FINITE ELEMENT ANALYSIS OF FAST-TRACK WALL HOUSING SYSTEM

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A project report submitted in partial fulfillment of
the requirements for the award of the degree of
Master of Engineering (Civil-Structures)

Faculty of Civil Engineering
Universiti Teknologi Malaysia

JANUARY 2012

Specially dedicated to my:

Supportive Father

Devoted Mother

Sincere Husband

Lovely Son

and everyone who had involved in this study.

ACKNOWLEDGEMENT

First of all, I would like to express my special thanks to my supervisor Assoc. Prof. Dr. REDZUAN ABDULLAH for his critics, advices, ideas and encouragement which have contributed thoroughly in this study. Next, I wish to thank Universiti Teknologi Malaysia for giving me chance to follow my study.

Also I would like to express my deepest gratitude to my family for their endless support throughout the process of this study. Without their continual support and guidance, this project report would not have been as presented here.

ABSTRACT

Fast-Track Wall (FTW) system is a load bearing wall system constructed by pouring concrete into a specially designed formwork of FTW. The construction time is reduced significantly compared to conventional brick wall system. The design procedure for the FTW system is according to plain concrete walls, where the wall contains either no reinforcement or less than 0.4% reinforcement. Reinforcement is only provided in FTW walls to control cracking, but not for strength.

This study focuses on the finite element linear elastic analysis of a double storey house under load combinations according to British Standard of Structural Use of Concrete (BS 8110), built using Fast-Track Wall system. A finite element software called LUSAS is used for the analysis and the stresses obtained from the analysis are compared with allowable tensile and compression stresses of the concrete. Also, critical stress locations in the wall with opening are defined based on an appropriate stress criterion. Finally, a stress based design equation that relates the rectangular opening sizes to the stress is proposed for FTW housing system. Besides evaluating stresses, suitable diagonal corners sizes based on the stresses in wall with rectangular opening is suggested.

ABSTRAK

Sistem Fast Track Wall (FTW) merupakan system dinding galas beban yang dibina dengan menuang konkrit ke dalam acuan yang direkabentuk khas. Kaedah pembinaan FTW sangat cepat berbanding dengan kaedah membina dinding batu bata secara konvensional. FTW direkabentuk mengikut kaedah rekabentuk dinding konkrit tanpa tetulang. Tetulang minimum sebanyak 0.4% diletak di dalam dinding hanya untuk mengatasi masalah retakan tetapi bukan untuk menambah kekuatan dinding.

Kajian ini tertumpu kepada analisis kaedah unsur terhingga anjal lelurus ke atas system FTW bagi rumah kediaman dua tingkat yang menangung beban mengikut BS 8110. Analisis dijalankan dengan menggunakan perisian LUSAS. Tegasan yang diperolehi daripada analisis dibandingkan dengan tegasan tegangan dan tegasan mampatan yang dibenarkan bagi konkrit. Lokasi tegasan yang kritikal di dalam dinding yang mempunyai bukaan juga ditentukan. Rumus rekabentuk yang berasaskan tegasan bagi dinding FTW yang mempunyai bukaan segiempat dicadangkan. Disamping kiraan tegasan, di dalam dinding yang mempunyai bukaan segiempat juga dicadang.

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LIST OF SYMBOLS

A_c	-	Area of concrete
A_s	-	Area of steel bars
b	-	Horizontal length of diagonal corners
c	-	Vertical length of diagonal corners
D.L.	-	Dead load on the wall
E_c	-	Young modulus of elasticity of concrete
E_s	-	Young modulus of elasticity of steel bars
f_{cu}	-	Characteristic strength of concrete
f_y	-	Characteristic strength of steel
G	-	Shear modulus
h	-	Height of the wall above the rectangular opening
I	-	Second moment of inertia
L	-	Length of the rectangular opening
l	-	Length of the upper part of the wall after adding diagonal corners
L.L.	-	Imposed loads on the wall

M	-	Moment in the wall
S1	-	Maximum principal stress in LUSAS
S2	-	Intermediate principal stress in LUSAS
S3	-	Minimum principal stress in LUSAS
S_1^*	-	Maximum principal stress at the mid-span of the wall above the rectangular opening
S.W.	-	Self weight of the wall
W.L.	-	Wind load on the wall
α	-	Coefficient of thermal expansion
γ_m	-	Partial safety factor for strength of materials
σ_1	-	Maximum principal stress
σ_2	-	Intermediate principal stress
σ_3	-	Minimum principal stress
σ_c	-	Uniaxial compression strength
σ_t	-	Uniaxial tension strength
σ_x	-	Normal stress in X direction
σ_y	-	Normal stress in Y direction
τ_{xy}	-	
υ	-	Poison's Ratio
ω	-	Ultimate critical load combination on the wall

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CHAPTER 1

INTRODUCTION

1.4 Background of Fast-Track Wall (FTW) System

Concrete walls are usually constructed by erecting form panels in parallel spaced apart and then pouring concrete in the space between the forms. Most common method of erecting concrete walls involves form panels of plywood and wood forming. If reinforcement is needed, rebar or other kinds of metal reinforcement is installed in the space between the forms. In some installations, metal reinforcement is installed prior to structural forms. After the space is filled with concrete, the wooden forms are removed.

This type of construction method of forming up and pouring concrete wall in-situ is cumbersome. The wood itself is relatively expensive and provision of wooden form is labor intensive. Skilled labors are needed to erect the wooden forms and the wooden forms need to be removed after poured concrete is set. Accordingly, erection operation for such construction method is time consuming and required considerable expensive skilled labors for erection. Moreover, a large proposition of form components or materials is non-reusable after the wooden forms are removed.

Although conventional building methods are well established and are generally effective for constructing traditional building structure, there is still a need for

constructing a building structure which is cost effective to implement and can be quickly and easily utilized so as to construct a desired building structure.

Fast-Track Wall (FTW) system [1] is an innovative method of construction which uses the inherent strength of concrete to produce cost effective and durable structures and generally relates to a formwork system and more particularly relates to a fast-track forming system for concrete or mortar wall. The normal method of constructing load-bearing concrete elements is to place the concrete into temporary formwork or moulds, which are then removed once the concrete has attained sufficient strength to be self-supporting and avoid damage.

Fast Track Wall system can be used on many types of projects. The idea behind fast track is to complete the overall project sooner by having portions of construction and design proceeding simultaneously.

Fast Track Wall system is casting concrete in a reusable mould and then transport to the construction site that will help to reduce the wastage in the construction industry by minimizing the conventional usage of timber. It is a formwork/mould system that helps to revolutionize the Malaysian tradition of constructing a single and double storey house. The roof structure can be of, for example, beams/trusses constructed either in horizontal or raked. The beams /trusses give added stability and strength to the top of building structure, and to support the roof and ceiling materials. This system has been successfully practiced where the site is difficult to be accessed by heavy machineries and vehicles.

The fast track project causes the structural engineer to design a building in reverse of how design is normally done. Structures are usually designed from the top down. Upper floors are designed first and gravity loads are tabulated from the roof down to the foundations.

It is to be found that by employing FTW system, a single storey house with two or three bed rooms can be completed within 20 days to 25 days respectively.

Figure 1.1 Concrete the wall in FTW system

1.1.1 Advantages of Fast Track Wall System

FTW system has benefits for both builders and owners. Builder benefits can be summarized in the following items:

- Savings on building structural steel and bracing
- Reduction on building foundation and footings
- Reduce the usage of labor by 20%
- Reduce the time of construction by 50%

- Reduces structural requirements
- Fast track construction
- Trade friendly walls on interior are ready set to receive mechanicals and finishes
- Easy to design load bearing and shear walls
- Saves on transportation cost due to light weight properties
- Can take lateral forces such as high velocity of wind and earthquake

Owner benefits are:

- Better indoor air quality for those with allergies and asthma
- Savings on building maintenance
- Longer life span of building
- Structural security from fires and natural disasters

Figure 1.2 Completed single storey house, constructed by FTW system

1.2 Problem Statement

Large openings in conventional construction require large headers and supporting posts. On the other hand size of openings and windows in the houses constructed by FTW system are limited and typically small. By adding large openings, Fast Track Wall system becomes more and more cost effective because large openings reduce the materials needed such as concrete, steel mesh, formwork, labor, etc. and reduce the construction duration.

1.3 Aim and Objectives

The main objectives of this research are:

- To study the stress distribution in double storey houses constructed by Fast-Track Wall (FTW) system
- To propose a design procedure based on stress criteria
- To define the optimum size of rectangular openings for the walls in Fast-Track Wall system
- To suggest the best haunch dimensions of the openings in the walls of Fast-Track Wall system

1.5 Scope of Study

The scopes of work for this research are as follow:

- 3D linear elastic analysis of wall system of double storey house made by Fast-Track Wall system
- Modeling of a proposed double storey house, using solid element, by LUSAS software
- Determine the stress distribution in concrete under typical domestic load cases.

1.5 Expected Findings

The following can be some of the outcomes:

- To define critical stress locations based on compression or tension stress limitations of concrete according to BS 8110
- To propose suitable size of rectangular openings in Fast Track Wall system
- To suggest a method to design the openings in walls of Fast-Track Wall system based on stresses limitations.

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