STABILITY AND RELIABILITY OF AMPHIBIOUS HOUSE FOR FLOODPLAIN AREAS IN MALAYSIA

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RELIABILITY AND STABILITY OF AMPHIBIOUS HOUSE FOR FLOODPLAIN AREAS IN MALAYSIA

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To my beloved wife, father and mother and my son

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ABSTRACT

Flooding is one of the most common natural disasters in Malaysia and this phenomenon has been worsening due to current global warming condition. The disaster cost the government a huge amount of money and effort to handle it in terms of its catastrophe and mitigation strategy. It also has an adverse effect on land value in the floodplain area. Therefore, it is crucial to resort for more effective flood mitigation approach in Malaysia. This need has motivated this research to develop a new sustainable and flexible flood mitigation measure known as amphibious house system within a floating urbanisation environment. This concept enabled the dwellers to live with flood rather than to confront it. The amphibious house system consists of the pit system concept with horizontal support, a specially formulated lightweight concrete material and special designed precast pontoon system, which provide floatation to the single storey house during flooding. This research is conducted in five main phases using qualitative and quantitative data collection approach to develop reliable and stable amphibious house. The initial approach consists of the interview with expert panels and using questionnaire survey to establish potential of using the amphibious house as a sustainable flood mitigation strategy. This followed with fuzzy materials selection for developing sustainable lightweight concrete pontoons composition and design. The amphibious house system has been vigorously analysed to meet the standard floatation and stability requirements in the hydraulic laboratory which includes hydraulic testing for drag forces, tilting angle and point load test on a floodplain model. Finally, this research produces an Excel based Visual Basic program to assist the designer to analyse the floating and stability of the amphibious system. The findings from this research have successfully established a novel concept of amphibious house system. This concept provides potential development of flood proof urbanisation especially in low lying area with very minimum risk to flood disaster.

ABSTRAK

Banjir adalah merupakan salah satu bencana alam semula jadi yang sering berlaku di Malaysia. Ia menjadi lebih buruk disebabkan oleh keadaan pemanasan global. Bencana ini telah mengakibatkan kerajaan terpaksa menanggung kos perbelanjaan yang besar bagi menghadapi dan mengatasinya. Banjir telah memberi kesan yang negatif terhadap nilai tanah dikawasan yang terdedah kepadanya. Maka adalah kritikal di Malaysia untuk mencari satu kaedah yang lebih berkesan untuk menghadapi bencana banjir. Cabaran ini telah memberi dorongan kepada penyelidikan ini untuk mencipta satu kaedah baru yang lebih lestari dan fleksibel sebagai strategi menghadapi bencana banjir. Kaedah ini dinamakan sebagai sistem rumah amfibia yang terdiri daripada sistem ruang kosong dibahagian bawah rumah, sistem sokongan mendatar dan sistem ponton yang diperbuat daripada konkrit ringan yang direkabentuk khas untuk memberi daya apungan kepada rumah satu tingkat semasa banjir. Penyelidikan ini telah dijalankan dalam lima fasa utama menggunakan kaedah kualitatif dan kuantitatif untuk membangunkan satu sistem rumah amfibia yang stabil dan boleh diharap. Diperingkat awal, kaedah temubual dengan pakar dan pengedaran borang soal selidik telah digunakan untuk mengkaji potensi penerimaan penggunaan konsep rumah amfibia. Ini diikuti pula dengan penggunaan kaedah logik fuzzy bagi proses pemilihan bahan untuk digunakan dalam rekabentuk konkrit ringan untuk pembinaan ponton. Sistem rumah amfibia ini telah diuji dan dianalisa dengan teliti dimakmal hidraulik termasuklah sudut putaran, daya seretan dan beban titik yang dijalankan didalam model banjir makmal. Penyelidikan ini telah membangunkan satu program Excel diatas platfom Visual Basic bagi membantu perekabentuk membuat analisa apungan dan kestabilan rumah amfibia. Hasil kajian penyelidikan ini secara umumnya telah berjaya mencipta satu konsep baru rumah amfibia untuk menangani masalah banjir. Konsep ini berpotensi untuk mewujudkan sistem perbandaran terapung bagi kawasan rendah dengan risiko yang paling minima terhadap kemusnahan akibat banjir.

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LIST OF SYMBOLS

A	-	Area
C_D	-	Drag coefficient
D, d	-	Diameter
$\tilde{D}_c$	-	Alternative score matrix
E	-	Elasticity module
$\tilde{e}_r$	-	Degree of effectiveness
F	-	Force
f	-	Frequency
F_D	-	Drag force
F_1	-	Upstream end Froude number
g	-	Gravity = 9.81 m/s
h^*	-	Relative depth
h_p	-	Height of pontoon
I	-	Moment of inertia
I_i	-	Preference selection index
L_p	-	Length of pontoon
l	-	Length
MG	-	Metacetric distance
m	-	Mass
N	-	Number of pontoons
$O\tilde{R}_{iz}$	-	Obligation fuzzy ranking
P	-	Pressure
PV_j	-	Preference variation index
Q	-	Volumetric flow-rate
$\tilde{R}_{pjz}$	-	Fuzzy rating
$R\tilde{M}S_{pz}$	-	Fuzzy rating Mean Score
S_i	-	Total importance for VIKOR
R_i	-	Maximum importance for VIKOR
$\overline{R}_j$	-	Mean of normalized ranking values
R_{ij}	-	Normalized aggregated values
r	-	Radius
s	-	Score given to the factors
t	-	Setting time

Re	-	Reynolds number
V	-	Volume (m^3)
v	-	Velocity
$\tilde{w}_{ij}$	-	Fuzzy weighting
$\tilde{WMS}_i$	-	Fuzzy weighted Mean Score
W	-	Width of the flume
W_j	-	Weighting factor
x'	-	Centroid for the volume of liquid
x	-	Displacement
$\tilde{x}_{ij}$	-	Aggregated fuzzy rating
X_{ij}	-	Defuzzified value
y_n	-	Normal upstream water level
z	-	Height
α	-	Angle of rotation
θ	-	Angle
ρ	-	Density
Φ_j	-	Deviation
ψ_j	-	Overall preference value
ν	-	Weight for the strategy
δ	-	Distance between centres of buoyancy
γ	-	Specific weight of the fluid

LIST OF ABBREVIATIONS

ANOVA	-	Analysis Of Variance
As	-	Arsenic
BMP	-	Best Management Practice
CFRP	-	Carbon Fibre Reinforced Polymer
CI	-	Conversion Index
CMS	-	Catenary Mooring Systems
EPA	-	Expanded Perlite
EPS	-	Expanded Polystyrene Bead
EU	-	European Union
FA	-	Fly ash
FB	-	Ground Fluidized Bed Combustion Fly Ash
FEMA	-	Federal Emergency Management Association
FTCT	-	Floating Transhipment Container Terminal
GHPC	-	Green High-Performance Concrete
GWT	-	German Water Permeability Test
H	-	High
HEPS	-	Expanded Polystyrene Bead
HPC	-	High-Performance Concrete
IMFS	-	International Marine Flotation Systems
ISAT	-	Initial Surface Absorption Test
L	-	Low
LVDT	-	Linear Variable Differential Transformer
LWAC	-	Lightweight Aggregate Concrete
M	-	Moderate
MF-PSI	-	Modified Fuzzy Preference Selection Index
MF-VIKOR	-	Modified Fuzzy VIKOR
MH	-	Moderate High
MHP	-	Modular Hybrid Pier
MK	-	Metakaolin
ML	-	Moderate Low
OPC	-	Ordinary Portland Cement
OPS	-	Oil Palm Shell
PC	-	Portland Cement
PEST	-	Political-Economical-Social-Technical
PFA	-	Pulverised Fuel Ash
POFA	-	Palm Oil Fuel Ash
PoI	-	Policy Index

RHA	-	Rice Husk Ash
RHBA	-	Rice Husk–Bark Ash
SF	-	Silica Fume
SMART	-	Stormwater Management and Road Tunnel
SPRC	-	Source-Pathway-Receptor-Consequence
SWOT	-	Strength, Weakness, Opportunity, Threat
VH	-	Very High
VL	-	Very Low
VLFS	-	Very Large Floating Structures
VMS	-	Vertical Moored Systems

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CHAPTER 1

INTRODUCTION

1.1 Introduction

Floods are the most damaging types of natural disaster in East Asia and Pacific region (Bakker, 2006). Population growth and environmental aggravation by urbanization have increased vulnerability to floods. Furthermore, because of the global warming and climate change, the intensity and frequency of floods start to rise dramatically. Destructive behaviour of this phenomenon force researchers to investigate for new solutions (Ashley et al., 2007). Different types of floods have a noticeable impact on societies and urban zones in Malaysia as a situated country in the tropical area. Floods frequently occur in Malaysia because of cyclical monsoons and overtopping the rivers during the local tropical wet season (Chan, 1997a). These flood events hit different big cities in Malaysia while they are apart from frequent rural flood events. Accordingly, rural and semi-urban communities in floodplain area in Malaysia partially or entirely wipe away by flood annually.

Malaysian government uses different types of flood protection systems and flood mitigation strategies to avoid property and life losses in floodplain area. Different strategies were conducted by researchers which cover protection, adaptation, and mitigation aspects. However, the current flood mitigation strategies become inadequate because of the ascending trend of frequency and intensity of floods in recent years (Bakker, 2006; Ashley *et al.*, 2007). Using ponds, dikes and

infiltration systems provides limited capacity to reserve water thus, these types of the current mitigation strategies are not enough anymore due to climate change. On the other hand, economic issue is the other important factor. A new mitigation strategy should be developed by affordable price. According to aforementioned issues, the need of new flood mitigation strategy is unavoidable. Flexible and multi-layered systems are required to treat with the forces of nature. This new strategy should be affordable, sustainable and completely flexible with varied floods and floodplains' diverse topography.

The idea of using floating house allows human beings to experience life on water. The costal and seaside areas normally use these types of the house, especially in Netherland. Current research employs this sustainable protection system against sea water as a new mitigation strategy in floodplain area and deltaic plains around Malaysia. Amphibious house is a type of floating house, which is designed to function as both on land and water. This system is constructed on dry land, but it has the ability to float during flooding time. This strategy is a response to the risk of floods in low-lying areas. It is a novel and sustainable solution to mitigate flood vulnerability. It has an easy construction procedure and flexible in the number of residents in its target societies. Amphibious house is an environmental friendly solution to align it with sustainability. Moreover, it is economic mitigation to implement in rural and low-income areas. It is a novel and simple solution to treat the flood rather than fighting with it. This research has made a significant contribution with regard to the following aspects:

- This research rationalized the using of the amphibious house as a strategy for flood mitigation system in Malaysia;
- This research developed pontoon system by using appropriate material selection technique;
- This research thoroughly analysed the stability of the house floating system.

Amphibious house allows a house to remain on land during normal, non-flood conditions, but enables the house to rise and float on the water's surface during a flood. It provides floating condition for the whole system by water level. In this situation, houses and structures are reliable.

1.2 Problem Statement

There is an urgent need to develop a new sustainable flood mitigation strategy for floodplain area in Malaysia. One of such strategy is by using amphibious house concept. The conventional flood mitigation strategies such as using dams, major drainage system and ponding are normally very costly (Graaf, 2009). They are also not quite environmental friendly (Pasche *et al.*, 2008; Graaf, 2009).

The amphibious house concept developed by this research adapt to the nature of flooding environment. However, there is a need to address the issue of stability of the house during flooding. Pontoon system provides good solution to ensure not only for floatation mechanism but also to provide stability of the house. This floating system has to be designed by using a suitable lightweight material which is strong enough, durable and sustainable. The house floating system need to be tested for its stability with acceptable tilting design tolerance during flood time.

1.3 Aim and Objective of the Research

The aim of this research is to develop amphibious house system, which can float during flooding by using the special lightweight concrete pontoon within pit system technology in floodplain areas in Malaysia. The objectives of this research are:

i. To evaluate alternative sustainable flood mitigation strategies in Malaysia;
ii. To evaluate the suitability of using amphibious house system as a flood mitigation strategy in Malaysia;
iii. To evaluate suitable lightweight concrete material for pontoon design;
iv. To develop the conceptual design of amphibious house system;
v. To evaluate and analyse the buoyancy and hydraulic reaction on amphibious house system;
vi. To develop a computer assisted system to analyse and design floating system for amphibious house.

1.4 Scope and Limitation of the Research

Floods can be categorized in two main types: riverine and coastal. In the case of riverine floods, they are mainly caused by the over flow of channels. Riverine or fluvial floods are common issues in Malaysia. Thus, in this research, the amphibious house is developed and evaluated for riverine (fluvial) floods. In general, this research is related to following main area of focus.

The first category is floating platform with buoyant compartments. More emphasize is given on the pontoon material selection. The shape of concrete pontoon considered as simple hollow boxes for economic purposes. The fabrication of pontoon component is made using IBS system. This research proposed the especial sustainable lightweight concrete as pontoon. The investigated cementing pozzolans are limited to: fly ash, silica fume, rice husk ash, palm oil fuel ash. Lightweight aggregates are limited to more common and available aggregate in Malaysia. The design of the floating platform is suitable for single unit house in the open area. The research is applied for flat floating platform to mount the house. The seismic consideration is neglected in this research. The internal design of houses is not considered.

The next area of focus is the hydro-force on the lateral support system. This research contains a physical model to establish, and analyse required loads for vertical support system. The models validate the lateral stability and anchoring of the house. Hydrodynamic reaction forces in the structure boundary estimate for river (fluvial) floods only in laboratory scale. The other area is the pit area. The research does not cover the detail design for pit system. The conceptual and geometrical designs of the pit with implementation steps are developed based on hydraulic results.

Finally, the computer assisted program is developed in the area of MS-Excel with Visual Basic. This program is able to check the tilting due to point load. It determines the number and pattern of pontoons for different types of house based on their areas and weights.

1.5 Significance of the Research

The significant of this research is to establish the importance of using amphibious house as a novel and sustainable flood mitigation strategy in Malaysia as:

i. This new strategy increases the usability of the low laying land in flood prone area.
ii. It helps to boost the land value in the floodplain area.
iii. This system provides economic and flexible solution for diverse urban societies in floodplain areas.
iv. This system is completely aligned with IBS technology.
v. The research provides novel strategy to mitigate riverine flood in Malaysia.
vi. It can reduce catastrophic vulnerability due to flooding and reduce the hassle to evacuate people and valuable things if the situation is merit.
vii. The research provides buoyancy for floating platform by a special designed pontoon system.

viii. The research determines sustainable and the most suitable lightweight concrete material to be used for reinforced concrete pontoons.

ix. The research provides maximum stability for the house and its occupants during the flood.

x. The research establishes the relationship between forces acting and suitable lateral restraining structure to support platform and the house system.

xi. The research provides non-turbulent area for flood water and initiates smooth uplift and settlement of the house by the pit system.

xii. The research develops the computer-assisted software for analysing the loads and design of the platform area and position of the buoyant components.

1.6 Brief Research Methodology

The structure of this research could be summarized by following flowchart of research (Figure 1.1). This brief research methodology provides a general plan and necessary steps to execute the research in a scientific manner. It is a logical model for collecting the information, analysing the data and interpreting the findings of the research. Thus Figure 1.1 tries to outline a flow chart for the methodology of this research.

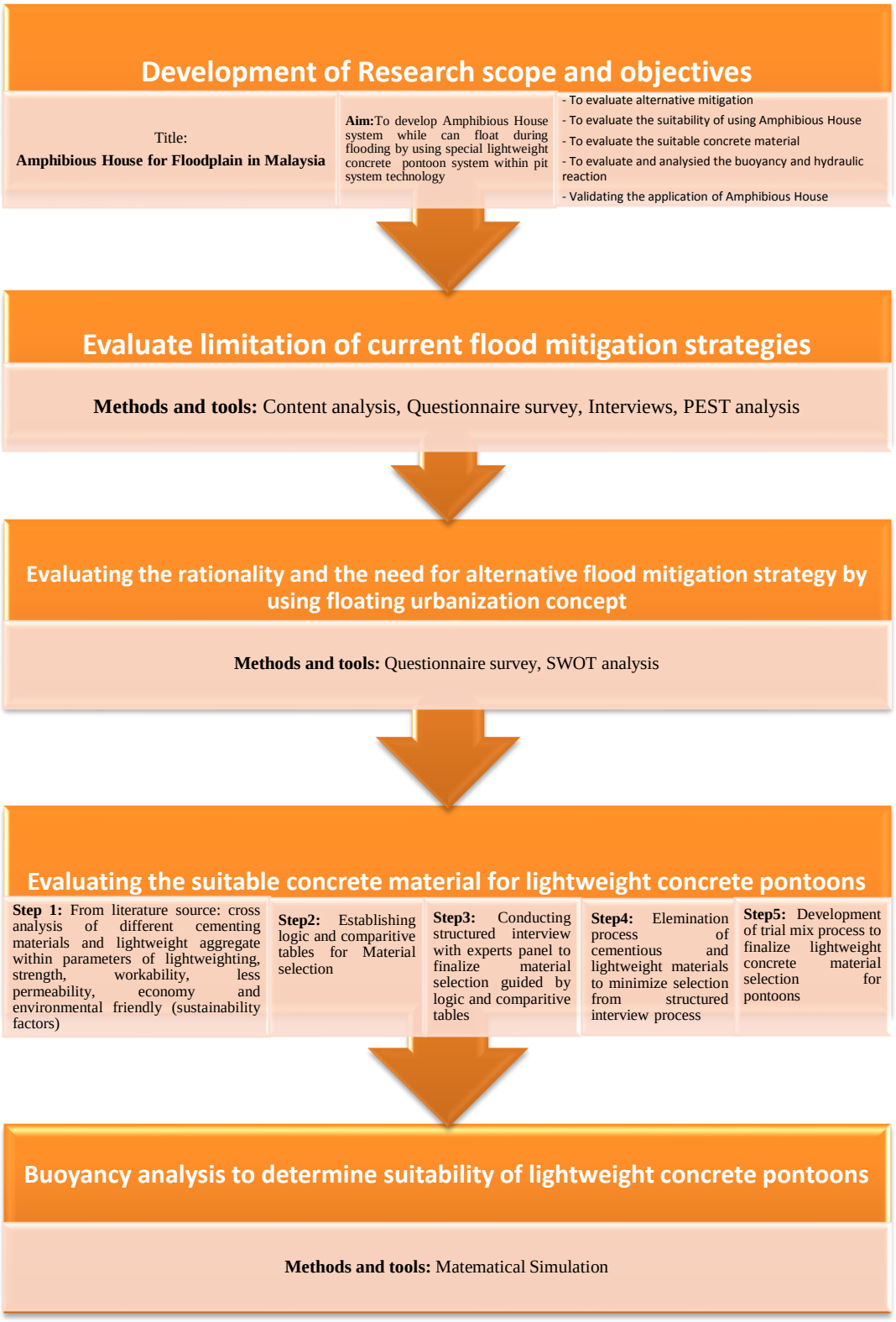

Figure 1.1 The flowchart of research (Cont.)

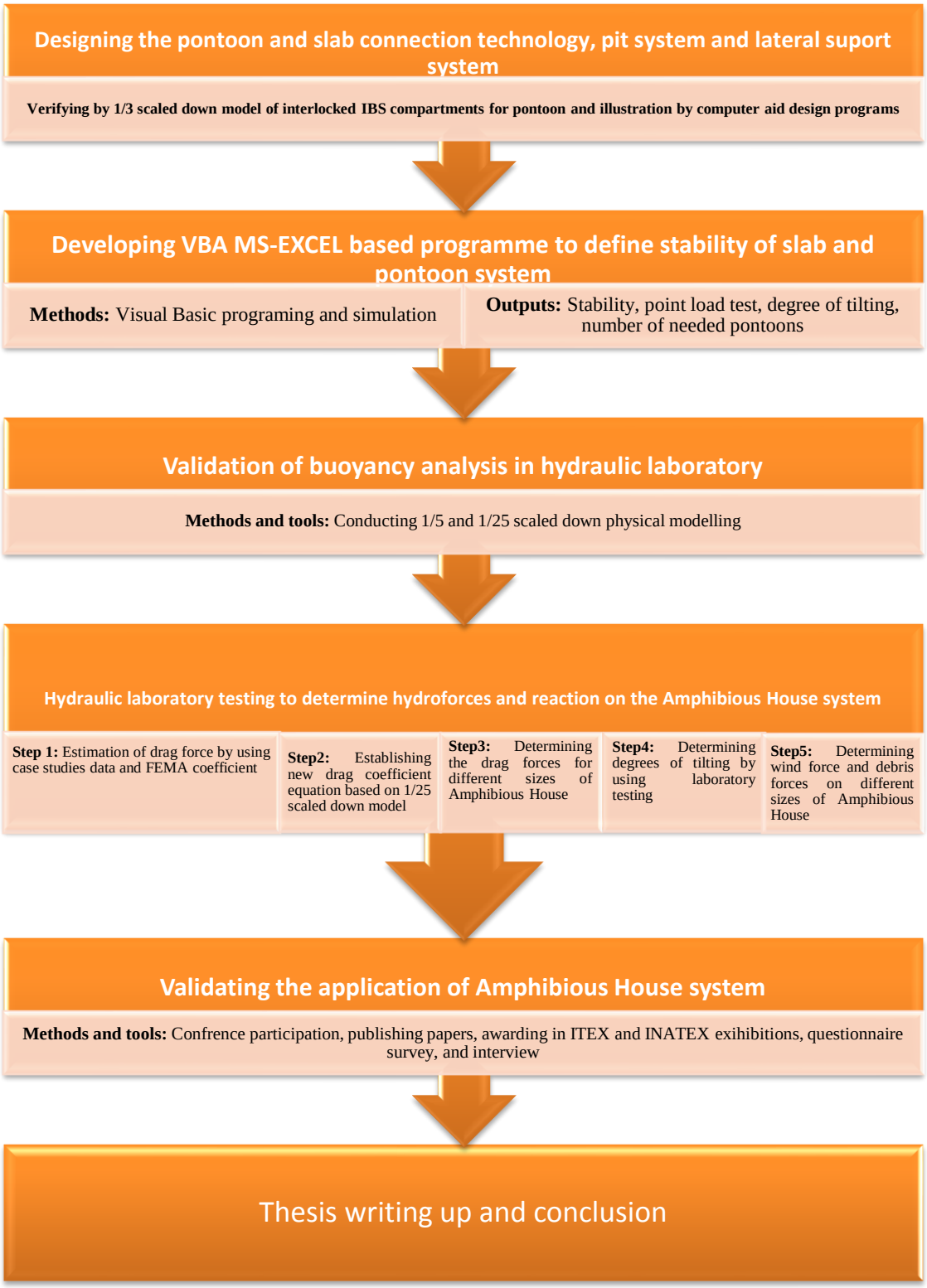

Figure 1.1 The flowchart of research

1.7 Summary of the Chapters

This thesis comprises four major components, which can be summarized as follows:

i. Providing background, identifying the problems of current flood mitigation strategies in Malaysia and application of floating urbanization as a flood mitigation strategy;
ii. Investigating the rationality and the need for alternative flood mitigation strategy by using floating urbanization concept through interviews with the professionals and a questionnaire survey;
iii. Making a contribution to the body of knowledge by evaluating the suitable concrete material for lightweight concrete pontoons;
iv. Making a contribution to the body of knowledge by designing, testing and analysing amphibious house through physical model, hydraulic tests and mathematical simulation by VBA-Excel based program.

These components of the research contribute reliability and stability of the amphibious house. These contributions are presented in eight chapters and are briefly mentioned in Figure 1.2 and described as follows:

Chapter 1 introduces the background of the research, its aim and objectives**.** It also discusses the significance of the research; the benefit and contributions; the scope of the research and a brief summary of the structure of the thesis.

Chapter 2 presents the findings from the literature review. It focuses on the issues of flood mitigation strategies and floating urbanization:

i. Flood and floodplain area in Malaysia;
ii. Classification and evaluation of different flood mitigation strategies;

iii. Amphibious house, floating urbanization and sustainable flood mitigation strategy;
iv. Significance, rationality and case studies of floating houses and amphibious structures;
v. Components of floating structures and principals of floatation.

This chapter helps to compare different flood mitigation and evaluate reliability of amphibious house as a flood mitigation strategy. The reliability is comprehensively investigated in chapter 5.

Chapter 3 focuses on the discussion related to the materials in sustainable lightweight concrete. This chapter presents the effect of different pozzolans and light weight aggregate on concrete characteristics. It presents the sustainability criteria for lightweight concrete from the literature.

Chapter 4 discusses the methodology adopted for this research. It starts by discussing the method used to justify the need for this research through the content analysis of the literatures and interviews, and questionnaire survey. Then it discusses the method used for material selection in concrete research. An explanation was given to each step in terms of their relation to this research, selection of criteria and the anticipated result of each method. Furthermore, it presents the comprehensive description on physical model and hydraulic testing methodology and the anticipated scaling terms in this research.

Chapter 5 presents the data analysis for the initial investigation to establish and justify the need for alternative flood mitigation strategy. It presents PEST analysis through the structured interviews. Moreover, it provides initial investigation on the suitability of using amphibious house in floodplain area and perception and awareness of dwellers and international experts regarding to use amphibious house as a flood mitigation strategy. Then the using and implementing of amphibious House was validated by comprehensive investigation on the important factors of floating structures'

codes and their relation to current design. The SWOT analysis covers different aspects of using this strategy in Malaysia. The results of this chapter evaluate the reliability of the amphibious house.

Chapter 6 presents the development of the proposed method to select the best material for lightweight concrete in concrete pontoons. It presents a cross analysis of different cementing materials and lightweight aggregate within sustainability factors. In the next step, it compares and eliminates some of the alternatives through structured interview and decision-making model by linguistic fuzzy variables. Then, it discusses on development of the trial mix process to finalize lightweight concrete material selection for pontoons and using the results of the concrete laboratory tests in the decision-making model. The result of this chapter defines material characteristics of the pontoons. These characteristics are needed to design and model the buoyancy and stability of the amphibious house in next chapter.

Chapter 7 discusses the flood force as drag force for two different case studies in Malaysia. The buoyancy simulation and validation of stability of this system are investigated comprehensively. It presents the results of hydraulic laboratory tests on 1/25 scale down model. The new equations for estimating drag coefficient developed based on novel methodology. Then it presents the results of the tilting tolerance and stability of the system. The overall result contributes stability of the amphibious house by scale down modelling. However, it is necessary to provide conceptual design of amphibious house and computer program to analyse stability of floating platform which are presented in next chapter.

Chapter 8 presents the finding of this research as a guide to design and implement amphibious house in the floodplain area in Malaysia. It also provides in details the findings on conceptual design of different parts of this system such as pit area, pontoons and lateral system. It discusses about design of pontoons and presents the application of developed VBA-Excel based program for simulation and estimating the number of pontoons. The results of this chapter helps designers to check the stability of amphibious house.

Chapter 9 concludes the results of the research. Discussions are made towards the achievement of the objectives of the research, on the contribution of the research to the existing knowledge, and recommendations are made for future research on the subject.

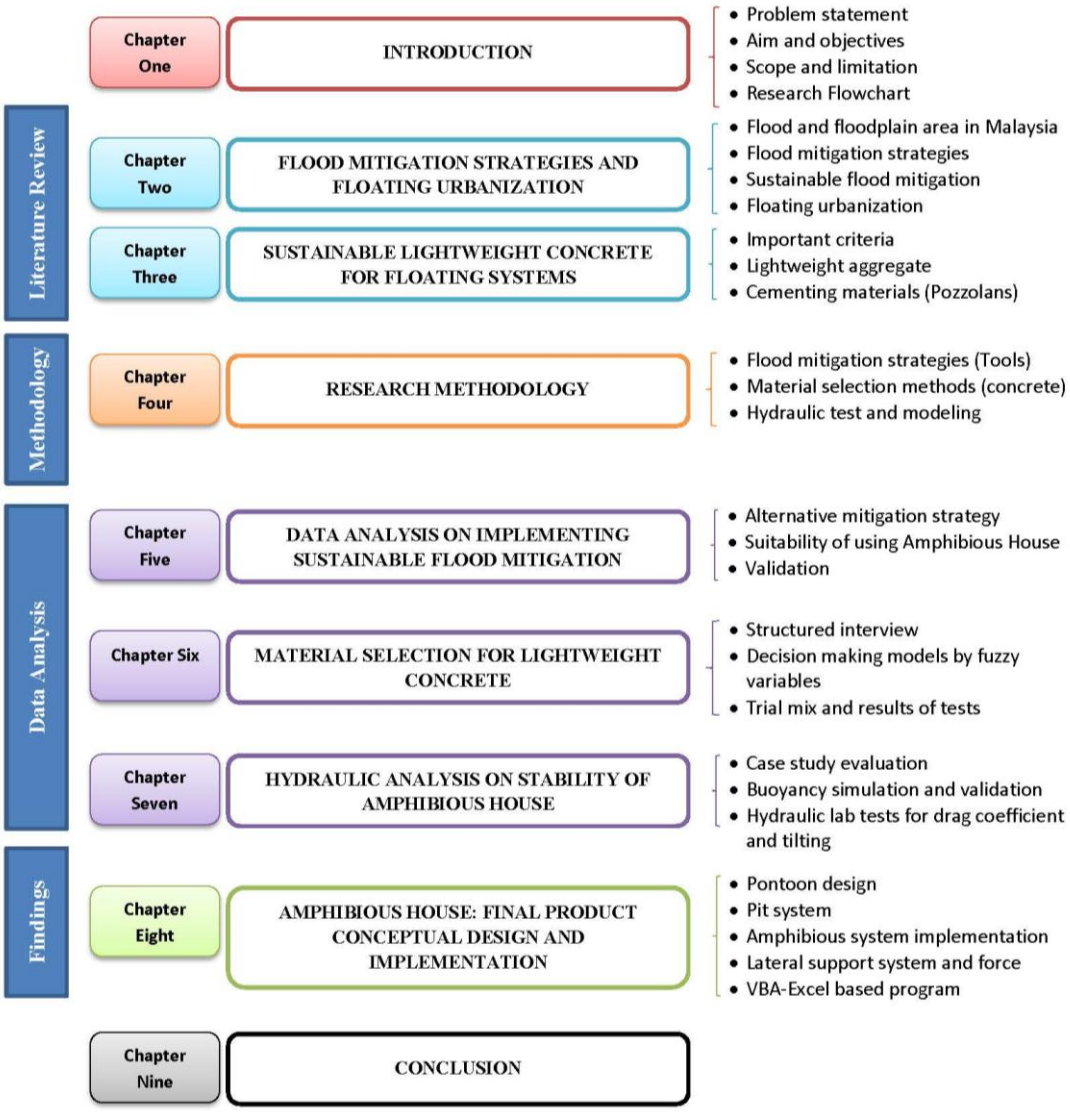

Figure 1.2 Summary of the chapters

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