DAMAGE ASSESSMENT OF OFFSHORE RISER-GUARDS UNDER IMPACT LOADING

By

Thuang Chee Kee

13865

Dissertation submitted in partial fulfillment of

the requirement for the

Bachelor of Engineering (Hons)

(Civil Engineering)

May 2014

Supervised by: Dr. Zubair Imam Syed

UNIVERSITI TEKNOLOGI PETRONAS

Bandar Seri Iskandar

31750 Tronoh

Perak Darul Ridzuan

CERTIFICATION OF APPROVAL

Damage Assessment of Offshore Riser-guards under Impact Loading

By

Thuang Chee Kee

13865

A project dissertation submitted to the

Civil Engineering Programme

Universiti Teknologi PETRONAS

in partial fulfilment of the requirement for the

BACHELOR OF ENGINEERING (Hons)

(CIVIL)

Approved by,

____

(Dr. Zubair Imam Syed)

UNIVERSITI TEKNOLOGI PETRONAS

TRONOH, PERAK

MAY 2014

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.

____

(THUANG CHEE KEE)

ABSTRACT

Steel riser-guards are installed on the offshore platforms to protect the risers against accidental vessel collisions. Offshore riser protection is important due to the flammable content it carries. In the absence of riser-guards, vessel collision can damage risers and hence leads to platform explosion. The conventional riser guards are designed to resist static force equivalent to vessel collision on any part of steel frame. Vessel collision with offshore structure has been highlighted in many design standards. However, those studies only limit to the structural response of the whole platform. In depth, investigation on the structural response and performance of riser guard has not been carried out. Therefore, this project was carried out to have better understanding on structural response of conventional riser guard in order to provide more economic and effective design of riser guard. In this project, finite element modelling of conventional riser guard under impact loading was performed using different Structural Analysis Computer System (SACS) modules to study its structural behavior. Different types of vessel collision scenario were studied in this research to understand the structural response and damage of steel riser-guards under different accidental vessel impacts. The riser-guards were modelled under impact load equivalent to vessel collision using SACS. The deformation, stress, strain and unity check values were analyzed to investigate the structural response and resulting damage to the riser-guards. Different magnitude of vessel impact loads were applied to the riser guard till its maximum capacity. The simulation shows that the maximum deformation occurs at the center of the riser guard. Collapse analysis was performed to study the plastic deformation of riser-guard and its plasticity. The structural response of offshore riser guard for different vessel collision scenarios was studied and presented in this paper.

ACKNOWLEDGEMENTS

First and foremost, I would like to thank Civil Department Final Year Project (FYP) Committee of Universiti Teknologi PETRONAS for the opportunity and platform provided for students to perform their final year project through a well-planned course. FYP committee provides clear guidance and advices for students to complete their final year project.

I would like to express my greatest gratitude and appreciation to my FYP supervisor, Dr. Zubair Iman Syed for all his guidance and advices throughout the completion of my final year project. His experience and knowledge in the civil engineering industry never fails to answer my queries and clear my doubts. With his supervision, I am able to complete my final year project successfully with the opportunity to learn and gain valuable knowledge in the engineering field.

Furthermore, a million thanks to Dinesh, a post graduate student for his suggestion, time, guidance and information towards this project completion.

In nutshell, I am blessed to be given the opportunity to work on my final year project under the supervision of my supervisor. The experience and knowledge gain will be valuable for my future undertaking. I would like to thank again everyone that has helped me throughout the completion of my final year project.

TABLE OF CONTENTS

LIST OF FIGURE

LIST OF TABLE:

CHAPTER 1

INTRODUCTION

1.1 BACKGROUND OF THE STUDY

Offshore platforms receive frequent visits from vessel during its operation. Throughout its operation, offshore platforms always threatened by accidental load such as vessel collision. Uncontrolled accidental collision between the vessel and platform can results in fatalities and major economic loss. Various types of riser protection systems are introduced to prevent vessel colliding against offshore riser.

Riser-guards are tubular steel space frame installed on fixed jacket platforms to protect riser from accidental vessel collision. The conventional riser-guards are designed to resist static force equivalent to a collision [1]. In an event of collision, any plastic deformation of riser guard must be followed by maintenance work, which requires the removal and replacement of the steel tubular member [2]. Protection for the riser is extremely crucial as there are high volumes of extremely flammable fluids flowing through the risers. With the absence of riser-guards, accidental vessel collision against riser can cause oil spill and even result in explosion. The Mumbai High North Platform Disaster is the significant prove for the importance of riser guard in oil and gas industry [3]. As a precaution against vessel collision, the riser-guards are installed on offshore platforms on Malaysian water to provide protection against accidental impact load.

The conventional riser-guards shown in Figure 1 consist of welded steel tubular members forming a mesh-like structure, shielding the riser against vessel. The current design of conventional riser-guards is an adoption of boat fender design criteria The design is plasticity based where it allows the riser-guard to undergo large deformation for higher energy dissipation and for reduction of impact force [1].

FIGURE 1: Conventional riser-guard

1.2. PROBLEM STATEMENT

The transport of hydrocarbons from subsea well to production or storage unit positioned at the sea surface is conducted by variety of risers [4]. The protection for risers is very vital to prevent casualties and economic loss due to accidental vessel collision against risers. The absence of riser-guard was made significant during the Mumbai High North Platform Disaster. The vessel collision resulted in 22 fatalities and a total damage amounting up to USD 195 million [3].

PETRONAS has been using a riser guard system that is similar to a boat fender on their fixed offshore platforms in Malaysian water. The conventional riser-guard adopts the design principle of boat fender as there is no riser-guard design standard established yet. The riser guard is designed to resist collision equivalent static force acting anywhere on the frame [1]. Vessel collision with offshore structures has been well studied and highlighted in many design manuals for offshore structures. However, there are no much studies on structural response and performance of conventional riser-guard. The adoption of the boat fender design criteria for conventional riser-guard can result in uneconomical design. Several issues have been raised over the use of conventional riser guard on fixed platforms [2]:

i. *Excessive weight*: A 14m wide and 10m high conventional riser-guard system weighs up to 63 tonnes.

ii. *Huge cost*: Due to its weight, floating vessel will have to be used during the installation of riser guard on platforms. The rate of floating vessel usage is estimated to be RM 500,000 (approximately 150,000 USD) per day.

iii. *Time consuming*: The installation of conventional riser-guard requires welding work that is time consuming and also raises safety issues.

Therefore, damage assessment of offshore riser-guards under impact loading should be studied. Proper understandings of mechanism for transfer of reaction force to the jacket legs are very vital for further improvement of the riser-guard design.

1.3 OBJECTIVES

The objectives of the project are:

- To perform finite element modelling of conventional riser guards under impact loading.
- To determine the structural capacity of riser guard under accidental impact loading.
- To perform damage assessment of riser guard under vessel impact.

1.4 SCOPE OF THE STUDY

This study focused on the structural analysis of steel conventional riser guard under accidental vessel impact load. The scope of analysis as of this report covers from the Linear Static in Place analysis, Ship Impact Analysis and the Non Linear Collapse analysis.This research will only focus on the assessment of conventional steel riser guard where any new innovation of riser guard is considered beyond the scope of study. The conventional riser guard will be simulated under impact loading equivalent to a vessel collision using Structural Analysis Computer System (SACS) modules. In this study, other loadings such as wave, current and sea-state load are considered negligible as compared to accidental vessel impact load. Thus, the effect of these loadings on performance of offshore riser guard is considered out of the scope. Non-linear structural analysis of riser guard will be performed in the study while experiment variation of the finite element result is considered beyond the scope of study. The structural behavior of conventional riser guard is studied and analyzed in accordance to American Petroleum Institute (API) standard and PETRONAS Technical Standard (PTS). The deformation, and stress of the model are analyzed to study the plasticity characteristic of riser guard and unity check will be performed to determine the actual capacity of the riser guard. The global deformation of offshore riser guard under impact loading was studied but localized deformation due to local denting was beyond the scope of the research.

CHAPTER 2

LITERATURE REVIEW

Continually growing world energy markets lead to increase of demand on oil and gas production. Offshore platforms contribute up to 30% of the world's oil production [5] and is needed for oil and gas exploration and production. Today, there are over 11095 offshore platforms around the world in water depth up to 2280m [5]. The riser protection system was introduced to protect the riser against vessel collision. This chapter summarizes various aspects of ship-platform collision, collision mechanics and review past research in the related area.

2.1 TYPES OF OFFSHORE PLATFORM

There are different types of offshore platforms depending on the depth of the water. The offshore platform can be classified into fixed structures and floating structures. Tables 1 summarize the total number of operational platform in world in year 2012. Researches have shown that 96.4% of offshore platforms are fixed platform [5].

TABLE 1: Operational Platform in year 2012 [5]

Type of Platform	Number	Percentage
Fixed Platform	10700	96.4%
Floating Platform	395	3.6%
Total	11095	100.0%

Fixed structures are extending to the seabed such as Fixed Jacket Platform, Compliant Tower, Gravity Based Structure (GBS) and Jack-up barges. Furthermore, floating structure is structure that float near the water surface [6]. Examples of floating structure are semisubmersible, spar, tension leg platform (TLP), floating production system (FPS) and FPSO [6]. Figure below shows different types of offshore platform in different water depth.

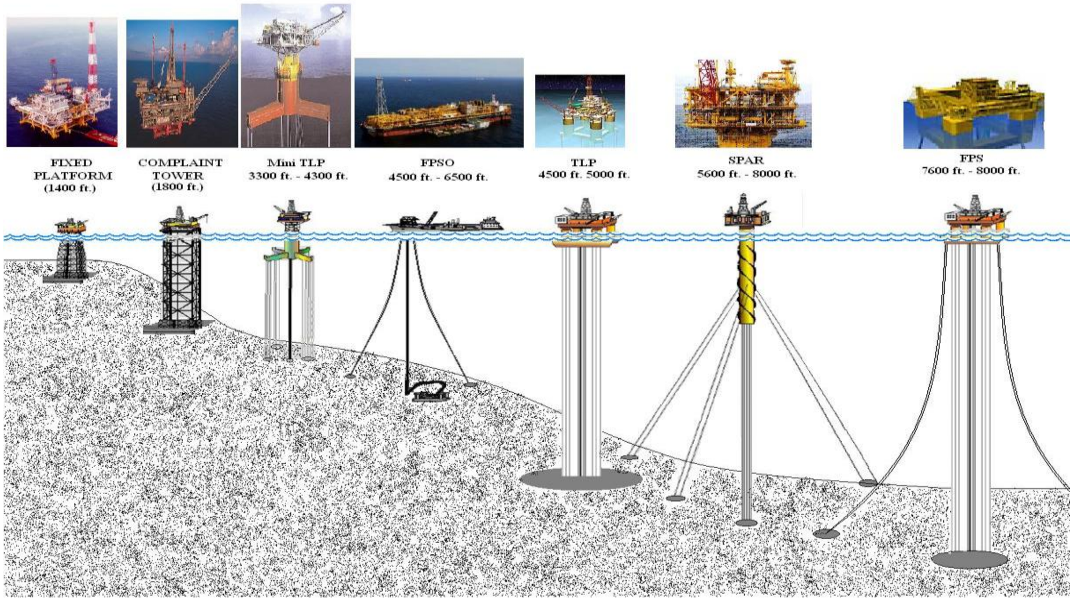


FIGURE 2: Different types of offshore platform

2.2 SHIP-PLATFORM COLLISION

Offshore platform will receive frequent visit from different type of vessels and vessel collision against offshore platform is unavoidable. Based on the database of collision incident produced by Offshore Division of the Health and Safety Executive, the summary of reported collision incident in UK Continental Shelf is shown in Table 2 [7].

TABLE 2: Reported Collision Incidents in the UK Continental Shelf from Year of 1975 to 2001 [7].

Vessel Type	Supply Vessel	Stand-by vessel	Attendant vessels	Passing vessels	Unspecified vessels
Number of Incidents	353	87	74	8	35
Percentage of Occurrence	63.4%	15.6%	13.3%	1.4%	6.3%

Table 2 indicate that there are total number of 557 incidents involving vessels and fixed platform from year 1975 to 2001. A review conducted based on the collision incident and the damage resulting from the collision incident from year 1975 to 2001 is summarized in Table 3 [7]. From the database, 17 incidents were classified as severe damage, 69 as moderate and 322 as minor. This indicates that 83.3% of collision incident will cause damage[7]. Therefore, the vessel collision against riser should be minimized by introducing several types of protection system.

TABLE 3: Damage resulting from Incidents in UK Continental Shelf from Year 1975 to 2001 [7]

	Damage Class				
	None	Minor	Moderate	Severe	Unspecified
Number	93	322	69	17	56
Percentage	16.7%	57.8%	12.4%	3.1%	10.1%

The extent of damage class and the criticality of the member involved is described as below [7]:

i. Severe: Damage affecting the integrity of an installation sufficient to require repair in the immediate or short term (up to 1 month). Where the actual date of repair could not be determined then the criticality of the damage damaged member was considered where this was available. In the absence of other repair information damage to non-redundant members was considered severe;
ii. Moderate: Damage requiring repair in the medium (up to 6 months) or longer term (over 6 months);
iii. Minor: Damage not affecting the integrity of the installation;
iv. None: No damage occurred;
v. Unspecified: Damage believed to have occurred but was not specified in reports

2.3 COLLISION MECHANICS

One of the main approaches for estimation of vessel collision is the Impulse-Momentum approach [8]. This approach equates the impulse force to the change of in momentum of the impacting vessel as shown in the following equation [9]:

$$\text{Impulse force,} \ F = \frac{m\alpha(v_i - v_f)}{t}$$

Where,

m = mass of vessel (kg)

$\propto$ = added mass coefficient (1.4 for broadside impact and 1.1 for bow/stern impact)

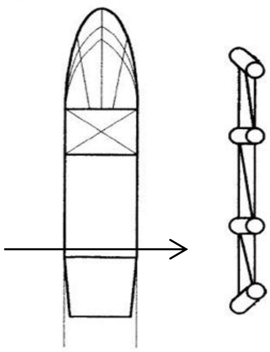
v_i = initial vessel velocity (m/s)

v_f = final vessel velocity (m/s)

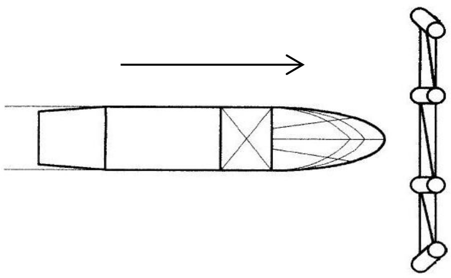
t = time taken for the vessel to stop (s)

In reality, three possible vessel collision scenarios that may occur are [10]:

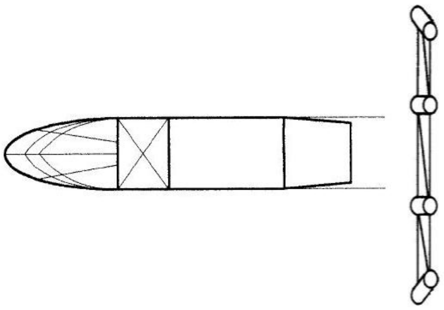
i. Broadside impact



ii. Bow impact



iii. Stern impact



Bow collision is more significant as compare to others collision as it induces larger vessel impulse force and result in more severe damage to the riser guard.

During vessel collision, an offshore riser guard absorbed the impact energy from ship by undergoes [11]:

i. local denting
ii. elastic beam bending
iii. Global structural deformation (elastic and plastic).

2.4 RISER SYSTEMS

A riser system is essentially conductor pipes connecting floaters on the surface and the wellheads at the seabed [12]. Riser system plays an important role in ensuring safety in all phases from drilling, completion, production to export [12]. Offshore riser is used to transport oils or gas from subsea oil well to platform. Additional functions of riser are provided as follows [13]:

- Conveys fluid between the wells and the floater for production and injection risers.
- Export fluid from floater to pipeline for export riser.
- Guide drilling or work over tools and tubular to and into the wells for drilling and work over riser.

2.5 RISER PROTECTION SYSTEM

Protection for risers is vital as to prevent vessel collision against riser. The vessel collision will result in huge explosion that cause fatalities due to the flammable contents it transport. Mumbai High North Platform disaster in July 2005 has raised the awareness on importance of riser protection system. With the absence of riser protection, this vessel collision accident in Mumbai High North Platform hits the riser and causing massive fire which destroyed the platform within 2 hours [14]. This accident cause major disruption and 22 fatalities and total damage up to USD 195 million[3].

As a lesson learnt from Mumbai High North Platform disaster, most of the offshore platforms are installed with riser protection system. Among the riser protection used are conventional riser guard system on fixed oil platform [1]. Riser protection net (RPN) [15], Marine Riser Protector [16] and Geobrugg's GBE system [17].

TABLE 4: Comparisons for different type of riser protection

Type of Riser Protection	Advantages	Disadvantages
Riser Guard	Can undergo large deformation for high energy dissipation [1]	Excessive weight, huge cost, time consuming and raises safety issues [1]
Riser Protection Net (RPN)	Capable of bearing maximum tensile load up to 650 tonnes [15].	Undergoes large deflection and is not apposite for fixed platform [15].
Marine Riser Protector	Can divert ice floes away from riser. [16]	Receive high wave impact and easily to detached [16]
Geobrugg's GBE system	Lighter and easier to attach Can sustain impact energy up to 8000 KJ [17]	Can only be used if the deflection upon impact can be controlled [17]

Table 4 compares the advantages and disadvantages of different type of riser protection system. However, the actual performance of these riser protection systems is not well studied. Better understanding of structural behaviour of riser protection system can provide more economical design of riser protection system.

CHAPTER 3

METHODOLOGY

This chapter presents the methodology that was followed in this study to attain the well-defined objectives for this research.

3.1 RESEARCH METHODOLOGY AND PROJECT ACTIVITIES

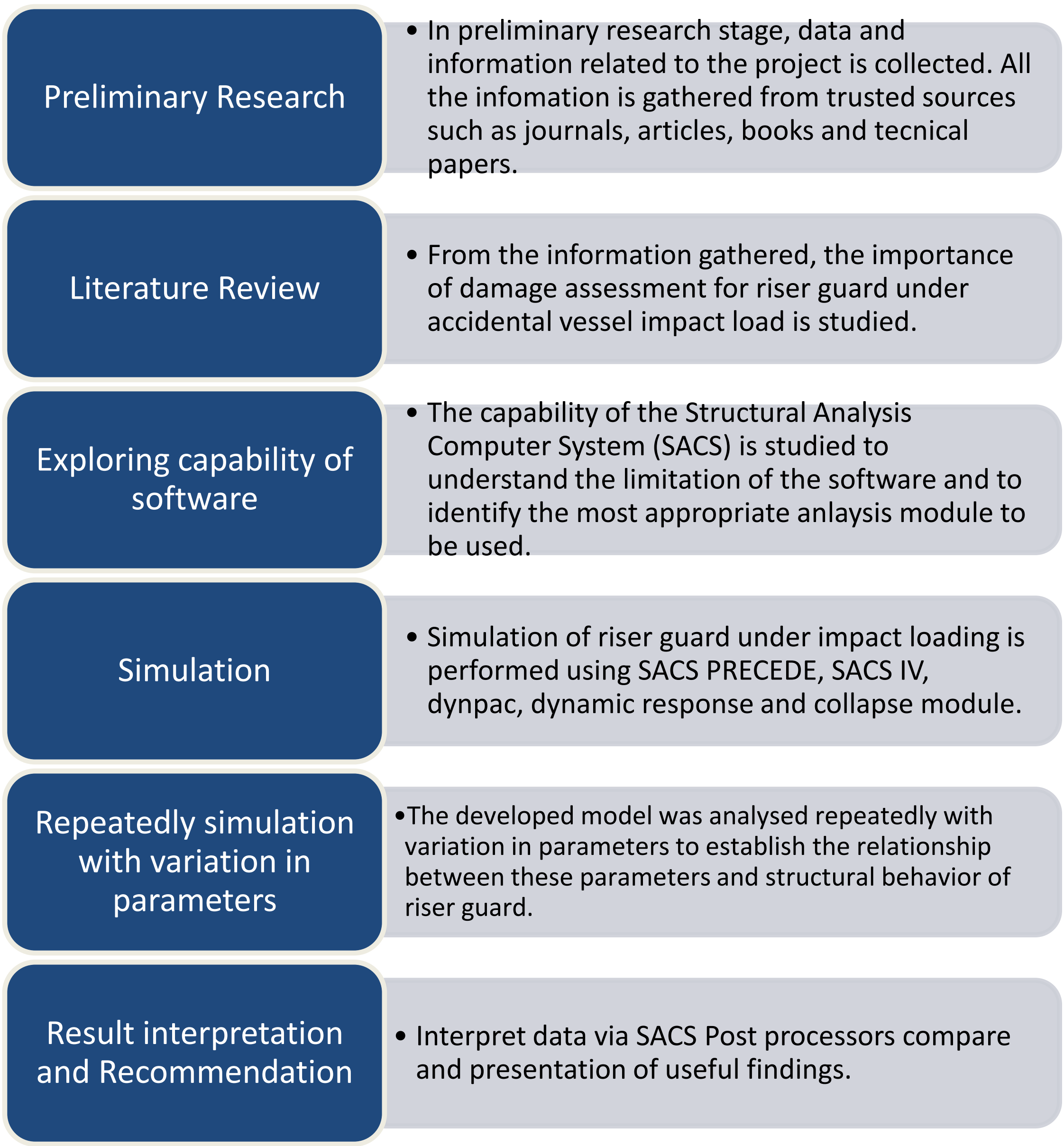


FIGURE 3: Project Activities

3.2. PARAMETRIC STUDY

A detail systematic parametric study was conducted to study various aspects associated with structural behaviour of offshore riser guard under vessel impact. The model was developed using SACS 5.3 software to stimulate the effect of accidental vessel impact on riser guard. Several important parameters were identified to provide better understanding of accidental impact phenomena as listed in Table 5. The developed model was analysed repeatedly with variation in parameter mentioned to study the sensitivity of these parameters. The results obtained from the parametric study were used to achieve the objectives of this project.

TABLE 5: Parametric Study

No	Parameters
1	Vessel mass
2	Type of collision
3	Velocity of vessel

3.3 MODELLING AND SIMULATION APPROACH

For the purpose of this project, SACS 5.3 Suite of Programs will be used extensively for both modelling and simulation. Several SACS modules will be used herein. The first is the PRECEDE program, to be used as the graphical user modeller. DYNPAC will be employed to generate the dynpac mode shape and mass file which is required for ship impact and collapse analysis. The DYNAMIC RESPONSE module will be used to simulate ship impact analysis while the COLLAPSE module will be used to perform the non-linear collapse analysis. The results can then be viewed in SACS post processors such as POSTVUE and COLLVUE which enables the author to interpret the results interactively and graphically. The general flow of the SACS modelling and simulation is illustrated as diagram below:

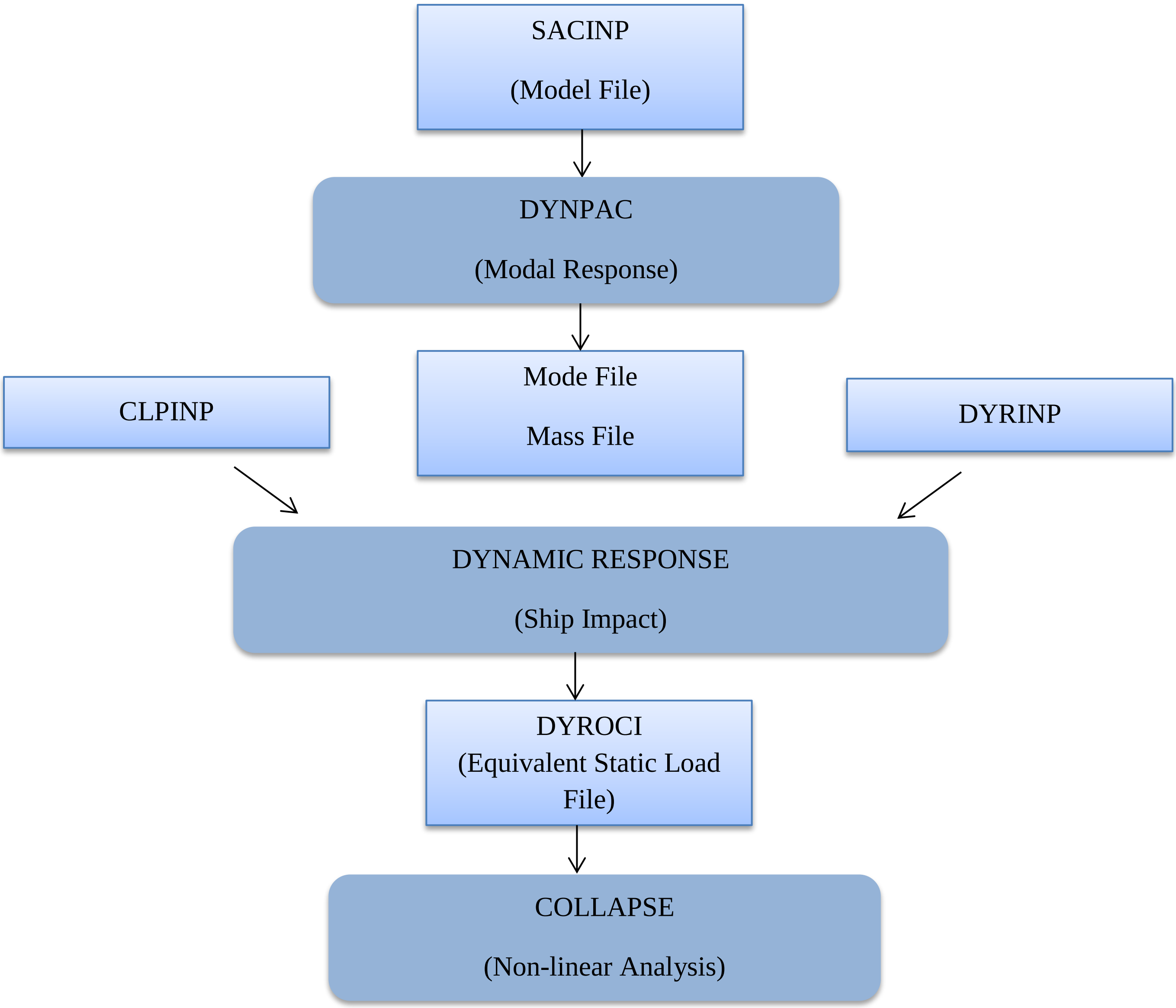


FIGURE 4: Flow Chart of SACS Simulation

3.3.1 SACS Modelling

The 14m wide and 10m height conventional riser guard is modeled in PRECEDE based on typical riser guard design to study its performance during accidental impact loading. The following shows the isometric view, front view, back view, side view and plan view of the typical conventional riser guard in SACS.

3.3.1.1 Isometric View

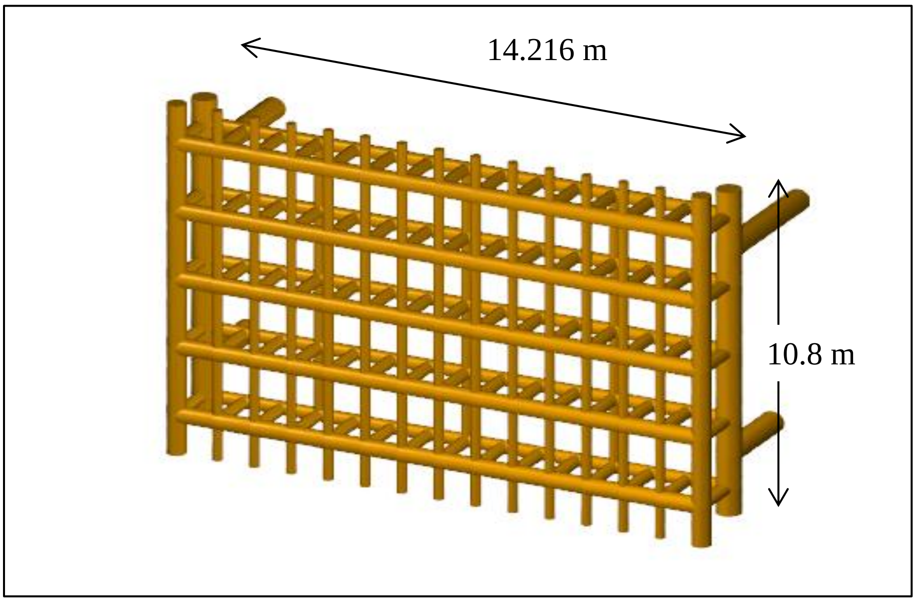


FIGURE 5: Isometric View of Riser Guard

3.3.1.2 Front View

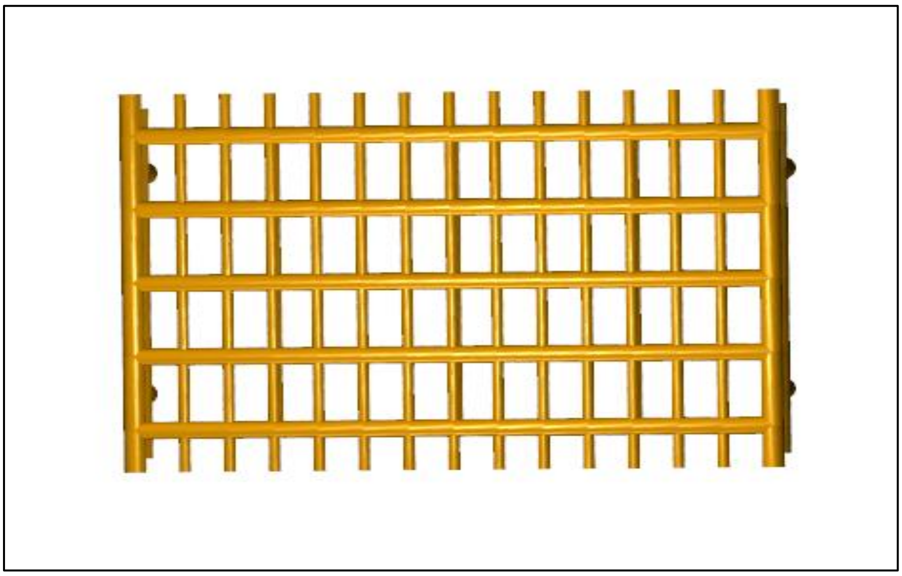


FIGURE 6: Font Elevation of Riser Guard

3.3.1.3 Back View

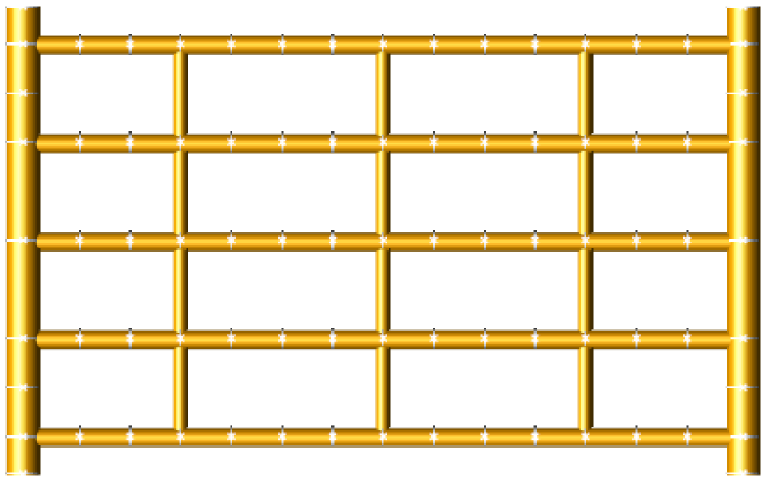


FIGURE 7: Back Elevation of Riser Guard

3.3.1.4 Side View

FIGURE 8: Side Elevation of Riser Guard

3.3.1.5 Plan View

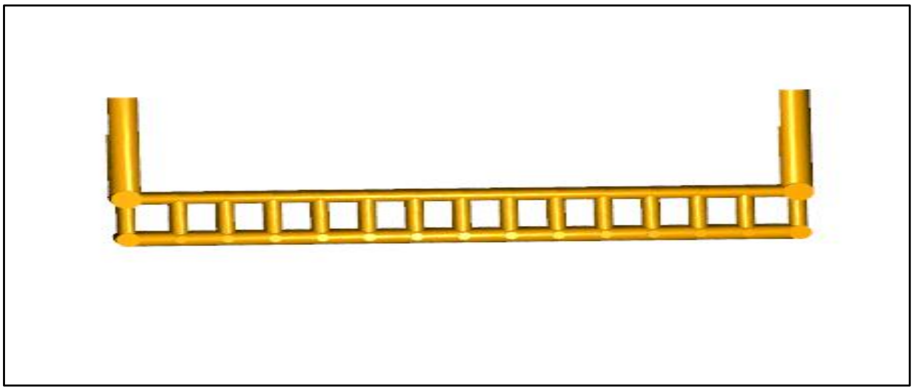


FIGURE 9: Plan View of Riser Guard

3.3.1.6 Fixity and Master Degree of Freedom (MDOF)

The support ends are modelled as completely fixed in all translational and rotational as specified as "111111". Master degree of freedom (MDOF) is specified at joint 0184, 0185, 0186 and 0187 as shown in Figure 10 where the joint Degree of freedom (DOF) is retained in all direction of translation ("222000"). Point mass related to translational DOF while inertia related to rotational DOF. In my study, rotary inertia effect has less significant as compared to mass effect. Hence, DOF is only retained in translation. The other nodes will act as slave degree of freedom. MDOF will control the vibration and the remaining DOF will just follow the pattern defined by the response of master node.

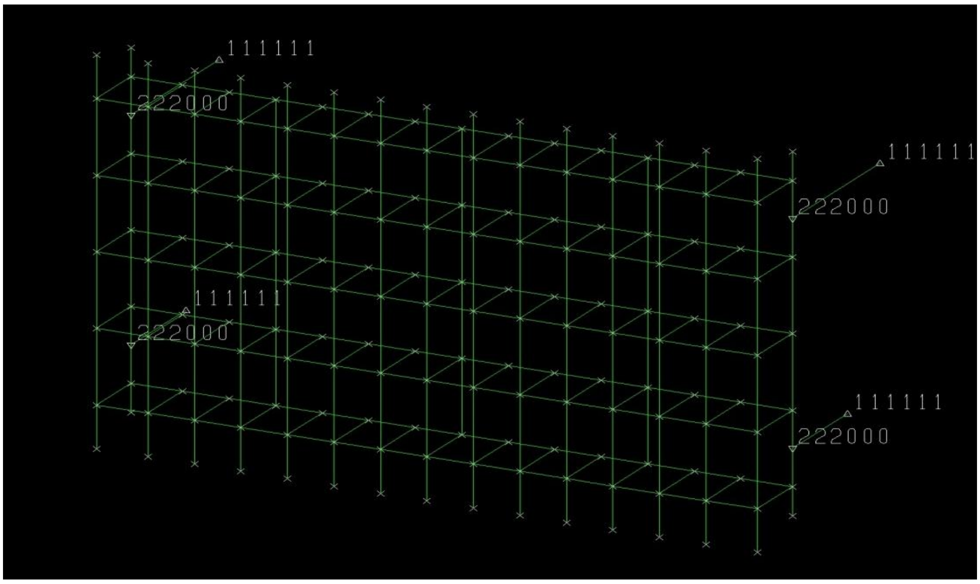


FIGURE 10: Joint Fixity and Master Degree of Freedom

3.3.2 DYNPAC Extract Mode Shape Module

Dynpac Extract Mode Shape Module is performed to generate the mode shape and mass file which is required for collapse analysis. SACINP is required in performing this simulation.

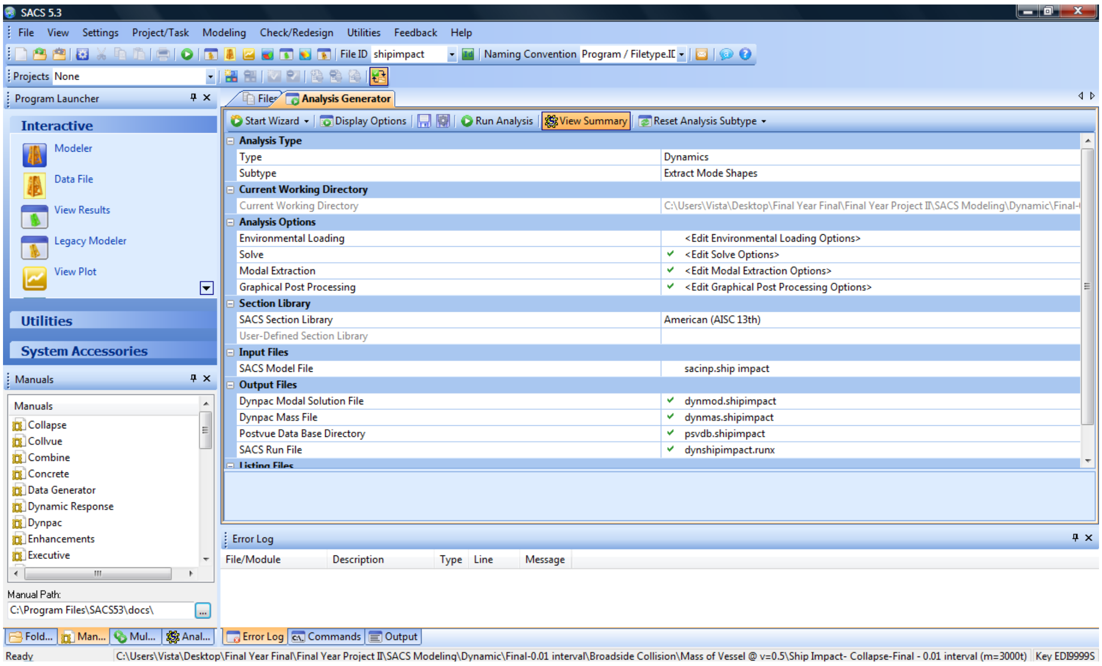


FIGURE 11: Dynpac Extract Mode Shape Module in SACS

3.3.3 Dynamic Response (ship impact analysis)

Once the dynpac mode shape and mass file is generated, the dynamic response (ship impact) file DYRINP is created as below:

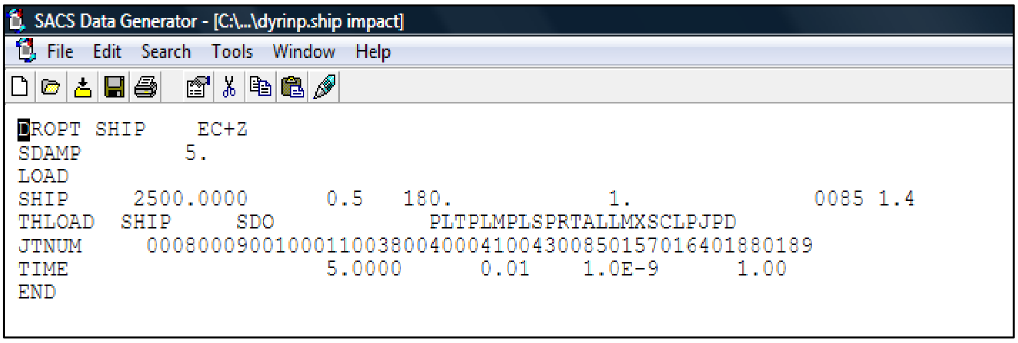


FIGURE 12: Dynamic response (ship impact) file

This analysis will generate DYROIC (equivalent static load) file where the inertial load correspondent with specific vessel mass and velocity is generated.

3.3.4 Collapse Analysis using Dynamic Response Inertial Loading

Collapse input file (CLPINP) have to be created prior to any collapse analysis. The CLPINP file created for the simulation of damage assessment or riser guard is shown in figure below:

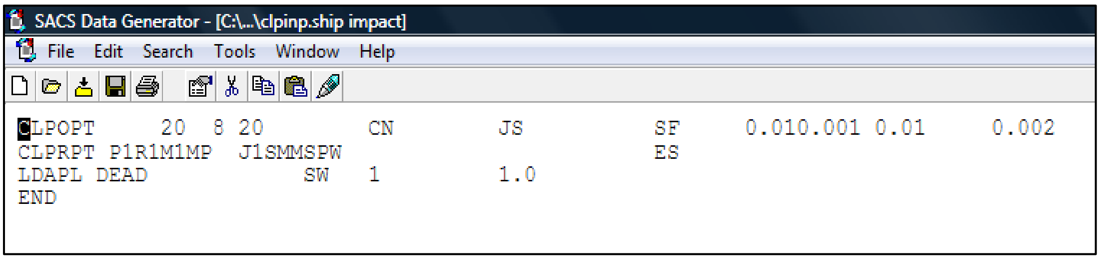


FIGURE 13: Collapse input file

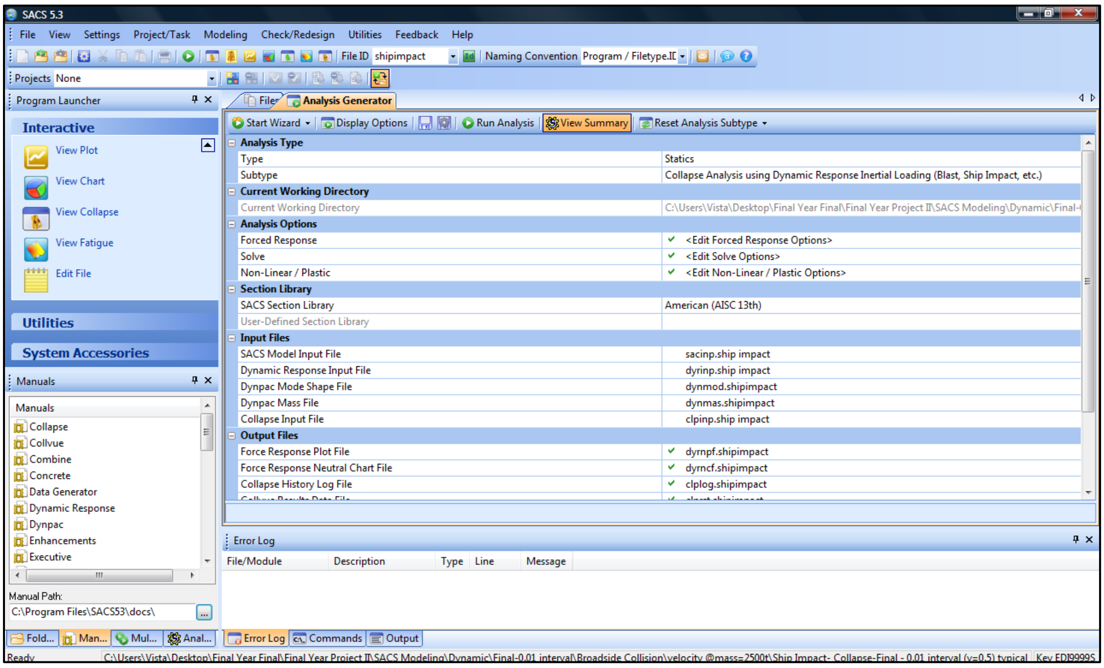


FIGURE 14: Collapse Analysis using Dynamic Response Inertial Loading

3.4 KEY MILESTONES & GANTT CHART

Week No / Progress	FYP 2													
	1	2	3	4	5	6	7	8	9	10	11	12	13	14
Non-linear Structural Analysis of Riser Guard	●	●												
Selection of suitable Master Degree of Freedom for the riser guard					●									
Ship impact analysis of riser guard under different collision scenario					●	●								
Submission of Progress Report							●							
Result and Data Analysis							●							
Determination of Actual Capacity of Riser Guard								●						
Pre-SEDEX														
Submission of Draft Final Report														
Submission of Dissertation (Soft Bound)														
Submission of Technical Paper														
Project Viva														
Submission of Dissertation (Hard Bound)														

● : Understanding of non-linear structural analysis

● : Study the performance of riser guard

● : Study the structural behavior of riser guard under different magnitude of impact load

CHAPTER 4

RESULTS AND DISCUSSION

4.1 INTRODUCTION

SACS 5.3 Suite of Programs will be used extensively for both modelling and simulation. Several SACS modules were used to perform damage assessment of riser guard under impact loading. SACS IV module was used to perform static analysis in order to determine the structural capacity of riser guard under vessel impact. DYNAMID RESPONSE module was employed to perform ship impact analysis while COLLAPSE modules for collapse analysis. Ship impact analysis was conducted to study the ship impact scenario as well as generate equivalent static load for collapse analysis. Collapse analysis was employed to study the linear and non-linear behaviour of riser guard. The results obtained from these simulations were interpreted and presented in this chapter.

4.2. STATIC IN-PLACE ANALYSIS

Static analysis of offshore riser guard under loading equivalent to vessel collision is performed using SACS. The static analysis was performed repeatedly with increment in load to determine the structural capacity of offshore riser guard under accidental vessel impact load. Different magnitudes of vessel impact load are applied to the riser guard to study its structural response.

4.2.1 Vessel Impact Load

The impact load equivalent to vessel collision is applied to the riser guard. In actual case, vessel impact will only hit part of the riser guard. Therefore, in this study, vessel impact load is assumed to be only applied at the center of the riser guard as illustrated in Figure 11.

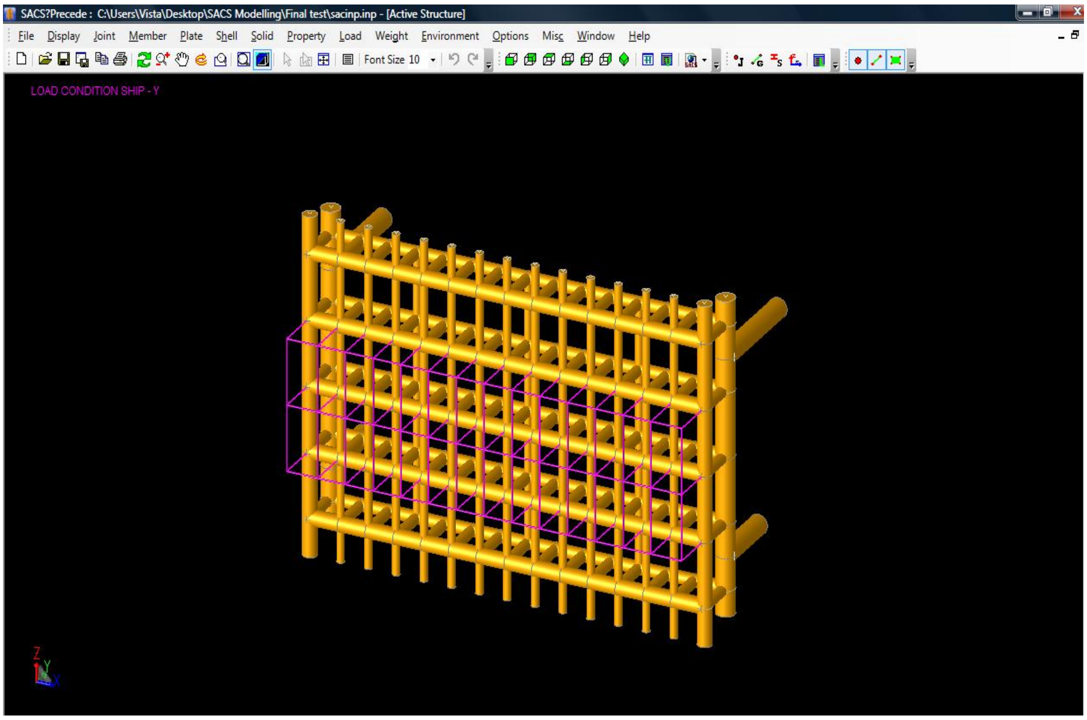


FIGURE 15: Vessel Impact Load on Riser Guard

4.2.2. Unity Check

Member Unity Check

The figure shows the member unity check for riser guard when total of 6560 KN area load is applied at the center of the riser guard. Member with red color indicates that the member is structurally failed as the unity check is more than 1. Figure 12 shows that all the members have passed the member unity check.

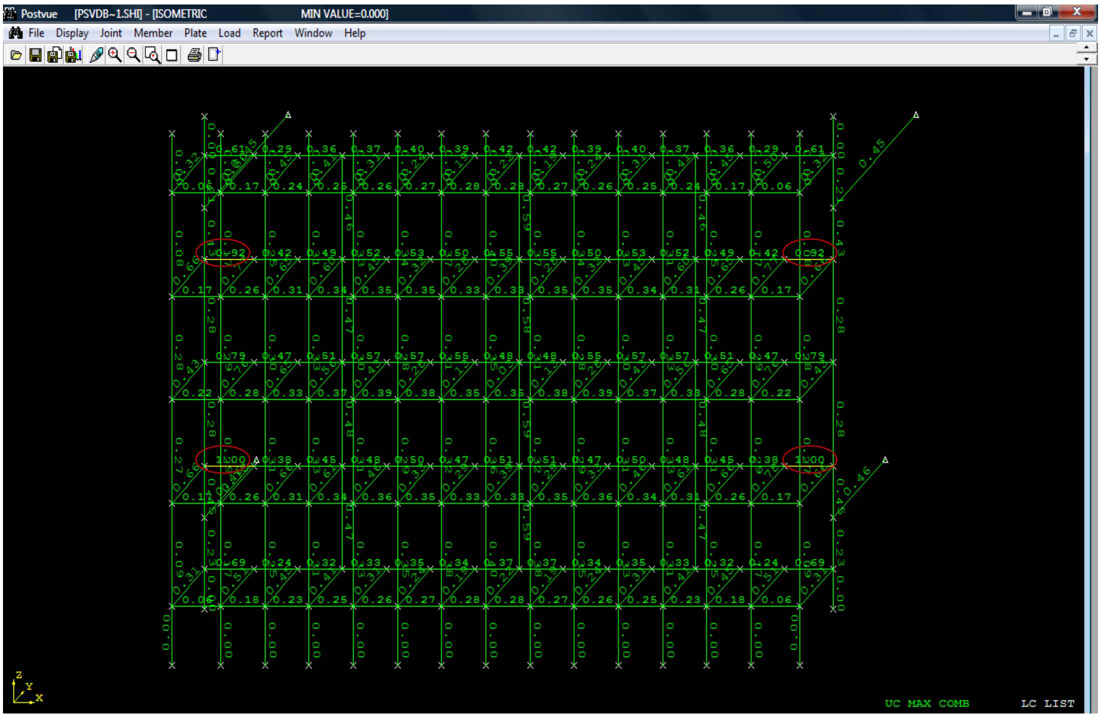


FIGURE 16: Member Unity Check for Riser Guard with applied load of 6560 KN

Member 0165-0166, member 0178-0179, member 0135-0136 and member 0148-0149 have higher unity check as compared to other tubular member. The unity check for these members is summarized as shown in table below:

TABLE 6: Member Stress at Critical Member

Member	Load Condition	Axial Stress (N/mm2)	Bending Stress	
			Y (N/mm2)	Z (N/mm2)
0135-0136	C1	-3.91	48.22	226.08
0148-0149	C1	-3.91	48.22	226.08
0165-0166	C1	-12.7	-57.07	233.73
0178-0179	C1	-12.7	-57.07	233.73

TABLE 7: Member Unity Check at Critical Member

Member	Critical Condition	Load Condition	Unity Check			
			Axial	Bend-Y	Bend-Z	Total
0165-0166	C<.15	C1	0.063	0.053	0.885	1.00
0178-0179	C<.15	C1	0.063	0.053	0.885	1.00
0135-0136	C<.15	C1	0.019	0.039	0.861	0.92
0148-0149	C<.15	C1	0.019	0.039	0.861	0.92

From Table 7, member 0165-0166 and member 0178-0179 have the highest unity check. In other word, failure will be occurred at member 0165-0166 and member 0178-0179 prior to other tubular members under combine loading. Compression with axial load ratio <0.15 is critical for the failure.

Joint Unity Check

Welding point is the weakest part of the offshore structure. Hence, joint unity check is crucial in offshore structure analysis. Joint can program is developed in SACS to perform the joint unity check in order to determines the adequacy of simple and overlapping tubular joints for punching shear. Area load of 6560 KN is applied to the centre of riser guard and the joint unity check is performed. Joint failure occurred if unity check is more than 1. Table 7 summarize the joint unity check at critical joint if 6560 KN area load is applied.

TABLE 8: Joint Unity Check at Critical Joint

Joint	Diameter	Thickness	Yield Stress	UC
136	40.64	1.57	345	0.96
148	40.64	1.57	345	0.96
68	50.8	1.905	345	0.935
104	50.8	1.905	345	0.935
157	40.64	1.87	345	0.917
66	50.8	1.905	345	0.901
102	50.8	1.905	345	0.901
168	40.64	1.57	345	0.89
176	40.64	1.57	345	0.89
138	40.64	1.57	345	0.878
146	40.64	1.57	345	0.878
167	40.64	1.27	345	0.849
177	40.64	1.27	345	0.849
108	40.64	1.57	345	0.84
116	40.64	1.57	345	0.84
142	40.64	1.87	345	0.838
172	40.64	1.87	345	0.832
123	40.64	1.57	345	0.828
131	40.64	1.57	345	0.828
137	40.64	1.27	345	0.816
147	40.64	1.27	345	0.816
152	40.64	1.27	345	0.816
162	40.64	1.27	345	0.816
39	50.8	1.905	345	0.812
42	50.8	1.905	345	0.812
74	50.8	1.905	345	0.81
98	50.8	1.905	345	0.81

At area load of 6560 KN, there is no structure failure occurred as all the structural members and joints pass the unity check.

4.2.3. Deformation Pattern

The deflection of riser guard is also studied as figure below. The white dash line indicates the deformation of the riser guard under vessel impact load. In this case, maximum deformation occurred at the center of the riser guard.

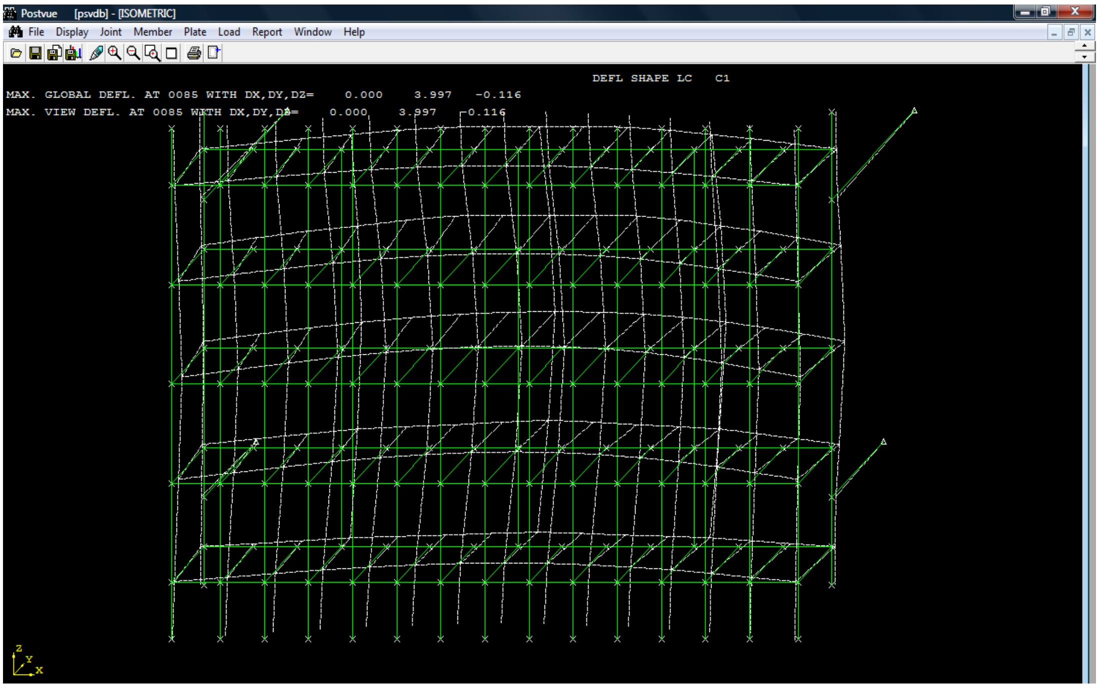


FIGURE 17: Deformation Pattern of Riser Guard

4.2.4. Structural Capacity

The riser guard is simulated under different magnitude of vessel impact loading to determine the actual capacity of the riser guard. The applied load is increased until it reaches the maximum load where the riser guard can take. Table below shows the applied load and its correspondent number of member and joint failed (Unity Check more than 1). The graph of area load versus number of structural component failed is plotted to determine the safe load for conventional riser guard. From the data, the maximum capacity of structural member is estimated to be 6560 KN.

TABLE 9: Area load applied with its correspondent number of structural component failed under vessel impact loading

Area Load (KN)	Number of member failed	Number of Joint failed
14000	122	102
12000	84	53
10000	38	25
8000	10	6
7000	2	0
6560	0	0

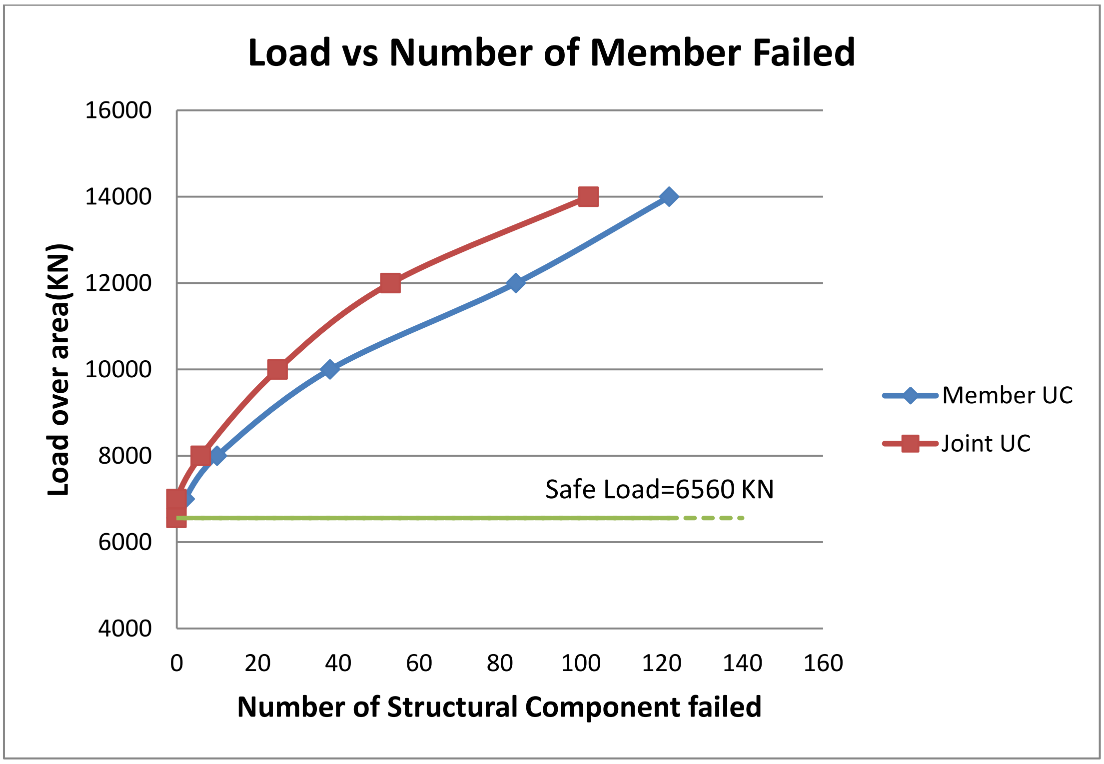


FIGURE 18: Graph of Area Load vs Number of Failed Structural Component

4.3. DYNAMIC ANALYSIS

The natural mode shape is generated from DYNPAC module after the master degree of freedom is identified. Its correspondent frequency, period and Eigenvalue are shown in Table 11.

TABLE 10: Natural Mode Shape

Mode	Freq.(cps)	Gen. mass	Eigenvalue	Period(secs)
1	11.766488	4.34E+01	1.83E-04	0.0849871
2	14.288871	7.76E+01	1.24E-04	0.0699845
3	19.71098	5.92E+01	6.52E-05	0.0507331
4	27.780892	5.02E+01	3.28E-05	0.035996
5	42.990555	3.32E+01	1.37E-05	0.0232609
6	55.4301	2.30E+01	8.24E-06	0.0180407

4.3.1 Extracted Mode Shape

The deformation of riser guard with six different mode shapes is illustrated as figure below. The white dashed line represents the deformation pattern of mode shape.

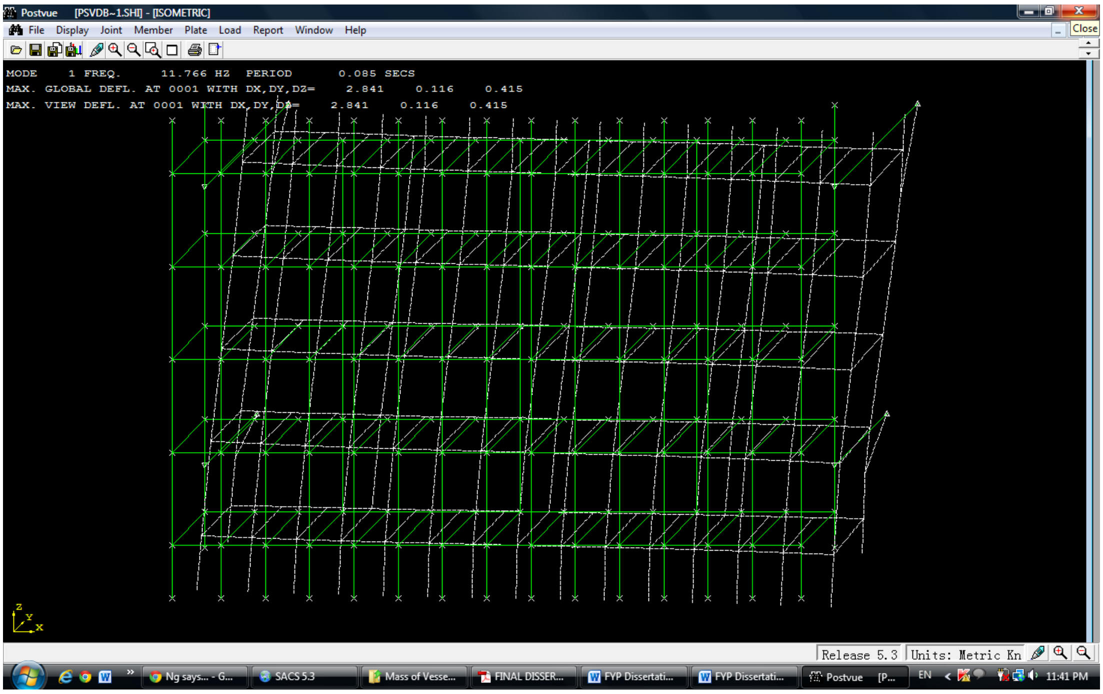


FIGURE 19: Deformation Pattern of Riser Guard for Mode 1

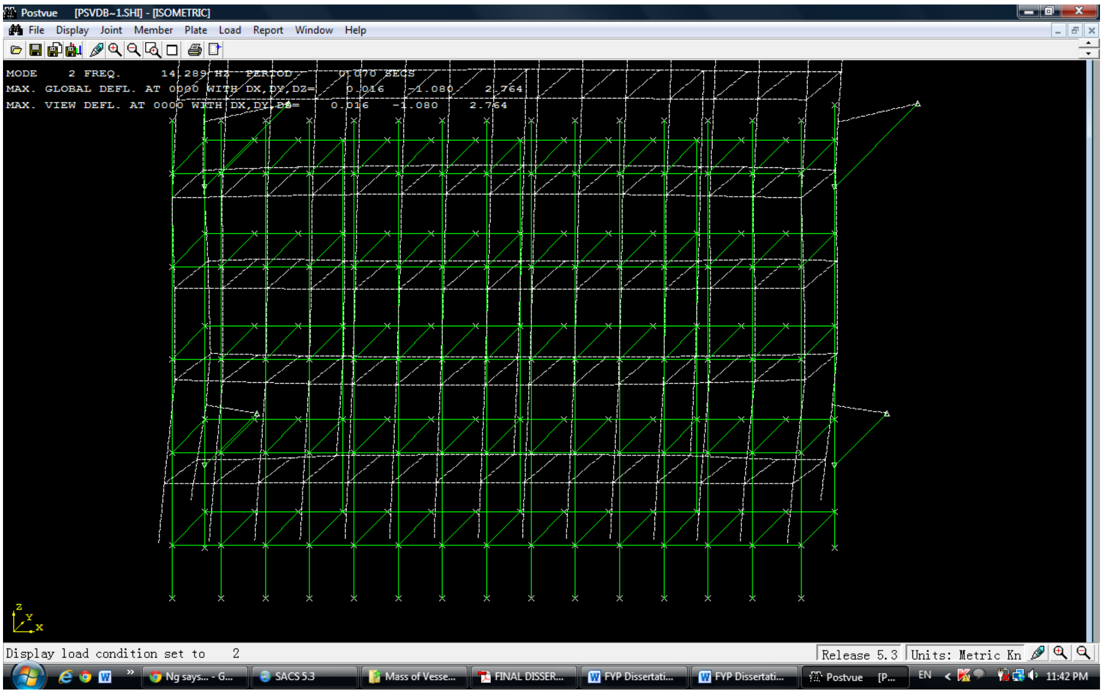


FIGURE 20: Deformation Pattern of Riser Guard for Mode 2

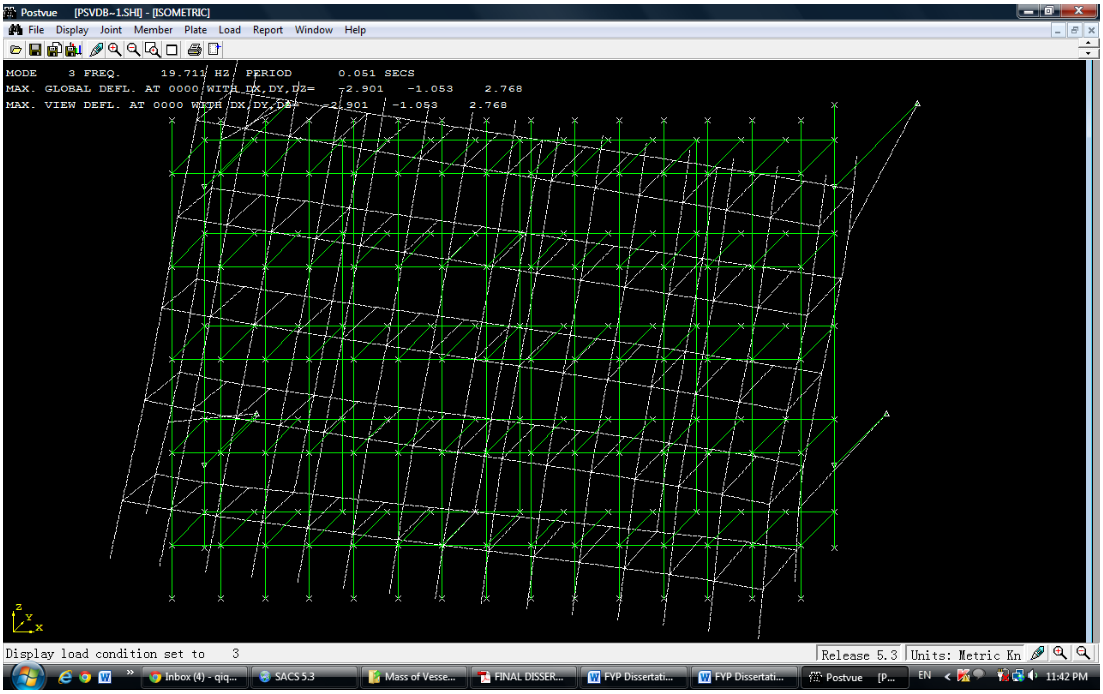


FIGURE 21: Deformation Pattern of Riser Guard for Mode 3

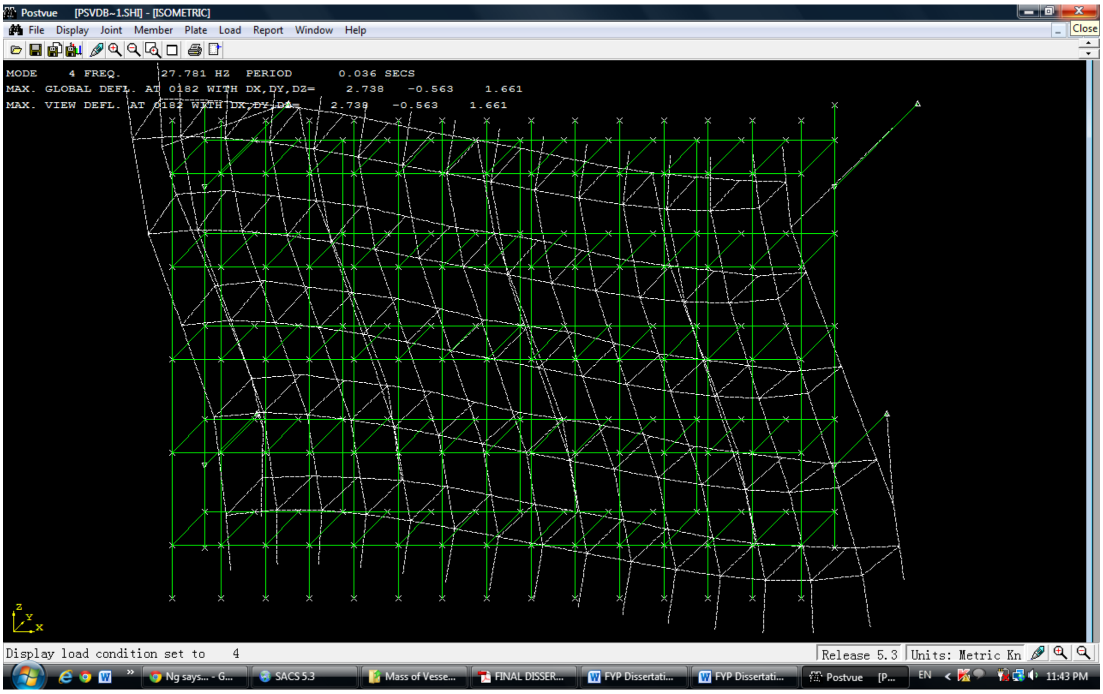


FIGURE 22: Deformation Pattern of Riser Guard for Mode 4

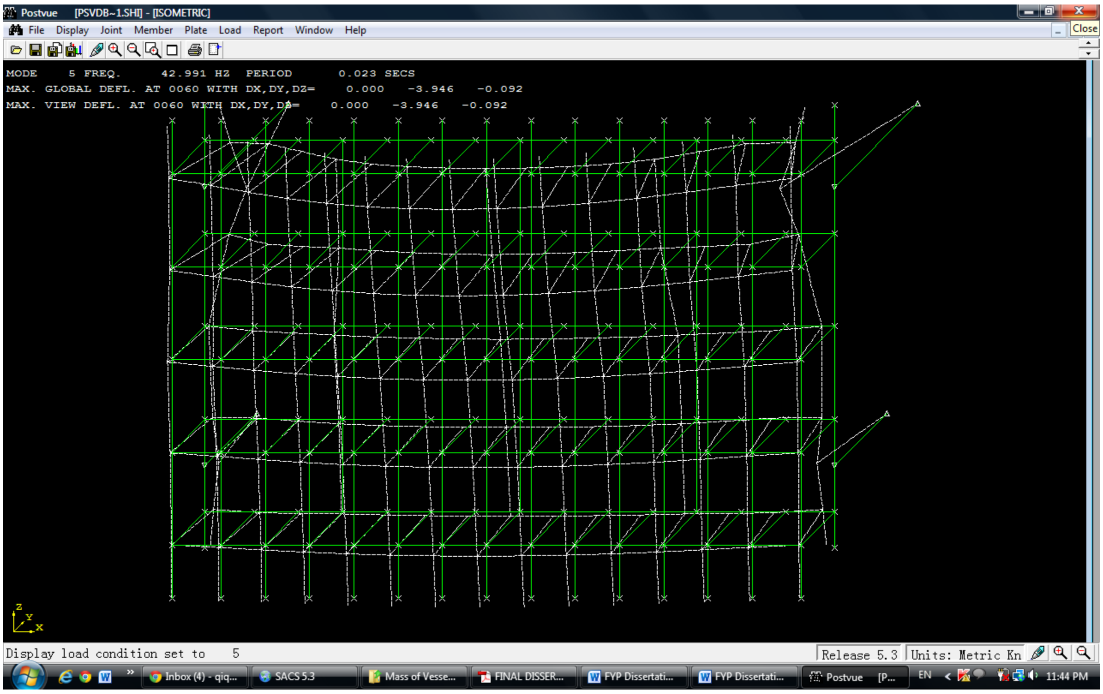


FIGURE 23: Deformation Pattern of Riser Guard for Mode 5

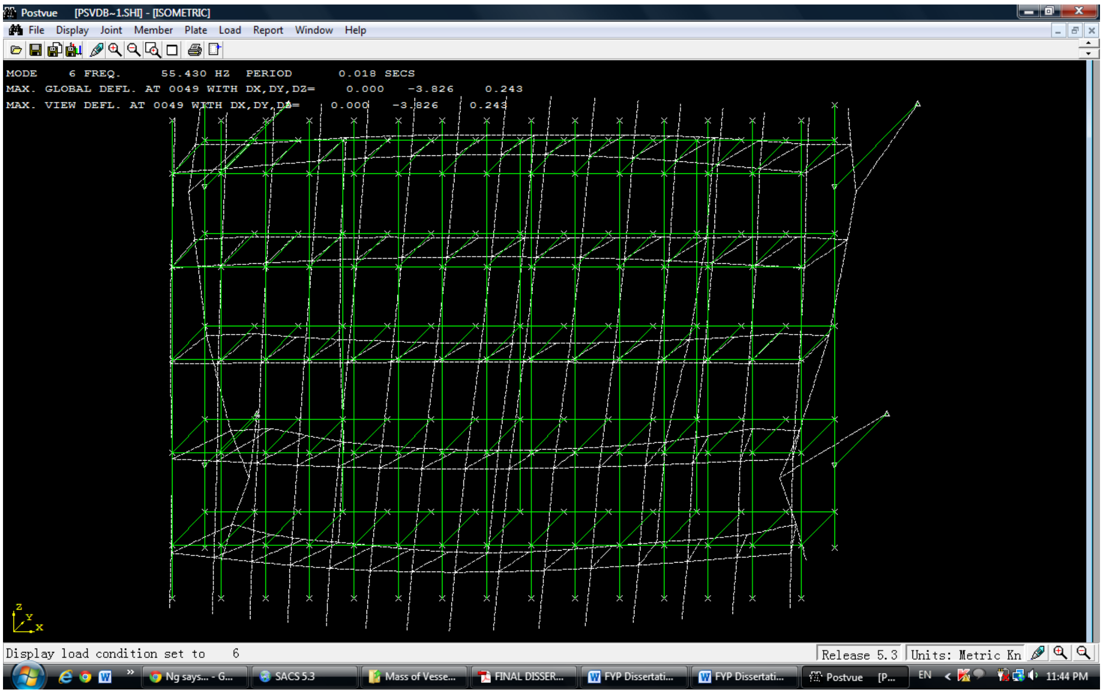


FIGURE 24: Deformation Pattern of Riser Guard for Mode 6

4.3.2. Parameter study

A parameter study of offshore riser guard under accidental vessel impact collisions was performed. My project will be mainly focused on two parameters which are mass of vessel and vessel impact velocity. Therefore, the discussion will be focused on the corresponding rate of deformation. Ship Impact Analysis and Collapse analysis were performed to study the deformation of riser guard upon vessel impact. The deformation of riser guard against broadside collision and stern/bow collision was tabulated in the table.

Stern/Bow Collision

Stern/Bow Collision			
Velocity (m/s)	Vessel Mass (Tonnes)	Ship Impact Force (KN)	Total displacement (cm)
0.5	2500	3745.47	68.439
1.0	3000	7504.76	73.137
2.5	4500	18803	96.211

Broadside Collision

Broadside Collision			
Velocity (m/s)	Vessel Mass (Tonnes)	Ship Impact Force (KN)	Total displacement (cm)
0.5	2500	3737.44	77.211
1.0	3000	7491.33	84.839
2.5	4500	18780.57	102.148

The broadside vessel collision scenario was defined as the situation in which vessel strikes most significant impact on offshore riser guard as compare to stern/bow vessel impact. When the accidental vessel collision occurred, offshore riser guard transform ship kinetic energy into strain energy by undergoes global deformation. Broadside collision will induce higher ship impact energy as compared to stern/bow collision. This is due to its larger surface area which lead to larger added mass resulting from its motion in water, thus the applied force to the riser guard is higher.

4.3.3 Stern/Bow Impact

4.3.3.1. Mass Deformation

Figure 21 presents the mass deformation relationship for different vessel mass and impact velocity. It can be seen that the offshore riser guard reach its maximum deformation at highest vessel mass. The force generate by the highest mass cause the riser guard to undergo large deformation which indicate that the riser guard induces large energy absorption. The offshore riser guard deforms 96.21 cm if it is hit by a 4500 tonnes vessel.

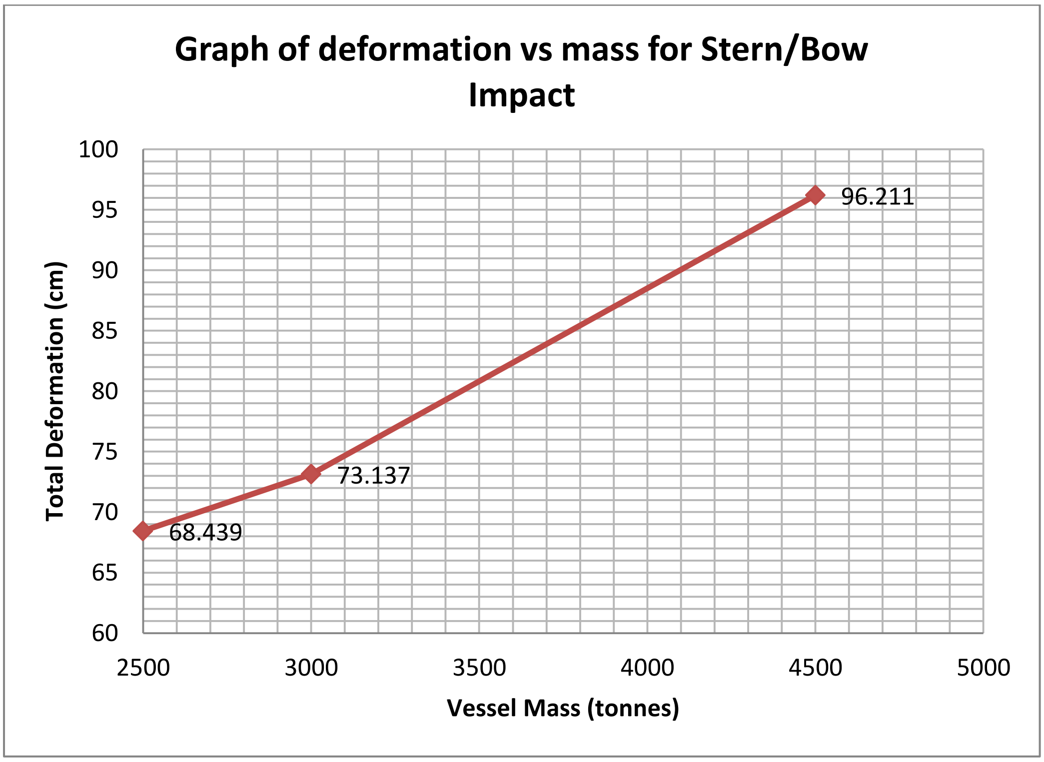


FIGURE 25: Mass-deformation (Stern/Bow Impact)

The design of riser guard is plasticity based where it allows the riser-guard to undergo large deformation for higher energy dissipation. The following figures show the plastic deformation of riser guard before collapse of the structure due to stern/bow collision impact at different vessel mass. Red colour members indicate that the member has reached its plasticity and plastic deformation has occurred. The load is applied to the structure incrementally. The nodal displacements and element forces are calculated for each load step and the stiffness matrix is updated. When the stress in a member reaches the yield stress plasticity is introduced. The introduction of plasticity reduces the stiffness of the structure and additional loads due to subsequent load increments will be redistributed to adjacent members to the members that have gone plastic. The structural behaviour of riser guard under vessel impact load before the structure collapse is illustrated in following figures:

4.3.3.2. Structural behaviour of riser guard

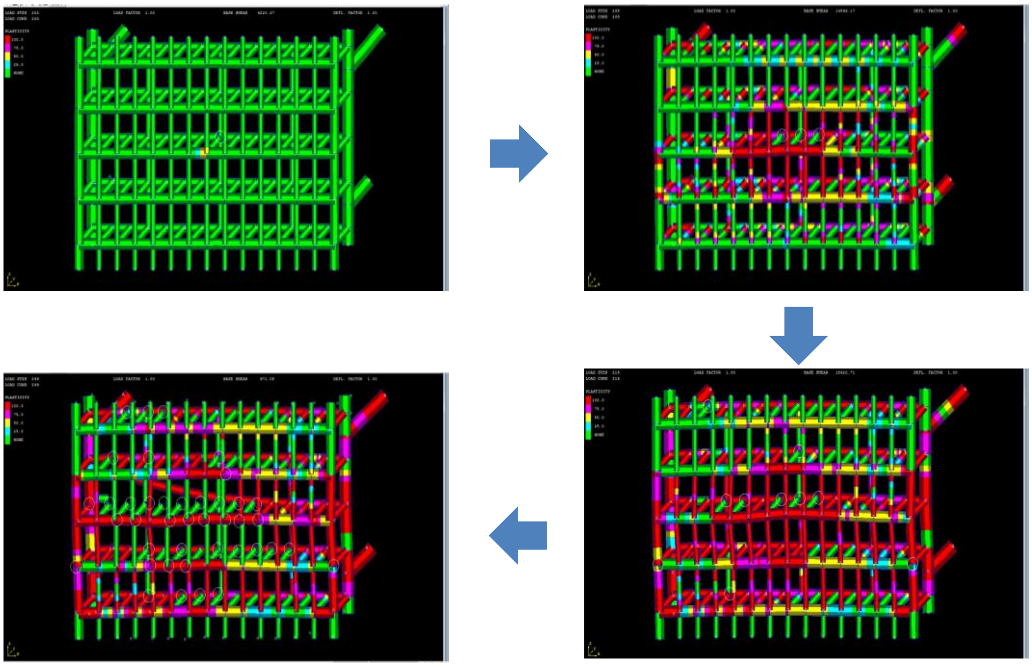


FIGURE 26: Structural behaviour of riser guard at 2500 tonnes (stern/bow impact)

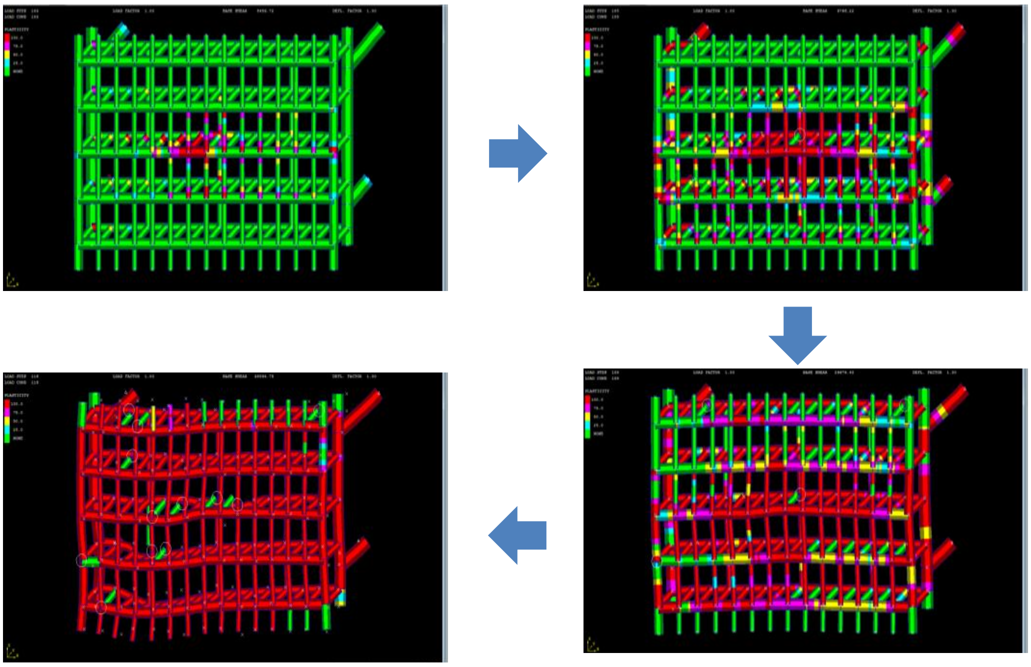


FIGURE 27: Structural behaviour of riser guard at 3000 tonnes (stern/bow impact)

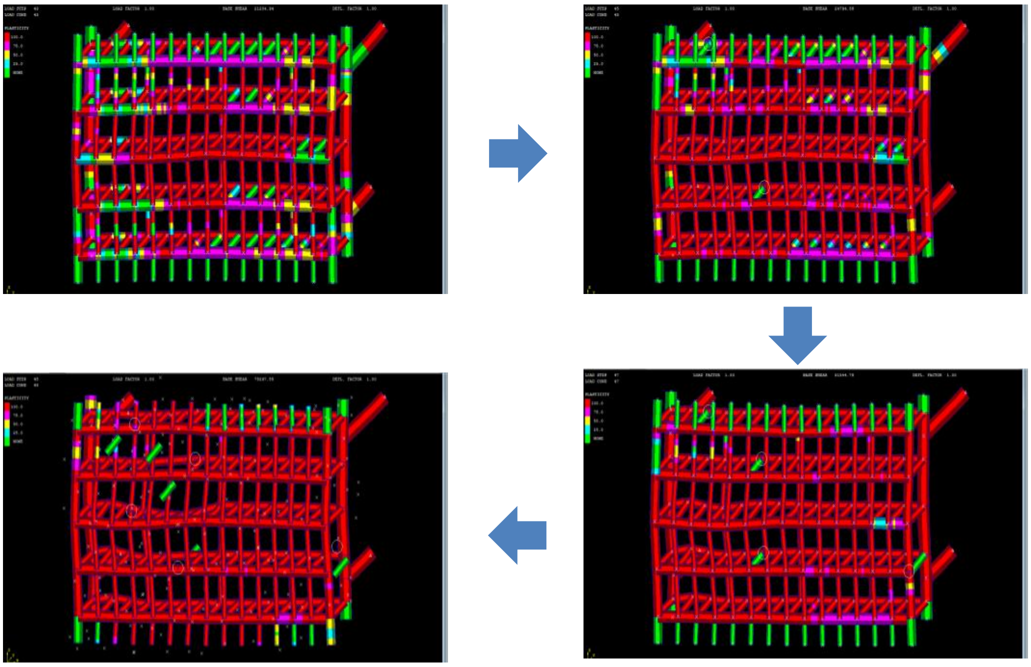


FIGURE 28: Structural behaviour of riser guard at 4500 tonnes (stern/bow impact)

These figures clearly show that number of member undergoes plastic deformation increases as the impact vessel mass increases. As the impact vessel mass and impact velocity increases, the impact force is increases. Thus number of member undergoes plastic deformation is increased for energy dissipation.

4.3.4. Broadside Impact

4.3.4.1. Mass Deformation

The relationship between the deformation and impact vessel mass were established by performing the collapse analysis. The following graph shows the deformation of riser guard at various impact vessel mass for broadside collision. From Figure 25, it can be seen that the maximum deformation occurred at vessel mass of 4500 tonnes. The offshore riser guard deforms 102.148cm if it is hit by a 4500 tonnes vessel. This indicates that the riser guard will undergo larger deformation if broadside collision occurred.

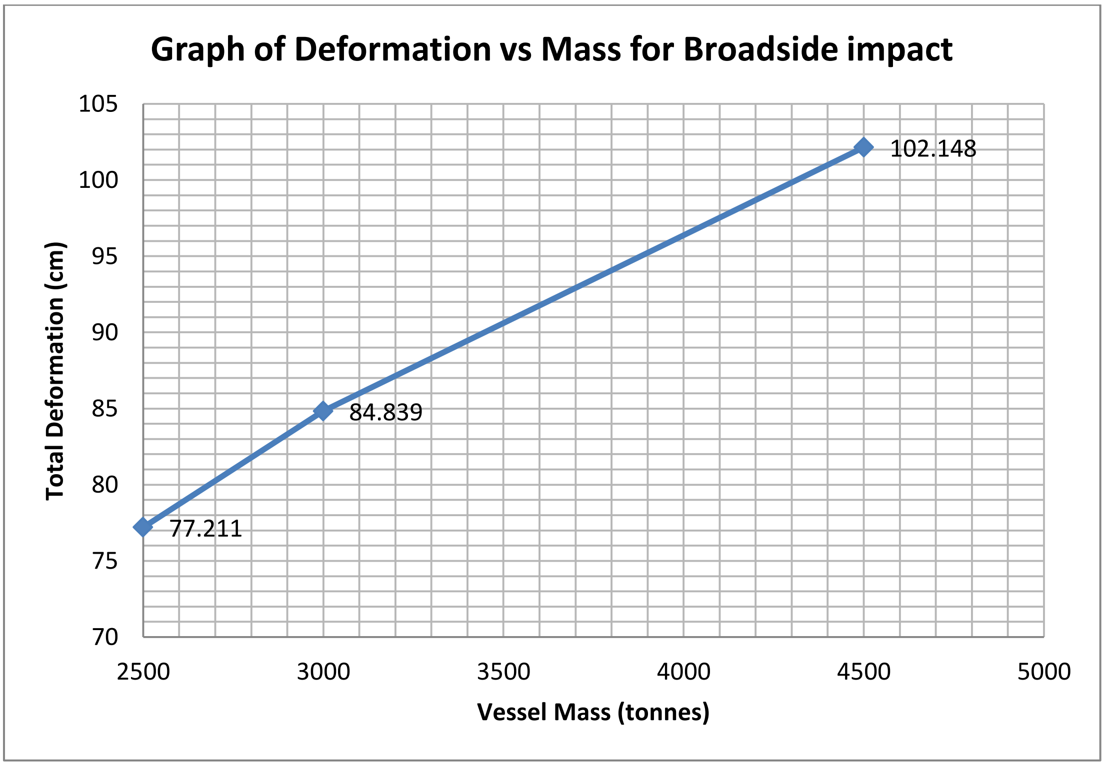


FIGURE 29: Mass-deformation (Broadside Impact)

The collapse analysis was performed to study the non-linear structural behaviour of offshore riser guard under different impact loading. The results obtained were presented in COLLVUE module in SACS. The COLLVUE modules below show the plastic deformation of riser guard and its plasticity under impact loading with various vessel mass for broadside impact collision. Red colour members indicate that the member has reached its plasticity and plastic deformation has occurred. When the stress in a member reaches the yield stress plasticity, stiffness of the structure and additional loads is reduced. Additional load due to subsequent load increments will be redistributed to adjacent members to the members that have gone plastic as illustrated in following figures.

4.3.4.2. Structural behaviour of riser guard

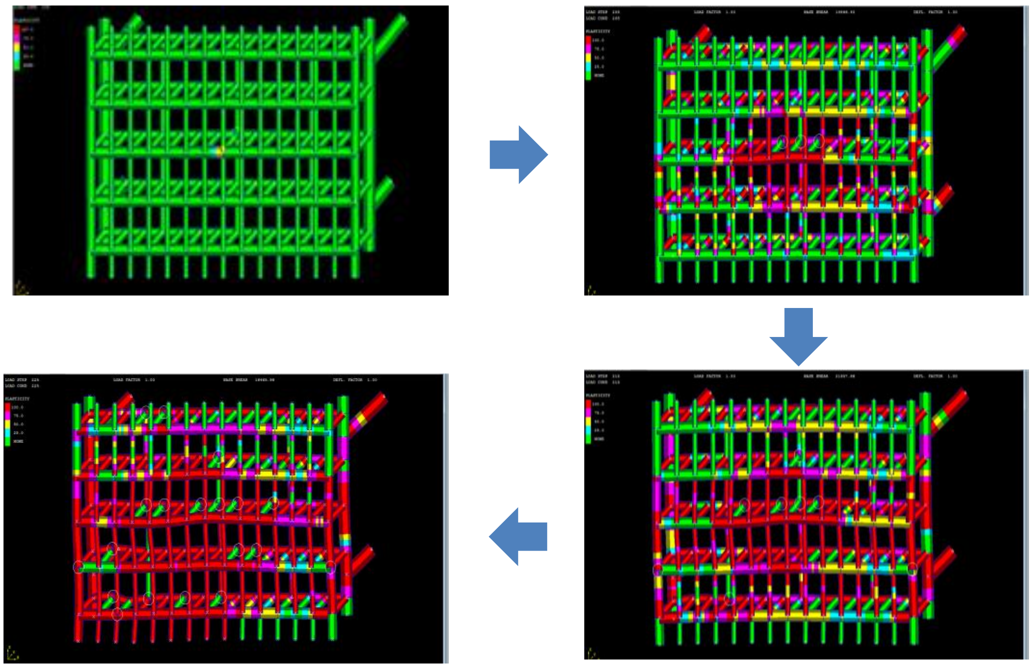


FIGURE 30: Structural behaviour of riser guard at 2500 tonnes (broadside impact)

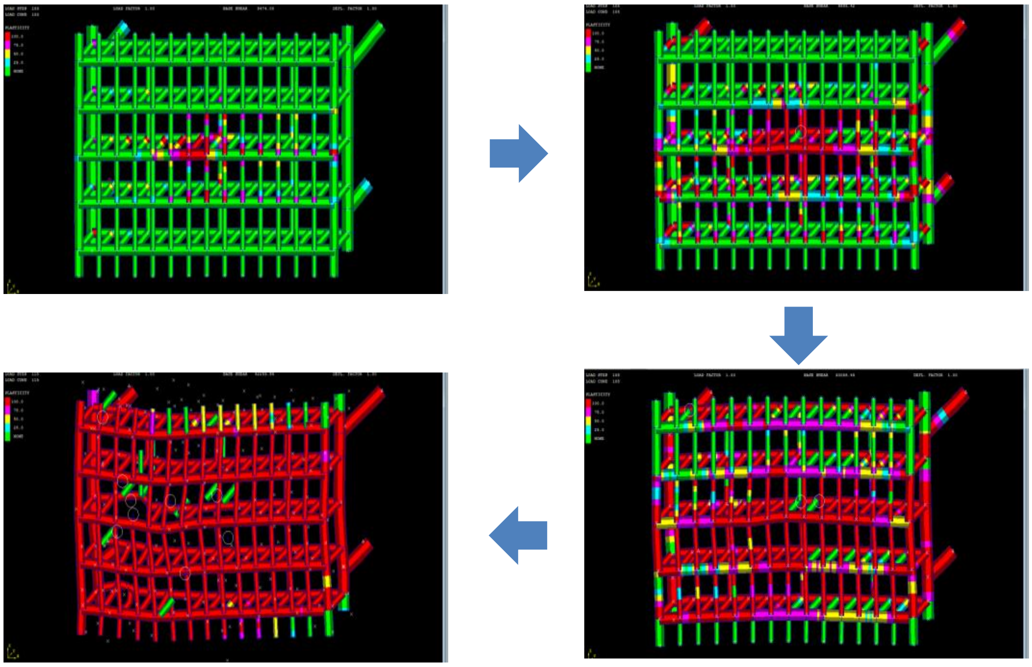


FIGURE 31: Structural behaviour of riser guard at 3000 tonnes (broadside impact)

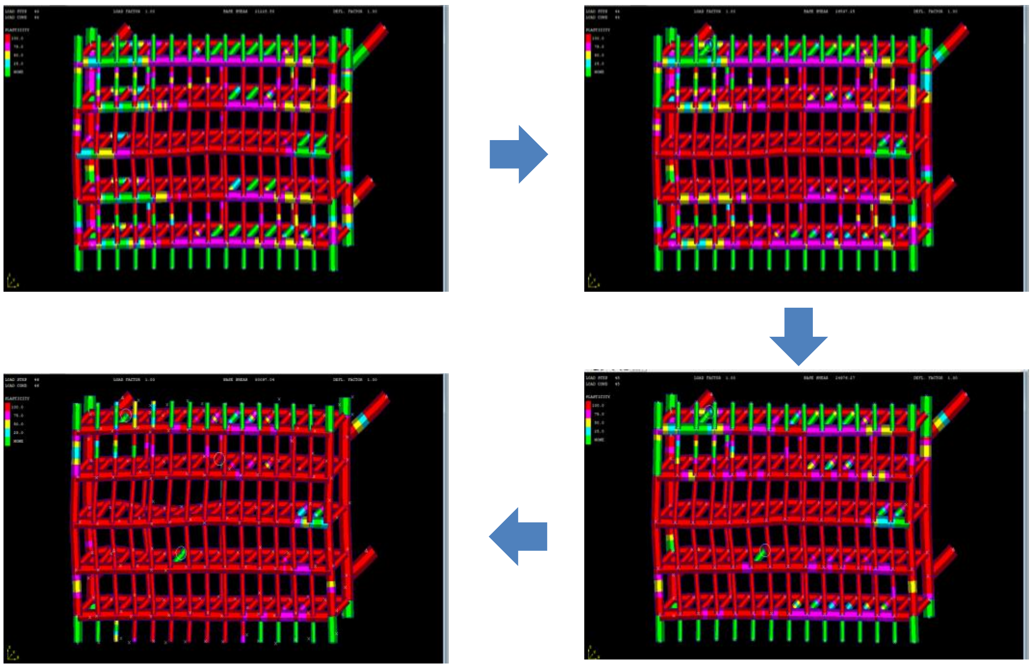


FIGURE 32: Structural behaviour of riser guard at 4500 tonnes (broadside impact)

In summary, these results show that:

i. As vessel mass increases, the ship impact force increases and hence riser guard will undergo larger deformation to dissipate the vessel kinetic energy.
ii. There is a significant increase in riser guard deformation when the impact velocity increases.
iii. As the load is applied to the structure incrementally, the nodal displacements and element forces are calculated for each load step. When the stress in a member reaches the yield stress plasticity is introduced. The introduction of plasticity reduces the stiffness of the structure and additional loads due to subsequent load increments will be redistributed to adjacent members to the members that have gone plastic.

4.3.5. Damage assessment of riser guard under different vessel collision scenario

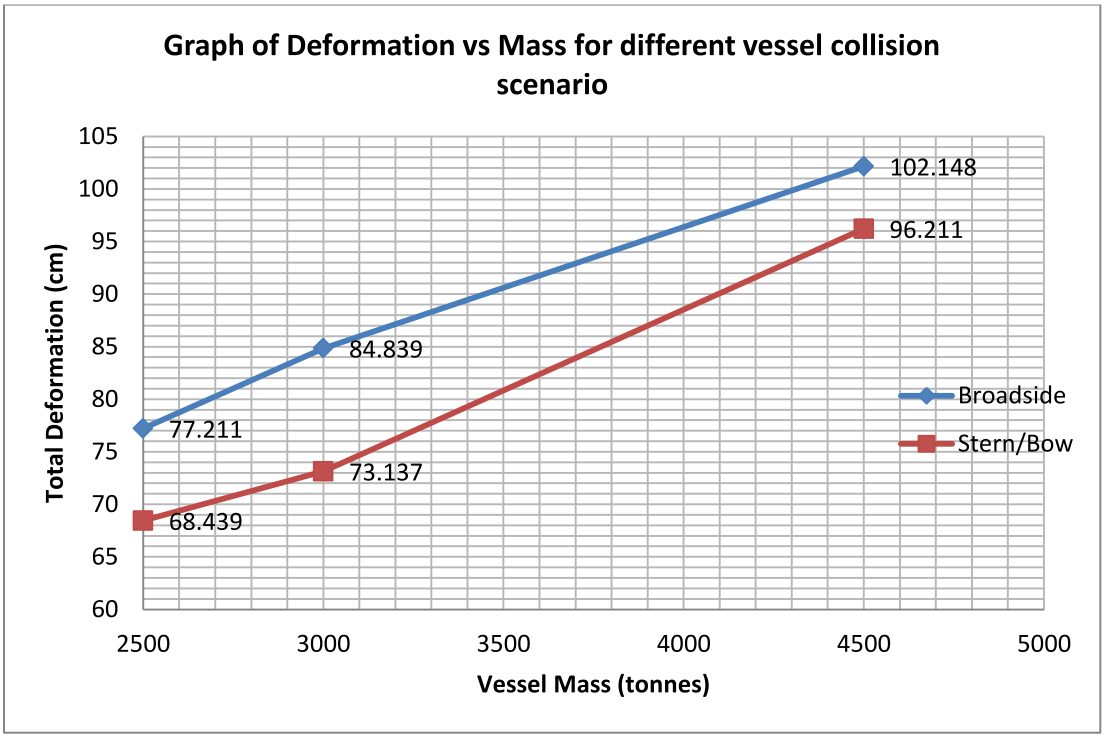


FIGURE 33: Mass-Deformation comparison of both scenarios

During impact, the kinetic of impacting vessel will partly remain as kinetic energy and partly dissipated as strain energy by riser-guard. Figure 29 show that broadside collision scenario will result in larger deformation of offshore riser guard. For broadside vessel collision, the ship impact force is higher due to its larger added mass resulting from its larger motion in water. In order to protect the risers against vessel collision, riser guard undergo larger deformation for higher energy dissipation and reduction in impact force. Stern/bow vessel collision has lower ship impact force and thus smaller deformation of riser guard occurred.

As per conclusion based on simulation based on all the scenarios, broadside collision impact will cause more severe damage to the riser guard as compared to stern/bow collision. As the impact velocity and vessel mass increases, the resulted deformation increases for both the broadside and stern/bow side collision. The structural capacity of offshore riser guard is 6560 KN.

CHAPTER 5

CONCLUSION AND RECOMMENDATIONS

Damage assessment of conventional riser guard is important to understand the performance and structural behavior of the riser guard. The capability of the Structural Analysis Computer Software (SACS) was explored and the static-in-place analysis of conventional riser guard under loading equivalent to vessel collision is carried out. The unity check and deformation pattern of riser guard was analyzed. The results obtained shows that the conventional riser guard can take up to 6560 KN of load before the member failed. The ship impact analysis of riser guard was also carried out to understand ship impact force and also to generate the equivalent static load for the simulation of collapse analysis. Furthermore, plastic collapse analysis of offshore riser guard was performed to study the linear and non-linear behavior of riser guards, local deformation of impacted member due to beam bending and global deformation of the riser guards. During impact, the kinetic of impacting vessel will partly remain as kinetic energy and partly dissipated as strain energy by riser-guard. In order to protect the risers against vessel collision, riser guard undergo larger deformation for higher energy dissipation and reduction in impact force. The structural behaviour of offshore riser guard under different vessel collision scenarios were studied and results shows that deformation increases if vessel mass and impact velocity increases. Riser guard will undergo larger deformation if broadside collision occurred. In future, further research can be done to study the localised deformation of offshore riser guard under accidental impact loading. During ship collision occurred, local denting can occurred at structure and cause localised deformation. Hence, further research can be done on localised deformation for better understanding on structural behaviour of offshore riser guard.

REFERENCE

[1] M. A. El-Reedy, *Offshore Structures: Design, Construction and Maintenance*, 2012.
[2] D. Palaniandy, Z. Syed, M. Liew, and S. Karuppanan, "Redefining Riser-Guard System for Fixed Offshore Platforms," *Energy (MJ)*, vol. 1000, p. 1500, 2000.
[3] N. K. Mitra, C. E. Bravo, and A. Kumar, "Revival of Mumbai High North-A Case Study," in *SPE Indian Oil and Gas Technical Conference and Exhibition*, 2008.
[4] D. N. Veritas, "Offshore Riser System," 2003.
[5] J. Ferentinos, "Global Offshore Oil and Gas Outlook," 2013.
[6] E. I. Admistration, "Natural Gas 1998: Issues and Trends," U. S. D. o. Energy, Ed., ed. Washington, 1999.
[7] J. K. Robson, "Ship/Platform Collision Incident Database," Norwich2003.
[8] A. Sayed and W. A. Attia, "Finite Elements Analysis Techniques of Vessel Collision with Cable-Stayed Bridge," *Life Science Journal*, vol. 9, pp. 1179-1190, 2012.
[9] D. K. Palaniandy, Liew,M.S., Karuppanan, S.3,Syed,Z.I., "Estimation of Vessel Stopping Time During Collision With Offhsore Riser Guard."
[10] H. Visser Consultancy, *HSE-Science and research-RR220-Ship collision and capacity of brace members of fixed steel offshore platforms*: Health and Safety Executive, 2004.
[11] W.-l. Jin, J. Song, S.-f. Gong, and Y. Lu, "Evaluation of damage to offshore platform structures due to collision of large barge," *Engineering structures*, vol. 27, pp. 1317-1326, 2005.
[12] H. Dikdogmus, "Riser Concepts for Deep Water," Department of Marine Technology, Norwegian University of Science and Technology, 2012.
[13] A. P. Institute, "API Recommended Practice 2RD " in *Design of Risers for Floating Production System (FPSs) and Tension-Leg Paltforms*, ed. USA, 1998.
[14] (2005, 14 February 2014). Mumbai High North.
[15] T. T. I. Ltd, "Riser Protection Nets," ed, 2005.
[16] "Marine Riser Protection for use on Offshore Oil Drilling Rigs in Icy Waters," Japan Patent, 1985.
[17] Available: http://www.geobrugg.com/contento/enus/tabid/2775/Default.aspx

APPENDICES

A. SACS Input File (SACINP)

SACS Data Generator - [C:\...\sacinp.ship impact]

File Edit Search Tools Window Help

```
OPTIONS       MN   DY  SDUC    1 1   DC  APT  PTPTPTPTPTPTPTPT
GRUP
GRUP 1           66.040 3.175 20.007.72424.80 1    1.001.00     0.500 7.8490
GRUP 2           27.300 1.270 20.007.72424.80 1    1.001.00     0.500 7.8490
GRUP 3           40.640 1.270 20.007.72424.80 1    1.001.00     0.500 7.8490
GRUP 4           50.800 1.905 20.007.72424.80 1    1.001.00     0.500 7.8490
GRUP 5           35.560 1.587 20.007.72424.80 1    1.001.00     0.500 7.8490
MEMBER
MEMBER 01050182 1                            F
MEMBER 01190183 1                            F
MEMBER 01200186 1                            F
MEMBER 01340184 1                            F
MEMBER 01350150 1                            F
MEMBER 01490164 1                            F
MEMBER 01500165 1                            F
MEMBER 01640179 1                            F
MEMBER 01650187 1                            F
MEMBER 01790185 1                            F
MEMBER 01800120 1                            F
MEMBER 01810134 1                            F
MEMBER 01840149 1                            F
MEMBER 01840188 1                            F
MEMBER 01850119 1                            F
MEMBER 01850189 1                            F
MEMBER 01860135 1                            F
MEMBER 01860190 1                            F
MEMBER 01870105 1                            F
MEMBER 01870191 1                            F
MEMBER 00050012 2                            F
MEMBER 00060013 2                            F
MEMBER 00120066 2                            F
MEMBER 00130102 2                            F
MEMBER 00140004 2                            F
MEMBER 00150007 2                            F
MEMBER 00160069 2                            F
MEMBER 00170072 2                            F
MEMBER 00180075 2                            F
MEMBER 00190078 2                            F
MEMBER 00200081 2                            F
MEMBER 00210084 2                            F
MEMBER 00220087 2                            F
```

SACS Data Generator - [C:\...\sacinp.ship impact]

File Edit Search Tools Window Help

```
JOINT 0151      1.      1.      5. 10.800 50.000 40.000
JOINT 0152      2.      1.      5. 10.800 50.000 40.000
JOINT 0153      3.      1.      5. 10.800 50.000 40.000
JOINT 0154      4.      1.      5. 10.800 50.000 40.000
JOINT 0155      5.      1.      5. 10.800 50.000 40.000
JOINT 0156      6.      1.      5. 10.800 50.000 40.000
JOINT 0157      7.      1.      5. 10.800 50.000 40.000
JOINT 0158      8.      1.      5. 10.800 50.000 40.000
JOINT 0159      9.      1.      5. 10.800 50.000 40.000
JOINT 0160     10.      1.      5. 10.800 50.000 40.000
JOINT 0161     11.      1.      5. 10.800 50.000 40.000
JOINT 0162     12.      1.      5. 10.800 50.000 40.000
JOINT 0163     13.      1.      5. 10.800 50.000 40.000
JOINT 0164     14.      1.      5. 21.600 50.000 40.000
JOINT 0165      0.      1.      3.        50.000 30.000
JOINT 0166      1.      1.      3. 10.800 50.000 30.000
JOINT 0167      2.      1.      3. 10.800 50.000 30.000
JOINT 0168      3.      1.      3. 10.800 50.000 30.000
JOINT 0169      4.      1.      3. 10.800 50.000 30.000
JOINT 0170      5.      1.      3. 10.800 50.000 30.000
JOINT 0171      6.      1.      3. 10.800 50.000 30.000
JOINT 0172      7.      1.      3. 10.800 50.000 30.000
JOINT 0173      8.      1.      3. 10.800 50.000 30.000
JOINT 0174      9.      1.      3. 10.800 50.000 30.000
JOINT 0175     10.      1.      3. 10.800 50.000 30.000
JOINT 0176     11.      1.      3. 10.800 50.000 30.000
JOINT 0177     12.      1.      3. 10.800 50.000 30.000
JOINT 0178     13.      1.      3. 10.800 50.000 30.000
JOINT 0179     14.      1.      3. 21.600 50.000 30.000
JOINT 0180      0.      1.     10.        50.000 40.000
JOINT 0181     14.      1.     10. 21.600 50.000 40.000
JOINT 0182      0.      1.      0.        50.000 40.000
JOINT 0183     14.      1.      0. 21.600 50.000 40.000
JOINT 0184     14.      1.      8. 21.600 50.000 55.000 222000
JOINT 0185     14.      1.      2. 21.600 50.000 25.000 222000
JOINT 0186      0.      1.      8.        50.000 55.000 222000
JOINT 0187      0.      1.      2.        50.000 25.000 222000
JOINT 0188     14.      5.      8. 21.600 27.500 55.000 111111
JOINT 0189     14.      3.      2. 21.600 86.000 25.000 111111
JOINT 0190      0.      5.      8.        27.500 55.000 111111
JOINT 0191      0.      3.      2.        86.000 25.000 111111
```

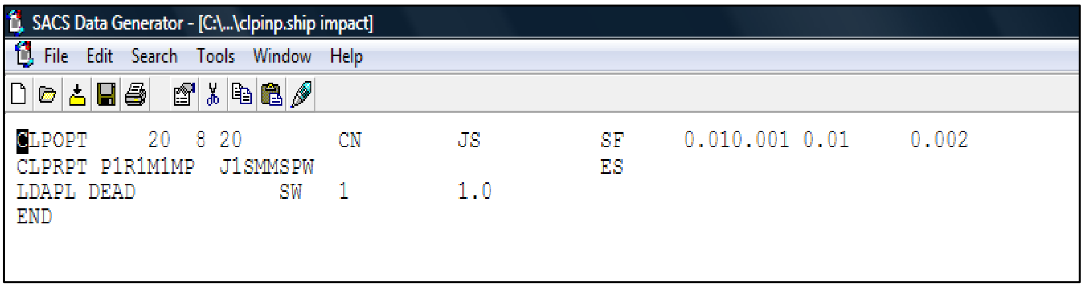
B. Dynamic Response Input File (DYRINP)

SACS Data Generator - [C:\...\dyrinp.ship impact]

File Edit Search Tools Window Help

```
DROPT SHIP     EC+Z
SDAMP         5.
LOAD
SHIP      2500.0000      0.5    180.            1.              0085 1.4
THLOAD  SHIP      SDO            PLTPLMPLSPRTALLMXSCLPJPD
JTNUM      00080009001000110038004000410043008501570164 0188 0189
TIME                   5.0000        0.01     1.0E-9      1.00
END
```

C. Collapse Input File (CLPINP)

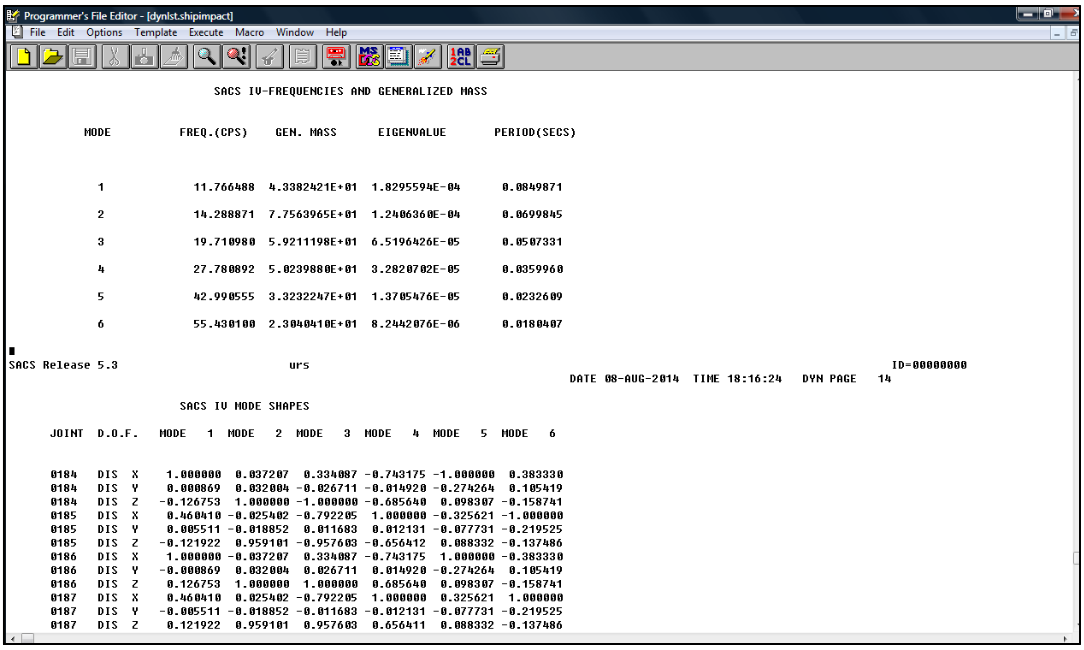


SACS Data Generator - [C:\...\clpinp.ship impact]

File Edit Search Tools Window Help

```
CLPOPT      20  8 20       CN        JS          SF     0.010.001 0.01      0.002
CLPRPT P1R1M1MP   J1SMMSPW                        ES
LDAPL DEAD              SW    1          1.0
END
```

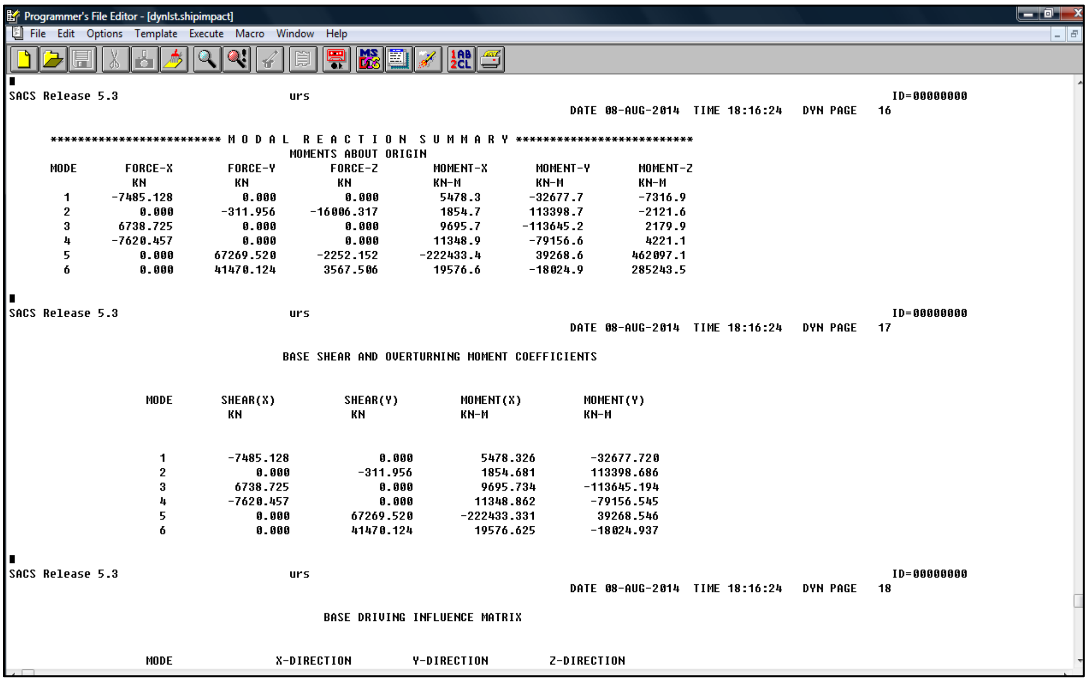
D. DYNPAC Output File (DYNLST)



Programmer's File Editor - [dynlst.shipimpact]

File Edit Options Template Execute Macro Window Help

```
                           SACS IV-FREQUENCIES AND GENERALIZED MASS

        MODE          FREQ.(CPS)    GEN. MASS      EIGENVALUE       PERIOD(SECS)


          1            11.766488  4.3382421E+01  1.8295594E-04      0.0849871

          2            14.288871  7.7563965E+01  1.2406360E-04      0.0699845

          3            19.710980  5.9211198E+01  6.5196426E-05      0.0507331

          4            27.780892  5.0239880E+01  3.2820702E-05      0.0359960

          5            42.990555  3.3232247E+01  1.3705476E-05      0.0232609

          6            55.430100  2.3040410E+01  8.2442076E-06      0.0180407

SACS Release 5.3                     urs                                                   ID=00000000
                                                                DATE 08-AUG-2014  TIME 18:16:24   DYN PAGE   14

                        SACS IV MODE SHAPES

     JOINT  D.O.F.   MODE   1  MODE   2  MODE   3  MODE   4  MODE   5  MODE   6


     0184   DIS  X    1.000000  0.037207  0.334087 -0.743175 -1.000000  0.383330
     0184   DIS  Y    0.000869  0.032004 -0.026711 -0.014920 -0.274264  0.105419
     0184   DIS  Z   -0.126753  1.000000 -1.000000 -0.685640  0.098307 -0.158741
     0185   DIS  X    0.460410 -0.025402 -0.792205  1.000000 -0.325621 -1.000000
     0185   DIS  Y    0.005511 -0.018852  0.011683  0.012131 -0.077731 -0.219525
     0185   DIS  Z   -0.121922  0.959101 -0.957603 -0.656412  0.088332 -0.137486
     0186   DIS  X    1.000000 -0.037207  0.334087 -0.743175  1.000000 -0.383330
     0186   DIS  Y   -0.000869  0.032004  0.026711  0.014920 -0.274264  0.105419
     0186   DIS  Z    0.126753  1.000000  1.000000  0.685640  0.098307 -0.158741
     0187   DIS  X    0.460410  0.025402 -0.792205  1.000000  0.325621  1.000000
     0187   DIS  Y   -0.005511 -0.018852 -0.011683 -0.012131 -0.077731 -0.219525
     0187   DIS  Z    0.121922  0.959101  0.957603  0.656411  0.088332 -0.137486
```

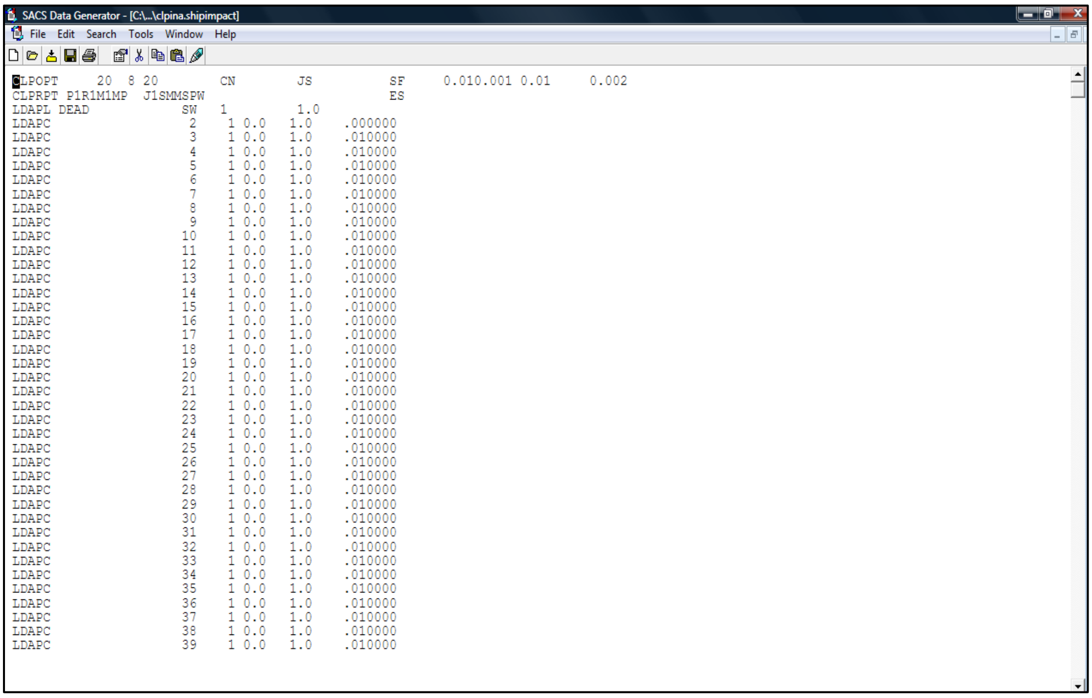


Programmer's File Editor - [dynlst.shipimpact]

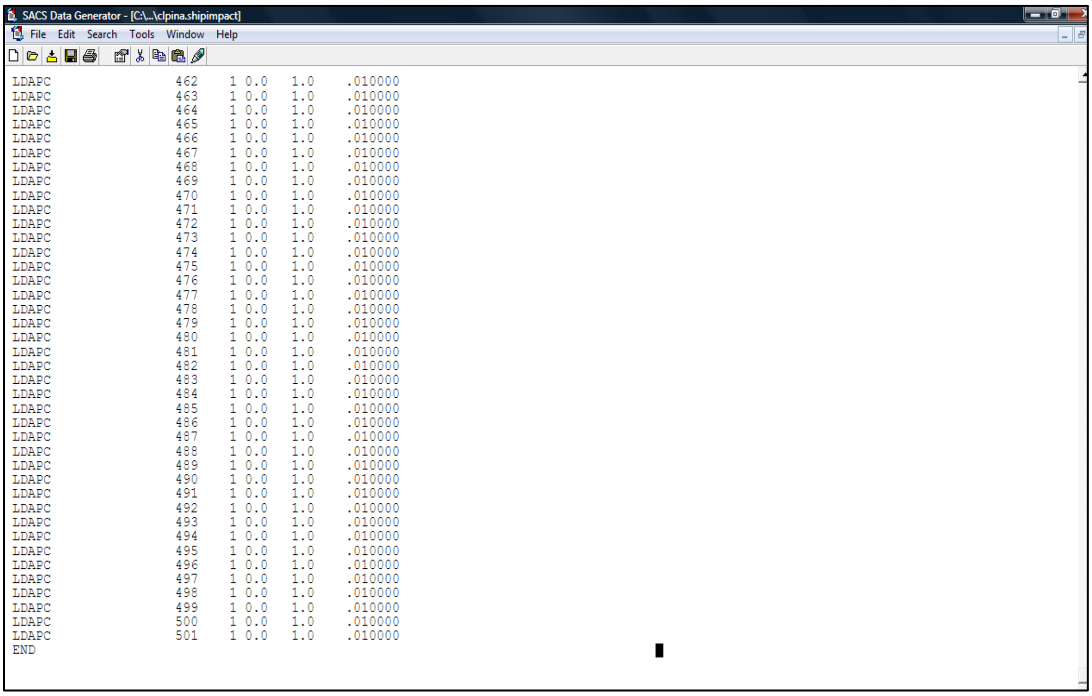
File Edit Options Template Execute Macro Window Help

```
SACS Release 5.3                     urs                                                   ID=00000000
                                                                DATE 08-AUG-2014  TIME 18:16:24   DYN PAGE   16

     ************************* M O D A L   R E A C T I O N   S U M M A R Y *************************
                                       MOMENTS ABOUT ORIGIN
     MODE        FORCE-X          FORCE-Y          FORCE-Z          MOMENT-X         MOMENT-Y         MOMENT-Z
                    KN               KN               KN              KN-M             KN-M             KN-M
       1       -7485.128           0.000            0.000           5478.3         -32677.7          -7316.9
       2           0.000        -311.956       -16006.317           1854.7         113398.7          -2121.6
       3        6738.725           0.000            0.000           9695.7        -113645.2           2179.9
       4       -7620.457           0.000            0.000          11348.9         -79156.6           4221.1
       5           0.000       67269.520        -2252.152        -222433.4          39268.6         462097.1
       6           0.000       41470.124         3567.506          19576.6         -18024.9         285243.5

SACS Release 5.3                     urs                                                   ID=00000000
                                                                DATE 08-AUG-2014  TIME 18:16:24   DYN PAGE   17

                                       BASE SHEAR AND OVERTURNING MOMENT COEFFICIENTS


                  MODE        SHEAR(X)           SHEAR(Y)           MOMENT(X)          MOMENT(Y)
                                KN                 KN                 KN-M               KN-M


                    1       -7485.128              0.000           5478.326         -32677.720
                    2           0.000           -311.956           1854.681         113398.686
                    3        6738.725              0.000           9695.734        -113645.194
                    4       -7620.457              0.000          11348.862         -79156.545
                    5           0.000          67269.520        -222433.331          39268.546
                    6           0.000          41470.124          19576.625         -18024.937

SACS Release 5.3                     urs                                                   ID=00000000
                                                                DATE 08-AUG-2014  TIME 18:16:24   DYN PAGE   18

                                           BASE DRIVING INFLUENCE MATRIX


                  MODE              X-DIRECTION        Y-DIRECTION        Z-DIRECTION
```

E. Collapse Dynamic Loading Input File (CLPINA)




```
CLPOPT      20  8 20         CN         JS           SF      0.010.001 0.01      0.002
CLPRPT P1R1M1MP  J1SMMSPW                            ES
LDAPL DEAD                SW   1         1.0
LDAPC                      2    1 0.0   1.0    .000000
LDAPC                      3    1 0.0   1.0    .010000
LDAPC                      4    1 0.0   1.0    .010000
LDAPC                      5    1 0.0   1.0    .010000
LDAPC                      6    1 0.0   1.0    .010000
LDAPC                      7    1 0.0   1.0    .010000
LDAPC                      8    1 0.0   1.0    .010000
LDAPC                      9    1 0.0   1.0    .010000
LDAPC                     10    1 0.0   1.0    .010000
LDAPC                     11    1 0.0   1.0    .010000
LDAPC                     12    1 0.0   1.0    .010000
LDAPC                     13    1 0.0   1.0    .010000
LDAPC                     14    1 0.0   1.0    .010000
LDAPC                     15    1 0.0   1.0    .010000
LDAPC                     16    1 0.0   1.0    .010000
LDAPC                     17    1 0.0   1.0    .010000
LDAPC                     18    1 0.0   1.0    .010000
LDAPC                     19    1 0.0   1.0    .010000
LDAPC                     20    1 0.0   1.0    .010000
LDAPC                     21    1 0.0   1.0    .010000
LDAPC                     22    1 0.0   1.0    .010000
LDAPC                     23    1 0.0   1.0    .010000
LDAPC                     24    1 0.0   1.0    .010000
LDAPC                     25    1 0.0   1.0    .010000
LDAPC                     26    1 0.0   1.0    .010000
LDAPC                     27    1 0.0   1.0    .010000
LDAPC                     28    1 0.0   1.0    .010000
LDAPC                     29    1 0.0   1.0    .010000
LDAPC                     30    1 0.0   1.0    .010000
LDAPC                     31    1 0.0   1.0    .010000
LDAPC                     32    1 0.0   1.0    .010000
LDAPC                     33    1 0.0   1.0    .010000
LDAPC                     34    1 0.0   1.0    .010000
LDAPC                     35    1 0.0   1.0    .010000
LDAPC                     36    1 0.0   1.0    .010000
LDAPC                     37    1 0.0   1.0    .010000
LDAPC                     38    1 0.0   1.0    .010000
LDAPC                     39    1 0.0   1.0    .010000
```




```
LDAPC                    462    1 0.0   1.0    .010000
LDAPC                    463    1 0.0   1.0    .010000
LDAPC                    464    1 0.0   1.0    .010000
LDAPC                    465    1 0.0   1.0    .010000
LDAPC                    466    1 0.0   1.0    .010000
LDAPC                    467    1 0.0   1.0    .010000
LDAPC                    468    1 0.0   1.0    .010000
LDAPC                    469    1 0.0   1.0    .010000
LDAPC                    470    1 0.0   1.0    .010000
LDAPC                    471    1 0.0   1.0    .010000
LDAPC                    472    1 0.0   1.0    .010000
LDAPC                    473    1 0.0   1.0    .010000
LDAPC                    474    1 0.0   1.0    .010000
LDAPC                    475    1 0.0   1.0    .010000
LDAPC                    476    1 0.0   1.0    .010000
LDAPC                    477    1 0.0   1.0    .010000
LDAPC                    478    1 0.0   1.0    .010000
LDAPC                    479    1 0.0   1.0    .010000
LDAPC                    480    1 0.0   1.0    .010000
LDAPC                    481    1 0.0   1.0    .010000
LDAPC                    482    1 0.0   1.0    .010000
LDAPC                    483    1 0.0   1.0    .010000
LDAPC                    484    1 0.0   1.0    .010000
LDAPC                    485    1 0.0   1.0    .010000
LDAPC                    486    1 0.0   1.0    .010000
LDAPC                    487    1 0.0   1.0    .010000
LDAPC                    488    1 0.0   1.0    .010000
LDAPC                    489    1 0.0   1.0    .010000
LDAPC                    490    1 0.0   1.0    .010000
LDAPC                    491    1 0.0   1.0    .010000
LDAPC                    492    1 0.0   1.0    .010000
LDAPC                    493    1 0.0   1.0    .010000
LDAPC                    494    1 0.0   1.0    .010000
LDAPC                    495    1 0.0   1.0    .010000
LDAPC                    496    1 0.0   1.0    .010000
LDAPC                    497    1 0.0   1.0    .010000
LDAPC                    498    1 0.0   1.0    .010000
LDAPC                    499    1 0.0   1.0    .010000
LDAPC                    500    1 0.0   1.0    .010000
LDAPC                    501    1 0.0   1.0    .010000
END
```

F. Collapse History Log File (CLPLOG)

Programmer's File Editor - [clplog.shipimpact]

File Edit Options Template Execute Macro Window Help

```
**** NON-LINEAR COLLAPSE ANALYSIS (LOAD SEQUENCE 1) ****

                   LOAD  LOAD    *DEFLECTION*    ROTATION    ** DEFLECTION **  % OF IMPACT
 NSLV  INC.  LOOP  CASE FACTOR   DIFF.  JNT DOF   DIFFERENCE  MAXIMUM  JNT DOF     ENERGY

    2    1    1   SW   1.000   0.0001 0049 DY   0.0000002   -0.302 0049 DZ
    2    1    2   SW   1.000   0.0000 0049 DZ   0.0000000   -0.302 0049 DZ
    4    2    1    2   1.000   0.0000 0060 DY   0.0000000   -0.302 0049 DZ
    4    2    2    2   1.000   0.0000 0049 DY   0.0000000   -0.302 0049 DZ
    6    3    1    3   1.000   0.0000 0044 DX   0.0000000   -0.302 0049 DZ
    6    3    2    3   1.000   0.0000 0060 DY   0.0000000   -0.302 0049 DZ
    8    4    1    4   1.000   0.0000 0125 DZ   0.0000000   -0.302 0049 DZ
    8    4    2    4   1.000   0.0000 0044 DX   0.0000000   -0.302 0049 DZ
   10    5    1    5   1.000   0.0000 0024 DZ   0.0000000   -0.302 0049 DZ
   10    5    2    5   1.000   0.0000 0125 DZ   0.0000000   -0.302 0049 DZ
   12    6    1    6   1.000   0.0000 0191 DX   0.0000000   -0.302 0049 DZ
   12    6    2    6   1.000   0.0000 0024 DZ   0.0000000   -0.302 0049 DZ
   14    7    1    7   1.000   0.0000 0191 DX   0.0000000   -0.302 0049 DZ
   14    7    2    7   1.000   0.0000 0191 DX   0.0000000   -0.302 0049 DZ
   16    8    1    8   1.000   0.0000 0191 DX   0.0000000   -0.302 0049 DZ
   16    8    2    8   1.000   0.0000 0191 DX   0.0000000   -0.302 0049 DZ
   18    9    1    9   1.000   0.0000 0191 DX   0.0000000   -0.302 0049 DZ
   18    9    2    9   1.000   0.0000 0191 DX   0.0000000   -0.302 0049 DZ
   20   10    1   10   1.000   0.0000 0191 DX   0.0000000   -0.302 0049 DZ
   20   10    2   10   1.000   0.0000 0191 DX   0.0000000   -0.302 0049 DZ
   22   11    1   11   1.000   0.0000 0191 DX   0.0000000   -0.302 0049 DZ
   22   11    2   11   1.000   0.0000 0191 DX   0.0000000   -0.302 0049 DZ
   24   12    1   12   1.000   0.0000 0191 DX   0.0000000   -0.302 0049 DZ
   24   12    2   12   1.000   0.0000 0191 DX   0.0000000   -0.302 0049 DZ
   26   13    1   13   1.000   0.0000 0191 DX   0.0000000   -0.302 0049 DZ
   26   13    2   13   1.000   0.0000 0191 DX   0.0000000   -0.302 0049 DZ
   28   14    1   14   1.000   0.0000 0191 DX   0.0000000   -0.302 0049 DZ
   28   14    2   14   1.000   0.0000 0191 DX   0.0000000   -0.302 0049 DZ
   30   15    1   15   1.000   0.0000 0191 DX   0.0000000   -0.302 0049 DZ
   30   15    2   15   1.000   0.0000 0191 DX   0.0000000   -0.302 0049 DZ
   32   16    1   16   1.000   0.0000 0191 DX   0.0000000   -0.302 0049 DZ
   32   16    2   16   1.000   0.0000 0191 DX   0.0000000   -0.302 0049 DZ
   34   17    1   17   1.000   0.0000 0191 DX   0.0000000   -0.302 0049 DZ
   34   17    2   17   1.000   0.0000 0191 DX   0.0000000   -0.302 0049 DZ
   36   18    1   18   1.000   0.0000 0191 DX   0.0000000   -0.302 0049 DZ
   36   18    2   18   1.000   0.0000 0191 DX   0.0000000   -0.302 0049 DZ
```

Programmer's File Editor - [clplog.shipimpact]

File Edit Options Template Execute Macro Window Help

```
  390  195    1  195   1.000   0.0000 0191 DX   0.0000000   -0.302 0049 DZ
  390  195    2  195   1.000   0.0000 0191 DX   0.0000000   -0.302 0049 DZ
  392  196    1  196   1.000   0.0000 0191 DX   0.0000000   -0.302 0049 DZ
  392  196    2  196   1.000   0.0000 0191 DX   0.0000000   -0.302 0049 DZ
  394  197    1  197   1.000   0.0000 0191 DX   0.0000000   -0.302 0049 DZ
  394  197    2  197   1.000   0.0000 0191 DX   0.0000000   -0.302 0049 DZ
  396  198    1  198   1.000   0.0000 0191 DX   0.0000000   -0.302 0049 DZ
  396  198    2  198   1.000   0.0000 0191 DX   0.0000000   -0.302 0049 DZ
  398  199    1  199   1.000   0.0000 0191 DX   0.0000000   -0.302 0049 DZ
  398  199    2  199   1.000   0.0000 0191 DX   0.0000000   -0.302 0049 DZ
  400  200    1  200   1.000   0.0000 0191 DX   0.0000000   -0.302 0049 DZ
  400  200    2  200   1.000   0.0000 0191 DX   0.0000000   -0.302 0049 DZ
  402  201    1  201   1.000   0.0000 0191 DX   0.0000000   -0.302 0049 DZ
  402  201    2  201   1.000   0.0000 0191 DX   0.0000000   -0.302 0049 DZ
  404  202    1  202   1.000   0.0000 0191 DX   0.0000000   -0.302 0049 DZ
  404  202    2  202   1.000   0.0000 0191 DX   0.0000000   -0.302 0049 DZ
  406  203    1  203   1.000   0.0125 0085 DY   0.0000902    2.140 0085 DY
  407  203    2  203   1.000   0.0049 0085 DY   0.0000481    2.145 0085 DY
 *** WARNING - JOINT FAILURE OCCURRED AT JOINT 0157 FOR BRACE MEMBER 0142-0157 AT LOAD STEP  202
  408  203    1  203   1.000   0.2384 0142 DZ   0.0018766    2.296 0085 DY
  409  203    2  203   1.000   0.0073 0085 DY   0.0000481    2.304 0085 DY
  409  203    3  203   1.000   0.2384 0142 DZ   0.0018766    2.296 0085 DY
  411  204    1  204   1.000   0.0464 0118 DX   0.0001121   -1.487 0006 DX
  412  204    2  204   1.000   0.0178 0185 DX   0.0000476   -1.494 0006 DX
  413  204    3  204   1.000   0.0076 0003 DX   0.0000202   -1.497 0006 DX
  413  204    4  204   1.000   0.0178 0185 DX   0.0000476   -1.494 0006 DX
  415  205    1  205   1.000   0.1340 0085 DY   0.0004297   -2.546 0085 DX
  416  205    2  205   1.000   0.0733 0085 DY   0.0003130   -2.574 0085 DX
  417  205    3  205   1.000   0.0477 0085 DY   0.0002535   -2.589 0085 DX
  418  205    4  205   1.000   0.0342 0085 DY   0.0001953   -2.599 0085 DX
  419  205    5  205   1.000   0.0266 0085 DY   0.0001536   -2.606 0085 DX
  420  205    6  205   1.000   0.0222 0085 DY   0.0001570   -2.612 0085 DX
  421  205    7  205   1.000   0.0188 0085 DY   0.0001231   -2.617 0085 DX
  422  205    8  205   1.000   0.0161 0085 DY   0.0000987   -2.621 0085 DX
  423  205    9  205   1.000   0.0153 0085 DY   0.0000864   -2.625 0085 DX
  424  205   10  205   1.000   0.0137 0085 DY   0.0000714   -2.628 0085 DX
  425  205   11  205   1.000   0.0118 0085 DY   0.0000601   -2.631 0085 DX
  426  205   12  205   1.000   0.0103 0085 DY   0.0000517    2.636 0085 DY
  427  205   13  205   1.000   0.0091 0085 DY   0.0000449    2.645 0085 DY
 *** WARNING - JOINT FAILURE OCCURRED AT JOINT 0157 FOR BRACE MEMBER 0085-0157 AT LOAD STEP  204
  428  205    1  205   1.000   0.1875 0157 DY   0.0013452    2.760 0085 DY
```

G. Dynamic Listing File (DYRLST)

Programmer's File Editor - [clplog.shipimpact]

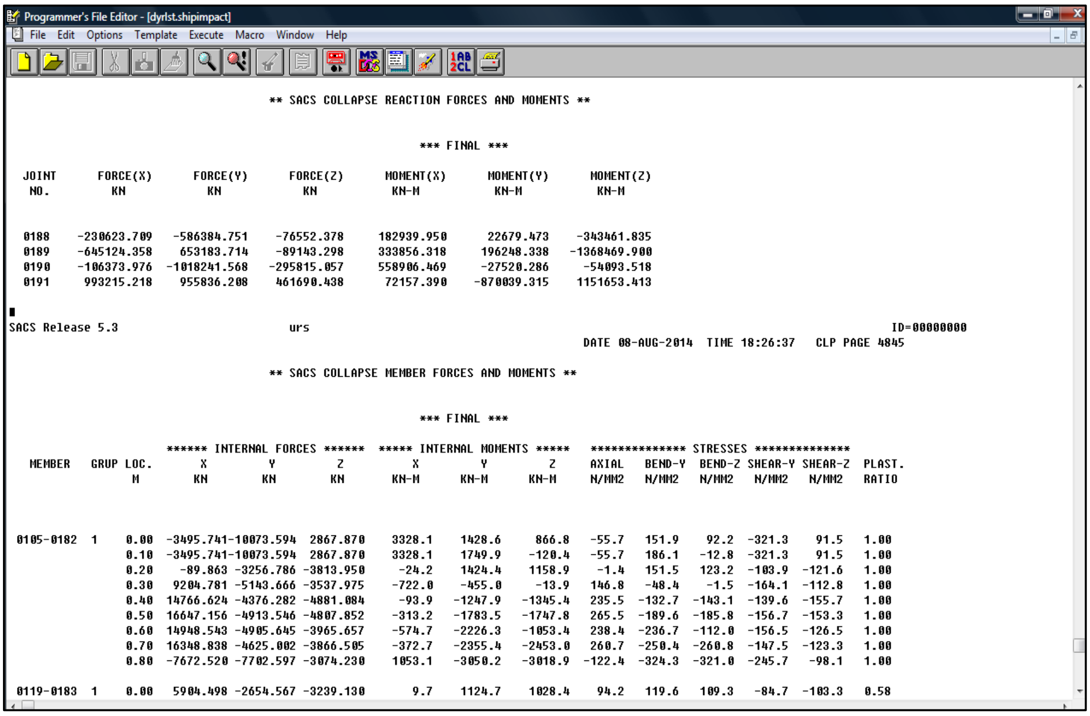
File Edit Options Template Execute Macro Window Help

```
  814  224    7  224    1.000   3.9340 0182 DY   0.0275428   -57.648 0085 DX
  815  224    8  224    1.000   4.9868 0182 DY   0.0337387   -58.326 0085 DX
  816  224    9  224    1.000   5.4098 0182 DY   0.0375179   -57.633 0085 DX
  817  224   10  224    1.000   6.8858 0182 DY   0.0463624   -58.596 0085 DX
  818  224   11  224    1.000   8.6429 0182 DY   0.0602400   -57.571 0085 DX
  819  224   12  224    1.000  10.0980 0182 DY   0.0686208   -59.104 0085 DX
  820  224   13  224    1.000  14.1593 0182 DY   0.0979955   -56.742 0085 DX
  821  224   14  224    1.000  14.6580 0182 DY   0.1007888   -59.174 0085 DX
  822  224   15  224    1.000  20.0506 0182 DY   0.1394834   -56.332 0085 DX
  823  224   16  224    1.000  15.9666 0182 DY   0.1095334   -59.207 0085 DX
  824  224   17  224    1.000  16.4294 0182 DY   0.1128230   -56.956 0085 DX
  825  224   18  224    1.000  12.3949 0182 DY   0.0844341   -59.072 0085 DX
  826  224   19  224    1.000  10.0266 0182 DY   0.0683247   -57.341 0085 DX
  826  224   20  224    1.000   6.1975 0182 DY   0.0422170   -58.347 0085 DX
 *** WARNING - JOINT FAILURE OCCURRED AT JOINT 0160 FOR BRACE MEMBER 0094-0160 AT LOAD STEP  224
  828  225    1  225    1.000  17.2635 0182 DY   0.1192466   -58.819 0085 DX
  829  225    2  225    1.000  80.8754 0182 DY   0.5537826   -52.489 0085 DX
  830  225    3  225    1.000   4.5237 0182 DY   0.0740700   -57.691 0085 DX
  831  225    4  225    1.000   2.2278 0108 DZ   0.0587329   -57.669 0085 DX
  832  225    5  225    1.000   3.7081 0108 DZ   0.0821231   -57.817 0085 DX
  833  225    6  225    1.000   2.6443 0045 DY   0.0608186   -57.867 0085 DX
  834  225    7  225    1.000  12.6303 0108 DZ   0.1704164   -58.049 0085 DX
  835  225    8  225    1.000   4.4855 0108 DZ   0.1155213   -58.022 0085 DX
  836  225    9  225    1.000   8.4820 0045 DY   0.0530795   -57.783 0085 DX
  837  225   10  225    1.000  10.2970 0108 DZ   0.1394541   -58.258 0085 DX
  838  225   11  225    1.000   5.9201 0108 DZ   0.1323841   -58.032 0085 DX
  839  225   12  225    1.000  17.0052 0045 DY   0.0838534   -57.792 0085 DX
  840  225   13  225    1.000  10.3967 0108 DZ   0.1861992   -58.278 0085 DX
  841  225   14  225    1.000   3.2302 0109 DZ   0.1307427   -58.167 0085 DX
  842  225   15  225    1.000   5.5562 0109 DZ   0.1037132   -58.175 0085 DX
  843  225   16  225    1.000   6.5064 0045 DY   0.0658671   -57.821 0085 DX
  844  225   17  225    1.000  31.7808 0108 DZ   0.3978164   -58.757 0085 DX
  845  225   18  225    1.000  59.2214 0045 DY   0.3242792   -56.206 0085 DX
  846  225   19  225    1.000 225.9433 0045 DY   1.6761273   212.402 0045 DY
  846  225   20  225    1.000  29.6107 0045 DY   0.1621396   -57.172 0085 DX
 *** WARNING - JOINT FAILURE OCCURRED AT JOINT 0116 FOR BRACE MEMBER 0036-0116 AT LOAD STEP  225
  848  226    1  226    1.0008062.7675 0047 DY  62.6648281 -7931.705 0047 DY
  848  226    2  226    1.000   0.0000 0047 DY   0.0000000 -7931.705 0047 DY
```

Programmer's File Editor - [dyrlst.shipimpact]

File Edit Options Template Execute Macro Window Help

```
                                                                                DATE 08-AUG-2014  TIME 18:26:37   CLP PAGE 4834

         **** FINAL DEFLECTIONS AND ROTATIONS FOR LOAD CASE  226 ****



                 ****** DEFLECTIONS ******   ******* ROTATIONS *******
         JOINT        X         Y        Z          X        Y        Z
                     CM        CM       CM        RAD      RAD      RAD


         0000      47.474-1345.537  478.130   -7.32123 -0.12034 -1.29926
         0001      -0.840  154.032  524.554   -0.55669 -0.61932  0.92183
         0002      11.339  108.648  202.822   -0.41350 -0.23074 -0.93216
         0003     844.847 -363.941  259.966   -1.31349 -0.75071  2.06606
         0004     639.679-3699.100 -587.290  -25.78566 -2.38307 -6.16545
         0005     -34.711  264.747  623.315   -0.57452 -0.92459  0.91301
         0006       4.523  243.871  171.166   -0.58616 -0.29773 -0.98423
         0007     769.183 -757.759  214.915   -2.13997 -0.29102  2.47636
         0008      71.761   85.716  522.501   -0.55671 -0.61931  0.92183
         0009      40.104   58.686  202.429   -0.41352 -0.23072 -0.93216
         0010      17.029 -472.535  555.998   -7.26837 -0.11525 -1.28667
         0011     756.166 -212.253  258.704   -1.31348 -0.75072  2.06606
         0012      74.217  192.923  619.126   -0.57464 -0.92452  0.91302
         0013      41.871  172.454  170.525   -0.58630 -0.29766 -0.98423
         0014     150.796-1030.074  365.873  -18.34058 -1.57784 -5.79769
         0015     738.555 -504.394  218.222   -2.13996 -0.29110  2.47636
         0016      76.288  290.074  716.576   -0.31231 -0.76535  0.89812
         0017      75.798  386.382  773.216    0.05067 -0.19425  0.90997
         0018      73.885  470.959  753.954    0.24237  0.52808  0.71231
         0019      72.518  527.816  658.586    0.30591  1.07128  0.40209
         0020      71.502  555.815  522.723    0.38262  1.27274  0.17236
         0021      69.685  561.872  385.666    0.37594  1.16374 -0.03045
         0022      66.292  547.320  273.043    0.21188  0.92660 -0.21488
         0023      61.670  514.314  190.707   -0.10477  0.63854 -0.39791
         0024      56.314  461.399  141.283   -0.47361  0.33004 -0.60126
         0025      50.657  385.411  124.800   -0.74231 -0.00139 -0.82244
         0026      45.498  284.296  140.928   -0.71739 -0.23746 -0.98035
         0027     329.130-1822.839   70.523  -28.58269 -2.12131 -6.25174
         0028     450.148-2510.488 -268.849  -37.89418 -0.69623 -4.60519
         0029     475.189-2751.321 -356.992  -39.39912  0.16773 -1.80768
```



Programmer's File Editor - [dyrlst.shipimpact]

File Edit Options Template Execute Macro Window Help

** SACS COLLAPSE REACTION FORCES AND MOMENTS **

*** FINAL ***

JOINT NO.	FORCE(X) KN	FORCE(Y) KN	FORCE(Z) KN	MOMENT(X) KN-M	MOMENT(Y) KN-M	MOMENT(Z) KN-M
0188	-230623.709	-586384.751	-76552.378	182939.950	22679.473	-343461.835
0189	-645124.358	653183.714	-89143.298	333856.318	196248.338	-1368469.900
0190	-106373.976	-1018241.568	-295815.057	558906.469	-27520.286	-54093.518
0191	993215.218	955836.208	461690.438	72157.390	-870039.315	1151653.413

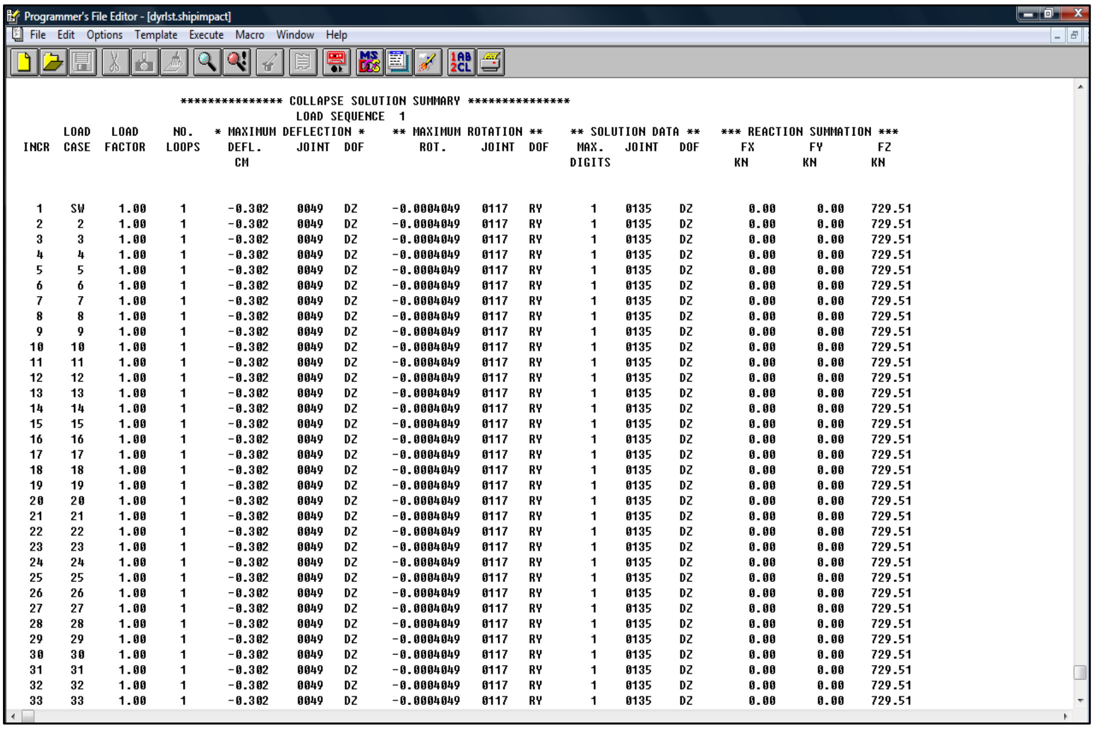
SACS Release 5.3 urs ID=00000000

DATE 08-AUG-2014 TIME 18:26:37 CLP PAGE 4845

** SACS COLLAPSE MEMBER FORCES AND MOMENTS **

*** FINAL ***

MEMBER	GRUP	LOC. M	****** INTERNAL FORCES ****** X KN	Y KN	Z KN	***** INTERNAL MOMENTS ***** X KN-M	Y KN-M	Z KN-M	************** STRESSES ************** AXIAL N/MM2	BEND-Y N/MM2	BEND-Z N/MM2	SHEAR-Y N/MM2	SHEAR-Z N/MM2	PLAST. RATIO
0105-0182	1	0.00	-3495.741	-10073.594	2867.870	3328.1	1428.6	866.8	-55.7	151.9	92.2	-321.3	91.5	1.00
		0.10	-3495.741	-10073.594	2867.870	3328.1	1749.9	-120.4	-55.7	186.1	-12.8	-321.3	91.5	1.00
		0.20	-89.863	-3256.786	-3813.950	-24.2	1424.4	1158.9	-1.4	151.5	123.2	-103.9	-121.6	1.00
		0.30	9204.781	-5143.666	-3537.975	-722.0	-455.0	-13.9	146.8	-48.4	-1.5	-164.1	-112.8	1.00
		0.40	14766.624	-4376.282	-4881.084	-93.9	-1247.9	-1345.4	235.5	-132.7	-143.1	-139.6	-155.7	1.00
		0.50	16647.156	-4913.546	-4807.852	-313.2	-1783.5	-1747.8	265.5	-189.6	-185.8	-156.7	-153.3	1.00
		0.60	14948.543	-4905.645	-3965.657	-574.7	-2226.3	-1053.4	238.4	-236.7	-112.0	-156.5	-126.5	1.00
		0.70	16348.838	-4625.002	-3866.505	-372.7	-2355.4	-2453.0	260.7	-250.4	-260.8	-147.5	-123.3	1.00
		0.80	-7672.520	-7702.597	-3074.230	1053.1	-3050.2	-3018.9	-122.4	-324.3	-321.0	-245.7	-98.1	1.00
0119-0183	1	0.00	5904.498	-2654.567	-3239.130	9.7	1124.7	1028.4	94.2	119.6	109.3	-84.7	-103.3	0.58



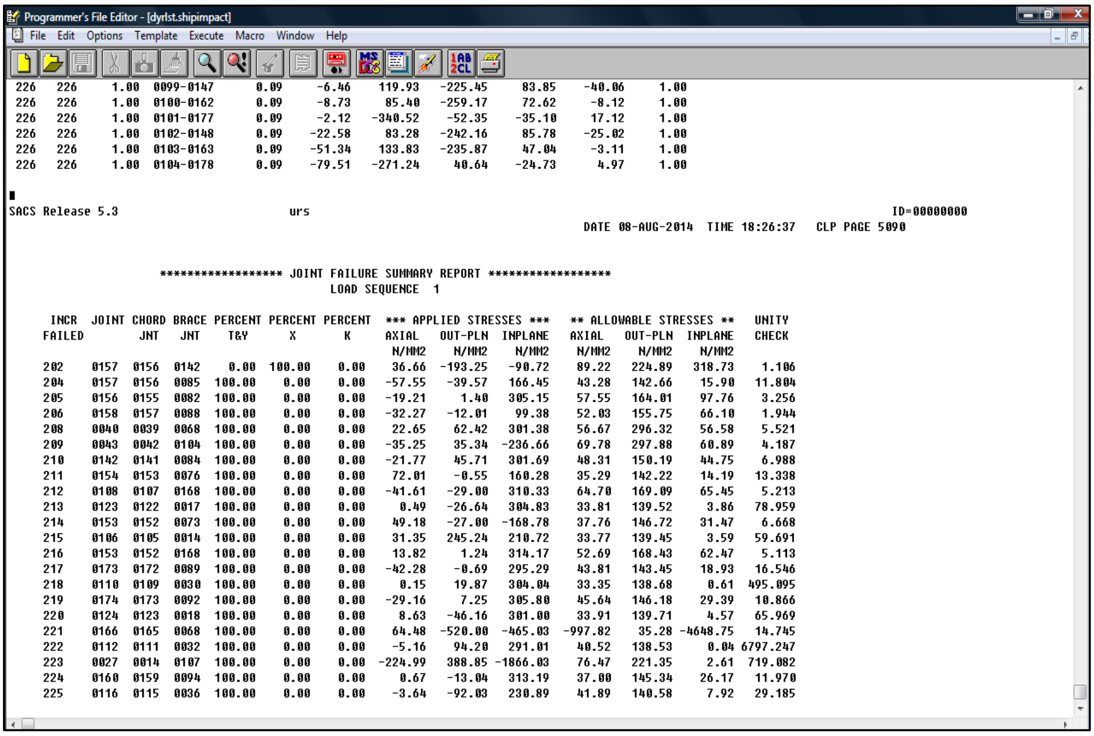
Programmer's File Editor - [dyrlst.shipimpact]

File Edit Options Template Execute Macro Window Help

*************** COLLAPSE SOLUTION SUMMARY ***************

LOAD SEQUENCE 1

INCR	LOAD CASE	LOAD FACTOR	NO. LOOPS	* MAXIMUM DEFLECTION * DEFL. CM	JOINT	DOF	** MAXIMUM ROTATION ** ROT.	JOINT	DOF	** SOLUTION DATA ** MAX. DIGITS	JOINT	DOF	*** REACTION SUMMATION *** FX KN	FY KN	FZ KN
1	SW	1.00	1	-0.302	0049	DZ	-0.0004049	0117	RY	1	0135	DZ	0.00	0.00	729.51
2	2	1.00	1	-0.302	0049	DZ	-0.0004049	0117	RY	1	0135	DZ	0.00	0.00	729.51
3	3	1.00	1	-0.302	0049	DZ	-0.0004049	0117	RY	1	0135	DZ	0.00	0.00	729.51
4	4	1.00	1	-0.302	0049	DZ	-0.0004049	0117	RY	1	0135	DZ	0.00	0.00	729.51
5	5	1.00	1	-0.302	0049	DZ	-0.0004049	0117	RY	1	0135	DZ	0.00	0.00	729.51
6	6	1.00	1	-0.302	0049	DZ	-0.0004049	0117	RY	1	0135	DZ	0.00	0.00	729.51
7	7	1.00	1	-0.302	0049	DZ	-0.0004049	0117	RY	1	0135	DZ	0.00	0.00	729.51
8	8	1.00	1	-0.302	0049	DZ	-0.0004049	0117	RY	1	0135	DZ	0.00	0.00	729.51
9	9	1.00	1	-0.302	0049	DZ	-0.0004049	0117	RY	1	0135	DZ	0.00	0.00	729.51
10	10	1.00	1	-0.302	0049	DZ	-0.0004049	0117	RY	1	0135	DZ	0.00	0.00	729.51
11	11	1.00	1	-0.302	0049	DZ	-0.0004049	0117	RY	1	0135	DZ	0.00	0.00	729.51
12	12	1.00	1	-0.302	0049	DZ	-0.0004049	0117	RY	1	0135	DZ	0.00	0.00	729.51
13	13	1.00	1	-0.302	0049	DZ	-0.0004049	0117	RY	1	0135	DZ	0.00	0.00	729.51
14	14	1.00	1	-0.302	0049	DZ	-0.0004049	0117	RY	1	0135	DZ	0.00	0.00	729.51
15	15	1.00	1	-0.302	0049	DZ	-0.0004049	0117	RY	1	0135	DZ	0.00	0.00	729.51
16	16	1.00	1	-0.302	0049	DZ	-0.0004049	0117	RY	1	0135	DZ	0.00	0.00	729.51
17	17	1.00	1	-0.302	0049	DZ	-0.0004049	0117	RY	1	0135	DZ	0.00	0.00	729.51
18	18	1.00	1	-0.302	0049	DZ	-0.0004049	0117	RY	1	0135	DZ	0.00	0.00	729.51
19	19	1.00	1	-0.302	0049	DZ	-0.0004049	0117	RY	1	0135	DZ	0.00	0.00	729.51
20	20	1.00	1	-0.302	0049	DZ	-0.0004049	0117	RY	1	0135	DZ	0.00	0.00	729.51
21	21	1.00	1	-0.302	0049	DZ	-0.0004049	0117	RY	1	0135	DZ	0.00	0.00	729.51
22	22	1.00	1	-0.302	0049	DZ	-0.0004049	0117	RY	1	0135	DZ	0.00	0.00	729.51
23	23	1.00	1	-0.302	0049	DZ	-0.0004049	0117	RY	1	0135	DZ	0.00	0.00	729.51
24	24	1.00	1	-0.302	0049	DZ	-0.0004049	0117	RY	1	0135	DZ	0.00	0.00	729.51
25	25	1.00	1	-0.302	0049	DZ	-0.0004049	0117	RY	1	0135	DZ	0.00	0.00	729.51
26	26	1.00	1	-0.302	0049	DZ	-0.0004049	0117	RY	1	0135	DZ	0.00	0.00	729.51
27	27	1.00	1	-0.302	0049	DZ	-0.0004049	0117	RY	1	0135	DZ	0.00	0.00	729.51
28	28	1.00	1	-0.302	0049	DZ	-0.0004049	0117	RY	1	0135	DZ	0.00	0.00	729.51
29	29	1.00	1	-0.302	0049	DZ	-0.0004049	0117	RY	1	0135	DZ	0.00	0.00	729.51
30	30	1.00	1	-0.302	0049	DZ	-0.0004049	0117	RY	1	0135	DZ	0.00	0.00	729.51
31	31	1.00	1	-0.302	0049	DZ	-0.0004049	0117	RY	1	0135	DZ	0.00	0.00	729.51
32	32	1.00	1	-0.302	0049	DZ	-0.0004049	0117	RY	1	0135	DZ	0.00	0.00	729.51
33	33	1.00	1	-0.302	0049	DZ	-0.0004049	0117	RY	1	0135	DZ	0.00	0.00	729.51



226	226	1.00	0099-0147	0.09	-6.46	119.93	-225.45	83.85	-40.06	1.00
226	226	1.00	0100-0162	0.09	-8.73	85.40	-259.17	72.62	-8.12	1.00
226	226	1.00	0101-0177	0.09	-2.12	-340.52	-52.35	-35.10	17.12	1.00
226	226	1.00	0102-0148	0.09	-22.58	83.28	-242.16	85.78	-25.02	1.00
226	226	1.00	0103-0163	0.09	-51.34	133.83	-235.87	47.04	-3.11	1.00
226	226	1.00	0104-0178	0.09	-79.51	-271.24	40.64	-24.73	4.97	1.00

SACS Release 5.3 urs ID=00000000

DATE 08-AUG-2014 TIME 18:26:37 CLP PAGE 5090

****************** JOINT FAILURE SUMMARY REPORT ******************

LOAD SEQUENCE 1

INCR FAILED	JOINT	CHORD JNT	BRACE JNT	PERCENT T&Y	PERCENT X	PERCENT K	*** APPLIED STRESSES *** AXIAL N/MM2	OUT-PLN N/MM2	INPLANE N/MM2	** ALLOWABLE STRESSES ** AXIAL N/MM2	OUT-PLN N/MM2	INPLANE N/MM2	UNITY CHECK
202	0157	0156	0142	0.00	100.00	0.00	36.66	-193.25	-90.72	89.22	224.89	318.73	1.106
204	0157	0156	0085	100.00	0.00	0.00	-57.55	-39.57	166.45	43.28	142.66	15.90	11.804
205	0156	0155	0082	100.00	0.00	0.00	-19.21	1.40	305.15	57.55	164.01	97.76	3.256
206	0158	0157	0088	100.00	0.00	0.00	-32.27	-12.01	99.38	52.03	155.75	66.10	1.944
208	0040	0039	0068	100.00	0.00	0.00	22.65	62.42	301.38	56.67	296.32	56.58	5.521
209	0043	0042	0104	100.00	0.00	0.00	-35.25	35.34	-236.66	69.78	297.88	60.89	4.187
210	0142	0141	0084	100.00	0.00	0.00	-21.77	45.71	301.69	48.31	150.19	44.75	6.988
211	0154	0153	0076	100.00	0.00	0.00	72.01	-0.55	160.28	35.29	142.22	14.19	13.338
212	0108	0107	0168	100.00	0.00	0.00	-41.61	-29.00	310.33	64.70	169.09	65.45	5.213
213	0123	0122	0017	100.00	0.00	0.00	0.49	-26.64	304.83	33.81	139.52	3.86	78.959
214	0153	0152	0073	100.00	0.00	0.00	49.18	-27.00	-168.78	37.76	146.72	31.47	6.668
215	0106	0105	0014	100.00	0.00	0.00	31.35	245.24	210.72	33.77	139.45	3.59	59.691
216	0153	0152	0168	100.00	0.00	0.00	13.82	1.24	314.17	52.69	168.43	62.47	5.113
217	0173	0172	0089	100.00	0.00	0.00	-42.28	-0.69	295.29	43.81	143.45	18.93	16.546
218	0110	0109	0030	100.00	0.00	0.00	0.15	19.87	304.04	33.35	138.68	0.61	495.095
219	0174	0173	0092	100.00	0.00	0.00	-29.16	7.25	305.80	45.64	146.18	29.39	10.866
220	0124	0123	0018	100.00	0.00	0.00	8.63	-46.16	301.00	33.91	139.71	4.57	65.969
221	0166	0165	0068	100.00	0.00	0.00	64.48	-520.00	-465.03	-997.82	35.28	-4648.75	14.745
222	0112	0111	0032	100.00	0.00	0.00	-5.16	94.20	291.01	40.52	138.53	0.04	6797.247
223	0027	0014	0107	100.00	0.00	0.00	-224.99	388.85	-1866.03	76.47	221.35	2.61	719.082
224	0160	0159	0094	100.00	0.00	0.00	0.67	-13.04	313.19	37.00	145.34	26.17	11.970
225	0116	0115	0036	100.00	0.00	0.00	-3.64	-92.03	230.89	41.89	140.58	7.92	29.185