# CONSERVATION SCIENTIFIC TEST PROCEDURES IN SELECTED MASONRY HERITAGE BUILDINGS IN MALAYSIA

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# CONSERVATION SCIENTIFIC TEST PROCEDURES IN SELECTED MASONRY HERITAGE BUILDINGS IN MALAYSIA

**by**

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## LIST OF ABBREVIATIONS

| | |
|---|---|
| ASTM | American Standards |
| BS | British Standards |
| CIS | The Malaysian Construction Industry Standard |
| DIN | German Standards |
| EDX | Energy Dispersive X-ray Spectroscopy |
| EN | European Standards |
| HABS | Historical Architectural Building Survey |
| IS | Indian Standards |
| L.O.I. | Loss on ignition |
| MS | Malaysian Standards |
| NF | French Standards |
| QLASSIC | Quality Assessment System in Construction |
| SEM | Scanning Electron Microscopy |
| UNESCO | United Nations Educational, Scientific and Cultural Organization |
| XRD | X-ray Diffraction |
| XRF | X-ray Fluorescence |

## LIST OF APPENDICES

**PROSEDUR UJIAN SAINTIFIK DALAM PEMULIHARAAN BANGUNAN WARISAN *MASONRY* TERPILIH DI MALAYSIA**

## ABSTRAK

Sejak zaman Portugis di Melaka pada abad ke-16, banyak bangunan warisan kolonial telah dibina di Semenanjung Malaysia dan Sarawak. Majoriti bangunan warisan ini merupakan bangunan berstruktur *masonry*. Selepas Melaka dan George Town diiktiraf oleh Konvensyen Warisan Dunia UNESCO sebagai Tapak Warisan Dunia pada 7 Julai 2008, pemuliharaan bangunan warisan di Malaysia telah menerima perhatian daripada pelbagai pihak. Semenjak penubuhan Jabatan Warisan Negara bawah Akta Warisan Kebangsaan 2005 (Akta 645) pada 1 March 2006 dengan tanggungjawab untuk memulihara, memelihara, melindungi dan mempromosikan kekayaan khazanah warisan Malaysia, pelaksanaan ujian saintifik dalam amalan pemuliharaan bangunan warisan di Malaysia adalah digalakkan dan disyorkan oleh Jabatan Warisan Negara. Namun begitu, biasanya ujian saintifik dijalankan dalam kerja-kerja pemuliharaan bangunan Warisan Kebangsaan, bangunan Warisan dan sesetengah bangunan warisan kategori I atau kelas I, ia adalah tidak wajib untuk semua projek pemuliharaan bangunan warisan kategori I, kelas I dan kategori II. Selain itu, ia masih kekurangan penyelidikan mengenai pelaksanaan ujian saintifik dalam pemuliharaan bangunan warisan di Malaysia. Objektif-objektif penyelidikan ini adalah untuk mengenal pasti kerosakan bangunan yang terdapat pada bangunan warisan *masonry* terpilih di Malaysia dan faktor penyebabnya, menyenaraikan ujian-ujian saintifik yang diperlukan untuk kerja-kerja pemuliharaan berdasarkan kerosakan bangunan yang terdapat pada bangunan warisan *masonry* terpilih di Malaysia dan menyediakan prosedur untuk menjalankan ujian-ujian

saintifik mengikut aspek dan kehendak yang khusus dalam amalan pemuliharaan bangunan warisan *masonry* di Malaysia. Pendekatan kajian kes diaplikasikan di mana tiga (3) kajian kes yang terdiri daripada Kubu Margherita di Kuching, Sarawak, Masjid Kampung Hulu di Melaka dan Makam Dato Koyah di George Town, Pulau Pinang telah dipilih bagi menyiasat aplikasi ujian-ujian saintifik dalam pemuliharaan bangunan warisan *masonry* di Malaysia untuk mencapai objektif-objektif penyelidikan ini. Penyelidikan ini mengenal pasti kerosakan bangunan yang terdapat pada bangunan warisan *masonry* terpilih di Malaysia dan faktor penyebabnya. Penemuan penyelidikan ini mendedahkan kepentingan ujian-ujian saintifik dalam pemuliharaan bangunan warisan *masonry* di Malaysia. Penemuan penyelidikan ini juga telah menyumbangkan prosedur bagi menjalankan ujian-ujian saintifik yang memperincikan prosedur operasi piawai untuk mengumpul sampel atau data dan mentafsirkan keputusan ujian-ujian saintifik berdasarkan aspek dan kehendak yang khusus dalam amalan pemuliharaan bangunan warisan berstruktur *masonry* di Malaysia. Prosedur yang diperoleh daripada penemuan penyelidikan ini bakal menjadikan panduan teknikal sokongan untuk Garis Panduan Pemuliharaan Bangunan Warisan (2017) terutamanya pada Bahagian 4.1.4 dan garis panduan pemuliharaan warisan tempatan yang lain seperti Rancangan Kawasan Khas untuk George Town Bandar Bersejarah di Selat Melaka (2016), Pelan Pengurusan Pemeliharaan untuk Bandaraya Bersejarah Melaka (2008) dan *Guideline on the Preservation and Occupation of Historical Buildings and Monuments* (2009) Sarawak.

# CONSERVATION SCIENTIFIC TEST PROCEDURES IN SELECTED MASONRY HERITAGE BUILDINGS IN MALAYSIA

## ABSTRACT

Since the Portuguese era in Malacca back in the 16th century, many authentic colonial heritage buildings were built in Peninsular Malaysia and Sarawak. Majority of these heritage buildings are masonry structural buildings. After Melaka and George Town were recognised by UNESCO World Heritage Convention as World Heritage Sites on 7th July 2008, heritage building conservation in Malaysia received attention from various parties. Since the establishment of the Department of National Heritage under the National Heritage Act 2005 (Act 645) on 1st March 2006 with the responsibility to preserve, conserve, protect and promote the rich treasures of Malaysian heritage, implementation of scientific tests in heritage building conservation in Malaysia is encouraged and recommended by the Department of National Heritage. However, scientific tests are normally conducted in conservation works of National Heritage buildings, Heritage buildings and some category I or class I heritage buildings, but not compulsory for all category I, class I and category II heritage building conservation projects. Besides, there is a lack of research on the practice of scientific test in heritage building conservation in Malaysia. Hence, the research objectives are to identify building defects in selected masonry heritage buildings in Malaysia and their causal factors, to outline the conservation scientific tests required in conservation works based on building defects in selected masonry heritage buildings in Malaysia and to develop procedures for conducting conservation scientific tests according to the specific aspects and needs in masonry heritage building conservation practice in Malaysia. Case study approach is applied

where three (3) case studies consisting of Fort Margherita at Kuching, Sarawak, Kampung Hulu Mosque at Melaka and Makam Dato Koyah at George Town, Penang, were selected to investigate the scientific tests applications in masonry heritage building conservation in Malaysia to achieve the research objectives. This research identifies the building defects found in selected masonry heritage buildings in Malaysia and their causal factors. The research findings revealed the importance of scientific tests in conservation of masonry heritage building in Malaysia. The research findings have contributed the procedures for conducting scientific tests that lay out the standard operating procedure to collect sample or data and interpreting test result of scientific tests according to specific aspects and needs in masonry structural heritage building conservation practice in Malaysia. The procedures derived from the research findings could become a supportive technical manual to the Guidelines on Heritage Building Conservation (2017), especially on Part 4.1.4 and other local heritage conservation guidelines including the Special Area Plan for George Town Historic Cities of the Straits of Malacca (2016), Conservation Management Plan for the Historic City of Melaka (2008) and Guideline on the Preservation and Occupation of Historical Buildings and Monuments (2009) Sarawak.

# CHAPTER 1

# INTRODUCTION

## 1.1 Introduction

The research presents the conservation scientific test procedures in selected masonry heritage buildings in Malaysia. It focuses on the function of scientific tests in selected masonry heritage buildings conservation in Malaysia and the process of conducting the scientific tests that could affect the quality of a masonry heritage building conservation project. This chapter addresses the background of research, problem statements, research questions, research aim, research objectives, scope of research, theoretical framework, conceptual framework, research methodology, significance of research, research implications and thesis organisation.

## 1.2 Background of Research

On 7th July 2008, at the 32nd session of the UNESCO World Heritage Convention held in Québec City, Canada, Melaka and George Town were inscribed as World Heritage Site known as the Melaka and George Town: Historic Cities of the Straits of Malacca. After the recognition by the UNESCO, heritage building conservation in Malaysia has attracted significant attention from various parties and government agencies. Since the era of Portuguese occupation of Malacca in 1511, many authentic colonial heritage buildings were built in Malaysia. Majority of these heritage buildings are masonry structural buildings which the main structures are masonry brickwork. As of January 2019, 72.73 % of National Heritage buildings and 84.87 % of Heritage buildings in Malaysia are masonry buildings (Department of National Heritage, 2019). The masonry heritage buildings in Malaysia possess

several combination of building materials and technologies such as masonry brickwork, timber roof structures, timber flooring system and other. These buildings are subject to building defects related to masonry structure and timber.

The National Heritage Act 2005 (Act 645), an act focuses on the conservation and preservation of natural heritage, tangible cultural heritage, intangible cultural heritage, underwater cultural heritage, treasure trove and heritage related matters was gazetted on 1st March 2006 in Malaysia. Under the National Heritage Act 2005 (Act 645), the Department of National Heritage was established on 1st March 2006 to preserve, conserve, protect and promote the rich treasures of Malaysian heritage. The Department of National Heritage encourages implementation of scientific tests in heritage building conservation practice in Malaysia through the Guidelines on Heritage Building Conservation (2017). Part 4.1.4 of the Guidelines on Heritage Building Conservation (2017) stated that "The investigation and tests on materials are paramount in determining the original building materials, their sources and durability, or causes of damage" (p. 109). Lazic et al. (2018) mentioned that cultural heritage consists of huge varieties of materials, structures and dimensions which caused it impossible to establish or create one analytical technique optimal for all restoration cases. Investigation and tests on the building material samples are important in gathering scientific information on a heritage building (Lazic et al., 2018). Scientific information is significant in building diagnostics and it is the main reference in the decision making process (Saba et al., 2019). Decision making process in cultural heritage conservation is a complex multi-criteria process that involves several cultural elements such as history, physical condition, social context and others (Kioussi et al., 2021). Siti (2020) stated that the information collected from scientific tests can be used as supporting materials and evidences during

decision-making process of building conservation works. Lee and Lim (2009) revealed that series of scientific studies and laboratory tests are important in decision making when it may be necessary to identify building defects and the most appropriate conservation techniques. Lee and Lim (2009) also mentioned that quantity surveyor would be aware of the types of materials to be used and prepare relevant specifications in Bill of Quantities (BQ) or tender document if there is any report of scientific studies and laboratory tests done previously as heritage building conservation practices, which its specialised works are different from the scope of work for new building construction.

Conservation scientific tests are normally conducted in conservation works of National Heritage buildings, Heritage buildings and some category I or class I heritage buildings with allocation of budget stated in project tender document or B.Q. It is not compulsory for all category I, class I and category II heritage buildings conservation projects in Malaysia. Meanwhile, there are no detailed specifications, requirements and guidelines or procedures for conducting scientific tests stated in related guidelines such as the Guidelines on Heritage Building Conservation (2017) by the Department of National Heritage, Special Area Plan for George Town Historic Cities of the Straits of Malacca (2016), Conservation Management Plan for the Historic City of Melaka (2008) and Guideline on the Preservation and Occupation of Historical Buildings and Monuments (2009) by the Sarawak Museum Department. In addition, the Malaysian Standards (MS) and the Standard Specifications for Building Works in Malaysia focus more on the requirements and tests for new or contemporary building materials and building technologies, but less so about the requirements or specifications for building materials and old building technologies for heritage building, such as old brick masonry structures construction and lime

plastering technique. Kamarul et al. (2008) found that current legislation on historic buildings in Malaysia is insufficient and there is a lack of technical knowledge in repairing and maintaining historic building. Most of the heritage building conservation projects require an understanding and analysis of building defect diagnostics. However, there is a dearth of research examining the practice of scientific tests in heritage building conservation in Malaysia as well as guidelines on conducting scientific tests for masonry heritage building conservation in Malaysia. The officers from the Department of National Heritage had requested for proposals and suggestions to revise and improve the Guidelines on Heritage Building Conservation (2017), especially on conducting scientific tests for heritage building conservation in Malaysia. On 6$^{th}$ and 9$^{th}$ October 2020, the Department of National Heritage organised a workshop and invited local heritage conservation experts to draft guidelines on preparation of conservation work scopes.

Besides, especially when there is budget limitation in the project, the project consultants would determine the building defect and scope of work for a masonry heritage building conservation project based on their experience and visual inspection on site, but not on scientific tests (Saba et al., 2019). This may result in false defect diagnostics and application of wrong conservation or restoration methods. The proposed conservation methods must be able to extend the lifespan and protect the authenticity of a heritage building, at the same time they would not increase the risk of causing more damage to a heritage building (Chong-Chen et al., 2019). Hence, this research studies the application of conservation scientific tests in selected masonry heritage building conservation practice in Malaysia. The research findings identify the building defects found in selected masonry heritage building in Malaysia and produce procedures for conservation scientific tests according to the specific

aspects and needs in masonry structural heritage building conservation practice in Malaysia.

## 1.3 Problem Statements

From 2007 to January 2019, there are total of sixty six (66) buildings in Malaysia that were listed under National Heritage Act 2005 (Act 645), section 67 as National Heritage. Forty eight (48) units of these National Heritage buildings are masonry buildings (Department of National Heritage, 2019). Meanwhile, eighty two (82) buildings, gateways, cemeteries and sites in George Town World Heritage Site, Penang are listed as category I buildings and sites as mentioned in the Special Area Plan for George Town Historic Cities of the Straits of Malacca (2016). Majority of these National Heritage buildings, Heritage buildings and category I heritage buildings are masonry structures. 72.73 % of National Heritage buildings and 84.87 % of Heritage buildings in Malaysia are masonry buildings (Department of National Heritage, 2019). The authenticity of these heritage buildings is the key attribute to its cultural significance. However, many heritage buildings were damaged and lost their authenticity due to wrong justification done by the consultants and building owners in the conservation works. Inappropriate restoration methods and building materials were used in heritage building repairing works and caused new damages to the heritage buildings (Harun, 2011). A pilot survey by Kamarul et al. (2008) revealed that seventy eight percent (78 %) of the two hundred and nine (209) historical buildings in four heritage towns and cities in Malaysia namely Kuala Lumpur, Ipoh, George Town and Melaka were not being conserved according to the basic principles and conservation guidelines.

Appropriate scientific tests and studies carried out before the conservation works are significant to identify the real problem of a heritage building (Figure 1.1) and assess the properties of building materials (Saba et al., 2019). In heritage building conservation, the sample collection of original materials is proved to be an extremely complicated process due to it is not allow to remove large quantity or portions of undamaged material from a historic site or heritage building (Torrealva et al., 2018). The sample collection and preparation process for conservation scientific tests may have an impact on the test result (Torrealva et al., 2018). Scientific tests that include on-site testing and laboratory test are important to determine the effectiveness of conservation works by comparing scientific tests results before and after conservation works. This is due to not all building defects and quality of building materials can be inspected visually with naked eyes. The data collected from scientific tests are crucial in the decision-making process of heritage building conservation works (Siti, 2020). However, current legislation on historic buildings in Malaysia is insufficient and there is a lack of technical knowledge in repairing and maintaining historic building (Kamarul et al., 2008). There are no detailed specifications, requirements and guidelines on conducting scientific tests mentioned in related guidelines such as the Guidelines on Heritage Building Conservation (2017), Special Area Plan for George Town Historic Cities of the Straits of Malacca (2016), Conservation Management Plan for the Historic City of Melaka (2008) and Guideline on the Preservation and Occupation of Historical Buildings and Monuments (2009) Sarawak. The Malaysian Standards (MS) and the Standard Specifications for Building Works in Malaysia focus on the requirements and tests for new or modern building materials and building technology, but less on the requirement or specification for building materials and old building technology for

heritage building such as old brick masonry structures construction and lime plastering technique. For instance, the Malaysian Standards MS 1569:2003 Specification for Putty Lime referred to Standards Australia, AS 4489.4.1-1997 Test Methods for Limes and Limestones as the requirements for putty lime intended for use in building and construction industry in Malaysia. The lime specifications and guidelines from other countries may not be appropriate for Malaysia as lime is a natural material with huge diversity and characteristics. These variations are the unique property of limes from around the world for its function and aesthetic value.

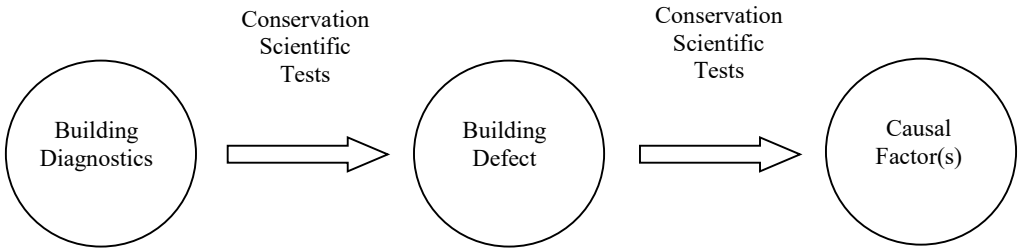


Figure 1.1: The Roles of Conservation Scientific Tests in Heritage Building Conservation

## 1.4 Research Questions

The literature implies that scientific tests are critical elements in ensuring an effective heritage building conservation project. It is important to identify aspects related to conservation scientific tests such as their application processes, interpretations of result and to determine the extent to which they impact the quality of a masonry heritage building conservation project, especially on identifying building defects and their causal factors. Issues related to scientific tests could influence the choices made in masonry heritage building conservation projects.

Studies on conservation scientific tests can help to understand current practices in masonry heritage building conservation in Malaysia and to establish procedures for conservation scientific tests in overcoming challenges such as building diagnostic in masonry heritage building conservation projects. Hence, the research will address the following research questions.

I. How to identify building defects in selected masonry heritage buildings in Malaysia and their causal factors?
II. Why conservation scientific test is important in masonry heritage building conservation in Malaysia?
III. How to conduct conservation scientific tests in masonry heritage building conservation in Malaysia?

## 1.5 Research Aim

The research aim is to determine the conservation scientific test procedures based on the building defects in selected masonry heritage buildings in Malaysia.

## 1.6 Research Objectives

I. To identify building defects in selected masonry heritage buildings in Malaysia and their causal factors based on scientific knowledge.
II. To outline the conservation scientific tests required in conservation works according to the building defects in selected masonry heritage buildings in Malaysia.

III. To develop procedures for conducting conservation scientific tests that lay out the standard operating procedure to collect sample or data and interpreting the test results based on specific aspects and needs in masonry heritage building conservation practice in Malaysia.

## 1.7 Scope of Research

The scope of this study includes identifying building defects in selected masonry heritage buildings in Malaysia and their causal factors. Case study approach was applied to study in detail on three (3) masonry heritage buildings in the Peninsular Malaysia and Sarawak. These masonry heritage buildings were selected based on the following criteria:

I. Listed as National Heritage building or site or category I or class I heritage building;

II. Heritage building carried out conservation works according to the National Heritage building or category I or class I requirements as stated in the Guidelines on Heritage Building Conservation (2017);

III. Conducted at least three (3) scientific tests during its conservation works in the past ten (10) years with proper documentation records.

The study focuses on the scientific tests required in conservation works according to the building defects in selected masonry heritage buildings in Malaysia to develop procedures for conducting scientific tests that lay out the standard operating procedure to collect sample or data and interpreting the test result of scientific tests according to the specific aspects and needs in masonry heritage

building conservation practice in Malaysia. The primary data collected from case studies and focus group interviews with laboratory officers and technicians, building's owners and consultants involved was analysed and examined together with the secondary data collected such as theories, principles and information of the related scientific tests from published materials and documents to achieve the research objectives.

## 1.8 Theoretical Framework

A review on literature had been used to assist the research design and establish theoretical framework and parameters for assessment of research findings. Theoretical framework is the application of a theory, or a set of concepts derived from same theory, to offer an explanation of an event, or phenomenon or research problem (Imenda, 2014). The theoretical framework provides foundation and justifies the method used for conducting this research. The theoretical framework is derived from a building defects investigation framework suggested by Douglas and Ransom (2013) (Figure 1.2). Douglas and Ransom (2013) have proposed an essential framework for investigating building defects which consisting of five (5) stages such as symptoms, condition, causes, effects and remedy (Figure 1.3). According to this framework, the condition, causes and effects of a symptoms should be investigated to obtain a remedy for building defect. The theoretical framework shows the effectiveness of a conservation project is depends on the building diagnostics and building material investigation which involve conservation scientific tests (Figure 1.2).

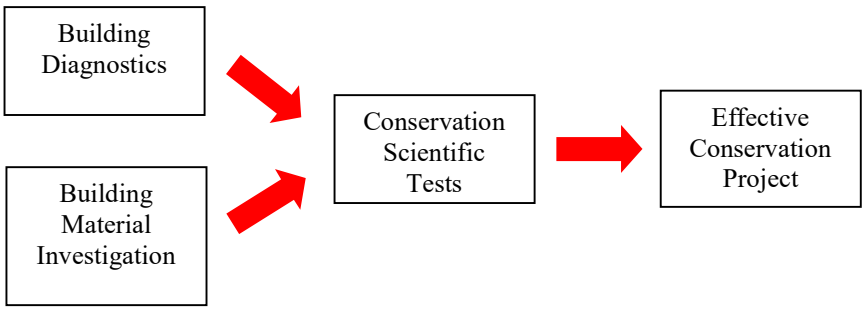


Figure 1.2: Theoretical Framework

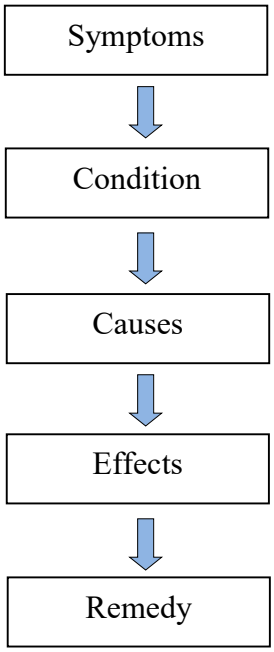


Figure 1.3: Building Defects Investigation Framework (Douglas & Ransom, 2013)

## 1.9 Conceptual Framework

The conceptual framework represents an integrated understanding of issues within the field of study to address research questions and research objectives. Conceptual framework also refers to the epistemological stance or paradigm adopted to investigate the research problem. It explains the research process and the phenomenon to be studied (Adom et al., 2018). A dependent variable is the subject of

research which its attributes are affected by the attributes of the other variables that it is associated (Richard & Anita, 2015). Meanwhile, an independent variable is a phenomenon where its attributes are controlled, selected and measured so that the relationship between the independent variable and the dependent variable can be examined (Richard & Anita, 2015). Figure 1.4 shows the conceptual framework with all the identified variables used to measure the purposes of conducting conservation scientific tests. In this research, the building defects and nature of the building materials are the independent variables, while the selection and application of scientific tests are the dependent variables. Apart from that, the sample collecting process, sample handling process in laboratory and interpretation of testing results are the independent variables, while the effectiveness of conservation methods is the dependent variable.

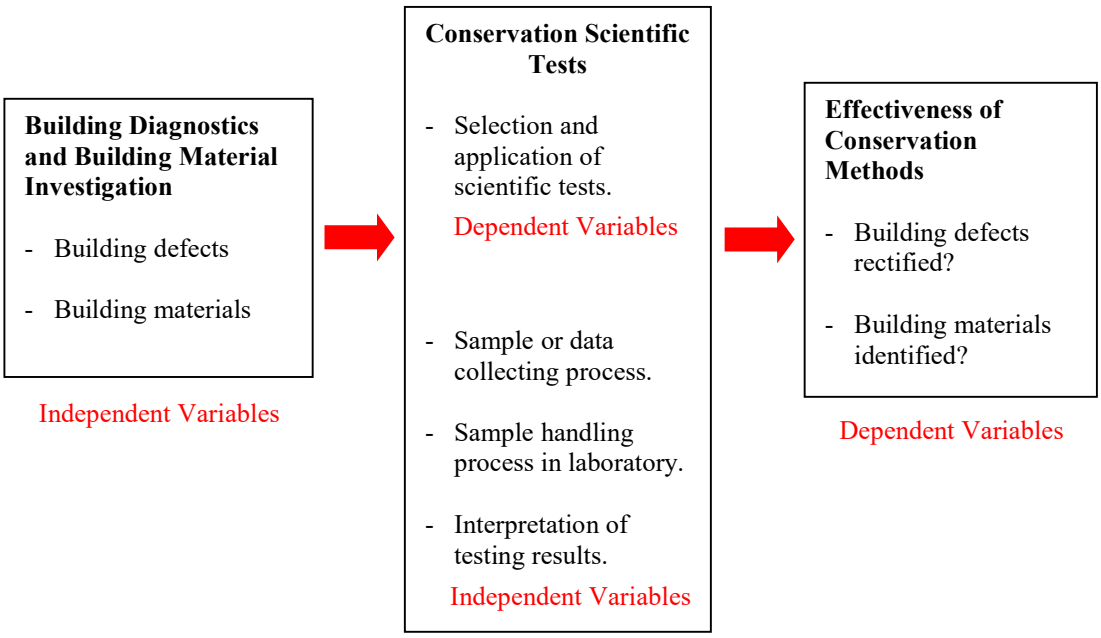


Figure 1.4: Conceptual Framework

## 1.10 Research Methodology

The nature of this research is a basic research with qualitative approach conducted using case studies approach as its empirical design. Case study approach facilitates in-depth investigation of a phenomenon, which instances are chosen to represent general cases. In this research, three (3) case studies consisting of Fort Margherita at Kuching, Sarawak, Kampung Hulu Mosque at Melaka and Makam Dato Koyah at George Town, Penang were selected to investigate the application of scientific tests in masonry heritage building conservation in Malaysia to achieve the research objectives. The research process begins with research background study and problem statements formulation to define the research questions, research objectives and scope of research (Figure 1.5). Literature review gives an overview of the knowledge and topics related to the conservation scientific tests in masonry heritage building. The information gathered from literature review is then critically analysed to identify the gaps in current knowledge. The data are collected from archival data, structured interviews, semi-structured interviews and observations. Peer debriefing and triangulation during the validation of the data collected ensure the validity of the research. At data analysis stage, thematic analysis method is employed. It involves reading through a data document, such as data collected from archival materials, hands on learning and observation, transcripts from structured interviews and semi-structured interviews, and identifying patterns or themes and sub-themes in meaning across the data. The coding structure is developed through line-by-line analysis of the text from the data collected for the occurrence of themes such as building defects and scientific tests, and sub-themes such as causal factors of the building defects, purpose of conducting the scientific tests and procedure of conducting the scientific tests. The

research findings are discussed to achieve the research objectives. The details of the research methodology are addressed in Chapter 3.

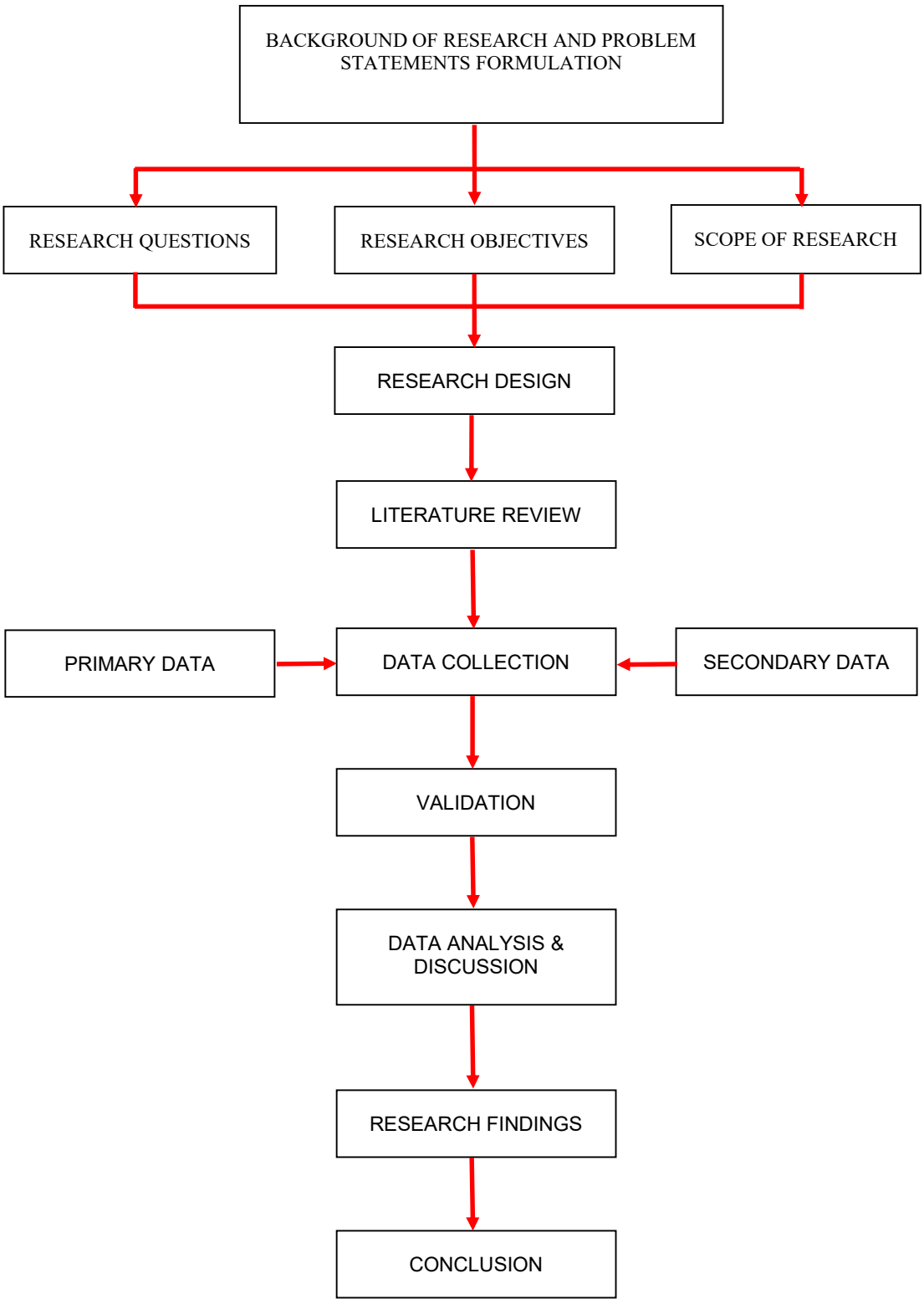


Figure 1.5: Flow Chart of Research Methodology

## 1.11 Significance of Research

Majority of the colonial heritage buildings in Malaysia were built with masonry structural building method. Usually, scientific tests are conducted in conservation works for National Heritage buildings, Heritage buildings and some category I or class I heritage buildings. However, according to the Guidelines on Heritage Building Conservation (2017) by the Department of National Heritage, Special Area Plan for George Town Historic Cities of the Straits of Malacca (2016), Conservation Management Plan for the Historic City of Melaka (2008) and Guideline on the Preservation and Occupation of Historical Buildings and Monuments (2009) by the Sarawak Museum Department, conservation scientific tests are not compulsory for all category I, class I and category II heritage buildings conservation projects in Malaysia. Although there has been several researches about scientific tests in heritage building conservation, but there is still a lack of in-depth research on the application of conservation scientific tests in masonry heritage building conservation in Malaysia such as the selection of scientific test according to building defect or conservation needs, sample or data collection procedure, as well as guidelines on conducting scientific tests. The findings of this study could benefit Malaysian society considering the importance of conservation scientific test in heritage building conservation practice in Malaysia today. Significant historical and cultural values of heritage building justify the need for more effective conservation approaches which includes scientific tests. Thus, the procedures of conservation scientific tests for specific aspects and needs in masonry heritage building conservation derived from the results of this study could assist heritage building conservation consultants in conserving masonry heritage buildings in Malaysia.

## 1.12 Research Implications

The study offers an evaluative perspective on the implication of conservation scientific test in selected masonry heritage building conservation practice in Malaysia. The selected masonry heritage building conservation projects were evaluated based on their building defects, defect causal factors, procedure of conducting scientific tests and their effectiveness. Therefore, the procedures for conducting the conservation scientific tests based on specific aspects and needs in masonry heritage building conservation derived from the findings of this study could become a supportive technical manual to the Guidelines on Heritage Building Conservation (2017) by the Department of National Heritage, especially on Part 4.1.4 and other local heritage conservation guidelines, such as the Special Area Plan for George Town Historic Cities of the Straits of Malacca (2016), Conservation Management Plan for the Historic City of Melaka (2008) and Guideline on the Preservation and Occupation of Historical Buildings and Monuments (2009) by the Sarawak Museum Department.

## 1.13 Thesis Organisation

There are six (6) chapters in this thesis. Chapter One describes the background of research, problem statements, research questions, research aim, research objectives, scope of research, theoretical framework, conceptual framework, research methodology, significance of research, research implications and thesis organisation. While, Chapter Two presents an overview of current literature related to the scientific tests in masonry heritage building conservation in Malaysia and research gap. It also explains building failures, building diagnostics principles and

common scientific tests conducted in heritage building conservation. Chapter Three outlines the research methodology such as research framework, research approach and research process which includes research building selection, data collection, data analysis and research output. Chapter Four presents the data collected and an overview of current practices in masonry heritage building conservation in Malaysia through three (3) selected case studies with at least three (3) types of scientific tests conducted during their conservation works done in the past ten (10) years with proper documentation.

In Chapter Five, the research data analysis and findings are presented in two (2) parts. In the first part, the building defects in selected case studies and their causal factors are tabulated and discussed. In part two of this chapter, the introduction, basic theory and purpose of conducting scientific tests in masonry heritage building conservation are presented. It clarifies and discusses the weaknesses of the operational procedure of scientific tests based on existing guidelines and laboratory requirements. Furthermore, a proposal of procedures for conducting conservation scientific tests in masonry heritage building conservation by taking current requirements, needs, rules and regulation in Malaysia into consideration were outlined and presented. Chapter Six concludes the key findings of the research and their contributions to the existing pool of literature, especially about conservation scientific tests in masonry heritage building conservation in Malaysia, as well as outlining possible directions for future research.

## 1.14 Summary

This chapter addresses the foundation of the research. It summarises the background and problem statements of the research by describing current masonry heritage building conservation practices in Malaysia and issues related to conservation scientific tests and conservation guidelines such as the lack of detailed specifications, requirements and guidelines or procedures for conducting scientific tests stated in related guidelines, namely the Guidelines on Heritage Building Conservation (2017) by the Department of National Heritage, especially on Part 4.1.4, Special Area Plan for George Town Historic Cities of the Straits of Malacca (2016), Conservation Management Plan for the Historic City of Melaka (2008), Guideline on the Preservation and Occupation of Historical Buildings and Monuments (2009) by the Sarawak Museum Department, Malaysian Standards (MS) and Standard Specifications for Building Works. Besides, the importance of conservation scientific tests in ensuring the success of a masonry heritage building conservation project is addressed. Research questions, research aim, research objectives, theoretical framework, conceptual framework, significance of research and research implications are formulated in this chapter. Meanwhile, the scope of research discusses the research area and the selection of three (3) case studies of masonry heritage buildings in Peninsular Malaysia and Sarawak. It also briefly illustrates the research methodology and thesis organisation.

# CHAPTER 2

# LITERATURE REVIEW

## 2.1 Introduction

According to Guidelines on Heritage Building Conservation (2017), heritage is defined as "something of significance or value that is inherited from one generation to another" (p. 68). National Heritage Act 2005 (Act 645) section 2 stated that building means "a building or groups of separate or connected buildings which, because of their architecture, their homogeneity or their place in the landscape, are of outstanding universal value from the point of view of history, art or science" (p. 95). Conservation is a process of protecting and maintaining tangible heritage which includes heritage building and/or site, from any damage due to natural factors and human factors such as improper restoration methods and vandalism or from undergoing works without proper planning and management (Guidelines on Heritage Building Conservation, 2017). It involves preserving original condition of a heritage building or site, including its historical and cultural significance (Guidelines on Heritage Building Conservation, 2017). Conservation includes preservation, restoration, reconstruction, rehabilitation and adaptation, or any combination [National Heritage Act 2005 (Act 645) and Regulations, 2012, p. 99]. The main objective of heritage building conservation is to protect and safeguard heritage building with proven and proper conservation approaches and techniques (Guidelines on Heritage Building Conservation, 2017). Architectural significance and authenticity are the key aspects in heritage building conservation especially for the heritage buildings which are listed as Heritage site or National Heritage site in Malaysia under National Heritage Act 2005 (Act 645) (Guidelines on Heritage

Building Conservation, 2017). The original building materials have significant value for a heritage building as they are historical evidence from the past (Guidelines on Heritage Building Conservation, 2017). The original building materials of a heritage building carry important information related to building technology, intelligence and knowledge in the past. Thus, the original building materials of a heritage building must be conserved with appropriate scientific conservation methods to safeguard its authenticity (Guidelines on Heritage Building Conservation, 2017). Scientific tests on existing building materials should be conducted before conservation works on site to provide sufficient information and minimise the risk during decision-making stage (Siti, 2020).

Several studies related to scientific tests such as X-ray fluorescence test, ion chromatography test, moisture & dampness test, Schmidt hammer rebound test and others in heritage building conservation have been carried out in Europe, Australia, Malaysia and other countries. A Ghafar and Haris (2010) revealed that salt attack and rising damp are the most common building defects in heritage buildings in Penang, Malaysia. The existence of mineral salts may weaken the building components (A Ghafar & Haris, 2010). Three (3) types of destructive soluble salts that are commonly found in masonry wall of heritage buildings are chlorides (Cl), nitrates ($NO_3$) and sulphates ($SO_4$) (A Ghafar & Haris, 2010). These soluble salts can be detected by conducting ion chromatography test (A Ghafar & Haris, 2010). Lourenço et al. (2014) reported the chemical, physical and properties of mortar, brick and masonry in a research paper and it revealed the possible causes of damage and the usage of scientific expert systems in building defects diagnosis. In other words, scientific test is an effective tool to diagnosis building defect and building material performance.

A Ghafar and Haris (2005) stated the important roles of several scientific tests such as X-ray fluorescence analysis, salt level test, Schmidt hammer rebound test and paint colour scheme analysis in heritage building conservation. They were carried out in Old City Hall, George Town building conservation project to safeguard its authenticity and historical value (A Ghafar & Haris, 2005). Furthermore, in Technical Guide of Salt Attack and Rising Damp, a guide to salt damp in historic and older buildings, David (2008) reported that accurate diagnosis is critical as there is no substitute for a thorough understanding of a building's behaviour and its response to changes over time. It only can be done by conducting systematic scientific tests (David, 2008). Hossam (2015) claimed that twelve (12) fresh and weathered stone samples collected from Dush Temple in El-Kharga Oasis were crushed and milled in an agate mortar to avoid contamination. The stone samples were then analysed with X-ray diffraction (XRD) method to identify their mineralogy and the findings are important to identify the main damaged factors at Dush Temple (Hossam, 2015). However, Nadia Bianco et al. (2018) mentioned that it is quite difficult to achieve satisfactory evaluation of the suitability of the mortars for restoration of cultural heritage due to the lack of proper reference standard and specifications responding to the necessary requirements in compatibility, harmfulness and effectiveness in preserving pre-existing materials and particular critical condition like the presence of soluble salts. The precedent study of previous studies on scientific tests in heritage building conservation have laid a foundation for this research to study on scientific tests in masonry heritage building conservation in Malaysia.

## 2.2 Cultural Heritage

Cultural heritage includes “tangible or intangible form of cultural property, structure or artefact and may include a heritage matter, object, item, artefact, formation structure, performance, dance, song, music that is pertinent to the historical or contemporary way of life of Malaysians, on or in land or underwater cultural heritage of tangible form but excluding natural heritage” (National Heritage Act 2005 [Act 645] and Regulations, 2012, p. 100). Tangible form of cultural property includes monuments, groups of buildings and sites. Monuments are “architectural works, works of monumental sculpture and painting, elements or structures of an archaeological nature, inscriptions, cave dwellings and combinations of features, which are of outstanding universal value from the point of view of history, art or science” (UNESCO, 1973, p. 136). Groups of buildings are “groups of separate or connected buildings which, because of their architecture, their homogeneity or their place in the landscape, are of outstanding universal value from the point of view of history, art or science” (UNESCO, 1973, p. 136). While, sites are “works of man or the combined works of nature and man, and areas including archaeological sites which are of outstanding universal value from the historical, aesthetic, ethnological or anthropological point of view” (UNESCO, 1973, p. 136).

## 2.3 Classification of Heritage Buildings in Malaysia

In Malaysia, there are two categories of heritage under National Heritage Act 2005 (Act 645), namely National Heritage and Heritage Site. National Heritage means “any heritage site, heritage object, underwater cultural heritage or any living person declared as a National Heritage under section 67” (National Heritage Act

2005 [Act 645] and Regulations, 2012, p. 100). According to the National Heritage Act 2005 (Act 645), only the Minister may, by order published in the Gazette, declare any heritage site, heritage object, underwater cultural heritage listed in the Register or any living person as a National Heritage. Site includes "any area, place, zone, natural heritage, monument or building attached to land, archaeological reserve and any land with building, garden, tree or archaeological reserve" (National Heritage Act 2005 [Act 645] and Regulations, 2012, p. 100). The Heritage Commissioner may designate any site in Malaysia which has natural heritage or cultural heritage significance to be a Heritage Site (National Heritage Act 2005 [Act 645] and Regulations, 2012, p. 111). From year 2009 to January 2019, there are seventy one (71) buildings or monuments in Malaysia that have been listed under National Heritage Act, section 67 as National Heritage Site (Department of National Heritage, 2019). Sixty six (66) units of these National Heritage are buildings. Among these listed National Heritage buildings, forty eight (48) units or 72.73% are masonry structural buildings (Table 2.1). Besides, one hundred nineteen (119) buildings were listed as Heritage Site under National Heritage Act, section 67 (Department of National Heritage, 2019) (Table 2.2). There are about one hundred and one (101) units or 84.87% of these Heritage buildings are masonry buildings.

### I. Section 67. Declaration of National Heritage

(1) "The Minister may, by order published in the Gazette, declare any heritage site, heritage object, underwater cultural heritage listed in the