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JUDUL: **DETERMINATION OF SLENDERNESS LIMIT OF COMPOSITE SLABS**

SESI PENGAJIAN : 2006/2007

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DETERMINATION OF SLENDERNESS LIMIT OF COMPOSITE SLABS

VIDAL PATRICK PATON-COLE

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
Universiti Teknologi Malaysia

APRIL 2007

I declare that this project report entitled *"DETERMINATION OF SLENDERNESS LIMIT OF COMPOSITE SLABS"* 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 aim to determine the slenderness limit of composite slabs, which is the value of shear span to effective depth ratio $\left(\frac{L_s}{d}\right)$ at which the slabs show a distinct characteristic in behavior. In composite slab design, slenderness is a significant parameter that influences the slabs' strength and behavior, it is therefore critical to be considered in the analysis and design. Three-dimensional finite element models of composite slabs were developed incorporating material nonlinearity of concrete, steel and shear interaction property. The shear interaction properties for various slab geometries were modeled with joint connector element available in LUSAS 13.6. Its property was obtained from small scale bending test and the models were calibrated with test data and quasi-static analysis data conducted earlier by other researcher. Parametric analysis was undertaken to determine the effect of variable slenderness on the performance and behavior of composite slabs. Based on the parametric analyses, it was shown that the composite slabs exhibited a distinct performance and behavior at a slenderness of 7.0 which was proposed as the slenderness limit of composite slabs.

ABSTRAK

Kajian ini bertujuan untuk menentukan had kelangsingan bagi papak rencam, iaitu nisbah panjang ricih terhadap kedalaman berkesan, $\left(\frac{L_s}{d}\right)$. Pada had ini kelakunan dan prestasi papak berubah dengan ketara. Bagi papak rencam, kelangsingan merupakan satu pemboleh ubah yang penting yang mempengaruhi kekuatan dan kelakunan papak. Dengan sebab itu ia sangat kritikal untuk dipertimbangan dalam analisis dan reka bentuk. Model unsur terhingga tiga dimensi tak lelurus menggunakan perisian LUSAS 13.6 telah dibangunkan dengan mengambil kira sifat ketaklelurusan konkrit, keluli dan interaksi ricih. Ciri interaksi ricih telah dimodelkan dengan menggunakan unsur penyambung. Prestasi model telah ditentukur dengan data ujikaji dan hasil analisis kuasi-statik yang dijalankan oleh penyelidik terdahulu. Analisis parameter telah dijalankan untuk menentukan kesan kelangsingan terhadap prestasi dan kelakunan papak rencam. Keputusan kajian ini telah mendapati bahawa prestasi papak rencam berubah dengan ketara pada kelangsingan 7.0. Nilai ini telah di cadangkan sebagai nilai menghad bagi kelangsingan papak rencam.

TABLE OF CONTENTS

LIST OF TABLES

LIST OF FIGURES

LIST OF SYMBOLS

2D – two dimensional

3D – three dimensional

d – effective depth of slab

d_s – steel deck depth

FE – finite element

L – total span length

L_s – shear span length

M – ultimate bending moment

P – point load

PSC – partial shear connection

t_c – concrete thickness

w - uniform load

W_{fe} – ultimate load from finite element analysis

W_{us} – ultimate load from small scale test

LIST OF APPENDICES

CHAPTER 1

INTRODUCTION

1.1. Background

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. Today, the use of composite floor slab systems in construction is common practices.

As defined by ASCE (1992) "*A composite slab system is one comprising of normal weight or lightweight structural concrete placed permanently over cold-formed steel deck in which the steel deck performs dual roles of acting as a form for the concrete during construction and as positive reinforcement for the slab during service*". Amongst the numerous advantages of composite slabs over reinforced concrete slabs are lightweight and easy handling in erection of steel decks. The deck also acts as temporary formwork for the fresh concrete, which saves time and reduces construction costs. Once the concrete has cured and the components become a composite system, the cold-formed steel deck serves as positive slab reinforcement. Other advantages of the system that attract structural engineers are elimination or significant reduction of the positive moment reinforcement and form work for concrete casting. This is in contrast to the early use (before 1950) of the steel deck-concrete floor, where the concrete was used only as a filling material as was reported by Widaja (1997). The feature of a composite slab section is shown in Figure 1.1.

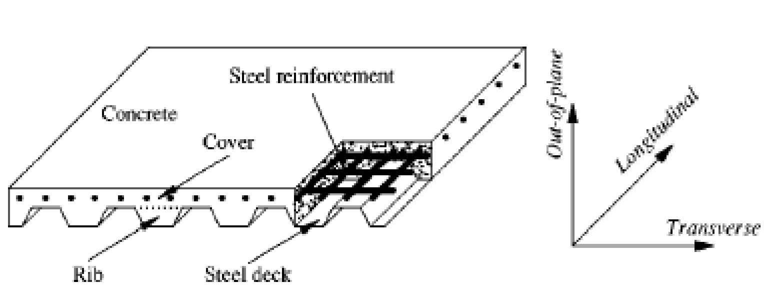

Figure 1.1 Geometric configuration of composite floor slab (Izzuddin, Tao and Elghazouli, 2004)

The knowledge of the composite interaction as well as the elemental behavior involved in the system has progressed rapidly during the past two decades. Much effort has been put forth to model the behavior of the system. Research on the elemental tests, full scale tests, numerical methods and mechanical models to predict the behavior of composite slab systems has therefore been conducted worldwide particularly in the U.S., Canada, Europe and Australia (Abdullah, 2004).

1.2 Behavior of Composite Slabs

Composite slab behavior is a function of the interactions amongst the components of the slab. Two of the most important interactions that significantly affect the slab behavior are: (i) the shear interaction at the interface of steel deck and concrete and (ii) the interaction between the concrete, steel deck and end condition at supports. Amongst others, the geometric properties of the steel decks significantly influence the interaction behavior. One of the purposes of understanding the behavior of composite slab is to provide tools suitable for design purposes. Methods based on simple mechanical model have been developed worldwide in the past two decades as reported by Abdullah (2004). Despite the complex nature of interactions inside composite slab systems, the models have demonstrated good performance in predicting the slab strength and practical behavior.

Composite slabs under bending can exhibit three major modes of failure: flexure failure at section 1-1, vertical shear failure at section 2-2 and horizontal shear failure at section 3-3 as shown in Figure 1.2 (Johnson, 1994).

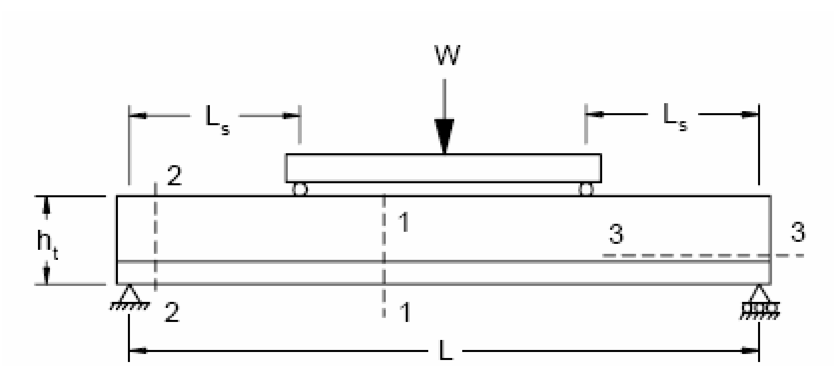

Figure 1.2 Modes of failure of composite slab (Johnson, 1994)

The flexure failure (mode 1) occurs when complete interaction at the interface between the concrete and steel is achieved. This type of failure usually occurs in long thin slabs. Analysis for this type of failure is quite easy, in which case ordinary reinforced concrete procedures can be followed (ASCE, 1992; Easterling and Young, 1992). The flexural failure however, is not a dominant design criterion because the steel and concrete interaction is usually incomplete and the slab length is always limited by the serviceability (deflection) limit.

The characteristic of the second mode, which is the vertical shear failure, was reported by Abdullah (2004). For this failure mode to be dominant, the slab has to be very short and thick with a high concentrated load near the supports. This is not common in construction practice, therefore, it has not been the subject of much research and the effect is usually ignored in design.

Failure mode 3, which is a horizontal shear failure or shear bond failure as it is commonly referred to, is the mode more likely to occur for most composite slab systems subjected to vertical loads. This is characterized by the development of an approximate diagonal crack under or near one of the concentrated loads just before failure, followed by an observable end-slip between the steel deck and the concrete within the concrete shear span L_s, as illustrated in Figure 1.3.

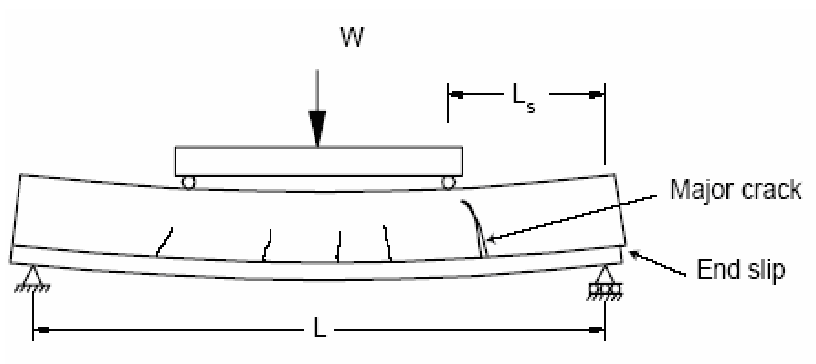

Figure 1.3 Horizontal shear failure (Abdullah, 2004)

Thus, the strength and behavior of composite slabs which fail by horizontal shear depend on several major factors such as shear transfer devices, steel thickness and slab slenderness. The shear transfer devices are usually a combination of steel profile shape, indentations or embossments on the steel surface and end anchorages.

1.3 Problem statement

There are two composite slab design methods that are widely followed. These are the shear bond method also known as the m-k method and the partial shear connection (PSC) method, both published in Eurocode 4 (1994). These design methods still suffer a major drawback in which the required parameters have to be obtained from full scale bending tests that are expensive and time consuming. Economic means to deduce the required design parameters are continuously been sought after by researchers. Elemental push-off test are usually conducted to determine the shear interaction between the steel deck and the concrete. This relationship is used as an input parameter for numerical analysis. By doing this, the need for full scale bending tests could be avoided. However, studies have shown that the push tests cannot represent the true behavior of the shear interaction involving different slabs slenderness. Abdullah (2004) proposed that the interaction properties need to be adjusted according to the slenderness of the slab in order to obtain good numerical results. These adjustments affect the slab strength and behavior significantly in the compact region while not so significant in the slender region.

In order to obtain more accurate numerical results, it is essential to model the relationship between the shear bond stress and its relationship with the slenderness of the slab. This will provide structural engineers an easy means by which they can verify design calculation. This study will further provide easy tools by which composite slabs with non-standard dimensions can be designed that are not usually available in steel deck manufacturer's tables. It can also aid the manufacturer wanting to produce a new sheeting profile to facilitate prediction of the load-deflection behavior.

1.4 Aims and Objectives

The aim of this study is to determine the slenderness limit of composite slab. The slenderness limit is the value of shear span to effective depth ratio $\left(\frac{L_s}{d}\right)$ at which the slabs show a distinct characteristic of either slender or compact (Abdullah, 2004). In order to achieve this aim, several objectives were outlined as below:

1. To develop 3D finite element models for various composite slabs. Joint connector elements at nodes will be used to represent the shear bond at the interface between the concrete and steel deck.

2. To perform nonlinear finite element analyses to determine how well the shear bond-stress slip relationship obtained from the small scale bending test can be applicable in the finite element (FE) analysis.

3. To perform parametric study on the behavior of composite slab as a function of slab geometry.

4. To examine the limit of slenderness at which the slab behaves as either compact or slender.

1.5 Scope and limitation of study

The FE analysis performed in this research was carried out on slabs that were tested by Abdullah (2004). Additional slab geometries were included to establish the parametric study for slenderness. Only material non-linearity of concrete, steel deck and shear bond interaction was considered in the analysis. The analyses were only applicable to Trapezoidal shape cold-formed steel decks manufactured by Vulcraft of Nucor Research and Development, USA. The detail study was limited to simply supported slab with two point loads only.

1.6 Organization of Report

This report is organized as follows: Following chapter 1, previous related research is presented in the literature review in Chapter 2. Details of the FE development, modeling and the use of shear bond properties are presented in Chapter 3. The interpretation and discussion of the results including the effect of slenderness on composite slabs behavior are discussed in Chapter 4. Finally, conclusions and recommendations are presented in Chapter 5.