FINITE ELEMENT ANALYSIS OF COMPOSITE SLABS

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STUDENT'S DECLARATION

I hereby declare that the work in this thesis is based on my original work except for quotations and citations which have been duly acknowledged. I also declare that it has not been previously or concurrently submitted for any other degree at Universiti Malaysia Pahang or any other institutions.

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ABSTRAK

Satu analysis unsur terhinggaslab komposit besi-konkrit tanpa sokongan dengan dek profil dibentangkan dalam kertas kerja ini. Pakej perisian FE, ABAQUS, digunakan untuk membangunkan model-model slab komposit. Model FE 3D terdiri daripada slab komposit biasa dan slab komposit diperkuat dengan *cold-formed C-channel* telah dibangunkan. Disamping itu, pengaruh C-channel terhadap slab komposit dan panjang slab komposit telah dikaji. Model FE ini mengambil kira ciri-ciri ketidakmalaran bahan terkandung di dalam slab komposit dan ketidakmalaran bentuk. Selain itu, interaksi hubungan yang sesuai antara permukaan komponen telah diwujudkan dalam setiap model FE slab komposit. Teknik pemodelan yang digunakan untuk membangunkan model FE yang direka bagi slab komposit telah disahkan berdasarkan hasil ujian eksperimen yang berbeza. Data eksperimen diperolehi daripada program eksperimen ujian lenturan empat-titik terhadap slab komposit dilakukan oleh Marimuthu et al. (2007). Hasil analisis FE menunjukkan graf beban-anjakan model slab komposit.

ABSTRACT

A finite element (FE) analysis of steel-concrete composite slab with profiled deck is presented in this paper. A FE software package, of ABAQUS, was used to develop the models. 3D FE models of consists of normal composite slabs and composite slabs strengthened with cold formed C-channels were developed. Besides the influence of C-channel, the influence of the composite slabs span also was investigated. The FE models considered materials and geometrical nonlinearities. Furthermore, appropriate contact interactions between components interfaces were assigned in the FE models of the composite slabs. The modelling techniques used to develop the proposed FE models of the composite slabs were verified based on disparate experimental test results. The disparate test results were obtained according to an experimental program on composite slabs under four-point bending test conducted by Marimuthu et al. (2007). Finite element analysis results demonstrated load-displacement curve of the composite slab. It is concluded that the composite slab showed significant improvement in strength by adding C-channel.

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LIST OF SYMBOLS

f_t	Tensile strength of concrete
W_c	Crack opening displacement at which stress can no longer be transferred
σc	Compressive stress in the concrete
εc	Compressive strain in the concrete

LIST OF ABBREVIATIONS

FE	Finite element
ECC	Engineered Cementitious Composite
SCC	Self-Consolidating Concrete
RC	Reinforced concrete
GFRP	Fibre reinforced polymer
DP	Drucker–Prager plasticity model
CDPM	Concrete damaged plasticity model
CDP	Concrete damaged plasticity
RP	Reference point
U	Displacement
IE	Internal energy
KE	Kinetic energy

CHAPTER 1

INTRODUCTION

1.1 Introduction

Construction industry nowadays continuing developed to find new alternatives in increasing construction speed. There are many modern buildings such as office building, residential and industrial buildings apply composite slabs as their floors substituting the conventional reinforced concrete slabs. Composite slabs are a combination of reinforced concrete slabs and profiled metal decking. This type of structure is widely used in construction industry because it has many advantages compared to the conventional reinforced concrete slabs. Composite slabs exhibits economical features and can reduce construction time efficiently. In addition, the structure is favourable in construction site since it is easy to handle due to the using of lightweight components and materials. The most important part is the profiled metal decking served as permanent formwork to the floor and also act as tension reinforcement (Gholamhoseini et al., 2014). It will support the construction loads and weight of the concrete before and after it has hardened. Generally, there are two types of composite slabs which are propped and unpropped during construction.

In real practice, most of the composite slabs are propped during construction stage especially when the span of the composite slab is quite long. On the other hand, unpropped composite slabs are seldom used in steel-concrete composite structures in particular for long span. Perhaps, this situation is contributed by the difficulty to limit the deflection of the composite slabs during construction stage as stipulated in design codes such as Eurocode 0(EN1990). To increase the resistance of the composite slab and reducing the deflection of the composite slab in unpropped situation, this study proposes a modified composite slab design where C-channels are bolted to the profiled steel deck. Therefore, this study is performed to investigate the response of the modified composite slabs and compared the results with conventional composite slabs i.e. without C-channel.

1.2 Problem Statement

The application of unpropped composite slabs in industry especially for steel-framed buildings become popular now as it promotes rapid construction (Glasle et al., 2005). However, it is only limit for short span composite slabs because most of the long span composite slabs are propped by temporary supports during construction. Perhaps, it is due to the risks and failures that may occur in the long span structure make it less favourable compared to short span slab. Unpropped composite slabs with long span resulting in large degree of deflection because lack of supports placed during construction. The possibility of the structure to fail may influenced by the lack of strength of profiled steel deck in carrying the wet concrete and construction load.

Due to the risk of failure of long span unpropped composite slabs, it might be possible to increase the stiffness of the composite slab cross-section by adding C-channels on top the rib of the profiled deck to increase the composite slabs flexural capacity. Therefore, this study investigates the behaviour of composite slabs strengthened with C-channel and evaluate the performance of the composite slabs. It is hope that this investigation could provide clear understanding on the unpropped composite slabs performance and their failures under flexural loading. Due to lack of experimental data, this study used FE software to perform this investigation where the FE models were verified against disparate experimental test results

1.3 Objectives

The objectives of this study are:

i. To develop FE models of the steel-concrete composite slabs
ii. To compare the response of composite slabs strengthen with 75mm cold form C-Channel with conventional composite slabs

iii. To investigate the performance of unpropped composite slab with various span length

1.4 Scope of Research

The study focused on the finite element (FE) analysis of half symmetry composite slab under four-point bending test by using ABAQUS software. Three Dimensional models of composite slab with supports and loading set up were created. The components involved in the models namely concrete slab, steel deck, C-channel and roller bar. The FE modelling technique was verified based on FE model of experimental program conducted on composite slabs.

Finite element analysis results demonstrated load-displacement curve of the composite slab. The load-displacement responses were observed to investigate the behaviour of the composite slab. Besides the influences of the composite span length to the performances of the composite slab also was studied. Half-symmetry of conventional and modified composite slab models with 1000 mm width and varying in span length were developed in the FE analysis.

1.5 Significant of Research

There were many previous research studies has been conducted that developed composite slabs with different types of concrete and its materials (Mohammed et al., 2011; Mohammed, 2010; Hossain et al., 2019; Bashar, 2010). However, limited research has been done on developed new design of composite slabs with additional reinforcement. This study able to improve the understanding on the behaviour of composite slab strengthened with additional reinforcement namely C-channel.

Long span unpropped composite slab more likely to fail due to the bending during construction compared to propped composite slab. The additional reinforcement is expected to enhance the flexural capacity and bending resistance of the composite slab. Unpropped composite slabs with better structural performances able to be developed in this study and able to promote its application in construction industry. The application of

REFERENCES

Abas, F. M., Gilbert, R. I., Foster, S. J., & Bradford, M. A. (2013). Strength and serviceability of continuous composite slabs with deep trapezoidal steel decking and steel fibre reinforced concrete. *Engineering Structures*, *49*, 866-875.

Abdullah, R., Paton-Cole, V. P., & Easterling, W. S. (2007). Quasi-static analysis of composite slab. *Malaysian Journal of Civil Engineering*, *19*(2).

Adawi, A., Youssef, M. A., & Meshaly, M. E. (2016). Finite element modeling of the composite action between hollowcore slabs and the topping concrete. *Engineering Structures*, *124*, 302-315. 7

Alkhalil, J., & El-Maaddawy, T. (2017). Finite element modelling and testing of two-span concrete slab strips strengthened by externally-bonded composites and mechanical anchors. *Engineering Structures*, *147*, 45-61.

Alashker, Y., El-Tawil, S., & Sadek, F. (2010). Progressive collapse resistance of steel-concrete composite floors. *Journal of Structural Engineering*, 136(10), 1187-1196.

British Standards Institution. (2004). *Eurocode 2: Design of concrete structures: Part 1-1: General rules and rules for buildings.* British Standards Institution.

Cifuentes, H., & Medina, F. (2013). Experimental study on shear bond behavior of composite slabs according to Eurocode 4. *Journal of Constructional Steel Research*, 82, 99-110.

Emami, F., & Kabir, M. Z. (2019, June). Performance of composite metal deck slabs under impact loading. In *Structures* (Vol. 19, pp. 476-489). Elsevier.

Florides, M. M., & Cashell, K. A. (2017, February). Numerical modelling of composite floor slabs subject to large deflections. In *Structures* (Vol. 9, pp. 112-122). Elsevier.

Gholamhoseini, A., Gilbert, R. I., Bradford, M. A., & Chang, Z. T. (2014). Longitudinal shear stress and bond–slip relationships in composite concrete slabs. Engineering structures, 69, 37-48.

Glasle, M., Bridge, R. Q., & Patrick, M. (2005). The effect of end diaphragms on the local and global buckling of a new cold-formed cellular deck. In Australian Structural Engineering Conference 2005 (p. 1094). Engineers Australia.

Hany, N. F., Hantouche, E. G., & Harajli, M. H. (2016). Finite element modeling of FRP-confined concrete using modified concrete damaged plasticity. *Engineering Structures*, *125*, 1-14.

Hibbitt, K. (2008). Sorenson Inc. ABAQUS Version 6.8: Theory Manual, Users' Manual, Verification Manual and Example Problems Manual.

Hind, M. K., Özakçab, M., & Ekmekyaparc, T. (2016). A Review on Nonlinear Finite Element Analysis of Reinforced Concrete Beams Retrofitted with Fiber Reinforced Polymers. *Journal of Advanced Research in Applied Mechanics*, 22(1), 13-48.

Hossain, K. M. A., Alam, S., Anwar, M. S., & Julkarnine, K. M. Y. (2016). High performance composite slabs with profiled steel deck and Engineered Cementitious Composite–Strength and shear bond characteristics. *Construction and Building Materials*, *125*, 227-240.

Hossain, K. M. A., Attarde, S., & Anwar, M. S. (2019). Finite element modelling of profiled steel deck composite slab system with engineered cementitious composite under monotonic loading. *Engineering Structures*, *186*, 13-25.

Hu, H. T., Huang, C. S., Wu, M. H., & Wu, Y. M. (2003). Nonlinear analysis of axially loaded concrete-filled tube columns with confinement effect. *Journal of Structural Engineering*, *129*(10), 1322-1329.

Jiang, J. F., & Wu, Y. F. (2012). Identification of material parameters for Drucker–Prager plasticity model for FRP confined circular concrete columns. *International Journal of Solids and Structures*, *49*(3-4), 445-456.

Jiang, J., Pintar, A., Weigand, J. M., Main, J. A., & Sadek, F. (2019). Improved calculation method for insulation-based fire resistance of composite slabs. *Fire Safety Journal*.

Kan, Y. C., Chen, L. H., & Yen, T. (2013). Mechanical behavior of lightweight concrete steel deck. *Construction and Building Materials, 42*, 78-86.

Katwal, U., Tao, Z., & Hassan, M. K. (2018). Finite element modelling of steel-concrete composite beams with profiled steel sheeting. *Journal of Constructional Steel Research*, *146*, 1-15.

Krätzig, W. B., & Pölling, R. (2004). An elasto-plastic damage model for reinforced concrete with minimum number of material parameters. *Computers & structures*, 82(15-16), 1201-1215.

Liu, X., Bradford, M. A., & Lee, M. S. (2014). Behavior of high-strength friction-grip bolted shear connectors in sustainable composite beams. *Journal of Structural Engineering*, *141*(6), 04014149.

Liu, X., Yan, M., Galobardes, I., & Sikora, K. (2018). Assessing the potential of functionally graded concrete using fibre reinforced and recycled aggregate concrete. *Construction and Building Materials*, *171*, 793-801.

Lubliner, J., Oliver, J., Oller, S., & Oñate, E. (1989). A plastic-damage model for concrete. *International Journal of solids and structures*, *25*(3), 299-326.

Majdi, Y., Hsu, C. T. T., & Zarei, M. (2014). Finite element analysis of new composite floors having cold-formed steel and concrete slab. *Engineering Structures*, *77*, 65-83.

Marie, I., & Quiasrawi, H. (2012). Closed-loop recycling of recycled concrete aggregates. *Journal of Cleaner Production*, *37*, 243-248.

Marimuthu, V., Seetharaman, S., Jayachandran, S. A., Chellappan, A., Bandyopadhyay, T. K., & Dutta, D. (2007). Experimental studies on composite deck slabs to determine the shear-bond characteristic (m–k) values of the embossed profiled sheet. *Journal of Constructional Steel Research*, *63*(6), 791-803.

Mohammed, B. S. (2010). Structural behavior and m–k value of composite slab utilizing concrete containing crumb rubber. *Construction and Building Materials*, *24*(7), 1214-1221.

Mohammed, B. S., Al-Ganad, M. A., & Abdullahi, M. (2011). Analytical and experimental studies on composite slabs utilising palm oil clinker concrete. *Construction and Building Materials*, 25(8), 3550-3560.

Qureshi, J., & Lam, D. (2012). Behaviour of headed shear stud in composite beams with profiled metal decking. *Advances in Structural Engineering*, *15*(9), 1547-1558.

Shamass, R., & Cashell, K. A. (2017, November). Behaviour of composite beams made using high strength steel. In *Structures* (Vol. 12, pp. 88-101). Elsevier.

Siddh, S. P., Patil, Y. D., & Patil, H. S. (2017). Experimental studies on behaviour of composite slab with profiled steel sheeting. *Materials Today: Proceedings*, *4*(9), 9792-9796.

Siva, A., & Sangeetha, S. A State of Art–Review of Composite Deck Systems.

Tank, T., & Modhera, C. D. (2017). Finite Element Modelling of RC Slab Strengthened with GFRP. *Materials Today: Proceedings*, *4*(9), 9784-9791.

Tomek, R. (2017). Advantages of precast concrete in highway infrastructure construction. *Procedia engineering*, *196*, 176-180.

Vakil, M. D., & Patel, H. S. (2017). Investigations on flexural capacity of steel concrete composite deck with diverse bond patterns.

Wahalathantri, B. L., Thambiratnam, D. P., Chan, T. H. T., & Fawzia, S. (2011, April). A material model for flexural crack simulation in reinforced concrete elements using ABAQUS. In *Proceedings of the first international conference on engineering, designing and developing the built environment for sustainable wellbeing* (pp. 260-264). Queensland University of Technology.

Yu, T., Teng, J. G., Wong, Y. L., & Dong, S. L. (2010). Finite element modeling of confined concrete-II: Plastic-damage model. *Engineering structures*, *32*(3), 680-691.

Zhou, M., Lu, W., Song, J., & Lee, G. C. (2018). Application of ultra-high performance concrete in bridge engineering. *Construction and Building Materials*, *186*, 1256-1267.