STATIC STRENGTH OF TUBULAR DT JOINTS USING LUSAS FINITE ELEMENT SOFTWARE

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A project report submitted in partial fulfillment of requirement for the award of the degree of Master of Engineering (Civil – Structure)

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APRIL 2005

DEDICATION

To father and mother
Thank you for your support
&
To sisters and brothers
thank you for eveything

ACKNOWLEDGEMENT

Alhmadulilah, Praise to Almighty Allah for the blessing and His permission, I am able to complete my master project.

I wish to extent my greatest thank you and gratefulness to my supervisor, Assoc. Prof. Dr. Sariffuddin Bin Saad for his valuable guidance, advice and suggestions throughout this project. With his effort and concern, I am able to complete my project. Thank you also to Mr. Koh Heng Boon of the Department of Civil Engineering at KUiTTHO, for his help and advise.

I am also grateful to my most beloved parents for their love and kindness towards me and for their strong support during my study period.

I wish to thank KUiTTHO and the Public Service Deparment for the financial support during my stay at UTM.

Finally, a lot of thank you to all staff of Faculty of Civil Engineering, University Teknologi Malaysia, Skudai, Johor and also for all my friends, student of postgraduate of Structural and Material Department for their support and cooperation throughtout my study.

Thank you very much.

ABSTRACT

Structural tubular are widely used in the construction of offshore structures. As these structures are located in hostile environment, these joints represent structural weak spots and so it is desirable to develop reliable methods of determining their static collapse loads. This studies focus on the analysis of static strength of tubular DT joints under brace compression loading by using LUSAS finite element software. The numerical static strength result is compared with an experimental test result obtained from the literature. The value of the static strength obtained in this work is 56% lower than that of the experimental test. A parameter study was performed to study the effect of the geometric parameters α, β, γ and τ as well as the effect of the yield strength σ_y on the static strength of DT joint model. Finally, a simple equation relating the static strength to the above parameters is proposed.

ABSTRAK

Struktur sambungan tubular lazimnya digunakan untuk pembinaan struktur lepas pantai. Oleh kerana struktur ini terletak di persekitaran yang agresif, ia akan menyebabkan sambungan tubular struktur tersebut menjadi lemah. Oleh itu, satu kaedah yang baik adalah perlu untuk menentukan beban kegagalan statik bagi sambungan tersebut. Oleh itu kajian ini tertumpu kepada analisis kekuatan statik bagi sambungan DT bila brace dikenakan beban mampatan dengan menggunakan perisian LUSAS. Nilai kekuatan statik ini kemudiannya telah dibandingkan dengan keputusan ujian makmal yang diperolehi daripada literatur. Dalam kajian ini, nilai kekuatan statik yang diperolehi adalah 56% lebih rendah daripada nilai ujian makmal. Kajian parameter telah dijalankan untuk mengkaji kesan parameter geometri α, β, γ dan τ serta juga kesan kekuatan alah σ_y kepada kekuatan statik sambungan model DT tersebut. Akhirnya, satu formula mudah yang menghubungkan kekuatan statik sambungan DT dengan parameter-parameter di atas telah dicadangkan.

CONTENTS

LIST OF TABLES

LIST OF FIGURES

NOTATION LIST

D = Chord outer diameter

d = Brace outer diameter

T = Chord thickness

T = Brace thickness

L = Total chord length

l = Total brace length

σ_y = Yield strength

N = Newton

α = Length parameter ($2L/D$)

β = Diameter ratio (d/D)

γ = Chord radius to thickness ratio ($D/2T$)

τ = Wall thickness ratio (t/T)

CHAPTER I

INTRODUCTION

1.1. Introducing to The Tubular Structure

Tubular members are widely used in both onshore and offshore structures. Their attributes such as the high strength-to-weight ratio, low drag coefficient, and the ability to use their internal space have made them particularly useful in the offshore industry over many years. A typical example of the use of tubular members in an offshore situation is the fixed offshore platform (see Figure 1.1), where tubular members form a space frame to support the topside structure. Tubular connection design is a major factor in the design of a structure and can even be the limiting factor in terms of the strength of the structure.

Circular hollow sections are widely used in the construction of offshore structures in Malaysia. These sections offer many advantages over other sections. The sections have the ability to distribute load consistently. From the architect point of view, it has a minimum amount of surface area to unclean matter effect, rust and other spoil. With a circular form, it has an advantage in reducing the effect of wind, wave and blast loadings.

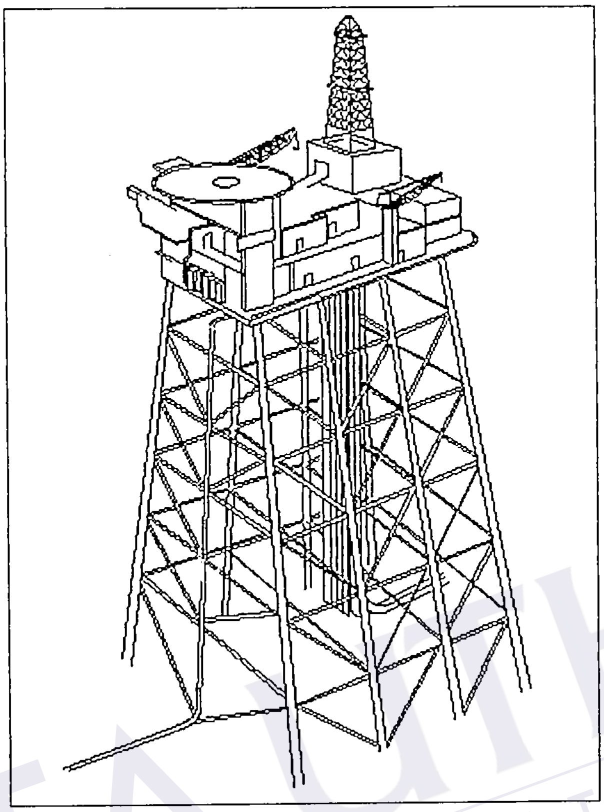


Figure 1.1: A typical jacket structure [1]

1.2. Problem of Study

Structural tubular joints are widely used in the construction of offshore structures. As these structures are located in hostile environment, these joints represent structural weak spots and so it is desirable to develop reliable methods of determining their static collapse loads.

It is impractical to test actual joints due to their massive sizes and also in view of the associated testing costs. Testing small-scale steel joint models of various shapes was widely carried out in the past. However, the manufacture of these joint models needs highly skilled welders and the exact shape of fillet welds is not repeatable.

An attractive alternative is to carry out finite element analysis using a suitable software to obtain the static strength results. If the results are good, this method can be used to performed a parameter study to investigate the effect various geometric parameters on a joint static strength.

1.3. Objectives of Study

The static strength of tubular DT joints will be studied using LUSAS finite element software [2]. Objectives of the study are:

a) to create a good finite element DT joint model.
b) to carry out a mesh convergence study.
c) to define the maximum load attained during the elastic plastic response of the joint.
d) to compare the static strength results of tubular DT joint between finite element software and previous experimental test.
e) to performed parameter study to investigate the effect of the various geometric parameters on the static strength of DT joints.
f) to develop a simple formula to calculate the static strength of DT joints.

1.4. Scope of Study

The LUSAS finite element software will be used to determine the static strength of tubular DT joint. In this study, the static strength of a tubular DT joint is defined as the maximum load attained during the elastic plastic response of the joint and this is shown in Figure 1.2. Data for the analysis are taken from a previous experimental testing on a similar DT joint performed by Kang et al.[3].

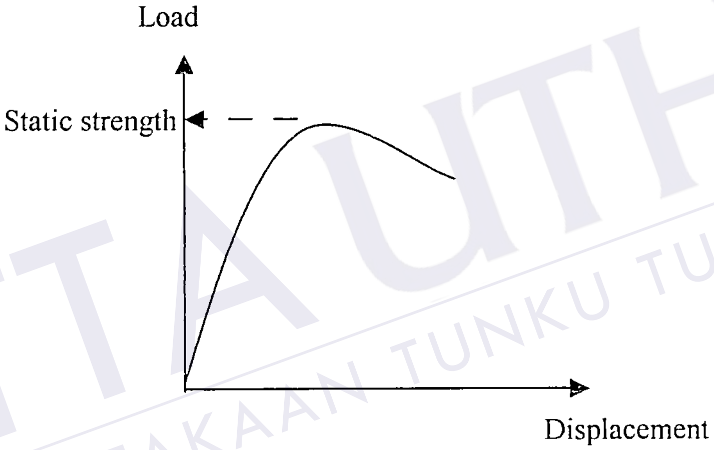


Figure 1.2: An elastic plastic response of the joint

To obtain the static strength by using LUSAS software, the dimensions of the DT joint finite element model had been based on the dimensions and data of the actual joint test performed by Kang et al.[3]. Before the comparison of the static strength result predicted by the LUSAS software and that of the actual test, a mesh refinement was conducted by performing non-linear analysis of the DT joint model under brace compression loading using different element density applied to the chord area near the brace wall.

CHAPTER II

REVIEW OF LITERATURE

2.1. Introduction

Tubular joint constitute one of the main problems and high cost areas in the design, construction and maintenance of steel structures and have been the subject of considerable research effort. The Department of Energy commissioned a study in 1980 of the various design documents, with particular emphasis on the static strength of tubular joints [4].

2.2. Tubular Structure

A tubular structure consists of a framework of hollow pipes made from steel. There are two types of hollow section used, circular and rectangular. However, circular hollow sections are more generally used in offshore structure construction. It is because these sections have a small surface area, can minimise the wind and wave load and also have a high ecstatic value.

2.3. Tubular Joint

A tubular joint is a joint between the brace and the chord. Figure 2.1 shows the various types of joint widely used for offshore construction work.

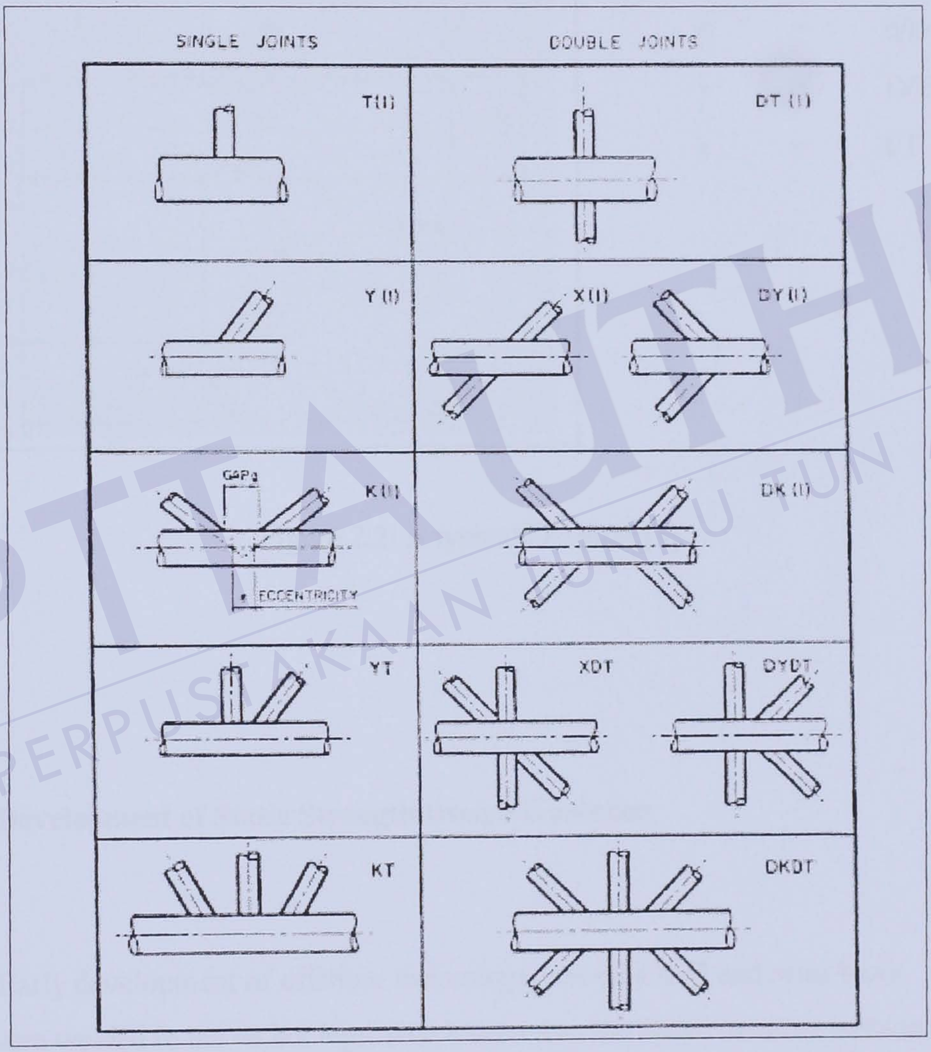
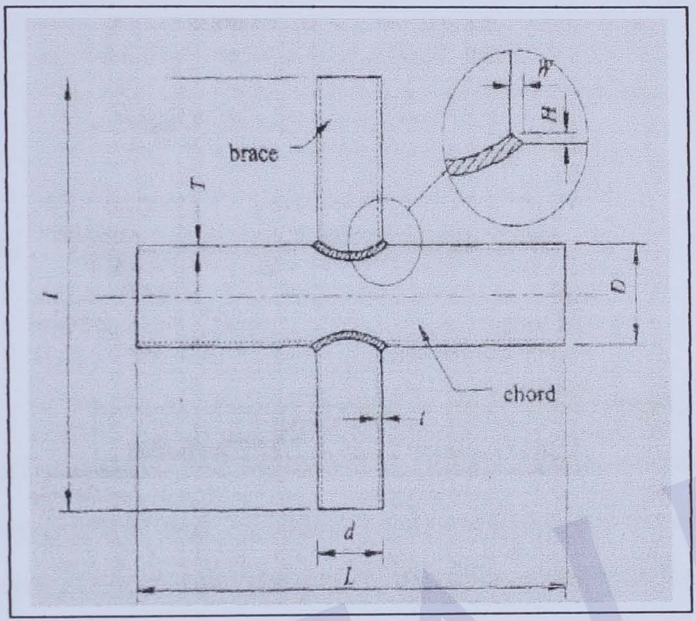


Figure 2.1: Various types of tubular joint [5]

Figure 2.2 shows a typical tubular DT joint showing the definition of the various geometric factors



$\alpha = 2L/D$

$\beta = d/D$

$\gamma = D/2T$

$\tau = t/T$

Figure 2.2: A typical DT joint [3]

2.4. Development of Static Strength Design Guidance

Early development of offshore technology was on a trial and error basis. Brace were welded to the jacket legs, which served as the chord member without any reinforcement. The first attempts at tubular joint design in the late 1950s were based on elastic analysis of the tubular shells. It quickly became apparent from a few tests in the early 1960s that there was little correlation between ultimate strength and elastic shell analysis.

This led to a series of tests in the mid 1960s and covered a limited range of joint types and geometries. These tests were recognised as mainly to investigate the relative importance of factors such as β (ratio of brace diameter to chord diameter) and γ (ratio of chord radius to chord wall thickness).

2.5. Previous Study of DT Tubular Joint

The earliest investigation on chord stress effects on DT joints were carried out by Togo [6] and Washio et al. [7][8]. A series of small-scale joints (D = 101.6 mm, β = 0.47 and γ = 16) were subjected to brace axial compression with various levels of chord axial stresses in DT joints which was found to generally reduce the joint capacity, whereas tension chord stresses have a minor effect on joint strength.

Following their work, a semi empirical formula was developed and a chord stress factor Q_f was introduced to account for the presence of chord stresses. The Washio Q_f expression was adopted by the API RP 2A code from 1975 to 1983 and also by other design codes.

The work on chord stress effect conducted by Boone et al. [9], Weinstein and Yura [10] and Sanders [11] at Texas University is the most complete. Boone et al. carried out 10 tests (including three tests without chord load used as base test) on large scale DT specimens (D = 407.7 mm), α = 17.5, β = 0.67, γ = 25.6 and τ = 0.8) to study the influence of chord axial compression, in plane bending (IPB) and out plane bending (OPB) on the joint strength. The test results showed that chord stress effects were most significant for brace IPB followed by axial loading and OPB.

Weinstein and Yura [10] carried out 10 DT joint tests to assess the influence of β on the chord stress effect. Seven specimens (with $\beta = 1$) were tested with either brace axial compression, IPB or OPB and three specimens ($\beta = 0.35$) were tested with brace axial compression. The chord geometry was identical to that used by Boone et al. [2], i.e. with $\gamma = 25.4$. Again, chord axial compression and bending stress were considered. For specimens with $\beta = 1$, the results showed that the chord stress has similar strength reduction effects compared to IPB loaded smaller β joints.

However, for axially loaded or OPB loaded joints, the results showed that the chord stress had no effect on the ultimate strength as only small deformations of the chord wall occurred at the saddle regions. However, the ultimate strength for $\beta = 1$ axially loaded joints with or without chord stress increased significantly compared to smaller β joints since most of the load was transferred through the short lengths of chord wall between the weld toes at the saddle locations.

For specimens subjected to brace OPB and chord axial compression, the joint failed by instability. It was also shown by Sanders [11] that the axial chord compression stress has no effect on $\beta = 1$ tension loaded DT joints. Results from test on $\beta = 0.34$ brace axially loaded specimens indicated that the strength reduction due to chord stresses is higher than that for specimens with $\beta = 0.67$.

In 1998, Kang et al.[3] carried out tubular DT joint tests. The objective was to assess the ultimate strength of DT joints under combined brace compression and chord compression. The work was carried out both experimentally and numerically.

Two methods were used in the numerical work to apply the chord and brace loading: (1) proportional loading and (2) nonproportional loading. The former method was adopted in the experimental work. The numerical calculations were done using the finite element analysis. The models were created using the P3/PATRAN mesh generation program and the static strength of the models was assessed using ABAQUS 5.4 finite element program.

Generally the results showed a significant and increasing reduction in the strength, from both FE and test result, as the applied nominal chord stress was increased. The FE models achieved higher ultimate loads than the corresponding experimental models.

From the preceding data, the experimental and numerical results have confirmed that the ultimate strength of DT joints under brace compressive loading could be reduced significantly when chord axial stress is present. They also found that, FE analysis could significantly over predicted the ultimate strength of such joints. The discrepancy may be caused by an instability in the joints that was accentuated at higher chord loads.

Figure 2.3 shows the DT joint test set up. The test of the DT joints was conducted in a 250-kN servohyraulic test machine. The joint specimens were mounted in the test facilities with the brace members in the vertical position and the chord in horizontal position. This arrangement allowed the brace members to be loaded in compression by test machine such that both the upper and lower brace were pushed into the chord member. The load-displacement graph for the brace compression test (without chord stresses) is shown in Figure 2.4 (Test A1).

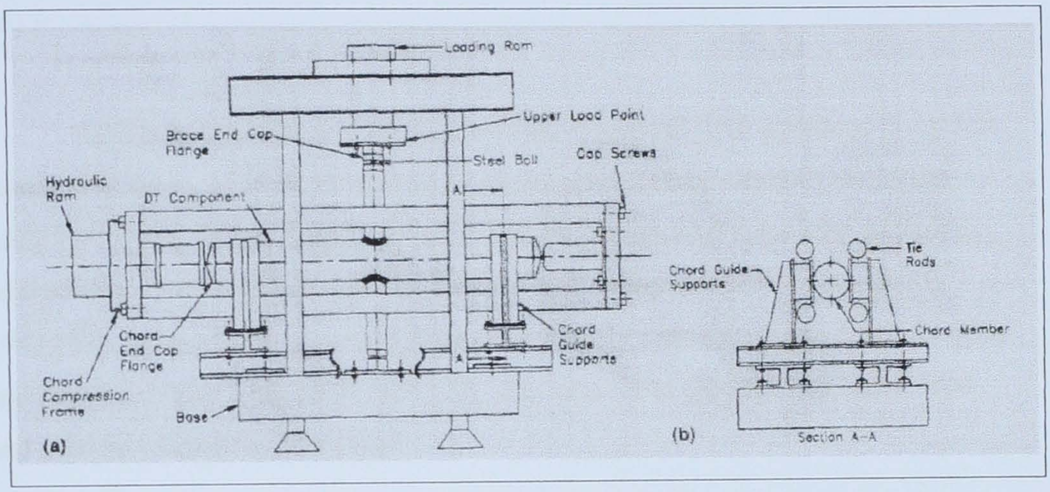


Figure 2.3: DT joint test setup[3]

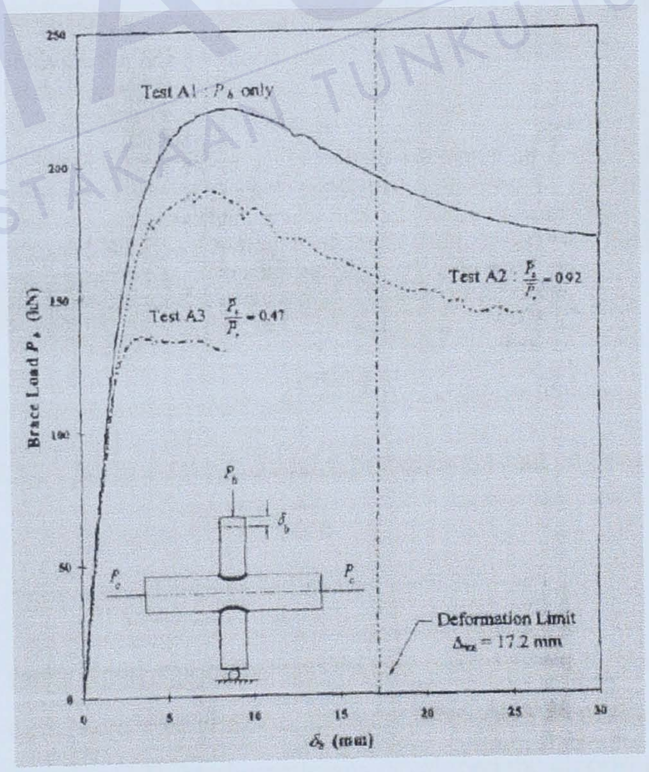


Figure 2.4: Experimental load-Displacement Curves for DT joints Under Brace/Chord Compression [3]

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