VULNERABILITY ASSESSMENT OF BLAST WALLS OF OFFSHORE STRUCTURE UNDER ACCIDENTAL EXPLOSION

by

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Dissertation submitted in partial fulfillment of

the requirements for the

Bachelor of Engineering (Hons)

(Civil Engineering)

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Universiti Teknologi PETRONAS

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31750 Tronoh

Perak Darul Ridzuan

CERTIFICATION OF APPROVAL

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Approved by,

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MAY 2013

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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MOHAMAD NAJIB B ABDUL RAHIM

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First and foremost I would like to praise Allah the Almighty which have help and guided me in completing my Final Year Project with the title Vulnerability Assessment of Blast Walls of Offshore Structure under Blast Loading. The project took 2 semesters with the total of 7 months to be completed and hopefully it will be useful to all the people that needed it.

My most gratitude goes to Dr. Zubair, my project for giving me the opportunity and support to complete this project. His full supports in emphasizing lessons learnt and experienced gave me a useful tool to successfully complete the project. I also would like to express my full appreciation towards all UTP civil engineering staff for being my best companion throughout project period. All of your guidance, supervision and leadership have been great in directing me through the correct path of becoming an engineer.

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ABSTRACT

Blast walls are provided in offshore structures for protecting critical structural components and personnel on offshore structure from accidental explosions. This study investigates the vulnerability of blast walls under different blast loading conditions. Although blast is a low probability event but can have devastating effect on an offshore structure and on the personnel working on it. Blast wall acts as a barrier to avoid the high magnitude of blast to affect the other parts of the structure like what happen in the Alpha Oil rig. Currently, there is no exact and well accepted guideline to design blast walls for offshore structures due lack of proper investigation on the structural response and vulnerability of blast walls under different blast loadings. Therefore, this research studies the structural response and vulnerability of blast walls to gain in-depth detailed response of blast walls under different blast loading. This study consists of 4 major elements which are the modelling, study of response, investigation on vulnerability and recommendations for design. The findings of this research are expected to help effective and economic design of blast walls for better protection. The results show that today's blast wall design is very vulnerable to blast overpressure exceeding 10 MPa because 10 MPa of blast overpressure will cause the blast wall to deform to more than 0.5 m. The deformation pattern also can be seen that the middle part of the blast wall is the most crucial part of the structure since it has the highest deformation compared to the other part of the blast walls.

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CHAPTER 1: INTRODUCTION

1.1 Background of the study

Offshore platforms are usually exposed to potential accidental explosions since the combustible crude oil that have been drilled. Since there are limited spaces on the offshore platform, failure of any part of an offshore structure would be highly devastating. Therefore high safety measure and precaution need to be made not only to protect the dormitory area of the members on board, but also to ensure that the whole structure does not collapse.

The installation of blast walls are intended to avoid the blast loading to spread out to the whole area of the platform. However, although blast walls are installed on the platform, there are still major accidents that happen. According to J.W. Boh [1], "The consequences of the lack of knowledge in blasting can be costly, such as the complete loss of the Alpha Piper oil rig platform and many lives following accidental explosions". The complete loss the Alpha Piper oil rig will be further discussed in chapter 2 of this study. Traditionally, concrete are used for building the blast wall in onshore structures due to the ability to absorb large amount of energy and the massiveness in size [1]. However, blast walls installed in the offshore structure are made from steel. Since weight plays an important role in designing a platform, steel is chosen since it is light in weight although the ability to absorb energy is lower compared to concrete.

1.2 Problem Statement

1.2.1 Problem identification

The blast load acts on a structure for a very short period of time. It is often challenging to predict the exact magnitude and location of blast for design purpose. Accidental blasts can cause the structure to [2]:

- Bend, break, or displace load-bearing panels, posts, and beams, possibly causing structural collapse
- Distort and possibly rupture pressure vessels. Pipes, valves, and instrumentation, releasing hazardous (toxic or explosive) materials into the environment
- Shock and vibration can break non-structural components (e.g., glass windows) far from incident.
- Create fragments which can travel long distances, causing facility damage and bodily injury.
- Start fires due to thermal radiation from fireballs and heat transfer from combustion products.

Explosions can cause the structure to fail not only at the blast location; it may extent to the whole structure. Therefore, blast wall plays an important role in order to act as a separator between the blast location and the other parts of the structure.

Besides that, there is an increase in the awareness of effect of blast not only on the blast wall, but to the extent of the whole structure. The complexity of material behaviour to such loading which is influenced by the effect of high strain rates, the non-linear inelasticity of materials subject to time-dependent blast etc. is another reason why blasting have receive high concerns from the public [3]. The safety of the people on board need to be carefully taken hence has to have the knowledge on how vulnerable the blast wall towards blasting is certainly a major concern.

As to date, there are actually no well defined guidelines on the requirement of blast wall design for offshore structure. The authority that handles the entire design requirement for the offshore structure in Malaysia is PETRONAS. Basically, PETRONAS will follow the American Petroleum Institute (API) guideline. In item 8.4 inside the API guideline, the guideline for blast wall is not comprehensive and often not specific. This effects the implementation and quality of the blast wall installation on offshore structures.

1.2.2 Significant of the project

From the information gathered, a finite element analysis will be conducted to determine the structural behaviour of a blast wall after a blast event. The analysis of the impact of the blast towards the surrounding also can be determined. The findings from the study and analysis have the potential to achieve some practical application such as [4];

- Immediate life safety consequence – by preventing damage to critical structures which will lead to injury or death.
- Controlling potential hazard – proper design and placement of blast wall can contain the release of combustible or flammable material that could result in fire or explosion.
- Economic loss – in-depth understanding of the behaviour of blast wall can help in destruction of high value processing equipment, loss of product, plant downtime, environmental cleanup, compensation of victims, litigation costs.

1.3 Objectives

The main objectives of this study can be summarized as,

- to identify the vulnerability of blast walls used in offshore structures due to various explosions,
- to analyse and assess the response of standard blast wall under blast load
- to identify the adequacy of existing design practices

1.4 Scope of the study

This research will be focusing on the blast effect on blast walls on offshore structures. The crucial element of the blast wall that will be highly focused on is the blast wall panel and the connection. The finite element analysis of the structure will be analysed to get the in-depth last reaction of the blast wall. The data of the blast will be collected based on past study and current event to be transformed into the analysis.

1.5 Relevancy of project

Most of the studies on offshore platform nowadays are focused on earthquake effect on offshore structure rather than accidental explosions. Blast can be significantly more devastating than earthquake depending if the magnitude and duration of blast loading is applied to the certain location. Therefore, the need to study on the behaviour of the blast wall on offshore structure towards the blasting effect is highly needed.

1.6 Feasibility of the project

This project involves advanced numerical simulation and modelling using relevant computational tools. The required resources were available to conduct the study successfully. The analysis was conducted in UTP using the commercial finite element package ANSYS. Computational fluid dynamics based software Air 3d was used to simulate blast load.

CHAPTER 2: LITERATURE REVIEW

2.1 Effect of Accidental Explosions on offshore structure

On site explosions may have a minor or severe impact on the offshore structure. The level of severity varies based on the level of blast that occur and how the safety measures been taken before, during and after the blast. Huge blast may result in a total loss of the structure as well as human loss in which the total effect is very high. Below are some actual cases which are the effect of blasting on the offshore structure.

2.1.1 Piper Alpha Oil Rig (6^{th} July 1988)

The Piper Alpha Oil rig tragedy is a very famous example of a complete total loss of an offshore structure due to blasting. The oil rig was built in the year 1976. It was initially built for oil production which was later converted into a gas production platform. In general, the tragedy was basically cause by human error rather than accidental error. The fire fighting system inside the platform was turned to manual which leaves only the blast wall to protect any possibilities of an explosion on the tragedy day. Due to the problems with the methanol system, hydrates had started to accumulate in gas compression pipe work which causes blockage [5]. Since the safety valve was also missing, the gas leaked out with high pressure causing high intensity blast which even the blast wall could not withstand. The oil rig was totally damaged in which only 61 people survives from the total 228 crew and the damage was estimated at 3.4 billion U.S dollars.

Figure 1: Picture of Alpha Rig Explosion

2.1.2 Steelhead Platform (20th Dec 1987)

The Steelhead platform is located in Cook Inlet, Alaska. The platform suffered a natural gas blowout while drilling a well. Since the crew was setting the casing at the particular time, gas from a shallow gas pocket flow through from the well [6]. The gas ignited and causing explosion on the platform. Fortunately, all 49 crew manage to survive. The fire destroyed the heli-deck and the accommodation module, drilling module and one of the cranes. The fire continues for several days. However, the platform was managed to be repaired and later continue its production. The total lost is estimated to be more than 10 million USD.

Figure 2: Steelhead Platform in Operation

2.2 Guidelines on blast wall design

Design guidelines are developed in order to have a better view on the design standard and how the guidelines involve with the health and safety at site. For the offshore structure in Malaysia, the authority involves setting up the guideline for offshore structure is PETRONAS. In most cases, PETRONAS adopted the American Petroleum Institute (API) guidelines.

API publications are published to facilitate the broad availability of proven, sound engineering and operating practices. An API guideline is the recommended design, practices and general guideline for incorporating hazard analysis output into structural response assessment in determining whether the structure or its component meets the specified criteria [7]. The guidelines for blast wall design are as follows:

Blast walls may be bulkhead walls or proprietary walls. Bulkhead walls are integrated with general structural form like ship bulkheads and usually built at the same time as the rest of the structure. Blast walls are usually designed to deform plasticity and act predominantly in bending to minimize the reaction on the primary structural members of the platform edge connections shall be so detailed so that the reaction loads are transmitted to the support without damaging the support steel work. The capacity of a blast wall with stiffened plate construction may be estimated using yield line analysis for the plate section

As shown in the API, the designs for blast wall are too general and there is no definite number or figure to support the design guidelines. There are still no certain criteria of blast wall design standard set by any organization up to date.

2.3 Importance of blast walls in offshore structures

Blast is very damaging to the structure. It can cause a structure to collapse in just a matter of time. Therefore having a blast wall is essential not only to protect the blast from damaging the structure, but also having the ability to protect people on the platform. The nature of the platform is having an enclosed area which can lead to blast overpressure which eventually it will be imparted to the walls and floors in an event of explosions [8]. Most of the blast walls in onshore structure are made out of concrete due to its massiveness and ability to absorb high amount of energy.

However, blast walls in offshore structure are often made out of stainless steel since weight plays a very important role in designing a platform. Besides that, blast walls must be made using fire resistant walls. Therefore it will have the ability to prevent the fire to propagate to another area of the platform. Any failure in the blast walls may have a vital effect towards the whole structure.

Figure 3: Example of a Blast Wall on a Platform

2.4 Blast wall components which are vital in the overall design

The connection details of the blast wall panels can significantly influence the response of the panel to air blast loading [9]. A study done by University of Liverpool [10], have the aim to check the performance of several test panels using pulse pressure test facility. Three types of panel/connection system were studied, namely, short, medium and long welded angle connections, to compare the influence of the angle length. In general, the flexibility of the angle connection and thus the test panel/connection system increases as the angle length increases and larger displacements are produced in the panel for a given test pressure [10]. Most of the blast wall nowadays are welded top and bottom and have certain angles. The effect on how this welding may or may not fail need to be studied. The locations of the highest blast load need to be tested on each area of the blast wall. Besides that, the critical part in the blast wall components is the connection details where most of the people are not well aware off.

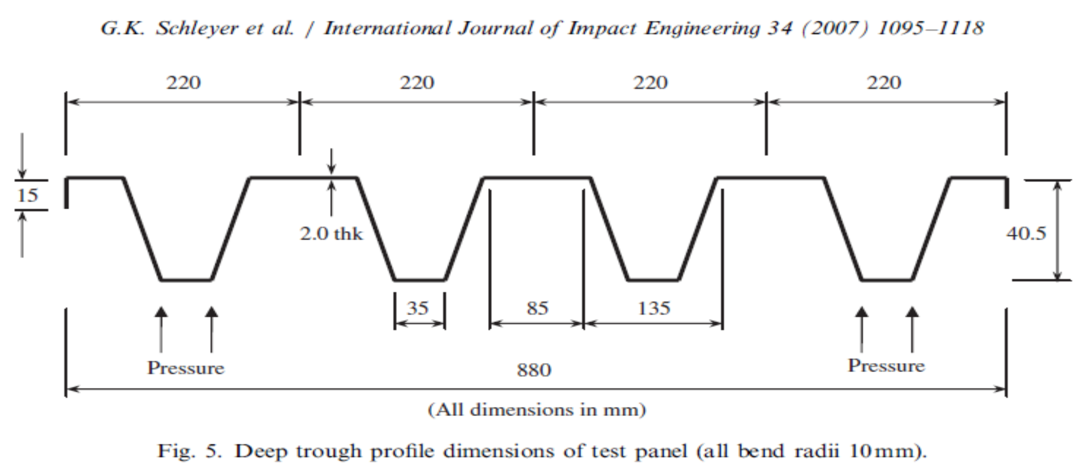

Figure 4: Profile Dimension of a Test Panel

CHAPTER 3: METHODOLOGY

3.1 Introduction

In this chapter, the methods in completing the analysis of blasting on blast walls of offshore structure is determine. After a series of assessing the best method to determine the effect of blasting, it is found out that the best way to determine it is by using the finite element analysis. The first step in determine the analysis is doing the data gathering, followed by the modeling using ANSYS software analysis. After the analysis is done, the effect and consequences of blasting will be determined in terms of the degree of injury and severances. The method can be summarized as below:

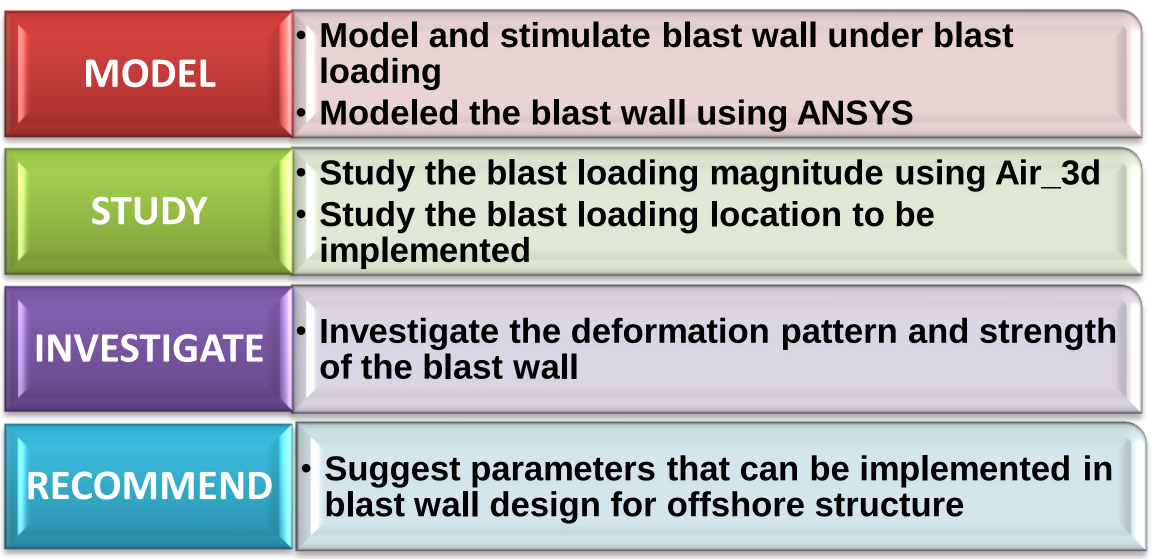

Figure 5: Process Flow of the Study

3.2 Modelling

During this modelling stage, the model of the blast wall will be made. The modelling of the blast wall will be modelled using ANSYS finite element analysis software for most of the time. Besides that a blast loading will be applied to required sections of the blast wall.

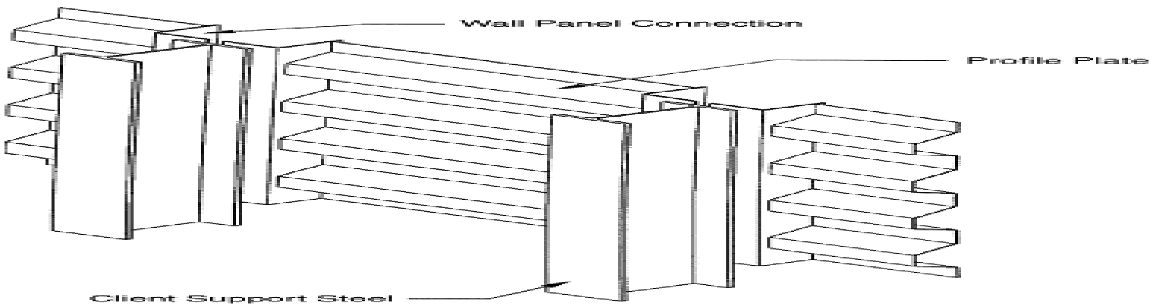

Figure 6: Example of Blast Wall Modelling

3.3 Studying

In this process, the response of the blast wall towards the loading applied will be studied. Not only that, the magnitude, direction and distributed of the load will be varied to study how the wall will react and respond.

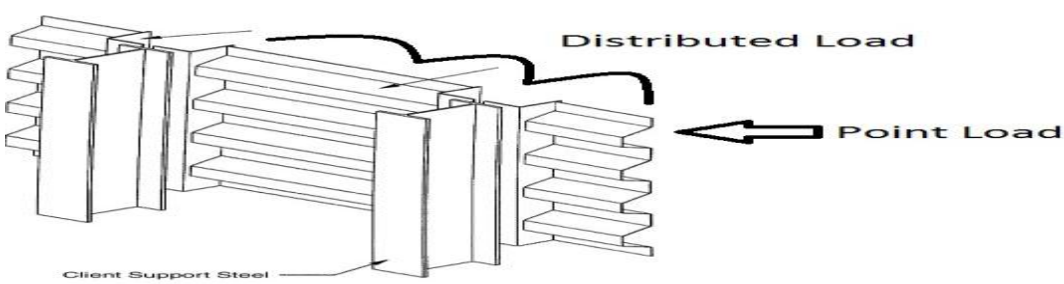

Figure 7: Blast Loading Distribution on the Structure

3.4 Investigating

After the studies have been made, the vulnerability of the blast wall in the offshore structure can be determined. By having to know condition of the vulnerability, the result can be compared with the actual blast wall that are current used and in the market.

3.5 Recommend

Recommendations will be made to the extent which of the criteria of the blast wall that is suitable to be used for implementation. Besides that, recommendation for the design criteria guidelines will also be given to improve the current guidelines available.

CHAPTER 4: RESULT AND DISCUSSION

4.1 Result Overview

The result of the modelling of the offshore structure was studied together with the blast loading using Air_3D software. The objective of the study which was to identify the vulnerability of offshore blast walls towards blasting. Besides that the adequacy of the current practices were studied and improvements for the practice was given further in this chapter.

The results and discussions in this chapter can be divided into 4 sections named the blast wall modelling result which will discussed on how the blast wall geometry were modelled and how does the model help in the successful of the project. Besides that, the blast loading magnitude and location were studied using the Air_3D program in order to determine the blast overpressure that need to be implemented on the blast wall.

The second section will be the blast wall analysis. This is the main and most critical part of the study. The blast wall analysis will show the critical locations of the blast wall that were vulnerable towards blast loading. Besides that, the deflection pattern of the blast wall will also be analysed to determine the effect of different blast overpressure towards the blast wall. The analysis were done using ANSYS program for each of the blast overpressure found during blast loading modelling stage.

The third section will more focus on the adequacy of today's blast wall design compared to the results found during the study. In this section, the effect of the blast wall deflections were analyzed and studied whether today's blast wall designs are adequate to cater the amount of such accidental blasts.

The final section of this study will eventually suggests and recommends features for the blast wall that can be applied to the current practice based on the result studied. Since there is no specific guidelines in the API regarding the blast wall design, it is best if some modifications are made to ensure that the blast wall design will have certain standard and criteria that can be followed for the protection of the offshore structures.

4.2 Blast Wall and Blast Modelling

The blast wall modelling was modelled using ANSYS version 14. The main factor in this modelling was to ensure all the properties were followed and properly modelled. This model can help in order to achieve the first objective of the study which was to identify the vulnerability of offshore structure towards blast loading. The blast wall properties used in this study was followed as suggested by G.K Schleyer [8]. The blast wall properties are a typical blast wall design used in most of the blast wall in the offshore structure whole over the world. The properties of the blast wall used in this project are as follows:

Profile width	220.0 mm
Profile depth from top surface to inside bottom surface	40.5 mm
Profile material density	7970.0 kg/m3
Profile weight per unit plan area	19.3 kg/m2
Blast wall height	10 m
Blast wall material	Stainless Steel

Table 1: Blast Wall Specifications

The blast wall geometry was done by custom made design since there is no blast wall geometry in the ANSYS program. The basic 2D shape of the blast wall was made and then extruded to have the 3D blast wall geometry. After that, all the properties of the blast wall such as the material density and the material were defined so that the blast wall will have the right and exact properties. The support condition which was fixed support was also defined for this blast wall. The blast wall geometry designs before any blast loading are as below. By finishing this blast wall design, it will mark the end of the modelling stage.

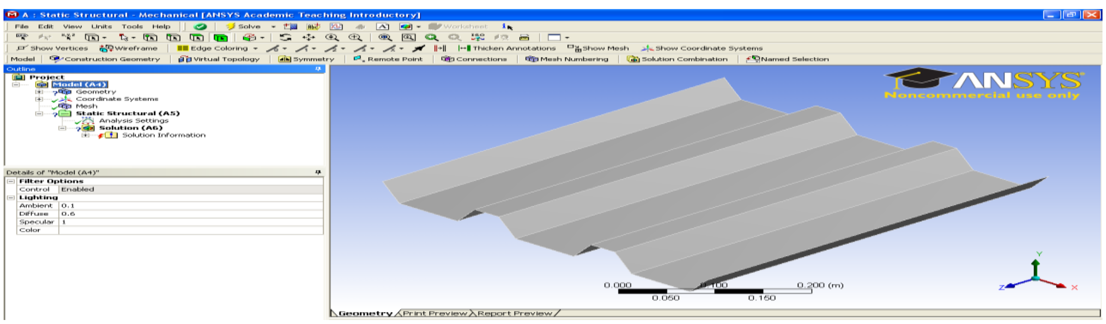

Figure 8: Blast Wall Isometric View

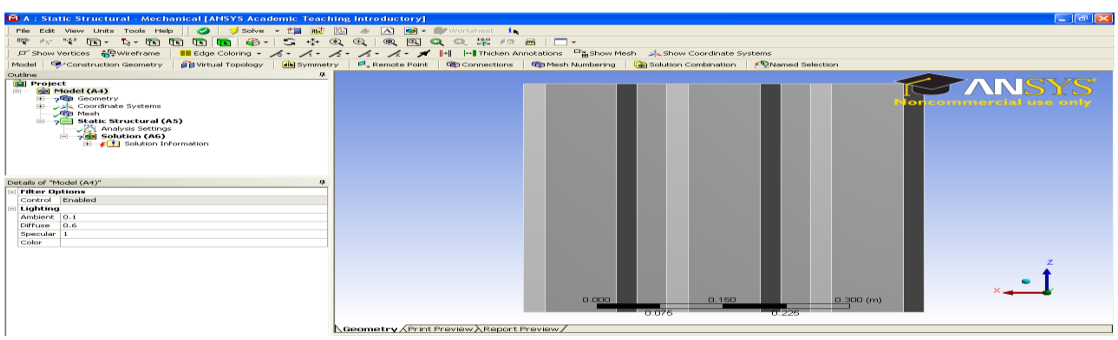

Figure 9: Blast Wall Side View

For the designing of the blast wall, some precautions are needed in order to prevent errors on the blast wall model. One of them is to make sure that the material model is defined correctly. Often analysis is performed for blast wall using elastic material models that often fail to represent the material behaviour accurately. For this project, elastic-plastic material model was used. The modulus of elasticity and modulus for plasticity were taken as E = 200 GPa and 0.2 E = 40 GPa, respectively. The relationship of the stress versus strain graph of the plastic hardening can be seen as below:

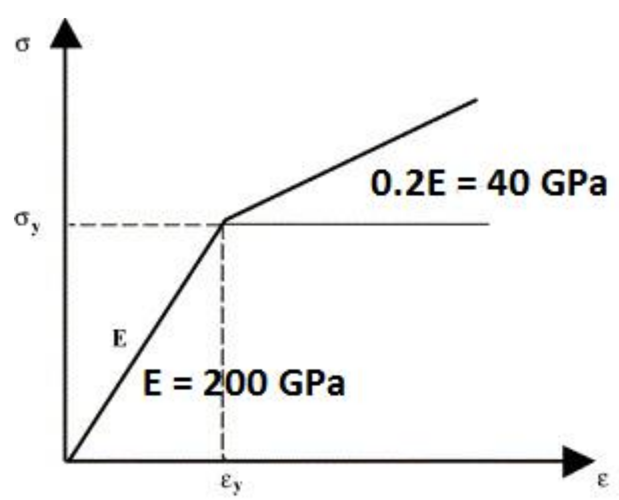

Figure 10: Bilinear Isotropic Relationship for the Blast Wall

As for the blast loadings, it was derived using the Air_3d software. In this study, the parameters that were varied are the blast load magnitude (in kg TNT) and the distance between the blast and the target (m). It is important to know that a typical chemical blast that is most probably to occur on an offshore structure will not exceed 100 kg of TNT equivalent blast.

0_najib_100_1 - Notepad

```
!-----------------------------------------------------------------------------
!
!  Magnitude 500 kg     Disance 20.0 m
!
SPHERICAL_INPUT---------------------------------------------------------------
!
500.0   0.0   0.0      Charge weight (kg), density (kg/m^3), energy (J/kg)
20.0                   problem radius    (m)
1.0E-3                 delta r           (m)
0                      Run option
1.0                    problem time      (sec)
0.0     75             display increment (sec) or cycles
1                      Plot variable
0.75                   CFL
T                      File flag (update existing TNT file)
0_plain_s.TNT          Output file
!
0 1 NOFORMAT STATIC    No. points, start, reformat flag, static/dynamic flag
!
!
!
RADIAL_INPUT__________________________________________________________________
!
  0.0   50.00         XS,XF
  0.0   16.00         YS,YF
200.0E-3              Cell size (25.0E-3)
1 1                  Display variables
1.2                  factor for switching to 2nd order
3                    Run option
T                    White background
500.0E-3               Finish time
0.0     50           Display/Save increment,
5.0E-1               Safety factor for timestep,
1.0                  Centre of gas Y
+1 +1                BXU,BYU
T                    File flag (update existing TNT file)
0_embassy_r.TNT        Output file
3  .001 .001         IXY (plotting), level
10.0  0.0            Scale factor for contour intervals
BEGIN_OBSTACLES
!CUBOID 3.5  4.0 0.0 3.0  FALSE
CUBOID 30.0 45.0 0.0 9.5  FALSE
CUBOID 35.0 45.0 9.5 13.0  FALSE
WEDGE  30.0 9.5   35.0 13.0  35.0 9.5  0.0 3 FALSE
!
END_OBSTACLES
3 1 NOFORMAT STATIC  No. points, start, reformat flag, static/dynamic flag
   29.999   2.0
   29.999   6.0
```

Table 2: Air_3d Input Example for Blast Magnitude of 500 kg TNT and at 20m Distance from target

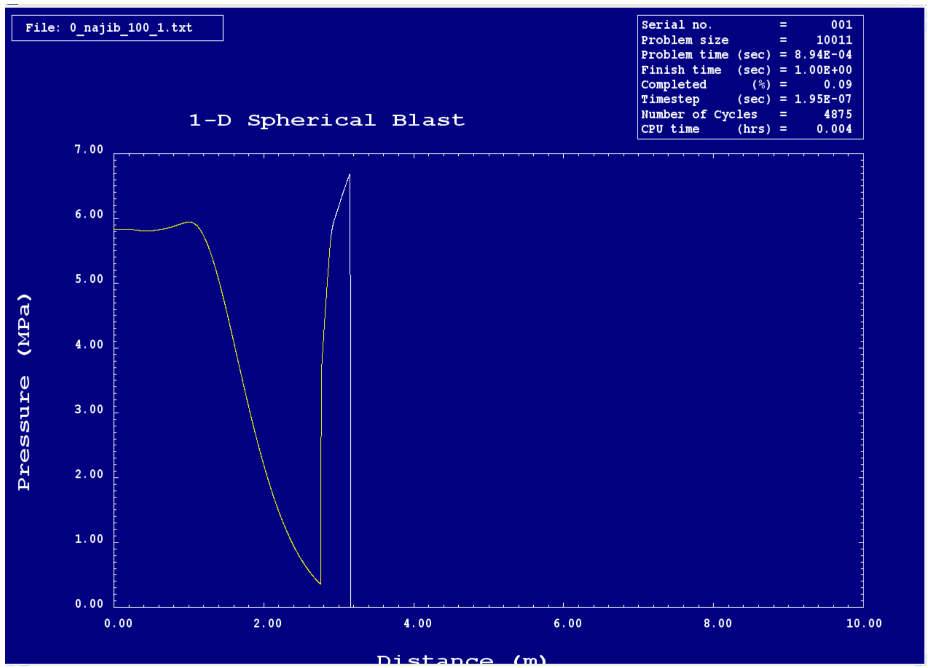

Figure 11: Relationship between the Distance and Pressure for the Blast Loading

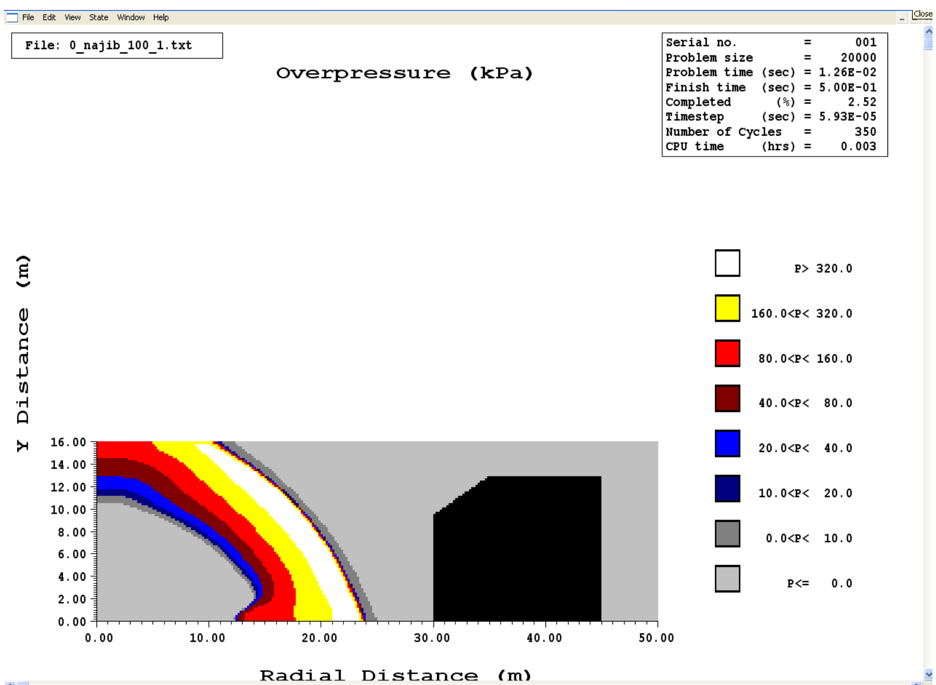

Figure 12: Propagation of Blast Overpressure for a given blast

For this study, there are 4 different type of blast magnitude were used which are 10 kg, 25 kg, 50 kg and 100 kg TNT equivalent blasts. Different magnitude of blast is needed in order to determine how the blast walls react to different magnitude of peak blast overpressure and also to determine the deflection pattern of the blast wall. The distance of the blast wall and the blast loading were also varied in order to get different blast overpressure based on the distance. The distance used in this study were 1 m, 2.5 m, 5 m, 10 m, 20 m and 30 m. The amount of blast overpressure obtained for each criterion is shown in the table below:

Blast Magnitude (KG) / Distance of Blast from Blast Wall (m)	10	25	50	100
1	7.500 MPa	8.800 MPa	10.100 MPa	16.200 MPa
2.5	1.570 MPa	1.800 MPa	2.400 MPa	3.100 MPa
5	0.105 MPa	0.140 MPa	0.300 MPa	0.580 MPa
10	0.035 MPa	0.041 MPa	0.050 MPa	0.077 MPa
20	0.002 MPa	0.005 MPa	0.009 MPa	0.011 MPa
30	0.001 MPa	0.002 MPa	0.004 MPa	0.005 MPa

Table 3: Blast Overpressure Value Based on Blast charge weight and Distance

From the table, the highest blast overpressure is 16.2 MPa which comes from 100 kg blast magnitude and 1 m distance. The result was as it was expected, for higher magnitude of blast at a close distance produced the highest overpressure. From the table also it was found out that as the blast move away from the blast wall, the blast overpressure will decrease exponentially showing that there are no significant effect on the target blast wall if the blast exceeds 20 m away from the wall. As for the blast magnitude, the blast magnitude and the blast overpressure is directly proportional to each other. The relationship can be further seen in the graph below:

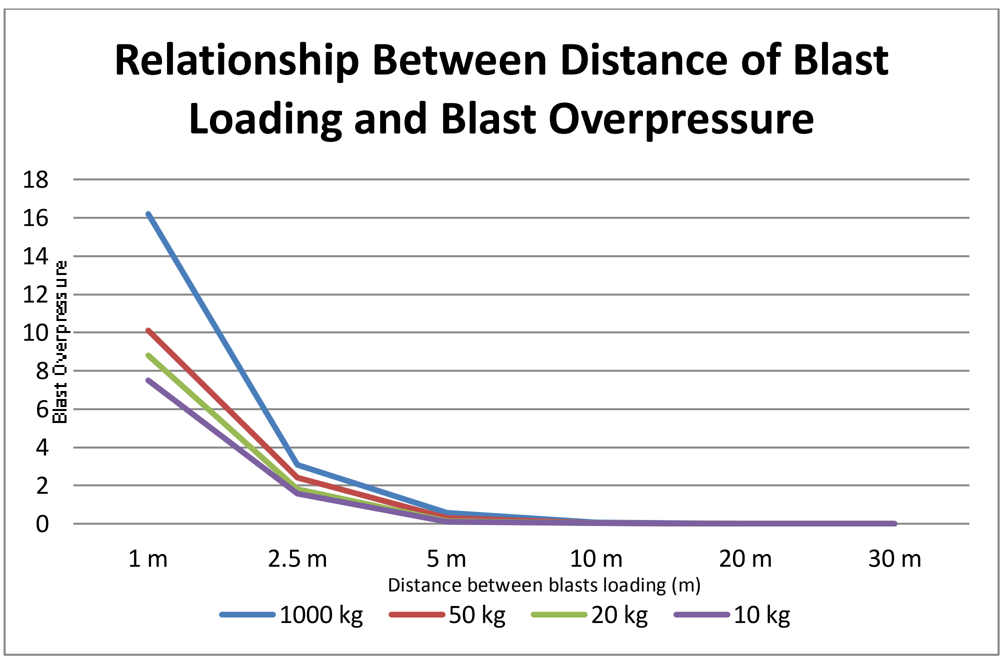

Figure 13: Relationship between Distance of Blast Loading and Blast Overpressure

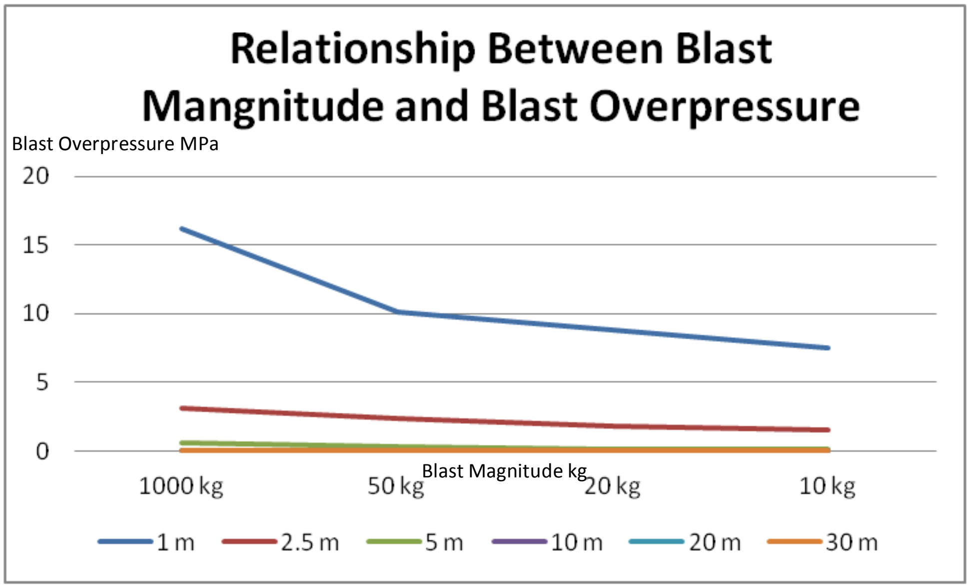

Figure 14: Relationship between equivalent explosion charge weight and blast peak overpressure

4.3 Blast Wall Analysis

In this section, the blast wall reactions towards the blast peak overpressure were analysed to identify the critical locations that have significant effect on the blast wall. Before testing on the blast peak overpressure on different locations, the blast overpressures were first analyzed as below:

Lowest Blast Overpressure	0.01 MPa
Highest Blast Overpressure	162 MPa
Blast Overpressure Median	22 MPa
1/3 of Blast Overpressure	65 MPa
1/4 of Blast Overpressure	80 MPa
1/6 of Blast Overpressure	107 MPa

Table 4: Blast Overpressure Analysis

All these values were tested on different locations on the blast wall. After a few of rounds of tests, it was found out that there were 3 different locations that have a significant effect on the deformation pattern and deformation value of the blast wall. The three locations can be defined as the Location 1, Location 2 and Location 3. The exact locations of the 3 location are show in Figures 16-18:

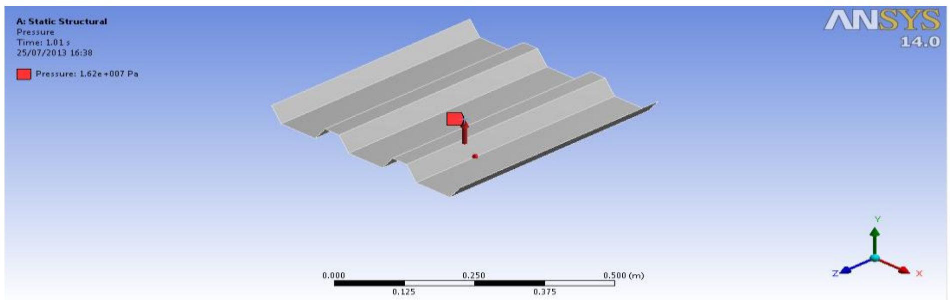

Figure 15: Location 1 for Blast Overpressure

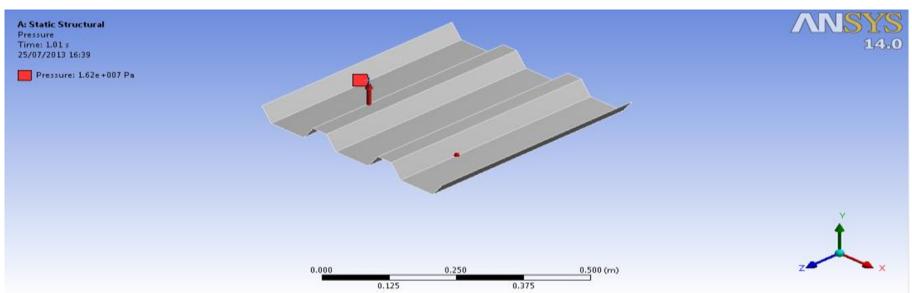

Figure 16: Location 2 for Blast Overpressure

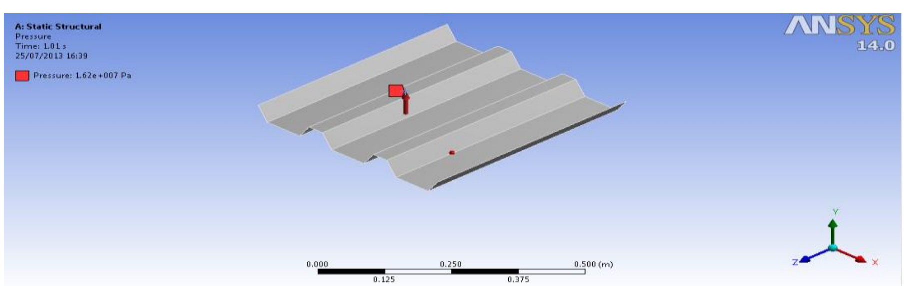

Figure 17: Location 3 for Blast Overpressure

Location 1 is defined as the middle part of the blast wall. From the deformation analysis, the middle section of the blast wall was proven to be the most vulnerable part of the blast wall. It will have the higher deformation pattern compared to the other location of the blast wall. This was due to no significant support to at the middle of the blast wall to support such high magnitude of blast overpressure. The stress distribution was also focused at the middle part of the blast causing it to have higher deformation rate compare to other locations.

Location 2 is located at the end of the blast wall. It had a lower deformation compared to Location 1 but slightly higher than Location 3. Since the stress is located at the end of the blast wall, the moment will be higher which causes the blast wall to deform a little bit higher than location 3.

As for location 3, since it is located in between the middle and the end of the blast wall, it has the lowest deformation compared to the other location. This is due to the stress distribution can be distributed evenly to the middle part and to the end part which has the fixed support. The even distribution of stress causes the deformation of the blast wall to become low.

For each location, the stress distributions are different for different blast overpressure. Due to the different in stress distribution, the blast wall deformation will also be different. The summary of the blast wall deformation against the blast overpressure are as follow:

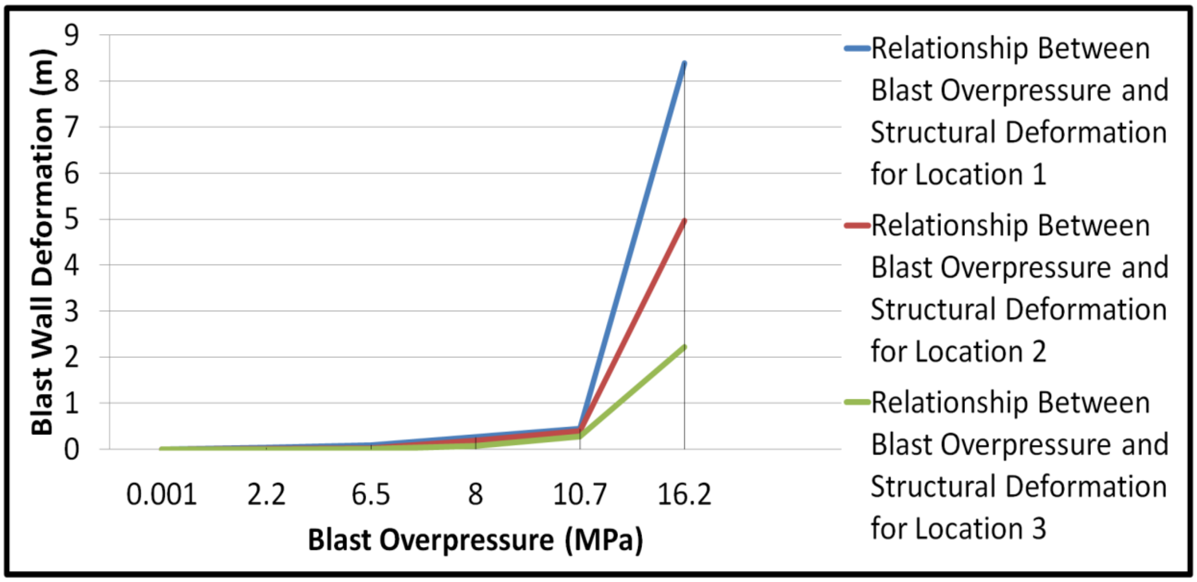

Figure 18: Relationship between Blast Wall Deformation and Blast Overpressure

Based on the graph, for lower value of blast overpressure, the deformations were almost the same for all different locations. However, once the blast overpressure reached 10 MPa, the deformation shoots up and changes for each location. Location 1 has the highest deformation followed by Location 2 and Location 3. Besides that, based on the graph after 0.5 m deformation, the blast deformation shoots up. This shows that 0.5 m is the ultimate limit for the blast wall to deform. After 0.5 the blast wall loses its elasticity causing higher deformation.

4.4 Adequacy of Existing Blast Wall Design

From the results in section 4.3, it shows that the existing blast wall design cannot withstand any blast overpressure more than 10 MPa. Although the tendencies of such blast are unlikely to happen on an offshore structure, precautions needed to be done to protect the offshore structure.

High blast overpressure causes the blast wall to deform away from its original shape. Since the location 1 have the highest deformation, today's blast wall design need to ensure that more protection is given to location 1 of the offshore structure.

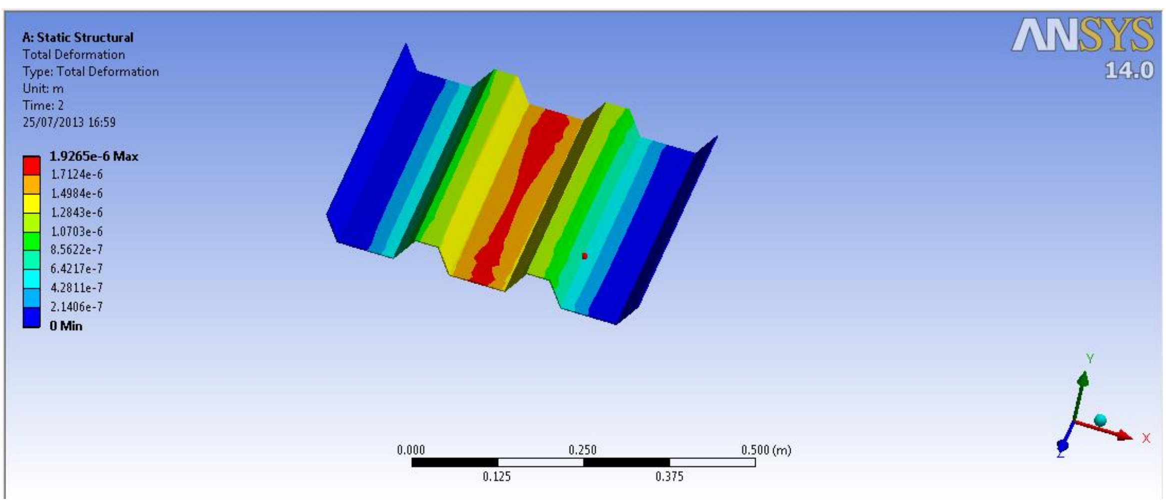

Figure 19: Blast Wall Deformation Example at Location 1

For location 3, it can be seen from the deformation pattern that that the deformation is much lower compared to location 1. Although the blast overpressure is located at location 3, most of the deflection will also occur at location 1 as figure below:

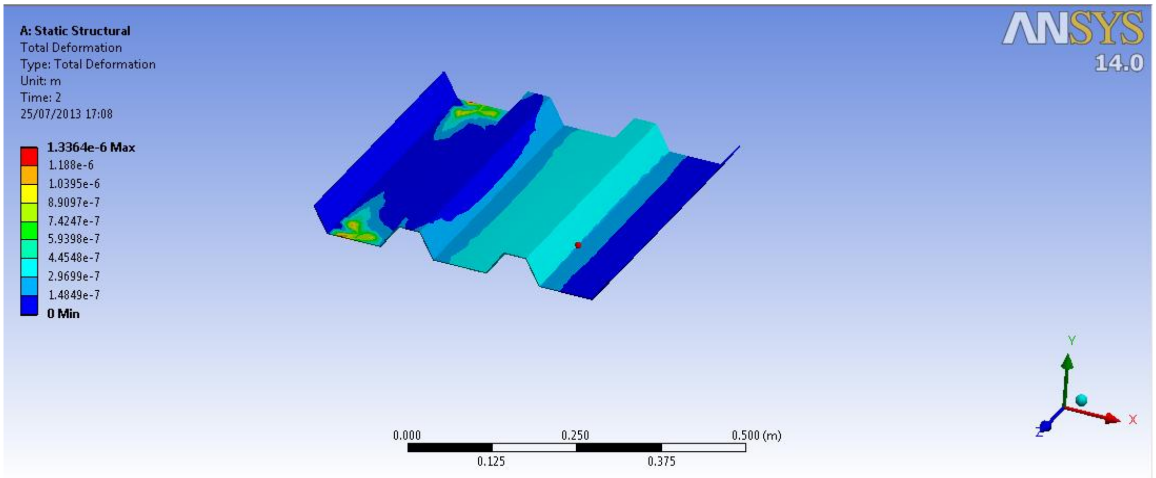

Figure 20: Blast Wall Deformation at Location 3

Therefore, the design of today's blast wall is not adequate for blast overpressure that located at the midpoint of the blast wall. The design of a new blast wall is required which will be discussed in the recommendation part later.

4.5 Blast Wall Design Improvements

As to date, there are many blast walls installed on offshore structure. Since the blast walls are not identical and have no specific guidelines. For the blast wall recommendation, the blast wall should have geometry improvements in terms of design to avoid high deflection to occur. A support beams or columns are needed so that the blast wall can withstand the blast overpressure at the middle of the blast wall. Having different improve geometry can also play a key in order to reduce the critical location for the deformation of the blast wall.

Besides that, the existing blast wall design must be able to cater blast overpressure more that 10 MPa. Since 10 MPa is the critical blast overpressure that caused different deformation, it is critical that all the location of the blast wall can withstand the blast overpressure of 10 MPa. Since the blast wall will lose its elasticity after at 0.5m, higher form of blast can cause the blast wall to break or explode.

As for the conclusion, parameters need to be set specifically so that all the new blast wall design follows the guidelines and able to avoid any unwanted fire and blast from spreading to the whole blast wall structure. The existing blast walls are also need to be revisited to check the adequacy of the design so that it will follow the new standard of the blast wall design.

CHAPTER 5: CONCLUSION & RECOMMENDATION

5.1 Conclusion

Based on the study made, it can be concluded that all the objectives of the study have been successfully fulfilled. The 3 objectives of the study are to identify the vulnerability of blast walls used in offshore structure due to various explosions, to analyze and assess the response of standard blast wall under blast load and to identify the adequacy of existing design practices.

For the first objective, the various blasts over pressure were obtained using the Air_3d program. A number blast overpressure value was taken to test on the blast wall vulnerability. From the study it shows that the blast wall is vulnerable to blast overpressure higher than 10 MPa.

As for the second objective, after the modelling of the structure done and the blast overpressure was applied to the structure it can be seen that the blast wall will deform higher at location 1 which is at the centre of the blast wall compared to location 2 (end of the blast wall) and location 3 (in between the middle and the end). It is also identified that the limit of the blast wall deformation is 0.5 m. If the blast wall deformation exceeds the 0.5 m, than the blast wall deformation will be so much bigger and the blast wall will fail completely.

The final objective is to identify the adequacy of design practices. By having the study, it can be concluded that the existing design practice is not adequate to cater blast loading higher than 10 MPa. The existing API code needs to be revisited and come out with a standard for blast wall design so that there will be a uniform standard to be followed for blast wall design. Besides that, it is also important for the old offshore blast wall structures to update with the new code to prevent any unwanted disaster to occur.

5.2 Recommendation for Future Studies

There are some recommendations that can be done if this any future studies are to be done for this topic. The first recommendation is that this study is done using different blast wall geometry. This is to study on the best type of geometry that can resist the deformation of the blast wall. Besides that, the difference in the stress distribution can also be studied on this different geometry. The results can be used to identify the best blast wall geometry to be implemented in the actual blast wall.

A study on additional features of the blast wall also can be done. This is to identify whether any extra additional features such as connections or beams can improve the vulnerability of blast wall against blast overpressure. The study can also be used to see whether the additional features can help the blast wall to resist the blast wall deformation at the critical location as been done in this study.

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APPENDICES

General Gantt Chart and key milestones

No	Activities/Week	1	2	3	4	5	6	7	8	9	10	11	12	13	14
1	Selection of Project Topic	■													
2	Preliminary research work	■	■	■											
3	Literature Review and Methodology			■	■	■	■								
4	Draft Extended Proposal					■	■								
5	Submission of Extended Proposal						★								
6	Proposal Defense									★					
7	Experimental works -prepare materials and equipments						■	■	■	■	■				
8	Experimental works - preliminary										■	■	■	■	■
9	Draft Report Interim													■	■
10	Submission of Interim Report														★

Work Progress ■

Milestones ★

Table 5: General Gantt Chart and Key Milestones

Gantt Chart

No	Detail/Work	Final Year Project 1							Final Year Project II														
		8	9	10	11	12	13	14	1	2	3	4	5	6	7	8	9	10	11	12	13	14
1	Modeling blast walls	■	■	■	■	■																
2	Modeling blast loading						■	■	■	■												
3	Combine the model						■	■	■	■												
4	Study the model with loading										■	■	■									
5	Investigate and compare with actual situation													■	■	■	■					
6	Recommendation to the vulnerability of the blast wall																	■	■	■	■	
7	Report Preparation	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■

Table 6: Project Gantt Chart

Key Milestones

No	Detail/Work	Final Year Project 1											Final Year Project II									
		8	9	10	11	12	13	14	1	2	3	4	5	6	7	8	9	10	11	12	13	14
1.	Completion of Blast Wall Modeling					●																
2.	Completion of Blast Loading Modeling									●												
3.	Completion of Study on Different Blast Loading												●									
4.	Completion of Investigation with Actual Structure																●					
5.	Completion of Recommendation																				●	
6.	Completion of Report																					●

Table 7: Key Milestones