



**Faculty of Engineering**

**BEHAVIOR OF COMPOSITE LAYERED SLAB OF EPS CONCRETE  
AND NORMAL CONCRETE**

**CHIA HUI CHING**

**Bachelor of Engineering with Honours  
(Civil Engineering)  
2009**



# UNIVERSITI MALAYSIA SARAWAK

## BORANG PENGESAHAN STATUS TESIS

Judul: Behavior of Composite Layered slab of EPS Concrete and Normal Concrete

SESI PENGAJIAN: 2005 – 2009

Saya CHIA HUI CHING  
(HURUF BESAR)

mengaku membenarkan tesis \* ini disimpan di Pusat Khidmat Maklumat Akademik, Universiti Malaysia Sarawak dengan syarat-syarat kegunaan seperti berikut:

1. Tesis adalah hakmilik Universiti Malaysia Sarawak.
2. Pusat Khidmat Maklumat Akademik, Universiti Malaysia Sarawak dibenarkan membuat salinan untuk tujuan pengajian sahaja.
3. Membuat pendigitan untuk membangunkan Pangkalan Data Kandungan Tempatan.
4. Pusat Khidmat Maklumat Akademik, Universiti Malaysia Sarawak dibenarkan membuat salinan tesis ini sebagai bahan pertukaran antara institusi pengajian tinggi.
5. \*\* Sila tandakan ( ✓ ) di kotak yang berkenaan

SULIT (Mengandungi maklumat yang berdarjah keselamatan atau kepentingan Malaysia seperti yang termaktub di dalam AKTA RAHSIA RASMI 1972).

TERHAD (Mengandungi maklumat TERHAD yang telah ditentukan oleh organisasi/ badan di mana penyelidikan dijalankan).

TIDAK TERHAD

Disahkan oleh

\_\_\_\_\_  
(TANDATANGAN PENULIS)

\_\_\_\_\_  
(TANDATANGAN PENYELIA)

Alamat tetap: 34B, KELAPA ROAD  
96000 SIBU  
SARAWAK

PROF. MADYA DR A.L.M. MAUROOF  
(Nama Penyelia)

Tarikh: 15 May 2009

Tarikh: \_\_\_\_\_

### CATATAN

- \* Tesis dimaksudkan sebagai tesis bagi Ijazah Doktor Falsafah, Sarjana dan Sarjana Muda.
- \*\* Jika tesis ini SULIT atau TERHAD, sila lampirkan surat daripada pihak berkuasa/organisasi berkenaan dengan menyatakan sekali sebab dan tempoh tesis ini perlu dikelaskan sebagai SULIT dan TERHAD.

Final Year Project Report below:

Title: Behavior of Composite Layered slab of EPS Concrete and Normal Concrete

Author: Chia Hui Ching

Metric No.: 13865

Has been read and certified by:

---

PROF. MADYA DR A.L.M. MAUROOF

Supervisor

---

Date

**BEHAVIOR OF COMPOSITE LAYERED SLAB OF EPS  
CONCRETE AND NORMAL CONCRETE**

**CHIA HUI CHING**

This project is submitted in partial fulfillment of  
the requirements for the Degree of Bachelor of Engineering with  
Honours (Civil Engineering)

*To my beloved family*

## ACKNOWLEDGEMENT

I am grateful for the contributions of the many people who helped in my final year project. Special thanks to Dr. A. L. M. Mauroof for his careful review and supervision on my entire work. With his invaluable knowledge and constructive comments, my final year project is going smoothly and investigates with full knowledge.

I am particularly indebted to my beloved parents for their love and caring giving to me during this demanding endeavor. They always give me the full support and encouragement. I would like to express my thankful to them and I am glad to be their daughter.

Thank also to my special assistant, Gz for his generous and unconditional help in my lab work. Without his helping, I am impossible to produce the specimen and do the testing smoothly. The continuous advice and support he given have encouraged me to keep going.

Lastly, I want to express my gratitude to my group of civil friends for sharing all the knowledge and experience with me. Their generous and kindness of sharing are the great bonus to me. Thanks for having them to walk with me along the journey of civilian and wishes them all the best in the future.

## **ABSTRAK**

Penggunaan konkrit berkomposisi polistirin telah menjadi semakin berleluasa dalam industri pembinaan pada zaman ini. Polistirin telah digunakan untuk mengganti bahagian bawah spesimen konkrit tetulang biasa pada kajian yang lepas. Konkrit komposisi polistirin ini biasanya digunakan sebagai konkrit berjisim ringan bertujuan untuk membina struktur struktur gergasi. Objektif utama kajian ini dilakukan ialah untuk mengkaji perbezaan daya kekuatan dan koduksi haba antara konkrit berkomposisi biasa dan polistirin dengan konkrit biasa. Konkrit berkomposisi polistirin disediakan dengan menggantikan 50% batu dan 50 % pasir dengan polistirin. Daya tekanan dikenakan ke atas spesimen-specimen ini dan pemerhatian telah dibuat. Kajian menunjukkan kekuatan konkrit berkomposisi biasa dan polistirin adalah lebih rendah jika dibandingkan dengan kekuatan konkrit biasa. Manakala kajian juga telah menunjukkan koduksi haba konkrit berkomposisi polistirin adalah lebih lambat jika dibandingkan dengan konkrit biasa. Beberapa kesimpulan dan cadangan untuk meningkatkan kualiti dan penggunaan konkrit komposisi polistirin ini telah dicatatkan dalam laporan ini.



## **ABSTRACT**

The use of expanded polystyrene (EPS) beads in fully or partially replacing the normal aggregate is prevalent in the construction industry nowadays. The present study covers the use of EPS concrete layer to replace the bottom concrete cover of normal reinforced concrete slab. The aim of this project is to study the flexural strength and thermal conductivity of the composite layered slab of EPS concrete and normal concrete. The EPS concrete is prepared by 50% replacing the coarse aggregate and 50% replacing the fine aggregate by volume with EPS beads. Two loading patterns are applied on the specimen: shear dominant loadings and bending dominant loadings. The flexural strengths of the composite layered slab for specimen subjected to shear dominant (SDEC) and specimen subjected to bending dominant (BDEC) is reduced 5.60% and 25.66% respectively as compared to the normal reinforced concrete slab. The results show that the replacement of EPS concrete with the normal concrete cover performs well under the shear dominant but reduce when subject to bending dominant. The thermal conductivity for composite layered specimen shows the temperature increment less than the normal concrete specimen. The EPS concrete layer acts as the bottom cover has decrease 5.00% from point at 75mm to 25mm from top. The closed air-filled cell structure of EPS beads inhibits the passage of heat and provides better thermal insulation. The composite layered slab of EPS concrete and normal concrete is recommended to utilize as roof slab.

# TABLE OF CONTENT

	<b>Page No.</b>
Dedication	ii
Acknowledgement	iii
Abstrak	iv
Abstract	v
Table of content	vi
List of tables	x
List of figures	xii
List of Abbreviations and Notations	xiv
List of Appendices	
<b>CHAPTER 1 INTRODUCTION</b>	
1.0 General	1
1.1 Background	1
1.2 Problem statement	2
1.3 Scope of study	4
1.4 Aim & Objective	5
1.5 Outline of project	5
<b>CHAPTER 2 LITERATURE REVIEW</b>	
2.1 General	7
2.2 Compressive strength of EPS concrete	7
2.3 Tensile strength of EPS concrete	9
2.4 Thermal conductivity of EPS concrete	12
2.5 Durability of EPS concrete	13
2.5.1 Water absorption	14
2.5.2 Chloride permeability	15
2.5.3 Potential & corrosion rate	16
2.5.4 Drying shrinkage	17

2.5.5	Moisture migration	18
2.6	Energy absorbing characteristics of EPS concrete	19
2.7	Segregation of EPS beads with matrix	21
2.8	Modulus of elasticity	22
2.9	Summary	
2.9.1	Advantage of EPS concrete	23
2.9.2	Disadvantage of EPS concrete	24
2.9.3	Recommendations for EPS concrete	25
<b>CHAPTER 3 METHODOLOGY</b>		
3.1	General	26
3.2	Background	27
3.3	Experimental investigation	
3.3.1	Materials	
3.3.1.1	Portland cement	28
3.3.1.2	Aggregate	29
3.3.1.3	Expanded polystyrene (EPS)	30
3.3.2	Formation of composite layered slab	31
3.3.3	Design mix proportion	33
3.3.4	Principle of mix design for composite layered slab	34
3.3.5	Work procedure	35
3.3.5.1	Procedure of making EPS concrete	35
3.3.5.2	Procedure of making normal concrete	36
3.4	Test program 1: Flexural strength test	37
3.4.1	Procedure	38
3.4.2	Loading pattern	39
3.4.2.1	Shear dominant loadings	39
3.4.2.2	Bending dominant loadings	40
3.4.3	Specimen tested	40

3.4.4	Flexural strength	42
3.5	Test program 2: Thermal conductivity test	42
3.5.1	Thermal conductivity specimen	43
3.5.2	Arrangement of thermal conductivity test	44
<b>CHAPTER 4 RESULT AND DISCUSSION</b>		
4.1	Flexural test	45
4.1.1	Flexural test result	45
4.1.2	Flexural strength	49
4.1.2.1	Flexural strength for specimen subjected to shear dominant loadings	49
4.1.2.2	Flexural strength for specimen subjected to bending dominant loadings	50
4.1.3	Discussion	51
4.2	Shear capacity	52
4.3	Crushing moment and ultimate moment resistance	53
4.4	Cracking behaviour	56
4.4.1	Cracking behaviour result	56
4.4.2	Crack pattern	57
4.4.3	Discussion	61
4.5	Thermal conductivity	62
4.5.1	Thermal conductivity result	62
4.5.2	Discussion	64
<b>CHAPTER 5 CONCLUSION AND RECOMMENDATION</b>		
5.1	Conclusion	69
5.1.1	Cracking load and ultimate load	69
5.1.2	Flexural strength	70
5.1.3	Crack behaviour and pattern	70

5.1.4	Thermal conductivity	71
5.2	Recommendations	72
<b>REFERENCES</b>		73
<b>APPENDIX</b>		

# LIST OF TABLES

<b>Table</b>		<b>Page</b>
2-1	Mix details of concrete investigated	8
2-2	Mix details of concrete investigated	11
2-3	Mechanical properties of PAC and normal concrete	12
2-4	Thermal conductivity, K values	13
2-5	Mix details of concrete investigated	15
2-6	Corrosion characteristics of EPS concretes (After 90 days immersion curing)	17
2-7	Mechanical properties of PAC and control concrete	22
3-1	Characteristics of Cement	29
3-2	Thermal Conductivity Values	31
3-3	Normal concrete mix proportion	33
3-4	EPS concrete mix proportion	33
3-5	Percentage of EPS replace the normal aggregate	34
3-6	Specimen of shear dominant loadings testing	41
3-7	Specimen of bending dominant loadings testing	41
3-8	Specimen prepared for thermal conductivity test	43
4-1	Result of shear dominant loadings testing	46
4-2	Result of bending dominant loadings testing	46

4-3	Flexural strength of specimen subjected to shear dominant loadings	50
4-4	Flexural strength of specimen subjected to bending dominant loadings	51
4-5	Design shear stress, $V$ ( $N/mm^2$ )	53
4-6	Maximum bending moment, $M$ (KNm)	55
4-7	Cracking behaviour of specimen subjected to shear dominants loadings	56
4-8	Cracking behaviour of specimen subjected to bending dominants loadings	56
4-9	Crack pattern	58
4-10	Thermal conductivity result (Measured 25mm from top)	62
4-11	Thermal conductivity result (Measured 75mm from top)	64
4-12	Final temperature for three difference samples	66

# LIST OF FIGURES

Figure		Page
2-1	Variations of compressive strength with age for different densities	9
2-2	Relationship between splitting tensile strength and compressive	10
2-3	Variation of split tensile strength with EPS volume	11
2-4	Variations of absorptions with time	14
2-5	Chloride permeability of EPS concretes	16
2-6	Relationship between drying shrinkage strain of EPS concrete and reference concrete with age	18
2-7	Variations of moisture migrations with time	19
2-8	Failure modes of EPS concretes containing different volumes of EPS	21
3-1	Composite layered slab	32
3-2	Flexural & transverse frame test equipment	37
3-3	Shear dominant loadings	39
3-4	Bending dominant loadings	40
3-5	Thermal Conductivity test	44
4-1	Ultimate loading strength of shear dominant loadings testing	47



4-2	Ultimate loading strength of bending dominant loadings testing	47
4-3	Summary of Ultimate loading strength of shear dominant loadings	48
4-4	Summary of Ultimate loading strength of bending dominant loadings	48
4-5	Stress and strain distributions and simplified stress block for singly reinforced beam (BS8110)	54
4-6	Thermal conductivity (Measured at 25mm from top)	63
4-7	Thermal conductivity (Measured at 75mm from top)	65
4-8	Final temperature for three different samples	67

# LIST OF ABBREVIATIONS AND NOTATIONS

mm	-	Millimeter
KN	-	Kilo Newton
m	-	Meter
kg	-	Kilogram
°C	-	Celcius
%	-	Percent
EPS	-	Expanded Polystyrene
SDNC	-	Shear dominant normal concrete
SDRC	-	Shear dominant reinforced concrete
SDEC	-	Shear dominant Expanded Polystyrene concrete
BDNC	-	Bending dominant normal concrete
BDRC	-	Bending dominant reinforced concrete
BDEC	-	Bending dominant Expanded Polystyrene concrete

# LIST OF APPENDIX

## Appendix

- A Calculation sheet for EPS mix proportion
- B Flexural strength test
- C Thermal conductivity test

# CHAPTER 1

## INTRODUCTION

### 1.0 General

Reinforced concrete is used in building construction due to its high compressive strength, form flexibility, durable and characteristics beneficial to environmentally sound practices. Reinforced concrete slabs are plate elements forming floors and roofs in building which normally carry uniformly distributed loads and concentrated loads acting normal to the plane of the slab.

### 1.1 Background

The ACI Code emphasizes design based on strength with serviceability checks and one of the important design considerations is the performance of structures at the service loads (Park & Gamble, 2000). Even the degree of safety against collapse is adequate but the performance of the structures at the service load may be failed. The slab system may exhibit excessive cracking or the deflections may be unacceptably large when subjected to service loads. Therefore, the slab should be designed with taking account of several limit states, the most important being strength at overloads, deflections at service loads, and crack widths at service loads.

Vibration and fatigue at reinforcing steels at service loads are the other possible limit states that should be considered. To check for deflections the minimum allowable slab thickness is specified to ensure adequate stiffness and ensure the deflections not exceeding specified maximum allowable values. The arrangements of reinforcement are limited to ensure that the crack widths are not excessive.

The concrete tensile stresses will be an appreciable fraction of the modulus of rupture, and cracking may occur at some time after first loading as a result of sustained tensile stresses. The occurrence of cracks in some regions of reinforced concrete slab systems is inevitable because of the low tensile strength of concrete so the tensile resistance of concrete is normally neglected in design. The tension zone is reinforced with reinforcement to provide the tensile forces needed for moment equilibrium after the first crack developed.

## **1.2 Problem statement**

For reinforced concrete ground slab the moisture migration always cause problem for the adhesion of floor covering materials. The sources of moisture are the concrete slab residue moisture, groundwater source and water vapor of damp soil. Concrete ground slab placed on different type of soil will have different level of moisture inflow. Placing on clay soil has highest moisture inflow and placed on gravel capillary break will reduce the initial moisture inflow by about one third of the clay soil's moisture inflow (Brewer, 1965).

To prevent the moisture inflow the contractors normally place vapor barrier over a gravel layer or compacted layer. However, the concrete slab placed directly over a vapor barrier will result in the greater water flow at the early age since mix water in concrete is restrained to be lost to the subgrade below. Besides, the fast track construction schedules exacerbate the problem as the contractor will install the floor-surfacing material before the concrete slab has dried to an acceptable level.

In addition, the roof slab is the most highly stressed part of a building. Heat and cold, dryness and wetness, storm act from the outside, internal relative humidity acts from inside which are the considerations to take into account for making the roof fulfill its protective functions. The water absorption, thermal conductivity and strength are the main considerations for roof slab design. However, normal concrete achieves higher values in water absorption and thermal conductivity which makes the roof slab theoretically not ideal in terms of protection of a building. To compensate the weakness of normal concrete, EPS concrete is utilized to upgrade the performance of reinforced concrete slabs.

EPS concrete is one of the lightweight concrete with density not exceeding  $1900\text{kg/m}^3$  but low in compressive strength (not more than 30MPa) as compared to the normal weight concrete. EPS concrete has low water absorption, thermal insulation, low moisture migration and good energy absorbing characteristics.

According to Fowler, polymer-impregnated concrete is the first concrete polymer composite to receive wide-spread attention with some commercial interest. Resistance to acid chemical attacks is one of the several distinguishing properties of this material.

The researches on EPS concrete can be traced back to 1973, when Cook investigated EPS as an aggregate for concrete. EPS beads have microcellular closed cell and making its excellent insulation properties which is an essential properties for roof slab while the low moisture migration improve the performance of ground slab.

In view of its low compressive strength the EPS concrete is unable to perform solely for reinforced concrete slab. Therefore, the composite layered slab of EPS concrete and normal concrete is proposed to improve the serviceability and behavior of the reinforced concrete slab.

### **1.3 Scope of study**

The bottom cover of reinforced concrete slab is proposed to be replaced by the EPS concrete. The EPS concrete has the greater thermal insulation and lower water impermeability as compared with normal concrete. It is believed that the characteristics of EPS concrete are able to improve the serviceability of the reinforced concrete slab. The replacement of bottom cover with EPS concrete will not affect the performance of normal reinforced concrete slab in ultimate limit state because the purpose of the cover is mainly for protecting the reinforcement against corrosion and against the fire.

Moreover, the bottom reinforced concrete slab is only sustaining the tensile stress created by the top of loading and EPS concrete is able to provide the adequate tensile strength. Nevertheless, the tensile strength of concrete will not contribute much since the tensile zone is reinforced with steel bars.

The scope of study covers the behavior of the composite layered slab of EPS concrete and normal concrete in term of the thermal conductivity and flexural strength performance. For EPS concrete it did not exhibit typical failure mode as normal weight concrete. It is observed to be more gradual (compressible) and capable of sustain the loads after failure without full disintegration (Babu et al, 2005).

#### **1.4 Aim & objectives**

The main objectives of the present work are

- I. To study the thermal conductivity characteristics of layered slab comprising of EPS concrete and normal concrete
- II. To check the strength

#### **1.5 Outline of project**

Chapter 1 introduces the basic knowledge on what are the conventional reinforced concrete slab and its weakness in durability and behavior. Then, it will introduce the new reinforced concrete slab whereby produce by composite the EPS concrete and normal concrete. The scope of study will be further discussed as well as the aim and objectives.

Chapter 2 provides the data and results done by researchers on the EPS concrete and the flexural strength of reinforced concrete slab. Meanwhile, the EPS concrete will compare with the normal concrete in many aspects. The weakness of