STRUCTURAL SENSITIVITY AND PARAMETER OF TARPON PLATFORM

by

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Dissertation submitted in partial fulfilment of the requirements for the
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Civil Engineering

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CERTIFICATION OF APPROVAL

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SEPTEMBER 2012

CERTIFICATION OF ORIGINALITY

This is to certify that I am responsible to the work submitted in this project, that the original work is my own except as specified in the references and acknowledgements, and that the original work contained herein have not been undertaken or done by unspecified sources and person.

(Mohamad Syamsul Faiz b Samsudin)

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....

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ABSTRACT

In oil and gas exploration and production, minimum platforms are becoming an increasingly popular solution for the development of marginal oil and gas fields because of their low fabrication cost and the possibility of standardizing the design (Tarpon System, 2008). The minimum platforms like monopod platforms are widely used and installed in marginal fields (low reservoir capacity) to gain a maximum profit by minimizing the capital investment. Tarpon platform is the latest design patented with a single central caisson guyed by 3 pairs of wire rope that anchored to the mudline. There are 51 installations of Tarpon platform worldwide and a lot of researches are carrying on in enhancing the strength of the platform. PETRONAS Management Team (PMT) has noticed that their Tarpon platforms installed in PMO and SBO waters are in very high risk condition due to various reasons. The authors will propose a new way of structural assessment by focusing to the effect of guy cables on the stability and strength of the platform. Tarpon platform will be remodel using SACS software and include the entire load acting. Author will analyse the displacement at the top of caisson by reducing the tension of guy cable as well as complete loss of the cables. The results will show the structural parameter used and sensitivity of the Tarpon platform.

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CHAPTER 1

INTRODUCTION

1.1 Project Background

Tarpon structure is one type of monopod platform that also known as guyed caisson structure. It was newly developed under PETRONAS Carigali (PCSB) for drilling purpose on marginal field. Tarpon has a unique design which is totally different with other platforms installed under PCSB. There are 51 installations worldwide starting from Gulf of Mexico when the design was patented (Tarpon System, 2008). In Malaysia, four (4) tarpon structures have been installed which are three (3) in Peninsular Malaysia (North Lukut, Penara and Ledang) and one (1) in Sabah (Semarang Kecil). All of them have repeated design for both superstructure and substructure. It can be installed in water depth range from 60m up to 350m and support 8 well configurations. Other than that, Tarpon structure can support topside weight up to 350 Tons.

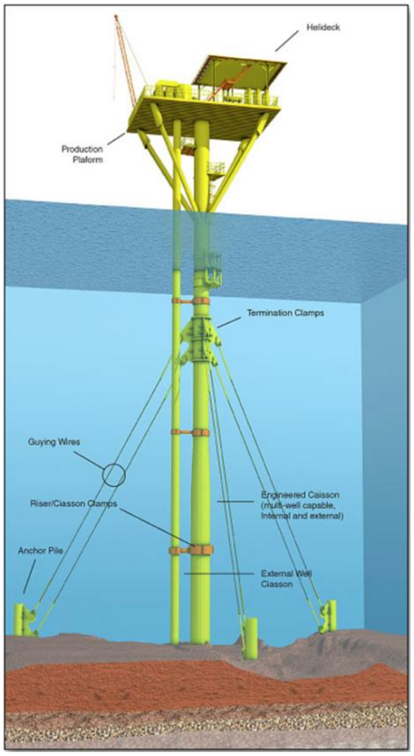


Figure 1: Tarpon Structure

1.2 Problem Statement

In June 2011, PETRONAS Management Team triggered to its management under Structural Health Cockpit traffic light system that the tarpon structures for both PMO and SBO operations were highlighted as Red (Very High Risk) due to the following reasons (GL Noble Denton, 2011) :

1. No availability of structural models
2. Inspection performed to date for these types of platforms appeared to be based on typical conventional jacket.

From the reasons above, PETRONAS has come out with some recommendation for further inspection and assessment plan on tarpon structures. The recommendations are including plan for underwater inspection and inspection interval, further assessment on Safety Critical Elements (SCEs) and additional monitoring on tarpon substructure as well as superstructure.

There is a requirement to assess the integrity of these platforms to verify the current state of the platforms which are currently operating to ensure they are safe to continuous producing and meeting the codes and standards as per design. It is also proposed as a part of this assessment to review the consequence of failure of the guy cables supporting the caisson

1.3 Objective and Scope of Study

In this proposal, the author will focus on a way to assess the stability and strength of the platform. The platform is a single central caisson guyed by three sets of two each pre-tensioned wire ropes and each set is attached to anchor pile driven symmetrically (120º apart) around the caisson. From the previous assessment, some of the Reserve Strength Ratio (RSR) of the structure was dropped below the acceptance criteria based on the six (6) critical scenarios. These scenarios based on the effect of guy cable to the strength of the platform. For this project, the author will assess on the sensitivity of platform due to the tension and the loss in guy cable system.

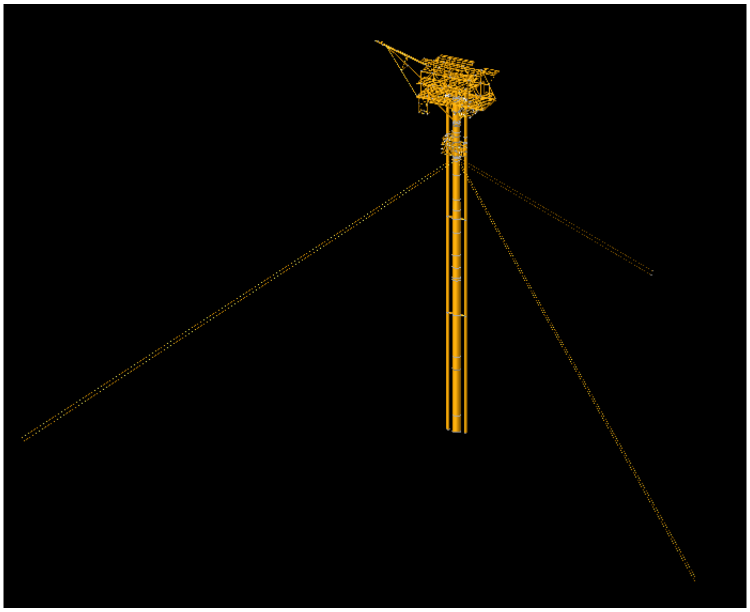


Figure 2: Arrangement of guy wire around the caisson

A single platform is selected to represent all the guyed caissons in the PCSB fleet. The result of this assessment can thus be inferred to all other platforms of the same design. Due to the availability of data in PCSB SICS (Structural Information Computer System), author has choose Ledang platform (LEDP-A) for his project research. Several likelihood of failure which is relevant and critical to guyed caisson structure has been considered in the platform selection. A qualitative rule-based system has been developed to perform platform selection considering the following likelihood of failures:

1. Platform Robustness: Year Design
2. Platform Present Condition: Water Depth
3. Platform Loading Susceptibility: Topside weight or structural natural period

CHAPTER 2

LITERATURE REVIEW

2.1 General

This chapter present on introduction to Tarpon structure, introduction and data for guy cable, environmental data for Peninsular Malaysia water, the platform components as well as design data collected from latest assessment on Tarpon structure.

2.2 Introduction to Tarpon Structure

2.2.1 Overview

There are now 51 cable-guyed caisson minimal production platforms operating in the Gulf of Mexico, West Africa and South East Asia. This type of platform also known as "Tarpon" was first patented and used in 1987. The patented design is fully owned by Stolt Comex Seaway (Oil and Gas Journal, 1999).

The Tarpon platform consists of a central caisson guyed and stabilized by three set of guy cables located 120 degrees apart and composed of two cables each. The cables are connected from the termination clamp attached on central caisson and pinned to the anchor piles at or below the mudline. The anchor cables make an angle of about 35 degrees relative to the mudline. Since the structure's inception, the concept has undergone three significant iterations:

- Original – Guyed with steel cables to underwater anchor piles through sheaves located on the caisson below water with the cables fixed to the caisson above the water through tensioning devices.

Figure 3: Original patented design

- Intermediate – Similar to the first system, except the cables were composed of steel and synthetic fibre with the fibre segment transiting the splash zone for corrosion protection.

- Present – Guyed to a termination clamp on the caisson located below water incorporating an adjustable terminator rod for hydraulic tensioning of the wire rope.

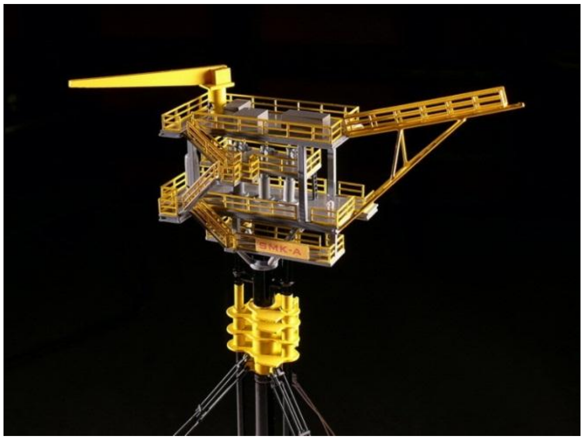


Figure 4: Latest patented design and modelled by Acergy Group

The present system eliminates the corrosion problem and the bending-tension (BT) fatigue concerns due cyclic loading at the shave system. Cathodic protection is provided by sacrificial anode installed on the caisson and anchor piles. To enhance the integrity of the guy cable, the cable end connections are speltered with epoxy resins to avoid the deterioration of these connection and the core wires is bonded to the caisson and piles to provide electrical continuity (Oil and Gas Journal, 1999).

2.2.2 Differentiation

The behaviour and motion of the Tarpon structure is governed by the tension in the guy cable system and the deck mass. The greater the pretension load in the wires, the more linear the wire spring system becomes which lowers the natural period of the platform (GL Noble Denton, 2011). This relation can reduce the deflection and improve the fatigue life of the structure.

Because of the relatively wide spread of the anchor piles, the caisson faces a larger lateral load capacity than typical braced systems platform (GL Noble Denton, 2011). The capacity provides greater reserve strength over a braced system and results in lower cost for water depth exceeding 120 feet. For water depths less than 120 feet, the system geometry allows 360 degree access by boat for servicing wells but it is limited for braced system platform and tripod alternate designs.

2.2.3 Advantages

The system is a cost-effective alternative to traditional fixed, multi-leg platforms and other minimal production platforms. With low construction costs can minimize the capital investment and hence increase the profit. Tarpon design and fabrication time can be as little as six to eight weeks compared to as much as six months for a conventional jacket platform. Other advantages as per listed below:

Commercially attractive:

- Low capital investment
- Early production availability through stock and pre-owned equipment
- Single point coordination – Engineering, fabrication and installation.

Commercial differentiation:

- Repeated design
- Simple fabrication with use of standard material
- Low maintenance cost
- Ease of abandonment

2.3 Introduction to guy cable

Guy cable or wire rope is made up with dozens of individual wires which formed and functioned at close tolerances to one another (Safety Sling, 2009).. In order to accommodate the differences in length between the inside and outside during the bending of wire rope, each of its wires will slide and adjust the shape.

Basically, wire rope has three components which are the wires, strands and core. The core can be either a fibre core (FC) such as sisal, manila and jute or Independent Wire Rope Core (IWRC). IWRC is a smaller wire rope within the strands of the outer wire rope. The wires are predominantly constructed from high-carbon steel, but also can be formed from various types of metal like iron, stainless steel and bronze. There are three grades of carbon steel wire rope that have been manufactured which are Improve Plow Steel (IPS), Extra Improve Plow Steel (EIPS) and Extra Extra Improved Plow Steel (EEIPS). EIPS is the most commonly used and manufactured grade for onshore and offshore purpose (Safety Sling, 2009).

For the corrosion protection, wire ropes will be coated with a galvanized, zinc coating, a tin coating or a synthetic coating such as vinyl or nylon (Safety Sling, 2009). Ropes with plastic coatings and plastic-filled interiors are also can be obtained. The coating on the ropes also will effect on the characteristics and breaking strength of the wire ropes.

Wire ropes are identified by classifications based upon the number of strands and nominal number of wires in each strand. A 6 x 19 classification for example, includes six strands with each strand consisting of 15-26 individual wires. The six strands of a 6 x 37 class wire rope are constructed of 27-49 individual wires. Other popular classifications of wire ropes include 19 x 7, 7 x 19 and 8 x 19.

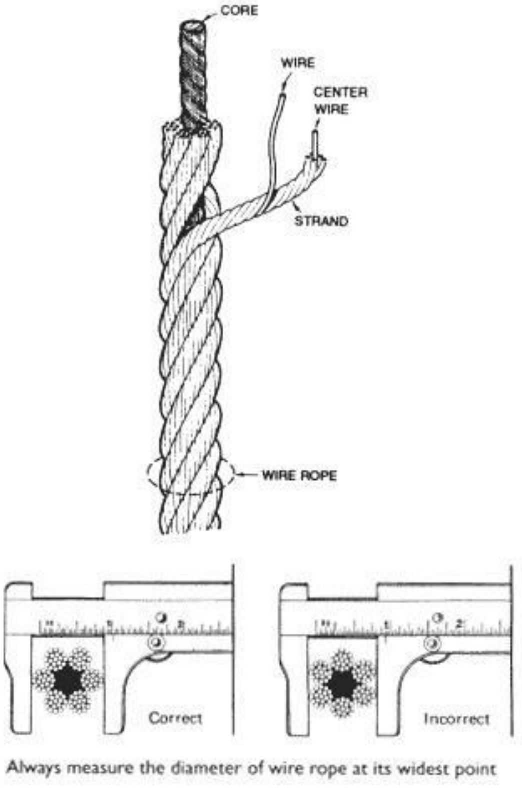


Figure 5: Component of wire rope

2.3.1 Guy cable data for LDPA platform

The cable system is pre-tensioned in order to control the deformations. This pretension is designed to elevate the cable behaviour above the range in which the sag deformations become significant. The axial strain provides resistance to the movements of the cable ends. An analogy can be made in stating that the compression capacity of a cable is its initial tension. This means once the cable has lost its pretension, it goes slack and does not contribute to the structural system in terms of strength or rigidity (Paul Gossen, 2004). For the tarpon platform, every guy cable is pre-tensioned by 100 kips (444.8 kN) and the tension of cables is adjustable for inspection and maintenance work.

Table 1: Guy cable data

Guy Cable Data		
Type	4” EIPS IWRC wire rope	
Effective area	4894 mm²/cable	Extract from Petronas email – Effective diameter is 4.395” which equates to effective area of two cables
Young Modulus	14,000,000 psi	Extract from Petronas email – ropes are considered as linear and “taut” over the displacement range of the in-place analysis. Load range is highest for the in-place analysis so 14,000,000 psi was used for Elastic Modulus per 3rd Edition Wire Rope User’s Manual 20 – 65% loading
Breaking Load	303 MT	

2.4 Platform component and function

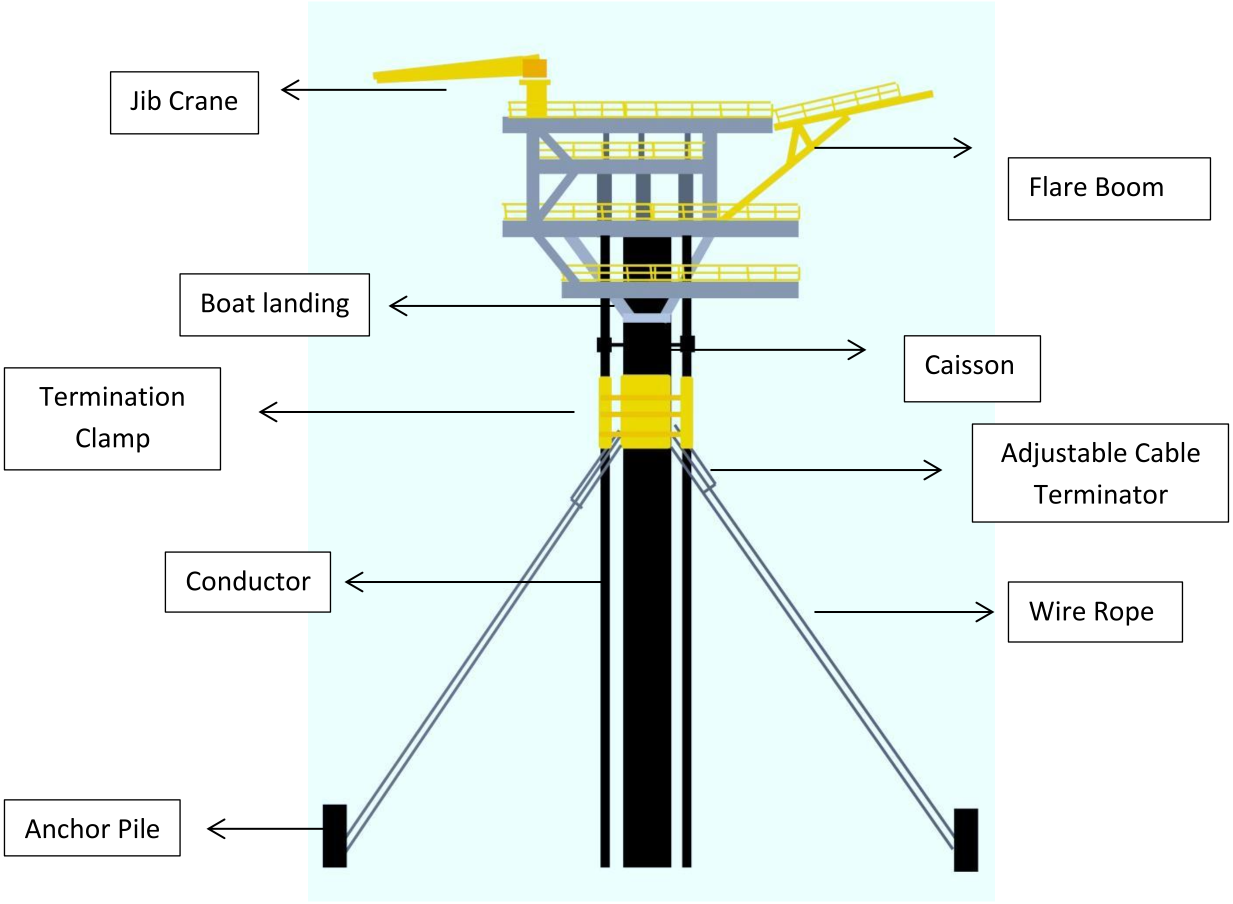


Figure 6: Structure components of Tarpon platform

1. Boat landing – a splash zone structure where people transfer from boat to platform or vice versa
2. Helideck – topside structure where people transfer from helicopter to platform or vice versa
3. Caisson – to protect the conductors, wells and acts as jacket leg.
4. Termination Clamp – connect the wire rope to the platform caisson
5. Adjustable Cable Terminators – to adjust the tension of wire rope
6. Anchor piles – to hold the wire rope to the ground

7. Jib crane – to lift equipment on deck
8. Flare boom – to release the unneeded gases during operation
9. Wire rope – to govern the motion and stabilized the platform
10. Conductor – protect the well and acts the well casing
11. Conductor clamp – to hold the conductors vertically

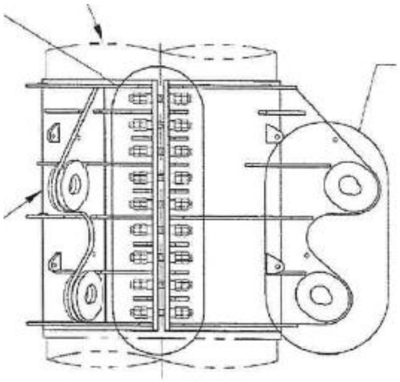


Figure 7: Termination clamp

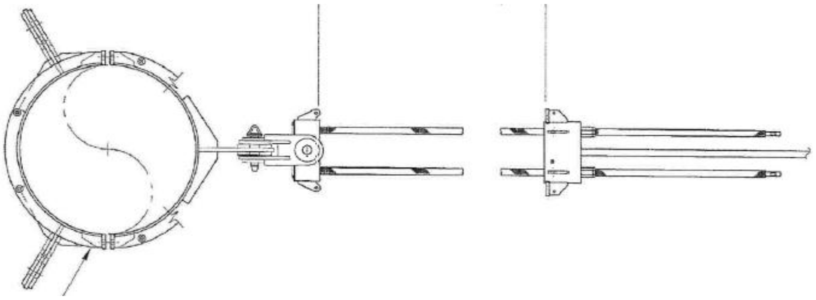


Figure 8: Adjustable cable terminator

2.5 Metocean data for PMO water

The environmental loads will affect the strength of the structure and it is arise from the action of waves, currents and winds. Since the author will assess on LEDP-A platform that installed in PMO water, so the metocean criteria are per below. The data is obtained from PTS 34.19.10.30 (Petronas Technical Standard – Design of fix offshore structure).

The water depth is 70 m

Table 2: Metocean data

Parameters	Units	Operating Criteria	100-year Storm Event
WIND			
1-min mean	m/s	20	29
3-sec Gust	m/s	22	33
WAVE			
Hs	m	4.38	5.77
Tz	sec	6.91	8.06
Tp	sec	9.74	11.37
Hmax	m	8.44	11.65
Tass	sec	8.38	9.64
OCEAN CURRENT			
At surface	m/s	1.24	1.67
At Mid-depth 0.5*D	m/s	0.98	1.33
At near seabed 0.01*D	m/s	0.27	0.36

2.6 LDP-A Characteristic and Design data

The platform characteristics and design data of the platform is important for the analysis. The details can be obtained from Structural Information Computer System developed by PCSB for integrity works.

Table 3: Characteristic data

PLATFORM DETAILS	
Platform Name	LDP-A
Field	PM9
Platform Type	Monopod platform
Platform Function	Drilling/production
Heritage	PCSB
Operator	PETRONAS
Operational Status	Active
Partner	no
Holding	100
Installation Method	Lifting
Year Installed	2006
# in complex	1
Linked Platform	0
Orientation *TN	-45
Lat	5˚13'59.175''
Long	105˚32'48.820''
Easting	578415
Northing	560596.7

GENERIC DETAIL	
Water Depth	76.2m
Jacket Height	82.2m
Air Gap	1.5
Deck Elevation	9.8m
Long Framing	no
Tran Framing	no
# of Bays	no
# of Legs	1
# of Piles	3
# of Leg Piles	0
# of Skirt Piles	0
Maximum Leg Diameter	1981.2mm
Grouted Piles	0
Deck Weight	184.8 MT
Jacket Weight	800MT
Pile Weight	150.34MT
Base Length	no
Base Width	no

OPERATIONAL DETAILS	
Manned	unmanned
Shore Distance	200km
Quarters Capacity	no
# of slots	3
# of caissons	1
# of conductors	3
# of riser	1
Max Cond diameter	0.762m
# of deck	3
# of cranes	1
Max crane size	3 MT
Boatlanding	1
Helipad	0
Helipad type	0
CP type	SA

Table 4: Design data

GENERIC DETAILS	
Water depth	76m
Design Service	D
Design Air gap	1.5
Design Deck Elevation	86.04m
Design Code	API RP2A 21st
Design Life	20 years
Design Return Period	100 years
Design Wave Height	11400mm
Design Current Speed	1.37m/s
Design Tide	1.06m
Design Caisson	1
Design Conductor	3
Design Risers	1
Design Marine Growth	0.153m
Design Scour	0.9m
Design Deck Weight	184.8 MT
Design Conductor Subsidence	0

2.7 Structural reassessment of guyed caisson platform (In-place analysis)

In-place and dynamic analyses results and supporting data were carried out for LEDP-A platform. The analysis is performed in accordance to API RP2A – 21st Edition and AISC ASD using SACS suite of engineering programs. The analysis procedure is based on a linear elastic response of the modelled structure under static loading conditions (GL Noble Denton, 2011).

The analyses is performed on a three dimensional (3D) model of the substructure. The model is a combined model of the substructure and topside. The topside is modelled to account for topside stiffness and also for the purpose of applying topside loads at the correct locations. The platform configuration consists of one inboard well and two outboard wells in approximately 77 meter of water (MSL). The platform is equipped with a multi-level production decks. Metocean and soil foundation design criteria are provided by PETRONAS Carigali Sdn. Bhd.

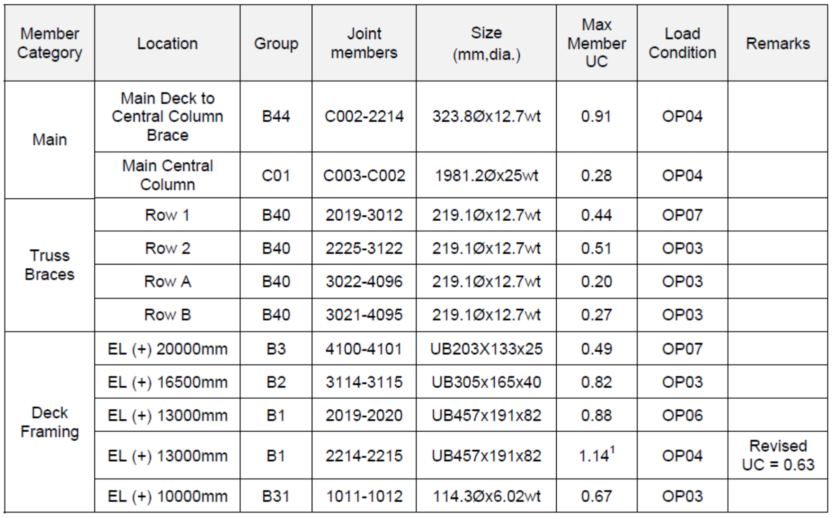
The single central caisson (2133.6mm & 1828.8mm diameter) is guyed by three sets of two each, 101.6 mm diameter, post-tensioned wire ropes each set attached to a 1828.8 mm diameter anchor piles driven symmetrically (120° apart) around the caisson.
The analyses performed and documented will be as follows:

- Topside and substructure in-place analysis (operating and storm).
- Dynamic analysis

Summary of the results:

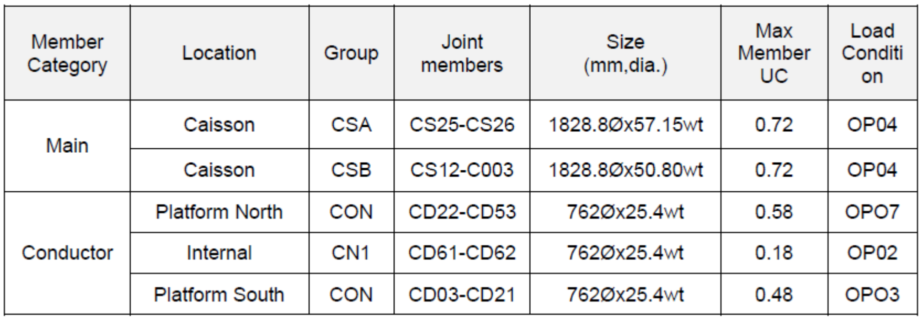
The model has been code checked against the requirements of API RP2A 21st Edition and AISC ASD 9th Edition for both storm and operating environmental conditions. Detail member UC list are attached in Appendix. UC plots are presented in Appendix and summary of maximum UCs for topside and substructure are shown in table below.

Table 5: Topside maximum unity check



Member Category	Location	Group	Joint members	Size (mm,dia.)	Max Member UC	Load Condition	Remarks
Main	Main Deck to Central Column Brace	B44	C002-2214	323.8Øx12.7wt	0.91	OP04	
	Main Central Column	C01	C003-C002	1981.2Øx25wt	0.28	OP04	
Truss Braces	Row 1	B40	2019-3012	219.1Øx12.7wt	0.44	OP07	
	Row 2	B40	2225-3122	219.1Øx12.7wt	0.51	OP03	
	Row A	B40	3022-4096	219.1Øx12.7wt	0.20	OP03	
	Row B	B40	3021-4095	219.1Øx12.7wt	0.27	OP03	
Deck Framing	EL (+) 20000mm	B3	4100-4101	UB203X133x25	0.49	OP07	
	EL (+) 16500mm	B2	3114-3115	UB305x165x40	0.82	OP03	
	EL (+) 13000mm	B1	2019-2020	UB457x191x82	0.88	OP06	
	EL (+) 13000mm	B1	2214-2215	UB457x191x82	1.14[1]	OP04	Revised UC = 0.63
	EL (+) 10000mm	B31	1011-1012	114.3Øx6.02wt	0.67	OP03	

Table 6: Substructure maximum unity check



Member Category	Location	Group	Joint members	Size (mm,dia.)	Max Member UC	Load Condition
Main	Caisson	CSA	CS25-CS26	1828.8Øx57.15wt	0.72	OP04
	Caisson	CSB	CS12-C003	1828.8Øx50.80wt	0.72	OP04
Conductor	Platform North	CON	CD22-CD53	762Øx25.4wt	0.58	OPO7
	Internal	CN1	CD61-CD62	762Øx25.4wt	0.18	OP02
	Platform South	CON	CD03-CD21	762Øx25.4wt	0.48	OPO3

2.8 Structural reassessment for guyed caisson platform (Ultimate strength analysis)

The ultimate strength analysis results and supporting data was carried out for the LEDP-A platform by GL Noble Denton. By using USFOS suite of programs, the analysis was performed in accordance to API RP 2A–WSD 21st Edition (GL Noble Denton).

The analysis was performed on a three dimensional (3D) model of the substructure that consists of both substructure and topsides. The topsides structure was modelled to account for topside stiffness and also for the purpose of applying topside loads at the correct locations. The analysis model was converted from the SACS model used in the in-place analysis.

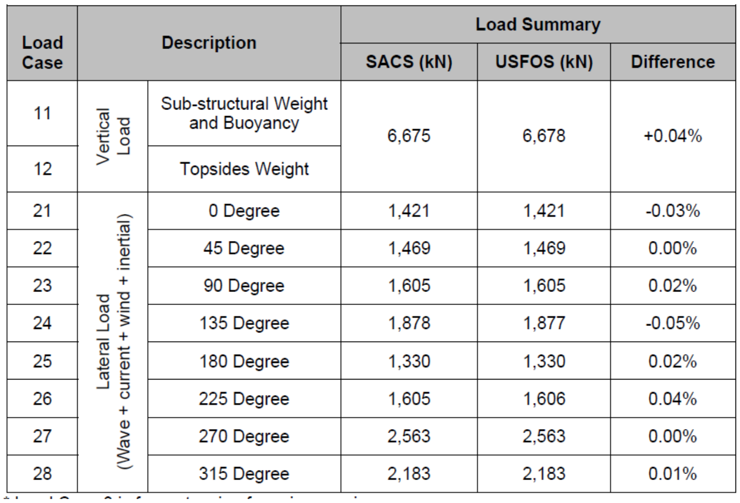
The analyses performed and documented are as follows:

- In-place ultimate strength analysis of the tarpon structure in intact condition to determine the structure's Reserve Strength Ratio (RSR) against the 100-year storm metocean event for eight wave approaching directions (omni direction)
- In-place ultimate strength analysis of the tarpon structure in degraded / damaged condition to determine the structure's RSR against the 100-year storm metocean event for one selected maximum environmental load. The selected wave approaching direction yields the minimum RSR.
- Probability of failure (POF) based on RSR results from ultimate strength assessments and hazard curve (RSR versus Return Period) provided by PCSB.
- Risk categorization the tarpon structure based on the risk matrix and consequence category provided by PCSB.

Summary of the results:

Loads applied in the ultimate strength analysis were directly converted to USFOS format from the SACS in-place analysis for the 100-year storm condition. A comparison of the converted USFOS loads against the original SACS loads for 100-year return storm condition is shown in table below.

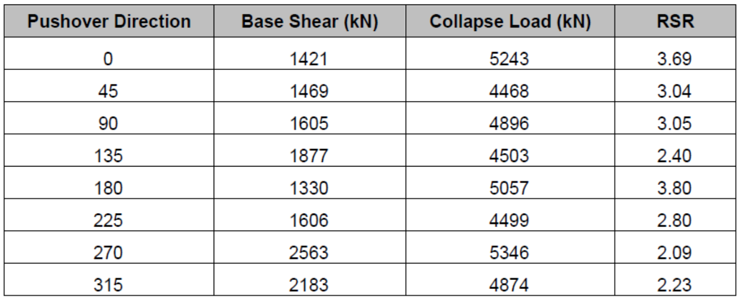
Table 7: Load summary



Load Case	Description		Load Summary		
			SACS (kN)	USFOS (kN)	Difference
11	Vertical Load	Sub-structural Weight and Buoyancy	6,675	6,678	+0.04%
12		Topsides Weight			
21	Lateral Load (Wave + current + wind + inertial)	0 Degree	1,421	1,421	-0.03%
22		45 Degree	1,469	1,469	0.00%
23		90 Degree	1,605	1,605	0.02%
24		135 Degree	1,878	1,877	-0.05%
25		180 Degree	1,330	1,330	0.02%
26		225 Degree	1,605	1,606	0.04%
27		270 Degree	2,563	2,563	0.00%
28		315 Degree	2,183	2,183	0.01%

Ultimate strength assessments of the tarpon structure for the intact condition were performed using 100-year return metocean criteria to determine the RSR. A total of eight (8) directions were included in the ultimate strength assessments. The assessment results for the eight directions are summarized in table beow. It has been observed that the minimum RSR was 2.09 derived from 270-degree pushover direction.

Table 8: Pushover analysis



Pushover Direction	Base Shear (kN)	Collapse Load (kN)	RSR
0	1421	5243	3.69
45	1469	4468	3.04
90	1605	4896	3.05
135	1877	4503	2.40
180	1330	5057	3.80
225	1606	4499	2.80
270	2563	5346	2.09
315	2183	4874	2.23

CHAPTER 3

METHODOLOGY

3.1 Project timeline

Table 9: FYP 1 Gantt Chart

No	Activities	Weeks														
		1	2	3	4	5	6	7		8	9	10	11	12	13	14
1	Selection of project topic	■	■													
2	Preliminary research works ; Collect, search and read related articles		■	■	■	■										
3	Draft the project methodology				■	■										
4	Progress on extended proposal					■	■									
5	Familiarization to SAP2000 Software							■		■	■					
6	Proposal Defence									■	■					
7	Design structure using SAP2000							■		■	■					
8	Result : Assess the sensitivity of the structure by varying the tension of wire rope											■	■	■		
9	Progress on interim draft report														■	■

Table 10: FYP 2 Gantt Chart

No	Activities	Weeks														
		1	2	3	4	5	6	7		8	9	10	11	12	13	14
1	Weekly meeting with supervisor	■	■	■	■	■	■	■		■	■	■	■	■		
2	Improve the literature review		■	■	■	■										
3	Draft the project methodology for FYP 2				■	■										
4	SACS Version 5.3 Program Training (Modelling)					■	■									
5	Structure modelling							■		■	■					
6	Draft on FYP 2 progress report							■		■	■					
7	SACS Version 5.3 Program Training (Analysis)									■	■	■				
8	Structure analysis (In-place analysis)											■	■	■		
9	Result and analysis												■	■		
10	Viva and draft of final report FYP														■	■

3.2 Project methodology

The methodology consists of three main parts. First part is data preparation. Second part is structural modelling using SACS software. Third part is variables design for both manipulative and response variable and the last part is to perform in-place analysis using Linear Static Analysis of SACS software; to determine the maximum joint displacement at top of the caisson based on tension and condition of guy cables.

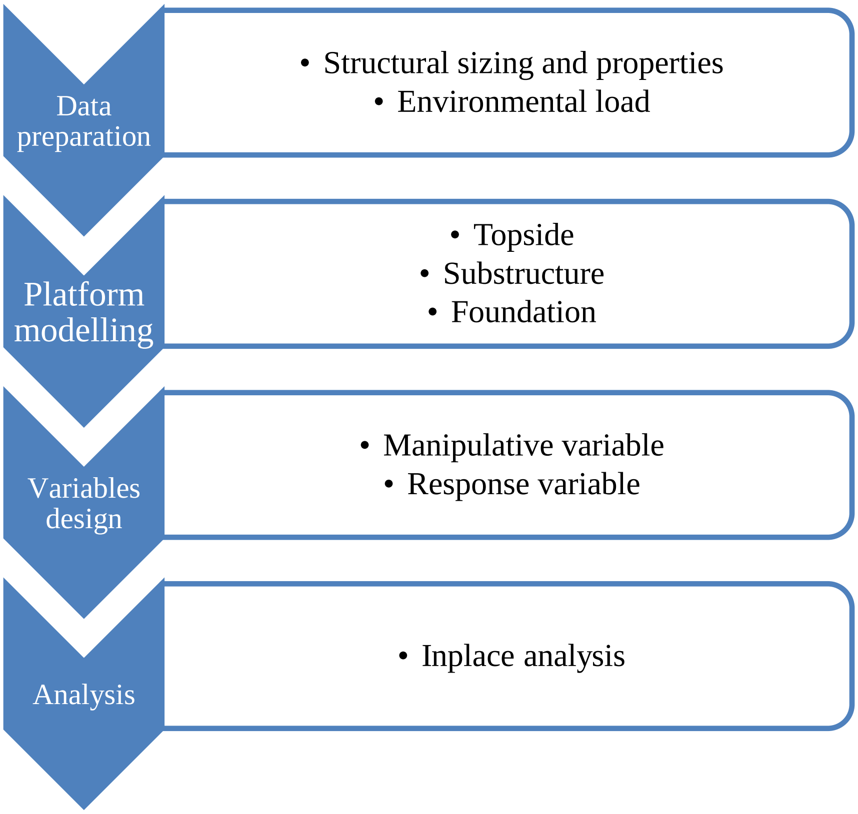


Figure 9: Project methodology

3.2.1 Data preparation

Firstly, review on structural configuration as properties of material were used in structural platform. Identification of dimension and structural properties of every member is important in platform modelling. The data can be obtained from structural drawings and Euro code steel section properties. The structural details of LEDP-A platforms included topside, jacket, guy cables and pile can be obtained from PETRONAS Structural Integrity Management System.

Then, environmental data in Peninsular Malaysia water include wind speed, wave height, current velocity and soil data, are studied and used for platform structures in this study. Based on previous study by PETRONAS, the environmental load that acting in the direction of 270° for the 100 year storm design wave is the maximum. The data for maximum environmental load is used for the analysis.

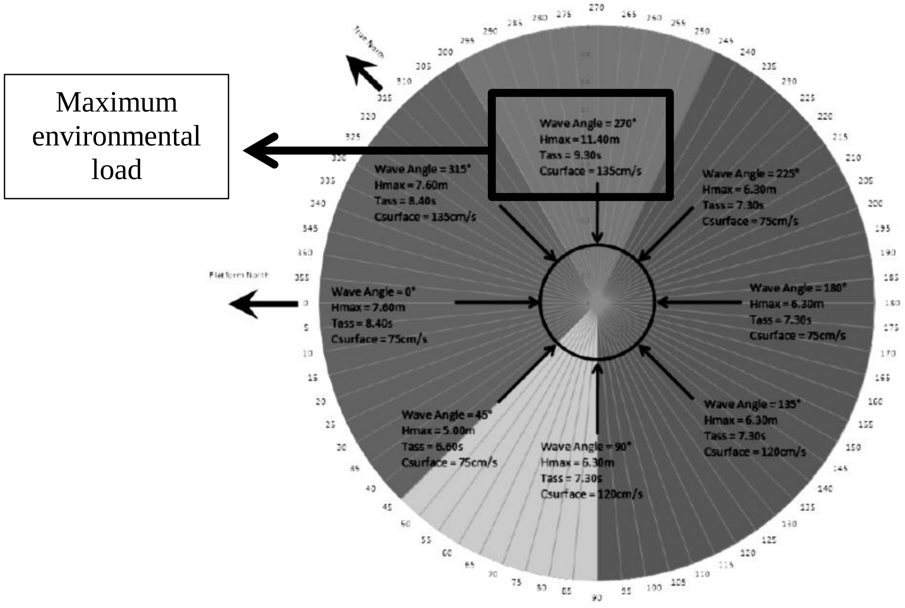


Figure 10: Maximum environmental load direction

3.2.1.1 Wave model

The wave model for 270° direction included the following parameters:

- Wave theory

The characteristics of the wave were determined by Stokes 5th order wave theory. This is as recommended in API RP2A code.

- Morison coefficient

The following Morison coefficients were used to generate the wave and current loads. This is recommended in Section 4.5(a) and Section 4.5(b) of PTS.

Table 11: Morison Coefficients

Member	Cd	Cm
Smooth member	0.683	1.600
Rough member	1.102	1.200

- Wave Kinematics factor

A wave kinematics factor of 0.9 will be used for the strength assessment.

- Wave load

Directional wave parameters are applied for operating and storm conditions. Refer to the following table.

Table 12: Wave load

Wave parameters	100-Year Storm Event Direction wave for 270° direction (Direction from platform north, measure anticlockwise)
Hmax (m)	11.40
Tass (sec)	9.30
Csurface (cm/s)	135

3.2.1.2 Design water depth

The MSL water depth at LEDP-A platform location is 77.11m. The maximum and minimum water depth for storm condition is shown in table below.

Table 13: Design water depth

Component	100-year Return Criteria	
	Min	Max
Mean Sea Level, MSL (m)	77.11	77.11
HAT (m)	-	1.06
LAT (m)	-1.13	-
Storm Surge (m)	-	0.70
Subsidence	-	-
Design Water Depth (m)	75.98	78.87

3.2.1.3 Marine growth

Marine growth thicknesses will be based on the findings of the recent study of marine growth trends in Malaysian regions. The actual values used will be dependent upon the platform location. The relevant thicknesses are presented in the tables below.

Table 14: Marine growth

Depth (m)	Thickness (cm)	Density (tonne/m^3)
0	3.09	1.3
47.11	12.7	1.3
77.11	12.7	1.3

3.2.1.4 Current

The following 270° degree current profiles are used in the analysis. The current is assumed to be acting concurrently with wave in the same direction. A 1/7 power current profile is used in the analysis. The 100-year return period is used for extreme storm condition.

Table 15: Current

Layers in the water column	Depth above seabed D = water depth	Distance (m)	100-Year Return Period Velocity (m/sec)
Surface	1.00 x D	77.11	1.35
Mid-depth	0.50 x D	35.56	1.2
Near-bottom	0.10 x D	7.71	0.95
Near-seabed	0.01 x D	0.77	0.7

3.2.1.5 Wind

For in-place analysis, the one-hour mean wind speed is used for calculating wind loads on the topsides corresponding with maximum wave forces on the substructure. For this analysis a storm condition with 100-year return period is used respectively. The values given are referenced to 10 m elevation above MSL. Wind is assumed to be omnidirectional and acting concurrently with wave in the same direction.

Table 16: Wind

Wind Speed	Return Period	
	1 year	100 year
1-hour mean (m/s)	17.0	23.0

3.2.2 Structure Modelling

3.2.2.1 General

The LEDP-A Tarpon platform is modelled for the topside, substructure and foundation that reflected the correct global stiffness of the structure and includes the caisson, guy cables, anchor piles, primary braces, secondary braces, topsides trusses and girders.

A three-dimensional computer model of the intact condition of tarpon structure is developed using SACS suite of computer programs 5.3 version.

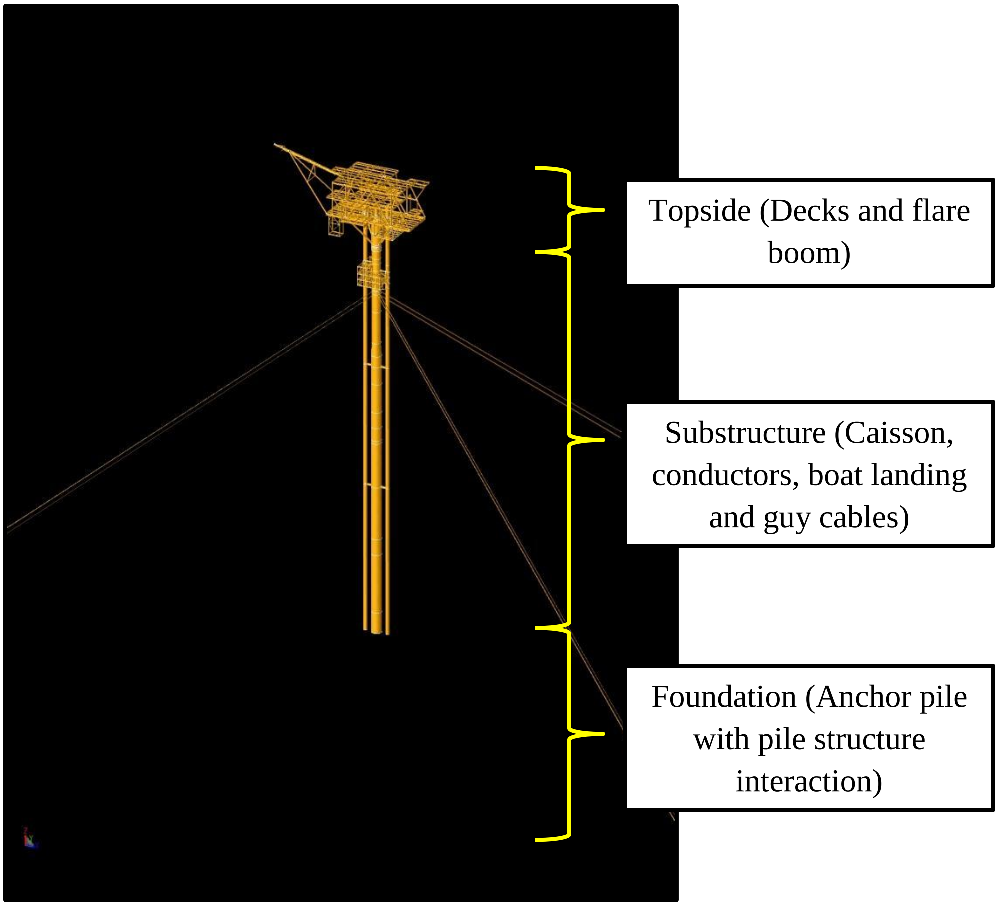


Figure 11: SACS model

3.2.2.2 Coordinate system and units

The platform is modelled in Cartesian coordinates system with Z-axis vertical and positive upwards, X- axis pointing to Platform South and Y-axis pointing Platform East. The origin is at the MSL in the geometric centre of the jacket main gridlines. Units used are as follows:

Length: metre (m)	Time: second (s)
Force: kilo Newton (kN)	Mass: kilogramme (kg)

3.2.2.3 Topside model

The topside model included a detailed model of the topsides structure including all deck elevations. The deck girders and other primary structural components were modelled as beam elements. Reference was made to as-built drawings for definition of geometry, member sizes and steel grades.

The member sizes, geometry and steel grades of structural member are summarized in the table below.

Table 17: Topside (Member size)

Structure	Cross section type	Section Properties	Steel grade
Primary beam	Wide flange	UB 305 x 165 x 40 UB 305 x 133 x 25	Type 1
Secondary beam	Wide flange	UB 203 x 133 x 25	Type 1
Flare boom	Tubular	OD : 32.38cm, WT : 1.27cm	Type 3
Wellhead support	Wide flange	UB 152 x 89 x 16	Type 1
Column and braces	Tubular	OD : 21.91, WT : 1.27cm	Type 3
Topside support	Tubular	OD : 32.38cm, WT : 1.27cm	Type 3

3.2.2.4 Substructure model

The caisson leg, conductors and anchor piles of the platform are modelled using tubular elements. The extent of the model is to the final penetration depth of the caisson and piles into the seabed foundation.

The member sizes, geometry and steel grades of structural member are summarized in the table below.

Table 18: Substructure (Member size)

Structure	Cross section type	Section Properties	Steel grade
Caisson	Tubular	OD : 213.36cm, WT : 3.17cm	Type 3
Conductor	Tubular	OD : 76.2cm, WT : 2.54cm	Type 3
Guy cable	Tubular	OD : 10.16cm, WT : 5.08cm	Type 3

The guy cables are model as a 101.6mm diameter and 50.79mm thick tubular with a cross sectional area of 48.94cm^2. The Young's modulus (E) is 14000000 psi or 9652.660kN/cm^2.

3.2.2.5 Foundation model (including pile soil model)

- **Piles below mud line**

The piles below mud line consist of 3 numbers of 1828.8mm diameter anchor pile and the 2133.6mm diameter caisson leg.

- **Soil data**

Soil data is based on Pile Foundation and Spud can Penetration Analyses for BH Anoa-L1 Ledang-Anoa Location Offshore Terengganu.

3.2.3. Variables design

3.2.3.1 General

Parallel to the research objectives, the author will focus on the effect of tension in guy cables to the platform stability for the analysis. Tension of guy cables is manipulated starting from the existing pre-tensioned of guy cables which is 100 kips. The displacement at a particular joint (top of caisson) is recorded to analyse the stability and strength of the platform.

3.2.3.2 Manipulative variable

Every guy cable is labelled in the direction from platform north, measure anticlockwise. Figure below indicate the label of every guy cable.

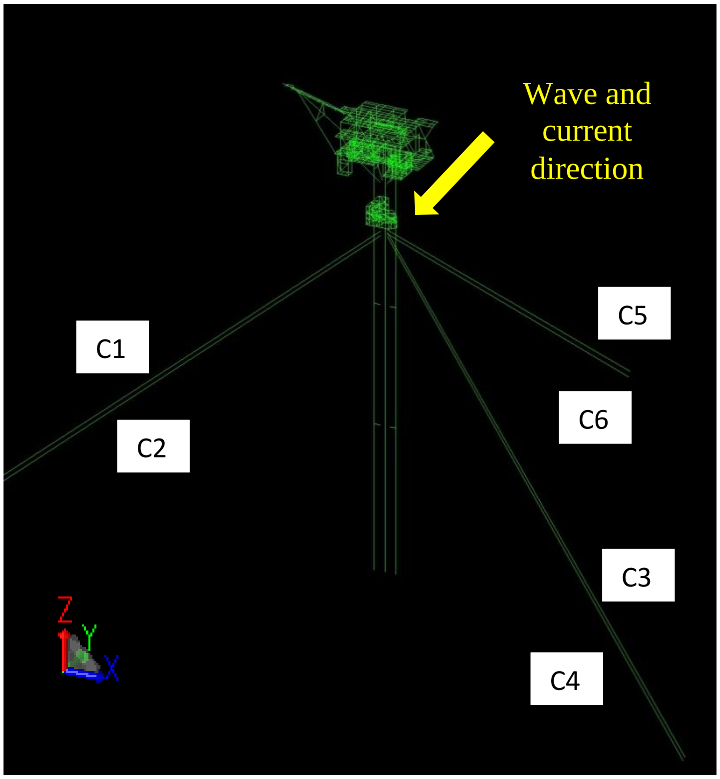


Figure 12: Label of cables

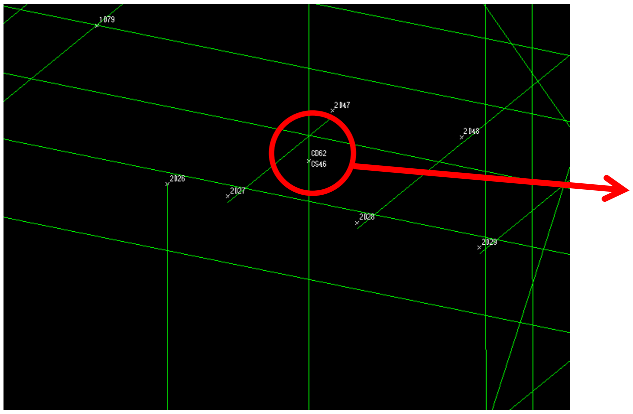
The tension in guy cable is reduced by every 10 per cent until it reaches zero tension and complete loss of the cable. The analysis starting with C1 until C6 and the data recorded until all the cables is completely loss (free standing platform).

The tension of cables can be change in **Member Details** option features in SACS software.

3.2.3.3. Response variable

The displacement of particular joint at the top of caisson for x, y and z direction is recorded as a response variable. The Author decided to take joint CD62 from the model as the reference joint for the analysis.

The displacement of the joint can be obtained from the Postvue report after the analysis completed.



Joint CD62

Top of caisson and the first joint that connect the topside with substructure

Figure 13: Joint CD62

3.2.4. Analysis

The in-place analysis for linear static analysis is conducted in order to obtain the result. The “sacs.inp” of the model is used as input file to run the analysis.

3.2.4.1 In-place analysis

The in-place analysis is use to stimulate the behaviour of structure as close as possible and to obtain the response to all loads during its service. From the analysis also we can check the global integrity of the structure against premature failure and can check the components (member and joint) against the load that they are carrying.

Displacement of the joint will be stated in report file form SACS Postvue after the analysis completed.

3.2.4.2 SACS Postvue

Postvue requires that a “database” of analysis results exist in the current working directory prior to execution. This “database”, referred to as the Postvue database, consists of a subdirectory containing files with analysis results and model information.

Output from Postvue consists an ASCII SACS model file if elements were redesigned, plot files and report files. Plot files may be output in SACS NPF. Report files are generated as ASCII text files.

CHAPTER 4

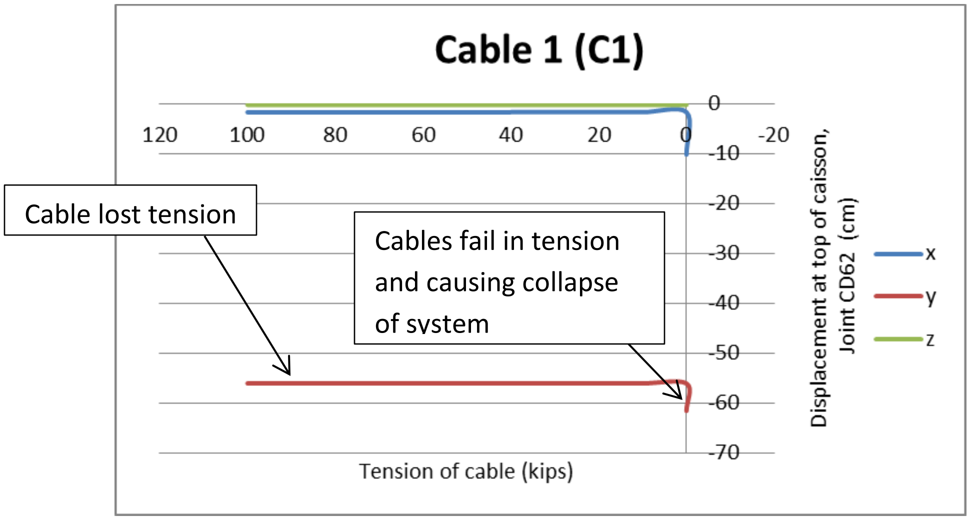
RESULT AND DISCUSSION

4.1 Joint displacement for every pair of cables

4.1.1 Pair 1

4.1.1.1 Cable 1 (C1)

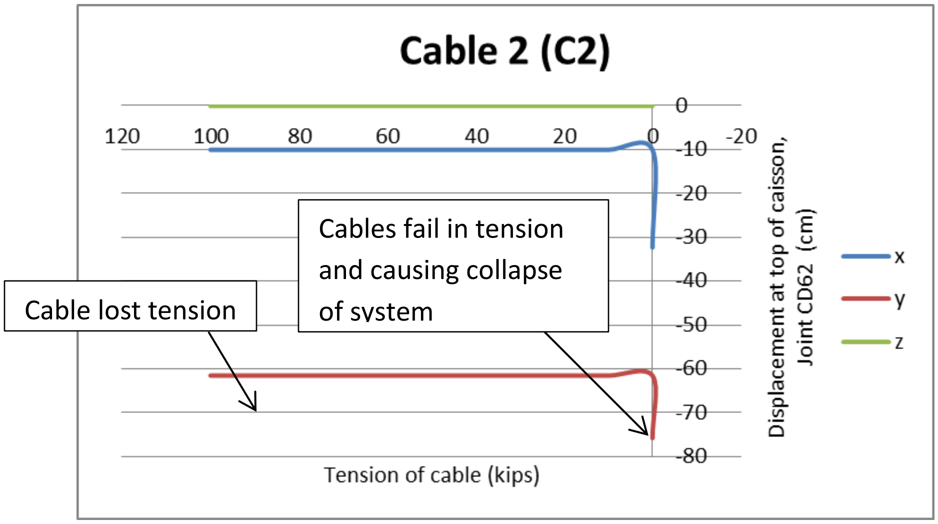
C1	Displacement at top of caisson, Joint CD62 (cm)		
	STM7		
Tension (kips)	x	y	z
100	-1.6155	-56.0048	-0.1435
90	-1.615	-56.0063	-0.1435
80	-1.6145	-56.0078	-0.1435
70	-1.6139	-56.0093	-0.1435
60	-1.6134	-56.0108	-0.1435
50	-1.6129	-56.0123	-0.1435
40	-1.6124	-56.0138	-0.1435
30	-1.6118	-56.0153	-0.1435
20	-1.6113	-56.0168	-0.1435
10	-1.6108	-56.0183	-0.1435
0	-1.6102	-56.0198	-0.1435
Complete loss	-10.1278	-61.5331	-0.1435



Relatively small displacements occur at the joint for both in negative x and y direction. It means that, 100 kips pre-tensioned cables is enough to make the platform stable when subjected to a maximum environmental load.

4.1.1.2. Cable 2 (C2)

C2	Displacement at top of caisson, Joint CD62 (cm)		
	STM7		
Tension (kips)	x	y	z
100	-10.1278	-61.5331	-0.1435
90	-10.1275	-61.5347	-0.1435
80	-10.1273	-61.5362	-0.1435
70	-10.127	-61.5377	-0.1435
60	-10.1268	-61.5392	-0.1435
50	-10.1266	-61.5408	-0.1435
40	-10.1263	-61.5423	-0.1435
30	-10.1261	-61.5438	-0.1435
20	-10.1258	-61.5453	-0.1435
10	-10.1256	-61.5469	-0.1435
0	-10.1253	-61.5484	-0.1435
Complete loss	-32.372	-75.7793	-0.1435



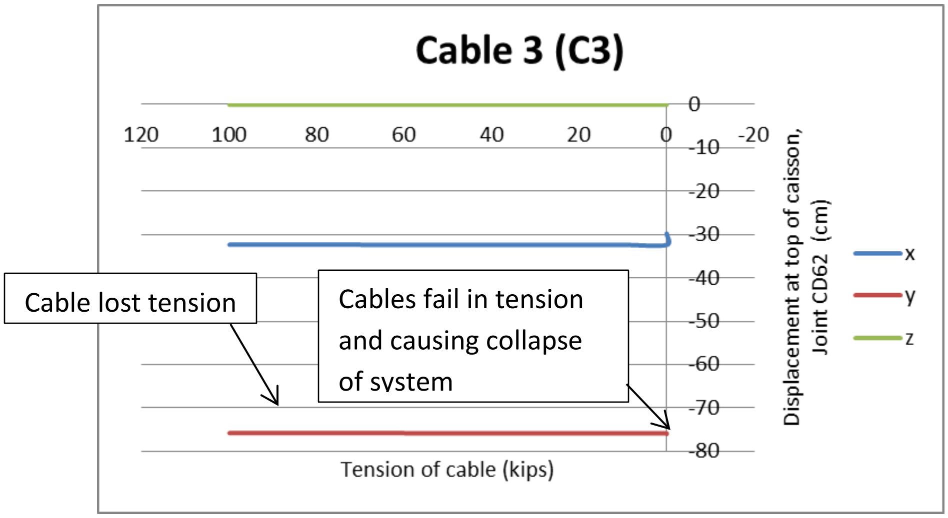
If one of cable (C1) is loss, the displacement rises 10 times greater in negative x and y direction. It means that the two pairs of cable (P1 and P2) are not enough to restrain the environmental load and this can cause a sag deformation in Cable 2.

The stability of platform is still in good condition because the joint displacement is only 10 cm due the loss of Cable 1. When it is come to loss of Cable 2, the displacement is increasing to 30 cm in negative x direction.

4.1.2. Pair 2

4.1.2.1. Cable 3 (C3)

C3	Displacement at top of caisson, Joint CD62 (cm)		
	STM7		
Tension (kips)	x	y	z
100	-32.372	-75.7793	-0.1435
90	-32.3771	-75.7844	-0.1435
80	-32.3822	-75.7894	-0.1435
70	-32.3874	-75.7945	-0.1435
60	-32.3925	-75.7995	-0.1435
50	-32.3976	-75.8046	-0.1435
40	-32.4027	-75.8097	-0.1435
30	-32.4078	-75.8147	-0.1435
20	-32.413	-75.8198	-0.1435
10	-32.4181	-75.8249	-0.1435
0	-32.4232	-75.8299	-0.1435
Complete	-29.7817	-75.985	-0.1435



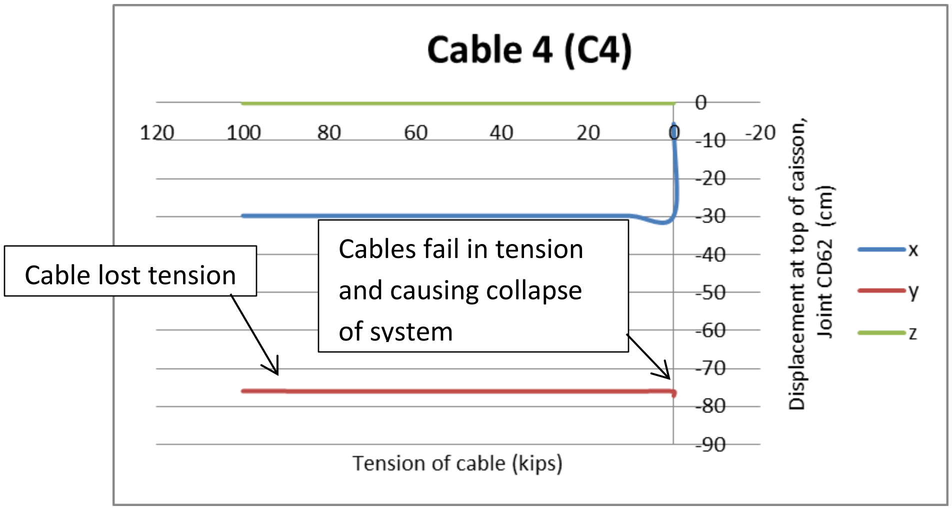
Cable lost tension

Cables fail in tension and causing collapse of system

Relatively small reducing in displacement of the joint occurs when the Cable 3 (C3) is loss. This is because of the reduction in pulling forces in the opposite direction of environmental load.

4.1.2.2. Cable 4 (C4)

C4	Displacement at top of caisson, Joint CD62 (cm)		
	STM7		
Tension (kips)	x	y	z
100	-29.7817	-75.985	-0.1435
90	-29.7884	-75.9896	-0.1435
80	-29.795	-75.9942	-0.1435
70	-29.8016	-75.9987	-0.1435
60	-29.8082	-76.0033	-0.1435
50	-29.8149	-76.0079	-0.1435
40	-29.8215	-76.0125	-0.1435
30	-29.8281	-76.017	-0.1435
20	-29.8347	-76.0216	-0.1435
10	-29.8414	-76.0262	-0.1435
0	-29.848	-76.0307	-0.1435
Complete	-5.5781	-77.2183	-0.1435



Cable lost tension

Cables fail in tension and causing collapse of system

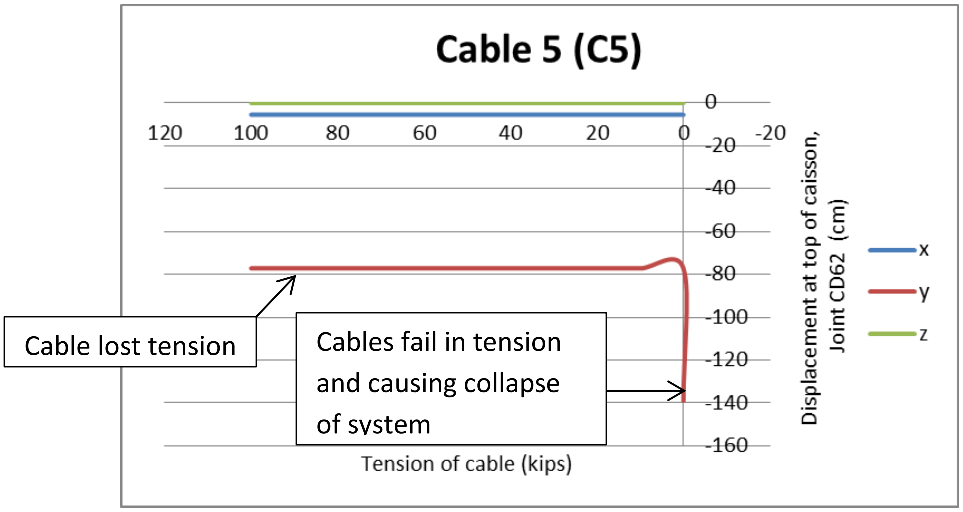
A large displacement toward the positive x-direction occurs when the Cable 5 is loss. There are no pulling forces in the direction that opposite to environmental load can cause a critical displacement of the joint.

The joint move towards the positive x-direction maybe because of a minor wave that coming from 0 degree direction. The cables P3 cannot resist the minor waves as it has to resist the major wave that acting directly to it.

4.1.3. Pair 3

4.1.3.1. Cable 5 (C5)

C5	Displacement at top of caisson, Joint CD62 (cm)		
	STM7		
Tension (kips)	x	y	z
100	-5.5781	-77.2183	-0.1435
90	-5.5815	-77.2195	-0.1435
80	-5.585	-77.2207	-0.1435
70	-5.5884	-77.2219	-0.1435
60	-5.5918	-77.2231	-0.1435
50	-5.5953	-77.2243	-0.1435
40	-5.5987	-77.2255	-0.1435
30	-5.6022	-77.2267	-0.1435
20	-5.6057	-77.2279	-0.1435
10	-5.6091	-77.2291	-0.1435
0	-5.6126	-77.2303	-0.1435
Complete	-5.6172	-138.9813	-0.1435



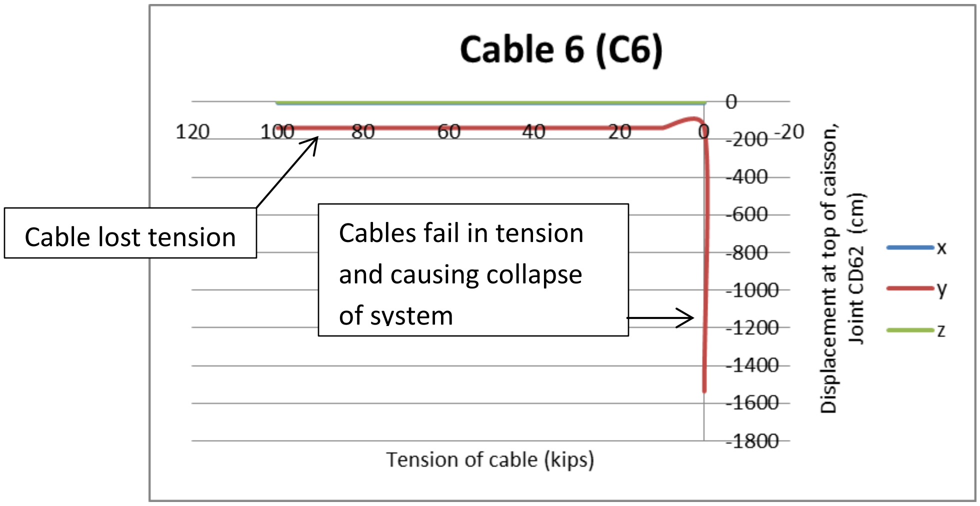
Cable lost tension

Cables fail in tension and causing collapse of system

The reduction of pulling forces that resist maximum environmental load can cause the large displacement toward the negative y-direction.

4.1.3.2. Cable 6 (C6)

C6	Displacement at top of caisson, Joint CD62 (cm)		
	STM7		
Tension (kips)	x	y	z
100	-5.6172	-138.9813	-0.1435
90	-5.6206	-138.9859	-0.1435
80	-5.6239	-138.9904	-0.1435
70	-5.6273	-138.9949	-0.1435
60	-5.6307	-138.9995	-0.1435
50	-5.634	-139.004	-0.1435
40	-5.6374	-139.0086	-0.1435
30	-5.6408	-139.0131	-0.1435
20	-5.6442	-139.0177	-0.1435
10	-5.6476	-139.0222	-0.1435
0	-5.651	-139.0267	-0.1435
Complete	-5.7339	-1537.2505	-0.1435



Cable lost tension

Cables fail in tension and causing collapse of system

Based on the result, a large displacement occurs if all the cables are loss. The platform cannot free stand if subjected to a maximum environmental load. About 10 meter displacement can cause a critical damage on structure especially to the topside facilities.

The critical displacement occurs in negative y-direction opposite to the direction of acting environmental load.

CHAPTER 5

RECOMMENDATION AND CONCLUSION

5.1 Recommendation

5.1.1 Recommendation for underwater inspection

It is understood from PCSB that underwater inspections that have been previously execute on the tarpon substructure were using the similar inspection strategy as for other conventional offshore fixed structures. No tarpon-specific inspection scopes have been developed to date. To ensure a comprehensive and effective inspection for tarpon substructure in future, a guideline must be developed in defining the minimum underwater inspection requirement which target specifically for tarpon substructures.

In developing the minimum underwater inspection requirements, the contractor in charge should identified all Safety Critical Element (SCEs) which should be focused on during inspection. These SCEs are determined based one previous experience; as-built drawings as well as result from the reassessment. Reassessment results especially from the sensitivity studies on the effect of loss of guy cable integrity have been used to define inspection acceptance criteria such as maximum allowable loss of wall thickness on guy wire.

Safety Critical Elements (SCEs) for Tarpon Substructure

SCEs serve as the barriers which prevent, control or mitigate the occurrence of the major accident scenarios. In the context of structure, the worst scenario will be the collapse of the platform. Besides considering the worst scenarios, accidents which will affect the operation have also been considered in identifying the SCEs for tarpon substructure.

Safety Critical Elements (SCEs) for tarpon substructure have been identified as the followings:

1. Termination clamp (including pad eyes)
2. Guy cables (including the adjustable cable terminator, pin connection, shackles at anchor piles and wire clip for CP connectivity)
3. Anchor piles (including pad eyes and anodes)
4. Guyed caisson
5. Conductor and riser
6. Conductor guide
7. Riser clamp
8. Sump caisson
9. Boat landing and riser guard

5.1.2 Recommendations for underwater inspection interval

Table 19: Underwater inspection interval

Inspection interval	SCEs to be inspected
3 years	1. Termination clamp (including pad eyes) 2. Guy cables (including adjustable cable terminator, pin connection, shackles at anchor piles and wire clip for CP connectivity) 3. Anchor piles
6 years	1. Guyed caisson 2. Conductor and riser 3. Conductor guide 4. Riser clamp (including attached anodes) 5. Sump or caisson and clamps 6. Boat landing ad riser guard

5.1.3 Recommendations for additional monitoring

In addition to underwater inspection, it is also recommended to carry out continuous on-line monitoring (OLM) for the measurement of the natural frequency of the tarpon structure. This can be achieved by installation of accelerators on the tarpon topside. The frequency monitoring can provide and record data which reflects the actual dynamic behaviour of the structure (GL Noble Denton, 2011). In the event that the monitored natural frequency has changed, an alarm should be flagged up within the platform operations team. Follow up assessment or inspection should be carried out after such event to ensure that there is no significant loss of tension in guy cables. It is recommended to implement OLM for the structural vibration throughout the service life of the tarpons.

5.1.4 Recommendations for further assessment

Based on the result from both in-place analysis and sensitivity study, the recommendations for further assessment are as below:

- Detailed check on ultimate capacity of the termination clamp
- Detailed check on the guy caisson considering the lock-in-stress which may have occurred due to actual guy cable pre-tensioning sequence

5.2 Conclusion

Based on the author’s research and analysis on the Tarpon platform, topside and substructure have been performed to determine platform’s sensitivity affect by guy cables system. The analysis results in the following conclusions:

- From the in-place analysis, member of guy cable result in maximum number of unity check (refer to Appendix 1). The member is inadequate.
- The behaviour and motion of the Tarpon structure is governed by the tension in the guy cable system and the deck mass.
- The pre-tensioned guy cable by 100kips is enough to minimize the movement and natural frequency of the topside.
- Tarpon platform cannot be free stand without having any guy cables to resist the load that acting on the structure. The loss of all cables can cause a large displacement on the topside which is approximately 10 m.
- Cables in Pair 3 (P3) play an important role to resist the maximum loading acting in 270 degree direction. Cables in P3 cannot resist the load if both P1 and P2 are loss.

The analysis results show that the sensitivity and stability of platform is limited by the strength of the guy cables. Therefore, the capacity of the cable termination clamps plays a critical role

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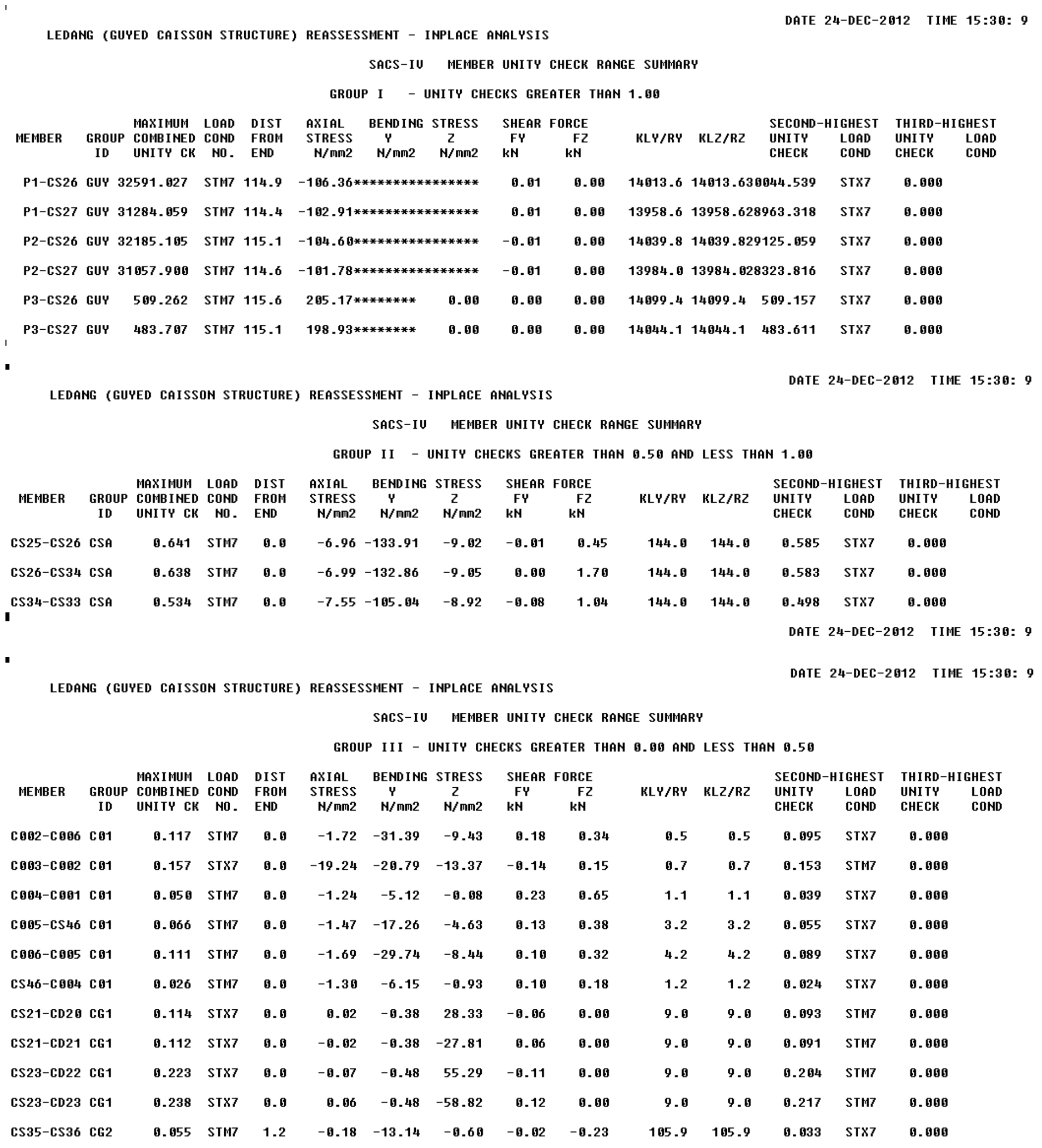
APPENDICES

Appendix 1 – Member unity check range summary



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                                                                                                    DATE 24-DEC-2012  TIME 15:30: 9
     LEDANG (GUYED CAISSON STRUCTURE) REASSESSMENT - INPLACE ANALYSIS

                                                 SACS-IV   MEMBER UNITY CHECK RANGE SUMMARY

                                            GROUP I   - UNITY CHECKS GREATER THAN 1.00

               MAXIMUM  LOAD  DIST    AXIAL    BENDING STRESS    SHEAR FORCE                      SECOND-HIGHEST  THIRD-HIGHEST
 MEMBER   GROUP COMBINED COND  FROM    STRESS     Y        Z       FY       FZ       KLY/RY  KLZ/RZ   UNITY    LOAD   UNITY    LOAD
            ID  UNITY CK  NO.  END     N/mm2    N/mm2    N/mm2   kN       kN                        CHECK    COND   CHECK    COND

  P1-CS26 GUY 32591.027  STM7 114.9  -106.36****************    0.01     0.00   14013.6 14013.630044.539   STX7    0.000

  P1-CS27 GUY 31284.059  STM7 114.4  -102.91****************    0.01     0.00   13958.6 13958.628963.318   STX7    0.000

  P2-CS26 GUY 32185.105  STM7 115.1  -104.60****************   -0.01     0.00   14039.8 14039.829125.059   STX7    0.000

  P2-CS27 GUY 31057.900  STM7 114.6  -101.78****************   -0.01     0.00   13984.0 13984.028323.816   STX7    0.000

  P3-CS26 GUY   509.262  STM7 115.6    205.17********     0.00    0.00     0.00   14099.4 14099.4  509.157   STX7    0.000

  P3-CS27 GUY   483.707  STM7 115.1    198.93********     0.00    0.00     0.00   14044.1 14044.1  483.611   STX7    0.000

                                                                                                     DATE 24-DEC-2012  TIME 15:30: 9
      LEDANG (GUYED CAISSON STRUCTURE) REASSESSMENT - INPLACE ANALYSIS

                                                  SACS-IV   MEMBER UNITY CHECK RANGE SUMMARY

                                             GROUP II  - UNITY CHECKS GREATER THAN 0.50 AND LESS THAN 1.00

                MAXIMUM  LOAD  DIST    AXIAL    BENDING STRESS    SHEAR FORCE                      SECOND-HIGHEST  THIRD-HIGHEST
  MEMBER   GROUP COMBINED COND  FROM    STRESS     Y        Z       FY       FZ       KLY/RY  KLZ/RZ   UNITY    LOAD   UNITY    LOAD
             ID  UNITY CK  NO.  END     N/mm2    N/mm2    N/mm2   kN       kN                        CHECK    COND   CHECK    COND

 CS25-CS26 CSA      0.641  STM7   0.0     -6.96 -133.91    -9.02   -0.01     0.45     144.0   144.0    0.585   STX7    0.000

 CS26-CS34 CSA      0.638  STM7   0.0     -6.99 -132.86    -9.05    0.00     1.70     144.0   144.0    0.583   STX7    0.000

 CS34-CS33 CSA      0.534  STM7   0.0     -7.55 -105.04    -8.92   -0.08     1.04     144.0   144.0    0.498   STX7    0.000
                                                                                                     DATE 24-DEC-2012  TIME 15:30: 9

                                                                                                     DATE 24-DEC-2012  TIME 15:30: 9
      LEDANG (GUYED CAISSON STRUCTURE) REASSESSMENT - INPLACE ANALYSIS

                                                  SACS-IV   MEMBER UNITY CHECK RANGE SUMMARY

                                             GROUP III - UNITY CHECKS GREATER THAN 0.00 AND LESS THAN 0.50

                MAXIMUM  LOAD  DIST    AXIAL    BENDING STRESS    SHEAR FORCE                      SECOND-HIGHEST  THIRD-HIGHEST
  MEMBER   GROUP COMBINED COND  FROM    STRESS     Y        Z       FY       FZ       KLY/RY  KLZ/RZ   UNITY    LOAD   UNITY    LOAD
             ID  UNITY CK  NO.  END     N/mm2    N/mm2    N/mm2   kN       kN                        CHECK    COND   CHECK    COND

 C002-C006 C01      0.117  STM7   0.0     -1.72  -31.39    -9.43    0.18     0.34       0.5     0.5    0.095   STX7    0.000

 C003-C002 C01      0.157  STX7   0.0    -19.24  -20.79   -13.37   -0.14     0.15       0.7     0.7    0.153   STM7    0.000

 C004-C001 C01      0.050  STM7   0.0     -1.24   -5.12    -0.08    0.23     0.65       1.1     1.1    0.039   STX7    0.000

 C005-CS46 C01      0.066  STM7   0.0     -1.47  -17.26    -4.63    0.13     0.38       3.2     3.2    0.055   STX7    0.000

 C006-C005 C01      0.111  STM7   0.0     -1.69  -29.74    -8.44    0.10     0.32       4.2     4.2    0.089   STX7    0.000

 CS46-C004 C01      0.026  STM7   0.0     -1.30   -6.15    -0.93    0.10     0.18       1.2     1.2    0.024   STX7    0.000

 CS21-CD20 CG1      0.114  STX7   0.0      0.02   -0.38    28.33   -0.06     0.00       9.0     9.0    0.093   STM7    0.000

 CS21-CD21 CG1      0.112  STX7   0.0     -0.02   -0.38   -27.81    0.06     0.00       9.0     9.0    0.091   STM7    0.000

 CS23-CD22 CG1      0.223  STX7   0.0     -0.07   -0.48    55.29   -0.11     0.00       9.0     9.0    0.204   STM7    0.000

 CS23-CD23 CG1      0.238  STX7   0.0      0.06   -0.48   -58.82    0.12     0.00       9.0     9.0    0.217   STM7    0.000

 CS35-CS36 CG2      0.055  STM7   1.2     -0.18  -13.14    -0.60   -0.02    -0.23     105.9   105.9    0.033   STX7    0.000
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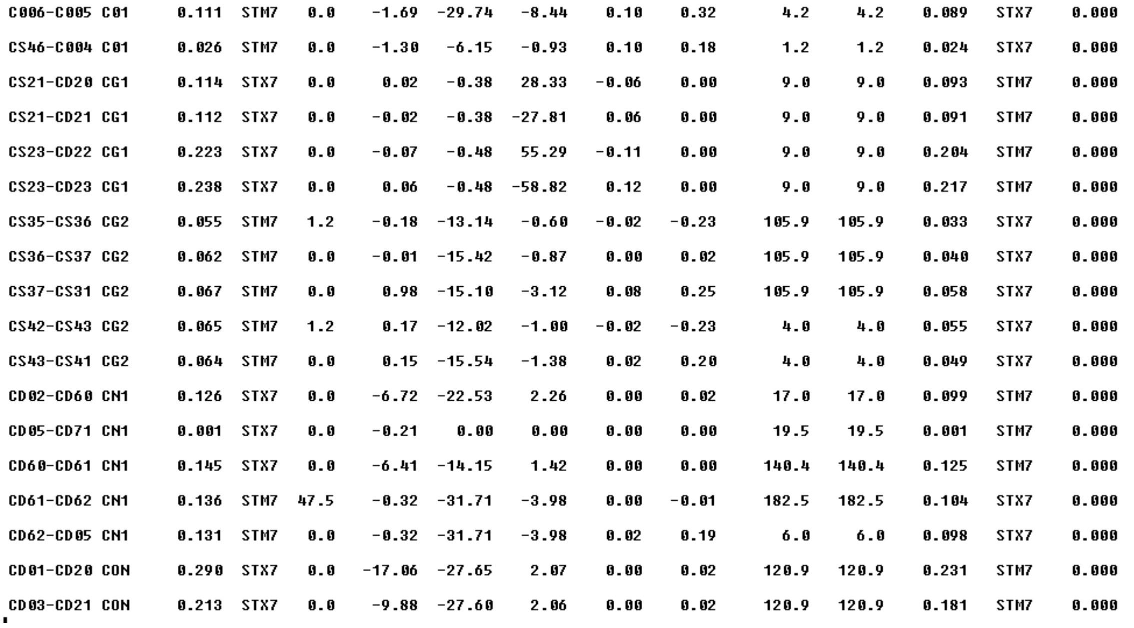

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C006-C005 C01      0.111  STM7   0.0    -1.69  -29.74   -8.44    0.10    0.32      4.2     4.2    0.089   STX7    0.000

CS46-C004 C01      0.026  STM7   0.0    -1.30   -6.15   -0.93    0.10    0.18      1.2     1.2    0.024   STX7    0.000

CS21-CD20 CG1      0.114  STX7   0.0     0.02   -0.38   28.33   -0.06    0.00      9.0     9.0    0.093   STM7    0.000

CS21-CD21 CG1      0.112  STX7   0.0    -0.02   -0.38  -27.81    0.06    0.00      9.0     9.0    0.091   STM7    0.000

CS23-CD22 CG1      0.223  STX7   0.0    -0.07   -0.48   55.29   -0.11    0.00      9.0     9.0    0.204   STM7    0.000

CS23-CD23 CG1      0.238  STX7   0.0     0.06   -0.48  -58.82    0.12    0.00      9.0     9.0    0.217   STM7    0.000

CS35-CS36 CG2      0.055  STM7   1.2    -0.18  -13.14   -0.60   -0.02   -0.23    105.9   105.9    0.033   STX7    0.000

CS36-CS37 CG2      0.062  STM7   0.0    -0.01  -15.42   -0.87    0.00    0.02    105.9   105.9    0.040   STX7    0.000

CS37-CS31 CG2      0.067  STM7   0.0     0.98  -15.10   -3.12    0.08    0.25    105.9   105.9    0.058   STX7    0.000

CS42-CS43 CG2      0.065  STM7   1.2     0.17  -12.02   -1.00   -0.02   -0.23      4.0     4.0    0.055   STX7    0.000

CS43-CS41 CG2      0.064  STM7   0.0     0.15  -15.54   -1.38    0.02    0.20      4.0     4.0    0.049   STX7    0.000

CD02-CD60 CN1      0.126  STX7   0.0    -6.72  -22.53    2.26    0.00    0.02     17.0    17.0    0.099   STM7    0.000

CD05-CD71 CN1      0.001  STX7   0.0    -0.21    0.00    0.00    0.00    0.00     19.5    19.5    0.001   STM7    0.000

CD60-CD61 CN1      0.145  STX7   0.0    -6.41  -14.15    1.42    0.00    0.00    140.4   140.4    0.125   STM7    0.000

CD61-CD62 CN1      0.136  STM7  47.5    -0.32  -31.71   -3.98    0.00   -0.01    182.5   182.5    0.104   STX7    0.000

CD62-CD05 CN1      0.131  STM7   0.0    -0.32  -31.71   -3.98    0.02    0.19      6.0     6.0    0.098   STX7    0.000

CD01-CD20 CON      0.290  STX7   0.0   -17.06  -27.65    2.07    0.00    0.02    120.9   120.9    0.231   STM7    0.000

CD03-CD21 CON      0.213  STX7   0.0    -9.88  -27.60    2.06    0.00    0.02    120.9   120.9    0.181   STM7    0.000
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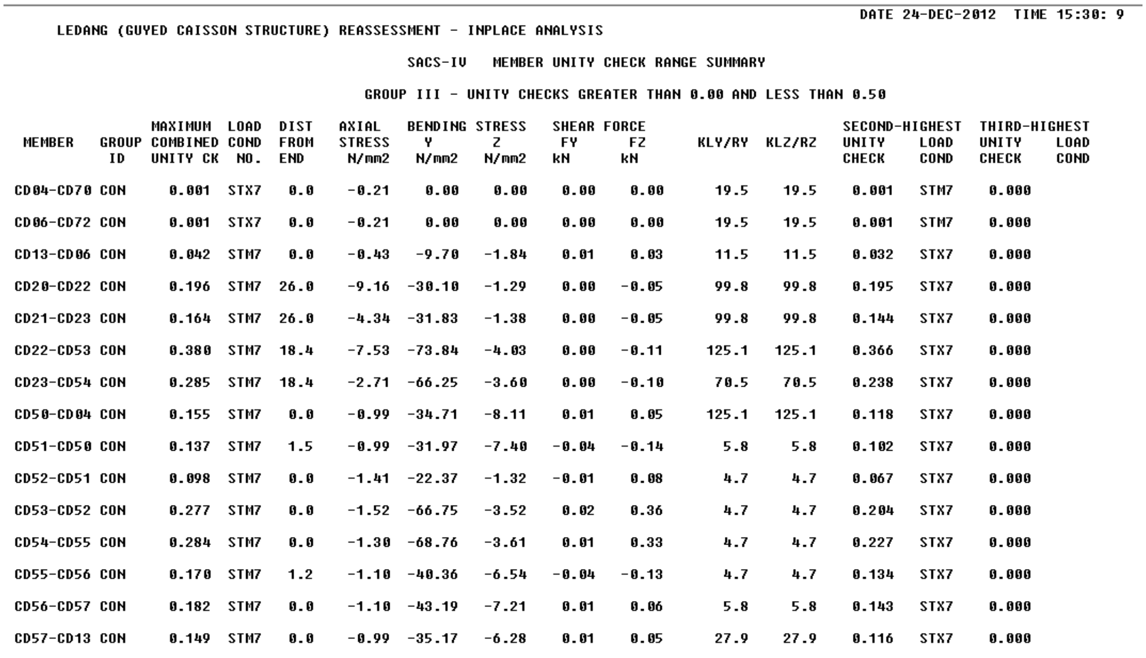

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                                                                                   DATE 24-DEC-2012  TIME 15:30: 9
     LEDANG (GUYED CAISSON STRUCTURE) REASSESSMENT - INPLACE ANALYSIS

                                            SACS-IV   MEMBER UNITY CHECK RANGE SUMMARY

                                      GROUP III - UNITY CHECKS GREATER THAN 0.00 AND LESS THAN 0.50

                    MAXIMUM  LOAD  DIST    AXIAL   BENDING STRESS   SHEAR FORCE                      SECOND-HIGHEST  THIRD-HIGHEST
  MEMBER     GROUP COMBINED COND  FROM    STRESS     Y       Z        FY     FZ      KLY/RY  KLZ/RZ  UNITY    LOAD   UNITY    LOAD
               ID  UNITY CK  NO.  END      N/mm2   N/mm2   N/mm2    kN     kN                       CHECK    COND   CHECK    COND

 CD04-CD70 CON      0.001  STX7   0.0    -0.21    0.00    0.00    0.00    0.00     19.5    19.5    0.001   STM7    0.000

 CD06-CD72 CON      0.001  STX7   0.0    -0.21    0.00    0.00    0.00    0.00     19.5    19.5    0.001   STM7    0.000

 CD13-CD06 CON      0.042  STM7   0.0    -0.43   -9.70   -1.84    0.01    0.03     11.5    11.5    0.032   STX7    0.000

 CD20-CD22 CON      0.196  STM7  26.0    -9.16  -30.10   -1.29    0.00   -0.05     99.8    99.8    0.195   STX7    0.000

 CD21-CD23 CON      0.164  STM7  26.0    -4.34  -31.83   -1.38    0.00   -0.05     99.8    99.8    0.144   STX7    0.000

 CD22-CD53 CON      0.380  STM7  18.4    -7.53  -73.84   -4.03    0.00   -0.11    125.1   125.1    0.366   STX7    0.000

 CD23-CD54 CON      0.285  STM7  18.4    -2.71  -66.25   -3.60    0.00   -0.10     70.5    70.5    0.238   STX7    0.000

 CD50-CD04 CON      0.155  STM7   0.0    -0.99  -34.71   -8.11    0.01    0.05    125.1   125.1    0.118   STX7    0.000

 CD51-CD50 CON      0.137  STM7   1.5    -0.99  -31.97   -7.40   -0.04   -0.14      5.8     5.8    0.102   STX7    0.000

 CD52-CD51 CON      0.098  STM7   0.0    -1.41  -22.37   -1.32   -0.01    0.08      4.7     4.7    0.067   STX7    0.000

 CD53-CD52 CON      0.277  STM7   0.0    -1.52  -66.75   -3.52    0.02    0.36      4.7     4.7    0.204   STX7    0.000

 CD54-CD55 CON      0.284  STM7   0.0    -1.30  -68.76   -3.61    0.01    0.33      4.7     4.7    0.227   STX7    0.000

 CD55-CD56 CON      0.170  STM7   1.2    -1.10  -40.36   -6.54   -0.04   -0.13      4.7     4.7    0.134   STX7    0.000

 CD56-CD57 CON      0.182  STM7   0.0    -1.10  -43.19   -7.21    0.01    0.06      5.8     5.8    0.143   STX7    0.000

 CD57-CD13 CON      0.149  STM7   0.0    -0.99  -35.17   -6.28    0.01    0.05     27.9    27.9    0.116   STX7    0.000
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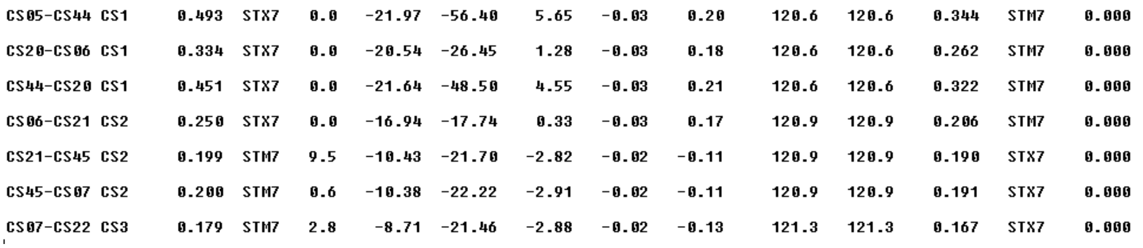

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CS05-CS44 CS1      0.493  STX7   0.0   -21.97  -56.40    5.65   -0.03    0.20     120.6   120.6    0.344   STM7    0.000

CS20-CS06 CS1      0.334  STX7   0.0   -20.54  -26.45    1.28   -0.03    0.18     120.6   120.6    0.262   STM7    0.000

CS44-CS20 CS1      0.451  STX7   0.0   -21.64  -48.50    4.55   -0.03    0.21     120.6   120.6    0.322   STM7    0.000

CS06-CS21 CS2      0.250  STX7   0.0   -16.94  -17.74    0.33   -0.03    0.17     120.9   120.9    0.206   STM7    0.000

CS21-CS45 CS2      0.199  STM7   9.5   -10.43  -21.70   -2.82   -0.02   -0.11     120.9   120.9    0.190   STX7    0.000

CS45-CS07 CS2      0.200  STM7   0.6   -10.38  -22.22   -2.91   -0.02   -0.11     120.9   120.9    0.191   STX7    0.000

CS07-CS22 CS3      0.179  STM7   2.8    -8.71  -21.46   -2.88   -0.02   -0.13     121.3   121.3    0.167   STX7    0.000
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                                        SACS-IV   MEMBER UNITY CHECK RANGE SUMMARY

                                   GROUP III - UNITY CHECKS GREATER THAN 0.00 AND LESS THAN 0.50

                MAXIMUM  LOAD  DIST   AXIAL   BENDING STRESS   SHEAR FORCE                       SECOND-HIGHEST THIRD-HIGHEST
 MEMBER   GROUP COMBINED COND  FROM   STRESS    Y       Z       FY      FZ      KLY/RY  KLZ/RZ   UNITY    LOAD  UNITY    LOAD
           ID   UNITY CK  NO.  END     N/mm2  N/mm2    N/mm2   kN      kN                        CHECK    COND  CHECK    COND

CS22-CS08 CS3     0.188  STM7   3.3    -8.36  -24.62   -3.32   -0.02   -0.15     121.3   121.3    0.170   STX7   0.000

CS08-CS09 CS4     0.186  STM7   6.1    -6.87  -28.24   -3.63   -0.02   -0.21     121.6   121.6    0.161   STX7   0.000

CS09-CS23 CS5     0.150  STM7   3.7    -5.85  -29.83   -3.64   -0.02   -0.25     122.0   122.0    0.137   STX7   0.000

CS23-CS10 CS5     0.165  STM7   2.4    -5.61  -35.89   -3.86   -0.02   -0.50     122.0   122.0    0.151   STX7   0.000

CS10-CS11 CS6     0.245  STM7   2.7    -6.36  -59.95   -5.68   -0.02   -0.53     131.7   131.7    0.220   STX7   0.000

CS11-CS24 CS7     0.340  STM7   6.7    -5.84  -88.44   -6.53   -0.02   -0.63     143.0   143.0    0.320   STX7   0.000

CS24-CS27 CS7     0.390  STM7   3.9    -5.46 -107.36   -7.02   -0.02   -0.71     143.0   143.0    0.366   STX7   0.000

CS27-CS25 CS7     0.391  STM7   0.0    -5.51 -107.44   -7.02   -0.01    0.51     143.0   143.0    0.367   STX7   0.000

C003-CS03 CS8     0.123  STM7   0.0    -0.43  -27.88   -7.53    0.08    0.50     142.5   142.5    0.092   STX7   0.000

CS03-CS13 CS8     0.108  STM7   0.0    -0.37  -24.41   -7.08    0.16    0.52     142.5   142.5    0.082   STX7   0.000

CS01-CS04 CS9     0.000  STX7   0.0    -0.02    0.00    0.00    0.00    0.00     141.5   141.5    0.000   STM7   0.000

CS02-CS01 CS9     0.070  STM7   0.0    -0.25  -15.66   -4.35    0.13    0.47     141.5   141.5    0.052   STX7   0.000

CS13-CS02 CS9     0.129  STM7   0.0    -0.43  -29.05   -8.39    0.16    0.52     141.5   141.5    0.098   STX7   0.000

CS30-CS12 CSA     0.411  STX7   0.0   -12.71  -49.76  -21.73   -0.02    0.59     144.0   144.0    0.407   STM7   0.000

CS32-CS30 CSA     0.441  STM7   0.0    -7.41  -82.21  -11.69   -0.12    0.67     144.0   144.0    0.427   STX7   0.000

CS33-CS32 CSA     0.485  STM7   0.0    -7.43  -93.34   -9.85   -0.08    1.01     144.0   144.0    0.458   STX7   0.000
```