY, MATERIAL TO BE REINSTATED.
  - FOR DETAIL WELD NUMBERING, MATERIAL IDENTIFICATION AND REFERENCES TO N.D.T. DOCUMENTATION SEE FABRICATION DRG. NO.  
C007-P-M22-NB-5130-01  
5134-01  
5140-01  
5144-01

ALL CHAMFERING ON THE BACK OF PLATES TO BE STOPPED AT A DISTANCE "T" FROM BOTH ENDS OF THE PLATE. THE DISTANCE "T" SHALL BE EQUAL TO, OR GREATER THAN, THE THICKNESS OF THE PLATE.

DRAWING NO.	REFERENCE DRAWINGS	REV.	REASON FOR ISSUE	DATE	ORIGIN	CHECK	MICRO.F.	DISC. SUP.	PT	REV.	REASON FOR ISSUE	DATE	ORIGIN	CHECK	MICRO.F.	DISC. SUP.	PT	SCALE	SYSTEM NO.	WORK PACK NO.	DRAWING NO.	PROJECT NO.	CONT.	AREA	CODE	NUMBER	SHT.NO.	REV.
										Z3	AS-BUILT INCLUDING Z2	15.08.93						1:20	92	EC	C007-C-M22-NB-147-01	Z3						
										Z1	ISSUED FOR "AS-BUILT"	15.07.91																
										0	ISSUED FOR CONSTRUCTION	1-2-90																
										3	ISSUED FOR TENDER	29-9-89																
										2	ISSUED FOR I.D.C.	7-7-89																
										1	ISSUED FOR INFORMATION	28-11-88																

**STATOIL**  
**SLEIPNER A PROJECT**

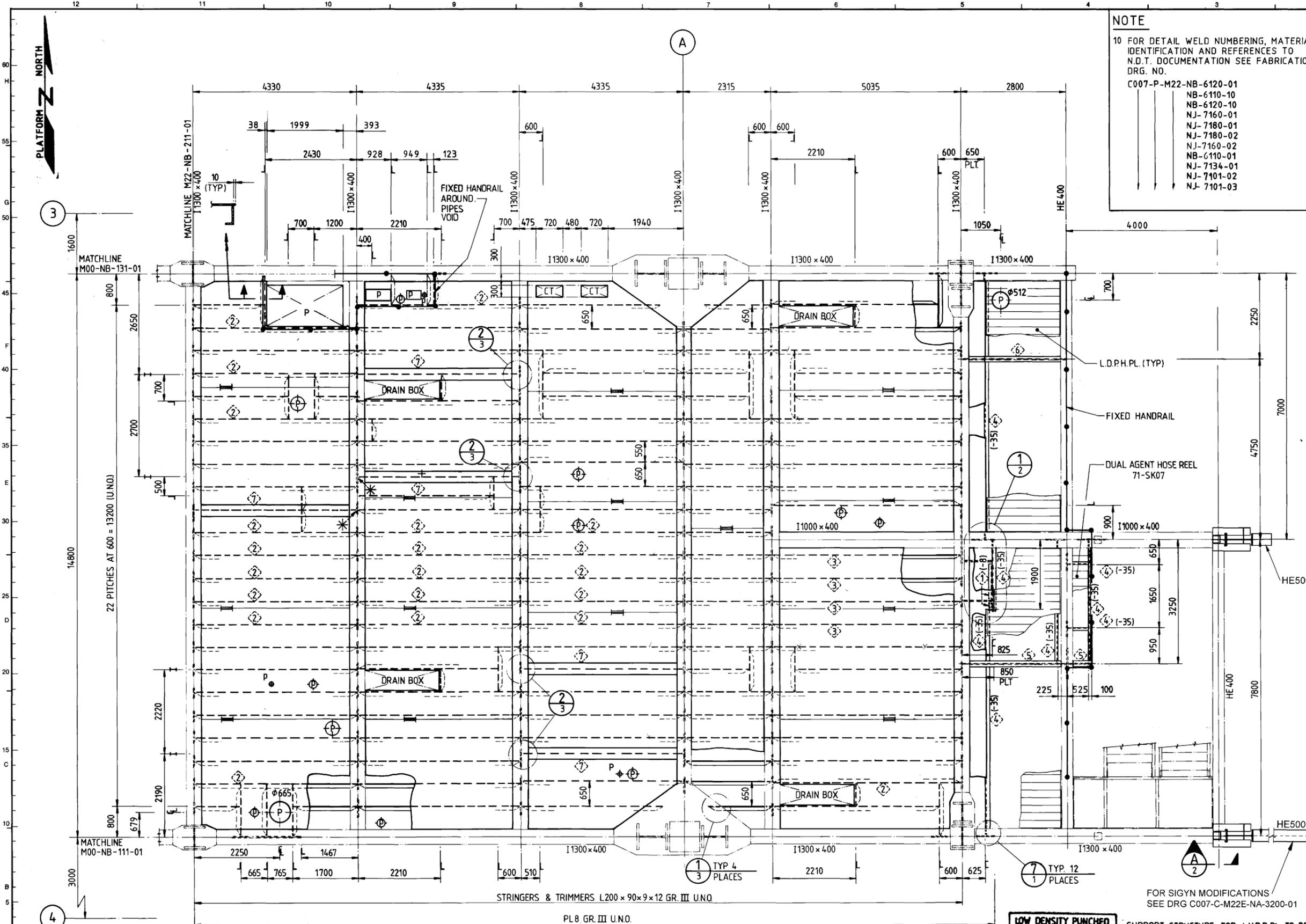
M22 - GAS SEPARATION MODULE  
MAIN STEEL  
CONNECTION DETAILS

Aker Engineering a.s.

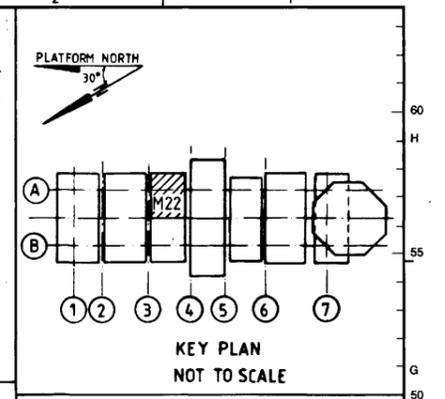
SCALE: 1:20  
SYSTEM NO.: 92  
WORK PACK NO.: EC

DRAWING NO.: C007-C-M22-NB-147-01  
PROJECT NO.: Z3





**NOTE**  
 10 FOR DETAIL WELD NUMBERING, MATERIAL IDENTIFICATION AND REFERENCES TO N.D.T. DOCUMENTATION SEE FABRICATION DRG. NO.  
 C007-P-M22-NB-6120-01  
 NB-6110-10  
 NB-6120-10  
 NJ-7160-01  
 NJ-7180-01  
 NJ-7180-02  
 NJ-7160-02  
 NB-6110-01  
 NJ-7134-01  
 NJ-7101-02  
 NJ-7101-03



- NOTES**
- FOR GENERAL INFORMATION SEE DRG. NO. C007-C-000-NT-100-01.
  - LEVELS DATUM:- EL. +500.000 (ARBITRARY) T.O.S. BOTTOM CHORD MODULE SUPPORT FRAME.
  - FOR CONNECTION DETAILS NOT SPECIFIED SEE DRG. NO. C-000-NT-101-01.
  - FOR PENETRATION DETAILS REFER TO DOCUMENT NO. C007-C-Z-SP-254 (U.N.O.)
  - THIS DRAWING TO BE READ IN CONJUNCTION WITH ALL RELEVANT :-  
 - PIPING DRAWINGS  
 - ELECTRICAL & INSTRUMENT DRAWINGS.  
 - H.V.A.C. DUCTWORK DRAWINGS.
  - FOR ADDITIONAL STIFFENERS/STARTER BARS DUE TO PIPE SUPPORTS, SEE PIPE SUPPORT DETAIL DRAWINGS.
  - FINAL POSITION OF PLATE SPLICES TO BE BY MODULE FABRICATOR.
  - HANDRAILS MUST BE PROVIDED IF THE CLEARANCE WITHIN A PENETRATION EXCEEDS 100mm.
  - \* BTM. FLG. TO BE WELDED HARD IN TO WEB

- LEGEND**
- ① L100x50x8 GR.V
  - ② L250x90x9x13 GR.III
  - ③ L300x100x10.5x15 GR.III
  - ④ UNP 200 GR.III
  - ⑤ IPE 400 GR.V
  - ⑥ IPE 300 GR.V
  - ⑦ HE400A GR.III

**PENETRATION KEY**

	P	PIPING PENETRATION
	DRAIN BOX	DRAIN BOX
	HV	H.V.A.C. PENETRATION
	H	HATCH.
	CT	CABLE TRANSIT.

3	M22-NB-243-01
2	M22-NB-242-01
1	M22-NB-241-01
REF NO	REF DRG NO

**PLAN MAIN DECK - EAST**  
 EL+515.950 T.O.S./TOG./TOPL.(U.N.O.)

000-NT-201-01	LOUVRE SUPPORTS - TYPICAL DETAILS
000-NT-171-01	DRAIN BOXES - TYPICAL DETAILS
000-NT-161-01	INSPECTION HATCHES - TYPICAL DETAILS
000-NT-156-01	HANDRAILS - TYPICAL DETAILS
000-NT-151-01	WALKWAYS & PLATFORMS - TYPICAL DETAILS
000-NT-146-01	SAFETY CHAIN FENCE - TYPICAL DETAILS
000-NT-131-01/132-01	FORKLIFT TRUCK SAFETY BARRIER - TYPICAL DETAILS
000-NT-101-01	TYPICAL CONNECTION DETAILS
M22-NB-111-01	MAIN STEEL - MAIN DECK

REV.	REASON FOR ISSUE	DATE	ORIGIN	CHECK	MICRO F.	DISC. SUP.	PT	REV.	REASON FOR ISSUE	DATE	ORIGIN	CHECK	MICRO F.	DISC. SUP.	PT
23	AS-BUILT INCLUDING Z2	15.08.93													
Z1	ISSUED FOR AS-BUILT	15.07.91													
A	RE-ISSUED FOR CONSTRUCTION	6-7-90													
0	ISSUED FOR CONSTRUCTION	1-2-90													
3	ISSUED FOR TENDER	29-9-89													
2	ISSUED FOR I.O.C.	18-8-89													
1	ISSUED FOR INFORMATION	16-6-89													

**STATOIL**

**Aker Engineering a.s.**

SCALE: 1:50

SYSTEM NO. 92

WORK PACK NO. EC

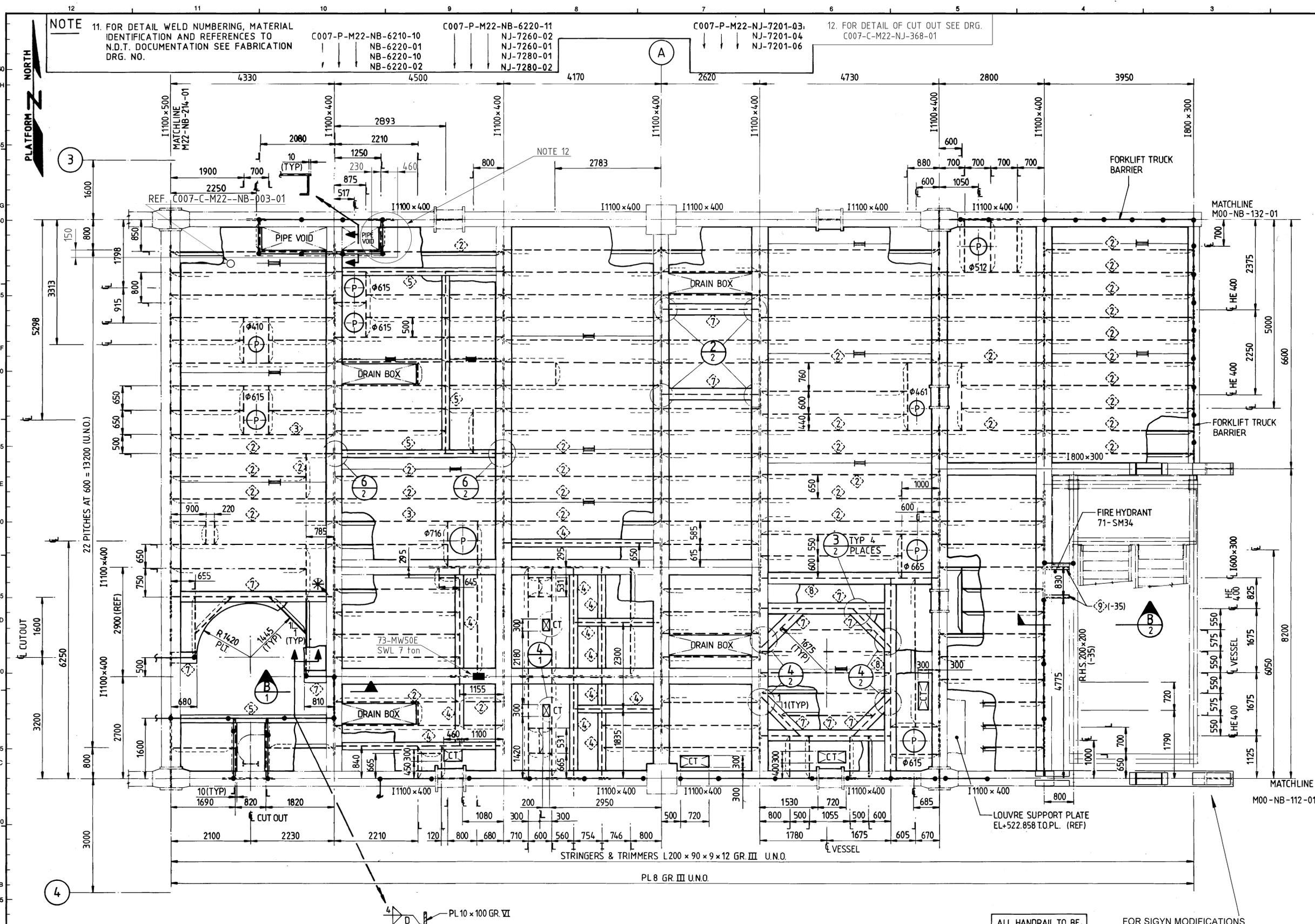
PROJECT NAME: **SLEIPNER A PROJECT**

M22 - GAS SEPARATION MODULE  
 SECONDARY STEEL  
 MAIN DECK - EAST

DRAWING NO. **C007-C-M22-NB-212-01**

PROJECT NO. CONT. AREA CODE NUMBER SHT. NO. REV.

**A3**



NOTE 11. FOR DETAIL WELD NUMBERING, MATERIAL IDENTIFICATION AND REFERENCES TO N.D.T. DOCUMENTATION SEE FABRICATION DRG. NO.

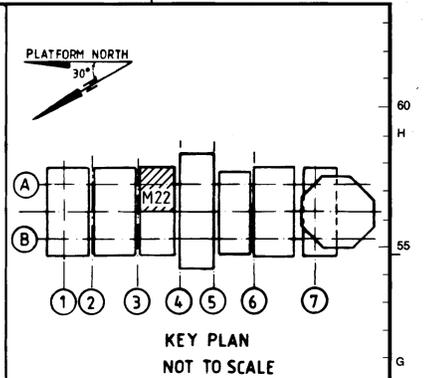
C007-P-M22-NB-6210-10 NB-6220-01 NB-6220-10 NB-6220-02

C007-P-M22-NB-6220-11 NJ-7260-02 NJ-7260-01 NJ-7280-01 NJ-7280-02

C007-P-M22-NJ-7201-03, NJ-7201-04 NJ-7201-06

C007-C-M22-NJ-368-01

NOTE 12. FOR DETAIL OF CUT OUT SEE DRG.



- NOTES**
- FOR GENERAL INFORMATION SEE DRG. NO. C007-C-000-NT-100-01.
  - LEVELS DATUM:- EL +500.000 (ARBITRARY). T.O.S. BOTTOM CHORD MODULE SUPPORT FRAME.
  - FOR CONNECTION DETAILS NOT SPECIFIED SEE DRG. NO. C-000-NT-101-01.
  - FOR PENETRATION DETAILS REFER TO DOCUMENT NO. C007-C-Z-SP-254 (U.NO.) WITH ALL RELEVANT:-  
- PIPING DRAWINGS  
- ELECTRICAL & INSTRUMENT DRAWINGS.  
- H.V.A.C. DUCTWORK DRAWINGS.
  - FOR ADDITIONAL STIFFENERS/STARTER BARS DUE TO PIPE SUPPORTS, SEE PIPE SUPPORT DETAIL DRAWINGS.
  - FINAL POSITION OF PLATE SPLICES TO BE BY MODULE FABRICATOR.
  - HANDRAILS MUST BE PROVIDED IF THE CLEARANCE WITHIN A PENETRATION EXCEEDS 100mm.
  - FOR BEAM PENETRATIONS SEE DRG. N° M22-NB-114-01
  - \* BTM. FLG. TO BE WELDED HARD IN TO WEB

- ② L250 x 90 x 9 x 13 GR. III
- ④ IPE 400 GR. V
- ⑤ IPE 400 GR. III
- ⑥ HE 300A GR. III
- ⑦ HE 400A GR. III
- ⑧ I600 x 300 x 12 x 25 GR. III
- ⑨ UNP 200 GR. III

**PENETRATION KEY**

⊕	P	PIPING PENETRATION
DRAIN BOX	DRAIN BOX	
HV	HV	H.V.A.C. PENETRATION
H	H	HATCH
CT	CT	CABLE TRANSIT

2	M22-NB-243-01
1	M22-NB-242-01
REF. N°	REF. DRG. N°

**PLAN LOWER MEZZANINE DECK - EAST**  
EL+523.950 T.O.S./TOPL. (U.NO.)

ALL HANDRAIL TO BE FIXED HANDRAIL U.N.O. ALONG SOUTH SIDE KICKPLATE TO BE WELDED TO DECK.

FOR SIGYN MODIFICATIONS SEE DRG C007-C-M22E-NA-3200-01 AND C007-C-M22E-NJ-3220-20

000-NT-201-01	LOUVRE SUPPORTS - TYPICAL DETAILS
000-NT-171-01	DRAIN BOXES - TYPICAL DETAILS
030-NT-161-01	INSPECTION HATCHES - TYPICAL DETAILS
000-NT-156-01	HANDRAILS - TYPICAL DETAILS
000-NT-151-01	WALKWAYS & PLATFORMS - TYPICAL DETAILS
000-NT-146-01	SAFETY CHAIN FENCE - TYPICAL DETAILS
000-NT-131-01/-132-01	FORKLIFT TRUCK SAFETY BARRIER - TYPICAL DETAILS
000-NT-101-01	TYPICAL CONNECTION DETAILS
M22-NB-113-01	MAIN STEEL - LOWER MEZZANINE DECK

REV.	REASON FOR ISSUE	DATE	ORIGIN	CHECK	MICRO.F.	DISC. SUP.	PT	REV.	REASON FOR ISSUE	DATE	ORIGIN	CHECK	MICRO.F.	DISC. SUP.	PT
Z1	ISSUED FOR "AS-BUILT"	15.07.91													
A	RE-ISSUED FOR CONSTRUCTION	6-7-90													
0	ISSUED FOR CONSTRUCTION	1-2-90													
4	RE-ISSUED FOR TENDER	1-12-89													
3	ISSUED FOR TENDER	29-9-89													
2	ISSUED FOR I.D.C.	18-8-89													
1	ISSUED FOR INFORMATION	16-6-89													

**STATOIL**

**Aker Engineering a.s.**

SCALE: 1:50

SYSTEM NO: 92

WORK PACK NO: EC

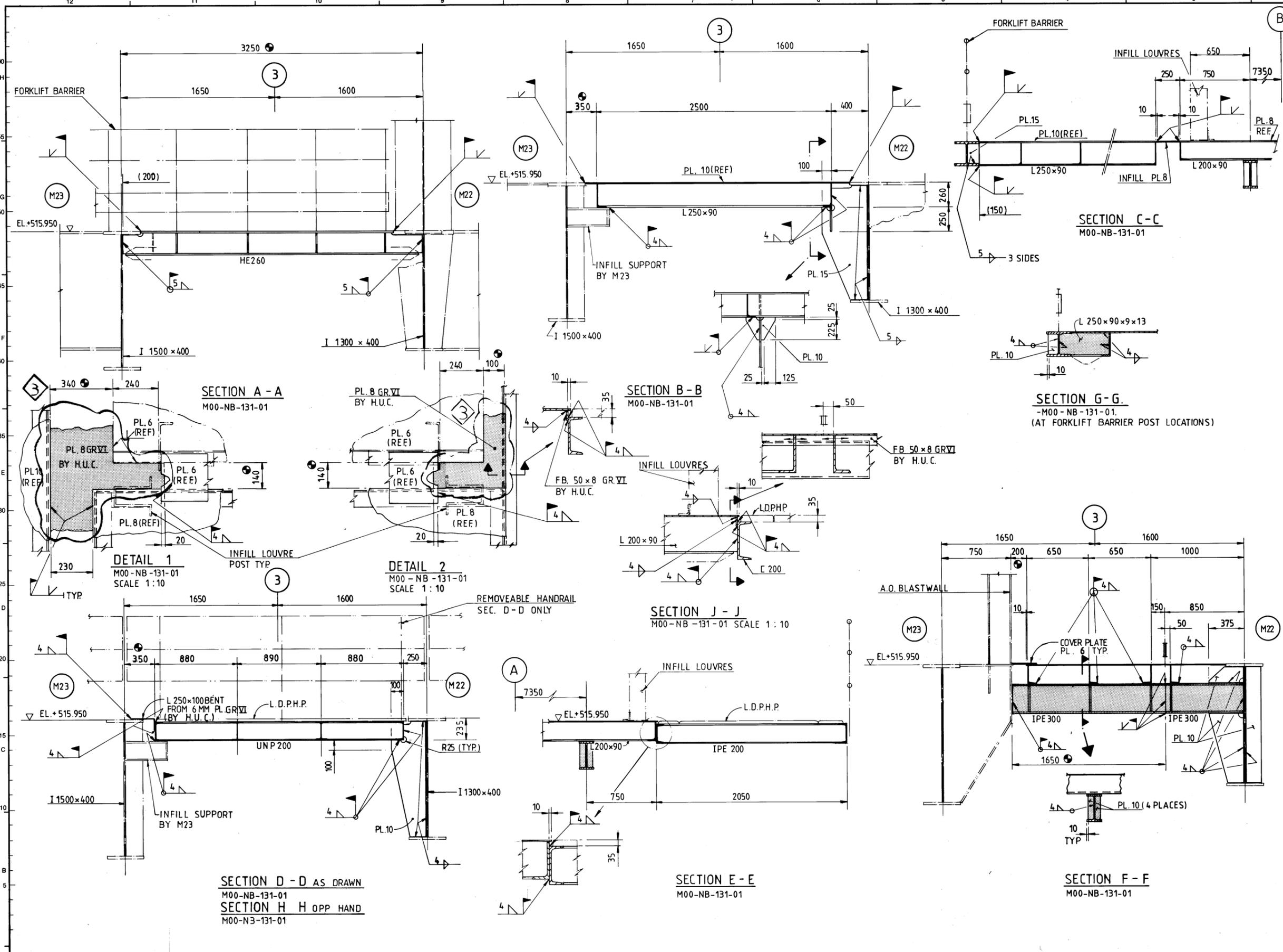
PROJECT NAME: **SLEIPNER A PROJECT**

M22 - GAS SEPARATION MODULE SECONDARY STEEL LOWER MEZZANINE DECK - EAST

DRAWING NO: **C007-C-M22-NB-215-01**

PROJECT NO: CONT: AREA: CODE: NUMBER: SHT. NO: REV.





- NOTES.**
- FOR GENERAL INFORMATION SEE DRG. No. C007-C-000-NT-100-01
  - LEVELS DATUM:- EL.+500.000 (ARBITRARY) T.O.S. BOTTOM CHORD MODULE SUPPORT FRAME
  - ALL MATERIAL TO BE GRADE ∇ UNO.
  - ALL WELDS TO BE INSPECTION CATEGORY "D".
  - ITEMS INDICATED THUS TO BE SUPPLIED, CUT TO SUIT & INSTALLED BY THE HOOK-UP CONTRACTOR ADDRESS MARK <M22/M23-2NB102--K>

- LEGEND**
- DIMENSION DEPENDANT ON INSTALLATION TOLERANCES.
  - INDICATES LENGTH & DIRECTION OF OVERSIZE REQUIRED FOR PREFABRICATED ITEMS.

DRAWING NO.	REFERENCE DRAWINGS	REV.	REASON FOR ISSUE	DATE	ORIGIN	CHECK	MICRO F.	DISC. SUP.	PT	REV.	REASON FOR ISSUE	DATE	ORIGIN	CHECK	MICRO F.	DISC. SUP.	PT		
C-000-NT-156-01	HANDRAILS TYPICAL									0	ISSUED FOR CONSTRUCTION	08.10.90	KN	SA	TH	DA	MS	WF	PT
C000-NT-201-01	LOUVRE SUPPORTS TYP DETAILS									3	ISSUED FOR IDC	31.08.90	SA	TH	DA	MS	WF	PT	
E000-NT-131/132-01	FORKLIFT TRUCK SAFETY BARRIER TYP DET.									2	ISSUED FOR HOOK-UP TENDER	02.05.90	SA	TH	DA	MS	WF	PT	
C-000-NT-101-01	TYP. CONNECTION DETAILS									1	ISSUED FOR TENDER M22	29.09.89	SA	TH	DA	MS	WF	PT	

**STATOIL**

**Aker Engineering a.s.**

PROJECT NAME: **SLEIPNER A PROJECT**

TITLE: **INFILL STEEL M22/M23 MAIN DECK DETAILS**

SCALE: 1:20 U.N.O.

SYSTEM NO. 92

WORK PACK NO. CB

DRAWING NO. C007-C-M00-NB-136-01

PROJECT NO. CONT. AREA CODE NUMBER SHT.NO. REV.

0

# APPENDIX E

## PICTURES OF C05E BALCONY

Picture 1 C05E balcony main frame



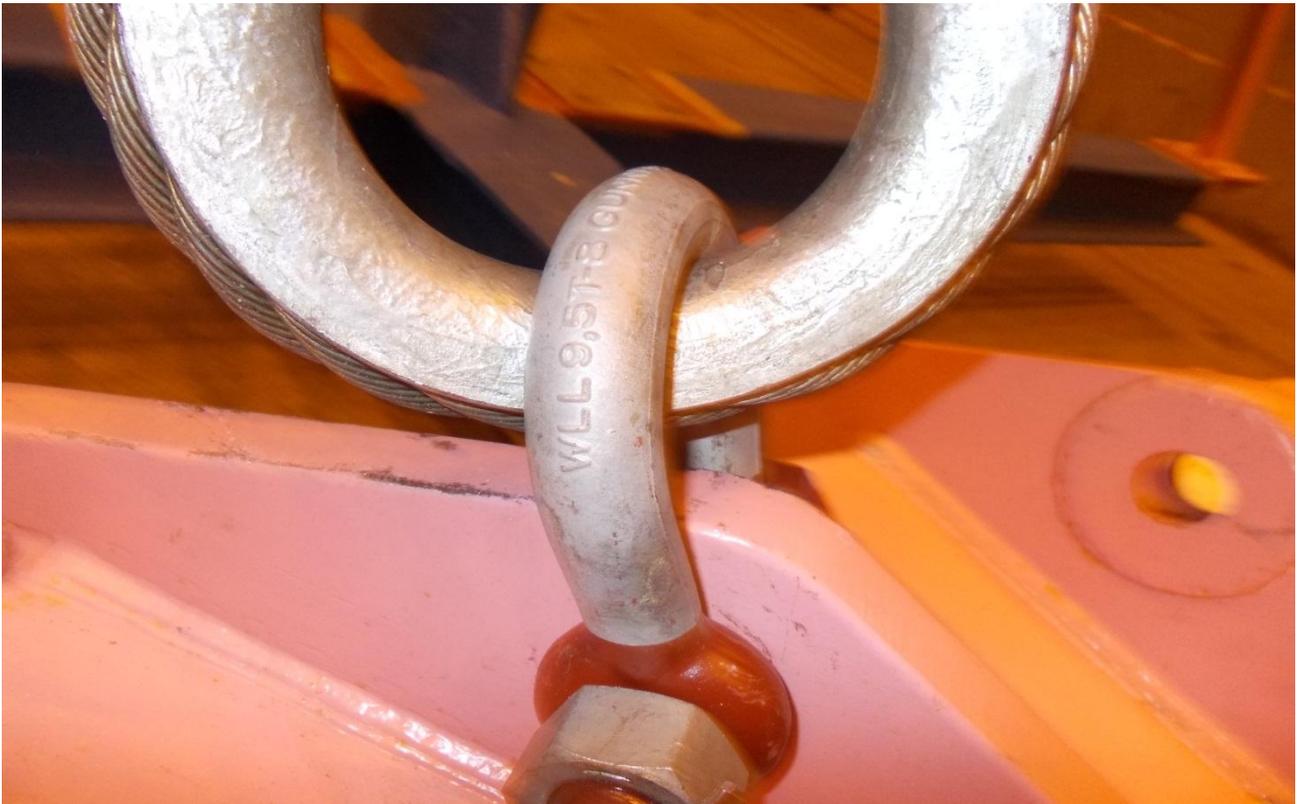
Picture 2 C05E balcony main frame, calibration certificate

 OFTENSIVT ARBEID I INSPEKSJON and CERTIFICATION Postboks 122, 4098 Tananger www.otic.no Tlf: 51 69 27 50 Fax 51 69 27 65				
<b>Calibration certificate /KALIBRERINGSSERTIFIKAT</b>				
<b>Customer/KUNDE:</b>	OTIC as	<b>Report no /RAPPORT NR.</b>	519/2013	
<b>ADDRESS / ADRESSE:</b>	TANANGER	<b>DATE / DATO:</b>	23.05.2013	
<b>Work description / ARBEIDSBESKRIVELSE</b>				
Kalibrering av 50 Tonn Teo Lastcelle.				
<b>EQUIPMENT / GJENSTAND</b>	50T Lastcelle			
<b>TYPE - SERIAL NO / TYPE-SERIE NR</b>	519			
<b>PERFORMED BY / UTFØRT AV:</b>	Fetter Meinich-Bach	<b>SIGNATURE / SIGNATUR:</b>	<i>Fetter Meinich-Bach</i>	
<b>APPROVED BY / GODKJENT AV:</b>	Tor Inge Olsen			
<b>REFERENCE / REFERANSE</b>	50Tonn Teo Lastcelle			
<b>TYPE</b>	502//50000-SK200			
<b>Reading Equipment /AVLESNINGSTYR</b>	Scala			
<b>CALIBRATE BY /KALIBRERT AV</b>	OTIC AS			
<b>RESULT/RESULTAT</b>				
<b>LOAD IN KG /PÅFØRT LAST KG</b>	<b>READING IN KG /AVLEST LAST I KG</b>			
	<b>SERIE 1</b>	<b>SERIE 2</b>	<b>SERIE 3</b>	<b>Average /GJENNOMSNITT</b>
5000.00	5000.00	5000.00	5000.00	5000.00
10000.00	9500.00	9600.00	9600.00	9566.67
15000.00	14600.00	14600.00	14700.00	14633.33
20000.00	19600.00	19550.00	19600.00	19583.33
25000.00	25600.00	25600.00	25600.00	25600.00
30000.00	29600.00	29700.00	29700.00	29633.33
35000.00	34600.00	34600.00	34700.00	34633.33
40000.00	39600.00	39700.00	39700.00	39666.67
45000.00	44600.00	44800.00	44900.00	44633.33
50000.00	49900.00	49900.00	50000.00	49933.33

Picture 3 C05E Balcony main frame, weight during test lift



Picture 4 C05E Balcony main frame, shackle WLL



Picture 5 C05E Balcony main frame, sling arrangement

