Structural Integrity of an Onshore Oil & Gas Platform due to Increasing Seismic Effect in Malaysia

By

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14504

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requirements for the
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CERTIFICATION OF APPROVAL

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A project dissertation submitted to the
Civil Engineering Programme
Universiti Teknologi PETRONAS
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Approved by,

____

(Dr. Ibrisam Akbar)

UNIVERSITI TEKNOLOGI PETRONAS
TRONOH, PERAK
Sept 2014

CERTIFICATION OF ORIGINALITY

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

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ABSTRACT

The increasing seismic activity form the Sumatran fault line raises uncertainties as most of the current structure in Malaysian Oil and Gas Industry are designed for seismic hazard in Zone 1 (Ground Acceleration = 0.075g) according to Uniform Building Code 1997 (UBC 1997) due to the factor that Malaysia is in the low seismic hazard zone. This study is to determine and compare the connection design for steel structure if the seismic zone in Malaysia increases from Zone 1 to Zone 2A (0.015g) and Zone 2B (0.2g). This study is carried out by simulating and modelling the existing Packinox gas vessel steel support structure in StaadPro V8i. By manipulating the seismic ground acceleration coefficient, the most critical joint resulting from the increasing ground acceleration factor is obtain. These critical forces induced on the joints are then used to design a simple bolted connection and used to compare the difference in the connection for higher seismic zones. As a result, it was found that the increasing ground acceleration factor from zone 1 to zone 2A does not effect the most joints with increase up to 9.42% and 5.23% for axial and tie force respectively. However, for Zone 2B, there are significant increase in the forces induced at the critical joints with increase up to 38.35% and 12.61% for axial force and tie force respectively.

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CHAPTER 1

INTRODUCTION

1.1 Project Background

Steel are widely used in the oil and gas industry in Malaysia. These structure are commonly used as support structures for gas equipment or vessels. Steel support structures are preferred in this industry due to its many advantages such as its strength/ weight ratio, ductility and speed of erection. As most of the equipment and vessel frequently undergo modification, usage of steel structure would make easier for structural modification.

The Packinox project is a framed steel structure to support a large gas vessel. Recently, the gas vessel is not adequate to accommodate the production and is proposed to change to a larger vessel. The new vessel which is larger and taller requires modification to the existing support structure. A portion of the existing structure is removed and new structure is to be erected. Modification to the existing structure should be made without interfering or reducing the overall structures integrity or strength. The new portion also should take into account of wind and seismic loads. The exiting structure is as in Figure 1.

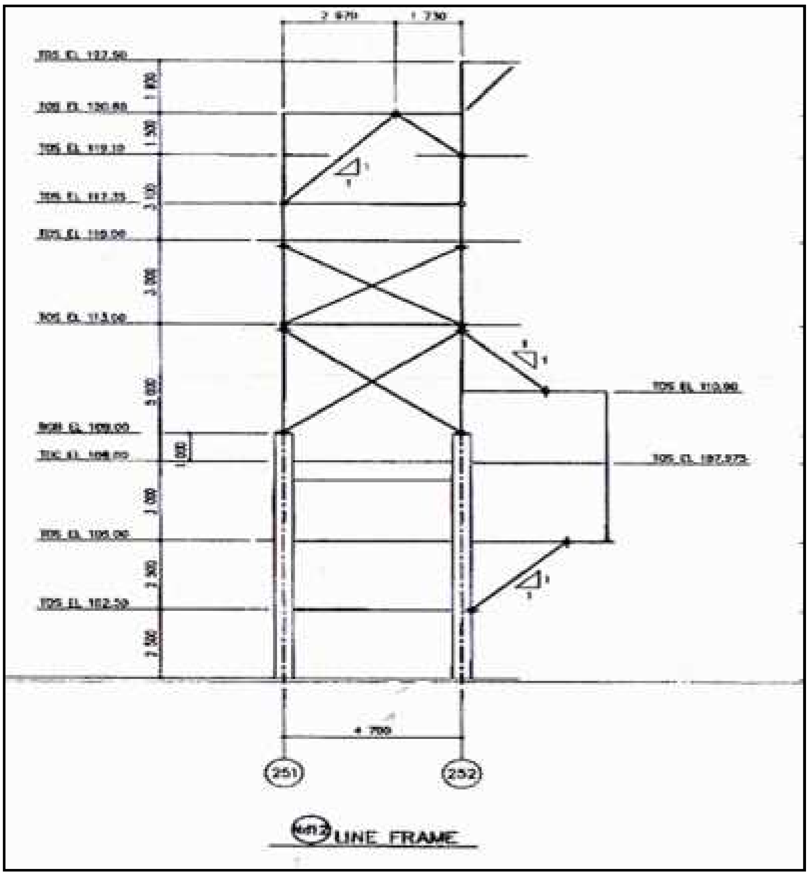


Figure 1: Existing Packinox Support Structure

1.2 Problem Statement

1.2.1 Earthquake and tremors from Sumatran Fault lines has increased the concern of the oil and gas industry in Malaysia. Recent Studies also shows that Malaysia is not immune to earthquake as its used to be. Research has shown that the effect of earthquake either originating from Malaysia or neighbouring countries could leave an impact on Malaysian structures.

1.2.2 Most of the current structure in Malaysian oil and gas industry has little or none seismic design specification or guidelines for earthquake-induced vibration due to the factor that Malaysia is in the low seismic hazard zone.

1.2.3 The increasing seismic activity resulting from the Sumatran fault line might cause Malaysia to be classified in a higher seismic activity zone.

1.3 Objective

1.1.1 To compare steel connection integrity of existing onshore oil & gas platform in Malaysia when the seismic zone increases from zone 1 to zone 2A and 2B using STAAD Pro.

1.4 Scope of Study

1.1.2 Framed structure from existing construction (Packinox gas vessel supporting structure)

1.1.3 Seismic effect Region 1, 2 and 3 of South East Asia (or Sumatera)

1.1.4 Connection design for bolt bonnections for simple connections

CHAPTER 2

LITERAURE REVIEW

2.1 Geological Background

The outermost layer of earth which is commonly known as lithosphere can be separated and classified into tectonic plates. These tectonic plates various from 70km to 150 km in thickness (M.C, et al., 2005). Currently there are three types of plates which are the primary, secondary and the tertiary plates. The primary plates covers most of the earth surface and the Pacific Ocean. The secondary plate are smaller than the primary and are usually not shown on maps due to the insignificant size. Lastly, the tertiary plates are commonly known as micro plates. The tertiary plates are extremely small and are usually found between the primary and secondary plates. Some of the tertiary plates are grouped together to form a secondary plate.

Earthquake occurs when there is a sudden release in energy stored due to the constant movement of the tectonic plates. The movements of the tectonic plates are relative to one another occurring along sides of the plates (Har, 2005). There are three type of tectonic plate movements which are convergent, transform and divergent where plates are moving towards, in parallel and away another plate respectively. These plate movement are as in Figure 2.

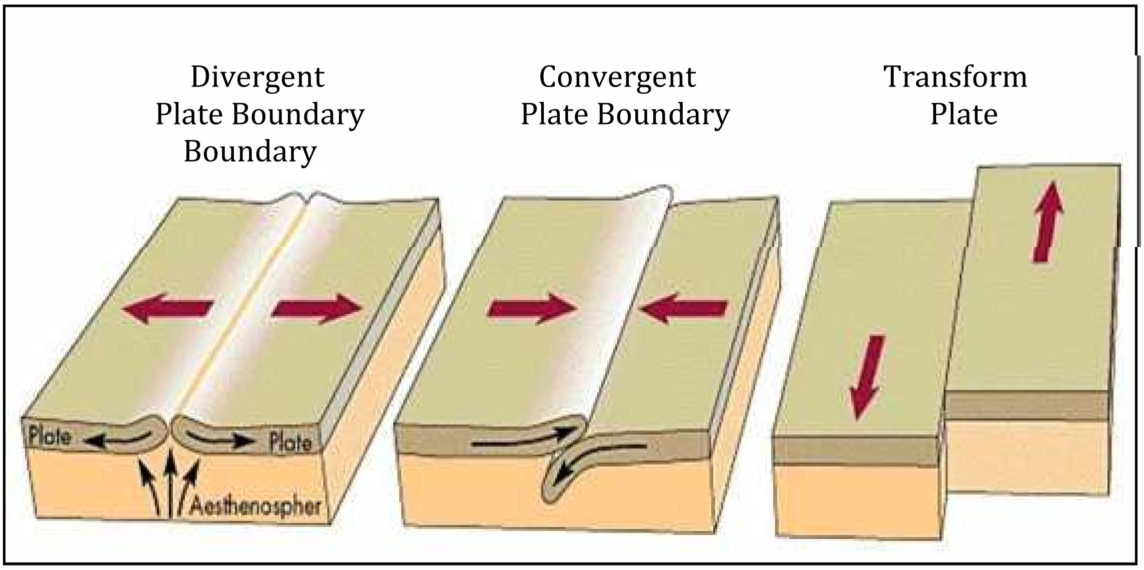


Figure 2: Plate Boundaries Movements

2.2 Seismicity in Peninsular Malaysia

Based on a seismotectonic study conducted by the Minerals and Geoscience Department of Malaysia, it was found that Malaysia is tectonically positioned in a stable Sunda Plate. Hence, Peninsular Malaysia is classified as low to medium seismicity group. Nevertheless, the previous occurrence of several large earthquakes near Sumatra should increase awareness and alertness and should serve as a sign that major earthquakes could cause significant damage although at a further distance. This is due to the characteristics of long period component of shear waves and local sites (Adnan et al.,2005).

However, most people assume that Malaysia is free from heavy damage causing or even life-threatening seismic disasters. The truth, seismic hazard in Malaysia is undeniable as there are seismic hazards originating from the increasingly seismic active Sumatran Fault line. The two most seismically active tectonic plate intersection are shown in Figure 3 which is the Sumatran subduction zone consisting of approximately 1600km long fault line and the Philippines plate have been producing consistent distant motions and have been recorded by Malaysian seismic network stations for the past years (Adnan et al.,2005). The 26th December 2004 Sumatra-Andaman earthquake originated from the Sumatra subduction zone was one of the largest tsunami generating seismic event with a 9.3 magnitude (Husen, et al.,2008).

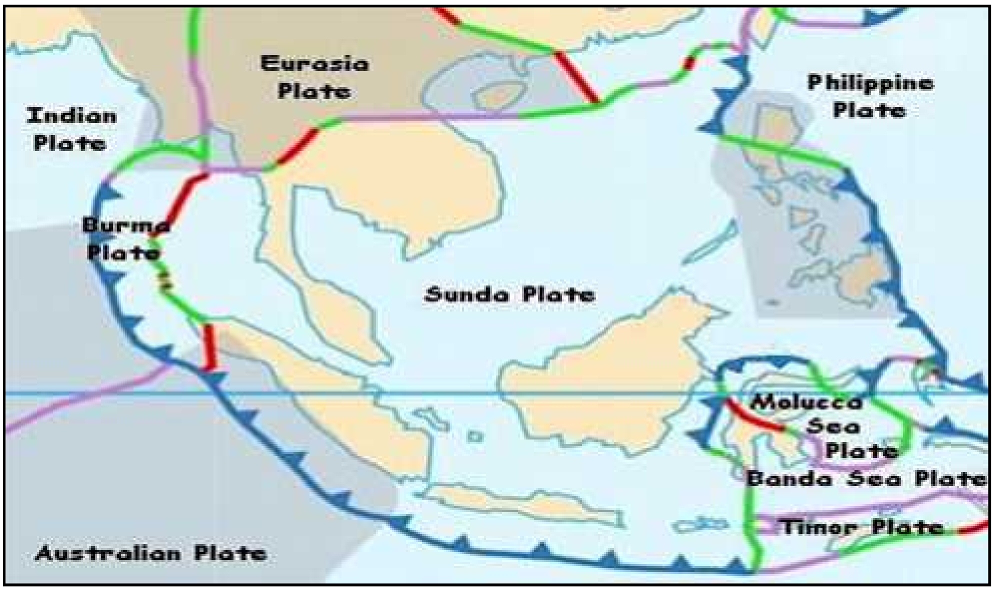


Figure 3: Tectonic Plates around Malaysia

In 2004, Adnan et al., (2005) mentioned that the future significant earthquake would be over the Sumatra Fault and might give Peninsular Malaysia effect especially in the Western part. The return period for earthquake with magnitude above 7 and slip rate of ± 15 is approximately 100 to 150 years. Studies made by Structural Earthquake Engineering Research (SEER), Faculty of Civil Engineering, Universiti Teknologi Malaysia has concluded that the earthquake of magnitude 7 that erupt in Sumatra Fault line will effect cities like Kuala Lumpur which are situated 350 km away.

Table 1 shows the data of experienced earthquakes in Malaysia are available from 1815 onwards but are insufficient and poorly correlated. However, since approximately 1909, information from Malaysian Meteorological Department (MMD) suggests that Peninsular Malaysia has been experiencing earthquakes of maximum intensity equivalent to VI on the Modified Mercalli Intensity Scale (MMI) (Ministry of Science,Technology and Innovation of Malaysia. (2009)).

Table 1: Frequency and intensity of felt earthquakes recorded from 1874 to 2010

State (1909-July 2010)	Frequency of Occurrence	Maximum Intensity (MMI)
Perlis	3	V
Kedah	18	V
Penang	41	VI
Perak	24	VI
Selangor	50	VI
Negeri Sembilan	14	V
Malacca	19	V
Johor	32	VI
Pahang	35	III
Terengganu	2	IV
Kelantan	3	IV
Kuala Lumpur	38	VI

2.3 Assessment of Possible Ground Movements

Assessment of ground movement is important in order to understand the behaviour of the force exerted to structures. Through this assessment, design for seismic resistance structure could be developed. In order to develop a design motion for earthquake resistant, plenty of data regarding the ground motion characteristics is required. Unfortunately, this data and information in Malaysia is insufficient due to Malaysia is located in region with low seismic activity (Zaini Sooria, et al., 2012).

Alternatively, through predicting the maximum magnitude earthquake from past data, the assessment of possible ground movement in Peninsular Malaysia could be conducted. Upon obtaining the maximum magnitude earthquake, the maximum acceleration and displacement that are predicted to occur could be easily determined.

Studies from SEER group that predicted the large earthquake of magnitude 7 in the Sumatra Fault line will generate a peak ground acceleration (PGA) in Peninsular Malaysia of 70gal (0.07g). Through the probabilistic analysis for Peninsular Malaysia, it was concluded that the maximum PGA for 500 years and 2500 years are 50 gal (0.05g) and 70 gal (0.07) respectively (Adnan et al.,2005).

The assessment for low seismic activity regions such as Malaysia, it is assumed that the largest past earthquake is the minimum value for a maximum earthquake estimate (Tenhaus, at al., 2003). The larges earthquake to ever recorded in Malaysia was in 1874 with magnitude 6.5M_b . Researchers has claimed that the Bukit Tinggi fault will be reactivated due to the occurrence of several earthquakes in the Sumatera (Shuib, 2009). Considering this fact, to estimate the maximum magnitude earthquake with a return period of 1000 years, it is predicted that earthquake with magnitude larger than 6.5M_b will occur. Earthquake with this intensity will cause surface rupture.

A study conducted in 2012 by Kyoto University, Japan has proposed that an earthquake with magnitude 6.5 is the maximum for Peninsular Malaysia. Based on this study also, it was estimated the Peak Ground Velocity (PGV) of 60 cm/s and Peak Ground Displacement of 150mm (Zaini Sooria, et al., 2012).

2.4 Response of Structures to Earthquake

Earthquake produces wave that causes the ground to vibrate in the horizontal direction. This results to horizontal loads applied to structures or buildings. This horizontal load is caused by the internally generated inertia produced by the vibration of the structures mass. The mass, size and shape are the main contributing factors that determines the effect of the seismic forces and also predict the performance of the structure when exposed to seismic loads.

Inertia is a force which is the product of mass and acceleration. Acceleration is the ground acceleration produced by the earthquake. Thus, the increase in weight will result in higher inertial force (Sorno, et al, 2005). The increase in height of a structure will result in higher damage as the structure undergoes resonance when the seismic loads is applies. Resonance in tall structures amplify the effect and could be destructive.

The time period for seismic load to be applied to a structure is relatively short. The longest period of earthquake vibration is only 10-20 seconds. The seismic loads also leaps from zero to maximum is seconds and sometimes even milliseconds. It is then reduced to zero and increased to maximum in the opposite direction. Thus, earthquake induces a shock effect on structures (Har, 2005).

The most effective reaction to counter the severe effect of earthquake is by ensuring the distribution of members in the structure and the continuity of vertical members. This is commonly known as the configuration of lateral force resisting members. This is important because this configuration regulates the vibration period, the damping and resonance characteristic of the structure. Hence, it results in the change in reaction of structure to seismic loads .

2.5 Connection Failure due to seismic activity

The seismic activity causes a structures joint to fail when the designed connection don’t accommodate the members of the structures to move independently from each other or insufficient clearance between member such as beam and column. The rigidity of these connections connecting two members allows little or no movement between the structure causing the structure to fail in the event of earthquake.

According to John Shipp (1994), there is a wide-ranging of in structures reporting connection failures. Structure location differs up to 25 km from the epicenter. Structure height is from 1 to 22 stories, and most of the structural failures occurred in the upper half of high-rise structure and at all levels in lower structure. Connection failure ranges from less than 10% to as high as almost 100%. Shipp also concluded that connection failure occurs with or without column-flange stiffeners, structures with smaller number of frame bays and structures with moment frame girder line.

2.6 Steel Connections

There are two primary types of connection which are simple connection and moment resisting connections. Simple connections are usually pinned connections that only transfer shear force only and have approximately zero resistance to rotation. Therefore, simple connections do not transfer moments at the ultimate limit state. Simple connections are usually used for beam-to-beam, beam-to-column and bracing connections where else, the moment resisting connections are used primarily for beam- to-column and in rare cases for beam-to-beam.

2.7 Conclusion of Literature Review

The literature is analysed to determine the scope and methodology of this project:

- Peak Ground Acceleration in 500 years is 0.05g (Adnan et al.,2005).This value is within Zone 2A in accordance to UBC 1997
- The increase in weight or accleration will result in higher inertial force (Sorno, et al, 2005). Thus, the assessment wil be conducted for different beam sizes.
- Earthquake with magnitude 6.5 (Zone 2A in UBC 1997) is the maximum for Peninsular Malaysia (Zaini Sooria, et al., 2012).

CHAPTER 3

METHODOLOGY

3.1 Project sequence

The summary of the project sequence are shown in Figure 4

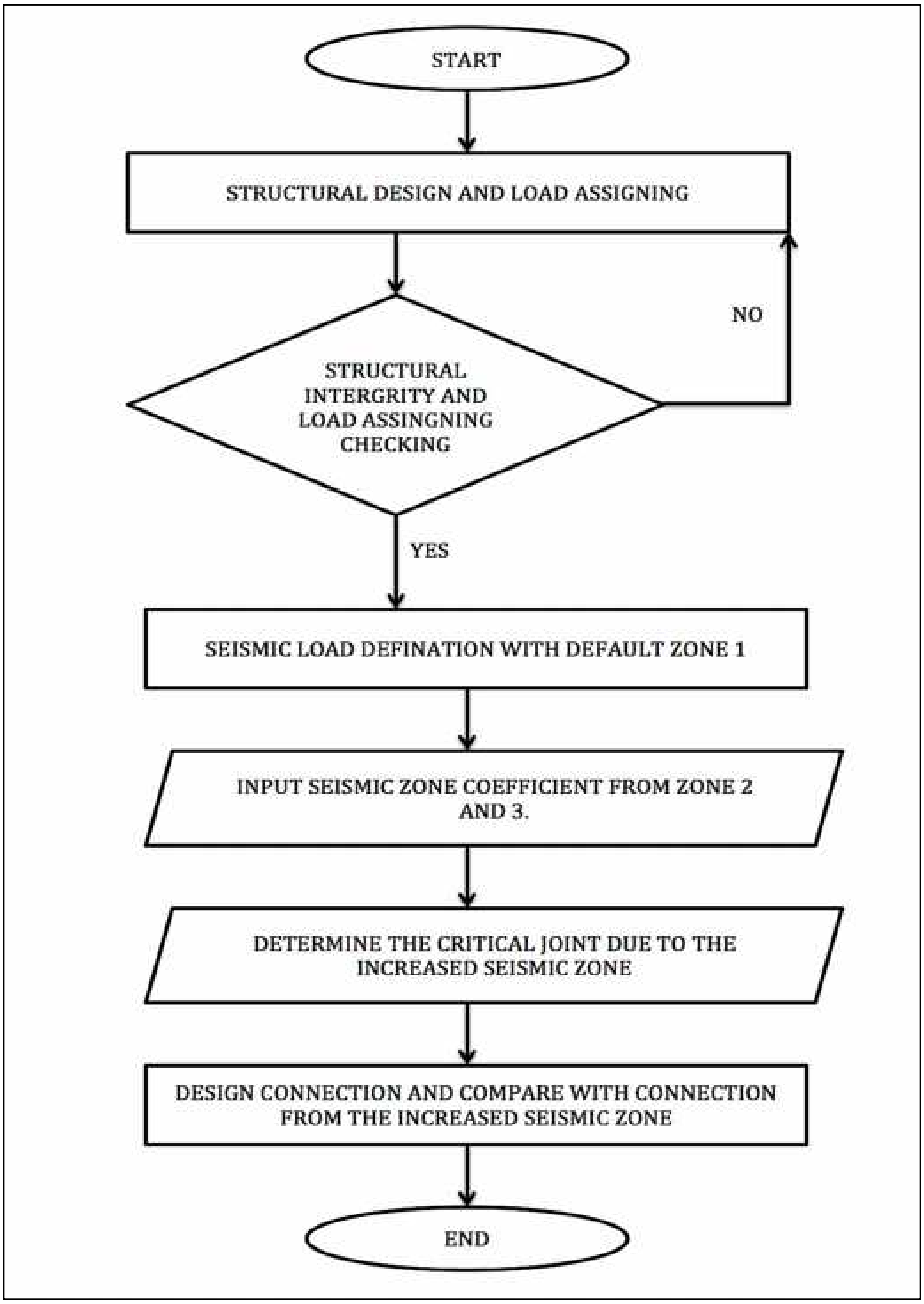


Figure 4: Flow Chart of the Study

3.1.1 Structure Design and Load Assigning in StaadPro

StaadPro V8i is used for the purpose of analysing the structure. The new portion of the Packinox steel framed support structure is modelled by converting the structural drawing. The structure is assumed fixed at the bottom as it is an extension of the existing structure. After completing the modelling, the loads are assigned and load cases are added.

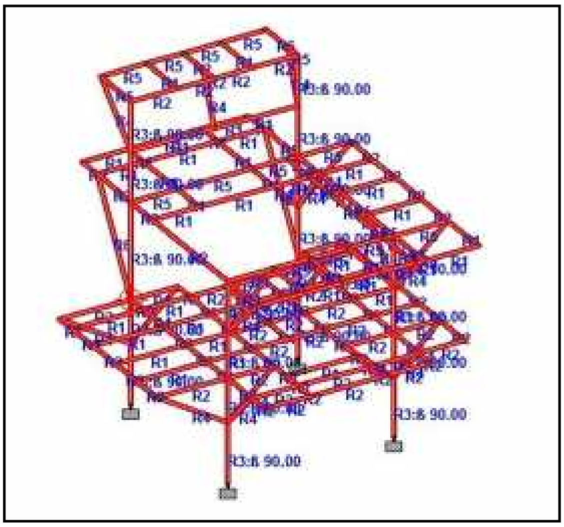
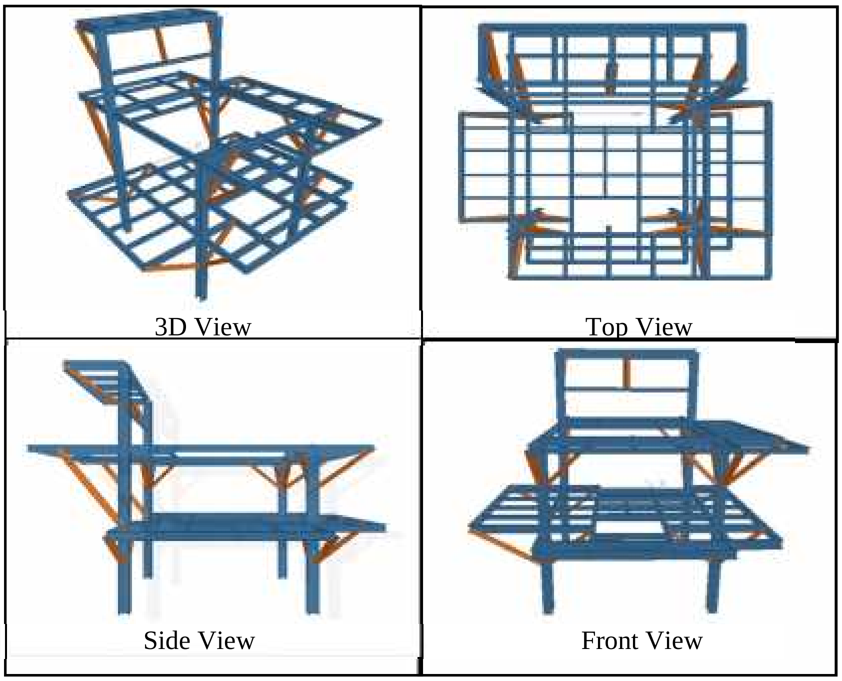


Figure 5: Modeled Section


3D View

Top View

Side View

Front View

Figure 6 : 4 views of the Modeled Structure

Loads such as Dead Load, Live Load, Seismic Load, Wind Load and Combination loads are assigned before performing the analysis. Table 2 shows the complete assigning of load

Table 2: Load Cases In Staad Pro

CASE NUMBER	LOAD CASE	COMBINATION
1	Dead Load	DEAD
2	Live Load	LIVE
3	Wind Load in X-Direction	WX
4	Wind Load in Z-Direction	WZ
5	Seismic Load in X-Direction	EQX
6	Seismic Load in Z-Direction	EQZ
7	Load Combination 1	1.4 DEAD + 1.6 LIVE
8	Load Combination 2	1.2 (DEAD + LIVE +WX)
9	Load Combination 3	1.2 (DEAD + LIVE -WX)
10	Load Combination 4	1.2 (DEAD + LIVE +WZ)
11	Load Combination 5	1.2 (DEAD + LIVE -WZ)
12	Load Combination 6	1.2 DEAD + 0.6 LIVE + 1 EQX
13	Load Combination 7	1.2 DEAD + 0.6 LIVE - 1 EQX
14	Load Combination 8	1.2 DEAD + 0.6 LIVE + 1 EQZ
15	Load Combination 9	1.2 DEAD + 0.6 LIVE - 1 EQZ

3.1.1.1 Dead Loads

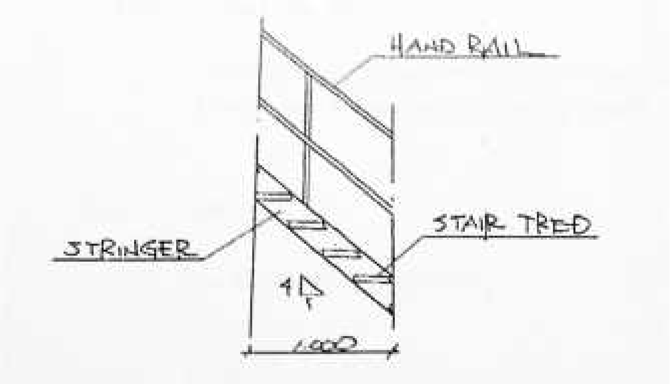
Dead loads are permanent downwards loads acting to the structure due the self weight and non-structural support component of the structure. For this project, the unit weight of materials are as in Table 3 below :

Table 3: Unit weight of Materials

Unit Weight of Materials	
Soil	1.8 ton/m^3
Sand (Wet)	2.00 ton/m^3
Gravel	1.90 ton/m^3
Granite in masonry	2.65 ton/m^3
Brick with cement mortar finish	1.90 ton/m^3
Plain concrete	2.30 ton/m^3
Reinforced Concrete	2.40 ton/m^3
Fire Proofing	0.80 ton/m^3
Steel	7.85 ton/m^3

The following dead load calculated and assigned to the StaadPro Model :

Grating	:	45 kg/m^2
Joist	:	14 kg/m^2
Beam	:	30 kg/m^2
Hand Rail	:	15 kg/m^2
Stair	:	160 kg/m^2



Stringer	:	12.8 m x 34.6 kg/m x 2	=	88.58 kg
Hand Rail	:	12.8 m x 15.0 kg/m x 2	=	38.4 kg
Stair Tred	:	(0.75 x 0.25 x 4 x 0.01 x 0.75 x 4) x 45 kg/m^2	=	35.1 kg
			=	162.08kg

3.1.1.2 Equipment Loads (Empty, Operating, Hydrostatic Test)

I. Empty Weight
  - Dead Weight of the vessel and inclusive protective layers

II. Operating Weight
  - Empty weight + weight of their maximum contents

III. Hydrostatic Test Load
  - Weight of equipment completely filled with water.

3.1.1.3 Piping Loads

The weight of the pipe rack, pipe sleeper and other piping line and instruments

3.1.1.4 Live Loads

The live load for this structure is 200 kg/m^3 as this structure is classified for equipment support structure and accounts for floor inspection and repairs.

3.1.1.5 Wind Loads

Wind loads were designed in accordance to PTS 34.00.01.30 and BS CP 3. The classifications for wind loads and design wind speed are as Tables 4 and 5 below.

Table 4: Classification of wind loads

Highest Mean Hourly Wind Speed	**V_{10} = 28.0 m/sec for 10.0m height**
Topography Category	1 (Extreme exposure)
Gust Duration	10 Sec
Gust Factor	1.3
Exponent Giving Variation	1/14

Table 5: Design wind speed

Height from Ground, z (m)	Wind Speed, Uz (m/sec)
<3	33.4
5	34.6
10	36.4
20	38.2
30	39.4
40	40.2
50	40.8
60	41.4
70	41.8
80	42.2
90	42.6
>100	42.9

The formula given is : $Pz = A \times 0.637 \times Uz^2 \times Cfm$

Where A : Total projected Area on each direction (m^2)

Uz : Design Wind Speed at height z (m/sec)

Cfm : Shape coefficient for total multi structure.

3.1.1.6 Earthquake Loads

Earthquake loads shall be designed in accordance to UBC 1997 Volume 2. The classification of earthquake loads are as table 6 below and the structural system and numeric coeficient in table 7 :

Table 6: Classification of earthquake loads

Seismic Zone Factor	**Z = 0.075 (zone 1)**
Soil Profile	SD
Occupancy Category	Standard Occupancy
Structural System	1) Ordinary Moment resisting frame (OMRF) 2) Ordinary braced frame

Design Base Shear

The formula given are :

$$V = \left[C \quad \times \frac{I}{R \times T} \right] \times W \qquad ; \quad V \leq V\max = (2.5 \ Ca \times I/R) \times W$$

$$V \leq V\min = (0.11 \times Ca \times I) \times W$$

where ;

Total Design Base Shear	V
Total Loads	W
Seismic Coefficient	Cv = 0.18
	Ca = 0.12
Seismic Importance Factor	I = 1.00
Structure period (sec)	$T = Ct \times h^{3/4}$
Height of Structure	h
Numerical Coefficient	R and Ct

Table 7: Structural System and Numerical Coefficient

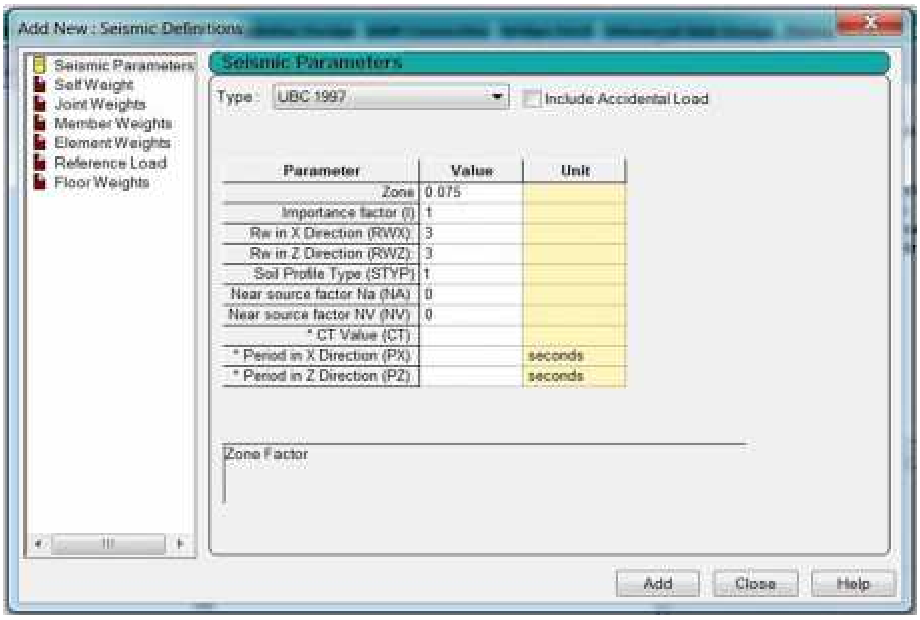
Structural System	**Material**	**R**	**Ct**
Ordinary Moment-Resisting frame (OMRF)	Steel	4.5	0.0853
	Concrete	3.5	0.0731
Ordinary Braced Frame	Steel	5.6	0.0488
	Concrete	5.6	0.0488

3.1.2 Structural Integrity and Load Checking

The assigned loads (excluding Seismic Load) is first analysed to ensure the structural integrity. The designed member are checked for failure for the assigned loads. If there is ay failure, the members and the assigned loads are checked, revised and changed to ensure the integrity of the structure.

3.1.3 Input seismic loads based on Zone 1, 2A and 2B.

The seismic conditions for the model in StaadPro V8i is changed from zone 1 to zone 2A and 2B. This is to generate new force acting on the member and joints in order to determine the end beam forces corresponding to the seismic condition. Each Zone has different seismic coefficient based on the ground acceleration. For instance, according to UBC 1997, Zone 1 has ground acceleration of 0.075g followed by 0.15g and 0.2g for Zone 2A and 2B respectively. The new critical reactions are then input in the completed connection design tool. Figure 7 shows the StaadPro interference for changing the seismic coeficient



Type: UBC 1997

☐ Include Accidental Load

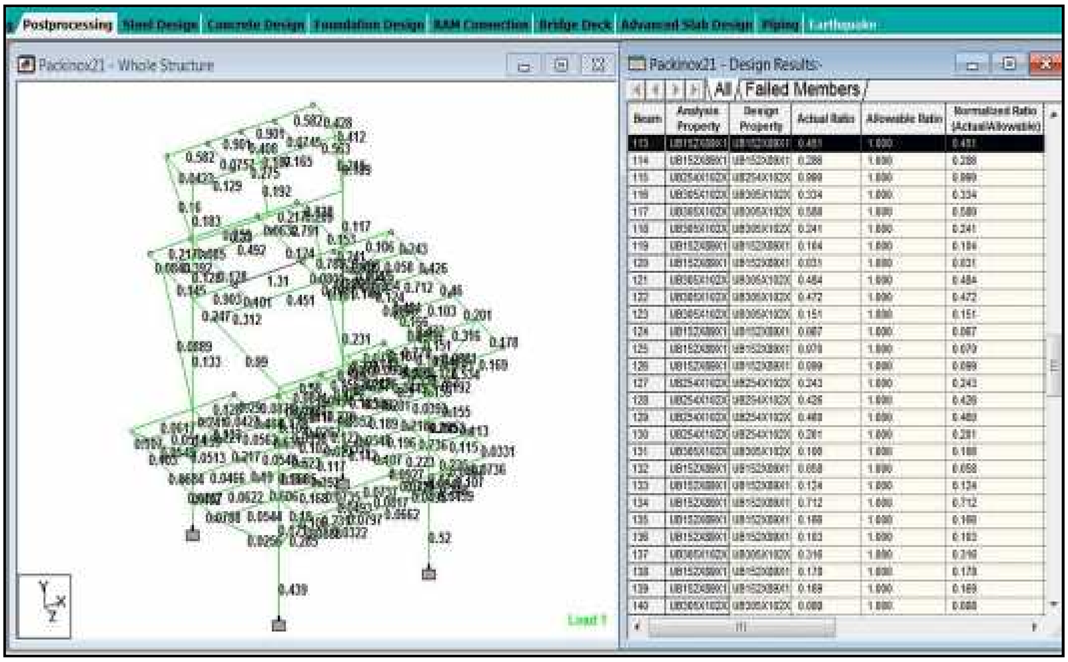
Parameter	Value	Unit
Zone	0.075	
Importance factor (I)	1	
Rw in X Direction (RWX)	3	
Rw in Z Direction (RWZ)	3	
Soil Profile Type (STYP)	1	
Near source factor Na (NA)	0	
Near source factor NV (NV)	0	
* CT Value (CT)		
* Period in X Direction (PX)		seconds
* Period in Z Direction (PZ)		seconds

Zone Factor

Figure 7 : Changing the Seismic Parameters in StaadPro V8i

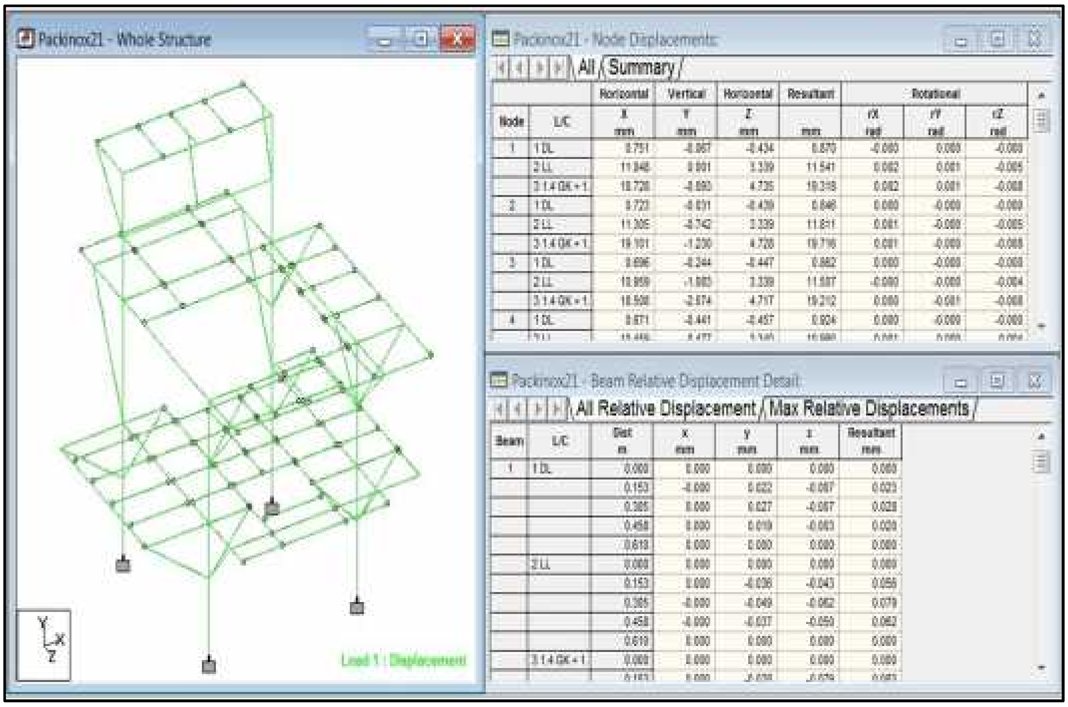
3.1.4 Structural Analysis

After assigning all the loads and load combinations, the model is analysed again to check for errors and failures in members and joints as in Figure 8. The horizontal, vertical and rotational force and reaction are obtained across each members and joints as shown in Figure 9.



Beam	Analysis Property	Design Property	Actual Ratio	Allowable Ratio	Normalized Ratio (Actual/Allowable)
113	UB152X89X1	UB152X89X1	0.481	1.000	0.481
114	UB152X89X1	UB152X89X1	0.288	1.000	0.288
115	UB254X102X	UB254X102X	0.999	1.000	0.999
116	UB305X102X	UB305X102X	0.334	1.000	0.334
117	UB305X102X	UB305X102X	0.588	1.000	0.588
118	UB305X102X	UB305X102X	0.241	1.000	0.241
119	UB152X89X1	UB152X89X1	0.164	1.000	0.164
120	UB152X89X1	UB152X89X1	0.031	1.000	0.031
121	UB305X102X	UB305X102X	0.484	1.000	0.484
122	UB305X102X	UB305X102X	0.472	1.000	0.472
123	UB305X102X	UB305X102X	0.151	1.000	0.151
124	UB152X89X1	UB152X89X1	0.087	1.000	0.087
125	UB152X89X1	UB152X89X1	0.079	1.000	0.079
126	UB152X89X1	UB152X89X1	0.099	1.000	0.099
127	UB254X102X	UB254X102X	0.243	1.000	0.243
128	UB254X102X	UB254X102X	0.426	1.000	0.426
129	UB254X102X	UB254X102X	0.489	1.000	0.489
130	UB254X102X	UB254X102X	0.281	1.000	0.281
131	UB305X102X	UB305X102X	0.188	1.000	0.188
132	UB152X89X1	UB152X89X1	0.058	1.000	0.058
133	UB152X89X1	UB152X89X1	0.124	1.000	0.124
134	UB152X89X1	UB152X89X1	0.712	1.000	0.712
135	UB152X89X1	UB152X89X1	0.188	1.000	0.188
136	UB152X89X1	UB152X89X1	0.183	1.000	0.183
137	UB305X102X	UB305X102X	0.316	1.000	0.316
138	UB152X89X1	UB152X89X1	0.178	1.000	0.178
139	UB152X89X1	UB152X89X1	0.169	1.000	0.169
140	UB305X102X	UB305X102X	0.088	1.000	0.088

Figure 8 : Unity Check is performed to analyze member or connection failure



		Horizontal	Vertical	Horizontal	Resultant	Rotational		
Node	L/C	X mm	Y mm	Z mm	mm	rX rad	rY rad	rZ rad
1	1 DL	0.751	-0.067	-0.434	0.870	-0.000	0.000	-0.000
	2 LL	11.848	0.001	3.339	11.541	0.002	0.001	-0.005
	3 1.4 GK + 1	18.728	-0.093	4.735	19.318	0.002	0.001	-0.008
2	1 DL	0.723	-0.031	-0.439	0.846	0.000	-0.000	-0.000
	2 LL	11.305	-0.742	3.339	11.811	0.001	-0.000	-0.005
	3 1.4 GK + 1	19.101	-1.230	4.728	19.716	0.001	-0.000	-0.008
3	1 DL	0.696	-0.244	-0.447	0.882	0.000	-0.000	-0.000
	2 LL	10.959	-1.883	3.339	11.587	-0.000	-0.000	-0.004
	3 1.4 GK + 1	18.508	-2.674	4.717	19.212	0.000	-0.001	-0.008
4	1 DL	0.871	-0.441	-0.457	0.924	0.000	-0.000	-0.000

Beam	L/C	Dist m	x mm	y mm	z mm	Resultant mm
1	1 DL	0.000	0.000	0.000	0.000	0.000
		0.153	-0.000	0.022	-0.007	0.023
		0.305	0.000	0.027	-0.007	0.028
		0.458	0.000	0.019	-0.003	0.020
		0.610	0.000	0.000	0.000	0.000
	2 LL	0.000	0.000	0.000	0.000	0.000
		0.153	0.000	-0.036	-0.043	0.056
		0.305	-0.000	-0.049	-0.062	0.079
		0.458	-0.000	-0.037	-0.050	0.062
		0.610	0.000	0.000	0.000	0.000
	3 1.4 GK + 1	0.000	0.000	0.000	0.000	0.000

Figure 9 : Member and Joint displacement and reactions

3.1.5 Determine the critical joint for the increased seismic activity

The analysis is repeated for structure under seismic Zones 1, 2A and 2B. For each analysis, the most critical joint and the forces on the joint is determined. The difference of the force induced on the joints are recorded for connection design.

3.1.6 Develop a connection design

The connection is design based on the forces imposed on the most critical joint. The connection design for seismic zone 1 is used as the baseline for existing structure to be compared to connection design for the increasing ground acceleration factor.

The larges positive and negative values from the StaadPro V8i End Force Beam is considered for the critical values. These end beam force acting on the joint in the X, Y and Z directions for the linear force and rotational force in the rX, rY and rZ direction are obtained to design the connection. The Figure 10 shows the forces extracted from StaadPro V8i

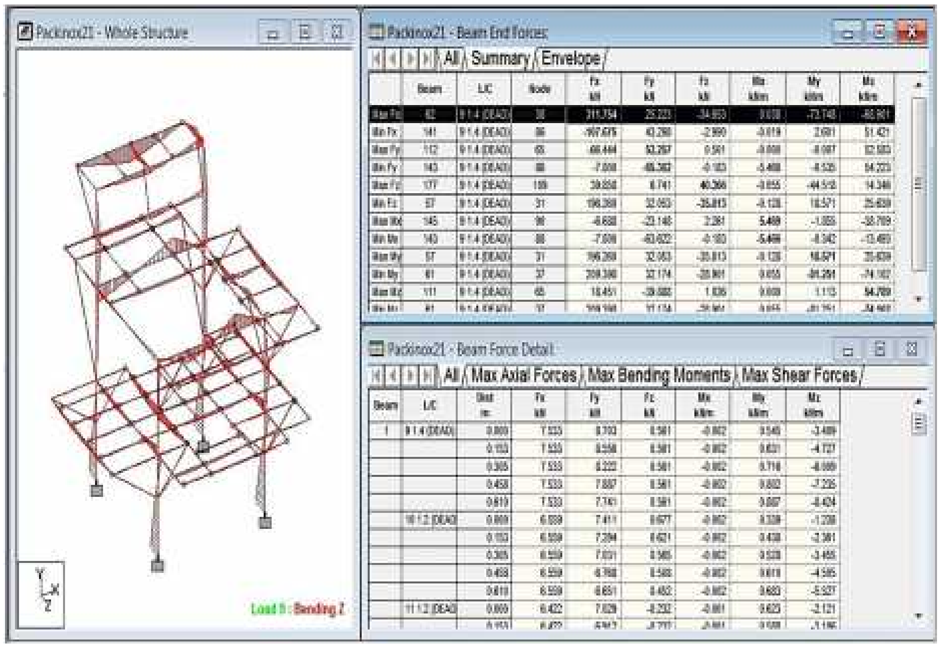


Figure 10 : Critical End Beam Forces

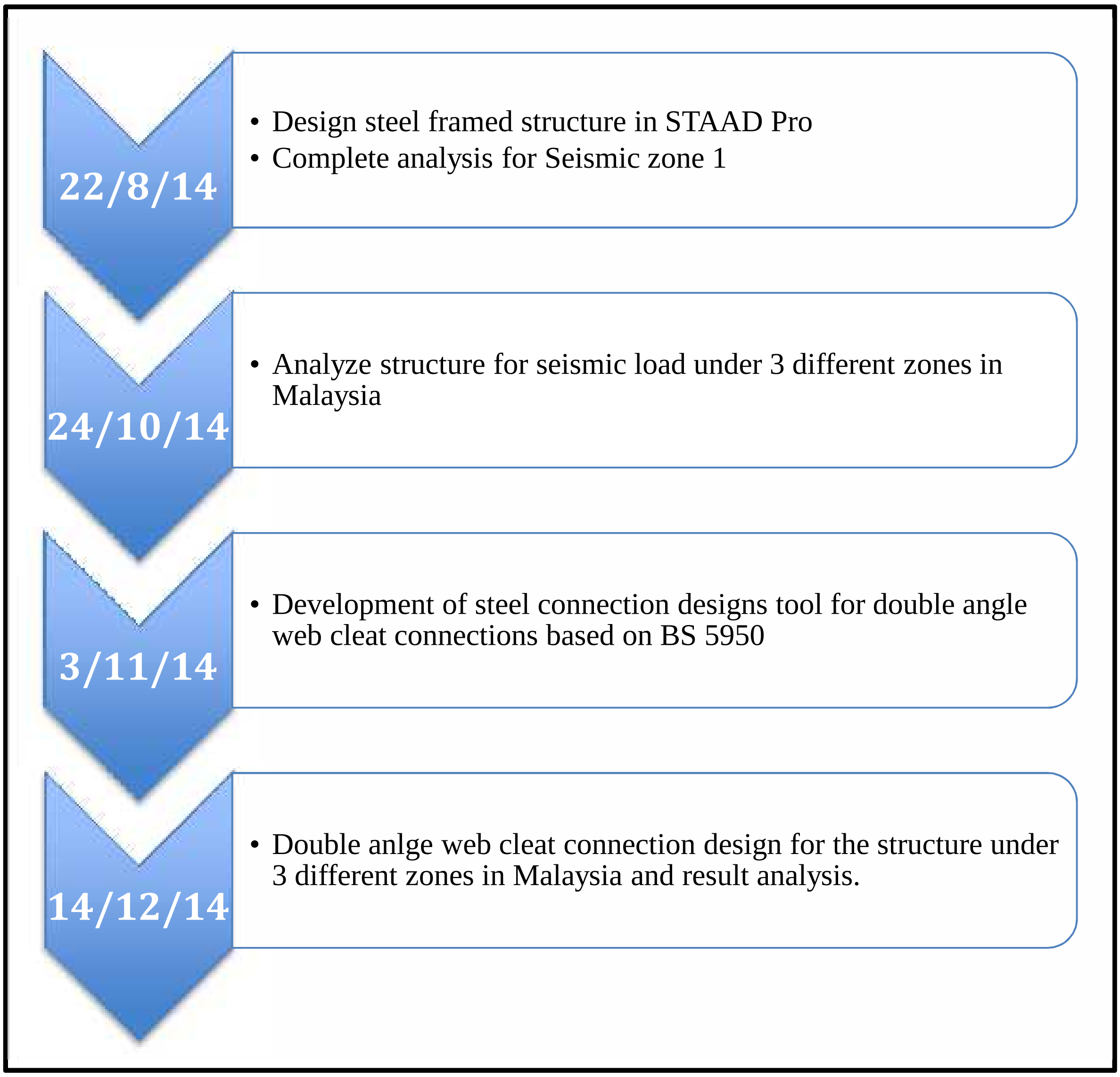
These values are used to design steel bolt connections based on the BS 5950. There are 14 checks that has to be complied in order for the connection to be in accordance of the BS 5950.

3.1.7 Recommendations to improve the structural integrity for connections

Propose recommendations to improve the structural integrity for connections for the steel structure if the connections fails. The structural recommendations are also based on the type of connection failure.

3.2 Key Milestone

The Figure 12 shows the key milestone that are to be achieved by the specific dates. This Milestone assists the author keep track on the progress of the project.



22/8/14

- Design steel framed structure in STAAD Pro
- Complete analysis for Seismic zone 1

24/10/14

- Analyze structure for seismic load under 3 different zones in Malaysia

3/11/14

- Development of steel connection designs tool for double angle web cleat connections based on BS 5950

14/12/14

- Double anlge web cleat connection design for the structure under 3 different zones in Malaysia and result analysis.

Figure 11 : Key Milestones

3.3 Gantt Chart

The project Gantt chart in Table 7 describes in detail the process of the study being carried out by the author. The dateline for project completion and submission are included in the Gantt Chart.

Table 8: Project Gantt Chart

No	Week Number/ Work Details	1	2	3	4	5	6	7	8	9	10	11	12	13	14
1	Topic Selection	🟦	🟦												
2	Research Work (Literature Review)			🟦	🟦	🟦	🟦	🟦	🟦	🟦					
2	Submission of Extended Proposal						●								
3	Proposal Defence										●				
4	Structural Design and Load Assigning							🟦	🟦	🟦	🟦	🟦			
5	Submission of Interim Report													●	
6	Structural Integrity and Load Checking											🟦	🟦		
7	Seismic Load for Zone 1 (Project Baseline)												🟦	🟦	🟦

No	Week Number/ Work Details	15	16	17	18	19	20	21	22	23	24	25	26	27	28
8	Seismic Load for Zone 2A & 2B	🟦	🟦	🟦											
9	Connection Design Tool Development				🟦	🟦	🟦	🟦	🟦	🟦					
10	Submission of Progress Report							●							
11	Connection Design & Results interpretation										🟦	🟦	🟦		
12	Preparation of Final Report												🟦	🟦	
13	Pre-SEDEX										●				
14	Submission of Final Report													●	
15	Submission of Technical Paper													●	
16	VIVA														●
17	Submission of Dissertation														●

CHAPTER 4

RESULTS AND DSCUSSION

4.1 Results

The analysis for the critical connection is done focusing on column-beam connections as it is crucial for lateral loads . Below are the figure for the Column-beam Joints for the Packinox gas vessel steel support structure.

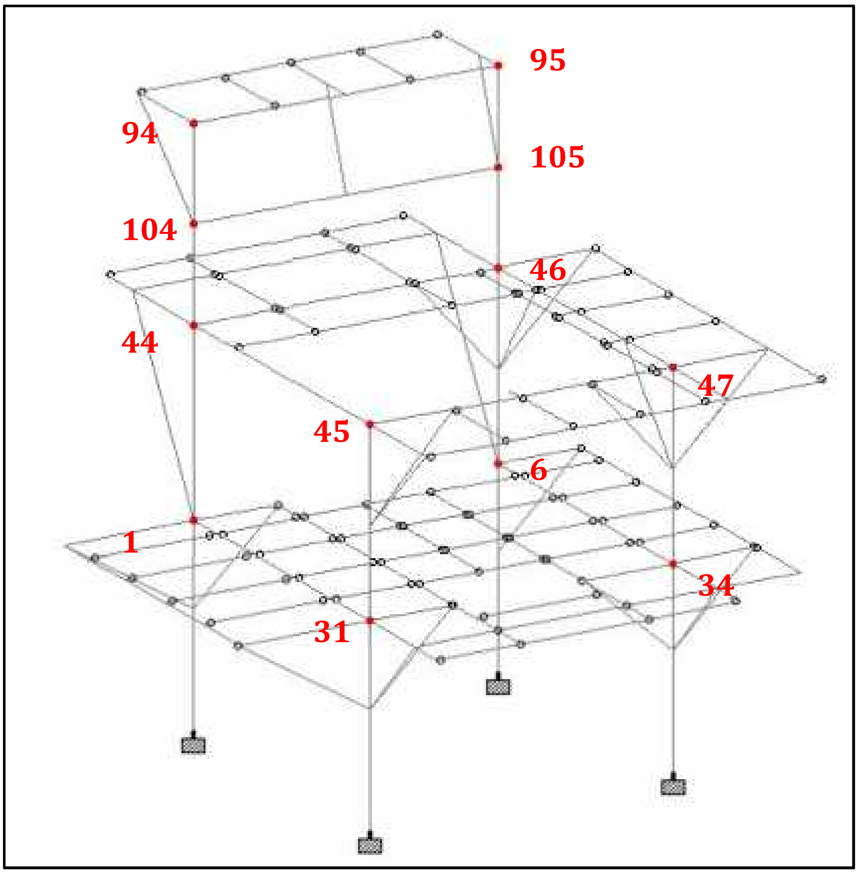


Figure 12 : Column-Beam Joints and Number

4.1.1 End Beam Forces

For the Packinox gas vessel steel support structure, there are two main Universal Beams used which are UB254 x 102 x 25 and UB305 x 102 x 28. The axial forces and maximum tie forces along the beams are tabulated in the sections below.

4.1.1.1 Universal Beam (UB) 254 x 102 x 25

Figure 13 shows the UB254 x 102 x 25 and the corresponding column attached. There are 8 column and beam connections for this beam size.

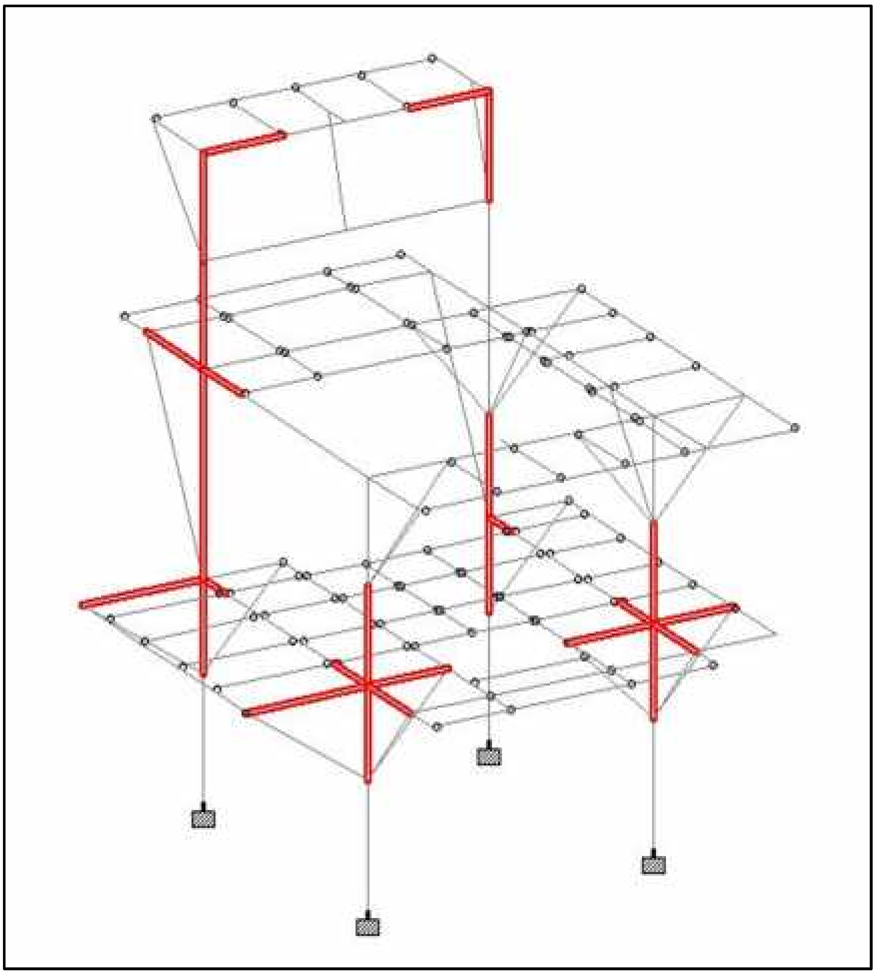


Figure 13 : UB 254 x 102 x 25 and Column connection members

Table 9 compares the end beam axial forces for UB254 x 102 x 25 for different seismic zones. The tabulated results compared the forces produced when the ground seismic acceleration increases from 0.075g to 0.15g and 0.2g.

Table 9 : Comparison for end beam axial forces for Seismic Zone 1, 2A and 2B for UB254 x 102 x 25

Joint	Zone 1 (0.075g) kN	Zone 2A (0.15g) kN	Percentage Increase From Zone 1 to 2A	Zone 2B (0.2g) kN	Percentage Increase From Zone 1 to 2B
1	23.552	24.315	3.14%	26.331	10.55%
6	20.096	20.744	3.12%	24.948	19.45%
31	55.064	57.16	3.67%	65.174	26.75%
34	-1.04	-1.311	20.67%	-5.523	81.17%
44	-20.858	-22.607	7.74%	-33.831	38.35%
45	38.749	36.988	4.76%	34.251	-13.13%
94	32.428	35.801	9.42%	36.4	10.91%
95	-41.247	-41.961	1.70%	-44.554	7.42%

Figure 14 show the increase in Axial Force for UB254 x 102 x 25. The difference in forces range from 0kN to 4kN when the seismic zone changes from Zone 1 to 2A and 3kN to 13kN for changes from Zone 1 to 2B.

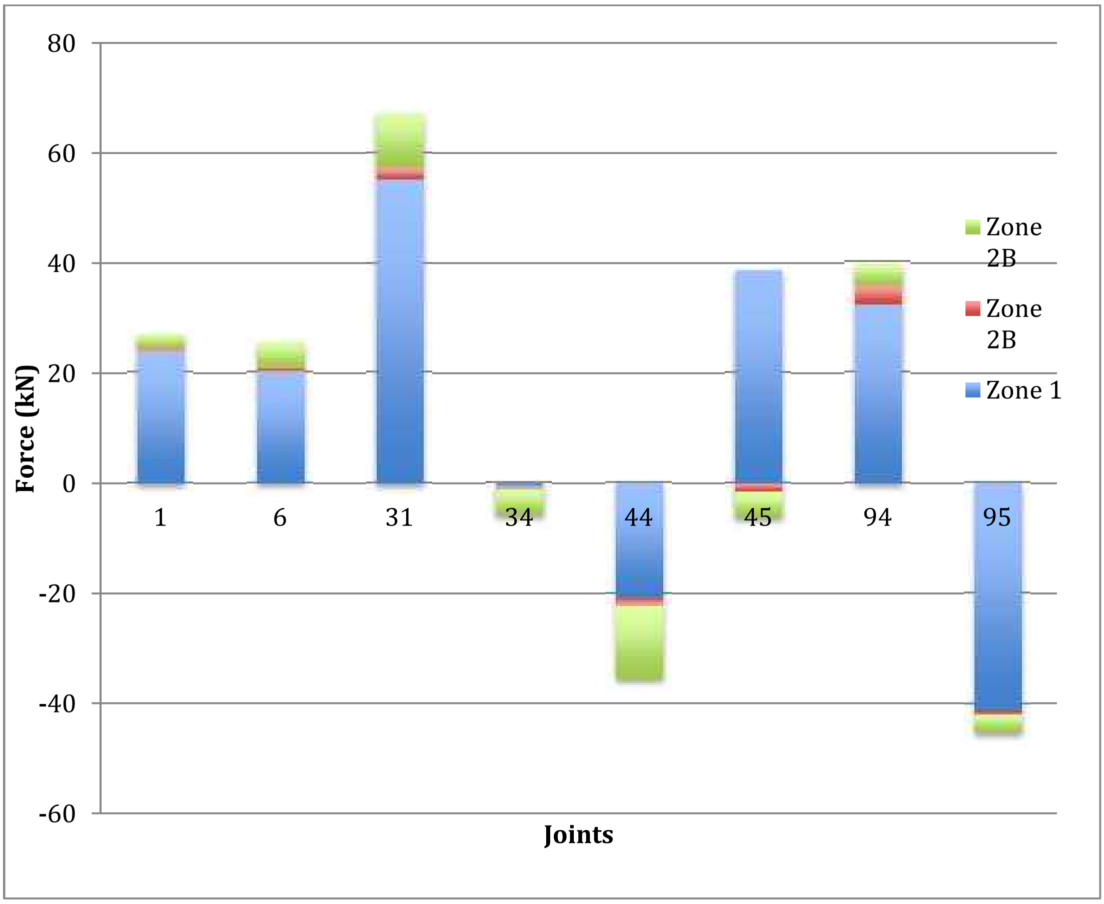


Figure 14 : Difference in Axial Force for UB254 x 102 x 25 when the Seismic Zone changes from Zone 1 to Zone 2A and 2B

Table 10 compares the maximum end beam tie forces for UB254 x 102 x 25 for different seismic zones. The tabulated results compared the forces produced when the ground seismic acceleration increases from 0.075g to 0.15g and 0.2g.

Table 10 : Comparison for maximum end beam tie forces for Seismic Zone 1, 2A and 2B for UB254 x 102 x 25

Joint	Zone 1 (0.075g), kN	Zone 2A (0.15g), kN	Percentage Increase From Zone 1 to 2A	Zone 2B (0.2g),kN	Percentage Increase From Zone 1 to 2B
1	-19.39	-20.46	5.23%	-19.34	-0.26%
6	10.338	10.338	0.00%	12.83	19.42%
31	-7.07	-7.17	1.39%	-7.08	0.14%
34	-0.895	-0.895	0.00%	-0.895	0.00%
44	-1.064	-1.064	0.00%	-1.064	0.00%
45	16.109	16.109	0.00%	16.109	0.00%
94	12.79	12.79	0.00%	12.922	1.02%
95	-19.39	-20.46	5.23%	-19.34	-0.26%

Figure 15 show the increase in Tie Force for UB254 x 102 x 25. The difference in forces range from 0kN to 2kN when the seismic zone changes from both Zone 1 to 2A and 2B.

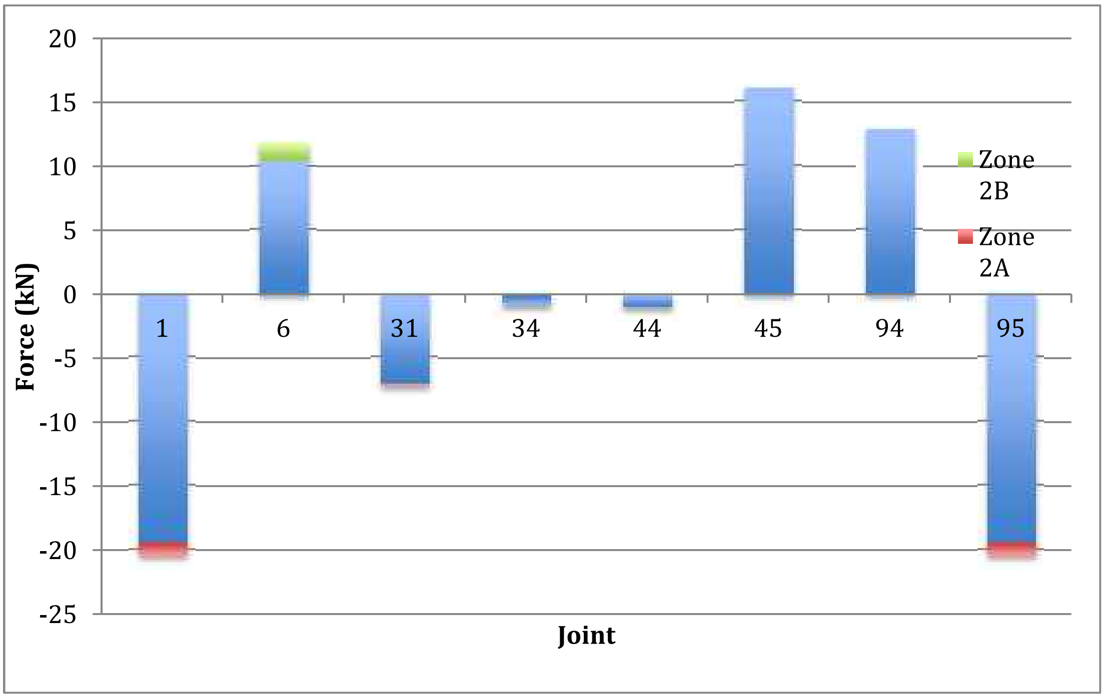


Figure 15 : Difference in Tie Force for UB254 x 102 x 25 when the Seismic Zone changes from Zone 1 to Zone 2A and 2B

4.1.1.2 Universal Beam (UB) 305 x 102 x 28

Figure 16 shows the UB305 x 102 x 28 and the corresponding column attached. There are 6 column and beam connections for this beam size

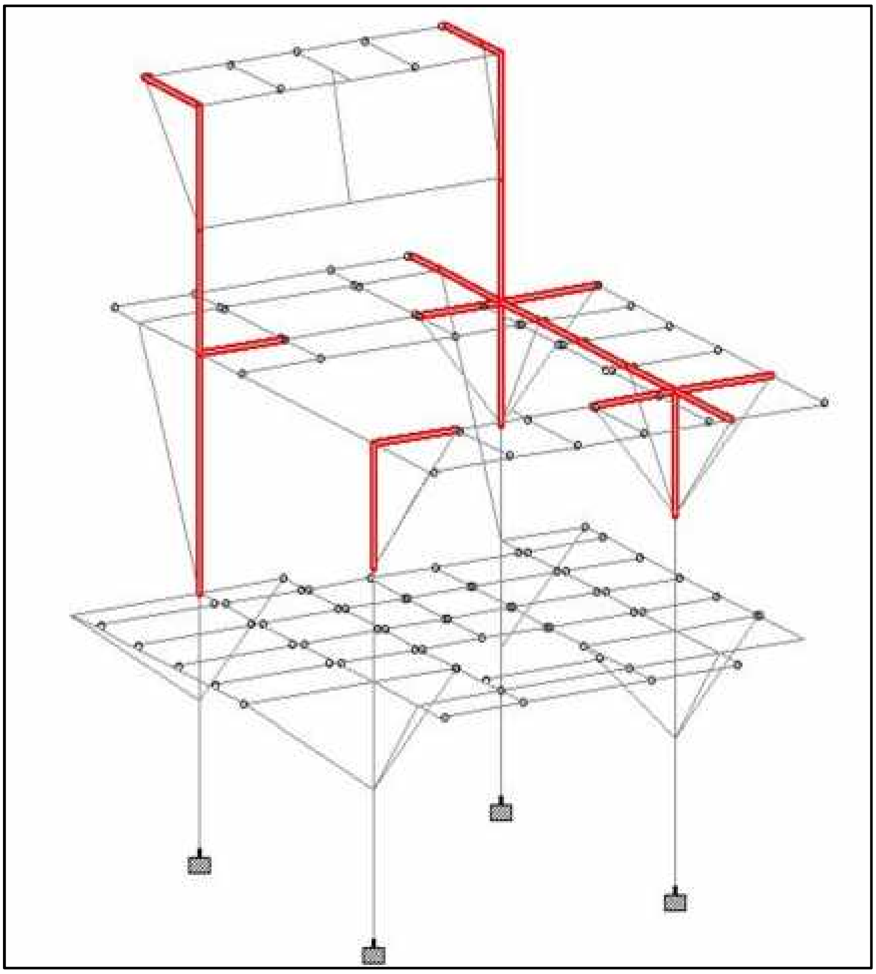


Figure 16 : UB 305 x 102 x 28 and Column connection members

Table 1 compares the end beam axial forces for UB305 x 102 x 28 for different seismic zones. The tabulated results compared the forces produced when the ground seismic acceleration increases from 0.075g to 0.15g and 0.2g.

Table 11 : Comparison for end beam axial forces for Seismic Zone 1, 2A and 2B for UB305 x 102 x 28

Joint	Zone 1 (0.075g) kN	Zone 2A (0.15g) kN	Percentage Increase From Zone 1 to 2A (%)	Zone 2B (0.2g) kN	Percentage Increase From Zone 1 to 2B (%)
44	-20.858	-22.607	7.74%	-33.831	38.35%
45	38.749	36.988	4.76%	34.251	-13.13%
46	50.474	54.878	8.03%	73.352	31.19%
47	106.092	106.377	0.27%	129.736	18.22%
94	32.428	35.801	9.42%	36.4	10.91%
95	-41.247	-41.961	1.70%	-44.554	7.42%

Figure 17 show the increase in Axial Force for UB305 x 102 x 28. The difference in forces range from 0kN to 5kN when the seismic zone changes from Zone 1 to 2A and 4kN to 24kN for changes from Zone 1 to 2B

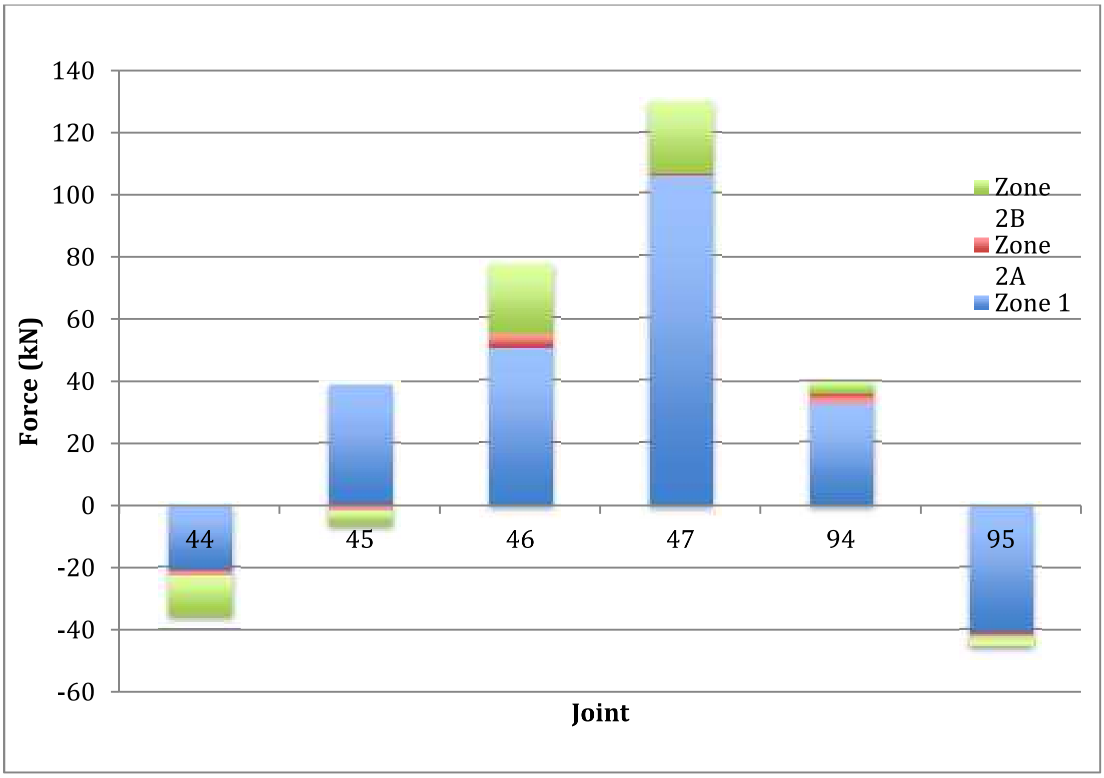


Figure 17 : Difference in Axial Force for UB305 x 102 x 28 when the Seismic Zone changes from Zone 1 to Zone 2A and 2B

Table 12 compares the maximum end beam tie forces for UB305 x 102 x 28 for different seismic zones. The tabulated results compared the forces produced when the ground seismic acceleration increases from 0.075g to 0.15g and 0.2g.

Table 12 : Comparison for maximum end beam tie forces for Seismic Zone 1, 2A and 2B for UB305 x 102 x 28

Joint	Zone 1 (0.075g), kN	Zone 2A (0.15g), kN	Percentage Increase From Zone 1 to 2A (%)	Zone 2B (0.2g),kN	Percentage Increase From Zone 1 to 2B (%)
44	19.348	19.348	0.00%	21.298	9.16%
45	40.779	40.779	0.00%	42.657	4.40%
46	65.95	65.95	0.00%	69.72	5.41%
47	-105.97	-105.97	0.00%	-113.76	6.85%
94	-0.965	-1.062	9.13%	-1.169	17.45%
95	1.725	1.949	11.49%	2.198	21.52%

Figure 18 show the increase in Tie Force for UB305 x 102 x 28. The difference in forces range from 0kN to 2kN when the seismic zone changes from both Zone 1 to 2A and 2B

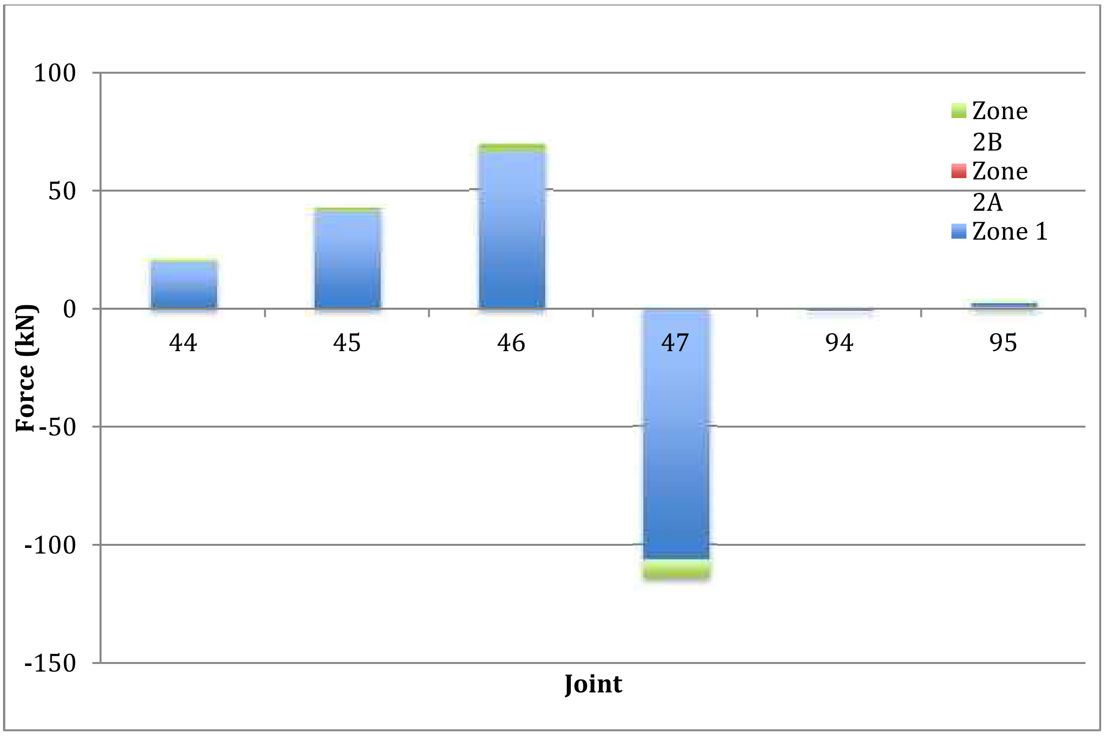


Figure 18 : Difference in Tie Force for UB305 x 102 x 28 when the Seismic Zone changes from Zone 1 to Zone 2A and 2B

4.1.2 Connection Design

4.1.2.1 Universal Beam (UB) 254 x 102 x 25

Table 13 show the connection design for the largest increase in axial and tie force for UB254 x 102 x 25. The table shows the requirement for bolt connection for the connection under Seismic Zone 1, 2A and 2B.

Table 13 : Connection Design for Connection at Joint 31

Parameters	Zone 1	Zone 2A	Zone 2B
Seismic Ground Acceleration	0.075g	0.15g	0.2g
Max Axial Force	55.064	57.16	65.174
Max Tie Force	10.338	10.338	11.83
Type of Connection	Double Angle Web Cleat Single Line of Bolt		
Number of Bolts	2 with Grade 8.8 on S275 member		
Size of Bolts	M12	M12	M16

4.1.2.2 Universal Beam (UB) 305 x 102 x 28

Table 14 show the connection design for the largest increase in axial and tie force for UB305 x 102 x 28. The table shows the requirement for bolt connection for the connection under Seismic Zone 1, 2A and 2B.

Table 14 : Connection Design for Connection at Joint 47

Parameters	Zone 1	Zone 2A	Zone 2B
Seismic Ground Acceleration	0.075g	0.15g	0.2g
Max Axial Force	106.092	106.377	129.736
Max Tie Force	-105.97	-105.97	-113.76
Type of Connection	Double Angle Web Cleat Single Line of Bolt		
Number of Bolts	3 with Grade 8.8 on S275 member		
Size of Bolts	M12	M12	M16

4.2 Discussion

4.2.1 Increase in Force from Zone 1, 2A and 2B

Based on the tabulated results, it was found that the end beam forces for Zones 1 to 2A has insignificant changes. This is because the critical forces in all 12 joints are generated by the Load Combination 1 (refer Table 2). As this load combination does not include seismic loads, the increasing ground acceleration has an insignificant effect on the structure and joints. Figure 19 and 20 shows the percentage difference for the force generated from Zone 1 to 2A and 2B. The percentage of axial forces increases ranging from 0% to 9.42% and 0% to 5.23% in tie force

For Zone 2B, there is a significant increase in the force induced at the joins as most of the end beam forces are generated by Load Combinations 6, 7, 8 and 9 (refer table 2). Thus, the increase in the ground acceleration will effect the connection design. The percentage of axial forces increases ranging from 7.42% to 38.35% and 0% to 12.61% when the seismic conditions changes from Zone 1 to Zone 2B.

Figure 19 : Percentage Difference in Axial Force for Changes from Zone 1 to 2A and 2B

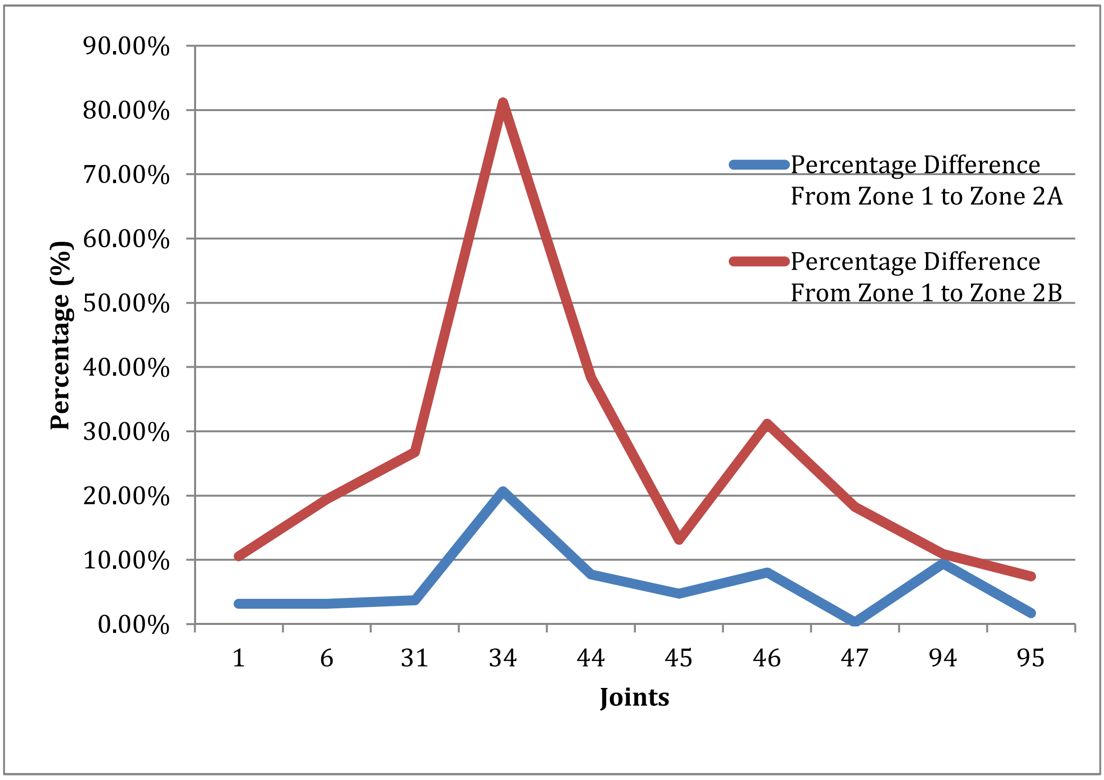
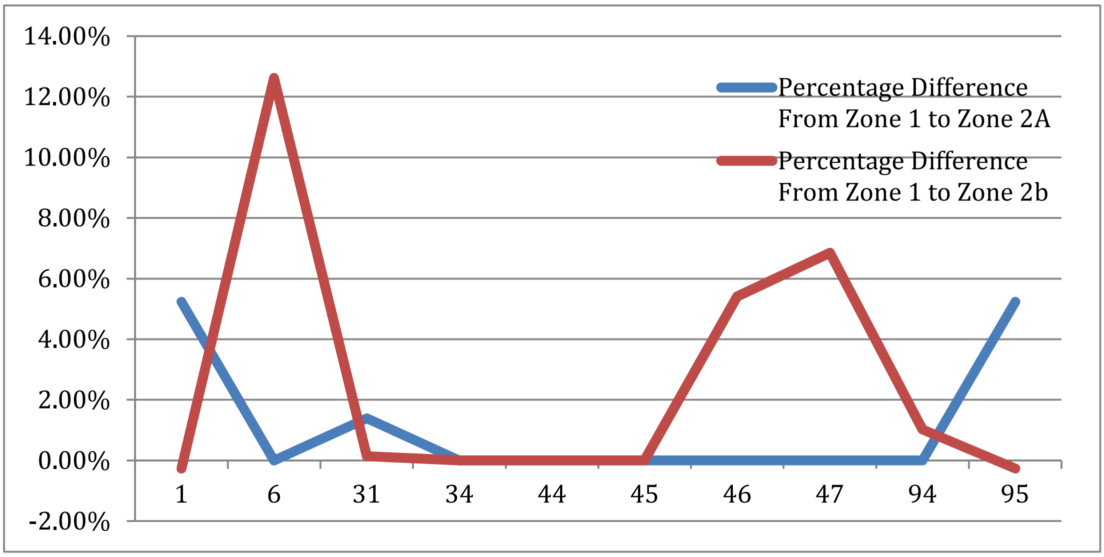


Figure 20 : Percentage Difference in Axial Force for Changes from Zone 1 to 2A and 2B



4.2.2 Connection design

Joint 31 has is the most effected joint when the seismic ground acceleration increases from Zone 1 to 2B for UB254 x 102 x 25. The largest difference in axial force is from Zone 1 to Zone 2B at joint 31 with and increase of 8.01kN. For tie force, the most significant difference is also at joint 31 with increase of 1.5 kN. Thus, by analysing that joint, the connection integrity of the structure could be determined.

Joint 47 has is the most effected joint when the seismic ground acceleration increases from Zone 1 to 2B for UB305 x 102 x 28. The largest difference in axial force is from Zone 1 to Zone 2B at joint 47 with and increase of 23.4kN. For tie force, the most significant difference is also at joint 47 with increase of 7.81 kN. Thus, by analysing that joint, the connection integrity of the structure could be determined.

4.2.3 The increase in size of bolts

In accordance to BS 5950, UB254 x 102 x 25 and UB 305 x 102 x 33 requires 2 and 3 bolts respectively. Thus, by varying the size of the bolts, the connection integrity was determined. For Zone 1 and 2A, M12 bolts were sufficient for the joint. However, the diameter of bolt increases form M12 to M16 when the seismic Zone changes from Zone 1 to 2B

CHAPTER 5

CONCLUSION AND RECOMMENDATION

Based on the literature, it was found that the maximum magnitude earthquake in Peninsular Malaysia is of magnitude 6.5 with PGV and PGD of 60 cm/s and 150mm respectively. According to the Modified Mercalli scale, ground velocity of 60 cm/s is categorized under severe shaking and with moderate to heavy damage. The ground acceleration is predicted to be between 0.34 g to 0.65 g. If an earthquake with this parameters occur in Peninsular Malaysia, structures will be damaged as structures in Malaysia is not catered to withstand earthquake of this intensity.

Based on the study, it was found that the packinox gas vessel support steel structure has the an insignificant changes in the end beam forces when the seismic conditions changes from Zone 1 to Zone 2. However, if seismic conditions changes to Zone 3, there will be a large difference in the forces in the end beam generated by the ground acceleration. This caused the current bolt connection to be insufficient and to fail. For Zone 1 and 2A, Grade 8.8 M12 bolts were required and M16 for Zone 2B.

For future recommendations, this project could be improved by investigating or analyzing ways to rectify or modify the connections that are predicted to fail when the seismic conditions changes from Zone 1 to Zone 2B. Seismic retrofitting is a method of modifying existing structure to improve the resistance to seismic activities, ground acceleration/motions and soil failure due to earthquakes. The understanding in seismic retrofication could improve the safety of Malaysian Oil and Gas Structure in the occurrence of devastating seismic activities.

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