

FINITE ELEMENT ANALYSIS OF RAPID FOOTING FOR
INDUSTRIALISED BUILDING SYSTEM

NUR ANIRA ASYIKIN BINTI HASHIM

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

FACULTY OF CIVIL ENGINEERING
UNIVERSITI TEKNOLOGI MALAYSIA

JANUARY 2014

*Specially dedicated to my beloved family
Thank you for all loves, cares and supports.*

ACKNOWLEDGEMENT

Hereby, I would like to express my greatest appreciation for all the people that guide me for completing this project especially my project supervisor, seniors and partner.

First and foremost, I would like to thanks my supervisor, Assoc. Prof. Dr. Abdul Kadir bin Marsono who concerned about my project progress all the time and came up with a short discussion every weeks to help me completing my final year project. From his guidance, advices and encouragement, I am able to have a very clear direction towards my research.

Secondly, I would like to acknowledge parents who have given me the opportunity of an education from the best institutions and support throughout my life.

Finally, I thank God for my health and success in all my education steps during these years.

ABSTRACT

The design and innovation of Industrialized Building System (IBS) requires lighter, stronger, better shape, and versatility. Therefore IBS has a common definition and perspective that coordinated in precision to form a structure. This paper presents finite element analysis on two different shape of rapid footing in order to obtain its potential to be immersed using forced vibration. The shapes are different in terms of the bearing area that in contact between footing and the soil surface. Tests were conducted on granular soils of elastic modulus of 0.0174 N/mm^2 and structures are vibrated vertically. The result obtained from the laboratory test on sand is compared with the result from finite element analysis for comparison. The vertical settlement of the footing of model 1 from laboratory test is 2 mm while from analysis is 3.40 mm. The vertical settlement of the footing of model 2 from laboratory test is 7 mm while from analysis is at 7.02 mm. Results showed that the footing with confinement wall experienced higher settlement than the footing without wall due to its small contact area.

ABSTRAK

Pada masa kini, reka bentuk dan inovasi Sistem Bangunan Perindustrian (IBS) kini menghasilkan komponen pembinaan yang lebih ringan, lebih kuat, lebih baik dari segi bentuk dan serba boleh. Oleh itu IBS mempunyai definisi biasa dan perspektif yang diselaraskan untuk membentuk struktur. Kajian ini memperkenalkan Analisis Unsur Terhingga keatas dua bentuk yang berbeza bentuk untuk mendapatkan potensi penurunan di bawah beban getaran. Bentuk adalah berbeza dari luas kawasan di atas permukaan tanah. Ujian dijalankan ke atas tanah pasir modulus elastik 0.0174 N/mm^2 dan struktur yang digetarkan menegak. Keputusan yang diperolehi daripada ujian makmal ke atas pasir dibandingkan dengan keputusan dari analisis untuk perbandingan. Keputusan menunjukkan bahawa asa dengan dinding mengalami penurunan lebih tinggi daripada asas yang tanpa dinding. Penurunan menegak asas model 1 daripada ujian makmal adalah 2 mm manakala dari analisis adalah 3.40 mm. Penyelesaian menegak kedudukan model 2 daripada ujian makmal adalah 7mm manakala dari analisis adalah di 7.02 mm.

TABLE OF CONTENT

CHAPTER	TITLE	PAGE
	DECLARATION	ii
	ACKNOWLEDGEMENT	iii
	ABSTRACT	vii
	ABSTRAK	viii
	TABLE OF CONTENT	ix
	LIST OF TABLES	x
	LIST OF FIGURES	xiii
	LIST OF APPENDIXES	xiv
1	INTRODUCTION	
	1.1 Problem Statement	2
	1.2 Objectives	3
	1.3 Scope of Study	3
	1.4 Significance of Study	3
	1.5 Expected Findings	4
2	LITERATURE REVIEW	
	2.1 Industrialized Building System (IBS)	5
	2.2 Classification of IBS	8
	2.2.1 Classification according structural system	8
	2.2.2 Classification according material	11
	2.2.3 Classification according relative weight	11
	2.3 Advantages of IBS	12
	2.4 Footing	13
	2.4.1 Depth of Footing	14

2.4.2	Pressure Distribution below Footing	15
2.5	Properties of Sand	16
2.6	Bearing Capacity of Soil	16
2.4.1	Ultimate Bearing Capacity of Soil	17
2.4.2	Allowable Bearing Capacity of Soil	17
2.4.3	Terzaghi's Bearing Capacity Theory	17
2.7	Modes of Shear Failure	19
2.7.1	General Shear Failure	20
2.7.2	Local Shear Failure	21
2.7.3	Punching Shear Failure	21
3	RESEARCH METHODOLOGY	
3.1	Modeling of element using Autodesk AutoCAD	24
3.1.1	Geometry and Characterization	25
3.1.2	Concrete	30
3.1.3	Steel	31
3.1.4	Soil	31
3.2	Laboratory Work	31
3.2.1	Concrete Trial Mix Design	32
3.2.2	Formwork, Bar Bending and Concrete Casting	33
3.2.3	Compression Test	36
3.2.4	Vibration Test	38
4	FINITE ELEMENT ANALYSIS	
4.1	Autodesk Simulation Multiphysics Analysis	42
4.1.1	Modeling of Element	43
4.1.2	Element, Geometry and Material Definition	44
4.1.3	Meshing of Element	48
4.1.4	Specify Parameter of Element, Constraints and Loading	50
4.1.5	Analyze and Visualize Result	53

5	RESULTS AND DISCUSSION	
	5.1 Experimental Results	54
	5.1.1 Compression Test for Cylinder	55
	5.1.2 Bearing capacity of the soil	57
	5.1.3 Settlement of the footing	58
	5.1.4 Inclination of the footing	59
	5.2 Finite Element Analysis Results	61
	5.2.1 Settlement of Footing Model	61
	5.3 Result Comparison	64
6	CONCLUSION AND RECOMMENDATION	
	6.1 Conclusion	65
	6.2 Recommendation	66
	REFERENCES	67
	APPENDIXES	
	A Technical Paper	69

LIST OF TABLES

TABLE NO.	TITLE	PAGE
3.1	Concrete Mixture Ratio	31
4.1	Concrete Element Material Properties	46
4.2	Steel Element Material Properties	47
4.3	Soil Element Material Properties	48
5.1	Compression test results	55
5.2	Macintosh probe results	57
5.3	Relation between Macintosh tool resistance and Safe Pressure	57
5.4	Settlement of the footings	58
5.5	Model 1 inclination	60
5.6	Model 2 inclination	60
5.7	Settlement On-site and in Analysis	64

LIST OF FIGURES

FIGURE NO.	TITLE	PAGE
2.1	Category of IBS system	8
2.2	Steel Frame System	9
2.3	IBS Panel System	10
2.4	Pressure distribution under footing	15
2.5	Terzaghi's concept of Footing	19
2.6	Footing on ground	20
3.1	Research Methodology Chart	23
3.2 (a)	Footing Scaled Model 1	24
3.2 (b)	Footing Scaled Model 2	25
3.3	Bar bending	25
3.4	Steel reinforcement case for model 2	26
3.5	Steel beam	27
3.6 (a)	Spiral Link	28
3.6 (b)	Steel spiral dimensions	28
3.7	Steel stump dimension	29
3.8	Arrangement of steel stump, spiral link and steel beam	29
3.9	Steel Connector	30
3.10	Plywood Formwork	33
3.11	Bended Spiral Reinforcement Bars	34
3.12	Bended Reinforcement Bars	34
3.13	Bars Arrangement	35
3.14	Casting of Model	36
3.15	Compression Test of Model 1 and Model 2 Specimens	38
3.16	Placing of Model	39

3.17	Inclinometer on Footing	39
3.18	Vibration on Testing	40
4.1	Procedure of Autodesk Simulation Multiphysics	42
4.2(a)	Footing Model 1 and Soil	43
4.2(b)	Footing Model 2 and Soil	44
4.3	Import model into Autodesk Simulation Multiphysics	45
4.4(a)	Concrete Element Material Selection	46
4.4(b)	Steel Element Material Selection	47
4.4(c)	Soil Element Material Selection	48
4.5	Meshing Process	49
4.6	Completion of Meshing	50
4.7	Fixed Boundary Condition	51
4.8	No Translation Boundary Condition	51
4.9	Static Load of 120N	52
4.10	Gravity Curve of Model 1	52
4.11	Gravity Curve of Model 2	53
5.1	Compression test result at 28 day for footing model 1	55
5.2	Compression test result at 28 day for footing model 2	56
5.3(a)	Time history for model 1	58
5.3(b)	Time history for model 2	59
5.4	Inclinometer positioning	59
5.5	Displacement of Model 1	61
5.6	Displacement of Model 2	62
5.7(a)	Analysis Result Model 1 footing	62
5.7(b)	Analysis Result Model 2 footing	63

LIST OF APPENDICES

APPENDIX	TITLE	PAGE
A	Technical Paper	69

CHAPTER 1

INTRODUCTION

Industrialised Building System (IBS) is a construction method where all or part of the components of the structure is prefabricated in the factory and assemble on site construction. IBS enables quality improvement beside reduction of labour intensity. IBS can be different things to different industry players. However, there are several definition from different resources that reflected the concept of IBS which widely accepted by the construction industry. IBS is best defined according to CIDB Malaysia (2001) as a construction technique in which component are manufactured in a controlled environment, transported, positioned and assembled into a structure with minimal additional site works.

The first precast panelised wood house was shipped from England in 1624 to provide temporary housing for fishing fleet. From then on many precast systems were introduced; with some success and failures. The Industrialised Building System was introduced Malaysia in 1964 when the government launched two pilot housing project constructed using IBS. It was Tuanku Abdul Rahman Flats in Kuala Lumpur and Riffle Range Road Flats in Penang. Since then, numerous projects in Malaysia have utilises IBS especially when the construction require to built up quickly and with high accuracy and quality.

Definitions of industrialised building system has also been given by Esa and Nuruddin (1998) in which IBS is a continuum beginning from utilising craftsmen for every aspect of construction to a system that use manufacturing production in order to minimise resource wastage and enhance value for end users. According to Badir-

Razali (1998), all building systems can be classified into four types of building system.

The implementation of IBS in Malaysia however was considered slow and not effective compared to developed countries such as United States, Europe and Japan. Although the government have introduced multiple initiatives of the use of IBS together with studies and solutions were introduced to increase the awareness of the usage of IBS in Malaysia. Besides that it is also to improve the implementation of IBS in terms of construction policy and guidelines to implement the use of IBS in the local construction industry.

1.1 Problem Statement

The traditional system cannot fulfill the housing demand without forfeiture of quality of the structures due to a disability of this conventional technique, IBS is an ideal conceptualization and a unique way of simplifying construction works. However, the study of the IBS footing are close to none due to unseen variability of soil to support the structure. Faster and quick developed construction need to be developed so that the structure and components can be easily fabricated, transported and erected on site. This study is focused on the total settlement of the footings when forced vibration load is applied vertically to them. The development of small-scale tests in this thesis is for the proof of concept of the development of a rapid IBS footing system.

1.2 Objectives

The objectives of the study are:

1. To analyze two models of rapid footing of IBS system with and without confinement walls.
2. To determine the ability of immersion of the footing into soil under vertical forced dynamic loads using Autodesk Simulation Multiphysic.
3. To compare the results of laboratory test and finite element analysis for the assessment of the real footing sizes.

1.3 Scope of Study

The study is focusing on the finite element analysis of two model of IBS footing. Model 1 is without the confinement wall and model 2 with the confinement wall of 40 mm thick around the footing. Vibration load as in on-site testing are applied vertically and the total settlement are compared with the on-site settlement measurement. Analysis of Autodesk Simulation Multiphysic is used to simulate for the similarity between the models infinite element and laboratory experiment .

1.4 Significance of Study

From the background of study of IBS, it is obviously that IBS is a better and more efficient system among all the methods in term of constructibility. In the future, IBS will become the priority of choice of the clients due to many advantages on environment and economy. Therefore, it is important to improve the productivity and quality of IBS. Hence, this research is supporting the initiative of new design of footing for Industrialize Building System.

1.5 Expected Finding

The expected findings generated from the study are a lean mix design that design to define strength and rheology of concrete for of component manufacturing.

REFERENCES

Basavanna, B.M., Joshi, V.H. and Prakash, S. (1974). "Dynamic bearing Capacity Of Soils under Transient Loading." Bull. Indian Soc. Earthquake Tech

Construction Industry Development Board (CIDB) Malaysia (2003a), "Survey on the Usage of Industrialised Building Systems (IBS) in Malaysian Construction Industry ", Construction Industry Development Board Malaysia (CIDB), Malaysia, Kuala Lumpur, 2003

Drosos V., Georgarakos T., Loli M., Anastasopoulos I., and Gazetas G. (2011), Non-linear Soil–Foundation Interaction : An Experimental Study on Sand, Proceedings of the 4th Japan–Greece Workshop, Kobe, October 2011.

Erickson, H.L., Drescher, A. (2002). Bearing capacity of circular footings. *Journal of Geotechnical and Geoenvironmental Engineering*, ASCE 128: 1, 38–43.

Frydman, S., Burd, H.J. (1997). Numerical studies of bearing capacity factor Ng. *Journal of Geotechnical and Geoenvironmental Engineering*, ASCE 123: 1, 20–29.

IBS Steering Committee (2006) Minute Meeting of IBS Steering Committee, Construction Industry Development Board (CIDB) Malaysia, Kuala Lumpur

J.L. Briaud P. and Jeanjean, Load settlement curve method for spread footings on sand, Proceedings of Settlement '94, Vertical and Horizontal Deformations of Foundations and Embankments, ASCE, Vol. 2, pp. 1774–1804, (1994).

J. Brinch Hansen, A general formula for bearing capacity, Danish Geotechnical Institute, Bulletin No. 11, Copenhagen, (1961).

Kolbuzewski, J. (1948) An experimental study on the maximum and minimum porosities of sands, *Proc. of the 2nd International Conference on Soil Mechanics and Foundation Engineering Rotterdam*, vol. I: 158-165.

Mohamad, Mohamad Ibrahim and Zawawi, Mardhiah and Nekooie, M. A. (2009) *Implementing industrialised building system (IBS) in Malaysia: acceptance and awareness level, problems and strategies*. Malaysian Journal of Civil Engineering, 21 (2). pp. 219-234. ISSN 1823-7843

R.A.P. Bement., A.R.Selby, (1996), *Compaction of granular soils by uniform vibration equivalent to vibrodriving of piles*.

Thanoon, W.A.M., Peng, L.W., Abdul Kadir, M.R., Jaafar, M.S. and Salit, M.S., "The Experiences of Malaysia and Other Countries in Industrialized Building System in Malaysia", *Proceeding on IBS Seminar*. UPM, Malaysia, 2003

Warszawski, A (1999) *Industrialized and Automated Building System*. Technion-Israel Institute of Technology. E & FN Spoon