RE-ASSESSMENT OF EXISTING OFFSHORE PLATFORM FOR LIFE EXTENSION

A PROJECT REPORT

SUBMITTED IN PARTIAL FULFILMENT OF THE REQUIREMENTS
FOR THE AWARD OF DEGREE
OF

MASTER OF TECHNOLOGY
IN
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Submitted by

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CANDIDATE'S DECLARATION

I, **Shikha Singh,** Roll no. **2k20/STE/17**, student of **M. Tech. (Structural Engineering)**, hereby declare that the project Dissertation titled "**Re-Assessment of Existing Offshore Platform for Life Extension**" is submitted by me to the Civil Engineering Department, Delhi Technological University, Delhi in partial fulfilment of the requirement for the award of degree of **Master of Technology in Structural Engineering**. The content of this thesis is original and not copied from any source without proper citation. This work has not previously formed the basis for the award of any Degree, Diploma Associates, Fellowship or other similar title or recognition.

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I hereby certify that the Project Dissertation titled "**Re-Assessment of Existing Offshore Platform for Life Extension**" which is submitted by **Shikha Singh**, Roll no. **2k20/STE/17**, Civil Engineering Department, Delhi Technological University, Delhi in partial fulfilment of the requirement for the award of the degree of **Master of Technology in Structural Engineering**, is a record of the project work carried out by her under my supervision. To the best of my knowledge this work has not been submitted in part or full for any Degree or Diploma to this University or elsewhere.

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ABSTRACT

Majority of offshore steel platforms in Mumbai High Field in Arabian Sea as well as around the world are about to reach their design life. To continue to operate the platforms after their design life, existing offshore platforms requires re-certification. Also change in design criteria, addition of new facility and damages of the structure may lead to a need for assessment. Underwater & topside surveys are carried out to collect sufficient information about the present condition of the structures for their engineering assessment. The method normally used for assessment of existing offshore structures is In-place analysis based on Design level & Ultimate level check. In-place analysis of the jacket structure has been carried out using SAC's software to evaluate the structural adequacy of the jacket structure in accordance with code API-RP2A criteria's for life extension.

In-place analysis is based on working stress and considers only linear analysis for the jacket structure. If platform does not pass design level analysis, advance analysis such as ultimate strength analysis needs to be carried out as per criteria of API-RP-2A to study failure mechanism of the structure and determine Reserve Strength Ratio (RSR). In ultimate strength analysis both material & geometrical nonlinearity is considered & incremental loading is applied to study the behaviour of the structure. This paper intends to provide Re-assessment of existing fixed offshore steel platform and results from the investigation are discussed and conclusions are drawn about the applicability of the proposed framework.

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ABBREVATIONS

API-RP-2A	=	American Petroleum Institute Recommended Practice -2A
LQ	=	Living Quarters
SACS	=	Structural Analysis Computer System
RSR	=	Reserve strength ratio
RP	=	Recommended practices
SIM	=	Structural Integrity Management
GoM	=	Gulf of Mexico
ISO	=	International Organization for Standardization
UC	=	Unity Check
CD	=	Chart Datum
LAT	=	Lowest Astronomical Tide
AT	=	Astronomical Tide
Cm	=	Coefficient of Mass
Cd	=	Coefficient of Drag
Tapp.	=	Apparent wave period
CBF	=	Current blockage factor
SWL	=	Still Water Level
S/D	=	Spacing to Diameter Ratio for Conductor

CHAPTER 1

INTRODUCTION

1.1 BACKGROUND

Offshore activities primarily involve the installation of structures in a sea environment for the production of oil and gas. Mainly comprises of extracting oil and gas from the sea and transporting it to land for use after some amount of processing. Fixed offshore steel platforms are commonly used to provide support for oil and gas exploration and production facilities. Majority of offshore steel platforms in Mumbai High Field in Arabian Sea as well as around the world are of fixed type installed at sea having shallow water depths, it comprises of mainly three parts, Jacket -Underwater Structure, Deck -Topside Structure & foundation.

Re-assessment of existing platforms is performed to extend service life of the over lived jacket structures. Also change in design criteria, addition of new facility and damages of the structure may lead to a need for assessment. From a commercial point of view, the use of existing platform in many cases is given preference, compared to installation of new platform. This will be acceptable for many platform structures even with major modifications. The purpose of the assessment of an existing platform is to ensure that the structure has an acceptable level of safety as compared to new designed platform. This paper intends to provide Re- assessment methodology of Jacket structure of the fixed offshore steel platform for life extension which is located in the Mumbai High Field in Arabian Sea.

1.1.1 Indian Western Offshore – Overview

- ONGC operates around ~250 fixed offshore platforms in western offshore.
- Water depth ranges from 55m to 90m.
- Designed based on API code for the design life of 25 years.
- More than 40% of the platforms have exceeded their design life. As a result, Life extension studies are therefore required to ensure their fitness for purpose for the extended life.

1.1.2 Components of Typical Fixed Platform

Components of typical fixed offshore platform are described in following points with the help of schematic of platform shown in Fig. 1.1.

- Tubular space frame structure to support platform topsides.
- Fixed to the seabed by driving piles through main legs or skirt piles around the legs.
- Typically used up to water depths of 120m to 150m.
- Self-weight of the jacket is governed by Water depth, Topside Weight, Environmental conditions.
- Top portion of a fixed platform which sits on the jacket and consists of the decks, accommodation and facilities required for processing oil/gas/ water injection.
- Mudmat is present at bottom-most level and prevents tilting of jacket due to settlement of seabed.
- Conductors are installed inside the jacket with guide frames at different levels, which assist in drilling and provide casing pipes through which oil/gas is taken out.

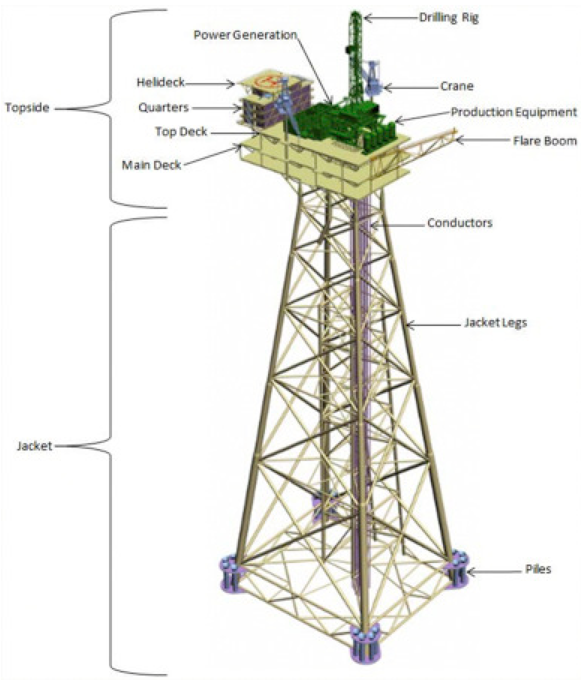


Fig. 1.1: Schematic of a generalized fixed offshore platform
(Ann Scarborough Bull & Milton, 2018)

1.2 FIXED PLATFORM CLASSIFICATION

For the last few decades, the fixed platform concept has been utilized extensively over 300m depth with various configurations as shown in Fig. 1.2.

1.2.1 Functional Classification

The offshore platforms for oil and gas exploration purpose can be classified based on functionality and purpose of installation.

- **Wellhead platform -** primarily meant for drilling and supporting wellhead equipment. It supports very few equipment such as wellhead control panel and piping. Occasionally it also supports helicopter landing structure for emergency evacuation.
- **Process Platform -** primary meant for production facilities (oil or gas) and it may support in addition to equipment for production, such as power generation, utilities and living quarters.
- **Riser Platform -** This is another kind of structure specially built to support all the incoming and outgoing risers on a planned complex. This will also be connected to the main platform by bridge.
- **Living Quarters Platform-** Sometimes due to safety requirements, the living quarters will be supported on a separate structure away from the wellhead and process platforms. This types of platform will be located at least 50m away from the neighbouring process platforms and will be connected by a bridge.
- **Flare Support Platform-** The flare boom structure to flare the excess gas from well reservoirs may be supported on a separate structure either a tripod or four legged jacket for safety reasons. This is to avoid excessive heat on wellhead and process equipment on the neighbouring platforms. Usually this will have located away by a distance to be calculated based on the heat output during flaring.

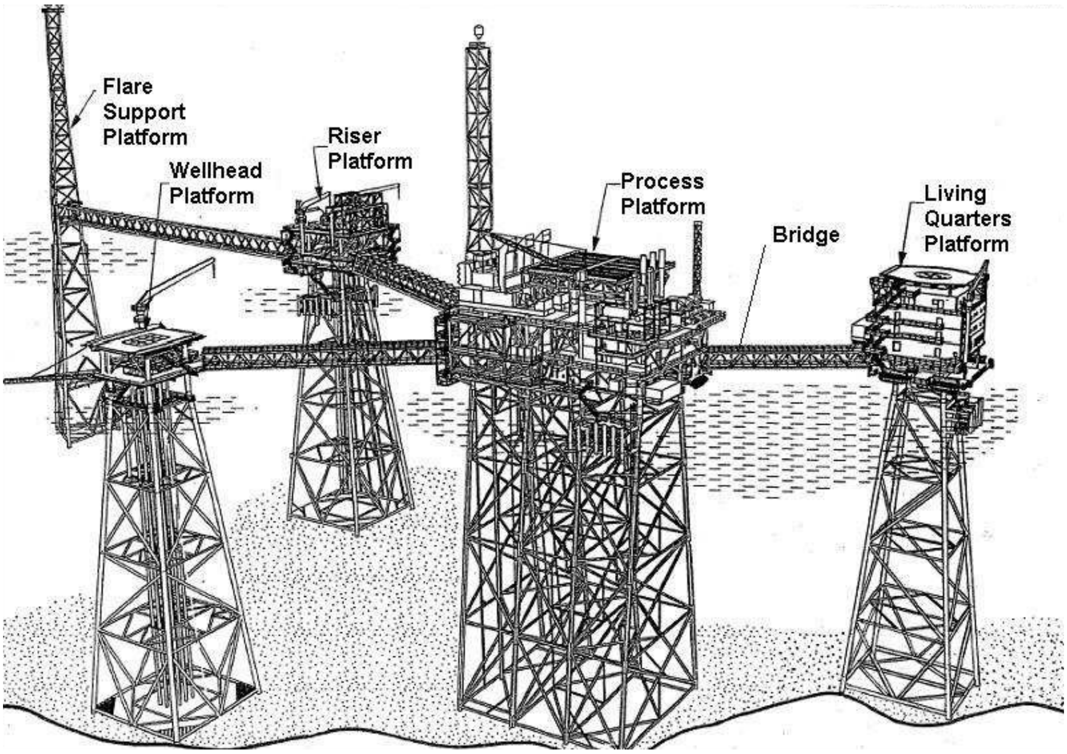


Fig. 1.2: Platform Complex (S. Nallayarasu)

1.2.2 Geometrical Classification

The structural configuration of fixed template type structures varies extensively from location to location depending on the requirement and environmental conditions such as water depth, wave and current loads etc. Based on geometry, jackets can be classified in to following categories.

- **Tripod -** basically to support minimum facility such as few wellhead and riser or to support a bridge between two major platforms or to support a flare boom
- **4 Legged-** typically for wellhead platforms
- **6 or 8 Legged -** mainly for process complex

1.2.3 Foundation Concepts

The offshore platforms shall be fixed to the seabed by means of piles either driven through the main legs of the jacket or through skirt sleeves attached to the jacket legs or the combinations of both main and skirt piles.

1.3 NEED OF THE ASSESSMENT

Platform design life is 25 years and the majority of the platforms around the world have exceeded their design life. API-RP-2A requires an assessment of an existing platform if any of the following indicators exists:

- Changes in design codes resulting in increased environmental loading.
- Damages such as dents / holes / cracks / parting of members.
- Additional facilities like clamp-on wells, riser, deck extension etc.
- Use of structure beyond design life.
- Structure is subjected to increased loading due to modifications in structures.

1.4 OBJECTIVE OF THE STUDY

The objectives of study can be outlined as follows:

1. The method normally used for assessment of existing offshore structures is In-place analysis based on Design level & Ultimate level check. In-place analysis of the jacket structure has been carried out using SACS software to evaluate the structural adequacy of the jacket structure in accordance with code API-RP2A criteria for life extension.

2. To perform inelastic pushover analysis to calculate RSR of fixed platform with respect to metocean data to assess the ultimate capacity of the platform. RSR is defined as the ratio of a platform's ultimate lateral load carrying capacity to its 100-year environmental condition lateral loading.

Based on the above analyses this study intends to provide Re-assessment of existing fixed offshore steel platform and results from the investigation are discussed and conclusions are drawn about the applicability of the proposed framework to give an up-to-date picture of platform strength. Then this picture is used to assess if the existing platform is still "fit-for-purpose", and to decide the suitability of structures for an extended lifetime.

1.5 ORGANIZATION OF THESIS

Chapter 1 gives a brief background of fixed offshore platforms, covering the overview in Indian western offshore and its classification. Also, need of assessment and objectives behind this study have been explained.

Chapter 2 gives the details about the literature review done for this dissertation work and which have been used throughout for investigation work. This also includes the required and detailed study of API RP-2A code. Chapter 3 gives a description of assessment methodology and procedures for assessment of existing structures.

Chapter 4 includes the various types of loads which are going to be encountered by offshore platform. Also, the various types hydrodynamic parameters considered for the wave force calculations for these types of structures are included and discussed.

Chapter 5 deals with brief Introduction & Validation to the software tool that used for the Re-assessment analyses of offshore platform for the dissertation work.

Chapter 6 interacts with the problem statement of the investigation, various input parameters, technical details, modelling and types of analysis done for dissertation work etc. is presented and the results obtained from the analysis are presented in Chapter 7. The conclusions drawn from the study and analysis which is done on the present model are defined in problem are included in Chapter 8. Also, the future scope for studies and work on this particular topic is included in same chapter.

CHAPTER 2

LITERATURE REVIEW

2.1 LITERATURE SURVEY

The necessary literature review and studies were carried out through national and international journals, conferences, books, codes of practice and the data available on the internet and sources.

Shehata E. Abdel Raheem, Elsayed M. Abdel Aal, Aly G. A. Abdel Shafy, Mohamed F. M. Fahmy, Mohamed Omar & Mahmoud H. Mansour (2020) used In-place analysis to verify that the platform structural members have the robustness and capability to support the loads in operating and storm conditions. A finite-element analysis is adopted to estimate the in-place behavior of a typical fixed offshore platform for reassessing design parameters based on measured performances. The SACS software is employed to find the dynamic characteristics and the displacement responses of platform consistent with in-place analysis aligned with the stresses at selected members and joints are examined based on unity checks.

It was found that the directions of environmental loads and water depth variations have significant effects on the results of the in-place behavior. The results confirm that the in-place analysis is quite essential for the reliable design of the offshore platform and assessment of existing offshore structures. It was concluded that main factors which drive and control the different storm conditions are the environmental loads return periods and the water depth variation.

Mohamed Mubarak Abdul Wahab & V. John Kurian & Mohd Shahir Liew & Do Kyun Kim (2020) gives this study, in which technical papers on structural condition assessment of aged fixed-type offshore platforms reported over the past few decades are presented. Other ancillary related works are also discussed. Large numbers of researches are available in the area of requalification for life extension of offshore jacket platforms. Many of these studies involve reassessment of existing platforms by means of conducting pushover analysis, a static nonlinear collapse analysis method to evaluate the structure nonlinear behaviour and capacity beyond the elastic limit.

Many studies are reported on reassessment of existing offshore jacket platforms by considering maintenance and/or decommissioning. They utilised numerous assessment methodologies, either deterministic or probabilistic types. In lieu of the current practice, probabilistic methodologies to conduct component and system reliability reassessments as an alternative to the current industry adopted approach are needed. In addition, the relationship between component and system reliability is preferred. With the developed methodologies, parametric study affecting the component and system reliability has been performed. The sensitivity study on parameters which contributes to the variation of the reliability indices has been conducted.

Ashish Aeran, Sudath C. Siriwardane, Ove Mikkelsen & Ivar Langen (2017) have proposed a framework which provides more precise corrosion models, new damage theories and assessment guidelines to predict the remaining fatigue life and check the structural adequacy in all the limit states during the whole extended service life. Initially, the paper presents the proposed framework in detail. The framework approach is then applied to an ageing jacket as a case study and results are compared with conventional approach.

The proposed approach results in a remaining life of ten years as compared to one year using the conventional approach. Thus, the jacket structure can be safely operated for an additional nine years using the proposed approach. Recommendations are also made on increasing the remaining fatigue life using life improvement techniques. Finally, the applicability, significance and validity of the proposed framework are discussed.

S. Ishwary, M. Arockiasamy and R. Senthil (2016) performed inelastic nonlinear pushover analysis on a 3-D model of a jacket-type offshore platform for the North Sea conditions. The structure is modelled, analysed and designed using finite element software SACS (structural analysis computer system). The behavior of jackets with different bracing systems under pushover analysis is examined. Further, by varying the leg batter values of the platform, weight optimization is carried-out. Soil-structure interaction effect is considered in the analyses and the results are compared with the hypothetical fixed-support end condition.

Static and dynamic pushover analyses are performed by using wave and seismic loads respectively. From the analyses, it is found that the optimum leg batter varies between 15 to 16 and 2% of weight saving is achieved. Moreover, it has been observed that the type of bracing does not play a major role in the seismic design of jacket platform considering the soil-structure interaction.

Yong Bai, Younghoon Kim, Hui-bin Yan, Xiao-feng Song & Hua Jiang (2016) provides Reassessment of a jacket structure subjected to corrosion damages was analysed in this study. Programme SACS was used for modelling and conducting pushover analysis for the jacket structure. There are two types of corrosion damage, 'general corrosion' and 'localised corrosion', and the general corrosion was applied on the structure. Corrosion rates of the jacket structure could be divided into three parts, atmospheric zone, splash zone and full immersion zone. Through the pushover analyses using SACS, the relation between time and RSR was established and it was verified which zone had more corrosion influence to the jacket structure.

In the analyses to define which zone has more influence on the jacket structure, it was proven that the full immersion zone has 3.5 times corrosion effect than the splash zone although the splash zone has larger coefficient than the full immersion zone. The reason of this is that the full immersion zone is including more elements of the structure than the splash zone. Further work is needed to establish more reliable relations between time and corrosion effects on the jacket structure which include local corrosion on the top-side and jacket structure. It may be more complicated because the top-side has more facilities and complex structure.

Mostafa Zeinoddini, Pooya Ranjbar, Hadi Khalili, Alireza Ranaei, Hamid Golpour and Javad Fakheri (2015) reviews the spectral fatigue analysis approach for evaluating the remaining life of an aging fixed offshore steel platform. The paper describes the principals and the outcomes of a numerical wave climate modelling approach for obtaining the scatter diagrams required for a spectral fatigue analysis. The available codes of practice, regarding the fatigue life assessment of existing offshore structures are also highlighted. The reliability of the fatigue life evaluations, possible remedy measures as well as means for fatigue health monitoring of existing steel platforms are discussed.

The methodology used for these assessments incorporates guidelines from different offshore codes. It had been tried to highlight the potential gaps between the regulations for the fatigue assessment of offshore platforms. The residual strength of the fatigue damaged platform has also been evaluated. In general, the current multidisciplinary case study provides a problem-based understanding of the fatigue integrity assessment of existing offshore platforms. It pinpoints some practical issues and implications related to the fatigue integrity assessment of the aging offshore platforms. The results can extend existing knowledge on the structural integrity assessment of offshore platforms.

Alireza Fayazi, Aliakbar Aghakouchak (2015) presents a detailed structural reliability procedure in order to achieve an acceptable safety margin for template type offshore platforms located in the Persian Gulf. Probability of failure in this study is calculated by considering the cumulative effects of all levels of wave loading during the lifetime of the structure and uncertainties associated with soil, material properties, connection strength and environmental conditions in the reliability analysis.

The presented procedure is capable of calculating the probability of failure during the lifetime of platform considering all extreme wave loading patterns. Furthermore, it is possible to take into account the uncertainty of all affecting parameters such as connections, soil capacity, wave in-deck, corrosion, wave period associated to maximum wave height, material yield strength. Besides, wave hazard curve for the Persian Gulf has been used to estimate the probability of failure for a sample four legged platform, which is found to be higher than what can be expected if the Reserve Strength Ratio, RSR, criteria were to be considered.

Mike Efthymiou and Jan Willem van de Graaf (2011) reviews the structural integrity and reliability of fixed steel offshore structures with a focus on in four key areas. The first area is the extreme environmental loading on an offshore platform; the second area is the joint occurrence of waves, winds and currents, i.e. accounting for the fact that these do not, in general, peak at the same time and do not act in the same direction. The third area is the estimation of the ultimate strength of a fixed steel platform & fourth and final area is the integration of the above models to estimate the probability of failure.

These results in a total of four exposure levels and target reliabilities for each have been developed. For each of the above target reliabilities, load factors for the extreme storm loading and corresponding RSR targets have been presented for key geographical areas. For GoM structures a significant improvement in the reliability of L-1 and L-2 structures can be achieved by a modest increase in deck elevation. The modifications to ISO and API RP 2A recommended achieving harmonization in design practices worldwide and convergence between ISO and API.

Gunnar Solland, Gudfinnur Sigurdsson & Anupam Ghosal (2011) discusses the overall assessment process for life extension and outline procedures connected to how to deal with the specific aspects that engineers meet when performing assessment for structural life extension. For various reasons these platforms will require an assessment of their structural integrity. As examples one may experience operational changes of the platform that may lead to increased loads or there may be damages that reduce the structural capacity. Consequently, the design premises may have changed significantly and may result in increased uncertainty about the safety of the structure. In such cases the assessment process is focused towards reassuring that the structure has adequate safety.

Even if the structure needs to carry more loads than originally designed for it is possible to show that the structure is still safe by utilizing refined analysis methods e.g. non-linear finite element methods. Refined methods can also be used when analysing damaged structures in order to avoid expensive repair. By refined methods it is also possible to show that the structure may operate beyond its original design life and by use of results from in-service experience, platforms can be safely operated even longer than theoretical determined life.

H.S. Westlake, F.J. Puskar, P.E. O'Connor and J.R. Bucknell (2006) provides an overview of ultimate strength assessments and their role in understanding the structural system response to extreme loads for defining appropriate risk-based inspection strategies and for demonstrating fitness for-purpose and also reviews future recommended practices (RPs) and regulations, & provides several informative studies to further demonstrate the role of ultimate strength assessments in the SIM of offshore structures.

In-service performance [Bucknell, et al., 2000] suggests that well-maintained platforms are more robust and damage tolerant than a component-based design approach would indicate. As a result of this inherent design ‘reserve-strength’, large numbers of fixed platforms are seeing safe service well beyond their intended design lives. It is apparent that engineers should use ultimate strength assessments as an important decision-making tool in the design of new structures and, more importantly, during the life-cycle SIM for existing offshore structures. Through more realistic simulation and visualization of a platform’s structural behavior, the engineer gets a better understanding of the structure’s integrity and susceptibility to damage. This increased knowledge can be used to determine the criticality of components within the structural system and to assess inspection and repair schemes.

2.2 GAP OF LITERATURE

Previously assessment was performed conservatively which suggests unnecessary need for strengthening or providing additional foundation supports, which is very expensive for offshore platforms. Such excessive costs could compromise the feasibility of oil and gas developments, thereby resulting in losses as a whole.

Therefore an ultimate strength analysis will be performed to reduce conservatism attempting to perform an unbiased estimate of platform capacity and focusing on system rather than component reliability. Such analysis reduces the potential for error in conducting platform assessments and improving efficiency.

CHAPTER 3

PROBLEM STATEMENT

3.1 PROBLEM STATEMENT

3.1.1 Structural Model

The Jacket structure analysed is comprised of a four legged Well platform in Mumbai high field. It is located in a water depth of 76.00m. The entire platform is considered supported and fixed to the sea bed by piled foundation system. Overall view of Offshore Platform in SACS software is shown in Fig. 3.1.

Topside consists of three decks, Main deck at (+23.00 m), Cellar deck at (+18.00 m) and Helideck at elevation (+33.00 m) w.r.t. chart datum. The cellar and the main deck framing is 28 x 17 m in plan. Jacket consists of four legs and five horizontal framings; top dimension (+6.70 m) is 18.25 × 9.50 m and base dimension on seabed (−75.00 m) is 28.50 × 30.00 m.

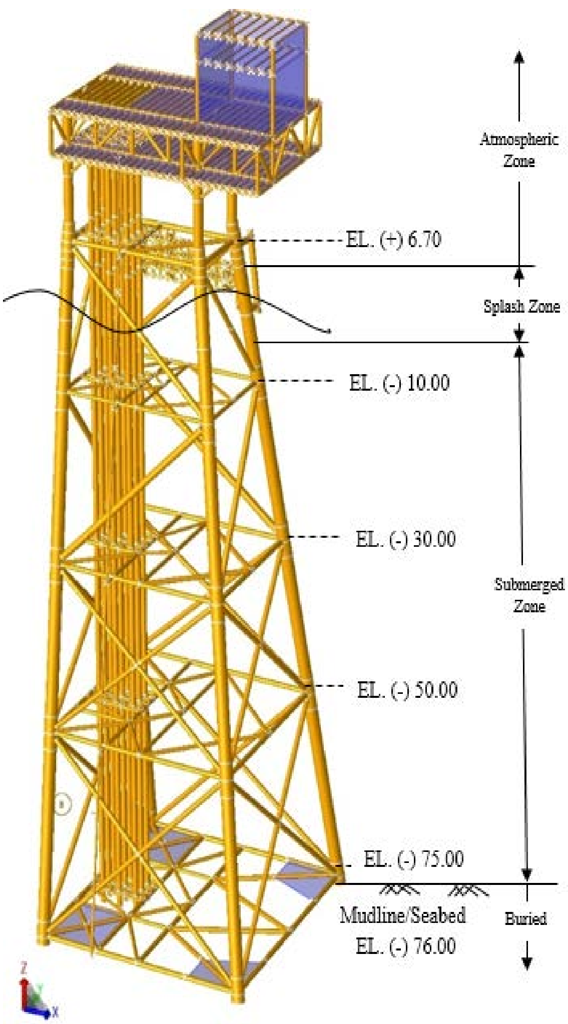


Fig. 3.1: Overall View of Offshore Platform

Steel Material Constants

- Young's Modulus: 200,000 N/mm2
- Shear Modulus: 80,000 N/mm2
- Steel density: 7850 kg/m3
- Minimum Yield Strength: 248 MPa
- Poisson's Ratio: 0.28

3.1.2 Assumptions and Modelling Features

Following are the salient modelling features:

- Conductors are modelled for environmental loads acting on them. The stiffness of conductors is not considered for analysis.
- Jacket appurtenances like Barge Bumper & Boat landings have been modelled as dummy structures to take into account the environmental forces acting on them but their stiffness is neglected in analysis.
- Risers are vertically supported from jacket walkway member and laterally supported at other horizontal levels. Stiffness of the risers is neglected in analysis.
- Drag forces on anodes have been considered in the model by increasing the marine growth thickness.
- Cd and Cm values for rough and smooth members have been given as per API.
- Position of wave for In-place analysis has been fixed on maximum shear for orthogonal direction and on maximum overturning moment for diagonal direction.
- Water depth for operating and storm condition is given as:
- Water depth = 76.00 +LAT + 50% AT + Storm surge
- Pile stub is has given fixity at the mudline level.
- Additional member thickness provided for members in splash zone is exempted for strength and stiffness calculation.
- All jacket appurtenances load has been considered in analysis.
- All jacket legs are considered as flooded and grouted for analysis.
- Conductor shielding factor has been considered for both orthogonal and diagonal directions based on S/D ratio. Effect of increase in diameter due to marine growth has been taken in to consideration in calculation of S/D ratio.
- The effective lengths coefficient considered for jacket members are as follows:

Table 3.1 Effective length coefficient

Member	Coefficient
Jacket Legs	1.0
Jacket Braces	0.8
X braces (Longer segment Length)	0.9

3.1.3 Global Axis System

The right hand rule coordinate system is used as follows:

- X axis in platform N-S direction, with X coordinates +ve towards platform SE.
- Y axis in platform W-E direction, with Y coordinates +ve towards platform NE.
- Z axis in vertical direction, with Z co-ordinates +ve upwards

3.1.4 Load Contingency factor

Following load contingency factors are considered for the analysis.

Contingency factor for substructure = 5 %

Contingency factor for superstructure = 10 %

Weld metal and mill tolerance factor = 3 %

Contingency factor considered for the analysis are as follows,

Super structure (Deck) = 10 + 3 = 13 %

Sub structure (Jacket) = 5 + 3 = 8 %

The above contingency has been taken care by increasing the density of modelled members from 7.85 t/m3 to 8.87 t/m3 for super structure and 8.478 t/m3 for sub-structure.

3.2 ANALYSIS BASIS

Structural analysis is performed by using the commonly used Structural Analysis Computer System (SACS) software. The SACS software presents the structural response in terms of member's stress utilization ratio and joint utilization ratios. The structure is defined as code compliant if all members have stress utilization ratio of less than 1.0. Following analysis has been performed to establish "Fit for Purpose" of the Over lived jackets.

3.2.1 Jacket In-Place Analysis

The platform has been analysed to resist environment loads and gravity loads in accordance with following environmental conditions:

- Extreme storm condition with 85 % environmental loading.
- Extreme storm condition with 100% environmental loading.

The In-place analysis has been carried out for a minimum of eight storm approach angles each for the extreme storm load combination. Still water depth has been taken as (CD) + (LAT) + (50% of Astronomical Tide) + (Storm Surge) for Storm Environment.

3.2.1.1 Design Level Analysis

Design level analysis has been carried out in accordance with section 17.7.2 of API-RP-2A-WSD-2007. Structure has been evaluated based on its current condition, accounting for any damage, repair, or other factors affecting its performance or integrity.

In-place static analysis has been carried out as per section 3, 4, 5, 6 &7 and 17 of API-RP-2A (WSD)-2007. Linear static global analysis has been carried out for 100-year extreme storm condition for 8 directions of wave, current and wind with other design loads. The adequacy check has been carried out for jacket only. Reduced "Assessment Criteria for Metocean loading" as per figure 17.5.2 of API-RP-2A-WSD-2007 has been used for the design level analysis. Accordingly, 85% of environmental loading caused by 100-year environmental condition has been used.

3.2.1.2 Ultimate Level Analysis

Ultimate Strength Analysis has been carried out as per section 17.7.3 of API-RP-2A-WSD-2007. Elastic In-place analysis has been carried out by simulating ultimate strength for 100% environmental loading, allowable stresses may be increased by 70 percent. These provisions permit minor yielding but no significant damage to occur.

3.2.2 Pushover Analysis

Jacket is subjected to lateral loads mainly due to waves & current. In order to determine the reserve strength ratio (RSR) of jacket structure, lateral loads are applied in incremental steps considering both material & geometric nonlinearity. First plastic hinge is formed at the worst loaded joint. As the load increases collapse mechanism is formed due to formation of multiple plastic hinges at joints/members. Ratio of maximum lateral load prior to collapse to design lateral loads gives the reserve strength ratio (RSR) of the structure.

A Reserve Strength Ratio (RSR) of 1.6 is permissible for high exposure category whereas a RSR of 0.8 is permissible for low exposure category as per clause no. 17.5.2 of API RP2A. However, all the platforms under requalification study will be considered as high exposure category. Evaluation of load factor at which first plasticity occurs in the Member/Joint, if it is more than 1.0, this indicate structure can withstand design load (Extreme Storm) without going in plastic zone.

3.3 LOAD CALCULATION

3.3.1 Dead Load

3.3.1.1 Structural Dead Loads

There are two types of structural dead loads:

i) Generated by SACS

ii) Non-generated loads

Following Non-generated dead loads have been considered for the analysis:

- Dead load from Jacket

Table 3.2: Jacket Un-Modelled Load

Sl. no	Description	Load -Joint (KN) / Member(kN/m)/ Pressure (kN/m^2)	Total load Applied in SACS (kN)
1	Anode	40.00	600.00
2	Corrosion allowance for brace	2.40	98.11
	Corrosion allowance leg	5.20	164.12
3	Grating Load	0.50	41.08
4	Handrail	0.45	49.20
5	Collapse Ring	1.50	30.00
6	Flooding and grouting lines	4.20	63.00
7	Rubstrip for Boat landing	0.40	28.68
8	Grout packer	36.0	144.00
9	Conductor Guide	2.00	90.00
10	Crown Shim plate	10.0	40.00
11	Boat landing stabbing guide	10.0	20.00
12	Riser clamp	10.0	40.00
13	Pile spacer	5.00	60.00
14	Mudmat	35.0	560.00
15	Riser load	-	118.00

- Dead load from Topside

Table 3.3: Deck Un-Modelled Load

Sl. no	Description	Load -Joint (KN) / Member(kN/m)/ Pressure (kN/m^2)	Total load Applied in SACS (kN)
1	Grating	0.50	36.00
2	Handrail	0.45	115.20
3	Stabbing guide	10.00	40.00
4	X-mas tree platform	5.00	20.00
5	Barrier wall	3.00	75.00
6	Lift eye	20.00	80.00
7	Conductor Guide	2.00	18.00

- Dead load from Jacket Appurtenants:

  Boat landing/Barge Bumper: The boat landing integrated with barge bumper is modelled in SACS to account for self-weight as well as wave forces calculation.

3.3.2 Live Load

- Uniformly distributed area live loads for plated area and all loading & unloading area of platform are considered as 1500 kg/m2.
- Grated area live load is considered as 500 kg/m2.

3.3.3 Design Environmental Loads

The environmental loadings were applied to approach angles from 0˚ to 315˚ at 45˚ intervals as shown in Figure 2. Still water depth has been taken as (CD) + (LAT) + (50% of Astronomical Tide) + (Storm Surge) for Storm Environment. Metocean data used for the In-Place & Pushover analysis of jacket structure are as shown in Table 3.4 & Table 3.5.

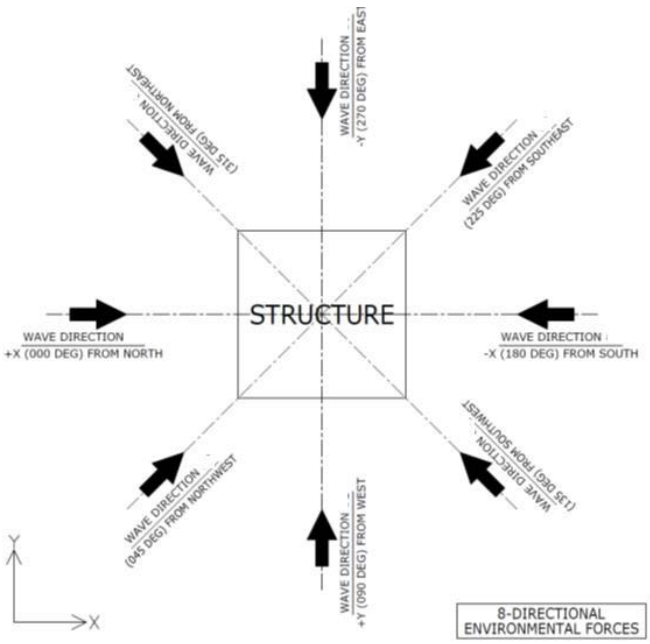


Fig. 3.2: SACS Direction Considered for Loading

Table 3.4: Extreme Storm Wave data

Wave Data								
Approach Direction	**0**	**45**	**90**	**135**	**180**	**225**	**270**	**315**
100 Year Wave Max. Ht. (m)	15.09	16.77	17.07	17.68	18.00	14.48	13.26	16.00
100 Year Wave Period (Sec)	13.00	13.70	13.90	14.20	14.40	12.50	11.80	13.80
Still Water Depth (m)	78.26	78.44	78.56	78.81	78.81	78.26	78.26	78.26

Table 3.5: Extreme Storm Current profile.

Elevation	Current Speed (m/s)							
	Approach Direction							
	0	**45**	**90**	**135**	**180**	**225**	**270**	**315**
Bottom	0.51	0.31	0.213	0.27	0.37	0.31	0.25	0.25
Y-1/4	0.97	0.69	0.609	0.66	0.81	0.72	0.65	0.65
Y-1/2	1.19	0.86	0.75	0.82	1.02	1.20	0.83	0.82
Y-3/4	1.40	1.02	0.90	0.99	1.21	1.08	0.95	0.98
Surface	1.64	1.23	1.09	1.18	1.45	1.27	1.16	1.22

3.3.4 Wind Loads

For Jacket analysis one-hour wind speed is used as wind loading is input in SACS as wind load areas. The entire area between cellar and main deck level is divided into different wind areas. The wind speeds used have been tabulated in Table 3.6.

Table 3.6: Extreme Storm Wind Speed Data

Sr. No.	Storm Condition	Direction from North	Design Wind Speed (m/sec)
1	Extreme	0	51.90
2	Extreme	45	49.70
3	Extreme	90	48.90
4	Extreme	135	50.60
5	Extreme	180	53.30
6	Extreme	225	53.30
7	Extreme	270	53.30
8	Extreme	315	53.30

3.3.5 Hydrodynamic coefficients

- Drag Coefficient (Cd) and Mass coefficient (Cm) values taken are as follows
- Smooth members, Cd = 0.65, Cm = 1.60, Rough members, Cd = 1.05, Cm = 1.20
- Lowest Astronomical Tide (LAT) = -0.183 meters
- Wave Kinematics Factor = 0.88
- Current Blockage Factors for four legged platforms in different current heading directions are as follows, End-on = 0.8, Diagonal = 0.85, Broad side = 0.8
- Marine Growth Profile & Zones:

Table 3.7: Marine Growth Profile

Item	From Elevation (m)	To Elevation (m)	Marine Growth Thk. on radius (mm)
Marine Growth Profile	(+) 3.0	(-) 30.0	100.0
	(-) 30.0	Mudline	50.0
Submerge Zone	(-) 1.8	Mudline	-
Splash Zone	(-) 1.8	(+) 6.0	-
Atmosphere Zone	(+) 6.0	Upwards	-

3.4 BASIC LOAD CASES AND LOAD COMBINATIONS

3.4.1 Basic Load cases

Table 3.8: Basic Load Cases

Load Case No.	Load case Description
1	Dead Load (Modelled)
2	Dead Load – Jacket (Un-modelled)
3	Dead Load – Deck (Un-modelled)
4	Blanket Live load – Deck
5	Building Module Dead Load
6	Building Module Live Load
7	Crane load
31 to 38	Wave, Current & Wind Extreme storm 0°,45°,90°,135°,180°,225°,270°,315°

3.4.2 Load Combinations

Table 3.9: Load Combination

Load Combination	**Load Case**	**Load Factor**	**Load Case**	**Load Factor**	**Load Case**	**Load Factor**
100	1	1.00	2	1.08	3	1.13
-	4	0.60	5	1.00	6	0.60
-	7	1.00	-	-	-	-
-	-	-	**Design Level**		**Ultimate Level**	
101	100	1.00	31	0.85	31	1.00
102	100	1.00	32	0.85	32	1.00
103	100	1.00	33	0.85	33	1.00
104	100	1.00	34	0.85	34	1.00
105	100	1.00	35	0.85	35	1.00
106	100	1.00	36	0.85	36	1.00
107	100	1.00	37	0.85	37	1.00
108	100	1.00	38	0.85	38	1.00

CHAPTER 4

ASSESSMENT METHODOLOGY

4.1 PLATFORM ASSESSMENT METHODOLOGY

Process flow of Platform Assessment Methodology based on API RP - 2A, Platform has to pass following:

- Platform selection: Functional basis or exposure category.
- Categorization: Based on platform configuration.
- Condition assessment: Survey based.
- Mitigation - Repairs / Reduction of loads.
- Design & Analysis checks.

4.1.1 Platform selection: Functional basis

API requires an assessment of an existing platform if any of the following indicators exists:

- Addition of facility.
- Increase loading.
- Inadequate deck height.

4.1.2 Categorization: Based on platform configuration

If a platform is selected for an assessment, it should have categorized with respect to human life safety (manned, non-evacuated, manned – evaluated and un-manned) and consequence of failure i.e. high or low.

4.1.3 Condition assessment: Survey based

The following parameters to be considered:

- Damage, accident with subsequent repairs.
- Corrosion, anodes maintenance.
- Records of marine growth thickness & cleaning operations, scour & debris observations.

4.1.4 Mitigation – Repairs / Reduction of loads

Options available for Mitigation measures:

- Load reduction by removal of redundant structures.
- Marine growth removal - Controlling marine growth thickness by reducing cleaning frequency.
- Increase / Restore capacity by repair damages by Underwater welding or member & joint strengthening by Grouted Clamp / mechanical clamp

4.1.5 Design and Analysis checks:

The two different analysis of the platform should be carried out to give an extended up to-date picture of platform strength & to confirm the suitability of structures for a lifetime.

4.1.5.1 In-place Analysis

In-place analysis was performed based on the 3-dimensional finite element model of the integrated platform including the topsides, substructure and piles. Both operating as well as extreme storm loading conditions were considered. Design level analysis considering linear static methodology is very conservative and do not utilize the reserved strength of jacket structure. Design level in-place analysis to assess the integrity of structure for present condition. The strength is expressed the maximum of all unity checks (UC's in case of components check). Members and joints are checked for yield / stability and punching shear.

4.1.5.2 Pushover Analysis

A pushover analysis is carried out using the SACS 'COLLAPSE' module. This program uses a large deflection, iterative, tangent direct stiffness solution technique to solve for the geometric and material non-linearity's associated with the ultimate load capacity of a structure. A progressive collapse analysis is performed to establish the residual strength Reserve Strength Ratio, RSR is the load factor applied to the design environmental load prior to collapse or prior to obtaining maximum displacement.

Overall Reserve Strength Ratio is the lowest RSR for all directions considered. RSR is a measure of platform strength when compared to design strength. The strength is measured in terms of the total load that can be resisted as shown in Fig. 4.1.

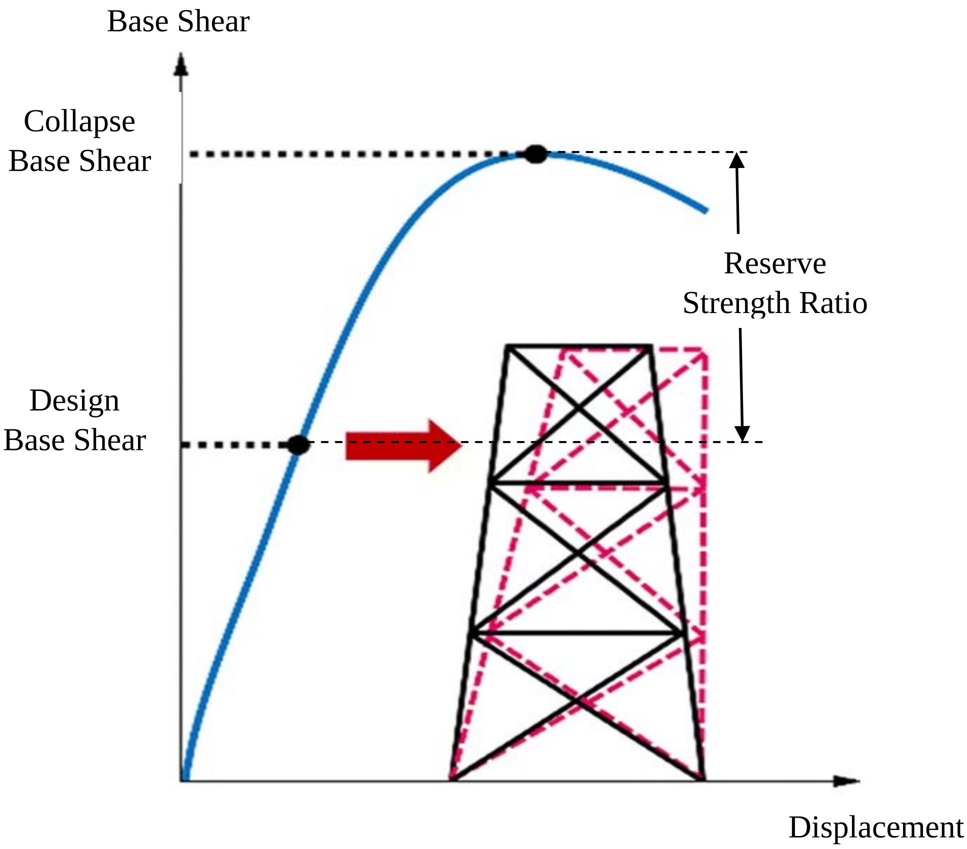


Fig. 4.1: Base shear from pushover analysis

(Abdul Wahab & John Kurian, 2020)

Gravity loadings are applied first to the model. The storm load case has been applied by factoring the environmental loading until the structure turns into a mechanism or any of defined failure criteria occurs. The environmental loading is applied to the structure in increments. The nodal deflection and member forces are calculated for every load step and the stiffness matrix is reformed at every step. When the stress in the member reaches the yield stress, plasticity occurs in the member. The presence of plasticity reduces the stiffness of the structure and additional loads due to subsequent load increments will be re-distributed to members adjacent to the members that have plasticity. This is continued until the whole structure is collapsed or pushed over.

4.2 ANALYSIS PROCEDURE

Assessment of existing fixed offshore steel platform is carried out in SACS software as per criteria of API-RP-2A [1] in three stages. The SACS software presents the structural response in terms of member's stress utilization ratio and joint utilization ratios. The structure is defined as code compliant if all members have stress utilization ratio of less than 1.0.

First stage involves In-Place analysis which is carried out to simulate the behaviour of the structure as close as possible to give the response of the structure during its service and it is performed with 85% of environmental load at design level and overstressed Joints/Members are identified from the analysis.

Further in second stage, these overstressed members & joints are to be checked in In-place analysis with 100% of environmental load at ultimate level. In the final stage overstressed joints and members identified in ultimate level check are further assessed by performing Non-linear analysis in SACS, where incremental environmental loading is applied on the structure till it collapses and reserve strength of the structure is achieved. If RSR of the structure is less than the desired criteria of API RP 2A, then strengthening of overstressed members & joints identified during ultimate analysis is provided to achieve the desire Reserve strength ratio (RSR)

CHAPTER 5

LOADS & HYDRODYNAMIC PARAMETERS

5.1 TYPE OF LOADS

Fixed offshore platforms are normally designed for service life of 25 years. Throughout service life, the platforms are exposed to many types of loading such as gravity loads, hydrostatic loads, environmental loads (winds, currents and waves loads), accidental loads (boat impact, dropped object, fire and explosion) and earthquake loads. Environmental loads play a major role governing the design of offshore structures. Before starting the design of any structure, prediction of environmental loads accurately is important.

5.1.1 Gravity Loads

Dead and live loads are due to gravity. Dead loads that are imposed on the platforms continuously are the weights of structural steel jacket and topside structures, production equipment and hydrostatic loads. Live loads are those loads that exist temporarily on the platforms, such as weight of consumables during maintenance works, helicopter weight, mooring loads and loads due to activities on the platforms.

5.1.1.1 Structure Dead Loads

It includes all the primary structural steel members as well as secondary structural items such as boat landing, handrail etc. Weight of the secondary structural steel item is calculated and applied to structural model at appropriate location. Program SACS using element areas and densities computes the dead weight of all jacket and topside structural elements. The weight of non-modelled components, such as leg diaphragms, pile sleeve guides and appurtenance steel will be input as additional member or joint loads, at appropriate points of application on the structure.

5.1.1.2 Facility Dead Loads:

The structure is built either as wellhead type platform or process type platform which supports various equipment and facilities like

- Mechanical Equipment.
- Electrical Equipment.
- Pipe connecting each equipment.
- Electrical cable trays.
- Instrumentation items.

5.1.1.3 Fluid Loads

The fluid loads are weight of fluid in the equipment and piping on the platform during operation. The weight of the fluid load shall be calculated accurately and applied at equipment and piping support locations.

5.1.1.4 Drilling Loads

Drilling Loads include reaction from Jack-up cantilever type rig or Deck mounted rigs.

- Dead loads.
- Movable Drill floor loads.
- Drill string weight.

Depending on the type of drilling rig used, this loads will vary. For shallow water depths, Jack-up type rig may be used.

5.1.1.5 Live Load

Live loads are defined as movable loads and will be temporary in nature. Live loads will only be applied on areas designated for the purpose of storage either temporary or long term. Further, the areas designed for lay down during boat transfer of materials from boat shall also be considered as live loads. Other live load includes open areas such as walkways, access platforms, galley areas in the living quarters, helicopter loads in the helipad, etc. These loads shall be applied in accordance with the requirement from the operator of the platform.

5.1.2 Environmental Loads

Environmental loads are due to wind, current and wave acting on the platforms. Current and wave loads contribute to 90% of the total environmental load and 10% is due to the wind.

5.1.2.1 Wave and Current Loading

- Unlike the onshore structures, where wind plays the predominant role, wave loading is the governing load in case of offshore structures.
- 1 year return period shall be considered for operating storm cases.
- 100 year return period shall be considered for extreme storm cases.
- Still water depth shall be taken as (CD) + (LAT) + (50% of Astronomical Tide) + (Storm Surge) for storm environment.

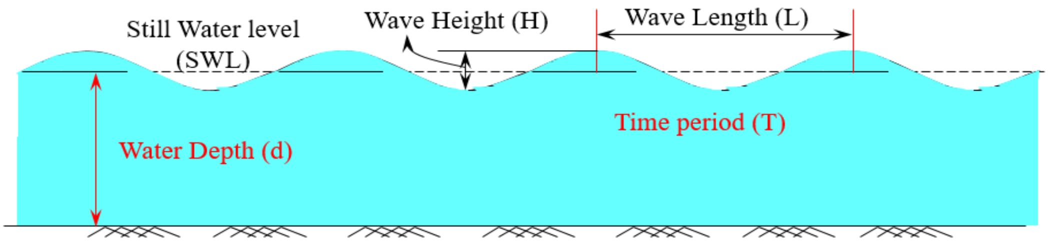


Fig. 5.1: Wave Parameters

Drag and inertia forces on individual members will be calculated using Morison's Equation. Shielding or interaction effects within the structure will be considered. Current and wave directions will always be assumed parallel and of the same sense; resultant particle velocities being the vector sum of these components.

Elements with attachments will have wave loading calculated based on the nominal member section with modified Cm and Cd values. Drag and inertia coefficients for non-tubular and/or complex geometry will be calculated using an equivalent diameter. The equivalent diameter will be based on the circumscribing circle. In the calculation of all effective drag and inertia coefficients, the increase in diameter due to marine growth of both the true structural members and the equivalent wave force members will be taken into account where appropriate.

5.1.2.2 Wind loads

The wind forces shall be calculated taking into consideration shielding, shape coefficients and variation of wind velocity with height as specified in API-RP 2A. Wind shall be assumed to act simultaneously and collinearly with wave and current forces. For Jacket In-place Analysis wind speeds shall be considered is of 1 Hr Average.

5.1.3 Seismic Loading

Seismic design is more critical for Process Platforms. In a well platform, the topside loads are very small. The base shear we get from storm waves is very large compared to the shear we get from seismic conditions. For Indian conditions, we do not check well platforms for seismic conditions. Since process platforms have a large topside mass, the seismic shear at deck level could be greater than wind / wave shear. It is therefore necessary to check platforms with large topside loads for seismic conditions.

API RP-2A recommends use of Response Spectrum Method. Standardised Non dimensional response spectrum is available which when multiplied with PGA (peak ground acceleration) gives Response Spectrum for a location. Plot of Sa/g with log T is available for various soil/sea bed conditions such as rock etc. 70% increase in permissible stresses is allowed. Structure is also to be designed for rare intense earthquake by using a factor of 2.0. Structure should not become a mechanism under this load. Earthquake loading is considered 100% in X & Y directions and 50% in vertical directions.

5.2 MAXIMUM GLOBAL LOADS

Maximum global loads on a platform can be calculated using two principles.

- Maximum Base Shear Method
- Maximum Overturning Moment Method

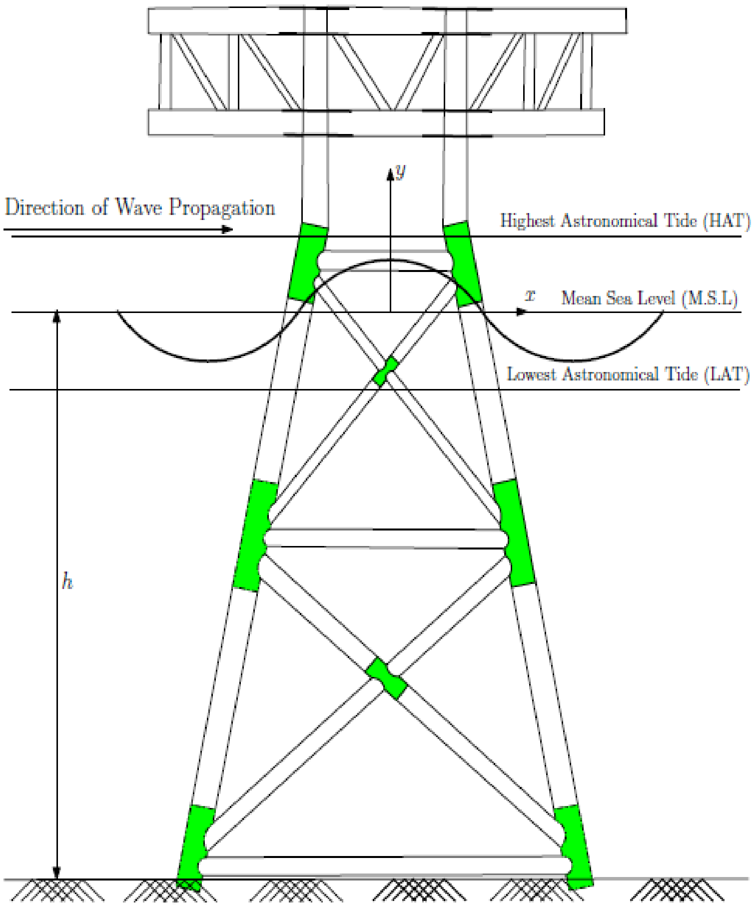


Fig. 5.2: Wave Loads on Jacket Structure (S. Nallayarasu)

It is important that the wave loads on the structure be checked for both conditions. The maximum overturning moment method will give more pile loads than the other. Similarly, the maximum base shear method may govern the design of some jacket leg members near seabed due to high shear.

5.2.1 Maximum Base Shear

Maximum base shear or maximum total force on a structure has to be determined for the global analysis of structures. As the wave propagates across structure wave force on each member is different and all the locations will not be attaining the maximum forces. To find the maximum total force a structure, following steps need to be considered.

- Position the wave crest at the origin of the structure as shown in Fig.5.2
- Divide one wave cycle into number of segments either in terms of μ or in terms of length.
- Compute the wave forces on all members at that instant of time using water wave velocities and accelerations computed.
- Sum up the forces in horizontal direction for all the members.
- Repeat the calculation in step 4 for all the points for one wave cycle.
- The maximum of all the total forces computed in step 5 is the maximum base shear or total force.

5.2.2 Maximum Overturning moment

Maximum overturning moment on a structure can be determined following the procedure for the maximum base shear case. In this case, the loads on the members shall be multiplied by the lever arm from mud-line. This shall be summed up and the procedure shall be repeated for all the steps in the wave.

5.3 WAVE FORCES CALCULATION BY API-RP-2A

The wave loads on a platform are dynamic in nature. For most design water depths presently encountered, these loads may be adequately represented by their static equivalents. For deeper waters or where platforms tend to be more flexible, the static analysis may not adequately describe the true dynamic loads induced in the platform. Correct analysis of such platforms requires a load analysis accounting for the dynamic response of the structure. The procedure, for a given wave direction, begins with the specification of the design wave height and associated wave period, storm water depth, and current profile. The wave force calculation procedure follows these steps.

An apparent wave period is determined, accounting for the Doppler effect of the current on the wave.

a) The two-dimensional wave kinematics are determined from an appropriate wave theory for the specified wave height, storm water depth, and apparent period.

b) The horizontal components of wave-induced particle velocities and accelerations are reduced by the wave kinematics factor, which accounts primarily for wave directional spreading.

c) The effective local current profile is determined by multiplying the specified current profile by the current blockage factor.

d) The effective local current profile is combined vectorially with the wave kinematics to determine locally incident fluid velocities and accelerations for use in Morison's equation.

e) Member dimensions are increased to account for marine growth.

f) Drag and inertia force coefficients are determined as functions of wave and current parameters, member shape, roughness (marine growth), size, and orientation.

g) Wave force coefficients for the conductor array are reduced by the conductor shielding factor.

h) Hydrodynamic models for risers and appurtenances are developed.

i) Local wave/current forces are calculated for all platform members, conductors, risers, and appurtenances using Morison's equation.

j) The global force is computed as the vector sum of all the local forces.

The sequence of steps in the calculation of deterministic static design wave forces on a fixed platform is shown graphically in Figure 5.3.

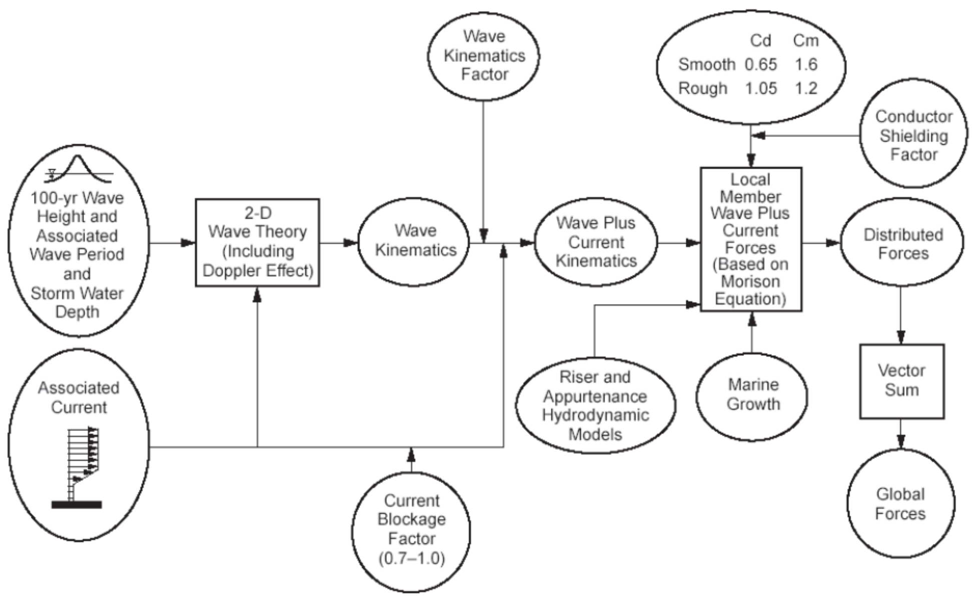


Fig. 5.3 Calculation Wave Plus Current Loads (Extract from API RP-2A)

5.4 IMPORTANT ASPECTS ASSOCIATED WITH WAVE FORCES CALCULATION

5.4.1 Apparent wave period

Due to superposition of current field on the wave, the time period of wave is changed. This has to be calculated by substituting value of wavelength as (L+VT), where VT is increase in wavelength due to current field. The revised time period is back calculated by using this wavelength is termed as Apparent Time Period.

T-app > T-orig. (if the current is in the same direction of wave)

If the current travels in the same direction as the wave, then the wave period becomes longer and it is called apparent wave period (Tapp). Recommendation of API RP2A shall be used to estimate the apparent wave period. The wave current interaction is an important phenomenon since the waves propagate on the current. Both current modifies the wave and wave modifies the current exist. But the former takes most priority in the calculations of wave loads. This interaction modifies the wave parameters and modifies the wave field. Depending on the direction of current in respect of wave direction, it either stretches the wave longer or shortens it.

5.4.2 Selection of wave theory

The computation of wave kinematics such as velocity and acceleration involves the equations from wave theory. There are various kinds of solutions available depending on the accuracy required, and parameters involved in the computation. The various wave theories are listed below.

- Linear / Airy Wave Theory
- Stokes Wave Theory
- Stream Function Wave Theory
- Cnoidal Wave Theory

Depending on the location such as deep water or shallow water and associated wave parameters, a suitable wave theory shall be selected for use. API RP 2A recommends to use a chart for such selection based on d/gT2 and H/gT2 as the X and Y axis. Refer to Fig. 5.4

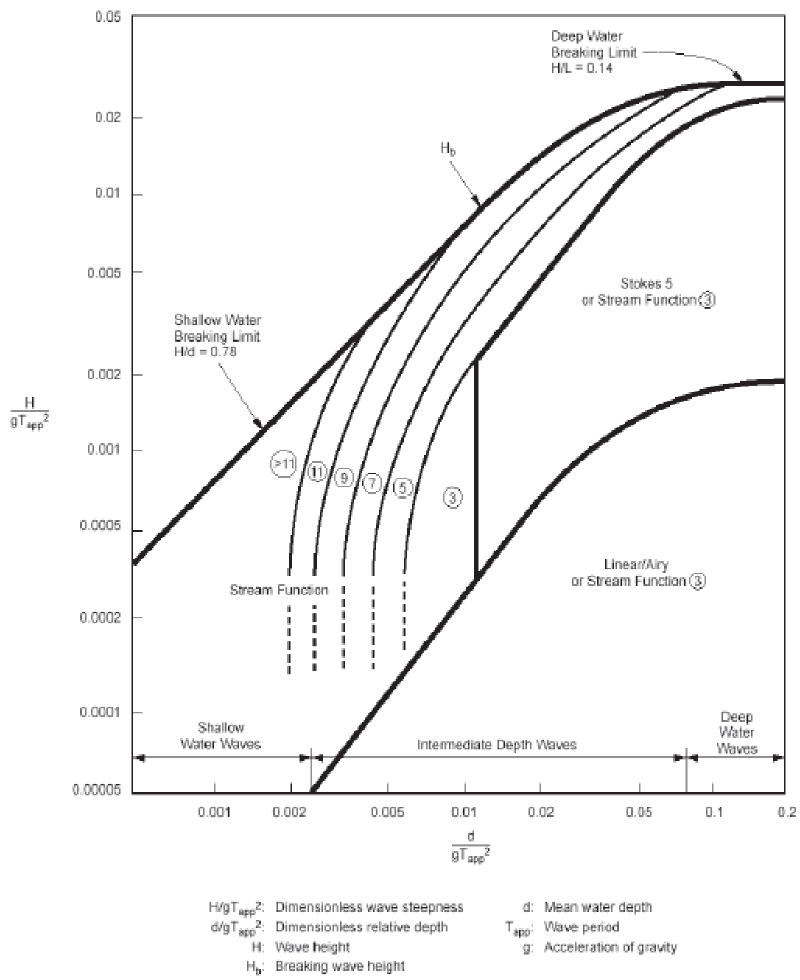


Fig. 5.4: Selection of wave theory for load calculation (Extract from API RP 2A)

5.4.3 Wave kinematics factor

Waves approach a particular member/ platform from different directions and a spreading effect takes place. This reduces the velocity, which is computed using a unidirectional approach wave. Since the calculated wave loading is based on 2-dimensional wave theory while the actual loading is 3-dimensional. A factor known as wave kinematics factor is used to reduce the value of velocity to be used for wave forces calculation. Typical value for Tropical cyclones is 0.88.

5.4.4 Current blockage factor (CBF)

Since the platform is an obstruction to the current field existing in sea it modifies the current field. It is found that velocity at the structure location is less than V at a location upstream of structure where flow is undisturbed. This reduction is calculated by multiplying velocity by CBF. A minimum CBF of 0.7 has to be used. CBF also depends on direction of wave and is higher for direction where projected area or blockage area is higher. Along depth of the structure CBF varies since at near surface boat landing etc., offer more obstruction to flow.

5.4.5 Marine growth

Marine growth is an important part in increasing the loads on offshore structures. Depending on availability of Oxygen and sun light marine growth takes place. The growth of marine algae increases the diameter and roughness of members which in turn cause the wave or current loading to increase. The thickness of marine growth generally decreases with depth from the mean sea level and it is maximum in the splash zone. The thickness of marine growth in the splash zone can be as much as 10cm and will reduce below to 5cm. In deeper zones, the thickness may be negligible.

Splash Zone is a region where the water levels fluctuate between low to high. The actual elevation of the bottom and top of these vary from location to location due to different tidal conditions. In general terms, the splash zone will vary from -1.8m to +6m. In structural analysis, the increased diameter of the member (D = d + tm) shall be included so that the wave and current loads can be calculated correctly. D and d are the diameter of increased member and original member respectively and tm is the thickness of marine growth.

There are some methods by which marine growth can be prevented from growing. These are covering with a Neoprene sheathing having Cu/Ni pellets embedded (Pellets have 90% Cu, 10% Ni, it is an alloy) or installing Ocean powered marine growth preventer as shown in Fig. 5.5. The later system has been successfully used in India.

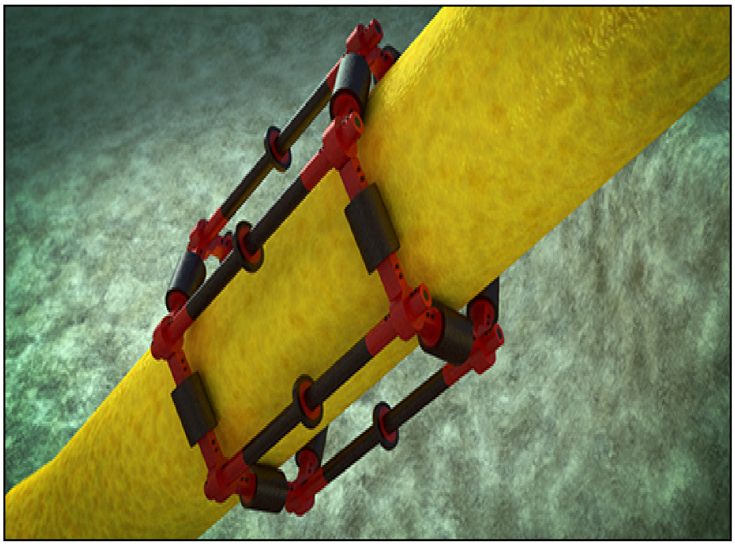


Fig. 5.5: Marine Growth Preventer (FoundOcean.)

5.4.6 Corrosion Allowance

- In addition to cathodic protection to the jacket member's corrosion allowance is also provided for structural members within splash zone.
- Except for removable and replaceable items such as hand railing, flooring, ladders, riser clamps, etc.
- This allowance shall be removed from the analysis as it is not available for strength. However, weight of such allowance is taken as additional weight.

5.4.7 Cathodic Protection

There many ways of protecting the structures against corrosion such as selecting a base material such that they have corrosion resistant property inherently, providing protective coating or other means to stop the environment from attacking the steel surface and Cathodic Protection by means of sacrificial anodes. This method is very suitable for offshore fixed type platforms.

This method does not require any maintenance and no external resources for operation. It is to be noted that the cathodic protection by means of sacrificial anodes does not work in the splash zone due to intermittent exposure. Hence the anodes need not be provided in the splash zone. A typical fixed offshore platform as shown in Fig. 5.6 is provided with many number of anodes distributed from mudline to LAT.

The amount of sacrificial anodes required to protect the structure depends on the following parameters and shall be carefully studied.

- Seawater Resistivity, Salinity, temperature and flow velocity
- Total Surface area to be protected
- Type of Anode Material and its composition, size and shape.

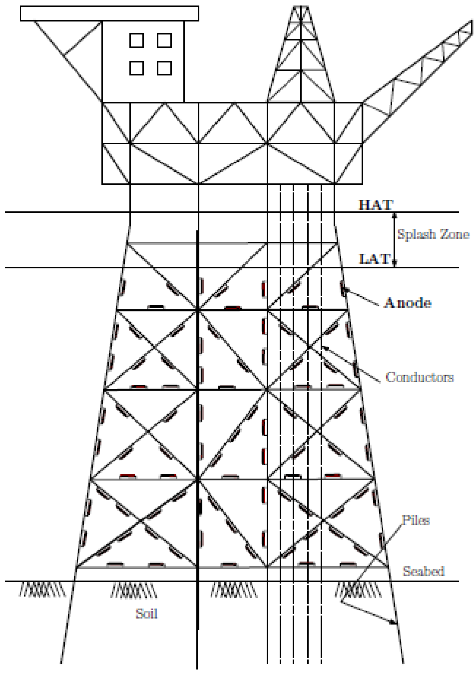


Fig. 5.6: Offshore platform protected with sacrificial anodes (S. Nallayarasu)

5.4.8 C_d & C_m Values

C_d, C_m depends upon the flow field & Structure size and related by Keulegan-Carpenter Number K. Basic C_d, C_m values for tubular members are as follows,

Table 5.1: C_d and C_m Values

Tubular Type	C_d	C_m
Smooth	0.65	1.60
Rough	1.05	1.20

5.4.9 Conductor shielding factor

This takes shielding effect of conductors on each other. Presence of rows of conductors provides shielding effect to the conductors behind. It depends on spacing & number of conductors.

5.4.10 Modelling of Appurtenances

These are appendages to jacket and are non-structural members.

- Risers for submarine pipe line,
- Boat landing / Barge Bumpers,
- Anodes for cathodic protection.

Since these do not provide stiffness to structure but increase the loads, these are modelled as non-load carrying members in analysis. Effect of anodes is catered to by suitably increasing the C_D value, or increasing the effective diameter by adding to marine growth.

5.4.11 Morison Equation

Wave and current loading can be calculated by Morison equation. Morison equation can be written as:

$$F_T = \frac{1}{2}\, C_D\, \rho_w\, D\, V\, |V| \;+\; \frac{\pi D^2}{4}\, C_M \rho_w\, a$$

where F_T is the total force, ρ_W is the density of water, C_D and C_M are the drag and inertia coefficients respectively, D is the diameter of the member including marine growth, V is the velocity and a is the acceleration.

The first term in the equation is drag component (F_D)and the second term is the inertia component (F_I). This can be expressed as,

$$F_T = F_D + F_I$$

Most of the time, current exist in the same direction of the wave propagation and hence the current shall be taken into consideration in the load calculation. However, algebraic sum of wave and current loads is different from calculation of load by adding the horizontal water particle velocity with the current velocity and computing the loads. This is because of nonlinear term in the drag equation.

Current velocity shall be added vectorially with the water particle velocity before computation of drag force, i.e. V = Vw + Vc where V is the total velocity, Vw is the Velocity due to waves and Vc is the velocity of current. This is required since there is a square term in the drag force equation.

5.4.12 Specific Problems in Wave Hydrodynamics

- Wave Slamming:

  This is the effect of wave on a member, which is above SWL. The wave gives horizontal force as well as uplift on the member. The load is critical for only horizontal members. Members have to be locally checked in design.

- Vortex Shedding:

  Steady flow is disrupted due to placement of an obstruction such as a tubular. As velocity of flow increases inline oscillation change to cross flow oscillation which are very critical in design. This happens due to eddy formation downstream of the obstruction. If eddy shedding frequency coincides with natural frequency of the member it can create resonance condition and cause extensive damage.

CHAPTER 6

OVERVIEW OF SOFTWARE AND ITS VALIDATION

6.1 OVERVIEW OF SACS SOFTWARE

Structural analysis is performed by using the commonly used Structural Analysis Computer System (SACS) software. The SACS software presents the structural response in terms of member's stress utilization ratio and joint utilization ratios. All structural data, geometry, member dimensions, material properties and environmental conditions are generated by the input generating programs and reside in the common input file. The solution programs operate on this data and produce the common solution file which contains joint displacements and element internal forces. The post processing programs, using this information, evaluate the performance of the structure with respect to any of several structural codes. Any structure not satisfying the code may be automatically redesigned. Additionally, plots of the structural geometry, deformed shapes and code checking information are available.

The system consists of numerous compatible program modules, all fully interfaced to one another. The following SACS modules have been used for performing the In-Place analysis & Pushover analysis.

PRECEDE - Model generation capabilities include geometry and loading.
SEASTATE - Environmental loads generator
JOINT CAN - Tubular joint code checks and redesign
PSI - To perform non-linear foundation analysis.
POSTVUE - Interactive graphics post-processor
COLLAPSE - To perform plastic non-linear pushover analysis.

A static inelastic pushover analysis is carried out using the SACS 'COLLAPSE' module. This program uses a large deflection, iterative, tangent direct stiffness solution technique to solve for the geometric and material non-linearity's associated with the ultimate load capacity of a structure.

6.2 MODELING IN SACS SOFTWARE

The two major components of a fixed offshore structure are Jacket and Topside. The in-place analysis involves 3D modelling of both the jacket and deck. This 3D modelling is done through the Precede Module of SACS & It includes following steps:

- Modeling all members of the jacket and deck as per actual diameter and thicknesses.
- Modeling all topside components and considering the appropriate loads due to these components.
- Applying all applicable environmental loads as per the available data.
- Preparing the joint can file for checking tubular to tubular punching.
- Jacket legs are modeled as grouted concentric tubular signifying the presence of pile inside the jacket legs.

6.2.1 Geometry

- Computer model of a structure is set of joints & members.
- Joints shall have X, Y & Z co-ordinates in global co-ordinate system.
- Members are formed by connecting to joints that may be noted as legs, braces etc.

6.2.2 Co-ordinate System

- Co-ordinates in X, Y & Z directions from origin shall be specified.
- Vertical axis (Z) = 0.00 at chart datum.
- Plan Axis (X and Y) = 0.00 at centre of jacket.

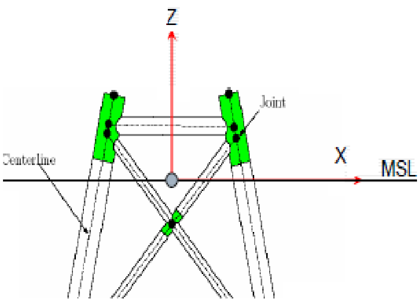


Fig. 6.1: Co-ordinate system in SACS

6.2.3 Support condition

The entire platform is considered supported and fixed to the sea bed by piled foundation system.

6.2.4 Joint & Member definition:

- Member is defined as structural element connected between two predefined joints.
- Beam element with 6 DOF at each joint is used for frame analysis.
- Members shall be defined with properties such as, Member sizes (Diameter & Wall thickness for tubes), Modulus of Elasticity (E) , Yield Strength (Fy), Shear modulus (G), Effective length factors (Kx , Ky) and End Releases.

6.3 VALIDATION OF SACS SOFTWARE

- **Validation Problem**

  A vertical cylindrical structural member of an offshore structure with diameter 1.0m is installed at a site where the water depth is 150m and the mean current is negligible as shown in Fig. 6.2. The design wave for the structural member has a height of 8m and period of 12sec. Calculate the maximum wave induced horizontal Drag and Inertia forces on the structural member.

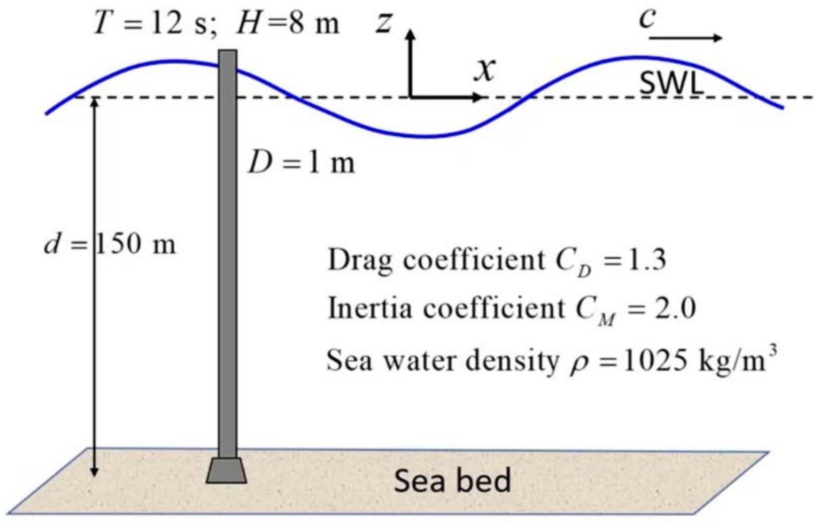


Fig. 6.2: Vertical cylindrical structural member

The maximum wave induced horizontal force is given by Morrison Equation,

$$F_T = \underbrace{0.5\rho C_D A_p V\left|V\right|}_{F_D} + \underbrace{C_M \rho \dot{V} V_{vol}}_{F_I}$$

Where,

F_T is the total instantaneous force.

V is the instantaneous water particle velocity.

$\tilde{V}$ is the instantaneous water particle acceleration.

A_p is the projected area

V_{vol} is the volume of structure

The maximum wave induced horizontal force calculated through manual calculation by using Morrison equation is,

F_T = 72.82 kN

The maximum wave induced horizontal force is given by SAC's Software is given by, F_T = 79.48 kN

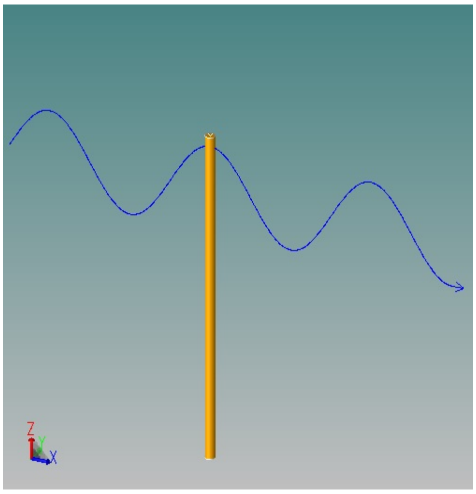


Fig.6.3: SACS Model of Member

The result obtained for maximum wave induced horizontal force is compared here for manual calculation method and SACS software:

Table 6.1: Maximum wave induced horizontal force

Manual Calculation	**SACS Software**	**Error (%)**
72.82 kN	79.48 kN	8.37

From comparison we can see that the values obtained by manual calculation and SACS software do not differ too much. So, SACS software is reliable to be used for the further study.

CHAPTER 7

RESULTS & DISCUSSION

7.1 DESIGN LEVEL ANALYSIS

It is seen from the results that no member has a UC value more than 1.0. However, few joints have seen with unity check value more than 1.0 shown in the following Table 7.1.

Table 7.1: Design Level Joint UC Summary

Joint	Location	UC ratio
0101	Row-B, X-Brace Joint at EL. (-) 61.774	1.196
0063	Row-2, X-Brace Joint at EL. (-) 38.823	1.153
0104	Row-1, X-Brace Joint at EL. (-) 38.823	1.114
0062	X-Brace Joint at EL. (-) 61.774 on Row-A	1.049
0084	Row-A, X-Brace Joint at EL. (-) 39.481	1.014

Above joint has a Load UC value greater than 1.0. These joints will further be checked in Ultimate strength analysis. Refer Appendix-5 for SACS output.

7.2 ULTIMATE LEVEL ANALYSIS

It is seen from the results that no member has a UC value more than 1.0. However, few joints have seen with Unity check value more than 1.0 shown in the following Table 7.2.

Table 7.2: Ultimate Level Joint UC Summary

Joint	Location	UC ratio
0101	Row-B, X-Brace Joint at EL. (-) 61.774	1.393
0063	Row-2, X-Brace Joint at EL. (-) 38.823	1.348
0104	Row-1, X-Brace Joint at EL. (-) 38.823	1.316
0062	Row-A, X-Brace Joint at EL. (-) 61.774	1.222
0084	Row-A, X-Brace Joint at EL. (-) 39.481	1.168
0102	Row-B, X-Brace Joint at EL. (-) 39.481	1.035

Above joint has a Load UC value greater than 1.0. These joints will further be checked in Pushover analysis. Refer Appendix-5 for SACS output.

7.3 PUSHOVER ANALYSIS

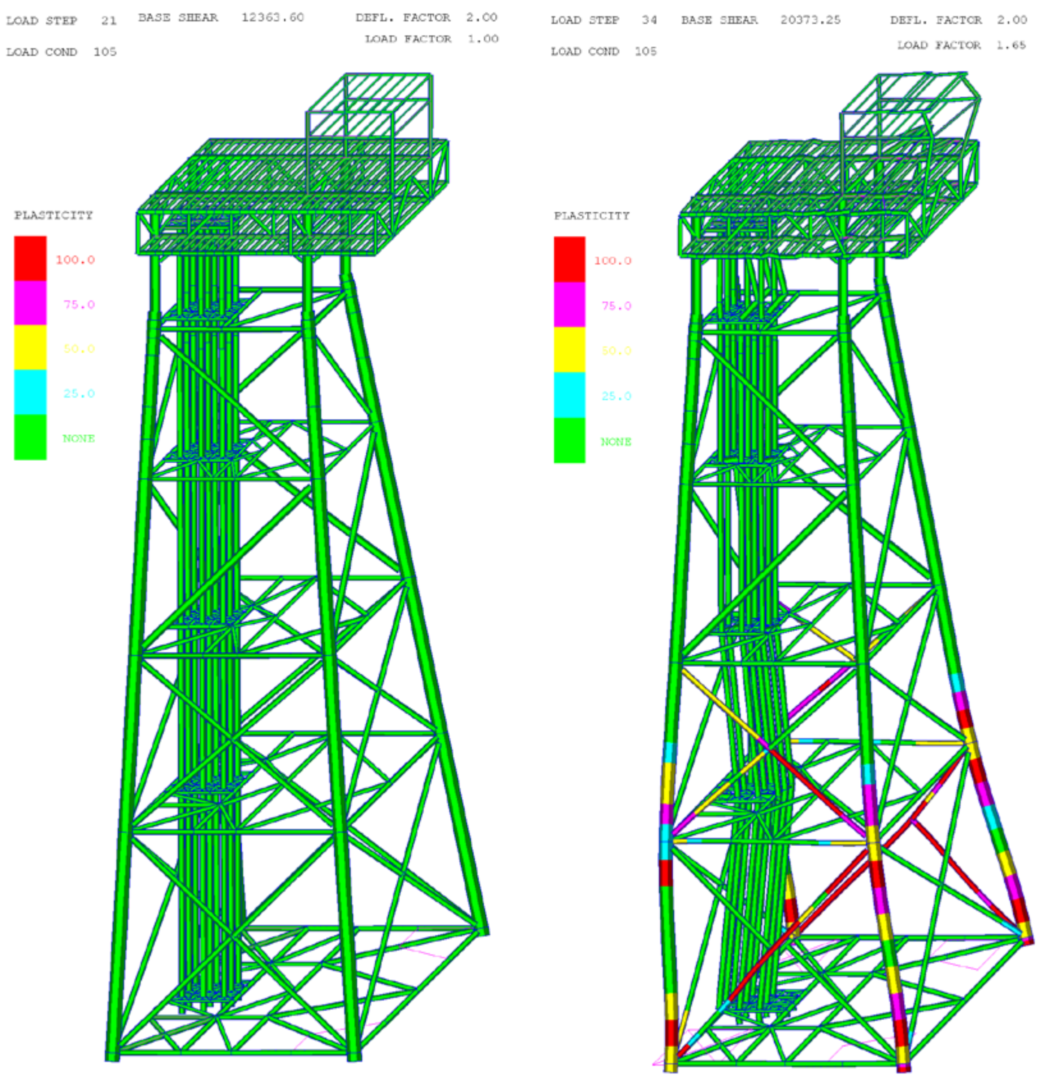
As per API RP2A a minimum RSR of 1.60 is necessary for a high exposure category platform. From the above results it is observed that RSR is more than 1.60 for all the load cases and no members and joints are undergone plasticity at 100 % environmental loading. Hence the jacket can withstand 100% environmental loading without collapse.

Table 7.3: Reserve Strength Ratio

Sl. No.	Load case	Reserve Strength Ratio (RSR)	Plasticity at 100% Environmental load
1.	101 (0 degree –Extreme Storm)	2.45	-
2.	102 (45 degree-Extreme Storm)	2.45	-
3.	103 (90 degree-Extreme Storm)	2.45	-
4.	104 (135 degree-Extreme Storm)	1.85	-
5.	105 (180 degree-Extreme Storm)	1.60	-
6.	106 (225 degree-Extreme Storm)	2.45	-
7.	107 (270 degree-Extreme Storm)	2.45	-
8.	108 (315 degree-Extreme Storm)	2.45	-

7.4 ANALYSIS FINDINGS

In-place analysis has been executed to check that the platform structural members with all appurtenances have the robustness and capability to support the applied loads in storm conditions. The total environmental loading on the jacket structures is translated into overturning moment and base shear at the mudline. The Base Shear and Overturning Moment increases with increase in wave height. The maximum overturning moment and Base Shear are in load case 105. Refer Appendix-3 for Seastate output. The obtained results may be summarised as follows:



Design Base Shear Collapse Base Shear

Fig.7.1: Pushover Analysis Plots at Design load and Collapse load condition

The results of the design level analysis are shown in Section-7.1 from that it is observed that no members are having UC ratio more than 1.00 and five joints are having UC ratio more than 1.00. The results of the Ultimate strength analysis are shown in Section-7.2 from that it is observed that no members are having UC ratio more than 1.278 and three joints are having UC ratio more than allowable UC ratio.

These members will be further checked in pushover analysis. Refer Appendix-4 &Appendix-5 for Member UC & Joint UC output.

The results of Pushover analysis are shown in section-7.3 shows that RSR is more than 1.60 for all the load cases & no members and joints have undergone plasticity at 100 % environmental loading. Refer Appendix-6 for SACS input / output of pushover analysis for the critical load condition 105.

CHAPTER 8

CONCLUSION & FUTURE SCOPE OF WORK

8.1 CONCLUSIONS

In this report, the research studies on structural condition assessment of ageing offshore jacket platforms reported in the literature over the past few decades are discussed. The degree of structural response to the extreme conditions is represented by the level of stress on the structure and it is quantified by using interaction ratio. The entire values of unity check for all members and joints fulfil the requirements of API RP 2A.

The results of pushover analysis show that platform has sufficient reserve strength ratio for all the load cases & no members and joints have undergone plasticity at 100% environmental loading. The results showed that the studied platform has adequate strength and can resist the environmental load.

Accordingly, it can be concluded that Jacket structure is “Fit for Purpose” with recommendation that in future additional facilities / appurtenances like risers, riser guards etc. over and above the existing facilities which will enhance loading on the jacket shall be avoided.

8.2 FUTURE SCOPE OF WORK

This thesis evaluates the jacket structures exposed to wave loading. Other structural parts such as piles and foundation are not evaluated. Piles will clearly be an important element of a full assessment of an existing structure for life extension. Piles will degrade due to fatigue and corrosion. It is also difficult to inspect the piles of an offshore jacket structure. Corrosion will definitely be an important hazard for the structure in cases where the corrosion protection is not sufficient for the extended life, or where corrosion allowance from design is not sufficient for the extended life. Hence, also corrosion effects on an ageing structure in a life extension would need a specific investigation.

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APPENDICES

APPENDIX-1

Conductor shielding factor

Calculation of conductor shielding factor for wells								
Wave direc tion	Elevation (m)	Conductor (762 dia.)			Shield ing Factor	Type of Surface	Cd	Cm
		Spacing (S) (m)	Diameter (D) (m)	S/D				
0	3 & ABOVE	2.500	0.762	3.281	0.820	SM	0.533	1.312
	-30 TO +3	2.500	0.962	2.599	0.650	RM	0.682	0.780
	-30 TO mudline	2.500	0.862	2.900	0.725	RM	0.761	0.870
45	3 & ABOVE	2.968	0.762	3.895	0.974	SM	0.633	1.558
	-30 TO +3	2.968	0.962	3.085	0.771	RM	0.810	0.926
	-30 TO mudline	2.968	0.862	3.443	0.861	RM	0.904	1.033
90	3 & ABOVE	1.600	0.762	2.100	0.525	SM	0.341	0.840
	-30 TO +3	1.600	0.962	1.663	0.416	RM	0.437	0.499
	-30 TO mudline	1.600	0.862	1.856	0.464	RM	0.487	0.557
135	3 & ABOVE	2.968	0.762	3.895	0.974	SM	0.633	1.558
	-30 TO +3	2.968	0.962	3.085	0.771	RM	0.810	0.926
	-30 TO mudline	2.968	0.862	3.443	0.861	RM	0.904	1.033
180	3 & ABOVE	2.500	0.762	3.281	0.820	SM	0.533	1.312
	-30 TO +3	2.500	0.962	2.599	0.650	RM	0.682	0.780
	-30 TO mudline	2.500	0.862	2.900	0.725	RM	0.761	0.870
225	3 & ABOVE	2.968	0.762	3.895	0.974	SM	0.633	1.558
	-30 TO +3	2.968	0.962	3.085	0.771	RM	0.810	0.926
	-30 TO mudline	2.968	0.862	3.443	0.861	RM	0.904	1.033
270	3 & ABOVE	1.600	0.762	2.100	0.525	SM	0.341	0.840
	-30 TO +3	1.600	0.962	1.663	0.416	RM	0.437	0.499
	-30 TO mudline	1.600	0.862	1.856	0.464	RM	0.487	0.557
315	3 & ABOVE	2.968	0.762	3.895	0.974	SM	0.633	1.558
	-30 TO +3	2.968	0.962	3.085	0.771	RM	0.810	0.926
	-30 TO mudline	2.968	0.862	3.443	0.861	RM	0.904	1.033

APPENDIX-2

Riser Load Calculation

Riser Load calculation:

Thk of concrete (mm)	25.400
Density of monel 5mm thick (t/m3)	8.930
Density of coat and wrap 5mm thick (t/m^3)	1.400
Cellar deck level	18.000
Density of steel t/m^3	7.850
Density of product water t/m^3	1.000
Water depth (m)	76.000
Thk of wrap coat(mm)	5.00
Density of concrete thick (t/m^3)	2.450
Density of sea water t/m^3	1.025
Thk of monel (mm)	5.000

Diameter of riser		Wall thickness	Inner dia. of riser	Weight of riser	Wt. of coat and wrap 5mm thk
(inches)	(mm)	(mm)	(mm)	(tonnes)	(tonnes)
12	304.8	12.7	279.400	8.600	0.506
Wt. of concrete 1" thick	Wt. of monel 5mm thick	Wt. of product water	Buoyancy wt.	Net weight (tonnes)	KN
(tonnes)	(tonnes)	(tonnes)	(tonnes)	(tonnes)	
4.935	0.339	5.763	8.178	11.965	117.37

APPENDIX-3

SEASTATE Output

****** SEASTATE BASIC LOAD CASE SUMMARY ******
RELATIVE TO MUDLINE ELEVATION
MARINE METHOD

LOAD CASE	LOAD LABEL	FX	FY	FZ	MX	MY	MZ	DEAD LOAD	BUOYANCY
		(KN)	(KN)	(KN)	(KN-M)	(KN-M)	(KN-M)	(KN)	(KN)
1	1	0.00	0.00	-15321.35	-5148.8	17467.2	0.0	30098.46	14776.93
2	2	0.00	0.00	-2123.49	1040.3	5968.0	0.0	0.00	0.00
3	3	0.00	0.00	-522.20	0.0	2178.8	0.0	0.00	0.00
4	4	0.00	0.00	-12608.24	54.3	79695.8	0.0	0.00	0.00
5	5	0.00	0.00	-990.00	0.0	13860.0	0.0	0.00	0.00
6	6	0.00	0.00	-225.00	0.0	3150.0	0.0	0.00	0.00
7	7	0.00	0.00	-400.00	-3400.0	3600.0	0.0	0.00	0.00
8	31	10180.35	-11.18	218.68	1002.0	618793.6	-9304.9	0.00	0.00
9	32	7526.96	8144.97	145.07	-504352.2	459562.0	-7813.6	0.00	0.00
10	33	-47.93	10108.13	37.35	-627527.0	-2665.2	3939.2	0.00	0.00
11	34	-8030.49	8601.20	-374.44	-532937.4	-489591.1	4876.1	0.00	0.00
12	35	-12374.41	20.29	-611.58	-1800.1	-744508.3	10879.5	0.00	0.00
13	36	-6155.96	-6670.21	-406.68	430132.4	-389493.8	6637.4	0.00	0.00
14	37	-21.99	-7390.84	-192.54	492013.6	-385.2	-4446.6	0.00	0.00
15	38	7016.49	-7610.94	118.46	476140.6	431752.2	-5894.6	0.00	0.00

***** SEASTATE COMBINED LOAD CASE SUMMARY *****
RELATIVE TO MUDLINE ELEVATION

LOAD CASE	LOAD LABEL	FX	FY	FZ	MX	MY	MZ
		(KN)	(KN)	(KN)	(KN-M)	(KN-M)	(KN-M)
16	100	0.00	0.00	-27294.74	-7392.7	93542.1	0.0
17	101	8653.30	-9.50	-27108.86	-6540.9	619516.7	-7909.2
18	102	6397.91	6923.22	-27171.43	-436092.0	484169.8	-6641.6
19	103	-40.74	8591.91	-27262.99	-540790.6	91276.7	3348.4
20	104	-6825.92	7311.02	-27613.02	-460389.4	-322610.3	4144.7
21	105	-10518.25	17.24	-27814.58	-8922.7	-539289.9	9247.6
22	106	-5232.56	-5669.68	-27640.42	358219.9	-237527.6	5641.8
23	107	-18.69	-6282.21	-27458.40	410818.9	93214.7	-3779.6
24	108	5964.01	-6469.30	-27194.05	397326.9	460531.5	-5010.5

APPENDIX-4

Member Unity Check Output

SACS-IV MEMBER UNITY CHECK RANGE SUMMARY

GROUP I - UNITY CHECKS GREATER THAN 0.00 AND LESS THAN 0.80

MEMBER	GROUP ID	MAXIMUM COMBINED UNITY CK	LOAD COND NO.	DIST FROM END	AXIAL STRESS N/MM2	BENDING STRESS Y N/MM2	BENDING STRESS Z N/MM2	SHEAR FORCE FY KN	SHEAR FORCE FZ KN	KLY/RY	KLZ/RZ	SECOND-HIGHEST UNITY CHECK	SECOND-HIGHEST LOAD COND	THIRD-HIGHEST UNITY CHECK	THIRD-HIGHEST LOAD COND
0005-543F	CG1	0.074	104	0.0	-9.87	0.34	-5.43	4.58	0.62	18.3	18.3	0.058	108	0.035	103
0006-543F	CG1	0.123	104	0.0	16.52	-0.31	-9.75	5.29	0.66	16.6	16.6	0.101	108	0.076	105
0008-548F	CG1	0.101	104	0.0	-12.86	-5.41	6.39	-4.13	1.80	15.9	15.9	0.094	105	0.081	108
0009-545F	CG1	0.048	104	0.0	-6.22	-2.81	2.80	-1.80	1.25	15.9	15.9	0.045	108	0.039	102
0009-547F	CG1	0.044	105	1.3	3.82	-5.69	1.95	2.39	-1.11	14.3	14.3	0.037	104	0.030	102
0009-548F	CG1	0.089	108	1.2	-12.14	5.12	3.89	2.25	0.94	12.7	12.7	0.084	104	0.068	103
0010-542F	CG1	0.073	102	1.5	-10.92	3.69	1.08	2.43	0.16	15.9	15.9	0.057	106	0.054	105
0010-545F	CG1	0.076	102	1.2	10.58	3.27	-4.46	-3.62	0.61	12.7	12.7	0.069	106	0.053	108
0011-541F	CG1	0.124	102	1.2	-15.37	3.94	10.19	2.57	0.63	12.7	12.7	0.109	106	0.105	105
0011-542F	CG1	0.133	102	0.0	12.06	0.24	17.80	-12.03	1.70	14.3	14.3	0.117	106	0.080	105
0012-549F	CG1	0.096	105	0.0	-11.50	-2.16	-8.65	5.64	1.39	15.9	15.9	0.086	101	0.079	102
0013-546F	CG1	0.042	101	1.3	4.77	4.47	0.83	1.86	0.62	14.3	14.3	0.042	102	0.038	108
0013-549F	CG1	0.046	108	1.2	-4.81	4.55	2.56	0.89	0.41	12.7	12.7	0.037	104	0.033	102
0014-542F	CG1	0.041	105	0.0	-5.35	1.65	-2.75	2.25	-0.29	12.7	12.7	0.039	101	0.035	108
0014-543F	CG1	0.040	102	1.3	-3.53	4.42	-3.23	-0.58	0.65	14.3	14.3	0.037	104	0.032	105
0015-543F	CG1	0.068	102	0.0	7.56	2.66	-6.80	2.21	0.43	15.9	15.9	0.065	105	0.062	106
0018-446F	CG1	0.046	102	0.0	-5.89	-0.56	-3.56	1.64	1.02	18.3	18.3	0.038	106	0.027	104
0018-449F	CG1	0.060	102	0.0	5.36	-0.45	-8.26	6.33	1.34	14.8	14.8	0.049	106	0.033	103
0019-443F	CG1	0.062	104	0.0	-7.54	-0.56	-5.44	3.70	0.46	18.3	18.3	0.053	108	0.035	103
0019-446F	CG1	0.073	104	0.0	8.34	-0.88	-7.65	4.71	0.99	14.8	14.8	0.061	108	0.038	103
0020-443F	CG1	0.091	105	1.5	14.05	0.43	-5.08	-2.68	1.03	16.6	16.6	0.089	104	0.074	101
0021-449F	CG1	0.068	105	0.0	8.83	-3.02	-4.98	3.28	1.31	18.3	18.3	0.056	101	0.049	102

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SACS-IV MEMBER UNITY CHECK RANGE SUMMARY

GROUP I - UNITY CHECKS GREATER THAN 0.00 AND LESS THAN 0.80

MEMBER	GROUP ID	MAXIMUM COMBINED UNITY CK	LOAD COND NO.	DIST FROM END	AXIAL STRESS N/MM2	BENDING STRESS Y N/MM2	BENDING STRESS Z N/MM2	SHEAR FORCE FY KN	SHEAR FORCE FZ KN	KLY/RY	KLZ/RZ	SECOND-HIGHEST UNITY CHECK	SECOND-HIGHEST LOAD COND	THIRD-HIGHEST UNITY CHECK	THIRD-HIGHEST LOAD COND
0022-447F	CG1	0.056	104	0.0	6.70	-1.80	-5.33	5.01	0.92	14.3	14.3	0.054	108	0.041	103
0022-448F	CG1	0.035	104	1.5	-4.74	1.22	-2.32	-1.38	0.71	15.9	15.9	0.034	108	0.026	103
0023-444F	CG1	0.048	108	1.3	-6.68	2.55	-1.88	0.17	-0.30	14.3	14.3	0.044	104	0.041	103
0023-445F	CG1	0.032	102	1.5	-3.50	3.21	-1.22	0.04	0.43	15.9	15.9	0.025	103	0.023	106
0023-447F	CG1	0.026	101	1.3	-2.71	2.87	0.23	-0.29	0.43	14.3	14.3	0.025	105	0.023	102
0023-448F	CG1	0.058	108	1.2	-7.90	3.68	1.94	0.81	0.34	12.7	12.7	0.052	104	0.042	103
0024-442F	CG1	0.049	102	0.0	-7.09	2.05	2.18	-2.65	0.29	15.9	15.9	0.037	106	0.030	105
0024-445F	CG1	0.048	102	1.2	6.26	3.64	-1.71	-1.13	0.53	12.7	12.7	0.041	108	0.040	103
0025-442F	CG1	0.040	102	1.3	3.34	3.84	-4.34	-2.06	1.13	14.3	14.3	0.031	101	0.029	106
0026-448F	CG1	0.059	108	1.2	-6.92	3.91	-4.19	-2.68	1.10	12.7	12.7	0.057	104	0.044	101
0026-449F	CG1	0.034	102	1.3	3.35	3.37	-2.51	-0.53	1.12	14.3	14.3	0.031	105	0.031	104
0027-445F	CG1	0.036	108	1.2	-3.29	4.01	-2.40	-0.88	0.73	12.7	12.7	0.030	104	0.028	103
0027-446F	CG1	0.029	102	1.3	2.28	3.26	-2.79	-0.68	0.70	14.3	14.3	0.023	104	0.019	106
0027-448F	CG1	0.015	101	1.5	-0.88	2.58	0.39	-0.10	0.10	15.9	15.9	0.014	108	0.010	104
0027-449F	CG1	0.036	108	0.0	-5.04	2.44	-0.22	1.37	-0.17	14.3	14.3	0.032	104	0.031	101
0028-442F	CG1	0.028	102	1.2	-2.32	3.54	1.80	0.83	0.48	12.7	12.7	0.027	108	0.024	104
0028-443F	CG1	0.051	105	1.3	9.36	0.26	0.91	0.14	0.10	14.3	14.3	0.045	104	0.043	102

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SACS-IV MEMBER UNITY CHECK RANGE SUMMARY

GROUP I - UNITY CHECKS GREATER THAN 0.00 AND LESS THAN 0.80

MEMBER	GROUP ID	MAXIMUM COMBINED UNITY CK	LOAD COND NO.	DIST FROM END	AXIAL STRESS N/MM2	BENDING STRESS Y N/MM2	BENDING STRESS Z N/MM2	SHEAR FORCE FY KN	SHEAR FORCE FZ KN	KLY/RY	KLZ/RZ	SECOND-HIGHEST UNITY CHECK	SECOND-HIGHEST LOAD COND	THIRD-HIGHEST UNITY CHECK	THIRD-HIGHEST LOAD COND
0032-647F	CG1	0.222	104	0.0	24.00	-25.06	0.15	1.96	6.37	16.5	16.5	0.200	108	0.171	103

0033-641F	CG1	0.198	102	0.0	-25.20	-16.18	3.22	-0.44	2.15	16.6	16.6	0.170	106	0.154	104
0033-644F	CG1	0.209	102	0.0	18.49	-22.76	17.41	-9.68	6.11	14.7	14.7	0.201	106	0.192	104
0034-649F	CG1	0.123	104	0.0	8.97	1.95	-19.19	13.90	2.32	14.7	14.7	0.109	108	0.085	102
0035-643F	CG1	0.097	108	1.7	13.42	5.75	4.63	2.90	-0.24	18.3	18.3	0.094	104	0.090	101
0036-641F	CG1	0.418	102	0.0	46.32	-29.73	34.70	-12.37	9.54	18.3	18.3	0.384	105	0.376	106
0037-643F	CG1	0.228	101	0.0	-20.39	3.70	29.72	-11.62	3.38	16.6	16.6	0.213	108	0.207	105
0040-647F	CG1	0.401	104	0.0	-41.81	-29.48	36.96	-16.48	6.21	16.6	16.6	0.332	108	0.298	103
0042-346F	CG1	0.022	106	1.7	2.36	1.50	-2.05	-1.19	0.47	18.3	18.3	0.019	108	0.018	102
0042-349F	CG1	0.024	102	1.4	2.51	2.53	1.29	0.63	1.12	14.8	14.8	0.021	106	0.020	105
0043-346F	CG1	0.030	104	1.4	3.37	2.02	2.67	2.08	1.04	14.7	14.7	0.022	102	0.019	108
0044-648F	CG1	0.079	104	1.5	-11.81	3.82	-2.00	0.09	1.69	15.9	15.9	0.077	108	0.054	103
0045-645F	CG1	0.092	104	1.5	-12.90	4.41	-4.25	-2.72	1.93	15.9	15.9	0.086	102	0.085	103
0045-647F	CG1	0.190	104	1.3	-26.76	-12.44	2.56	-0.98	-6.01	14.3	14.3	0.160	103	0.134	108
0045-648F	CG1	0.096	108	1.2	-11.60	6.48	6.20	4.55	3.47	12.7	12.7	0.090	104	0.065	107
0046-642F	CG1	0.111	102	0.0	-15.51	-1.49	7.34	-5.69	2.96	15.9	15.9	0.082	103	0.078	106
0046-644F	CG1	0.137	102	1.5	-16.72	-8.04	9.23	4.12	-3.63	15.9	15.9	0.105	106	0.095	103
0046-645F	CG1	0.126	102	1.2	19.14	6.72	-3.05	-3.56	2.77	12.7	12.7	0.102	106	0.086	103
0047-642F	CG1	0.154	102	1.3	23.69	8.46	0.08	1.05	3.14	14.3	14.3	0.145	105	0.132	101
0048-649F	CG1	0.070	102	1.3	6.75	8.19	-3.51	-1.74	0.59	14.3	14.3	0.069	108	0.066	101
0049-646F	CG1	0.064	102	1.3	3.50	10.06	-5.79	-2.78	1.69	14.3	14.3	0.051	101	0.051	100
0049-649F	CG1	0.095	108	1.3	-8.95	9.94	6.58	3.43	-0.16	14.3	14.3	0.076	101	0.074	104

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SACS-IV MEMBER UNITY CHECK RANGE SUMMARY

GROUP I - UNITY CHECKS GREATER THAN 0.00 AND LESS THAN 0.80

MEMBER	GROUP ID	MAXIMUM COMBINED UNITY CK	LOAD COND NO.	DIST FROM END	AXIAL STRESS N/MM2	BENDING STRESS Y N/MM2	BENDING STRESS Z N/MM2	SHEAR FORCE FY KN	SHEAR FORCE FZ KN	KLY/RY	KLZ/RZ	SECOND-HIGHEST UNITY CHECK	SECOND-HIGHEST LOAD COND	THIRD-HIGHEST UNITY CHECK	THIRD-HIGHEST LOAD COND
0050-643F	CG1	0.129	102	1.3	-14.47	11.47	-6.78	-4.41	1.78	14.3	14.3	0.115	101	0.089	105
0050-646F	CG1	0.102	105	1.3	-12.61	7.18	-5.60	-3.41	-0.46	14.3	14.3	0.097	101	0.086	102
0051-642F	CG1	0.108	102	0.0	-13.17	9.19	-3.52	3.78	-1.45	14.3	14.3	0.092	101	0.074	105
0051-643F	CG1	0.103	101	0.0	14.36	7.36	-2.16	2.01	-0.29	15.9	15.9	0.101	105	0.091	102
0052-343F	CG1	0.054	105	0.0	4.74	-2.07	-7.09	3.66	1.41	16.5	16.5	0.050	104	0.028	106
0053-349F	CG1	0.048	105	0.0	4.39	-1.69	6.26	-3.07	1.14	18.3	18.3	0.037	106	0.024	102
0054-347F	CG1	0.025	108	1.3	-3.25	2.02	-0.37	0.10	0.07	14.3	14.3	0.021	106	0.021	104
0054-348F	CG1	0.034	104	1.5	-4.93	1.93	0.68	0.28	0.56	15.9	15.9	0.032	108	0.030	105
0055-344F	CG1	0.032	104	1.3	5.33	1.00	0.91	-0.35	-0.09	14.3	14.3	0.027	108	0.025	105
0055-345F	CG1	0.028	108	1.5	3.52	2.63	0.17	0.18	0.34	15.9	15.9	0.022	104	0.022	106
0055-347F	CG1	0.035	108	1.3	5.16	2.12	-0.79	-0.26	0.32	14.3	14.3	0.034	106	0.031	107
0055-348F	CG1	0.030	108	1.2	-2.82	3.48	1.51	1.08	0.53	12.7	12.7	0.029	104	0.025	102
0056-341F	CG1	0.032	102	0.0	4.52	2.28	-0.31	0.51	-0.20	14.3	14.3	0.032	104	0.032	103
0056-342F	CG1	0.027	102	1.5	-3.00	2.54	-0.86	-0.21	0.16	15.9	15.9	0.021	106	0.020	103
0056-344F	CG1	0.034	102	1.3	-3.95	2.78	1.80	0.46	0.47	14.3	14.3	0.030	106	0.025	105
0056-345F	CG1	0.034	102	1.2	3.77	3.70	-0.63	-0.75	0.66	12.7	12.7	0.030	103	0.027	104
0057-341F	CG1	0.030	102	1.2	-3.56	2.76	0.60	0.14	0.59	12.7	12.7	0.023	104	0.023	103
0057-342F	CG1	0.040	102	1.3	4.96	3.70	0.22	0.36	1.04	14.3	14.3	0.038	105	0.034	101
0058-348F	CG1	0.027	105	1.2	2.96	2.73	-1.24	-0.45	0.80	12.7	12.7	0.027	108	0.027	101
0058-349F	CG1	0.028	105	1.3	-3.48	1.65	1.72	1.31	0.65	14.3	14.3	0.023	101	0.022	102
0059-345F	CG1	0.024	104	1.2	2.42	2.72	1.08	0.36	0.59	12.7	12.7	0.023	103	0.021	105
0059-346F	CG1	0.018	101	1.3	1.25	2.87	-0.13	0.12	0.53	14.3	14.3	0.018	108	0.018	102

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SACS-IV MEMBER UNITY CHECK RANGE SUMMARY

GROUP I - UNITY CHECKS GREATER THAN 0.00 AND LESS THAN 0.80

MEMBER	GROUP ID	MAXIMUM COMBINED UNITY CK	LOAD COND NO.	DIST FROM END	AXIAL STRESS N/MM2	BENDING STRESS Y N/MM2	BENDING STRESS Z N/MM2	SHEAR FORCE FY KN	SHEAR FORCE FZ KN	KLY/RY	KLZ/RZ	SECOND-HIGHEST UNITY CHECK	SECOND-HIGHEST LOAD COND	THIRD-HIGHEST UNITY CHECK	THIRD-HIGHEST LOAD COND
0059-348F	CG1	0.020	105	1.5	-2.24	1.37	-1.49	-0.72	0.09	15.9	15.9	0.019	101	0.018	108
0059-349F	CG1	0.021	105	0.0	2.56	1.56	1.12	-0.72	-0.09	14.3	14.3	0.020	104	0.016	100
0060-342F	CG1	0.027	105	1.2	-2.91	2.11	2.10	1.54	0.40	12.7	12.7	0.025	101	0.024	102
0060-343F	CG1	0.022	105	1.3	3.03	1.58	-0.82	-0.29	0.24	14.3	14.3	0.020	106	0.018	104
0060-345F	CG1	0.020	106	1.5	2.26	2.06	-0.85	-0.15	0.33	15.9	15.9	0.020	105	0.019	102
0060-346F	CG1	0.017	101	0.0	1.32	2.60	0.01	0.18	-0.19	14.3	14.3	0.016	102	0.016	108

0061-342F	CG1	0.023	102	1.3	-2.26	2.80	0.22	-0.29	0.31	14.3	14.3	0.023	105	0.022	101
0061-343F	CG1	0.028	105	1.5	-3.54	1.25	-2.04	-1.22	0.32	15.9	15.9	0.024	104	0.020	101
0064-246F	CG1	0.014	104	1.7	-1.28	1.65	0.43	0.00	0.61	18.3	18.3	0.012	108	0.012	103
0064-249F	CG1	0.011	102	1.4	1.27	1.15	0.41	0.14	0.66	14.8	14.8	0.011	104	0.010	103
0065-243F	CG1	0.010	104	0.0	-1.36	-0.17	-0.74	0.71	0.31	18.3	18.3	0.008	108	0.008	102
0065-246F	CG1	0.015	102	1.4	1.17	2.24	0.73	0.40	1.18	14.8	14.8	0.014	104	0.014	103
0067-249F	CG1	0.017	102	1.7	-0.99	2.89	0.48	0.46	1.53	18.3	18.3	0.015	100	0.015	106
0068-247F	CG1	0.010	104	0.0	1.38	0.67	0.10	0.28	-0.33	14.3	14.3	0.009	108	0.008	105
0068-248F	CG1	0.024	105	1.5	-1.68	3.69	0.51	0.23	0.41	15.9	15.9	0.022	104	0.022	101
0069-244F	CG1	0.016	104	1.3	1.22	2.46	0.65	0.07	0.13	14.3	14.3	0.016	108	0.015	103
0069-245F	CG1	0.019	104	1.5	-1.33	2.99	-0.13	-0.07	0.21	15.9	15.9	0.018	108	0.017	105
0069-247F	CG1	0.032	104	1.3	-2.25	5.05	0.34	0.08	1.16	14.3	14.3	0.031	105	0.030	108
0069-248F	CG1	0.016	104	1.2	0.97	2.67	-0.59	-0.28	0.47	12.7	12.7	0.016	108	0.016	102
0070-241F	CG1	0.026	102	1.3	1.91	4.06	0.26	0.04	0.11	14.3	14.3	0.026	105	0.023	101
0070-242F	CG1	0.012	104	1.5	-0.91	1.72	-0.08	-0.02	0.03	15.9	15.9	0.012	102	0.011	103
0070-244F	CG1	0.021	102	1.3	-1.06	3.89	0.67	0.13	1.19	14.3	14.3	0.020	103	0.020	100

GROUP I - UNITY CHECKS GREATER THAN 0.00 AND LESS THAN 0.80

MEMBER	GROUP ID	MAXIMUM COMBINED UNITY CK	LOAD COND NO.	DIST FROM END	AXIAL STRESS N/MM2	BENDING STRESS Y N/MM2	BENDING STRESS Z N/MM2	SHEAR FORCE FY KN	SHEAR FORCE FZ KN	KLY/RY	KLZ/RZ	SECOND-HIGHEST UNITY CHECK	SECOND-HIGHEST LOAD COND	THIRD-HIGHEST UNITY CHECK	THIRD-HIGHEST LOAD COND
0070-245F	CG1	0.023	102	1.2	1.23	4.06	-0.26	-0.19	0.42	12.7	12.7	0.021	100	0.020	105
0071-242F	CG1	0.028	105	1.3	-1.74	4.59	-0.49	-0.31	0.89	14.3	14.3	0.026	102	0.026	101
0072-248F	CG1	0.017	100	1.2	0.01	3.19	0.00	0.00	0.63	12.7	12.7	0.017	104	0.017	108
0072-249F	CG1	0.011	102	1.3	1.01	1.27	-0.72	-0.26	0.13	14.3	14.3	0.010	105	0.009	101
0073-245F	CG1	0.020	100	1.2	0.00	3.76	0.00	0.00	0.90	12.7	12.7	0.016	102	0.016	101
0073-246F	CG1	0.015	102	1.3	0.90	2.51	-0.60	-0.10	0.54	14.3	14.3	0.014	105	0.014	101
0073-248F	CG1	0.017	102	1.5	0.79	3.18	-0.04	-0.31	0.57	15.9	15.9	0.017	105	0.017	100
0073-249F	CG1	0.012	100	0.0	0.00	2.19	0.01	-0.01	-0.11	14.3	14.3	0.010	101	0.010	102
0074-243F	CG1	0.012	100	1.3	0.00	2.24	0.00	0.00	0.35	14.3	14.3	0.010	102	0.010	101
0074-245F	CG1	0.015	100	1.5	0.00	2.88	0.00	0.00	0.53	15.9	15.9	0.013	101	0.012	103
0074-246F	CG1	0.013	104	0.0	-0.98	1.90	0.37	-0.70	-0.11	14.3	14.3	0.012	105	0.012	108
0075-243F	CG1	0.010	104	0.0	-1.06	0.90	0.74	-0.89	-0.06	15.9	15.9	0.009	108	0.009	105
0078-541F	CG1	0.158	106	0.0	-17.93	-6.11	-14.55	8.33	1.76	18.3	18.3	0.151	102	0.135	103
0079-547F	CG1	0.118	104	0.0	-11.93	-8.33	10.84	-5.20	1.11	16.5	16.5	0.101	108	0.086	103
0080-544F	CG1	0.087	102	0.0	-11.37	-1.85	6.52	-4.89	1.93	16.6	16.6	0.072	104	0.065	106
0080-547F	CG1	0.117	104	0.0	14.22	-3.05	10.89	-8.67	0.80	16.5	16.5	0.108	108	0.101	102
0081-541F	CG1	0.140	102	0.0	-18.74	-0.36	10.50	-7.09	1.58	16.5	16.5	0.116	106	0.077	103
0081-544F	CG1	0.152	102	0.0	19.71	-1.84	13.03	-7.87	1.00	16.5	16.5	0.145	106	0.122	103
0085-447F	CG1	0.043	102	0.0	-4.12	-1.48	5.01	-3.06	1.47	16.5	16.5	0.042	104	0.039	103
0086-441F	CG1	0.117	104	0.0	10.60	-2.20	15.50	-9.42	0.72	18.3	18.3	0.116	103	0.101	102
0087-441F	CG1	0.073	102	0.0	-10.40	-0.51	4.57	-3.18	1.51	16.5	16.5	0.064	106	0.063	103
0087-444F	CG1	0.095	102	0.0	11.52	0.31	9.21	-5.81	0.70	16.5	16.5	0.090	103	0.088	104

GROUP I - UNITY CHECKS GREATER THAN 0.00 AND LESS THAN 0.80

MEMBER	GROUP ID	MAXIMUM COMBINED UNITY CK	LOAD COND NO.	DIST FROM END	AXIAL STRESS N/MM2	BENDING STRESS Y N/MM2	BENDING STRESS Z N/MM2	SHEAR FORCE FY KN	SHEAR FORCE FZ KN	KLY/RY	KLZ/RZ	SECOND-HIGHEST UNITY CHECK	SECOND-HIGHEST LOAD COND	THIRD-HIGHEST UNITY CHECK	THIRD-HIGHEST LOAD COND
0088-444F	CG1	0.049	102	0.0	-6.63	-1.23	3.32	-2.40	1.71	16.5	16.5	0.047	106	0.040	108
0088-447F	CG1	0.072	104	0.0	8.16	-2.39	7.28	-5.96	0.86	16.5	16.5	0.069	108	0.068	102
0091-341F	CG1	0.066	104	0.0	5.84	-2.14	8.86	-5.89	1.02	18.3	18.3	0.055	103	0.050	102
0092-341F	CG1	0.042	102	0.0	-4.91	-0.93	3.90	-2.58	1.36	16.5	16.5	0.039	104	0.036	106
0092-344F	CG1	0.061	104	0.0	6.51	-1.79	6.79	-5.18	1.05	16.5	16.5	0.044	103	0.037	105
0093-344F	CG1	0.051	106	0.0	5.17	-1.69	-5.95	4.38	1.05	16.5	16.5	0.041	102	0.037	105
0093-347F	CG1	0.050	104	0.0	4.52	-1.51	6.55	-4.73	0.98	16.5	16.5	0.037	106	0.035	108
0094-347F	CG1	0.068	106	0.0	6.14	-2.03	-8.93	5.99	1.10	16.5	16.5	0.057	108	0.051	107
0097-247F	CG1	0.044	104	1.5	-3.79	6.08	0.06	-0.46	2.36	16.5	16.5	0.041	105	0.040	108
0098-241F	CG1	0.038	102	1.7	3.21	5.45	-0.18	-0.46	1.84	18.3	18.3	0.037	105	0.033	106
0099-244F	CG1	0.026	104	1.5	-2.00	3.88	-0.65	-0.69	0.91	16.5	16.5	0.025	103	0.025	108
0099-247F	CG1	0.021	104	0.0	1.94	2.56	1.32	-0.91	-0.87	16.5	16.5	0.020	108	0.019	103

0100-241F	CG1	0.015	102	0.0	-1.77	1.08	1.10	-0.76	0.08	16.6	16.6	0.014	103	0.013	104
0100-244F	CG1	0.022	102	0.0	1.79	2.83	1.54	-0.82	-0.02	16.5	16.5	0.020	103	0.019	104
241F-0071	CG1	0.010	102	0.0	-1.28	0.83	-0.05	-0.27	-0.18	12.7	12.7	0.008	105	0.008	103
242F-0074	CG1	0.022	100	0.0	-0.01	4.04	0.00	0.00	-1.02	12.7	12.7	0.021	104	0.021	105
242F-0075	CG1	0.013	102	0.0	-0.60	2.34	-0.15	-0.22	-0.12	14.3	14.3	0.012	105	0.012	100
243F-0066	CG1	0.019	104	1.5	1.22	-2.70	1.51	0.77	-1.90	16.6	16.6	0.016	108	0.015	105
343F-0043	CG1	0.023	104	0.0	-3.26	1.19	0.99	-0.91	-0.32	18.3	18.3	0.020	105	0.018	108
441F-0024	CG1	0.056	104	1.3	8.68	-0.61	-2.89	-0.19	-0.18	14.3	14.3	0.056	103	0.051	108
441F-0025	CG1	0.081	102	0.0	-8.69	3.45	-8.14	6.46	-1.01	12.7	12.7	0.064	106	0.057	103
444F-0024	CG1	0.047	102	0.0	-4.99	3.33	-4.13	1.71	-0.56	14.3	14.3	0.038	106	0.032	101

SACS-IV MEMBER UNITY CHECK RANGE SUMMARY

GROUP I - UNITY CHECKS GREATER THAN 0.00 AND LESS THAN 0.80

MEMBER	GROUP ID	MAXIMUM COMBINED UNITY CK	LOAD COND NO.	DIST FROM END	AXIAL STRESS N/MM2	BENDING STRESS Y N/MM2	BENDING STRESS Z N/MM2	SHEAR FORCE FY KN	SHEAR FORCE FZ KN	KLY/RY	KLZ/RZ	SECOND-HIGHEST UNITY CHECK	SECOND-HIGHEST LOAD COND	THIRD-HIGHEST UNITY CHECK	THIRD-HIGHEST LOAD COND
541F-0010	CG1	0.055	106	0.0	-6.96	-1.59	4.51	-1.71	0.63	14.3	14.3	0.054	102	0.051	103
542F-0015	CG1	0.136	102	1.3	-10.21	2.95	20.43	15.93	-0.43	14.3	14.3	0.119	106	0.119	104
544F-0009	CG1	0.057	108	1.3	-8.11	3.63	0.16	-2.27	0.74	14.3	14.3	0.052	102	0.049	106
544F-0010	CG1	0.074	102	0.0	-7.93	3.36	-7.25	3.02	-0.12	14.3	14.3	0.060	106	0.055	105
545F-0013	CG1	0.040	108	0.0	-3.20	4.59	3.73	-1.28	-0.35	12.7	12.7	0.031	101	0.030	104
545F-0014	CG1	0.040	104	0.0	5.81	-0.52	-2.49	1.61	0.44	15.9	15.9	0.038	101	0.036	105
546F-0004	CG1	0.058	102	0.0	-8.57	2.87	-1.55	1.01	-0.41	18.3	18.3	0.042	106	0.042	104
546F-0005	CG1	0.072	104	1.4	9.55	-0.03	5.82	3.99	-0.72	14.7	14.7	0.061	102	0.056	108
546F-0014	CG1	0.042	102	0.0	3.33	2.34	5.83	-4.18	0.64	14.3	14.3	0.041	106	0.030	105
547F-0008	CG1	0.087	104	0.0	11.68	1.01	-6.87	2.67	-1.75	14.3	14.3	0.084	108	0.073	103
548F-0012	CG1	0.101	104	1.2	10.98	-3.13	10.92	10.22	-1.37	12.7	12.7	0.097	105	0.090	108
548F-0013	CG1	0.048	102	1.5	5.09	3.57	4.20	4.82	0.15	15.9	15.9	0.044	101	0.039	105
549F-0004	CG1	0.079	102	1.5	9.82	1.08	7.15	6.08	-0.79	16.5	16.5	0.062	106	0.044	101
549F-0007	CG1	0.084	102	1.5	-9.68	1.90	8.09	5.21	-0.81	16.6	16.6	0.066	106	0.056	101
641F-0046	CG1	0.187	105	0.0	-28.31	-8.70	-4.39	3.73	2.59	14.3	14.3	0.169	106	0.165	102
641F-0047	CG1	0.145	102	0.0	-18.98	-11.49	1.14	-1.82	4.61	12.7	12.7	0.137	105	0.128	106
642F-0050	CG1	0.096	105	1.2	-13.09	6.46	2.90	2.77	0.16	12.7	12.7	0.092	101	0.084	102
644F-0045	CG1	0.134	104	0.0	13.20	-9.33	-13.81	9.77	3.04	12.7	12.7	0.122	108	0.089	103
645F-0049	CG1	0.063	102	1.2	5.36	8.80	1.82	2.31	0.44	12.7	12.7	0.061	106	0.060	103
645F-0050	CG1	0.080	102	1.5	-9.77	6.91	-1.93	0.44	0.24	15.9	15.9	0.069	101	0.060	103
646F-0034	CG1	0.092	104	0.0	-11.59	7.52	-1.10	0.54	-0.18	18.3	18.3	0.088	108	0.061	101
646F-0035	CG1	0.115	104	0.0	13.61	8.48	-7.79	6.86	-1.11	14.8	14.8	0.101	108	0.081	102

SACS-IV MEMBER UNITY CHECK RANGE SUMMARY

GROUP I - UNITY CHECKS GREATER THAN 0.00 AND LESS THAN 0.80

MEMBER	GROUP ID	MAXIMUM COMBINED UNITY CK	LOAD COND NO.	DIST FROM END	AXIAL STRESS N/MM2	BENDING STRESS Y N/MM2	BENDING STRESS Z N/MM2	SHEAR FORCE FY KN	SHEAR FORCE FZ KN	KLY/RY	KLZ/RZ	SECOND-HIGHEST UNITY CHECK	SECOND-HIGHEST LOAD COND	THIRD-HIGHEST UNITY CHECK	THIRD-HIGHEST LOAD COND
647F-0044	CG1	0.126	104	0.0	17.02	-9.05	-3.95	1.00	2.61	14.3	14.3	0.121	108	0.093	105
648F-0048	CG1	0.102	108	1.2	-10.29	9.56	-7.40	-7.64	0.97	12.7	12.7	0.097	101	0.084	104
648F-0049	CG1	0.034	103	1.5	-2.47	5.04	1.32	2.20	0.38	15.9	15.9	0.033	102	0.030	100
649F-0041	CG1	0.176	101	1.7	-14.34	7.38	23.80	8.75	-1.56	18.3	18.3	0.175	102	0.174	105
041C-241C	CON	0.058	100	0.0	-8.52	0.00	0.00	0.00	0.00	7.7	7.7	0.055	105	0.051	106
042C-242C	CON	0.053	100	0.0	-7.81	0.00	0.00	0.00	0.00	7.7	7.7	0.042	107	0.041	108
043C-243C	CON	0.061	100	0.0	-9.00	0.00	0.00	0.00	0.00	7.7	7.7	0.048	105	0.048	106
044C-244C	CON	0.055	100	0.0	-8.11	0.00	0.00	0.00	0.00	7.7	7.7	0.050	105	0.047	104
045C-245C	CON	0.052	100	0.0	-7.57	0.00	0.00	0.00	0.00	7.7	7.7	0.039	101	0.039	102
046C-246C	CON	0.057	100	0.0	-8.37	0.00	0.00	0.00	0.00	7.7	7.7	0.043	105	0.043	104
047C-247C	CON	0.059	100	0.0	-8.58	0.00	0.00	0.00	0.00	7.7	7.7	0.055	105	0.052	104
048C-248C	CON	0.054	100	0.0	-7.90	0.00	0.00	0.00	0.00	7.7	7.7	0.042	103	0.041	104
049C-249C	CON	0.062	100	0.0	-9.15	0.00	0.00	0.00	0.00	7.7	7.7	0.049	104	0.049	105
0000-604L	H1A	0.345	105	0.0	37.29	37.43	10.41	-12.18	-23.65	41.5	41.5	0.322	101	0.314	104
0001-602L	H1A	0.449	100	0.0	-16.74	59.71	2.88	-2.15	-52.26	41.5	41.5	0.387	106	0.387	105
0032-0040	H1A	0.235	104	1.6	-17.39	-13.36	-33.62	-99.48	-65.40	7.1	7.1	0.179	103	0.167	102

MEMBER	GROUP ID	MAXIMUM COMBINED UNITY CK	LOAD COND NO.	DIST FROM END	AXIAL STRESS N/MM2	BENDING STRESS Y N/MM2	BENDING STRESS Z N/MM2	SHEAR FORCE FY KN	SHEAR FORCE FZ KN	KLY/RY	KLZ/RZ	SECOND-HIGHEST UNITY CHECK	SECOND-HIGHEST LOAD COND	THIRD-HIGHEST UNITY CHECK	THIRD-HIGHEST LOAD COND
0033-0032	H1A	0.169	102	0.0	-20.31	12.95	9.66	-18.23	-24.31	7.1	7.1	0.149	103	0.125	104
0036-0033	H1A	0.266	102	0.0	-15.45	13.66	44.38	-112.33	-0.18	7.1	7.1	0.208	105	0.197	101
0036-601L	H1A	0.398	102	1.5	-9.97	6.40	85.93	554.04	-31.16	6.6	6.6	0.278	101	0.268	105
0040-603L	H1A	0.377	103	1.5	-25.33	-32.31	52.09	279.02	-85.62	6.6	6.6	0.369	104	0.314	102
0306-0000	H1A	0.351	104	0.0	29.78	27.28	-41.64	85.71	18.04	11.3	11.3	0.344	101	0.323	105
0464-0306	H1A	0.337	104	0.9	27.06	27.28	-41.64	-42.01	89.05	4.2	4.2	0.297	105	0.275	101

SACS-IV MEMBER UNITY CHECK RANGE SUMMARY

GROUP I - UNITY CHECKS GREATER THAN 0.00 AND LESS THAN 0.80

MEMBER	GROUP ID	MAXIMUM COMBINED UNITY CK	LOAD COND NO.	DIST FROM END	AXIAL STRESS N/MM2	BENDING STRESS Y N/MM2	BENDING STRESS Z N/MM2	SHEAR FORCE FY KN	SHEAR FORCE FZ KN	KLY/RY	KLZ/RZ	SECOND-HIGHEST UNITY CHECK	SECOND-HIGHEST LOAD COND	THIRD-HIGHEST UNITY CHECK	THIRD-HIGHEST LOAD COND
601L-0001	H1A	0.623	105	0.0	-36.35	-101.37	-40.11	53.85	156.92	31.6	31.6	0.603	100	0.567	104
602L-604L	H1A	0.460	107	0.0	-43.62	-54.40	-24.36	37.16	97.27	34.4	34.4	0.422	108	0.359	106
603L-0464	H1A	0.585	104	0.0	24.34	-90.05	70.73	-179.75	174.90	16.1	16.1	0.555	105	0.538	100
0001-0037	H1B	0.313	102	0.0	10.55	-4.93	-64.17	172.09	23.61	13.6	13.6	0.283	105	0.276	101
0001-604L	H1B	0.295	104	13.1	-24.24	-30.58	13.60	23.40	-30.94	75.8	75.8	0.265	103	0.235	102
0034-0041	H1B	0.190	101	1.6	6.26	5.59	38.77	83.02	-11.61	9.2	9.2	0.168	105	0.160	108
0035-0034	H1B	0.103	102	0.0	11.22	11.09	2.86	-6.16	-1.26	9.2	9.2	0.095	103	0.082	104
0037-0035	H1B	0.242	102	0.0	12.66	8.21	43.43	-93.59	8.65	9.2	9.2	0.183	101	0.141	105
0041-0000	H1B	0.316	101	2.3	3.77	-7.83	-73.21	-180.95	-23.95	13.6	13.6	0.308	102	0.232	108
0032-0045	H1C	0.162	104	0.0	6.67	-29.49	12.31	-7.38	7.95	24.8	24.8	0.158	100	0.151	105
0033-0046	H1C	0.164	100	0.0	0.40	-29.95	0.35	-0.12	8.51	24.8	24.8	0.161	105	0.154	106
0036-0047	H1C	0.419	105	0.0	-34.72	-46.86	-38.41	14.86	14.96	24.8	24.8	0.404	102	0.365	106
0040-0044	H1C	0.308	104	0.0	-17.15	-39.40	36.45	-17.64	12.59	24.8	24.8	0.267	108	0.239	103
0044-0045	H1C	0.070	104	0.0	-3.06	-0.48	-13.42	11.28	1.72	14.4	14.4	0.059	108	0.042	105
0044-0048	H1C	0.076	108	2.5	-5.87	11.18	-0.01	-2.39	1.29	22.5	22.5	0.070	101	0.066	100
0045-0046	H1C	0.076	104	1.6	-8.57	5.08	5.89	4.83	0.91	14.4	14.4	0.063	105	0.055	102
0045-0049	H1C	0.061	100	2.5	-0.59	10.57	0.16	0.08	2.75	22.5	22.5	0.057	102	0.057	101
0046-0047	H1C	0.078	102	1.6	-1.09	0.73	17.80	15.66	-2.57	14.4	14.4	0.063	105	0.058	106
0046-0050	H1C	0.060	101	2.5	2.00	11.70	-4.02	-2.66	2.58	22.5	22.5	0.058	102	0.057	100
0047-0051	H1C	0.101	104	2.5	-11.71	9.42	-1.68	1.43	1.47	22.5	22.5	0.088	105	0.088	108
0048-0041	H1C	0.184	101	2.7	-15.77	5.26	24.11	9.16	-5.35	24.8	24.8	0.171	108	0.162	105

SACS-IV MEMBER UNITY CHECK RANGE SUMMARY

GROUP I - UNITY CHECKS GREATER THAN 0.00 AND LESS THAN 0.80

MEMBER	GROUP ID	MAXIMUM COMBINED UNITY CK	LOAD COND NO.	DIST FROM END	AXIAL STRESS N/MM2	BENDING STRESS Y N/MM2	BENDING STRESS Z N/MM2	SHEAR FORCE FY KN	SHEAR FORCE FZ KN	KLY/RY	KLZ/RZ	SECOND-HIGHEST UNITY CHECK	SECOND-HIGHEST LOAD COND	THIRD-HIGHEST UNITY CHECK	THIRD-HIGHEST LOAD COND
0049-0034	H1C	0.066	101	0.0	3.52	11.81	2.41	-1.32	-0.06	24.8	24.8	0.065	108	0.064	104
0049-0050	H1C	0.042	101	0.0	-4.63	3.16	-3.26	1.36	0.08	14.4	14.4	0.040	102	0.039	105
0050-0035	H1C	0.077	101	0.0	6.09	11.23	2.30	-1.22	-0.03	24.8	24.8	0.071	108	0.067	105
0050-0051	H1C	0.058	101	1.6	-2.66	-0.34	10.97	10.41	-2.11	14.4	14.4	0.056	105	0.048	102
0051-0037	H1C	0.193	102	2.7	-17.24	3.53	-24.65	-6.91	-5.21	24.8	24.8	0.181	101	0.144	105
0076-0105	H2A	0.153	102	2.5	21.56	4.16	10.27	18.50	-3.52	14.4	14.4	0.128	101	0.109	105
0077-0106	H2A	0.201	105	2.5	29.08	10.42	8.41	16.16	4.78	14.4	14.4	0.157	104	0.144	102
0078-0081	H2A	0.175	103	0.0	25.81	11.03	-0.18	0.93	-8.40	9.2	9.2	0.173	108	0.170	104
0079-503L	H2A	0.268	103	3.6	17.04	-30.02	33.74	48.21	-22.51	20.9	20.9	0.263	107	0.248	108
0080-0079	H2A	0.188	108	1.6	-23.69	9.70	13.36	23.17	4.64	9.2	9.2	0.169	107	0.145	103
0081-0080	H2A	0.168	108	1.6	-26.90	7.40	-1.15	-14.41	9.05	9.2	9.2	0.149	104	0.143	103
0105-504L	H2A	0.163	105	9.0	-13.56	8.36	-18.53	-11.32	-2.54	52.2	52.2	0.161	101	0.130	102
0106-502L	H2A	0.242	105	0.0	38.78	9.66	-6.23	5.09	0.91	52.2	52.2	0.212	101	0.201	104
0109-504L	H2A	0.238	104	6.0	-17.76	-21.81	-26.79	-15.86	-17.17	34.8	34.8	0.211	103	0.194	108
501L-0077	H2A	0.248	105	0.0	19.71	-28.97	-22.87	16.93	19.89	41.4	41.4	0.179	104	0.175	102
501L-0078	H2A	0.326	108	0.0	-32.38	-25.94	30.89	-38.10	21.41	20.9	20.9	0.281	107	0.267	104
502L-0109	H2A	0.165	103	0.0	-7.10	12.79	28.28	-23.99	-4.64	34.8	34.8	0.137	107	0.123	104
503L-0076	H2A	0.277	105	0.0	-20.51	-35.66	17.33	-12.12	20.85	41.4	41.4	0.214	106	0.172	102
0004-0007	H2B	0.054	104	0.0	-7.48	3.60	-1.44	-0.76	-2.79	11.5	11.5	0.054	108	0.045	105
0005-0004	H2B	0.057	102	0.0	4.73	6.58	4.90	-6.90	-1.64	11.5	11.5	0.056	105	0.050	104
0006-0005	H2B	0.067	102	1.6	7.90	6.83	0.49	-2.75	1.82	11.5	11.5	0.048	105	0.047	101
0007-0076	H2B	0.123	105	4.5	-10.74	-3.24	15.39	16.22	-2.66	32.2	32.2	0.094	101	0.092	104

SACS-IV MEMBER UNITY CHECK RANGE SUMMARY

GROUP I - UNITY CHECKS GREATER THAN 0.00 AND LESS THAN 0.80

MEMBER	GROUP ID	MAXIMUM COMBINED UNITY CK	LOAD COND NO.	DIST FROM END	AXIAL STRESS N/MM2	BENDING STRESS Y N/MM2	BENDING STRESS Z N/MM2	SHEAR FORCE FY KN	SHEAR FORCE FZ KN	KLY/RY	KLZ/RZ	SECOND-HIGHEST UNITY CHECK	SECOND-HIGHEST LOAD COND	THIRD-HIGHEST UNITY CHECK	THIRD-HIGHEST LOAD COND
0008-0079	H2B	0.077	104	2.7	2.77	-9.03	-12.70	-13.97	-2.07	19.8	19.8	0.059	108	0.056	105
0008-0107	H2B	0.165	105	1.2	10.40	-7.10	27.00	49.01	-3.04	9.0	9.0	0.119	104	0.117	101
0011-0078	H2B	0.131	102	0.0	-10.19	2.09	19.06	-15.91	-2.91	19.8	19.8	0.118	106	0.095	103
0011-0108	H2B	0.273	102	1.2	-22.25	1.95	39.23	79.69	-1.13	9.0	9.0	0.236	106	0.187	103
0012-0007	H2B	0.052	102	2.7	5.34	4.75	3.86	5.02	-0.31	19.8	19.8	0.042	101	0.034	106
0015-0006	H2B	0.058	104	0.0	-0.45	-1.21	-13.72	12.01	1.34	19.8	19.8	0.055	102	0.052	108
0077-0006	H2B	0.177	105	0.0	-16.74	-2.18	20.88	-19.56	1.72	32.2	32.2	0.150	104	0.138	101
0105-0109	H2B	0.181	102	12.0	12.79	-0.53	28.78	21.42	2.27	86.5	86.5	0.170	103	0.162	106
0106-0110	H2B	0.134	105	0.0	-10.70	-1.57	17.56	-17.71	1.84	49.4	49.4	0.102	101	0.092	104
0107-0012	H2B	0.166	105	0.0	-13.96	-8.17	21.87	-48.50	6.58	9.0	9.0	0.147	101	0.118	102
0107-0076	H2B	0.119	105	6.0	14.78	-5.31	9.80	9.67	-1.42	43.1	43.1	0.115	104	0.106	108
0108-0015	H2B	0.178	104	0.0	-8.07	-3.05	33.63	-69.82	3.16	9.0	9.0	0.156	108	0.155	102
0108-0077	H2B	0.178	105	6.0	23.11	-1.17	-15.20	-12.65	0.48	43.1	43.1	0.157	101	0.131	102
0108-501L	H2B	0.252	105	5.2	-23.15	-23.07	19.57	3.48	-7.78	37.0	37.0	0.250	106	0.203	102
0109-0106	H2B	0.303	104	0.0	-20.74	-3.85	-38.30	24.17	4.10	86.5	86.5	0.207	103	0.203	108
0110-0105	H2B	0.118	104	6.9	-12.14	-7.11	8.99	8.48	-2.72	49.4	49.4	0.114	105	0.084	101
503L-0107	H2B	0.247	104	0.0	-20.20	-32.51	-6.56	4.41	10.43	37.0	37.0	0.228	105	0.151	108
0006-0106	H2C	0.174	105	5.1	22.03	1.08	-15.48	-10.46	-0.50	46.5	46.5	0.152	104	0.149	101
0007-0110	H2C	0.057	102	0.0	6.21	6.25	1.49	-4.99	-1.46	31.5	31.5	0.049	101	0.041	106
0008-0009	H2C	0.056	107	0.0	-2.54	5.46	9.21	-8.82	0.29	14.5	14.5	0.055	106	0.053	103
0009-0010	H2C	0.054	103	1.6	5.11	5.58	4.39	4.12	1.62	14.5	14.5	0.053	104	0.051	102

SACS-IV MEMBER UNITY CHECK RANGE SUMMARY

GROUP I - UNITY CHECKS GREATER THAN 0.00 AND LESS THAN 0.80

MEMBER	GROUP ID	MAXIMUM COMBINED UNITY CK	LOAD COND NO.	DIST FROM END	AXIAL STRESS N/MM2	BENDING STRESS Y N/MM2	BENDING STRESS Z N/MM2	SHEAR FORCE FY KN	SHEAR FORCE FZ KN	KLY/RY	KLZ/RZ	SECOND-HIGHEST UNITY CHECK	SECOND-HIGHEST LOAD COND	THIRD-HIGHEST UNITY CHECK	THIRD-HIGHEST LOAD COND
0009-0080	H2C	0.033	102	2.7	1.01	-2.53	-6.45	-5.91	-2.03	25.0	25.0	0.031	106	0.031	104
0010-0011	H2C	0.077	104	1.6	6.23	4.60	-10.40	-10.69	-1.10	14.5	14.5	0.068	103	0.067	102
0010-0014	H2C	0.031	102	2.5	-2.59	3.20	-2.81	0.09	0.16	22.7	22.7	0.029	105	0.028	101
0010-0081	H2C	0.044	102	2.7	-1.06	-2.22	-9.15	-7.62	-1.88	25.0	25.0	0.043	106	0.041	103
0012-0013	H2C	0.074	105	0.0	-2.97	2.95	-14.11	16.05	1.81	14.5	14.5	0.063	101	0.052	104
0013-0004	H2C	0.025	101	0.0	-0.51	4.74	-2.67	1.64	-0.75	25.0	25.0	0.021	102	0.019	108
0013-0014	H2C	0.043	102	1.6	4.25	5.22	-0.93	1.01	0.58	14.5	14.5	0.039	106	0.036	105
0014-0005	H2C	0.023	101	0.0	-1.04	4.21	0.79	-0.63	-0.54	25.0	25.0	0.022	102	0.017	104
0014-0015	H2C	0.099	102	1.6	6.04	4.81	16.36	16.38	-0.85	14.5	14.5	0.085	106	0.072	103
0105-0007	H2C	0.088	105	0.0	8.64	-1.74	-10.87	8.69	1.05	46.5	46.5	0.078	101	0.075	104
0110-0006	H2C	0.060	102	3.5	-4.33	8.26	-3.72	-1.98	1.49	31.5	31.5	0.048	104	0.040	103
0082-0112	H3A	0.196	105	4.0	-33.99	3.99	-2.65	-6.50	8.77	19.1	19.1	0.152	106	0.139	102
0083-0113	H3A	0.246	105	0.0	42.03	-1.13	8.29	-10.48	5.92	19.1	19.1	0.193	106	0.164	104
0085-403L	H3A	0.210	103	6.1	18.11	-19.55	22.11	28.70	-16.45	29.3	29.3	0.190	104	0.160	102
0086-0087	H3A	0.160	104	0.0	25.20	6.08	5.34	-21.52	-3.81	7.7	7.7	0.147	103	0.112	108
0087-0088	H3A	0.140	104	0.0	23.04	5.03	-2.90	6.12	-6.38	7.7	7.7	0.128	103	0.110	108
0088-0085	H3A	0.138	104	1.6	21.35	0.16	-7.60	-16.42	-9.22	7.7	7.7	0.130	103	0.112	108
0112-404L	H3A	0.255	105	10.0	-27.89	20.13	-15.46	-13.32	8.82	48.0	48.0	0.183	104	0.166	106
0113-402L	H3A	0.309	105	10.0	45.47	10.43	16.67	14.21	3.16	48.0	48.0	0.212	106	0.193	104
0115-404L	H3A	0.218	108	8.5	24.98	13.07	18.58	12.81	11.47	40.8	40.8	0.202	104	0.182	103
401L-0083	H3A	0.340	105	0.0	40.14	-19.88	-27.58	30.92	14.99	34.2	34.2	0.244	104	0.219	106
401L-0086	H3A	0.250	104	0.0	27.21	5.77	-27.46	28.86	0.91	29.3	29.3	0.220	103	0.219	108

SACS-IV MEMBER UNITY CHECK RANGE SUMMARY

GROUP I - UNITY CHECKS GREATER THAN 0.00 AND LESS THAN 0.80

MEMBER	GROUP COMBINED	MAXIMUM COND	LOAD FROM	DIST STRESS	AXIAL Y	BENDING STRESS Z	SHEAR FORCE FY	FZ	KLY/RY	KLZ/RZ	SECOND-HIGHEST UNITY	LOAD	THIRD-HIGHEST UNITY	LOAD

MEMBER	ID	UNITY CK	NO.	END	N/MM2	N/MM2	N/MM2	KN	KN			CHECK	COND	CHECK	COND
402L-0115	H3A	0.157	103	0.0	-11.39	16.17	16.04	-13.81	-9.94	40.8	40.8	0.134	104	0.129	108
403L-0082	H3A	0.273	105	0.0	-34.43	-19.17	13.06	-11.57	13.03	34.2	34.2	0.201	106	0.179	101
0018-0021	H3B	0.068	105	1.6	-4.03	3.62	11.20	29.19	-0.80	9.1	9.1	0.065	102	0.065	101
0019-0018	H3B	0.069	102	0.0	7.39	4.64	6.36	-7.97	-2.95	9.1	9.1	0.053	105	0.051	101
0020-0019	H3B	0.078	102	0.0	9.39	4.66	-6.11	18.35	-0.35	9.1	9.1	0.062	105	0.062	101
0020-401L	H3B	0.117	105	9.8	-8.23	-12.47	10.70	-1.12	-2.84	55.8	55.8	0.093	102	0.092	106
0021-0082	H3B	0.051	105	7.0	-0.26	-1.58	12.31	15.49	-0.08	39.8	39.8	0.047	102	0.044	101
0022-0026	H3B	0.042	108	0.0	-4.71	4.25	-0.91	4.33	-0.73	14.3	14.3	0.034	101	0.030	104
0022-0085	H3B	0.039	103	2.7	-1.27	-2.08	-7.69	-11.16	-2.39	15.7	15.7	0.033	104	0.029	102
0025-0029	H3B	0.066	102	0.0	-8.83	4.36	-2.47	-1.92	-0.53	14.3	14.3	0.046	101	0.046	106
0025-0086	H3B	0.065	103	2.7	-1.94	-1.27	-13.65	-22.25	-2.23	15.7	15.7	0.062	104	0.060	102
0026-0021	H3B	0.057	108	0.0	-7.80	4.01	0.94	1.31	-3.55	15.7	15.7	0.054	104	0.049	101
0029-0020	H3B	0.078	105	2.7	11.20	-4.20	3.44	3.81	-2.80	15.7	15.7	0.078	102	0.062	101
0083-0020	H3B	0.080	105	0.0	-2.08	-1.80	16.73	-18.99	-0.14	39.8	39.8	0.075	104	0.057	108
0112-0114	H3B	0.070	104	0.0	-5.34	-3.21	-8.82	8.85	0.08	53.5	53.5	0.067	105	0.048	108
0114-0113	H3B	0.115	105	9.4	-11.03	-0.28	-12.01	-16.81	0.18	53.5	53.5	0.082	104	0.065	101
403L-0021	H3B	0.167	105	0.0	-21.02	-9.42	1.09	5.34	2.00	55.8	55.8	0.154	104	0.109	102
0112-0115	H3C	0.102	102	14.4	7.38	2.18	15.67	22.10	7.95	68.0	68.0	0.099	106	0.079	105
0115-0113	H3C	0.117	104	0.0	-4.59	4.17	-20.88	24.83	-2.29	68.0	68.0	0.095	108	0.085	103
0020-0113	H3D	0.128	105	8.0	15.64	-0.33	-12.23	-10.76	-0.20	57.8	57.8	0.109	104	0.093	101
0021-0114	H3D	0.077	105	0.0	-11.88	0.15	2.73	0.27	0.27	33.5	33.5	0.061	106	0.056	101

SACS-IV MEMBER UNITY CHECK RANGE SUMMARY

GROUP I - UNITY CHECKS GREATER THAN 0.00 AND LESS THAN 0.80

MEMBER	GROUP ID	MAXIMUM COMBINED UNITY CK	LOAD COND NO.	DIST FROM END	AXIAL STRESS N/MM2	BENDING STRESS Y N/MM2	BENDING STRESS Z N/MM2	SHEAR FORCE FY KN	SHEAR FORCE FZ KN	KLY/RY	KLZ/RZ	SECOND-HIGHEST UNITY CHECK	SECOND-HIGHEST LOAD COND	THIRD-HIGHEST UNITY CHECK	THIRD-HIGHEST LOAD COND
0114-0020	H3D	0.058	105	0.0	9.65	-0.71	-2.14	2.11	0.75	33.5	33.5	0.055	102	0.052	101
0022-0023	H3E	0.022	108	1.6	0.52	3.22	-3.71	-3.14	1.13	14.4	14.4	0.021	104	0.020	102
0023-0024	H3E	0.032	104	1.6	2.96	3.38	2.66	1.15	0.39	14.4	14.4	0.029	103	0.026	108
0023-0027	H3E	0.026	108	0.0	-2.48	2.72	-1.62	1.95	-0.01	22.5	22.5	0.023	104	0.021	103
0023-0088	H3E	0.022	104	2.7	0.91	-2.56	-3.35	-2.88	-0.57	24.8	24.8	0.022	103	0.020	102
0024-0025	H3E	0.043	102	1.6	2.59	1.17	7.38	6.27	-1.26	14.4	14.4	0.041	103	0.033	104
0024-0028	H3E	0.024	101	0.0	-1.83	3.40	0.80	-0.56	0.09	22.5	22.5	0.021	105	0.019	102
0024-0087	H3E	0.035	103	2.7	-2.18	-0.83	-5.60	-4.83	-0.53	24.8	24.8	0.033	102	0.031	104
0026-0027	H3E	0.025	104	1.6	-1.67	3.16	2.50	1.68	1.74	14.4	14.4	0.023	108	0.022	105
0027-0018	H3E	0.021	101	0.0	-1.26	3.26	-1.31	1.01	-0.66	24.8	24.8	0.021	105	0.020	102
0027-0028	H3E	0.018	105	0.0	0.87	3.39	0.55	1.27	-0.11	14.4	14.4	0.018	106	0.018	102
0028-0019	H3E	0.026	104	2.7	0.52	-1.05	5.62	3.89	-0.36	24.8	24.8	0.024	105	0.021	108
0028-0029	H3E	0.034	105	1.6	-2.06	-0.03	-5.73	-6.56	-1.67	14.4	14.4	0.029	104	0.027	102
0089-0116	H4A	0.215	104	5.0	34.63	-9.18	3.53	6.28	1.24	23.7	23.7	0.195	103	0.169	105
0090-0117	H4A	0.152	107	5.0	21.13	-10.01	-4.92	-5.89	-1.85	23.7	23.7	0.149	108	0.147	106
0091-0092	H4A	0.173	105	1.6	30.62	1.44	-4.34	-5.75	2.38	7.6	7.6	0.125	104	0.116	106
0092-0093	H4A	0.171	105	0.0	30.25	1.55	-4.34	-0.95	-0.81	7.6	7.6	0.121	104	0.119	106
0093-0094	H4A	0.173	105	0.0	30.63	1.46	-4.33	5.27	-2.25	7.6	7.6	0.123	106	0.114	104
0094-0121	H4A	0.176	105	3.0	29.32	-1.81	6.53	11.86	-0.80	14.2	14.2	0.133	106	0.111	104
0116-304L	H4A	0.316	104	11.5	38.55	27.63	-10.33	-1.42	17.46	54.6	54.6	0.311	105	0.236	103
0117-302L	H4A	0.248	105	11.5	23.57	27.07	15.94	8.63	16.31	54.6	54.6	0.243	106	0.205	107
0118-304L	H4A	0.236	101	11.0	29.87	20.30	3.96	-4.12	16.82	52.2	52.2	0.221	108	0.185	102

SACS-IV MEMBER UNITY CHECK RANGE SUMMARY

GROUP I - UNITY CHECKS GREATER THAN 0.00 AND LESS THAN 0.80

MEMBER	GROUP ID	MAXIMUM COMBINED UNITY CK	LOAD COND NO.	DIST FROM END	AXIAL STRESS N/MM2	BENDING STRESS Y N/MM2	BENDING STRESS Z N/MM2	SHEAR FORCE FY KN	SHEAR FORCE FZ KN	KLY/RY	KLZ/RZ	SECOND-HIGHEST UNITY CHECK	SECOND-HIGHEST LOAD COND	THIRD-HIGHEST UNITY CHECK	THIRD-HIGHEST LOAD COND
0121-303L	H4A	0.208	105	5.6	29.30	4.52	-14.05	-6.95	6.82	26.6	26.6	0.175	106	0.115	102
0122-0091	H4A	0.168	105	0.0	29.03	-2.03	4.85	-9.83	1.10	14.2	14.2	0.132	104	0.111	106
301L-0090	H4A	0.202	108	0.0	20.86	21.58	9.58	-2.91	-14.87	33.9	33.9	0.167	107	0.135	101
301L-0122	H4A	0.192	105	0.0	28.99	3.68	-10.42	3.25	-6.34	26.6	26.6	0.190	104	0.116	103
302L-0118	H4A	0.230	102	0.0	27.83	19.43	10.12	-1.87	-14.61	52.2	52.2	0.220	101	0.174	100

MEMBER	GROUP ID	MAXIMUM COMBINED UNITY CK	LOAD COND NO.	DIST FROM END	AXIAL STRESS N/MM2	BENDING STRESS Y N/MM2	BENDING STRESS Z N/MM2	SHEAR FORCE FY KN	SHEAR FORCE FZ KN	KLY/RY	KLZ/RZ	SECOND-HIGHEST UNITY CHECK	SECOND-HIGHEST LOAD COND	THIRD-HIGHEST UNITY CHECK	THIRD-HIGHEST LOAD COND
303L-0089	H4A	0.217	103	0.0	27.99	17.91	-4.97	-2.55	-15.24	33.9	33.9	0.215	104	0.190	102
0042-0053	H4B	0.062	105	1.6	8.89	1.68	-3.93	-5.56	-1.59	9.1	9.1	0.055	106	0.045	104
0043-0042	H4B	0.054	105	0.0	8.26	2.91	0.77	-1.45	-0.34	9.1	9.1	0.049	106	0.042	104
0052-0043	H4B	0.064	105	0.0	8.91	1.58	-4.47	6.06	1.54	9.1	9.1	0.050	106	0.048	104
0053-0119	H4B	0.086	105	0.0	10.12	1.79	-8.59	8.68	-5.35	17.1	17.1	0.069	100	0.063	106
0090-0120	H4B	0.039	104	0.0	-2.03	1.82	6.62	-6.09	-1.72	37.0	37.0	0.034	105	0.031	103
0116-0118	H4B	0.075	102	17.2	3.00	3.68	14.41	12.14	4.43	97.9	97.9	0.058	106	0.056	105
0116-0119	H4B	0.102	105	0.0	15.38	-3.24	-5.16	6.65	-1.69	46.7	46.7	0.100	104	0.060	103
0116-0123	H4B	0.126	105	0.0	-12.79	3.76	-9.69	11.62	-2.95	67.8	67.8	0.102	104	0.064	106
0118-0117	H4B	0.117	104	0.0	-6.30	3.29	-15.74	13.17	-1.88	97.9	97.9	0.078	105	0.073	108
0119-0089	H4B	0.037	105	6.5	-0.44	-0.57	8.54	10.21	1.03	37.0	37.0	0.028	101	0.025	102
0119-0123	H4B	0.037	108	0.0	-2.70	4.91	-2.24	1.48	-3.90	42.0	42.0	0.033	104	0.031	103
0120-0052	H4B	0.091	105	3.0	10.26	1.52	-9.65	-10.99	5.35	17.1	17.1	0.069	100	0.068	106
0120-0117	H4B	0.097	105	8.2	15.02	-2.10	-4.91	-6.08	2.05	46.7	46.7	0.081	106	0.067	104
0121-0119	H4B	0.033	108	0.0	-1.03	5.33	-4.12	4.22	-2.05	45.7	45.7	0.031	101	0.030	103
0122-0120	H4B	0.031	102	0.0	-0.68	4.27	5.28	-4.94	-1.51	45.7	45.7	0.031	103	0.029	108

SACS-IV MEMBER UNITY CHECK RANGE SUMMARY

GROUP I - UNITY CHECKS GREATER THAN 0.00 AND LESS THAN 0.80

MEMBER	GROUP ID	MAXIMUM COMBINED UNITY CK	LOAD COND NO.	DIST FROM END	AXIAL STRESS N/MM2	BENDING STRESS Y N/MM2	BENDING STRESS Z N/MM2	SHEAR FORCE FY KN	SHEAR FORCE FZ KN	KLY/RY	KLZ/RZ	SECOND-HIGHEST UNITY CHECK	SECOND-HIGHEST LOAD COND	THIRD-HIGHEST UNITY CHECK	THIRD-HIGHEST LOAD COND
0123-0120	H4B	0.048	104	7.4	-5.37	3.55	-2.22	-5.96	3.10	42.0	42.0	0.044	103	0.034	108
301L-0120	H4B	0.092	101	0.0	6.85	13.57	4.41	0.37	-5.28	53.9	53.9	0.082	100	0.081	102
303L-0119	H4B	0.099	100	0.0	4.13	13.18	-0.70	0.22	-6.23	53.9	53.9	0.090	108	0.087	101
0054-0058	H4C	0.035	105	0.0	-4.19	1.85	2.75	-1.50	0.36	18.0	18.0	0.028	106	0.027	101
0054-0094	H4C	0.050	105	0.0	-6.54	1.76	-3.41	2.71	-2.28	19.8	19.8	0.046	104	0.043	108
0057-0061	H4C	0.036	105	0.0	-4.17	2.00	-2.82	1.57	0.16	18.0	18.0	0.032	104	0.027	101
0057-0091	H4C	0.053	105	0.0	-6.97	1.93	3.37	-2.62	-2.51	19.8	19.8	0.045	102	0.041	104
0058-0053	H4C	0.028	105	2.7	-1.04	-1.97	-5.24	-4.56	-2.62	19.8	19.8	0.024	108	0.023	106
0061-0052	H4C	0.030	105	2.7	-1.01	-1.86	5.79	4.98	-2.41	19.8	19.8	0.027	104	0.023	102
0119-0094	H4C	0.078	104	8.5	9.28	1.90	-7.54	-5.89	0.67	61.4	61.4	0.074	108	0.054	105
0120-0091	H4C	0.082	102	8.5	-8.99	2.48	-5.74	-4.87	-0.02	61.4	61.4	0.058	105	0.058	106
0054-0055	H4D	0.019	104	1.6	1.09	1.53	2.91	2.24	0.87	14.4	14.4	0.018	105	0.016	108
0055-0056	H4D	0.017	104	1.6	0.99	1.67	2.48	1.40	0.23	14.4	14.4	0.016	106	0.015	105
0055-0059	H4D	0.019	100	2.5	0.75	2.51	0.11	0.01	0.04	22.5	22.5	0.018	108	0.016	107
0055-0093	H4D	0.018	104	2.7	-0.82	-1.48	-3.16	-2.03	-0.89	24.8	24.8	0.018	102	0.017	106
0056-0057	H4D	0.018	102	1.6	-0.54	0.42	3.73	3.53	-0.63	14.4	14.4	0.018	105	0.015	104
0056-0060	H4D	0.018	100	0.0	0.72	2.47	-0.18	0.04	-0.02	22.5	22.5	0.016	106	0.015	108
0056-0092	H4D	0.018	104	2.7	-1.14	-1.39	-2.73	-2.09	-0.86	24.8	24.8	0.017	101	0.017	102
0058-0059	H4D	0.017	105	0.0	0.39	0.19	-3.77	3.75	0.79	14.4	14.4	0.012	104	0.009	106
0059-0042	H4D	0.016	101	0.0	0.32	3.46	-0.08	0.01	-0.84	24.8	24.8	0.014	108	0.014	102
0059-0060	H4D	0.010	105	0.0	-0.29	1.99	-0.13	0.87	-0.14	14.4	14.4	0.009	104	0.008	108
0060-0043	H4D	0.016	101	0.0	0.43	3.35	0.11	-0.03	-0.81	24.8	24.8	0.014	102	0.014	108

SACS-IV MEMBER UNITY CHECK RANGE SUMMARY

GROUP I - UNITY CHECKS GREATER THAN 0.00 AND LESS THAN 0.80

MEMBER	GROUP ID	MAXIMUM COMBINED UNITY CK	LOAD COND NO.	DIST FROM END	AXIAL STRESS N/MM2	BENDING STRESS Y N/MM2	BENDING STRESS Z N/MM2	SHEAR FORCE FY KN	SHEAR FORCE FZ KN	KLY/RY	KLZ/RZ	SECOND-HIGHEST UNITY CHECK	SECOND-HIGHEST LOAD COND	THIRD-HIGHEST UNITY CHECK	THIRD-HIGHEST LOAD COND
0060-0061	H4D	0.019	105	1.6	0.54	-0.10	-3.95	-3.88	-1.04	14.4	14.4	0.012	104	0.012	106
0095-0130	H5A	0.064	100	0.0	0.03	11.92	-0.01	0.03	-4.19	26.5	26.5	0.053	101	0.053	102
0096-0129	H5A	0.054	100	0.0	0.00	9.98	0.02	-0.04	-2.96	26.5	26.5	0.045	101	0.044	108
0097-0125	H5A	0.089	100	0.0	0.03	16.59	-0.02	0.09	-2.52	17.6	17.6	0.072	102	0.071	103
0098-0100	H5A	0.085	100	1.6	0.05	15.76	-0.02	-0.05	1.76	7.1	7.1	0.072	105	0.071	104
0099-0097	H5A	0.089	100	1.6	0.05	16.42	-0.01	0.05	1.80	7.1	7.1	0.074	105	0.072	102
0100-0099	H5A	0.086	100	1.6	0.05	15.97	-0.03	-0.01	1.77	7.1	7.1	0.073	105	0.070	101
0125-203L	H5A	0.192	100	8.6	0.02	-35.71	-0.08	-0.08	-33.66	37.9	37.9	0.152	103	0.151	104
0126-0098	H5A	0.084	100	4.0	0.03	15.59	-0.02	-0.09	5.52	17.6	17.6	0.070	104	0.068	103
0129-0308	H5A	0.066	100	7.0	0.01	12.28	0.02	0.04	5.60	30.9	30.9	0.055	105	0.053	106
0130-0307	H5A	0.064	100	7.0	0.03	11.84	-0.01	-0.03	4.51	30.9	30.9	0.054	105	0.053	104

0131-0408	H5A	0.065	100	7.6	0.07	12.05	-0.01	-0.02	8.65	33.3	33.3	0.052	108	0.051	105
0307-204L	H5A	0.168	100	6.6	0.03	-31.29	-0.05	-0.04	-37.75	29.3	29.3	0.134	101	0.132	108
0308-202L	H5A	0.159	100	6.6	0.01	-29.64	0.06	0.04	-36.67	29.3	29.3	0.127	101	0.126	102
0408-204L	H5A	0.148	100	6.6	0.05	-27.45	-0.04	-0.03	-34.78	29.1	29.1	0.115	104	0.115	103
0409-0131	H5A	0.065	100	0.0	0.07	12.03	-0.01	0.02	-8.74	33.3	33.3	0.052	102	0.052	103
201L-0096	H5A	0.141	100	0.0	0.00	-26.17	-0.09	0.11	29.43	31.6	31.6	0.117	105	0.114	104
201L-0126	H5A	0.201	100	0.0	0.02	-37.35	-0.10	0.11	37.02	34.2	34.2	0.157	108	0.156	106
202L-0409	H5A	0.148	100	0.0	0.05	-27.37	-0.05	0.04	34.69	29.1	29.1	0.113	108	0.113	106
203L-0095	H5A	0.148	100	0.0	0.01	-27.48	0.07	-0.07	28.91	35.3	35.3	0.123	105	0.118	104
0002-0016	H5B	0.014	100	0.0	0.02	2.58	-0.02	0.02	-4.05	30.3	30.3	0.013	103	0.012	104

SACS-IV MEMBER UNITY CHECK RANGE SUMMARY

GROUP I - UNITY CHECKS GREATER THAN 0.00 AND LESS THAN 0.80

MEMBER	GROUP ID	MAXIMUM COMBINED UNITY CK	LOAD COND NO.	DIST FROM END	AXIAL STRESS N/MM2	BENDING STRESS Y N/MM2	BENDING STRESS Z N/MM2	SHEAR FORCE FY KN	SHEAR FORCE FZ KN	KLY/RY	KLZ/RZ	SECOND-HIGHEST UNITY CHECK	SECOND-HIGHEST LOAD COND	THIRD-HIGHEST UNITY CHECK	THIRD-HIGHEST LOAD COND
0003-0403	H5B	0.115	100	8.1	0.06	20.87	0.02	0.02	17.26	38.5	38.5	0.098	105	0.097	104
0016-0130	H5B	0.029	105	0.0	-1.09	5.34	1.33	-4.68	-5.61	40.7	40.7	0.028	100	0.025	106
0016-0131	H5B	0.034	100	0.0	0.00	6.21	0.00	0.00	-8.74	75.0	75.0	0.033	102	0.031	103
0017-0096	H5B	0.069	100	0.0	0.00	-12.53	0.03	-0.04	5.35	27.8	27.8	0.055	105	0.054	106
0017-0127	H5B	0.094	100	5.9	0.01	17.15	0.00	0.00	13.19	27.8	27.8	0.076	102	0.075	105
0030-0095	H5B	0.066	100	0.0	0.00	-12.13	-0.02	0.03	4.68	27.8	27.8	0.054	104	0.053	105
0030-0124	H5B	0.094	100	5.9	0.01	17.15	-0.01	0.00	11.45	27.8	27.8	0.076	104	0.075	105
0064-0067	H5B	0.047	105	1.6	-2.08	8.54	-2.53	-4.55	0.34	7.6	7.6	0.047	100	0.045	104
0065-0064	H5B	0.047	100	1.6	0.00	8.52	0.00	0.00	1.10	7.6	7.6	0.046	105	0.043	101
0066-0065	H5B	0.046	100	1.6	0.00	8.31	0.00	0.07	1.97	7.6	7.6	0.045	105	0.043	102
0067-0124	H5B	0.049	105	0.0	-1.97	8.85	-2.91	3.99	-3.58	18.9	18.9	0.047	100	0.046	104
0096-0127	H5B	0.036	100	0.0	0.00	-6.65	0.01	0.00	0.54	40.7	40.7	0.032	105	0.030	106
0124-0095	H5B	0.034	100	8.6	0.00	-6.18	0.00	0.00	-0.82	40.7	40.7	0.030	105	0.029	104
0125-0030	H5B	0.067	100	5.9	0.00	-12.25	0.01	0.01	-6.00	27.8	27.8	0.054	105	0.054	104
0126-0017	H5B	0.070	100	5.9	0.00	-12.81	-0.02	-0.02	-5.86	27.8	27.8	0.056	105	0.055	106
0127-0066	H5B	0.046	105	4.0	-1.96	8.17	-2.89	-3.94	4.25	18.9	18.9	0.044	100	0.043	102
0129-0003	H5B	0.029	105	8.6	-1.08	5.33	1.30	4.66	5.85	40.7	40.7	0.028	104	0.028	100
0131-0003	H5B	0.036	104	15.8	-0.42	6.79	-4.52	-6.55	8.70	75.0	75.0	0.036	100	0.033	103
0309-0016	H5B	0.114	100	0.0	0.06	20.79	0.01	-0.02	-16.92	38.5	38.5	0.097	105	0.092	106
0403-202L	H5B	0.170	100	7.9	0.02	-31.03	0.04	0.01	-19.19	37.2	37.2	0.135	101	0.135	108
201L-0017	H5B	0.211	100	0.0	0.01	-38.56	-0.13	0.14	27.93	23.8	23.8	0.171	105	0.168	106
203L-0030	H5B	0.206	100	0.0	0.02	-37.68	0.09	-0.08	24.84	27.8	27.8	0.168	104	0.166	105

SACS-IV MEMBER UNITY CHECK RANGE SUMMARY

GROUP I - UNITY CHECKS GREATER THAN 0.00 AND LESS THAN 0.80

MEMBER	GROUP ID	MAXIMUM COMBINED UNITY CK	LOAD COND NO.	DIST FROM END	AXIAL STRESS N/MM2	BENDING STRESS Y N/MM2	BENDING STRESS Z N/MM2	SHEAR FORCE FY KN	SHEAR FORCE FZ KN	KLY/RY	KLZ/RZ	SECOND-HIGHEST UNITY CHECK	SECOND-HIGHEST LOAD COND	THIRD-HIGHEST UNITY CHECK	THIRD-HIGHEST LOAD COND
204L-0309	H5B	0.175	100	0.0	0.02	-31.87	0.03	-0.01	19.53	37.2	37.2	0.139	102	0.139	101
0002-0127	H5C	0.096	100	8.8	0.00	17.94	0.01	0.00	7.57	50.1	50.1	0.076	102	0.076	103
0124-0002	H5C	0.099	100	0.0	0.00	18.47	0.01	0.00	-7.90	50.1	50.1	0.078	108	0.078	104
0124-0016	H5C	0.085	100	0.0	0.06	15.70	0.02	-0.01	-9.80	34.3	34.3	0.070	102	0.069	101
0124-0125	H5C	0.037	100	0.0	0.00	6.82	0.01	0.00	-4.67	45.7	45.7	0.030	102	0.029	101
0126-0127	H5C	0.035	100	8.0	0.00	6.55	0.01	0.00	4.66	45.7	45.7	0.028	108	0.028	101
0127-0003	H5C	0.082	100	0.0	0.05	15.10	-0.02	0.01	-9.46	34.3	34.3	0.067	101	0.067	108
0127-0129	H5C	0.022	105	0.0	1.81	-1.21	-2.82	3.80	-1.80	59.9	59.9	0.019	102	0.016	101
0130-0124	H5C	0.021	105	0.0	1.80	0.37	-2.88	3.80	-2.31	59.9	59.9	0.020	104	0.017	108
0097-0124	H5D	0.032	104	0.0	3.23	2.03	3.34	-3.13	-0.41	64.3	64.3	0.030	108	0.028	105
0098-0127	H5D	0.032	102	0.0	-2.81	2.02	2.95	-2.78	-0.40	64.3	64.3	0.027	105	0.025	101
0068-0069	H5E	0.029	100	1.6	0.01	5.47	0.02	0.01	2.09	14.4	14.4	0.024	105	0.024	102
0068-0072	H5E	0.019	102	2.5	1.18	3.30	0.17	0.43	0.05	22.5	22.5	0.017	100	0.017	105
0068-0097	H5E	0.034	105	0.0	-2.82	4.65	0.67	-0.64	-2.33	24.8	24.8	0.030	101	0.030	104
0069-0070	H5E	0.028	100	1.6	-0.01	5.28	0.00	0.00	0.06	14.4	14.4	0.024	105	0.023	104
0069-0073	H5E	0.013	100	0.0	-0.01	2.35	0.01	0.00	-0.15	22.5	22.5	0.012	101	0.012	102

MEMBER	GROUP ID	MAXIMUM COMBINED UNITY CK	LOAD COND NO.	DIST FROM END	AXIAL STRESS N/MM2	BENDING STRESS Y N/MM2	BENDING STRESS Z N/MM2	SHEAR FORCE FY KN	SHEAR FORCE FZ KN	KLY/RY	KLZ/RZ	SECOND-HIGHEST UNITY CHECK	SECOND-HIGHEST LOAD COND	THIRD-HIGHEST UNITY CHECK	THIRD-HIGHEST LOAD COND
0069-0099	H5E	0.010	100	0.0	0.00	1.82	0.00	0.00	-0.27	24.8	24.8	0.009	102	0.009	101
0070-0071	H5E	0.026	100	0.0	0.00	4.83	0.01	-0.01	-1.59	14.4	14.4	0.021	104	0.021	105
0070-0074	H5E	0.013	100	0.0	-0.01	2.41	0.00	0.00	-0.19	22.5	22.5	0.012	101	0.012	108
0070-0100	H5E	0.011	100	0.0	0.00	2.02	0.00	0.00	-0.39	24.8	24.8	0.010	108	0.010	101
0071-0075	H5E	0.020	104	0.0	-1.34	3.28	0.02	-0.37	-0.21	22.5	22.5	0.019	108	0.018	100

SACS-IV MEMBER UNITY CHECK RANGE SUMMARY

GROUP I - UNITY CHECKS GREATER THAN 0.00 AND LESS THAN 0.80

MEMBER	GROUP ID	MAXIMUM COMBINED UNITY CK	LOAD COND NO.	DIST FROM END	AXIAL STRESS N/MM2	BENDING STRESS Y N/MM2	BENDING STRESS Z N/MM2	SHEAR FORCE FY KN	SHEAR FORCE FZ KN	KLY/RY	KLZ/RZ	SECOND-HIGHEST UNITY CHECK	SECOND-HIGHEST LOAD COND	THIRD-HIGHEST UNITY CHECK	THIRD-HIGHEST LOAD COND
0072-0067	H5E	0.023	100	2.7	0.01	-4.19	-0.02	-0.01	-2.19	24.8	24.8	0.022	104	0.021	105
0072-0073	H5E	0.021	100	1.6	0.00	3.89	0.01	0.01	1.31	14.4	14.4	0.017	102	0.017	106
0073-0064	H5E	0.010	100	0.0	-0.01	1.76	0.00	0.00	-0.88	24.8	24.8	0.009	101	0.009	102
0073-0074	H5E	0.023	100	0.0	0.00	4.32	0.00	0.00	-0.18	14.4	14.4	0.018	105	0.018	102
0074-0065	H5E	0.009	100	0.0	-0.01	1.63	0.00	0.00	-0.83	24.8	24.8	0.009	108	0.009	101
0074-0075	H5E	0.022	100	0.0	0.00	4.17	0.01	-0.01	-1.63	14.4	14.4	0.018	104	0.018	108
0075-0066	H5E	0.021	100	2.7	0.00	-3.85	0.02	0.01	-1.95	24.8	24.8	0.020	102	0.019	105
101L-201L	L1A	0.358	105	0.0	-44.78	1.84	32.66	-2653.37	-572.40	1.8	1.8	0.325	106	0.212	107
102L-202L	L1A	0.310	108	0.0	-49.77	14.61	-0.89	-72.34	-1442.27	1.8	1.8	0.262	101	0.236	104
103L-203L	L1A	0.395	104	0.0	-55.23	12.19	-26.08	2120.80	-1333.94	1.8	1.8	0.369	105	0.258	103
104L-204L	L1A	0.328	102	0.0	-52.12	16.16	1.96	-112.83	-1536.59	1.8	1.8	0.264	101	0.244	103
201L-301L	L1B	0.422	106	2.0	-59.86	6.30	10.74	-69.44	-24.02	46.0	46.0	0.418	105	0.298	107
202L-302L	L1B	0.443	108	2.0	-65.36	8.92	-1.79	16.43	-33.44	46.4	46.4	0.366	101	0.296	107
203L-303L	L1B	0.506	104	2.0	-69.74	6.47	-16.09	119.33	-23.16	46.0	46.0	0.434	105	0.352	103
204L-304L	L1B	0.467	102	2.0	-68.47	9.97	1.64	-6.73	-43.69	46.4	46.4	0.365	101	0.354	103
301L-401L	L1C	0.296	106	18.2	-43.60	7.61	4.80	70.51	59.13	36.8	36.8	0.269	105	0.222	107
302L-402L	L1C	0.335	108	18.3	-51.98	5.92	-2.39	-26.82	63.22	37.1	37.1	0.270	101	0.252	107
303L-403L	L1C	0.339	104	18.2	-49.41	3.38	-10.52	-136.36	32.52	36.8	36.8	0.270	105	0.253	103
304L-404L	L1C	0.360	102	18.3	-54.29	8.69	-2.72	-11.76	84.78	37.1	37.1	0.299	103	0.275	101
401L-501L	L1D	0.200	106	2.0	-28.64	7.34	0.74	-37.81	-83.66	36.8	36.8	0.179	107	0.148	108
402L-502L	L1D	0.253	108	2.0	-39.20	4.40	-1.91	28.08	-48.02	37.1	37.1	0.236	101	0.186	107
403L-503L	L1D	0.239	105	2.0	-31.92	-1.07	-12.31	137.65	26.17	36.8	36.8	0.238	104	0.161	103

SACS-IV MEMBER UNITY CHECK RANGE SUMMARY

GROUP I - UNITY CHECKS GREATER THAN 0.00 AND LESS THAN 0.80

MEMBER	GROUP ID	MAXIMUM COMBINED UNITY CK	LOAD COND NO.	DIST FROM END	AXIAL STRESS N/MM2	BENDING STRESS Y N/MM2	BENDING STRESS Z N/MM2	SHEAR FORCE FY KN	SHEAR FORCE FZ KN	KLY/RY	KLZ/RZ	SECOND-HIGHEST UNITY CHECK	SECOND-HIGHEST LOAD COND	THIRD-HIGHEST UNITY CHECK	THIRD-HIGHEST LOAD COND
404L-504L	L1D	0.298	103	2.0	-45.29	3.87	-5.97	100.27	-11.63	37.1	37.1	0.288	102	0.256	104
501L-0451	L1E	0.099	105	4.5	-13.72	-3.66	-3.76	-65.26	11.34	7.7	7.7	0.096	106	0.077	107
502L-0157	L1E	0.213	108	8.3	-32.75	-6.84	4.00	-11.76	-54.44	15.0	15.0	0.205	107	0.200	100
503L-0452	L1E	0.121	104	4.5	-13.05	-2.98	10.51	156.11	-104.22	7.7	7.7	0.116	103	0.109	102
504L-0181	L1E	0.233	102	8.3	-30.44	-15.98	-2.84	-96.79	-174.25	15.0	15.0	0.232	101	0.219	103
0455-601L	L1F	0.060	105	1.0	-8.01	-3.34	3.57	179.05	-38.56	1.8	1.8	0.053	100	0.052	106
0456-604L	L1F	0.155	100	1.0	-14.38	-10.42	-2.90	-69.24	-156.91	1.8	1.8	0.134	104	0.131	103
0457-602L	L1F	0.141	100	1.0	-14.61	-7.67	-1.87	-39.34	-124.57	1.8	1.8	0.137	107	0.128	108
0458-603L	L1F	0.058	102	1.0	-7.69	-1.73	4.40	316.83	290.96	1.8	1.8	0.057	103	0.053	104
601L-701L	L1G	0.051	105	0.0	-1.81	-3.08	10.03	-361.26	146.97	1.8	1.8	0.044	106	0.033	104
602L-702L	L1G	0.125	100	0.0	-13.86	-5.18	-2.67	8.49	803.49	1.8	1.8	0.124	103	0.123	102
603L-703L	L1G	0.036	105	0.0	-2.00	-2.14	-6.04	238.92	118.18	1.8	1.8	0.035	104	0.032	106
604L-704L	L1G	0.146	100	0.0	-15.39	-7.81	0.16	30.69	959.67	1.8	1.8	0.142	104	0.140	105
701L-801L	L1H	0.103	105	0.0	-4.31	-5.23	19.19	-347.59	142.27	1.9	1.9	0.089	106	0.064	101
702L-802L	L1H	0.328	100	1.0	-34.53	16.31	-6.54	8.49	794.97	1.9	1.9	0.318	107	0.305	108
703L-803L	L1H	0.076	104	0.0	-5.85	5.74	-9.69	200.18	17.94	1.9	1.9	0.072	105	0.071	103
704L-804L	L1H	0.342	100	1.0	-38.40	15.34	1.54	30.69	951.14	1.9	1.9	0.336	103	0.335	102
0038-0427	L1L	0.104	106	0.0	-11.45	-8.67	-2.24	-8.83	-20.40	10.7	10.7	0.101	105	0.089	104
0181-0404	L1L	0.228	102	0.0	-30.01	-15.98	-2.84	-50.28	-10.95	10.8	10.8	0.228	101	0.227	100
0451-0038	L1L	0.103	106	3.7	-11.45	-8.67	-2.24	-8.83	-20.40	6.8	6.8	0.100	105	0.088	104
0452-0039	L1L	0.149	103	3.7	-14.57	-14.81	3.75	1.97	-161.27	6.8	6.8	0.148	104	0.147	105

SACS-IV MEMBER UNITY CHECK RANGE SUMMARY

GROUP I - UNITY CHECKS GREATER THAN 0.00 AND LESS THAN 0.80

MEMBER	GROUP ID	MAXIMUM COMBINED UNITY CK	LOAD COND NO.	DIST FROM END	AXIAL STRESS N/MM2	BENDING STRESS Y N/MM2	BENDING STRESS Z N/MM2	SHEAR FORCE FY KN	SHEAR FORCE FZ KN	KLY/RY	KLZ/RZ	SECOND-HIGHEST UNITY CHECK	SECOND-HIGHEST LOAD COND	THIRD-HIGHEST UNITY CHECK	THIRD-HIGHEST LOAD COND
0157-0457	L1X	0.219	107	6.9	-32.72	-6.73	6.79	77.47	-30.63	14.5	14.5	0.217	100	0.212	108
0404-0456	L1X	0.231	100	1.0	-22.38	-12.85	-3.16	-54.24	-155.02	3.5	3.5	0.219	102	0.208	103
0427-0455	L1X	0.094	106	0.0	-10.70	-7.79	-0.40	63.80	44.43	3.5	3.5	0.090	105	0.084	100
0454-0458	L1X	0.113	103	0.0	-13.36	-8.21	3.54	-3.27	152.91	3.5	3.5	0.109	104	0.107	102
0412-501L	R1A	0.379	102	8.1	53.14	-17.67	21.05	38.51	-37.53	35.7	35.7	0.371	103	0.347	106
504L-0413	R1A	0.393	103	8.1	-64.21	-9.29	2.38	-3.07	10.00	35.9	35.9	0.365	104	0.324	107
402L-504L	R1B	0.595	108	23.1	-58.96	28.07	-8.31	-28.20	47.90	88.0	88.0	0.549	107	0.420	106
501L-403L	R1B	0.712	103	0.0	-74.76	25.01	-5.50	3.68	-42.93	87.6	87.6	0.638	102	0.589	104
301L-0104	R1C	0.354	106	0.0	-47.96	0.28	-10.99	12.53	6.33	65.8	64.4	0.336	108	0.320	107
302L-0063	R1C	0.315	108	0.0	-39.84	1.22	14.55	-15.98	6.35	66.0	64.7	0.263	107	0.214	106
303L-0104	R1C	0.358	104	0.0	-45.75	-0.06	-15.69	17.63	-8.23	65.8	64.4	0.353	103	0.321	102
304L-0063	R1C	0.375	103	15.0	-53.39	7.28	0.05	-0.44	13.11	66.0	64.7	0.346	102	0.332	104
401L-0104	R1C	0.388	103	0.0	-50.64	14.02	-8.38	4.83	-14.61	51.8	64.4	0.363	104	0.361	102
402L-0063	R1C	0.399	103	0.0	-53.48	12.61	7.10	-4.09	-12.79	52.0	64.7	0.373	104	0.353	102
403L-0104	R1C	0.374	106	0.0	-48.44	-11.29	11.67	-15.47	11.98	51.8	64.4	0.363	108	0.333	107
404L-0063	R1C	0.320	108	0.0	-40.06	-12.23	-11.32	17.14	14.70	52.0	64.7	0.277	107	0.248	106
201L-0103	R1D	0.325	106	0.0	-38.16	-0.44	-10.58	9.37	0.90	84.9	81.7	0.267	105	0.249	108
202L-0031	R1D	0.328	108	0.0	-38.07	-0.25	11.11	-10.69	1.03	85.3	82.0	0.222	107	0.222	101
203L-0103	R1D	0.404	104	0.0	-43.34	-1.45	15.91	-14.96	3.01	90.8	81.7	0.331	103	0.290	102
204L-0031	R1D	0.311	102	0.0	-35.19	-0.08	-12.31	11.99	1.15	85.3	82.0	0.273	103	0.234	104
301L-0103	R1D	0.359	104	0.0	-42.87	-8.52	-8.86	14.57	8.78	67.1	81.7	0.323	103	0.269	102
302L-0031	R1D	0.291	102	0.0	-34.68	-8.13	6.48	-12.17	8.35	67.4	82.0	0.282	103	0.216	104

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SACS-IV MEMBER UNITY CHECK RANGE SUMMARY

GROUP I - UNITY CHECKS GREATER THAN 0.00 AND LESS THAN 0.80

MEMBER	GROUP ID	MAXIMUM COMBINED UNITY CK	LOAD COND NO.	DIST FROM END	AXIAL STRESS N/MM2	BENDING STRESS Y N/MM2	BENDING STRESS Z N/MM2	SHEAR FORCE FY KN	SHEAR FORCE FZ KN	KLY/RY	KLZ/RZ	SECOND-HIGHEST UNITY CHECK	SECOND-HIGHEST LOAD COND	THIRD-HIGHEST UNITY CHECK	THIRD-HIGHEST LOAD COND
303L-0103	R1D	0.308	106	0.0	-37.73	-8.14	4.57	-8.60	7.33	67.1	81.7	0.247	107	0.238	108
304L-0031	R1D	0.314	108	0.0	-37.64	-8.07	-6.91	11.63	8.02	67.4	82.0	0.230	107	0.197	101
0413-602L	RA1	0.469	103	9.4	-65.77	21.30	-11.23	-11.87	18.70	43.4	43.4	0.452	104	0.411	107
603L-0412	RA1	0.420	103	0.0	61.96	-26.60	-2.14	1.77	55.29	43.1	43.1	0.409	102	0.359	104
0410-604L	RAB	0.617	105	11.8	-85.80	23.17	-17.69	-17.48	10.84	46.7	46.7	0.483	104	0.454	106
0411-601L	RAB	0.616	105	12.6	74.99	-57.26	13.97	11.90	-101.11	49.6	49.6	0.509	104	0.476	106
404L-503L	RAC	0.607	105	27.8	98.67	-25.05	-8.90	-12.30	-34.77	88.0	88.0	0.557	101	0.459	104
302L-0084	RAD	0.394	105	0.0	75.23	1.05	-3.47	1.23	6.55	69.6	69.6	0.361	104	0.329	101
304L-0102	RAD	0.356	105	0.0	67.65	-1.91	3.12	-1.30	9.43	69.6	69.6	0.311	101	0.293	102
401L-0084	RAD	0.417	105	0.0	74.72	-5.75	-8.04	4.53	5.82	62.7	62.7	0.345	104	0.326	101
403L-0102	RAD	0.393	105	0.0	66.88	-13.06	4.83	-2.81	12.06	62.7	62.7	0.319	101	0.291	104
201L-0062	RAE	0.655	105	0.0	-88.05	-6.87	1.12	-0.83	9.33	78.2	75.1	0.486	104	0.462	106
203L-0101	RAE	0.707	105	0.0	-90.43	7.76	0.85	-0.64	-10.09	83.4	75.1	0.600	104	0.407	106
302L-0062	RAE	0.661	105	0.0	-88.11	-10.94	3.54	-1.43	11.21	69.5	75.1	0.475	104	0.456	106
304L-0101	RAE	0.694	105	0.0	-90.46	14.56	1.93	-0.85	-13.49	69.5	75.1	0.573	104	0.387	106
202L-0062	RAX	0.390	101	0.0	-49.77	6.75	1.17	-1.18	-9.68	82.4	74.5	0.376	108	0.376	105
204L-0101	RAX	0.454	102	0.0	-52.25	4.97	-16.93	13.15	-8.09	82.4	74.5	0.446	101	0.430	105
301L-0062	RAX	0.386	105	0.0	70.20	-6.24	-5.01	2.73	4.05	73.3	73.3	0.385	101	0.363	108
303L-0101	RAX	0.440	102	0.0	-52.56	11.22	15.08	-15.37	-12.18	73.3	74.5	0.434	101	0.428	105
301L-0084	RAY	0.445	105	0.0	-64.23	6.42	3.59	-1.56	4.16	65.4	63.4	0.353	104	0.316	106
303L-0102	RAY	0.651	105	0.0	-93.72	9.37	-2.40	0.91	1.79	65.4	63.4	0.524	104	0.413	106

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SACS-IV MEMBER UNITY CHECK RANGE SUMMARY

GROUP I - UNITY CHECKS GREATER THAN 0.00 AND LESS THAN 0.80

MEMBER	GROUP ID	MAXIMUM COMBINED UNITY CK	LOAD COND NO.	DIST FROM END	AXIAL STRESS N/MM2	BENDING STRESS Y N/MM2	BENDING STRESS Z N/MM2	SHEAR FORCE FY KN	SHEAR FORCE FZ KN	KLY/RY	KLZ/RZ	SECOND-HIGHEST UNITY CHECK	SECOND-HIGHEST LOAD COND	THIRD-HIGHEST UNITY CHECK	THIRD-HIGHEST LOAD COND
404L-0102	RAY	0.661	105	0.0	-93.55	-13.99	-3.29	2.61	11.16	58.9	63.4	0.522	104	0.419	106

502L-0411	RBA	0.478	105	0.0	71.41	-29.32	-1.55	-3.19	58.00	44.0	44.0	0.424	104	0.373	106
503L-0410	RBA	0.552	105	10.9	-83.91	-18.41	4.82	-6.22	7.00	41.5	41.5	0.466	104	0.371	106

SACS-IV MEMBER UNITY CHECK RANGE SUMMARY

GROUP II - UNITY CHECKS GREATER THAN 0.80 AND LESS THAN 1.00

MEMBER	GROUP ID	MAXIMUM COMBINED UNITY CK	LOAD COND NO.	DIST FROM END	AXIAL STRESS N/MM2	BENDING STRESS Y N/MM2	BENDING STRESS Z N/MM2	SHEAR FORCE FY KN	SHEAR FORCE FZ KN	KLY/RY	KLZ/RZ	SECOND-HIGHEST UNITY CHECK	SECOND-HIGHEST LOAD COND	THIRD-HIGHEST UNITY CHECK	THIRD-HIGHEST LOAD COND
401L-502L	RAC	0.824	105	26.2	-84.80	33.12	10.23	13.71	62.83	82.8	82.8	0.628	104	0.522	106

SACS-IV MEMBER UNITY CHECK RANGE SUMMARY

GROUP III - UNITY CHECKS GREATER THAN 1.00

** NO UNITY CHECKS IN THIS GROUP **

APPENDIX-5

Joint Unity Check Output

* * J O I N T   C A N   S U M M A R Y * *
(UNITY CHECK ORDER)
**************** ORIGINAL *************   ***************** DESIGN **************

JOINT	DIAMETER	THICKNESS	YLD STRS	UC	DIAMETER	THICKNESS	YLD STRS	UC
(CM)	(CM)	(N/MM2)		(CM)	(CM)	(N/MM2)		
0101	66.000	1.900	248.000	1.196	66.000	1.900	248.000	1.196
0063	66.000	1.600	248.000	1.153	66.000	1.600	248.000	1.153
0104	66.000	1.600	248.000	1.114	66.000	1.600	248.000	1.114
0062	66.000	1.900	248.000	1.049	66.000	1.900	248.000	1.049
0084	66.000	2.500	248.000	1.014	66.000	2.500	248.000	1.014
0102	66.000	2.500	248.000	0.895	66.000	2.500	248.000	0.895
203L	168.800	5.441	248.000	0.837	168.800	5.441	248.000	0.837
201L	168.800	5.441	248.000	0.817	168.800	5.441	248.000	0.817
0103	66.000	2.200	248.000	0.720	66.000	2.200	248.000	0.720
0036	66.000	1.900	248.000	0.708	66.000	1.900	248.000	0.708
641F	27.300	1.000	248.000	0.656	27.300	1.000	248.000	0.656
0031	66.000	2.200	248.000	0.583	66.000	2.200	248.000	0.583
0040	66.000	1.900	248.000	0.578	66.000	1.900	248.000	0.578
647F	27.300	1.000	248.000	0.560	27.300	1.000	248.000	0.560
603L	168.800	5.441	248.000	0.488	168.800	5.441	248.000	0.488
601L	168.800	5.441	248.000	0.461	168.800	5.441	248.000	0.461
604L	168.800	5.441	248.000	0.451	168.800	5.441	248.000	0.451
204L	168.800	5.441	248.000	0.448	168.800	5.441	248.000	0.448
404L	168.800	5.441	248.000	0.439	168.800	5.441	248.000	0.439
503L	168.800	5.441	248.000	0.426	168.800	5.441	248.000	0.426
0001	66.000	1.900	248.000	0.419	66.000	1.900	248.000	0.419
0000	66.000	1.900	248.000	0.413	66.000	1.900	248.000	0.413
642F	27.300	1.000	248.000	0.403	27.300	1.000	248.000	0.403
202L	168.800	5.441	248.000	0.398	168.800	5.441	248.000	0.398
303L	168.800	5.441	248.000	0.388	168.800	5.441	248.000	0.388
304L	168.800	5.441	248.000	0.374	168.800	5.441	248.000	0.374
401L	168.800	5.441	248.000	0.372	168.800	5.441	248.000	0.372
302L	168.800	5.441	248.000	0.367	168.800	5.441	248.000	0.367
502L	168.800	5.441	248.000	0.363	168.800	5.441	248.000	0.363
403L	168.800	5.441	248.000	0.361	168.800	5.441	248.000	0.361
0108	40.600	1.270	248.000	0.351	40.600	1.270	248.000	0.351
0032	66.000	1.900	248.000	0.343	66.000	1.900	248.000	0.343
402L	168.800	5.441	248.000	0.342	168.800	5.441	248.000	0.342
0046	32.400	1.000	248.000	0.341	32.400	1.000	248.000	0.341
602L	168.800	5.441	248.000	0.338	168.800	5.441	248.000	0.338
643F	27.300	1.000	248.000	0.338	27.300	1.000	248.000	0.338
501L	168.800	5.441	248.000	0.333	168.800	5.441	248.000	0.333
644F	27.300	1.000	248.000	0.332	27.300	1.000	248.000	0.332
645F	27.300	1.000	248.000	0.313	27.300	1.000	248.000	0.313
0045	32.400	1.000	248.000	0.310	32.400	1.000	248.000	0.310
0033	66.000	1.900	248.000	0.305	66.000	1.900	248.000	0.305
504L	168.800	5.441	248.000	0.300	168.800	5.441	248.000	0.300
0021	50.800	1.270	248.000	0.294	50.800	1.270	248.000	0.294
0124	61.000	1.270	248.000	0.283	61.000	1.270	248.000	0.283
0020	50.800	1.270	248.000	0.278	50.800	1.270	248.000	0.278
0116	61.000	1.270	248.000	0.272	61.000	1.270	248.000	0.272
0127	61.000	1.270	248.000	0.269	61.000	1.270	248.000	0.269
301L	168.800	5.441	248.000	0.265	168.800	5.441	248.000	0.265
544F	27.300	1.000	248.000	0.249	27.300	1.000	248.000	0.249
0119	50.800	1.270	248.000	0.245	50.800	1.270	248.000	0.245
649F	27.300	1.000	248.000	0.245	27.300	1.000	248.000	0.245
0107	40.600	1.270	248.000	0.240	40.600	1.270	248.000	0.240
541F	27.300	1.000	248.000	0.239	27.300	1.000	248.000	0.239
0006	40.600	1.270	248.000	0.237	40.600	1.270	248.000	0.237
0117	61.000	1.270	248.000	0.232	61.000	1.270	248.000	0.232
646F	27.300	1.000	248.000	0.226	27.300	1.000	248.000	0.226
0120	50.800	1.270	248.000	0.214	50.800	1.270	248.000	0.214
648F	27.300	1.000	248.000	0.213	27.300	1.000	248.000	0.213
547F	27.300	1.000	248.000	0.211	27.300	1.000	248.000	0.211
548F	27.300	1.000	248.000	0.205	27.300	1.000	248.000	0.205
543F	27.300	1.000	248.000	0.203	27.300	1.000	248.000	0.203
542F	27.300	1.000	248.000	0.198	27.300	1.000	248.000	0.198
443F	27.300	1.000	248.000	0.196	27.300	1.000	248.000	0.196
0091	61.000	1.270	248.000	0.195	61.000	1.270	248.000	0.195
0106	50.800	1.900	248.000	0.194	50.800	1.900	248.000	0.194
0011	40.600	1.270	248.000	0.187	40.600	1.270	248.000	0.187
0094	61.000	1.270	248.000	0.185	61.000	1.270	248.000	0.185
0023	32.400	1.000	248.000	0.184	32.400	1.000	248.000	0.184
0037	50.800	1.900	248.000	0.182	50.800	1.900	248.000	0.182
0050	32.400	1.000	248.000	0.182	32.400	1.000	248.000	0.182
0041	50.800	1.900	248.000	0.180	50.800	1.900	248.000	0.180
0047	32.400	1.000	248.000	0.180	32.400	1.000	248.000	0.180

0109	50.800	1.900	248.000	0.174	50.800	1.900	248.000	0.174
0049	32.400	1.000	248.000	0.172	32.400	1.000	248.000	0.172
0015	40.600	1.270	248.000	0.163	40.600	1.270	248.000	0.163
0051	32.400	1.000	248.000	0.158	32.400	1.000	248.000	0.158
545F	27.300	1.000	248.000	0.158	27.300	1.000	248.000	0.158
0114	50.800	1.270	248.000	0.155	50.800	1.270	248.000	0.155
0014	32.400	1.270	248.000	0.153	32.400	1.270	248.000	0.153
0077	50.800	1.900	248.000	0.152	50.800	1.900	248.000	0.152
0009	32.400	1.270	248.000	0.152	32.400	1.270	248.000	0.152
0044	32.400	1.000	248.000	0.150	32.400	1.000	248.000	0.150
0105	50.800	1.900	248.000	0.149	50.800	1.900	248.000	0.149
0003	61.000	1.270	248.000	0.148	61.000	1.270	248.000	0.148
0024	32.400	1.000	248.000	0.145	32.400	1.000	248.000	0.145
441F	27.300	1.000	248.000	0.144	27.300	1.000	248.000	0.144
0048	32.400	1.000	248.000	0.142	32.400	1.000	248.000	0.142
0078	50.800	1.900	248.000	0.142	50.800	1.900	248.000	0.142
0016	61.000	1.270	248.000	0.140	61.000	1.270	248.000	0.140
448F	27.300	1.000	248.000	0.140	27.300	1.000	248.000	0.140
0113	61.000	1.900	248.000	0.137	61.000	1.900	248.000	0.137
0076	50.800	1.900	248.000	0.132	50.800	1.900	248.000	0.132
347F	27.300	1.000	248.000	0.131	27.300	1.000	248.000	0.131
0081	50.800	1.900	248.000	0.129	50.800	1.900	248.000	0.129
549F	27.300	1.000	248.000	0.126	27.300	1.000	248.000	0.126
0010	32.400	1.270	248.000	0.124	32.400	1.270	248.000	0.124
0007	40.600	1.270	248.000	0.123	40.600	1.270	248.000	0.123
0118	61.000	1.270	248.000	0.122	61.000	1.270	248.000	0.122
0121	61.000	1.270	248.000	0.122	61.000	1.270	248.000	0.122
0079	50.800	1.900	248.000	0.120	50.800	1.900	248.000	0.120
449F	27.300	1.000	248.000	0.119	27.300	1.000	248.000	0.119
0030	61.000	1.270	248.000	0.117	61.000	1.270	248.000	0.117
0035	50.800	1.900	248.000	0.115	50.800	1.900	248.000	0.115
0013	32.400	1.270	248.000	0.114	32.400	1.270	248.000	0.114
0008	40.600	1.270	248.000	0.112	40.600	1.270	248.000	0.112
0034	50.800	1.900	248.000	0.110	50.800	1.900	248.000	0.110
0122	61.000	1.270	248.000	0.109	61.000	1.270	248.000	0.109
445F	27.300	1.000	248.000	0.109	27.300	1.000	248.000	0.109
446F	27.300	1.000	248.000	0.108	27.300	1.000	248.000	0.108
0004	40.600	1.270	248.000	0.107	40.600	1.270	248.000	0.107
546F	27.300	1.000	248.000	0.106	27.300	1.000	248.000	0.106
0092	61.000	1.270	248.000	0.105	61.000	1.270	248.000	0.105
0019	50.800	1.270	248.000	0.102	50.800	1.270	248.000	0.102
0080	50.800	1.900	248.000	0.101	50.800	1.900	248.000	0.101
0005	40.600	1.270	248.000	0.100	40.600	1.270	248.000	0.100
342F	27.300	1.000	248.000	0.100	27.300	1.000	248.000	0.100
444F	27.300	1.000	248.000	0.099	27.300	1.000	248.000	0.099
0112	61.000	1.900	248.000	0.093	61.000	1.900	248.000	0.093
0012	40.600	1.270	248.000	0.092	40.600	1.270	248.000	0.092
0090	61.000	1.270	248.000	0.090	61.000	1.270	248.000	0.090
247F	27.300	1.000	248.000	0.090	27.300	1.000	248.000	0.090
0055	32.400	1.000	248.000	0.088	32.400	1.000	248.000	0.088
344F	27.300	1.000	248.000	0.087	27.300	1.000	248.000	0.087
0086	61.000	1.900	248.000	0.087	61.000	1.900	248.000	0.087
0028	32.400	1.000	248.000	0.085	32.400	1.000	248.000	0.085
0056	32.400	1.000	248.000	0.084	32.400	1.000	248.000	0.084
0093	61.000	1.270	248.000	0.081	61.000	1.270	248.000	0.081
345F	27.300	1.000	248.000	0.080	27.300	1.000	248.000	0.080
0087	61.000	1.900	248.000	0.080	61.000	1.900	248.000	0.080
348F	27.300	1.000	248.000	0.078	27.300	1.000	248.000	0.078
341F	27.300	1.000	248.000	0.076	27.300	1.000	248.000	0.076
0123	50.800	1.270	248.000	0.075	50.800	1.270	248.000	0.075
442F	27.300	1.000	248.000	0.075	27.300	1.000	248.000	0.075
447F	27.300	1.000	248.000	0.074	27.300	1.000	248.000	0.074
0052	50.800	1.270	248.000	0.073	50.800	1.270	248.000	0.073
0110	40.600	1.270	248.000	0.071	40.600	1.270	248.000	0.071
0067	61.000	1.270	248.000	0.071	61.000	1.270	248.000	0.071
0070	32.400	1.000	248.000	0.070	32.400	1.000	248.000	0.070
0025	50.800	1.270	248.000	0.070	50.800	1.270	248.000	0.070
0088	61.000	1.900	248.000	0.070	61.000	1.900	248.000	0.070
349F	27.300	1.000	248.000	0.069	27.300	1.000	248.000	0.069
0029	50.800	1.270	248.000	0.067	50.800	1.270	248.000	0.067
0018	50.800	1.270	248.000	0.066	50.800	1.270	248.000	0.066
0017	61.000	1.270	248.000	0.066	61.000	1.270	248.000	0.066
0053	50.800	1.270	248.000	0.065	50.800	1.270	248.000	0.065
0115	61.000	1.900	248.000	0.063	61.000	1.900	248.000	0.063
0026	50.800	1.270	248.000	0.063	50.800	1.270	248.000	0.063
0066	61.000	1.270	248.000	0.062	61.000	1.270	248.000	0.062
0082	61.000	1.900	248.000	0.062	61.000	1.900	248.000	0.062
0096	66.000	1.900	248.000	0.062	66.000	1.900	248.000	0.062
0069	32.400	1.000	248.000	0.061	32.400	1.000	248.000	0.061
242F	27.300	1.000	248.000	0.060	27.300	1.000	248.000	0.060
0027	32.400	1.000	248.000	0.060	32.400	1.000	248.000	0.060
0022	50.800	1.270	248.000	0.059	50.800	1.270	248.000	0.059
0095	66.000	1.900	248.000	0.057	66.000	1.900	248.000	0.057
0083	61.000	1.900	248.000	0.055	61.000	1.900	248.000	0.055
346F	27.300	1.000	248.000	0.054	27.300	1.000	248.000	0.054

244F	27.300	1.000	248.000	0.052	27.300	1.000	248.000	0.052
0085	61.000	1.900	248.000	0.051	61.000	1.900	248.000	0.051
343F	27.300	1.000	248.000	0.051	27.300	1.000	248.000	0.051
245F	27.300	1.000	248.000	0.051	27.300	1.000	248.000	0.051
0098	66.000	1.900	248.000	0.049	66.000	1.900	248.000	0.049
0097	66.000	1.900	248.000	0.049	66.000	1.900	248.000	0.049
0073	32.400	1.000	248.000	0.048	32.400	1.000	248.000	0.048
0074	32.400	1.000	248.000	0.045	32.400	1.000	248.000	0.045
0002	61.000	1.270	248.000	0.045	61.000	1.270	248.000	0.045
0043	50.800	1.270	248.000	0.044	50.800	1.270	248.000	0.044
248F	27.300	1.000	248.000	0.040	27.300	1.000	248.000	0.040
0057	40.600	1.270	248.000	0.039	40.600	1.270	248.000	0.039
0126	66.000	1.900	248.000	0.039	66.000	1.900	248.000	0.039
0125	66.000	1.900	248.000	0.037	66.000	1.900	248.000	0.037
246F	27.300	1.000	248.000	0.037	27.300	1.000	248.000	0.037
0089	61.000	1.270	248.000	0.036	61.000	1.270	248.000	0.036
0060	32.400	1.000	248.000	0.035	32.400	1.000	248.000	0.035
0059	32.400	1.000	248.000	0.035	32.400	1.000	248.000	0.035
243F	27.300	1.000	248.000	0.034	27.300	1.000	248.000	0.034
0054	40.600	1.270	248.000	0.034	40.600	1.270	248.000	0.034
0042	50.800	1.270	248.000	0.033	50.800	1.270	248.000	0.033
0100	66.000	1.900	248.000	0.032	66.000	1.900	248.000	0.032
0071	32.400	1.000	248.000	0.031	32.400	1.000	248.000	0.031
0068	32.400	1.000	248.000	0.030	32.400	1.000	248.000	0.030
249F	27.300	1.000	248.000	0.029	27.300	1.000	248.000	0.029
0099	66.000	1.900	248.000	0.029	66.000	1.900	248.000	0.029
241F	27.300	1.000	248.000	0.028	27.300	1.000	248.000	0.028
0064	61.000	1.270	248.000	0.026	61.000	1.270	248.000	0.026
0061	40.600	1.270	248.000	0.026	40.600	1.270	248.000	0.026
0058	40.600	1.270	248.000	0.026	40.600	1.270	248.000	0.026
0065	61.000	1.270	248.000	0.025	61.000	1.270	248.000	0.025
0130	66.000	1.900	248.000	0.022	66.000	1.900	248.000	0.022
0072	32.400	1.000	248.000	0.018	32.400	1.000	248.000	0.018
0075	32.400	1.000	248.000	0.018	32.400	1.000	248.000	0.018
0129	66.000	1.900	248.000	0.017	66.000	1.900	248.000	0.017
0131	66.000	1.900	248.000	0.014	66.000	1.900	248.000	0.014

APPENDIX-6

Collapse Input & Output files for Critical Load Condition- 105

Collapse Input file

```
CLPOPT    100  8 40        CN  LBJFPPJS            MG   0.100.001 0.01 300.0.002
CLPRPT P0R0M0MP    SM
LDSEQ AAAA           100   1         1.0 101  50         2.5
GRPELA         CDA CDB CDC CDD DLC HDA HDB HDC MDA MDB VB1 VB1 VB3 VB4
PGRELA     PL1  CDP  MDP
END
```

Collapse Output file

```
                          ***** COLLAPSE ANALYSIS PARAMETERS *****

                    COLLAPSE VERSION ............................. 12.0.0.34

                    NUMBER ITERATIONS ALLOWED .................... 100

                    NUMBER OF MEMBER SEGMENTS ....................   8

                    DEFLECTION PRINT OPTION ......................FINAL ONLY

                    CREATE SACS FILE OPTION ......................NO

                    CONTINUE AFTER ALLOWABLE ITERATIONS EXCEEDED...YES

                    JOINT FLEXIBILITY INCLUDED ...................YES (FESSLER JOINT FLEXIBILITY)

                    PILE/STRUCTURE NON-LINEARITIES INCLUDED ......NO

                    SKIPPED MEMBERS AUTOMATICALLY LINEAR .........YES

                    MAXIMUM DEFLECTION ALLOWED BEFORE COLLAPSE ....   300.0 CM

                    DEFLECTION TOLERANCE FOR CONVERGENCE .........  0.1000 CM

                    ROTATION.. TOLERANCE FOR CONVERGENCE .........0.001000 RAD

                    STRAIN HARDENING RATIO .......................0.002000

                    YIELD STRENGTH FACTOR ........................ not set

                    YIELD STRENGTH UNIVERSAL OVERRIDE............. not set

                    JOINT STRENGTH OPTION ........................YES

                    ALL MEMBERS ELASTIC ..........................NO

                    ALL PLATES ELASTIC ...........................NO

                    MEMBER LOCAL BUCKLING CHECKED ................YES

                    SUPER ELEMENT INCLUDED .......................NO

                    BUCKLING INTERACTION INCLUDED ................NO

                          BUCKLING CRITERIA ......................MARSHALL GATES


                    ***** JOINT STRENGTH PARAMETERS *****

                    MINIMUM GAP .........................,,,,,.... -254.00 CM

                    MAXIMUM GAP .........................,,,,,.... 2540.00 CM

                    RELIEF OPTION ................................NO

                    EFFECTIVE THICKNESS OPTION ...................NO

                    EFFECTIVE THICKNESS LIMIT RATIO ..............    1.75

                    MINIMUM UNITY CHECK PRINT LEVEL ..............    0.00

                    JOINT FRACTURE CHECK .........................NO
             ***** FIRST LOAD PATH *****   **** SECOND LOAD PATH ****    ***** THIRD LOAD PATH *****
LOAD  LOAD   LOAD   NO.   START   END     LOAD   NO.   START    END     LOAD   NO.   START    END
SEQ.   ID    CASE  INCR.  FACTOR  FACTOR   CASE  INCR.  FACTOR  FACTOR   CASE  INCR.  FACTOR  FACTOR

  1   AAAA   100     1     0.000   1.000   101    50     0.000   2.500

*** PLASTICITY OCCURRED ON MEMBER 404L-503L AT LOAD STEP   48
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