CAPACITY DETERMINATION OF INTERMODAL CONTAINER FRAME IN RESISTING HOUSING LOAD

ONG ZHEN LING

A project report submitted in partial fulfilment of the
requirements for the award of the degree of
Master of Engineering (Structure)

School of Civil Engineering
Faculty of Engineering
Universiti Teknologi Malaysia

JANUARY 2019

DEDICATION

This project report is dedicated to my father, who taught me that the best kind of knowledge to have is that which is learned for its own sake. It is also dedicated to my mother, who taught me that even the largest task can be accomplished if it is done one step at a time.

ACKNOWLEDGEMENT

In preparing this project report, I was in contact with many people, researchers, academicians, and practitioners. They have contributed towards my understanding and thoughts. In particular, I wish to express my sincere appreciation to my main project report supervisor, Associate Professor Dr. Arizu Bin Sulaiman, for encouragement, guidance, critics and friendship. Without his continued support and interest, this project report would not have been the same as presented here.

My fellow postgraduate student should also be recognised for their support. My sincere appreciation also extends to all my colleagues and others who have provided assistance at various occasions. Their views and tips are useful indeed. Unfortunately, it is not possible to list all of them in this limited space. I am grateful to all my family member.

ABSTRACT

The shipping container has only been around for the last 50 years. The common functional period of a shipping container in its logistic service can last 10 to 12 years. Used shipping container from logistic service are re-trade in aftermarket for other purposes and usually can sustain for another 10 more years of usage. The increasing numbers of shipping containers which have survived from their serving life span in the logistic service will be considered as “junk” and causing pollution issue. The concept of recycling shipping container into residential usage can mitigate the issue of the unaffordable demand for rebuilt houses in short period of time for the homelessness due to natural disaster, like flooding in Malaysia which is currently faced by the country government in terms of supplying temporary houses in the short time and budgeted paid to the contractor. However, availability of published and research information on shipping containers utilized as inhabitable purpose is still difficult to obtain as most available publication have not included the topic of the shipping container structural strength and the corresponding structural behavior of shipping containers with other loading scenarios or modification. The purpose of this study is to investigate the capacity of shipping container frame members in resisting residential load and determine the maximum allowable span length of the frame members if stress exceeds the yield strength or deflection exceeds the allowable limit. LUSAS software is used to model the container frame and run using linear analysis. Only edge frame of shipping container is taken into consideration in order to provide more flexibility for builder or architect to modify the shipping container up to their desired standard whereby the corrugated wall or cross members can be removed. The ultimate load combination and deflection limit used is based on BS5400: 2000. The model is built using simple line element with each section properties determined beforehand using section property calculator of LUSAS and assigned accordingly. The results show that intermediate supports are required and necessary to be added so that the maximum member span length is controlled within 2.1 *m* for top side rails. Additional supports are also required to avoid cantilever structural behaviour within the container.

ABSTRAK

Kewujudan perkapalan kontena hanya sekitar 50 tahun yang lepas. Tempoh fungsional yang biasa untuk perkapalan kontena dalam perkhidmatan logistiknya boleh bertahan 10 hingga 12 tahun. Perkapalan kontena yang telah digunakan dari perkhidmatan logistic akan didagang semula dalam pasaran semula untuk kegunaan lain dan penggunaannya biasa boleh bertahan selama 10 tahun dan lebih. Peningkatan bilangan perkapalan kontena yang telah sampai tempoh jangka hayat mereka dalam perkhidmatan logistic akan dianggap sebagai "sampah" dan menyebabkan pencemaran. Konsep kitar semula perkapalan kontena untuk kegunaan kediaman boleh mengurangkan masalah keperluan rumah dalam jangka masa yang singkat untuk tempat tinggal akibat bencana alam, seperti banjir yang kini dihadapai di Malaysia dari segi membekal rumah sementara dalam masa yang singkat dan bayaran bajet kepada kontraktor. Ketersediaan maklumat yang diterbitkan dan penyelidikan mengenai kontena perkapalan yang digunakan sebagai kediaman masih sukar diperolehi kerana kebanyakan penerbitan yang tersedia tidak termasuk topik kekuatan struktur kontena perkapalan dan tingkah laku struktur dengan scenario pemampatan atau pengubahsuaian lain. Kajian ini dilakukan bertujuan menyiasat kapasiti rangka perkapalan kontena untuk menentang beban kediaman dan menentu maksimum panjang rentang yang dibenarkan sebelum rangka melebihi kekuatan alah atau had pesongan yang dibenarkan. LUSAS software digunakan untuk memodelkan rangka kontena dan proses analisis dijalankan dengan mengguna linear analisis. Hanya rangka kontena diambil kira dalam kajian ini bertujuan memberi fleksibiliti pada pembina dan arkitek untuk mengubah suai kontena sekiranya dinding beralun dan ahli silang perlu dikeluearkan dari kontena untuk memenuhi aspek estetik. Kombinasi beban muktamad dan had pesongan dari BS5400: 2000 digunakan dalam kajian ini. Unsur garis mudah digunakan untuk pemodelan rangka kontena. Seksyen sifat bahan untuk setiap ahli rangka ditentukan dengan menggunakan fungsi "Section Property Calculator" dalam LUSAS dan ditetapkan pada ahi rangka yang berkenaan. Keputusan nenunjukkan bahawa sokongan perantaraan diperlukan dan perlu ditambah supaya Panjang span anggota maksimum dikawal dalam jarak 2.1 *m* untuk landasan sisi atas.

TABLE OF CONTENTS

LIST OF TABLES

LIST OF FIGURES

LIST OF ABBREVIATIONS

TEUS	-	Twenty-foot equivalent unit
ISO	-	International Organization for Standardization
CSC	-	Convention for Safe Containers
BTS3	-	Thick 3D Straight Beam

LIST OF SYMBOLS

U	-	Nodal degrees of freedom in X direction
V	-	Nodal degrees of freedom in Y direction
W	-	Nodal degrees of freedom in Z direction
θ_x	-	Rotation about X axis
θ_y	-	Rotation about Y axis
θ_z	-	Rotation about Z axis
F_x	-	Forces in local X direction
F_y	-	Forces in local Y direction
F_z	-	Forces in local Z direction
M_x	-	Moment about local X axis
M_y	-	Moment about local Y axis
M_z	-	Moment about local Z axis
l	-	Length
E	-	Young's modulus
υ	-	Poisson's ratio
f_y	-	Yield strength
DL	-	Dead load
SDL	-	Superimposed dead load
LL	-	Live load
M	-	Bending moment
σ	-	Stress
y	-	Vertical distance away from neutral axis
I	-	Moment of inertia around the neutral axis
δ	-	Deflection
M_c	-	Moment capacity
A	-	Area
I_{xx}	-	Moment of inertia about X-X axis
I_{yy}	-	Moment of inertia about Y-Y axis
I_{xy}	-	Moment of inertia about X-Y axis

J	-	Torsional constant
A_{sy}	-	Shear area in Y direction
A_{sx}	-	Shear area in X direction
UDL	-	Uniform distributed load
ρ	-	Density

LIST OF APPENDICES

CHAPTER 1

INTRODUCTION

1.1 Introduction

The shipping container has only been around for the last 50 years. Malcolm Mclean from USA invented and patented the first standard shipping container in 1956. The idea of creating a shipping container came after 20 year of observation on the inadequacy of the dock loaders unloading freight from trucks and transferring it to ships. The US Government pushed-forward and urged ISO and IMO for the standardization in 1967 for the US military usage in terms of transportation and housing overseas. In 1972, the ISO Container is standardized and certified. The global transportation industry has since responded rapidly to this invention of shipping container and the world entrepreneurs also began to find more uses for this “super box”, and not just for shipping.

Referring to Table 1.1, it can be seen that the total amount of shipping container at Port Klang alone comprising of import, export and transhipment sum up to a total of 11,978,466 units in 2017 alone.

Table 1.1 Container Information (TEUS)
(www.pka.gov.my/index.php/component/content/article/127-port-klang-statistics.html (09-12-2018) - information last updated on 06-09-2018.)

YEAR	IMPORT	EXPORT	TRANSHIPMENT	TOTAL
2005	1,342,901	1,276,661	2,923,965	5,543,527
2006	1,403,946	1,367,625	3,554,724	6,326,295
2007	1,527,893	1,474,193	4,116,628	7,118,714
2008	1,629,977	1,598,544	4,745,058	7,973,579
2009	1,515,743	1,478,354	4,315,682	7,309,779
2010	1,716,304	1,718,845	5,436,596	8,871,745
2011	1,794,508	1,720,542	6,088,876	9,603,926
2012	1,872,867	1,821,995	6,306,633	10,001,495
2013	1,907,497	1,860,613	6,582,299	10,350,409
2014	1,962,431	1,942,773	7,040,600	10,945,804
2015	1,992,460	1,962,237	7,931,988	11,886,685
2016	2,063,736	2,038,527	9,067,314	13,169,577
2017	2,176,055	2,161,053	7,642,358	11,978,466

1.2 Problem Background

According to (Container Technology Inc.), the common functional period of a shipping container in its logistic service can last 10 to 12 years. Used shipping container from logistic service are re-trade in aftermarket for other purposes and usually can sustain for another 10 more years of usage. A "One Trip" container not utilized in shipping service is loaded one time only with cargo and then re-trade in the aftermarket for other purposes and usually can sustain for another 25 more years of usage. As shown in Table 1.1, the amount of containers in Port Klang alone is huge and keep increasing each year. The increasing numbers of shipping containers which have survived from their serving life span in the logistic service will be considered as "junk" and causing pollution issue (Josefina S.d.A). Despite not knowing the originated concept of utilizing the shipping container as residential purposes, recycling of these outlived shipping containers into residential or building usage seems to be one of the solution to the issue mentioned above. This concept can mitigate the issue of the unaffordable demand for rebuilt houses in short period of time for the homelessness due to natural disaster, like flooding in Malaysia which is currently faced by the country government in terms of supplying temporary houses in the short time and budgeted paid to the contractor. Converting shipping container to houses can be done provided that the heat insulation and sufficient air ventilation in internal and preventive corrosion at external of the shipping container is done. Figure 1.1 as below shows an affordable and simple modified container home at Amsterdam.

Figure 1.1 Modified container home at Amsterdam

1.3 Problem Statement

Despite numerous examples could be noticed around the world of adopting shipping container as individual inhabitable unit and as simple 2 to 4 stories building complex with simple layouts, availability of published and research information on shipping containers utilized as inhabitable purpose is still difficult to obtain as most available publication have not included the topic of the shipping container structural strength and the corresponding structural behavior of shipping containers with other loading scenarios or modification. Therefore, in this study, the capacity of the shipping container frame will be studied. LUSAS software is used to run the model using linear analysis to determine the resultant force and deflection for each element in the frame. The results are then checked against the allowable limit. The maximum limit of the span length of the elements where supports need to be added is also determined where corrugated wall is not considered part of the supporting system. This would provide a good data for builders or architect when huge modification such as total disposal of all sides of corrugated wall is required by replacing with other component such as glass or other material for aesthetic purposes.

1.4 Research Goal

The purpose of this study is to investigate the capacity of shipping container frame members in resisting residential load and also the maximum allowable span length of the frame members if stress exceeds the yield strength or deflection exceeds the allowable limit.

1.4.1 Research Objectives

The objectives of the research are:

(a) To determine the section properties of shipping container frame members.

(b) To determine the maximum capacity length of shipping container frame members in resisting residential loading.

(c) To determine the behaviour and capacity of the shipping container frame members with cantilever portion under residential loading.

1.5 Research Scope

In this research, container of size 20’ x 8’ x 8’6” is used. The shop drawings attached in technical specification for Steel Dry Cargo Container by CTX CONTAINEX is used where the section of the container frame members are modelled in LUSAS software and analyzed using section property calculator to obtain the section properties.

The model is analyzed using LUSAS software. This study aims for simplicity in terms of determining the capacity of the container frame members. Thus, linear analysis is used and the model is built using line elements only where the section properties are determined using Section Property Calculator of LUSAS and are assigned to the corresponding line element. The material properties assigned for the member frame will be following the same material properties used by Kevin G. (2012) which will be mentioned in Section 2.5. As the modification of shipping container is intended for housing purpose, residential loads is applied.

The capacity of the frame member is determined by referring to the stress output and deflection results. The member is considered fail when the stress exceeds the yield strength of the corresponding member frame or when the deflection exceeds the allowable limit as stipulated in British Standard. Once a member exceeds the capacity, support will be added to reduce the span length and the maximum allowable span length is determined.

1.6 Organization of the Thesis

The following chapters include Chapter 2 literature review which discuss on researches done by other researcher, example of recycled shipping container turned as home, structural component of shipping containers, types of foundation and connection for shipping containers, modelling information used by other researchers and model configuration in LUSAS. Chapter 3 methodology for determining the capacity of shipping container frame members and also assumptions being made in modelling, Chapter 4 results and Chapter 5 which is discussion and conclusion.

REFERENCES

CSC. International convention for safe containers. 4th ed. London: International Maritime Orgnization; (1996).

Coduto D.P. (2001) "Foundation design-principles and practices", end ed. New Jersey; Prentice Hall.

Enitan Oloto, Anthony K. Adebayo "BUILDING WITH SHIPPING CONTAINERS: A SUSTAINABLE APPROACH TO SOLVING HOUSIG SHORTAGE IN LAGOS METROPOLIS", Department of Architecture, University of Lagos, Akoka, Nigeria.

Hermann N., Gehle J. (2007) "249th Engineers Company operations building", Speech presented at U.S. Army Corps of Engineers.

ISO/TC 104. ISO 1496-1 : 1990 Series 1 frieight containers-specification and testing – Part 1: General cargo containers for general purposes. Geneva (Switzerland): International Organization for Standardization; (1990).

ISO/TC 104. ISO 3874: 1997 series 1 freight containers-handling and securing. Genava (Switzerland): International Organization for Standardization; (1997).

Josefina Santos de Asis "POTENTIAL OF CONTAINER HOUSING IN THE PHILIPINES", Research and Development Office, Technological Institude of the Philipines.

Kevin G., Halil S., Rebecca B. D. (2012) "Evaluation, modelling, and analysis of shipping container building structures", *ELSEVIER*, *Engineering Structures 43*, pp. 48-57.

Luis F. A. Bernardo, Luiz A. P. Oliveira, Miguel C. S. Nepomuceno, Jorge M. A. Andrade (2013) "Use of Refurbished Shipping Containers for the Construction of Housing Buildings: Details for the Structural Project", *Journal of Civil Engineering and Management, Volume 19(5)*, pp. 628-646.

SolidWorks [Computer program] (2011), Waltham (MA, USA): DassaultSystemes.

Hypermesh [Computer program] (2009), Troy (MI, USA): Altair.

Abaqus/CAE [Computer program] (2010), Providence (RI, USA); Simulia.

http://containertech.com/about-containers/how-durable-are-shipping-containers/ (09-12-2018) www.pka.gov.my/index.php/component/content/article/127-port-klang-statistics.html (09-12-2018) - information last updated on 06-09-2018.