



UNIVERSITI PUTRA MALAYSIA

***NONLINEAR FINITE ELEMENT ANALYSIS OF
INTEGRAL BRIDGE INCLUDING FOUNDATION SOIL
INTERACTION (WINKLER ANALOGY)***

MOHAMMAD SOFFI BIN MD. NOH

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INTEGRAL BRIDGE INCLUDING FOUNDATION SOIL
INTERACTION (WINKLER ANALOGY)**

By

MOHAMMAD SOFFI BIN MD. NOH

GS 15733

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ABSTRACT

Bridges without expansion joints are called “integral bridges.” Eliminating joints from bridges creates concerns for the piles and the abutments of integral bridges because the abutments and the piles are subjected to temperature-induced lateral loads. This kind of bridges are becoming very popular due to different aspects such as good response under seismic loading, low initial costs, elimination of bearings, and less maintenance. However, the main issue related to the analysis of this type of structures is dealing with the soil-structure interaction of the abutment walls and the supporting piles.

This study describes the implementation of a two dimensional finite element model of integral bridge system which explicitly incorporates the nonlinear soil response. The superstructure members have been represented by means of three-noded isoperimetric beam elements with three degree of freedom per node which take into account the effect of transverse shear deformation.

The soil mass is idealized by eight noded isoperimetric quadrilateral element at near field and five noded isoperimetric infinite element to simulate the far field behavior of the soil media. The nonlinearity of the soil mass has been represented by using the Duncan and Chang approach. In order to study the behavior of integral bridge under varies loading condition including the effect of temperature load, three type of

analysis was carried out, which are Winkler's spring analysis, linear analysis and nonlinear analysis. The results show that, the soil nonlinearity has significant effect on the results, where the displacement which obtained form nonlinear analysis is much higher than that obtained from linear analysis and spring analysis.



APPROVAL SHEET

This project attached here, entitled “ **NONLINEAR FINITE ELEMENT ANALYSIS OF INTEGRAL BRIDGE INCLUDING FOUNDATION SOIL INTERACTION (WINKLER ANALOGY)** ” prepared and submitted by **MOHAMMAD SOFFI BIN MD. NOH (GS 15733)** in partial fulfillment of the requirements for the Degree in Master of Science in Structural Engineering and Construction is hereby approved.

..... Date:

Supervisor

(ASSOC. PROF. DR. JAMALODIN NOORZAEI)

Department of Civil Engineering, UPM

..... Date:

Panel Examiner

(ASSOC. PROF. DR. MOHD SALEH JAAFAR)

Department of Civil Engineering, UPM

..... Date:

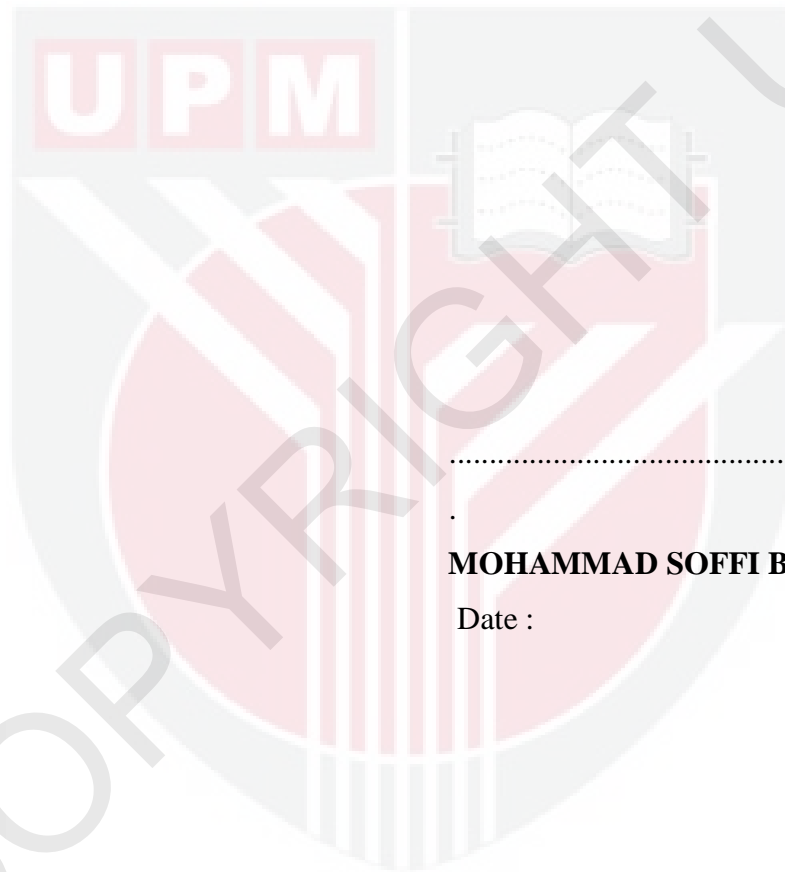
Panel Examiner

(ASSOC. PROF. DR. MOHD. RAZALI B. ABDUL KADIR)

Department of Civil Engineering, UPM

DECLARATION

I hereby declare that the 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 UPM or other institutions.



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MOHAMMAD SOFFI BIN MD NOH

Date :

TABLE OF CONTENTS

ACKNOWLEDGEMENT	i
ABSTRACTS	ii
TABLE OF CONTENTS	iv
LIST OF TABLES	x
LIST OF FIGURES	xii
CHAPTER 1 – INTRODUCTION	
1.1 Introduction of Bridge Structure	1
1.2 Design Selection of Bridge	2
1.3 Nature of Problem	3
1.4 Objectives of Study	5
1.5 Scope of Study	5
1.6 Organization of Report	6
CHAPTER 2 – LITERATURE VIEW	
2.1 What is an Integral Bridges?	8
2.2 Characteristic of Integral Bridges	11
2.3 Integral Bridge Elements	12
2.3.1 Integral Abutment	13
2.3.1.1 Type of Integral Abutments	13
2.3.2 Deck Slabs / Continuous Slabs	16
2.3.3 Approach Slabs	16

2.4	General Aspects of Integral Bridges	17
2.5	Advantages of Integral Bridges	18
2.5.1	Simplified Construction	18
2.5.2	No Bearings and Joints	19
2.5.3	Reduced Life Cycle Cost and Long Term Maintenance	19
2.5.4	Improved Design Efficiency	20
2.5.5	Enhanced Load Distribution	20
2.5.6	Simplified Widening and Replacement Detail	20
2.6	Problems and Uncertainties Associated with Integral Bridges	21
2.7	Thermal Bridge Displacements	22
2.7.1	Factors Affecting Bridge Temperatures	23
2.7.2	Bridge Displacement with Temperature	24
2.7.3	Earth Pressures on the Abutment	25
2.8	Behavior of Integral Bridges	27
2.8.1	Behavior of Superstructure	28
2.8.2	Behavior of Piles	28
2.8.3	Behavior of Pile Supporting the Abutment	28
2.8.4	Behavior of Approach System	31
2.9	Overview of the Research on Integral Bridge	32
2.10	Concluding Remarks	37

CHAPTER 3 - METHODOLOGY

3.1	Introduction	38
3.2	Research Methodology	39
3.3	Finite Element Method	40

3.3.1	Energy Method	40
3.4	Finite Element Formulation	42
3.4.1	Three-Noded Isoparametric Beam Bending Element	42
3.4.1.1	Shape Functions	42
3.4.1.2	Strain-displacement Relationship	44
3.4.1.3	Stress-strain Relationship	44
3.4.1.4	Stiffness Matrix	45
3.4.2	2-D Eight-Noded Isoparametric Element	45
3.4.2.1	Shape Functions	46
3.4.2.2	Strain-displacement Relationship	47
3.4.2.3	Stress-strain Relationship	47
3.4.2.4	Stiffness Matrix	48
3.4.3	Five-Noded Mapped Infinite Element	49
3.5	Loads on Integral Bridge System	50
3.5.1	Permanent Loads	51
3.5.1.1	Dead Load	51
3.5.1.2	Superimposed Dead Loads	52
3.5.2	Transient Loads	53
3.5.2.1	Temperature Loads	53
3.5.2.2	Primary Highway Bridge Live Loads	55
3.5.2.2.1	HA Loading	56
3.5.2.2.2	HB Loading	57
3.5.3	Load Combinations	58
3.5.3.1	Load Combination 1	58
3.5.3.2	Load Combination 2	59

3.5.3.3	Load Combination 3	59
3.5.3.4	Load Combination 4	59
3.5.3.5	Load Combination 5	60
3.6	Winkler Analogy	60
3.7	Nonlinear Elastic Model	61
3.8	Computer Implementation	64
3.8.1	Learning Process	65
3.8.2	Calibration Process	68
3.9	Concluding Remark	70
 CHAPTER 4 – ANALYSIS AND RESULTS		
4.1	Introduction	72
4.2	Selection of Case Study and Bridge Dimension	73
4.3	Loading Calculation	74
4.3.1	Dead Load and Superimposed Dead Load	75
4.3.2	Live Load	76
4.3.2.1	HA Loading	76
4.3.2.2	HB Loading	78
4.3.2.3	Temperature Loading	79
4.3.3	Load Combinations	80
4.4	Physical Modeling of an Integral Bridge	83
4.5	Soil Data	84
4.6	Winkler Modulus of Subgrade Reaction (Spring Constants, K_s)	85
4.7	Nonlinear Soil Parameter	87
4.8	Results and Discussion	92

4.8.1	Results of Spring Analysis	93
4.8.1.1	Comparison Results for Girder Vertical Displacement	94
4.8.1.2	Comparison of Result for Abutment Displacement.	97
4.8.1.3	Comparison of Result for Pile Displacement.	99
4.8.2	Results of Linear Analysis	102
4.8.2.1	Comparison Results for Girder Vertical Displacement	103
4.8.2.2	Comparison of Result for Abutment Displacement.	106
4.8.2.3	Comparison of Result for Pile Displacement.	108
4.8.3	Results of Nonlinear Analysis	112
4.8.3.1	Comparison Results for Girder Vertical Displacement	112
4.8.3.2	Comparison of Result for Abutment Displacement.	115
4.8.3.3	Comparison of Result for Pile Displacement.	118
4.8.4	Comparative Study between Winkler's Spring Analysis, Linear and Nonlinear Analysis.	121
4.8.4.1	Comparison Results for Girder Vertical Displacement	122
4.8.4.2	Comparison of Result for Abutment Displacement.	123
4.8.4.3	Comparison of Result for Pile Displacement.	126
4.9	Concluding Remarks	128

CHAPTER 5 - CONCLUSIONS AND RECOMMENDATIONS

5.1 Conclusion 129

5.2 Recommendations 131

References 133

Appendix A 137

Appendix B 138

Appendix C 139



LIST OF TABLES

CHAPTER 2 – LITERATURE VIEW

Table 2.1:	Range of design criteria for selection of integral bridge	18
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CHAPTER 3 - METHODOLOGY

Table 3.1:	Application of Dead Load	52
------------	--------------------------	----

CHAPTER 4 – ANALYSIS AND RESULTS

Table 4.1:	Properties of soils	84
Table 4.2:	Typical values of coefficient of subgrade reaction, K_s (Terzaghi 1955)	85
Table 4.3:	Value of subgrade reaction are used in the study	86
Table 4.4:	Laboratory results at shearing stage	88
Table 4.5:	Nonlinear soil parameters	89
Table 4.6:	Material properties used in this study	91
Table 4.7:	Load cases and analysis considered for this study	93
Table 4.8:	Maximum vertical displacement of girder	96
Table 4.9:	Lateral displacement at top of abutment	99
Table 4.10:	Maximum lateral displacement of piles	102
Table 4.11:	Maximum vertical displacement of girder	103
Table 4.12:	Lateral displacement at top of abutment	108
Table 4.13:	Maximum lateral displacement of piles	111
Table 4.14:	Maximum vertical displacement of girder	114
Table 4.15:	Lateral displacement at top of abutment	118
Table 4.16:	Maximum lateral displacement of piles	121

Table 4.17:	Maximum vertical displacement of girder	122
Table 4.18:	Lateral displacement of abutment	125
Table 4.19:	Lateral displacement of pile	126



LIST OF FIGURES

CHAPTER 2 – LITERATURE VIEW

Figure 2.1:	Integral and Semi-Integral Abutments	9
Figure 2.2:	Integral Bridge Abutment System	10
Figure 2.3:	Integral Bridge Elements	12
Figure 2.4:	Full integral abutment on pile – Steel girder	13
Figure 2.5:	Full integral abutment on pile – Precast girder	14
Figure 2.6:	Full integral abutment on spread footing	14
Figure 2.7:	Pinned-integral abutment	15
Figure 2.8:	Semi-integral abutment with sliding bearings	15
Figure 2.9:	Approach Slab in Integral Bridges	17
Figure 2.10:	Illustration of abutment rotations due to pile constraints and the backfill soil pressure	30
Figure 2.11:	Interaction mechanism between abutment and approach fill	32

CHAPTER 3 - METHODOLOGY

Figure 3.1	Research Methodology Flow Chart	39
Figure 3.2:	One-dimensional beam bending element in natural coordinate system	42
Figure 3.3:	2-D Eight-noded isoparametric element using natural coordinate system	46
Figure 3.4:	2-D Five noded infinite element	50
Figure 3.5:	Dimensions of HB Vehicle	57
Figure 3.6:	Hyperbolic stress-strain curve for soil	64

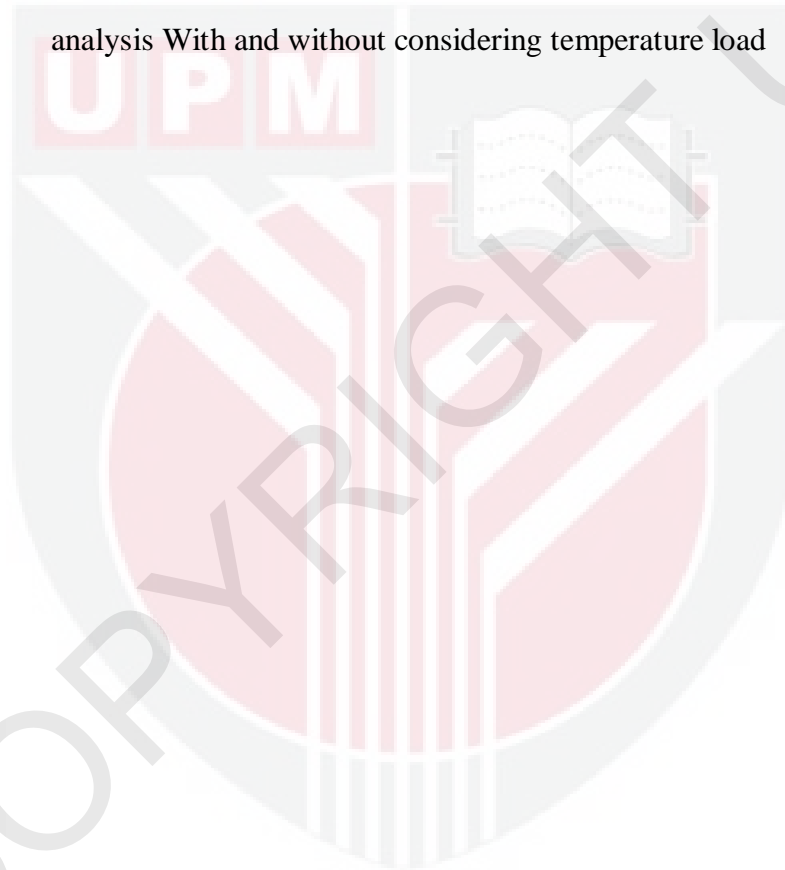
Figure 3.7:	Geometry of example	65
Figure 3.8:	Input data of example	66
Figure 3.9	Geometry of Example 1	68
Figure 3.10	Input Data File	68
Figure 3.11	Output Data File	69

CHAPTER 4 – ANALYSIS AND RESULTS

Figure 4.1:	Longitudinal Geometry of Sg. Rawang Bridge	73
Figure 4.2:	Transverse Geometry of Sg. Rawang Bridge	73
Figure 4.3:	Bridge Dimension of Transverse Section	74
Figure 4.4:	Beam Cross Section	76
Figure 4.5:	Application of HB Loading	78
Figure 4.6:	Maximum Differential Temperature Change in Rawang area	80
Figure 4.7:	Loading Arrangement	83
Figure 4.8:	Winkler Spring Model	86
Figure 4.9:	The stress-strain relationship for sandy SILT	87
Figure 4.10:	Transformed stress-strain curves for corresponding strain	89
Figure 4.11:	Logarithmic Plotting of Minor Stress against Elastic Modulus	91
Figure 4.12:	Finite – infinite element discretization of proposed integral bridge	92
Figure 4.13:	Vertical displacement of girder at 0.0L load position	94
Figure 4.14:	Vertical displacement of girder at 0.25L load position	94
Figure 4.15:	Vertical displacement of girder at 0.50L load position	95

Figure 4.16:	Vertical displacement of girder for varies load position	96
Figure 4.17:	Lateral displacement of abutment s at 0.0L load position	97
Figure 4.18:	Lateral displacement of abutment at 0.25L load position	98
Figure 4.19:	Lateral displacement of abutment at 0.50L load position	98
Figure 4.20:	Lateral displacement of pile at 0.0L load position	100
Figure 4.21:	Lateral displacement of pile at 0.25L load position	100
Figure 4.22:	Lateral displacement of pile at 0.50L load position	101
Figure 4.23:	Vertical displacement of girder at 0.0L load position	104
Figure 4.24:	Vertical displacement of girder at 0.25L load position	104
Figure 4.25:	Vertical displacement of girder at 0.50L load position	105
Figure 4.26:	Lateral displacement of abutment at 0.0L load position	106
Figure 4.27:	Lateral displacement abutment at 0.25L load position	107
Figure 4.28:	Lateral displacement of abutment at 0.50L load position	107
Figure 4.29:	Lateral displacement of pile at 0.0L load position	109
Figure 4.30:	Lateral displacement of pile at 0.25L load position	110
Figure 4.31:	Lateral displacement of pile at 0.50L load position	110
Figure 4.32:	Vertical displacement of girder at 0.0L load position	113
Figure 4.33:	Vertical displacement of girder at 0.25L load position	113
Figure 4.34:	Vertical displacement of girder at 0.50L load position	114
Figure 4.35:	Lateral displacement of abutment at 0.0L load position	116
Figure 4.36:	Lateral displacement of abutment at 0.25L load position	116
Figure 4.37:	Lateral displacement of abutment at 0.50L load position	117
Figure 4.38:	Lateral displacement pile at 0.0L load position	119
Figure 4.39:	Lateral displacement of pile at 0.25L load position	119
Figure 4.40:	Lateral displacement of pile at 0.50L load position	120

Figure 4.41:	Vertical displacement of girder for different method of analysis	122
Figure 4.42:	Lateral displacement of abutment for different method of analysis without considering temperature load	124
Figure 4.43:	Lateral displacement of abutment for different method of analysis with considering temperature load	124
Figure 4.44:	Lateral displacement of piles for different method of analysis With and without considering temperature load	127



CHAPTER 1

1.0 INTRODUCTION

1.1 Introduction of Bridge Structure

Bridge structure built to provide ready passage over natural or artificial obstacles, or under another passageway. Bridges serve highways, railways, canals, aqueducts, utility pipelines, and pedestrian walkways. In many jurisdictions, bridges are defined as those structures spanning an arbitrary minimum distance, generally about 10–20 ft (3–6 m); shorter structures are classified as culverts or tunnels. In addition, natural formations eroded into bridge like form are often called bridges. This article covers only bridges providing conventional transportation passageways.

Bridges generally are considered to be composed of three separate parts: substructure, superstructure, and deck. The substructure or foundation of a bridge consists of the piers and abutments which carry the superimposed load of the superstructure to the underlying soil or rock. The superstructure is that portion of a bridge or trestle lying above the piers and abutments. The deck or flooring is supported on the bridge superstructure; it carries and is in direct contact with the traffic for which passage is provided.

Bridges are classified in several ways. Thus, according to the use they serve, they may be termed railway, highway, canal, aqueduct, utility pipeline, or pedestrian bridges. If they are classified by the materials of which they are constructed (principally the superstructure), they are called steel, concrete, timber, stone, or aluminum bridges. Deck bridges carry the deck on the very top of the superstructure. Through bridges carry the deck within the superstructure. The type of structural action is denoted by the application of terms such as truss, arch, suspension, stringer or girder, stayed-girder, composite construction, hybrid girder, continuous, cantilever, or orthotropic (steel deck plate).

Bridge designs differ in the way they support loads. These loads include the weight of the bridges themselves, the weight of the material used to build the bridges, and the weight and stresses of the vehicles crossing them. There are basically eight common bridge designs: beam, cantilever, arch, truss, suspension, cable-stayed, movable, and floating bridges. Combination bridges may incorporate two or more of the above designs into a bridge. Each design differs in appearance, construction methods and materials used, and overall expense. Some designs are better for long spans. Beam bridges typically span the shortest distances, while suspension and cable-stayed bridges span the greatest distances.

1.2 Design Selection of Bridge

Engineers must consider several factors when designing a bridge. They consider the distance to be crossed and the feature, such as a river, valley, or other transportation

routes, to be crossed. Engineers must anticipate the type of traffic and the amount of load the bridge will have to carry and the minimum span and height required for traffic traveling across and under the bridge. Temperature, environmental conditions, and the physical nature of the building site (such as the geometry of the approaches, the strength of the ground, and the depth to firm bedrock) also determine the best bridge design for a particular situation.

Once engineers have the data they need in order to design a bridge, they create a work plan for constructing it. Factors to be considered include availability of materials, equipment, and trained labor; availability of workshop facilities; and local transportation to the site. These factors, in combination with the funding and time available for bridge design and construction, are the major requirements and constraints on design decisions for a particular site.

1.3 Nature of Problem

A bridge should be designed such that it is safe, aesthetically pleasing, and economical. Prior to the 1960s, almost every bridge in the world was built with expansion joints and bearings. These traditional expansion joint/bearing systems has been found to perform more or less as intended conceptually but at the cost of being a high maintenance item, especially for relatively short-span bridges. The primary problem is the corrosion and other physical deterioration of the bridge bearings that occurs with time. They required considerable maintenance, which undermined the economical operation of the bridges. Therefore, integral bridges have been found to

outperform jointed bridges, decreasing maintenance costs, and enhancing the life expectancy of the superstructures. Integral abutment and joint-less bridges cost less to construct and require less maintenance than equivalent bridges with expansion joints and bearings.

Because of the increased use of integral bridge, there is now greater awareness of and interest in their post-construction, in-service problems. Fundamentally, these problems are due to a complex soil structure interaction mechanism involving relative movement between the bridge (more specifically, its abutments) and adjacent retained soil. Because this movement is the result of natural, seasonal thermal variations, it is inherent in all integral bridges.

The main issue related to the analysis of integral abutment bridge is dealing with the soil-structure interaction of the abutment walls and the supporting piles. The behavior of the structural components including the piles can either be linear or nonlinear depending on the amount of the applied forces. The behavior of the soil on the other hand is nonlinear. Therefore, the analysis of integral bridge should take into account the nonlinearity of soil behind the abutment and the piles foundation.

1.4 Objectives of Study

The primary objectives of this study are:

1. Investigate the behavior of structural elements of the integral bridge under various load cases through finite element analysis.
2. Study the significance of thermal expansion load induced displacement.
3. Investigate the significance differences and similarities between the Winkler's spring analysis, linear analysis and nonlinear analysis of integral bridges.

1.5 Scope of Study

In order to study the behavior of integral bridge under different of load cases, this study have been carried out within the following scope.

1. Finding a literature review to establish the current state of knowledge with regard to the behavior of integral abutment bridges.
2. Implement finite element analysis for three different type of analysis which is Winkler spring, linear elastic and nonlinear elastic analysis.

3. Discretized the finite element models through the following elements;
 - a) Three noded beam bending element
 - b) Eight noded isoparametric elements
 - c) Five noded infinite elements
4. Loading analysis of integral bridge is based on code of practice, BD 37/88.
5. Collect the actual temperature data based on the Malaysian temperature different obtained from Department of Meteorology Malaysia.
6. Preparation of the actual data required for the nonlinear elastic analysis based on Malaysian soil condition.
7. Analyze the structure and soil media using existing two dimensional finite element program available at Structural Engineering Unit, Civil Engineering Department, Universiti Putra Malaysia.

1.6 Organization of Report

In order to achieve the objectives of this study, this report is implemented and organized as follows.

Chapter 2: Present an overview of integral bridge in order to enhance the current state of knowledge with regard to behavior of integral bridge system, characteristic

and type of integral abutment of the bridge. Advantages and problem associated with integral bridge also discussed in this chapter.

Chapter 3: Present the formulation of finite element and infinite element of structure and surrounding soil media, it also present the load of integral bridge which has been taken in consideration in the analysis. The non-linear elastic model (Duncan 1970) and Winkler's model was discussed in details in this chapter. Explanation of the computer implementation (2-D finite element program) also discussed in this chapter.

Chapter 4: Presents the selection of case study and bridge dimension and load calculation for gravity, highway bridge live load and thermal expansion loads. Defined the finite element meshing and also the derivation of the soil parameters according to actual laboratory tests for Malaysian soil, and calculation of the Winkler spring constant. It also presents the results and discussion obtained from the analysis of integral bridge by using different techniques. Finally, presents the comparative study on different proposed models.

Chapter 5: Contains the conclusions and recommendations drawn from the research. Recommendations for future studies and research are given at the end of this chapter.

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