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FINITE ELEMENT ANALYSIS OF A COMPOSITE WALL MADE OF CONCRETE AND COLD FORMED STEEL SHEETING

YASSER SALEM MUZAHEM BAGABER

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

Faculty of Civil Engineering
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NOVEMBER 2007

I declare that this project report entitled *“FINITE ELEMENT ANALYSIS OF A COMPOSITE WALL MADE OF CONCRETE AND COLD FORMED STEEL SHEETING”* is the result of my own research except as cited in the references. The report has not been accepted for any degree and is not concurrently submitted in candidature of any other degree.

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To my beloved family

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ABSTRACT

This study is carried out to determine the feasibility of the use of load bearing wall made of concrete and cold formed steel deck. The study uses finite element method where the finite element model for the composite wall are developed using LUSAS 13.6. The emphasis of the model is the establishment of modeling method for a concrete wall reinforced by corrugated steel deck considering the non-linear behavior of the materials. The predicted axial compressive load-deformation relationship is compared with available experimental and analytical results to validate the finite element model. A parametric study is conducted to investigate the effects of different thickness of steel deck and different height of walls for the perfect and imperfect models on the strength and behavior of composite walls. The results indicate that the ultimate compressive strength of the wall increases as the thickness of the steel deck increases. However, in perfect long wall models there are no change in the load bearing capacity with the changing of the height. In imperfect wall models the load bearing capacity decreased by 28-33% from the perfect models but not less than the design load. The finite element results show a strong indication that the load bearing wall system using cold formed steel deck is feasible to be used up to the material strength without buckling and hence warrant further research and development.

ABSTRAK

Kajian ini dijalankan untuk mengetahui kebolehgunaan dinding rencam galas beban yang dibina dengan konkrit dan dek keluli. Kajian dilaksanakan dengan pemodelan unsur terhingga menggunakan LUSAS 13.6. Kaedah pemodelan yang diberi penekanan adalah ikatan antara muka di antara konkrit dengan dek keluli dan juga sifat tak-lelurus bahan. Hubungan beban paksi mampatan dengan pesongan yang dihitung dengan kaedah unsur terhingga telah di bandingkan dengan data ujikaji dan hasil kiraan analitik, untuk memastikan model yang dibina memberikan keputusan yang boleh diterima. Kajian parameter juga dilaksanakan untuk mengkaji kesan ketebalan dek keluli dan kelangsingan dinding bagi model sempurna dan model tak sempurna. Keputusan kajian menunjukkan kekuatan mampatan muktamat dinding bertambah dengan pertambahan ketebalan keluli. Bagi dinding sempurna, tiada perubahan pada beban muktamad yang berlaku walaupun kelangsingannya berbeza-beza. Bagi model dinding tak sempurna, beban muktamad berkurang sebanyak 28-33% berbanding dengan beban muktamad model sempurna. Walau bagaimanapun, nilai beban muktamad bagi semua model dinding yang dikaji tidak kurang daripada nilai beban reka bentuk. Keputusan analisis unsur terhingga memberi satu indikasi yang jelas bahawa dinding galas beban menggunakan konkrit dan dek keluli terbentuk sejuk boleh dibina untuk menanggung beban hingga mencapai tahap kekuatan bahan tanpa gagal secara lengkokan. Dengan ini kajian lanjutan dinding rencam galas beban menggunakan konkrit-dek keluli sememangnya patut diteruskan.

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LIST OF SYMBOLS

2D	–	Two dimensional
3D	–	Three dimensional
δ_y	–	Deflection
A_c	–	Area of concrete
A_s	–	Area of steel
$A_{s\ eq}$	–	Equivalent area of steel
E	–	Modulus of Elasticity
E_c	–	Secant or static modulus of concrete
E_s	–	Young's modulus of steel
F_{cu}	–	Characteristic strength of concrete
F_y	–	Characteristic strength of reinforcement
FE	–	Finite element
I	–	Second moment of inertia
k	–	Effective length factor
L	–	Total length of the wall
l_e	–	Effective wall height
m	–	Modulus ratio
N	–	Wall design load
$N_{crushing}$	–	Crushing load of wall
P_c	–	Buckling load
r	–	Radius of gyration

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CHAPTER 1

INTRODUCTION

1.1 Background

In load-bearing wall system, reinforced concrete and concrete masonry unit (CMU) are commonly used. The popularity of masonry walls and reinforced concrete walls is due to a number of factors. Among these are durability, ease of maintenance, design flexibility, attractive appearance and competitive cost. However, the reinforced concrete and CMU is time consuming to construct and require skill labor. In addition reinforced concrete is tedious in that the reinforcements need to be tied by conventional method.

Load-bearing wall system using precast wall panels can meet aggressive deadlines and achieve early occupancy which assures a faster return on investment dollars. In addition, wall panels, constructed in off-site production facility under controlled situations, provide consistent structural strength, aesthetic quality and timely erection in a variety of weather conditions. The use of precast concrete units to form load-bearing walls solves all problems associated with separation in time and place of fabrication and assembly.

Industrialized Building System (IBS) is being promoted by the Construction Industry Development Bored (CIDB) of Malaysia as an alternative to the conventional construction method (IBS Survey, 2003). The IBS approach to construction is very efficient and non-labor intensive. As such, implementation of IBS not only competitive, but also can reduce the dependency on foreign labors. Other benefits of IBS include minimal wastage, efficient, tidier and safer worksites, better quality control, faster project completion, and lower total construction costs.

A combination of steel and concrete is one of possible composite structural components that can be developed further as an IBS system. The system is simple and requires no skill labor to construct. Also the use of composite construction together with steel framing allows a faster construction.

Steel-concrete composite systems (also called mixed or hybrid systems) have seen widespread use in recent decades because of the benefits of combining the two construction materials. Composite system are formed by combination of two or more materials that retain their respective characteristic when combined together to achieve properties (physical, chemical, etc.) that are superior to those of individual constituents. Nowadays, composite construction are getting more and more popular. This is due to the ability of composites to meet diverse design requirements with significant weight saving as well as high strength-to-weight ratio as compared to conventional materials (Nangia et al. 2001).

Composite components typically used in building construction utilize concrete and steel section for beam and column, while concrete and profiled steel deck mostly used as composite floor system.

1.2 Steel Deck:

Profiled steel deck is made from a thin sheet of high tensile steel. The profile is obtained by cold forming structural grade sheet steel into a repeating pattern of parallel ribs. The strength and stiffness of the panels are a result of the shape of the ribs and the material properties of the steel. Deck lengths can be varied to suit job conditions but, because of shipping considerations, are usually less than 12m. Standard deck width varies with the product used but full sheets are usually 300, 455, 610, 760 or 915mm. The deck is typically furnished in a standard width with ends square cut. Figure 1.1 shows a trapezoidal deck that is possible for use in composite wall construction.

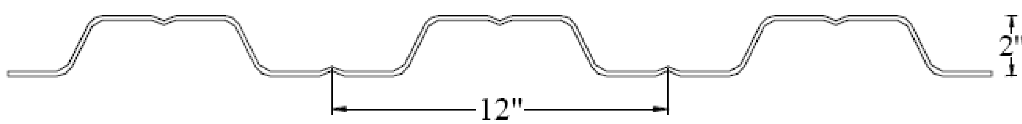

Figure 1.1 Deck cross section (O. Avci, 2002)

The application of profiled steel sheeting as both permanent formwork and reinforcement to concrete slabs was first developed in America in the early 1950s. Following its introduction into the United Kingdom in the 1970s it has become the most common form of floor system for steel framed buildings.

The use of composite slabs with profiled steel deck for fastrack construction had grown rapidly since early 1980s replacing traditional reinforced concrete flooring system. Extensive research on composite slabs by Ekberg and Schuster, Porter and Ekberg formed the basis for the ASCE standard on composite slabs and led to the development of linear regression method that also formed the basis for the testing requirements included in the BS 5950 Part 4.

As with composite flooring, the advantages of composite walling lie on the speed and convenience of construction. However, it is still necessary to establish the structural behavior of the system when resisting construction and service loading.

The usage of steel decking is cheaper compared to the other types of composite system. The reason behind the savings is the speed and ease of installation compared with the other precast components. This means that buildings can be erected faster, enabling projects to be completed earlier and within the budget without compromising on quality. Other benefits offered by steel decking are:

- Provides a stable working platform for the concrete gangs or other trades.
- Lightweight and easily transported.
- Galvanizing provides a level of corrosion protection that is suitable for most applications.
- Increasing the potential for standardization and repetition.

These benefits when combined will give an economical solution with significant cost savings compared to other types of construction system.

1.3 Problem statement

Numerical techniques have now become an invaluable part of most structural research, because they can be employed as an economical and efficient tool for analyzing the behavior of structures. Provided that suitable care is taken to ensure that the numerical model is appropriate and the input parameters are accurately specified. The sensitivity to changes in these parameters also needs to be properly understood. Since it is not practical to verify all structural design guides by testing, a better approach is to first conduct some tests, then to replicate the testing procedures using numerical techniques. Once the numerical models have been verified, further results can be generated by running the model using different input parameters that are of interest to the study.

A composite load-bearing wall panel is one of the new types of load-bearing wall currently being studied at UTM (Por, 2007). The panel is constructed using steel deck as reinforcement in the wall instead of reinforcement bars. Deriving benefits from combining the structural steel and reinforced concrete, this system possess great potential for use in construction due to its excellent load-carrying capacity, simple construction, and high stiffness owing to composite action. Preliminary experimental investigations of the composite panel using stub column test have been carried out to study the strength and the behavior of composite load-bearing wall panel.

1.4 Aims and Objectives

The aim of this project is to conduct a numerical study on a new type of composite load bearing wall panel using concrete and steel deck. In order to achieve this aim, several objectives are outlined below:

1. To develop finite element models for the steel deck-concrete composite walls.

2. To perform non-linear finite element analysis to obtain load-deformation responses.

3. To perform parametric study on the behavior of composite wall as a function of steel deck thickness and wall geometry.

1.5 Scope

In order to develop a new type of composite load-bearing wall panel, the FE analyses performed in this research was carried out on composite load-bearing wall panels and compared the results with available experimental and analytical results to validate the finite element model. A parametric study was conducted to investigate the effects of different thickness of steel deck and different height of walls for the perfect and imperfect slender wall models on the strength and behavior of composite walls. Material non-linearity of concrete and steel deck was considered in the analysis of short model while material and geometric non-linearity was considered in the slender model.