NUMERICAL MODELLING OF CONTACT ELEMENT FOR CONCRETE-TO-CONCRETE BOND

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Specially dedicated to my beloved family, supervisor, friends and course-mates.

Thank you for all effort, guidance and support.

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ABSTRACT

Interface shear strength is an essential requirement to ensure composite action of a composite slab. In order to achieve full composite action, the shear strength at the interface must be strong enough to resist horizontal shear which totally depends on bond and shear of the contacted surfaces. The horizontal shear must be effectively transferred through the interface of the elements. This research is aimed to investigate the shear strength at interface of existing concrete with new layer of concrete topping by use of numerical analysis. The importance of such knowledge is enhanced by the fact that precast slab is mostly preferable in construction of floor and roof system because of the economical use of the concrete and its light weight properties. In this study, two contact elements namely Rigid Body and Slide Line are used to model concrete-to-concrete bond of existing concrete and new layer of concrete topping. To this regard, the proposed material modelsare integrated into finite element software through a basis of experimental data from small scale push-off test. The main consideration include in model are details of the structural components, contact condition between existing concrete and new layer of concrete topping, associated boundary conditions and loading. The load-slip relationship of finite element analysis result is then verified with the experimental test. From the finite element analysis result, the Slide Line contact element shows good agreement with experimental result with 20.12% difference compare to 28.41% by Rigid Body contact element.

ABSTRAK

Kekuatan ricih antara permukaan adalah penting bagi memastikan tindakan komposit berlaku pada papak komposit. Bagi membolehkan tindakan komposit berlaku sepenuhnya, kekuatan ricih antara permukaan iaitu ikatan antara permukaan yang bersentuhan haruslah mencukupi untuk menahan daya ricih mendatar yang bertindak. Daya ricih mendatar yang bertindak pada papak komposit hendaklah dipindahkan dengan berkesan antara dua permukaan tersebut. Kajian ini adalah bertujuan untuk menyiasat kekuatan ricih antara permukaan konkrit tersedia dan lapisan konkrit baru melalui kaedah analisis berangka. Kepentingan terhadap pengetahuan sebegini adalah berikutan dengan penggunaan papak pra-tuang secara meluas dalam pembinaan lantai dan sistem bumbung kerana penggunaan konkritnya yang ekonomi dan ringan. Dalam kajian ini, dua elemen digunakan untuk memodelkan ikatan antara dua permukaan konkrit iaitu elemen hubungan *Rigid Body* dan *Slide Line*. Bagi tujuan tersebut, model yang dicadangkan disepadukan ke dalam perisisan unsur terhingga dengan menggunakan data yang diperoleh melalui ujian makmal iaitu ujian tolakan berskala kecil. Antara pertimbangan utama yang diambil kira dalam membina model adalah butiran komponen struktur, keadaan permukaan konkrit, keadaan sempadan dan beban. Hubungan beban-anjakan daripada analisis berangka kemudiannya dibandingkan dengan keputusan ujian makmal. Daripada perbandingan tersebut, model yang menggunakan elemen hubungan *Slide Line* memberikan keputusan yang lebih hampir dengan ujian makmal dengan perbezaan sebanyak 20.12% berbanding 28.41% bagi model yang menggunakan elemen hubungan *Rigid Body*.

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τ	-	Interface shear stress
σ_n	-	Normal stress
α	-	Angle of inclination
c	-	Cohesion coefficient
μ	-	Friction coefficient
b_v	-	Breadth of contact area
d	-	Effective depth
f_{yi}	-	Reinforcement tensile stress
f_{cd}	-	Concrete design strength
V_u	-	Applied shear force
V_{nh}	-	Nominal horizontal shear strength
V_{Edi}	-	Design shear stress
V_{Rdi}	-	Design shear resistance
l_m	-	Evaluation length
$y(x)$	-	Profile height at position x
z_i	-	Peak-to-valley height in each cut-off length
p_i	-	Peak height in each cut-off
p_{max}	-	Maximum peak height
v_{max}	-	Maximum valley depth
v_i	-	Valley depth
R_a		Average roughness
R_z	-	Mean peak-to-valley height in each cut-off
R_{max}	-	Maximum peak-to-valley height
R_{3z}	-	Mean third highest peak-to-valley height
R_{3zi}	-	Third highest peak-to-valley height

R_{3max}	-	Maximum highest third peak-to-valley height
$R_{z(ISO)}$	-	Ten point height
R_y	-	Total roughness
R_{pm}	-	Mean peak height
R_p	-	Maximum peak height
R_{vm}	-	Mean valley depth
R_v	-	Maximum valley depth

CHAPTER 1

INTRODUCTION

1.1 Background

Precast concrete slabs are one of the reasonable tools for construction throughout the world as the most common load bearing concrete elements. There are variety of standard shapes that have gained wide use amongst engineers and designers. One of the preferable precast concrete slabs is hollow core units because of their light weight and the economical use of the concrete. Hollow core units are plant-manufactured concrete member with continuous voids to reduce weight and cost. This not only makes the design much more efficient, but it helps to reduce the size and overall shape of the hollow core unit that allows lighter cross section with larger span length.

As the units span one-way, hollow core unit requires a layer of cast in-situ concrete topping which some two-way spanning capability to increases the shear strength and connects the slab units together laterally. For several decades, hollow core unit have been used with the application of cast-in-situ concrete topping, without any special connectors between hollow core unit and in-situ concrete topping for the purpose of making a complete floor finish or to enhance the structural performance of the floor by producing a composite structure.

Common design practice for the hollow core unit and in-situ concrete topping is to act as composite system for live and dead loads. The stresses developing in this composite system increase as the span length have become longer. It is important that interface shear stress been carried in both the topping and slab can readily cross the interface zone between these two members. Figure1.1 shows an illustration of the interface shear stress. The transfer of this shear stress is commonly known as interface shear transfer.

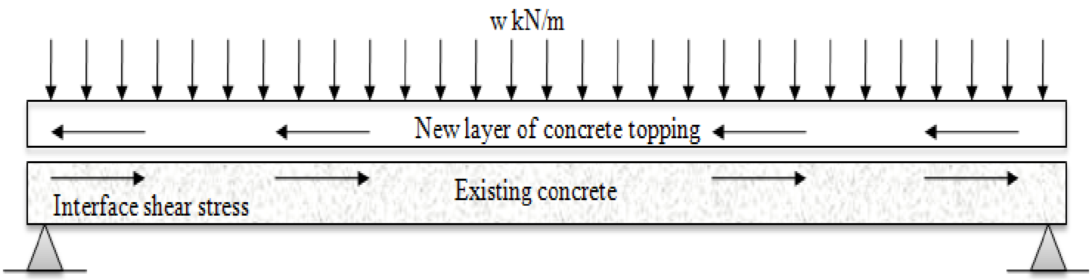

Figure 1.1 The interface shear stress.

In order to achieve full composite action, the shear strength of concrete to concrete bond at the interface depends on the concrete cohesion, friction and dowel action. However, dowel action only applied if shear reinforcement crossing the interface is provided.

Meanwhile, both cohesion and friction at the interface are influenced by surface texture or roughness at the interface. As for that reason, various equation and standard specification to determine nominal shear resistance have been developed. The design equations consider both mechanical and frictional shear transfer in determining the nominal shear resistance of an interface zone.

Composite floor incorporating hollow core unit and in-situ concrete topping is an economical developed system for building structures. Compare with the traditional floor systems such as reinforced concrete slab and metal profiled decking floor system, hollow core unit save construction time and cost, therefore, it is more popular in current construction market. When this form of concrete becomes popular, rapid studies have been conducted to optimize the use of the materials for purpose of providing most efficient and economical design.

Although the structural behaviour of hollow core unit has been extensively investigated, their behaviour with in-situ concrete topping has not received the same level of attention. Furthermore, because experimental tests of whole structures or sub-assemblies are not always feasible, computer analysis becomes the only alternative. However, a simple analysis is too crude to capture the development of the composite action. Therefore, comprehensive finite element analysis to model the load-slip behaviour of hollow core unit as the existing concrete with new layer of concrete topping is the best alternative.

1.2 Problem Statement

A proper shear and bond strength at the interface is required for composite action. However, cross sectional geometry and manufacturing process of hollow core unit restricts the use of reinforcements. Therefore, in order to achieve full composite action, the shear and bond strength of hollow core unit with concrete topping entirely depends on the cohesion and friction of contacted surface.

Although there are many experimental and theoretical studies have been conducted to study the effect of concrete topping on the shear capacity of hollow core unit and adequacy of the shear or bond strength of interface, but studies involving numerical analysis of hollow core unit with in-situ concrete topping are not been attempted that far in research community. It is unknown whether current finite element codes can accurately capture this type of behaviour. Current research includes experimental studies on push-off specimens but numerical studies are lacking. Thus, in this study, finite element analysis of hollow core unit as the existing concrete with new layer of concrete topping with the focus on the effect of variable contact elements on the result of the analysis was carried out and the findings are presented.

1.3 Objectives

The aim of this study is to investigate the load-slip behaviour at interface of existing concrete with new layer of concrete topping by use of numerical analysis. Therefore, the objectives to be achieved in this study are as follows:

1. To carry out finite element analysis by modeling the contact element for existing concrete and new layer of concrete topping.
2. To analyse the model under different contact element using finite element method.
3. To compare the results from the finite element analysis with the experimental test.

1.4 Scope of Study

The scopes of this study consist of:

1. Material and physical properties of existing concrete used as provided by manufacturer.
2. New layer of concrete topping depth is fixed to 75 mm.
3. Concrete strength C50/60 is applied for existing concrete and C25/30 for new layer of concrete topping.
4. Interface between existing concrete and new layer of concrete topping is triangular shape.
5. Roughness amplitude, R_z = 2 mm used in modeling the interface.
6. Analysis conducted until non-linear state.
7. Experimental test result obtained from previous researcher.
8. Contact element used in analysis only those that available in ABAQUS software.

1.5 Significance of Study

The advancement of the state of knowledge in composite action of concrete to concrete bond can possibly lead to a better design of structures. In order to study the interface shear strength of the composite existing concrete and new layer of concrete topping, the best way is by carrying out experimental tests. However, due to expenses and limitation of experimental tests, non-linear finite elements method is an attractive tool for investigating composite action between concrete to concrete bonds.

The use of finite element could explore large number of variables and potential failure modes, which could complement the experimental study. This study will provide a numerical assessment of the current ability of the finite element analysis to accurately represent the load slip in push-off specimens. Once this is accomplished, the model can further be used to study and the give predictions on the ultimate shear strength and shear slip load push-off specimens with varied parameter. Precise numerical analysis helps providing designers with guideline which conserves, simple and allow analysis to be run in shorter time.

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