

EVALUATION ON ROOF COMPARTMENTATION FOR
FIRE SAFETY IN NATIONAL SECONDARY SCHOOLS
IN MALAYSIA

BY

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ABSTRACT

Schools are public facilities that play an integral component in the built environment. The school's design is significant to achieve a conducive learning environment that will influence the students' and staff's experiences. Schools can pose a significant fire hazard if not designed effectively. This research aimed to examine the existing provisions of compartmentation for fire safety in passive design strategy. The study focuses on roof compartmentation and its regulating provisions in national secondary school buildings in Malaysia. Research in the field of fire safety conducted by many indicated that the catastrophic fire hazards that occur in school buildings are caused by uncontrollable fire and smoke spread in roof voids or cavities. Most of their findings would come to an agreement on the construction and technical deficiencies aspects, mainly insufficient fire compartmentation separation (compartment walls and cavity barriers), poor construction quality, improper and non-compliance materials installation and insufficient active fire detection. The researchers found similar findings that the primary causes contributed to losses of life, building property and interruption to school operations after a tragic fire hazard occurrence. Qualitative and quantitative approaches have been adopted to achieve the aim and objectives of this research. Case studies of national secondary school buildings are selected to provide evidence-based research analysing the building and fire codes and standards for passive compartmentation. Key elements under investigation are, 1) compartmentation maximum limit, 2) compartment walls and floors, 3) undivided concealed spaces in roof voids, 4) cavity barriers and 5) fire detection provisions. The study revealed significant technical deficiencies in the roof compartmentation of national secondary school buildings, primarily caused by, 1) inconsistent implemented enforcement of standard building plan approval process (prior to implementation of Standard Operating Procedure (SOP) Procurement of Lead Consultant (LC), 2) fragmented and disjointed fire safety provisions in the building and fire codes and standards and 3) a knowledge gap in understanding the fire codes and standards. In conclusion, the study recommends for a comprehensive regulatory framework in order, 1) to promote a common understanding of the Building and Fire Codes and Standards among all stakeholders, 2) to enhance the implementation of an Integrated Fire Fighting System to improve fire safety performance, 3) to foster engagement between Designers and Fire Experts and 4) to prioritise persistent building maintenance to ensure a more consistent and effective enforcement and understanding of fire safety design standards in schools for fire safety compliance. These are crucial regulatory conditions for the safety and well-being of students and staff, mitigating potential loss of life, property damage and educational operations disruptions.

خلاصة البحث

المدارس هي مرافق عامة تلعب دوراً لا يتجزأ في البيئة المبنية. ويعد تصميم المدارس مهماً لتحقيق بيئة تعليمية مواتية تؤثر على تجارب الطلاب والموظفين. يمكن أن تشكل المدارس خطراً كبيراً للحرائق إذا لم يتم تصميمها بشكل فعال. يهدف هذا البحث إلى دراسة الأحكام الحالية للتقسيم من أجل السلامة من الحرائق في استراتيجية التصميم السلبي. تركز الدراسة على تقسيم الأسطح وأحكامها التنظيمية في مباني المدارس الثانوية الوطنية في ماليزيا. لقد أشارت الأبحاث في مجال السلامة من الحرائق التي أجراها العديد من الأشخاص إلى أن مخاطر الحرائق الكارثية التي تحدث في المباني المدرسية ناجمة عن حريق لا يمكن احتواؤه وانتشار الدخان في فراغات أوتجاويف السقف. سنتفق معظم النتائج التي توصلوا إليها على جوانب القصور في البناء والتقنية، وخاصة الفصل غير الكافي بين أقسام الحرائق (جدران الأقسام وحواجز التجاويف)، وجودة البناء الرديئة، وتركيب المواد غير المناسبة وغير المتوافقة، وعدم كفاية الكشف النشط عن الحرائق. وجد الباحثون نتائج مماثلة مفادها أن الأسباب الرئيسية ساهمت في خسائر الأرواح وممتلكات المباني وانقطاع عمليات المدرسة بعد وقوع خطر حريق مأساوي. وتم تبني منهج نوعية وكمية لتحقيق هدف وأغراض هذا البحث. كما تم اختيار دراسات الحالة للمباني المدرسية الثانوية الوطنية لتوفير بحث قائم على الأدلة لتحليل قواعد ومعايير البناء والحرائق للتقسيم السلبي. كانت العناصر الرئيسية قيد التحقيق هي، (1) الحد الأقصى للتقسيم، (2) جدران وأرضيات المقصورة، (3) المساحات المخفية غير المقسمة في فراغات السقف، (4) حواجز التجاويف و (5) أحكام الكشف عن الحرائق. كشفت الدراسة عن أوجه قصور فنية كبيرة في تقسيم أسطح المباني المدرسية الثانوية الوطنية، والتي ترجع في المقام الأول إلى، (1) التنفيذ غير المتسق لعملية الموافقة على خطة البناء القياسية (قبل تنفيذ إجراءات التشغيل القياسية (SOP) لتعيين استشاري رئيسي (LC)، (2) أحكام السلامة من الحرائق المجزأة وغير المترابطة في قواعد ومعايير البناء والحرائق و (3) فجوة معرفية في فهم قواعد ومعايير الحرائق. في الختام، توصي الدراسة بوضع إطار تنظيمي شامل من أجل: (1) تعزيز الفهم المشترك لقواعد ومعايير البناء والحرائق بين جميع أصحاب المصلحة، (2) تعزيز تنفيذ نظام الحرائق المتكامل لتحسين أداء السلامة من (3) تعزيز المشاركة بين المصممين وخبراء الحرائق و (4) إعطاء الأولوية لصيانة المباني المستمرة لضمان إنفاذ وفهم أكثر اتساقاً وفعالية لمعايير تصميم السلامة من الحرائق في المدارس للامتثال للسلامة من الحرائق. هذه شروط تنظيمية حاسمة لسلامة ورفاهية الطلاب والموظفين، والتخفيف من الخسائر المحتملة في الأرواح، وتلف الممتلكات وانقطاع العمليات التعليمية.

APPROVAL PAGE

I certify that I have supervised and read this study and that in my opinion, it conforms to acceptable standards of scholarly presentation and is fully adequate, in scope and quality, as a dissertation for the degree of Master of Science in Building Services, Asset and Facilities Management.

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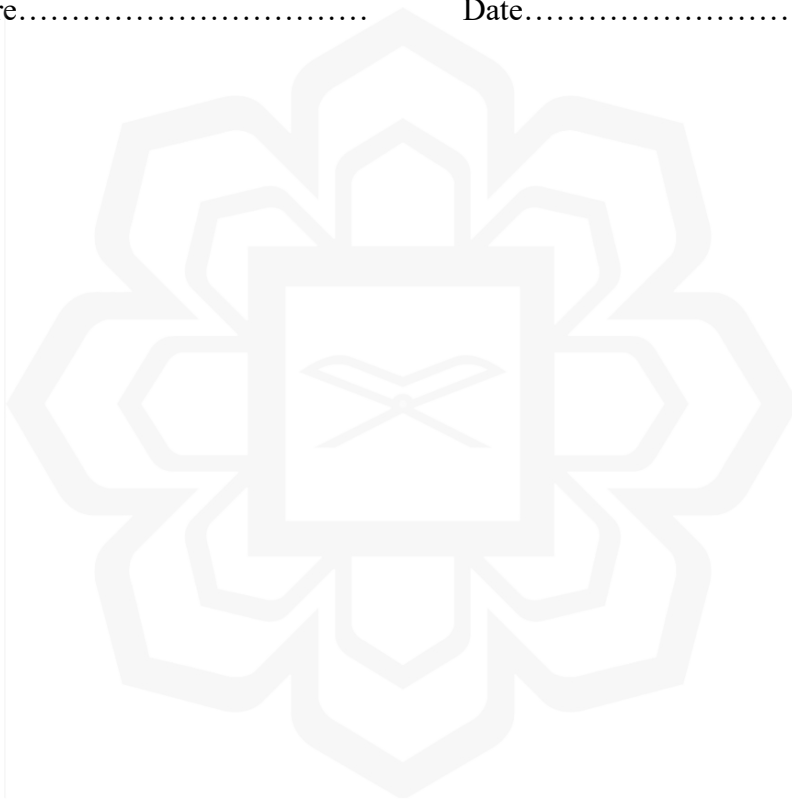
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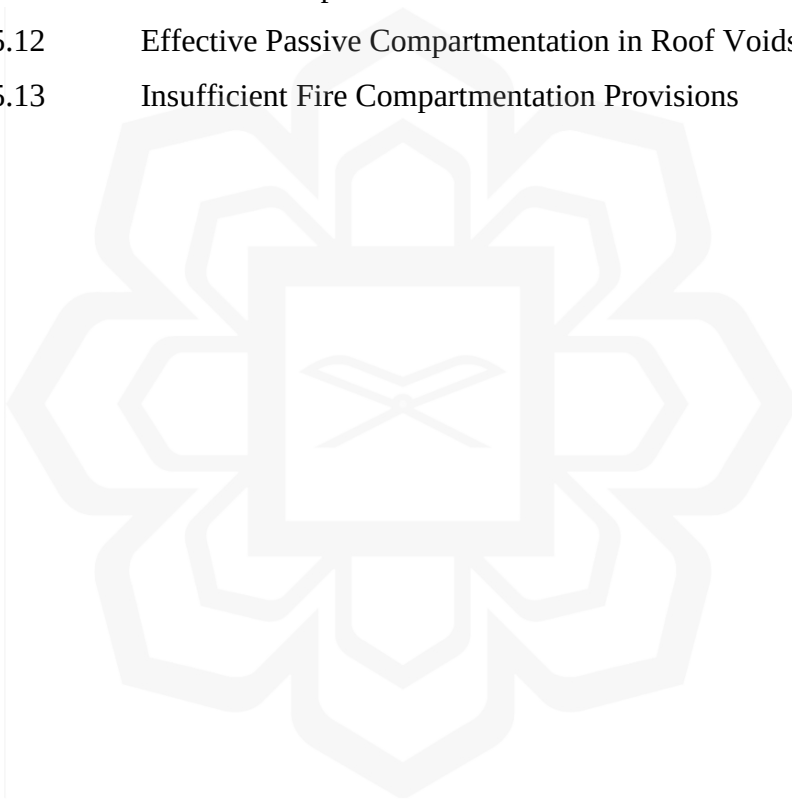
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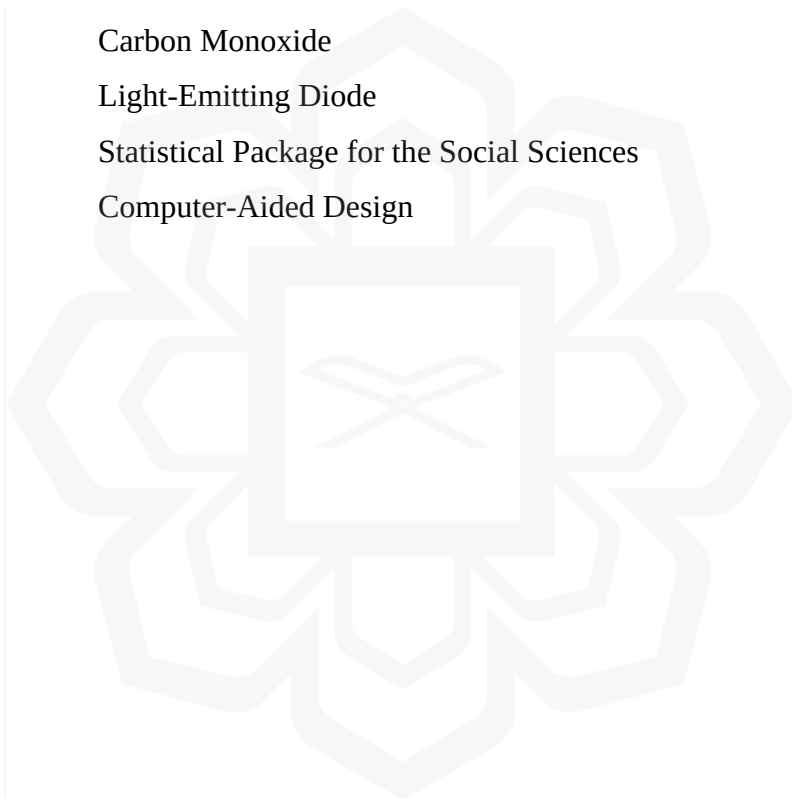
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LIST OF ABBREVIATIONS

MOE	Ministry of Education
PPKI	Program Pendidikan Khas Integrasi
PdPR	Teaching and Learning at Home
NEP	National Education Philosophy
SED	State Education Department
DEO	District Education Office
PPKI	Program Pendidikan Khas Integrasi
UKSK	Ujian Kemasukan Sekolah Khas
KPKT	Kementerian Perumahan dan Kerajaan Tempatan
MHLG	The Ministry of Housing and Local Government
CIDB	Malaysian Construction Industry Development Board
PPJ	Putrajaya Corporation
MARA	Council of Trust for the Bumiputera of Malaysia
MECD	Ministry of Entrepreneurial and Co-operative Development
PPP	Public Private Partnership
CCM	Companies Commission of Malaysia
MOH	Ministry of Health Malaysia
DBKL	Dewan Bandaraya Kuala Lumpur
BRE	Building Research Establishment
UNESCO	United Nations Educational, Scientific and Cultural Organization
IWK	Indah Water Consortium
JPS	Irrigation and Drainage Department
DOE	Department of Environment
SKMM	Malaysian Communications and Multimedia Commission
TNB	Tenaga Nasional Berhad
JMG	Department of Minerals and Geosciences or Jabatan Mineral dan Geosains Malaysia
CAAM	Civil Aviation Authority of Malaysia
ATL	Agensi Teknikal Luaran or External Technical Agencies
ATD	Agensi Teknikal Dalaman or Internal Technical Agencies

PBT	Pihak Berkuasa Tempatan
PAP	Pre-Approved Plan
DO	Development Order
KM	Kebenaran Merancang or Planning Permission
BP	Building Plans
CCC	Certificate of Completion and Compliance
CFO	Certificate of Fitness for Occupation
SP	Submitting Person
PSP	Principal Submitting Person
LC	Lead Consultant
HOPT	Head of Project Team
HODT	Head of Design Team
SOP	Standard Operating Procedure
KSU	Ketua Setiausaha
SMK	Sekolah Menengah Kebangsaan
SMKHK	SMK Hulu Kelang
SMKTM	SMK Taman Melawati, Selangor
SMKSP	SMK Sungai Pusu, Selangor
EPU	Economic Planning Unit
PWD	Public Works Department
FRDM	Fire and Rescue Department of Malaysia
UBBL	Uniform Building By-Laws (UBBL) 1984 (Revision 2021)
SUBBL	Selangor Uniform Building By-Laws (SUBBL) 1986 (Revision 2012)
MS:1183	Fire Safety in the Design, Management and Use of Buildings
MS	Malaysian Standard
LAM	Lembaga Arkitek Malaysia
PAM	Pertubuhan Arkitek Malaysia
ACEM	Association of Consulting Engineers Malaysia
DSM	Department of Standards Malaysia
IEM	Institute of Engineers Malaysia
MFPA	Malaysian Fire Protection Association
DCLG	Department for Communities and Local Government

NFPA	National Fire Protection Association
BBR	Boverket Building Regulations
IFEM	Institute of Fire Engineers (UK) Malaysia Branch
CCOHS	Canadian Centre for Occupational Health and Safety
IFSS-CP	International Fire Safety Standards - Common Principles
AFSS	Automated Fire Suppression System
OSHMS	Occupational Safety and Health Management System
CCOHS	Canadian Centre for Occupational Health and Safety
OSHMS	Occupational Safety and Health Management
CO ²	Carbon Dioxide
CO	Carbon Monoxide
LED	Light-Emitting Diode
SPSS	Statistical Package for the Social Sciences
CAD	Computer-Aided Design



CHAPTER ONE

INTRODUCTION

1.1 INTRODUCTION

This research explores passive compartmentation within the context of passive fire design strategy. This research examines the effectiveness of passive compartmentation in roof voids of Malaysian national secondary schools to improve fire safety. National secondary schools in Malaysia are essential education and learning governmental institutions represented as the building typology in this research. This initial chapter establishes the research context by examining the occurrence of fire hazards in schools and discusses prominent research conducted by previous scholars. The chapter continues by presenting the problem statements, the aim of the study, the research objectives, the significance of the study and the thesis framework. All these components will be addressed in this chapter.

Cases of fire in schools have increased in recent years. This has caused interruption to the school's operations affecting students' well-being and has caused structural failure and collapses causing severe damage to the school structure extensively. Compartmentation for fire safety in passive design strategy for roof voids or cavities are crucial to be implemented to allow for a more effective and adequate fire containment within a small, localised and specific compartmentalised areas. The application of passive fire compartmentation in roof voids for national secondary school buildings is anticipated to minimize the impact and severity of damages to the school's structural integrity and the operational management after a fire hazard incident while safeguarding the safety of the users and occupants.

1.2 BACKGROUND RESEARCH

Schools serve as educational facilities as well as a temporary gathering place for students, teachers and parents. It represents a significant and valuable government

resource that needs to be protected (Nadzim, N., & Taib, 2014). However, the destruction resulting from a school fire can be severe causing damages and losses of life, property and school operation (Hassanain et al., 2022).

Children primarily occupy schools and their well-being is dependent on several factors. A legal term known as “In Loco Parentis” refers to the teacher’s obligation to act as parental substitutes while children attend school sessions (Mat Saad, 2019). Therefore, safe schools are required to protect the positive development of these children, as well as teachers and other users from fire hazards, as fire hazards pose a serious threat in schools (Bhebhe et al., 2019).

Fire Hazards can be defined as the potential of accidents or intentional fire endangering life safety and structural collapse of a building (Kodur et al., 2020). Fire safety is defined as the set of practices and regulations to be complied with to prevent the occurrence of fire hazards and to manage fire growth by accidental or intentional fires while keeping resulting losses to an acceptable level (Kodur et al., 2019). Passive fire design strategy plays a crucial role in reducing or preventing the spread of fire and smoke. This involves constructing compartments within the building and in the event of a fire, it will be contained to one specific area (Furness & Muckett., 2007).

Passive fire design strategy involves fire protection systems installed in a building that are accessible and available at all times whether or not a fire crisis exists (Fitzgerald, 2004, as cited in Hassanain, 2009). Fire protection systems refer to devices, features and characteristics that are part of a process or structure installed to prevent fire ignition, limiting fire development and growth from spreading into buildings (Justina et al., 2014). Aker (2008) emphasizes properly installed fire protection systems in a building with properly sealed penetrations and protected with suitable fire stop will ensure the fire barriers to function more effectively.

Some prominent studies on passive compartmentation on roof voids have been recorded through the years in countries such as the United Kingdom, Sweden and New Zealand. In the United Kingdom, 7,281 fire hazard incident cases were reported between the year 2009 until year 2019. Evidence revealed that since the year 2010, incidents of fire and smoke spread rapidly in British buildings, including residences,

nursing homes, hospitals and schools (Littlewood et al., 2017). The issues regarding fire and smoke spread were initiated based on research conducted by the Building Research Establishment (BRE) regarding fire hazard incidents reported to the Department for Communities and Local Government (DCLG) between the year 2003 and year 2013 involving different types of buildings.

The main issues identified were the cavities in roof compartmentation and cavity barriers for concealed spaces (Shipp et al., 2015). These findings were persistent with Littlewood et al (2015; 2016). The findings suggest thermal performance and acoustic performance, known as the Performance Gap, as well as fire safety performance, also known as the Safety Gap (Littlewood et al., 2017) were both compromised due to the unwanted air leakage pathway penetrating through the compartmentation due to technical deficiency of the cavity barriers.

Arson-caused fires in schools are significant in Sweden with an average of one or two school fire hazard incidents occurring every day. Most of the time, arson is the cause of a fire hazard incident and contributes to more than 40% of the 400 to 500 fires that occur annually in Swedish school buildings, including pre-schools and schools (Johansson et al., 2012). Earlier works on arson fires in Sweden have been recorded. In 2007, the Swedish Fire and Research Board (Brandforsk) initiated a multi-disciplinary initiative focusing on arson fires. According to Van Hess et al (2013), the most severe fire was found to be ignited on the exterior façade of schools and traveled up the façade and spreading through ventilation openings and into the roof elongation voids or cavities.

Schools in New Zealand were identified as having internal layouts, large ceiling void spaces, open plan layout configurations, classrooms block with long corridors connecting many rooms and service ducts (contained in roofs and walkways) that permitted fire and smoke to spread unrestricted and uncontrolled between rooms and contributed to the significance impact on the spread of fire and smoke (School Fires in New Zealand, 2002).

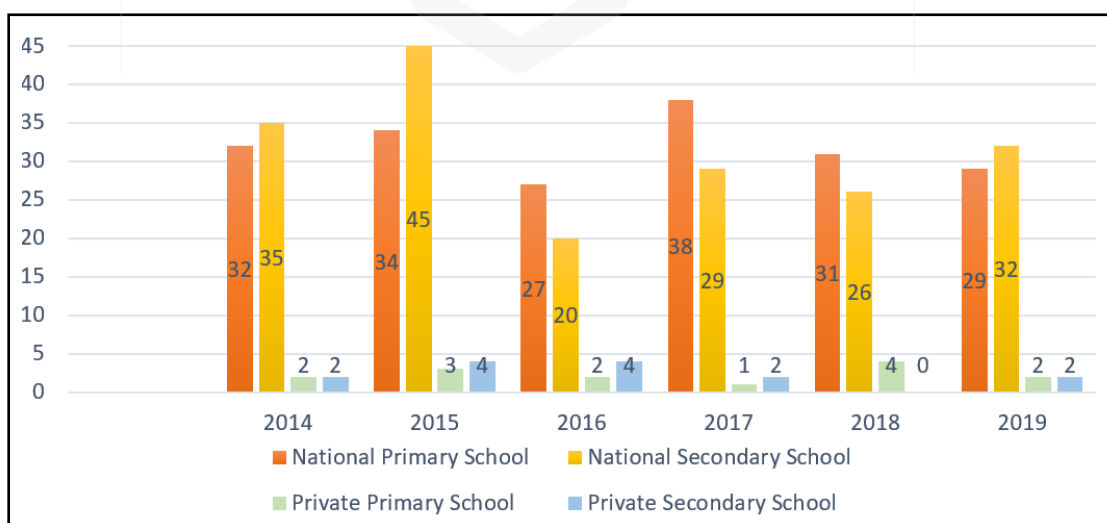
In Malaysia context, several scholars have carried out research on national schools concerning fire safety management (Nadzim, N., & Taib, 2014); (Aminrrasyid,

M.A., & Ramele. R, 2022), fire safety provision (Rosli, S.N., & Hashim, N., 2018), occupational safety (Subramaniam, 2022) and fire statistics analysis (Abdul Rahim, 2015). However, there is very few and limited research conducted on passive fire safety strategies in national secondary schools in Malaysia, particularly in relation to passive compartmentation for the spread of fire and smoke within roof voids or cavities. Therefore, the need for understanding the fundamentals and importance of passive compartmentation in roof voids is crucial and highly desirable. Compartmentation is the primary passive fire design strategy in fire-fighting protection and essentially safeguards the life safety of users especially school children in fire hazard incidents.

1.3 PROBLEM STATEMENTS

In Malaysia, fire hazard occurrences in national schools have received significant attention in the past few years. According to the statistics produced by the Fire and Rescue Department of Malaysia (FRDM), there were a total of 378 fire hazard incidents in national schools between the years 2014 to 2019, both primary and secondary with an average of 63 fire incidents occurring annually. This equates to approximately five incidents per month with the highest rate occurring in year 2015 as shown in Table 1.1.

Table 1.1: Statistics of Fire Cases in Schools in Malaysia



(Source: Fire and Rescue Department of Malaysia (FRDM), 2024)

Furthermore, based on the same statistics, fire occurrence in national schools for both primary and secondary schools was recorded as being the highest from the year 2014 until the year 2019, in comparison to privatised primary and secondary schools.

On July 31, 2022, at Sekolah Menengah Kebangsaan Agama Dato' Haji Abu Hasan Haji Sail in Pedas, Negeri Sembilan Darul Khusus (Berita Harian, 2022). A total of 668 students were affected by the incident forcing the school administration to conduct Teaching and Learning at Home (PdPR) sessions for a month. While no casualties were reported, the fire hazard caused severe damage to the upper floor and the structural roof.

A recent fire hazard incident in another national school was reported on April 21, 2024, at Sekolah Kebangsaan Laka Selatan, Kedah (NST, 2024). The fire incident involved five (5) classrooms on the third uppermost floor of the school block, which firefighters managed to extinguish before the fire spread up to the roof structure. The presence of a large cavity area within the roof space above the classrooms could cause fire and smoke to spread through the entire elongated roof of the building causing severe damage to the school's structural integrity. Therefore, this study intends to explore the potential of containing fire and smoke spread in roof voids or cavities in national secondary schools by improving passive compartmentation at roof voids to enhance fire safety in passive fire design strategy.



Figure 1.1 Fire Hazards in National Schools

(Source: Astro Awani, <https://www.astroawani.com/>)

1.4 RESEARCH QUESTIONS

The Research Questions were established for this research:

- i. What would be the current practices and provisions for national secondary school design to achieve fire safety on passive compartmentation at roof voids locally and internationally?
- ii. What are the existing conditions of fire safety design provision for passive compartmentation in particular vertical separation at roof voids in national secondary schools locally?
- iii. To what extent could passive compartmentation at roof voids be implemented in national secondary schools in Malaysia to achieve fire safety in a passive fire design strategy?

1.5 RESEARCH AIM AND OBJECTIVES

1.5.1 Research Aim

The research aims to investigate whether passive compartmentation at roof voids needed to be implemented for safety at national secondary schools in Malaysia as passive design strategy.

1.5.2 Research Objectives

Three (3) key objectives of the research were established to achieve the aim of the research:

- i. To review the current practices and provisions for national secondary school design to achieve fire safety on passive compartmentation at roof voids locally and internationally.
- ii. To identify and evaluate the existing conditions of fire safety design provision for passive compartmentation in particular vertical separation at roof voids in national secondary schools locally.

- iii. To provide recommendations on passive fire design strategy on compartmentation in roof voids implemented in national secondary schools in Malaysia for fire safety.

1.6 SIGNIFICANCE OF STUDY

Compartmentation at roof voids is essential in passive fire design strategies as cited by previous studies conducted in countries such as Britain (Shipp, 2014; Littlewood et al., 2016; Johansson et al., 2012; Littlewood et al., 2017). The studies have emphasized compartmentation as the primary component required in passive fire design strategy before any suppression system or active fire fighting comes into the role. In Sweden, the issue of fire and smoke spread within roof voids has been extensively researched and discussed (Johansson, 2012; Andersson, 1995; Brodin 2009, van Hess et al., 2010).

In Malaysia, previous scholars have studied national schools in relation to fire safety management. In Malaysia context, several scholars have carried out research on national schools concerning fire safety management, fire safety provision, occupational safety and analysis of fire statistics.

As identified above the absence of passive compartmentation research is significant to be explored further to fill the gaps for a more specific understanding with respect to the study on passive compartmentation at roof voids concerning national secondary schools in Malaysia. The findings of this study are to enhance the understanding and knowledge of the fire safety provisions and highlight the strategies for effective fire safety compliance in national secondary schools for the benefit of various stakeholders.

1.7 SCOPE OF THE RESEARCH

The research shall focus on case studies of national secondary schools that are the common dominator, providing a common ground for investigation and analysis. The case studies selection for this research shall include school buildings in the state of

Selangor in compliance with Selangor Uniform Building By-Laws 1986 (Revision 2012). The scope shall focus on the current practices and provisions and existing conditions of fire safety design provisions for passive compartmentation in particular vertical separation at roof voids concerning upper floor row classrooms in connection with the longitudinal roof structure. The study shall be an evidence-based study on passive compartmentation analysis concerning 1) compartmentation maximum limit, 2) compartment walls and floors, 3) undivided concealed spaces in roof voids, 4) cavity barriers and 5) fire detection provisions.

1.8 RESEARCH METHODOLOGY

The research methodology for this study was established with the research questions and research objectives. A mixed methodology of qualitative and quantitative methods from primary and secondary data was adopted in this study. The primary data was obtained using two (2) methods, the key informant's questionnaire and on-site observation. A site visit to three (3) national secondary schools was conducted to evaluate the current practices and provisions and existing conditions on passive fire design strategy on compartmentation in roof voids implemented in national secondary schools in the state of Selangor.

1.8.1 Qualitative Method: Literature Review (Secondary Data)

The purpose of the literature review is to develop an understanding of the research topic and all related contents. The qualitative data was obtained from various academic publications, research papers, dissertations, government statistics, building and fire codes, fire standards, online newspaper and web articles to comprehensively explore the concept and fundamentals of fire in national secondary schools. A comparative study was conducted between four (4) significant countries including Malaysia to identify building and fire codes and standards involved in this study.

1.8.2 Qualitative Method: Key Informants Questionnaire (Primary Data)

The questionnaire was designed to gather information related to the research problem. A structured questionnaire was employed as the data collection instrument for this study. This method allowed for a structured approach with close-ended questions consisting of numerical responses with multi-choice answers. Likert scales were adopted as rating scales. This quantitative data was later analysed using statistical analysis.

Open-ended questions allowed the respondents to provide detailed text-based answers to explore emerging themes that offered insights from the key informants based on their knowledge and experiences. The qualitative data collected was later analysed using thematic analysis. A total of twenty-two (22) respondents were selected as key informants for this survey. The respondents possessing a range of fire safety expertise, provided a rich diversity of perspectives and enriched the data collection.

1.8.3 Quantitative Method: On-site Investigation (Primary Data)

This observation method was conducted to gain a comprehensive understanding of the current practices and provisions and existing conditions on passive fire design strategy on compartmentation in roof voids. The observation involved a systematic on-site inspection of three (3) selected national secondary schools. A structured observational approach was adopted to ensure a thorough and accurate data collection was obtained. The data-gathering technique adopted was observing, measuring, note-taking and photographic recording. On-site measurements were conducted to establish the dimensions and heights of the classrooms. While, field notes, photographic recordings and observation checklists were employed to record all relevant data collected during the site visits. The research framework is presented in Figure 1.2.

1.9 RESEARCH FRAMEWORK

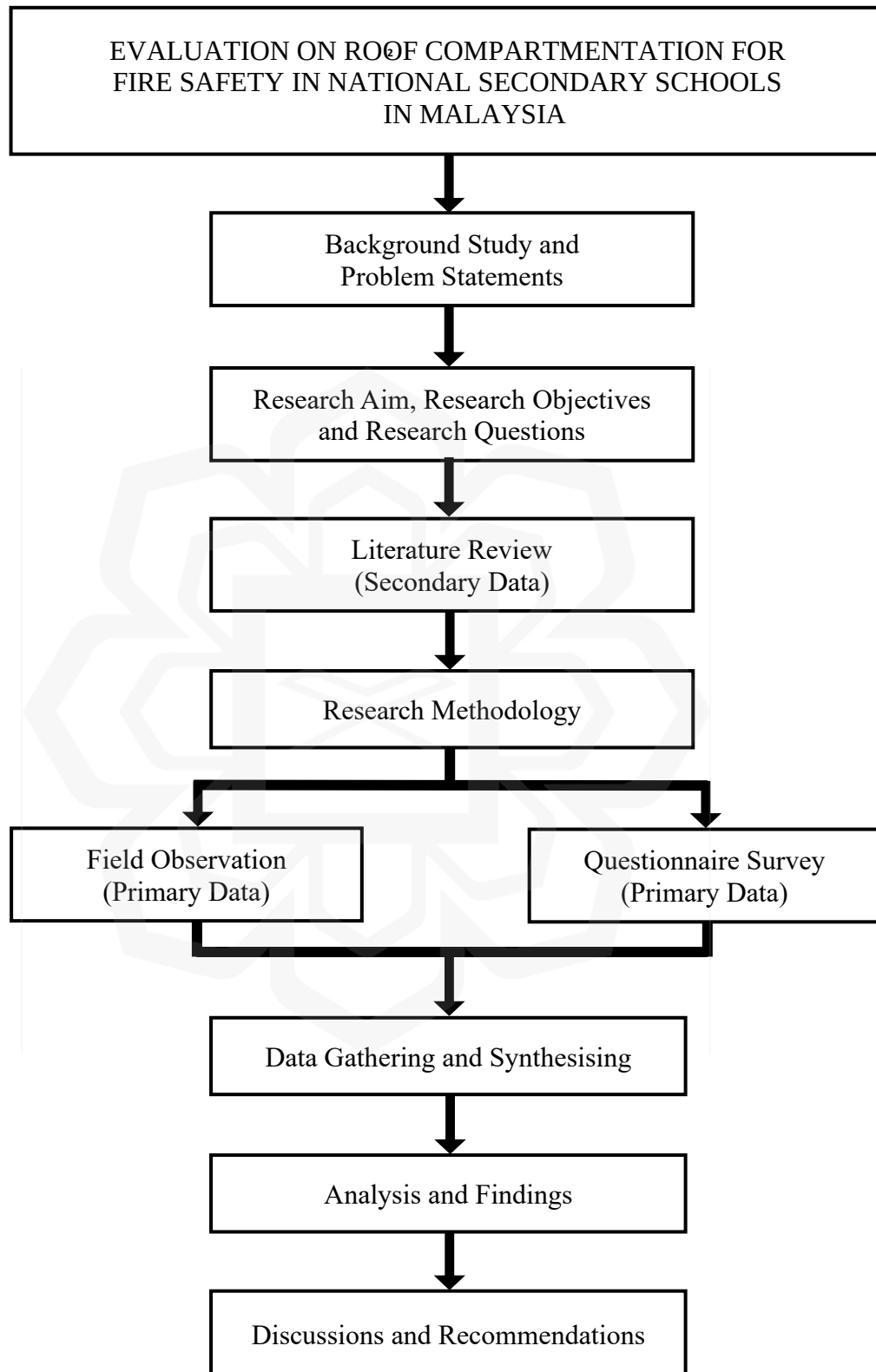


Figure 1.2 Research Framework

1.10 STRUCTURE OF RESEARCH

This research consists of 6 chapters, 1) Introduction, 2) Education System in Malaysia and The Concept of Fire Safety, 3) Compartmentation in Roof Voids for Passive Fire Design Strategy, 4) Research Methodology, 5) Result and Discussion and 6) Conclusion and Recommendations. Each chapter is briefly outlined in the following.

Chapter One: Introduction

This chapter introduces the background of the problem and issues of the research. Then, problem statements were determined by the issues leading to the research questions, research aim and research objectives. The significance of the study and the scope of the research are also presented in this chapter. The selected research methodology and thesis framework outline the research process that enables the researcher to systematically investigate and answer the research questions.

Chapter Two: Education System in Malaysia and The Concept of Fire Safety

This chapter presents a comprehensive review of the literature on the Malaysian education system and the physical development of the national secondary schools in Malaysia. Additionally, the science of fire, principles of fire propagation and concept of fire safety in compliance with Selangor Uniform Building By-Laws (SUBBL) 1986 (Revision 2012) are discussed. This chapter provides a contextual understanding of the research by exploring the educational setting, building characteristics, fire science principles and the fire safety regulatory framework.

Chapter Three: Compartmentation in Roof Voids for Passive Fire Design Strategy

This chapter presents a detailed examination of passive fire compartmentation design practices in the context of Malaysian fire safety regulations as well as other significant countries. The study highlights the specific requirements outlined in the building and

fire codes and standards for achieving compartmentation in school buildings. In order to establish a broader understanding and perspective, this chapter also incorporates an analysis of passive fire regulations and practices implemented in other globally recognized jurisdictions including Malaysia. By comparing and contrasting this regulatory framework, the study aims to identify effective strategies for enhancing passive fire safety design and to highlight potential areas for improvement in the Malaysian context.

Chapter Four: Research Methodology

This chapter summarizes the methodology involved in this research. A mixed-method approach was adopted, combining both qualitative and quantitative techniques. Data was collected through questionnaires, both close-ended and open-ended questions and on-site observations using field notes, photographs and observation checklists.

Chapter Five: Result and Discussion

This chapter discusses the evaluation of the actual implementation of passive fire compartmentation design strategy in roof voids of the three (3) selected schools. The evidence-based assessment collected through on-site observation provided firsthand insights into the current practices and provisions and existing conditions of fire safety measures in schools. This chapter also incorporates findings from questionnaires administered to the key informants. Visual presentations of key findings are presented in the form of statistical analysis and thematic analysis. Additionally, photographs and checklists are also presented from the data obtained from on-site observations by analysing the recorded field notes, photographic evidence and observation checklists.

Chapter Six: Conclusions and Recommendations

This chapter presents a discussion and analysis of roof compartmentation findings and provides recommendations for improving fire safety in Malaysian secondary national

schools. By implementing a comprehensive regulatory framework for consistent and effective enforcement of fire safety design standards in schools, for the safety and well-being of students and staff, mitigating potential loss of life and property damage.

1.11 CHAPTER SUMMARY

This chapter established the foundation for this research by setting the aim and establishing the Research Aim, Research Objectives and Research Questions. The research methodology and research framework are further proposed for the research to be conducted. The research conducted is narrated by forming six (6) chapters for the thesis. The subsequent chapter will present a thorough literature review to contextualize the research in understanding the research topic. The chapter will include the Malaysian educational system and secondary school infrastructure in Malaysia, fire science and fire safety regulations under the (SUBBL) 1986 (Revision 2012). This contextual overview establishes the foundation for the research to be conducted.

CHAPTER TWO

EDUCATION SYSTEM IN MALAYSIA AND THE CONCEPT OF FIRE SAFETY

2.1 INTRODUCTION

The literature review was conducted based on secondary data that included various academic publications, research papers, dissertations, government statistics, building and fire codes, fire standards, online newspaper and web articles. School buildings in Malaysia will be the subject of investigation. Therefore, it is imperative to understand the Malaysian Education System in place, particularly the classification of types of national secondary schools and the way classrooms are designed and configured. The review was also made on the science of fire and principles of fire propagation. This would assist the researcher in understanding the concept of Selangor Uniform Building By-Laws (SUBBL) 1986 (Revision 2012).

2.2 AN OVERVIEW OF THE EDUCATION SYSTEM IN MALAYSIA

The Malaysian education system has experienced transformative changes throughout its history, from the pre-colonial to post-independence period. Based on Malaysia's multi-ethnic, religious, linguistic and cultural society, a comprehensible philosophy of education was needed while respecting the long tradition of Malay and Islamic-based education. The Eastern and Western philosophies introduced by the Chinese and Indian communities in Malaysia were also acknowledged (Khairul, 2011). This has resulted in the National Education Philosophy (NEP) establishment to integrate and harmonise its diverse educational influences.

Malaysia's education system is federally governed and managed by the Ministry of Education (MOE). The Malaysian National Education System consists of five phases: 1) preschool, 2) primary education, 3) lower secondary education, 4) upper

secondary education and 5) post-secondary/ tertiary education (Malaysia Education Blueprint (2013 – 2025), 2013).

2.2.1 History and Direction of Education System in Malaysia

Sivalingam (2020) provided a comprehensive overview of Malaysian education history. Before British colonization in 1924, Malaysian education was informal and focused on religious teachings, values, morality, spirituality, martial arts and handicrafts. It involved practical survival skills including agriculture, fishing and hunting (Husin, 1989). Meantime, the Islamic religious education system was in existence, known as “Pondok” (small hut) (Muhammad et al. 1992).

Between 1824 and 1941, before World War II, the British colonial administration in Malaya implemented a “Divide and Rule” education policy (Husin, 1989). This led to the establishment of four (4) separate school systems with different language streams for Malay, Chinese, Tamil and English-speaking students. Japanese occupation in Malaya during World War II (1941-1946) disrupted the existing education system, imposing the Japanese language and culture. While English and Chinese education was suppressed, Malay and Tamil schools adapted to the new regime (Husin, 1989). This period highlighted Malay awareness of the need for independent education (Muhammad, et al, 1992).

Post-independence Malaysia, beginning in the year 1957, established a comprehensive education system through the National Education Policy enacted in 1961. Subsequent policies, include the New Economy Policy 1979 -1990 (which led to the Education Act of 1961 and revised to the Education Act 1996), the Education Development National Development Policy 1991 - 2000, the Education Development Plan 2001 - 2010 and the Malaysian Education Blueprint 2013- 2025 have shaped the Malaysian educational landscape. These policies have provided the basis for the needs of physical infrastructure and facilities, curriculum developments, human resources capital and financial allocations in the Malaysian educational system.

2.2.1.1 National Education Philosophy (NEP)

The National Education Philosophy (NEP) was developed in Malaysia following a 1979 Cabinet Committee Report under the Review of Education Policies Implementation and was implemented in 1988. The NPE was based on national ideologies, namely the National Principle or “Rukun Negara”, reflecting Malaysian societal values and emphasizing rational and critical thinking.

According to the National Philosophy of Malaysia, Malaysia’s education aims to develop well-rounded individuals emphasizing intellectual, spiritual, emotional and physical balance. The ultimate goal is to cultivate knowledgeable, competent, honourable and responsible citizens who contribute in achieving peace and well-being in society and the nation (Department of Education Selangor, 2013).

Education in Malaysia is monitored and governed federally. Schools are categorized as government-run, government-aided or privatized. The education system follows a centralised structure, comprising four (4) tiers; federal, state, district and school. These levels are represented by the Ministry of Education (MOE), state education departments, district education officials and schools respectively as illustrated in Figure 2.1.

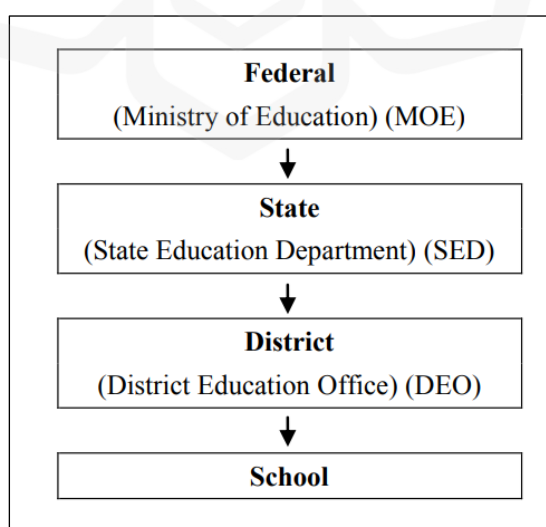


Figure 2.1 Education Management in Malaysia
(Source: Ministry of Education (MOE), 2004)

2.2.1.2 Ministry of Education (MOE)

The Ministry of Education (MOE) is responsible for providing education at the pre-tertiary level, as enacted under the Education Act 1996. The MOE has established a comprehensive schooling system from the stage of pre-school to secondary school. The MOE outlines the strategies for enhancing education excellence through the Malaysian Education Blueprint 2013-2025. Children in Malaysia can begin their education as early as at the age of four (4) years old at pre-schools and primary education starts at age six (6). Both primary and secondary education are compulsory with the government providing free education for six (6) years at the primary level and five (5) years at the secondary level. After completing secondary education, students can choose to pursue higher education with appropriate required academic grades and funding.

2.2.1.3 Act 550 National Education Act 1996

The replacement of the National Education Act 1961 to National Education Act of 1996 is the primary legislation governing education in Malaysia. It covers pre-school education, primary education, secondary education, post-secondary education, higher education, teacher education, special education, religious teachings, technical education, national and private educational institutions, but excludes education in foreign school systems, for example, international and expatriate schools (Education Act, 1996).

The Act mandates the use of Bahasa Melayu as the national language as the medium of instruction in all educational institutions within the national education system, exceptional for national-type schools or other institutions exempted by the Ministry of Education (MOE). All schools under the MOE are required to follow a national curriculum and prepare students for common public examinations unless otherwise exempted.

2.2.1.4 Malaysian National Curriculum

The National Curriculum specifies a list of subjects for all levels of schooling, categorized as: 1) ‘core subjects’ that must be learned by all students in government, government-aided and private schools, 2) ‘compulsory subjects’ that includes all non-core subjects that must be learned by students in government and government-aided schools, 3) ‘additional subject’ that is taught in accordance with the Act in government and government-aided schools and 4) ‘elective subjects’ that are non-compulsory and non-core subjects chosen by students in government and government-aided schools based on their interests, talents, abilities and potential (Malaysia Education Blueprint (2013 – 2025), 2013).

2.2.1.5 Malaysian Education Blueprint, 2013 – 2025

Malaysia is currently implementing the Malaysian Education Blueprint 2013-2025, an extensive plan initiated by the Ministry of Education (MOE) in 2013 to establish an inclusive, efficient and high-quality education system. The goal is to produce Malaysians who are value-driven, knowledgeable, capable and critical and creative thinking, effective communicators and possess leadership skills. The Blueprint reflects the government’s commitment to continuously improve the education system and aims to provide Malaysian students with a well-rounded education that enables students to reach their full potential. In achieving its vision, the Malaysian Education Blueprint 2013-2025 includes eleven (11) strategic and operational shifts focused on improving access to education, raising quality standards, reducing achievement gaps, promoting unity amongst students and optimizing system efficiency (Malaysia Education Blueprint (2013 – 2025), 2013).

2.2.2 Types of Secondary Schools in Malaysia

Three (3) categories of educational institutions are specified by the National Education Act of 1996, that are government educational institutions, government-aided educational institutions and private educational institutions. The National Education

Act 1996 defined ‘Government-aided schools’ as institutions that receive a capital grant and full grant-in-aid, whereas a ‘private school’ or ‘private educational institution’ are schools or education institutions that are not a government or government-aided school or education institution, that includes international and expatriate schools (UNESCO, 2011) as illustrated in Table 2.1.

Table 2.1 Types of Secondary Schools in National Education of Malaysia

Types of Secondary Schools	Administrative Authority
National Secondary School (Sekolah Menengah Kebangsaan)	Ministry of Education (MOE)
Regular secondary schools	MOE and Private Organizations
National Religious Schools (Sekolah Agama Bantuan Penuh Kerajaan)	MOE
Government-aided Religious Schools Sekolah Agama Bantuan Kerajaan (SABK)	MOE and the state religious authority or school’s board of trustees
Government-aided Religious Schools Sekolah Agama Rakyat (SAR) Sekolah Agama Persendirian (SAP)	MOE and State Islamic Religious Department, or State Islamic Religious Council, or State Islamic Foundation, or Private Organizations
National Religious Schools	State Religious Department or Private Organizations
Fully Residential Schools	MOE
MARA Junior Science Colleges	Council of Trust for the Bumiputera of Malaysia (MARA) and Ministry of Entrepreneurial and Co- operative Development (MECD)
Military Colleges	Ministry of Defense
Special Model Secondary Schools	MOE
Sports Schools	MOE
Performing Arts Secondary Schools	MOE
Independent Chinese Schools	Private Organizations
Trust School (based on Trust School Framework)	Public Private Partnership (PPP) Yayasan Amir
Special Model Schools	Private Organizations
<i>International schools</i>	Organizations registered with the Companies Commission of Malaysia (CCM)
School in Hospital (SDH) program program	Public Private Partnership (PPP) Ministry of Health Malaysia (MOH)
School in Prison program	Public Private Partnership (PPP) Department of Prison Malaysia

(Source: Adapted from United Nations Educational, Scientific and Cultural Organization (UNESCO), 2011)

2.2.3 Physical Development of National Schools in Malaysia

Schools or educational buildings are designed and constructed based on the National Education Policy. The guidelines control the continuity of the school design to be in line with the National Education Philosophy. Schools are often designed as complexes where several building blocks with different functions are combined on one site, for instance, a school complex may include pre-school buildings, schools, canteens, workshops, laboratories and multipurpose halls. The area of these complexes is guided by the norms stated in the guidelines based on: 1) building category, 2) allowable floor area and 3) finish specifications (Economic Planning Unit, 2015).

According to Liew et al (1981), the design of a school involves a process from the time it is planned, followed by the construction process and then evaluated for its effectiveness. This process involves planning the construction program of a school so that it can be effectively implemented and the resources used more efficiently. A total of 10,117 school buildings excluding the number of pre-schools were recorded in Malaysia (Roslizar et al., 2014).

2.2.3.1 Classroom Module Design

A secondary school building is classified under A2.0: Educational Building in the EPU 2015 Book of Guideline and Regulations for Building Design and can be categorized into administration, academic, other facilities and special education. According to the Guideline and Regulations for Building Design (2015), the standard floor area of a classroom is 67.5 m² per classroom or 2.25 m² per student and a classroom in a secondary school building should have a maximum of 30 students (Norazman et al., 2019).

At its inception, the design approach of national secondary schools in Malaysia has been standard and typical design. Most schools are built on a standard layout developed by the Malaysian Public Works Department (PWD), resulting in similar building designs across school design planning configurations. The space planning of schools is influenced by the most recent primary and secondary school curriculums,

with the number of classrooms being determined by the courses or subjects offered (Denan, et al., 2018). On average, a typical classroom dimension is 9m in length and 7.5m in width, which is equivalent to 67.5 m² or 726. 57 ft². This is based on 2.2 m² per student in a typical classroom. The grid system of 9m in length and 7.5m in width has been adopted in the configuration of a typical classroom layout as shown in Figure 2.2. Subsequently, a typical block section is shown in Figure 2.3.

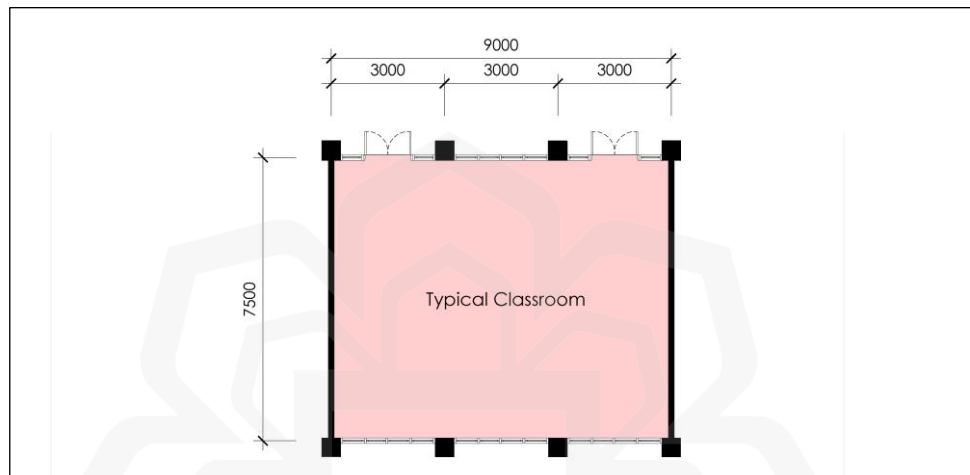


Figure 2.2 Typical Classroom Layout

(Source: Public Works Department (PWD) Pre-Approved Plan (PAP), 2015)



Figure 2.3 Typical Block Section

(Source: Public Works Department (PWD) Pre-Approved Plan (PAP), 2015)

2.2.3.2 Public Works Department (PWD) Module School Design 2020

In the year 2020, the Malaysian Public Works Department (PWD) embraced the new modular system for the design of national schools. The proposed modular planning layout systems are 3M, 4M, 6M and 6M+ as illustrated in Figure 2.4.

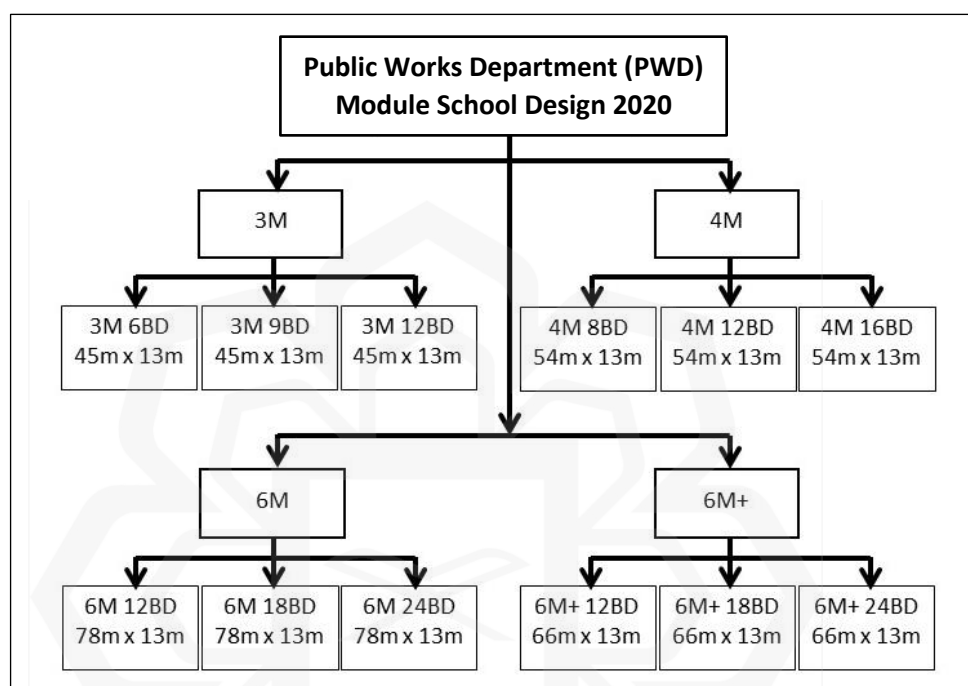
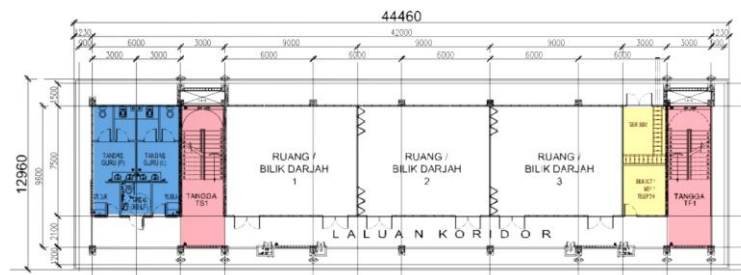


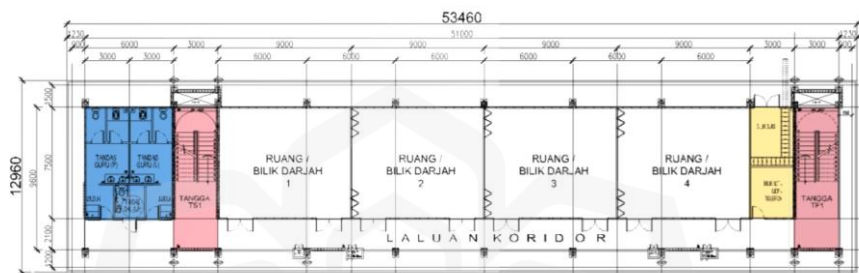
Figure 2.4 Public Works Department (PWD) Module School Design 2020
(Source: Public Works Department (PWD) Module School Design 2020, 2020)

Figure 2.5 (a), (b), (c) and (d) shows the four (4) typical floor plans with the following permutations:

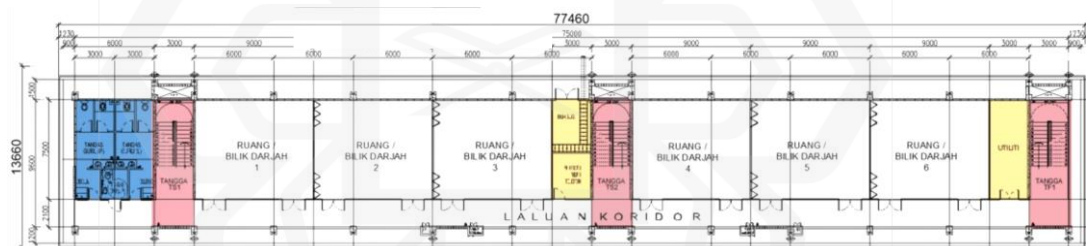
- 1) 3M floor plan with three (3) numbers of classrooms per floor,
- 2) 4M floor plan with four (4) numbers of classrooms,
- 3) 6M floor plans with six (6) numbers of classrooms per floor, and
- 4) 6M+ floor plan with three (3) numbers of classrooms to accommodate and facilitate the Program Pendidikan Khas Integrasi (PPKI).



(a) Typical Floor Plan 3M



(b) Typical Floor Plan 4M



(c) Typical Floor Plan 6M



(d) Typical Floor Plan 6M+

Figure 2.5 (a), (b), (c), (d) Typical Module Floor Plans developed by PWD
(Source: Public Works Department (PWD) Module School Design 2020, 2020)

2.3 The Science of Fire

Fire can be defined as "A rapid oxidation process, which is a chemical reaction resulting in the evolution of light and heat in varying intensities." (NFPA 921). Fire could also be defined as uncontrolled combustion (Phillip Ackland Holdings Ltd.,2012). The NFPA 921 definition of combustion is "A chemical process of oxidation that occurs at a rate fast enough to produce heat and usually light in the form of either a glow or flame." To understand the behavior of a fire in a building for instance a school, it is essential to understand the principles of fire science.

2.3.1 The Triangle and Fire Tetrahedron

The basic concept of fire is about a chemical reaction between three elements of a fire triangle which are fuel, oxygen and heat for a combustion or fire to occur as illustrated in Figure 2.6. Fuel is any substance that can undergo combustion, while heat is the energy above the minimum level necessary to release fuel vapors resulting in fire ignition. Oxygen acts as the oxidizing agent that is available in the atmosphere. This self-sustaining combustion that continues when sufficient heat is known as an uninhibited chemical chain reaction. These four elements are considered to form the Fire Tetrahedron as explained in Figure 2.7. These elements are required to start and sustain a fire in the smoldering mode.

Fire is an oxidation process that releases heat, light and sound, often with great intensity and this instantaneous energy release can cause temperatures to rise, sometimes by thousands of degrees. This results in the production of smoke and toxic waste of fire's leftovers (NFPA, 2022). Fire can occur when these four (4) elements are present in sufficient measure.

However, a fire cannot occur or continue to burn if one of the elements is eliminated. This principle forms the foundation for fire safety measures as in fire prevention practices and fire extinguishing strategies that will break up the uninhibited chain reaction of the combustion (NFPA, 2022).

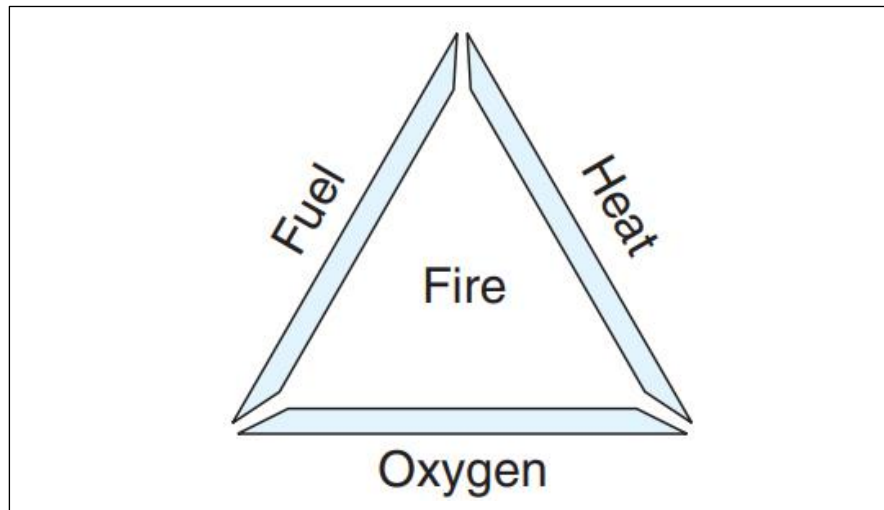


Figure 2.6 The Fire Triangle
(Source: National Fire Protection Association (NFPA), 2022)

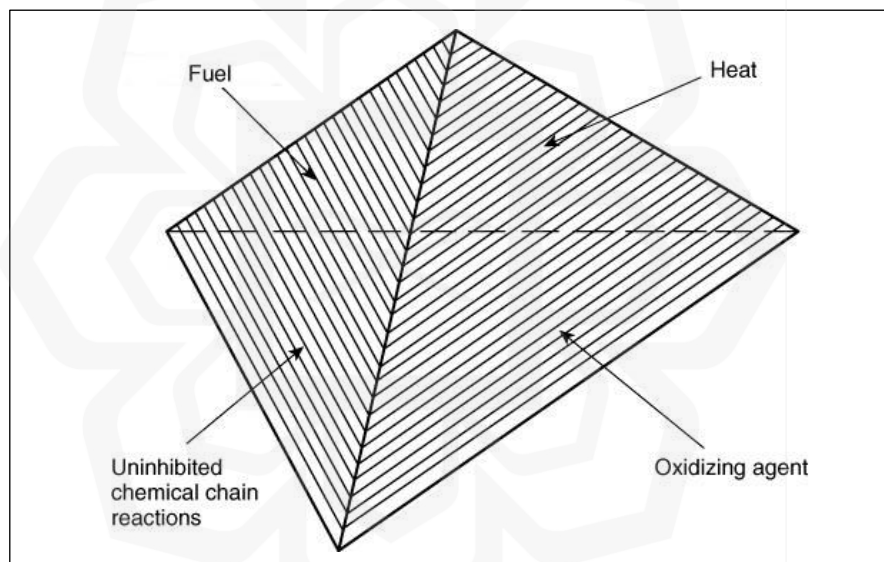


Figure 2.7 The Fire Tetrahedron
(Source: Goetsch, 2011)

2.3.2 Principles of Fire Propagation

Fire propagates when heat energy is transferred to nearby fuel in the presence of oxygen through conduction, convection and radiation. Conduction is the transfer of heat within solids through the vibrations and direct contact of molecules. Convection is the transfer of heat through gas or liquid and involves the movement of the medium. Radiation is the transfer of heat in the form of rays or waves and does not require an intervening

medium between the source and receiver. These modes of heat transfer play a prominent role in the propagation of the fire as they help it grow and reach other sources of fuel in the surroundings.

2.3.2.1 Stages of Fire Development

There are four essential stages of fire development namely, 1) inception stage, 2) growth; 3) fully developed and 4) decay or burnout. Figure 2.8 shows a Fire Curve that demonstrates the development of each stage over the period of time.

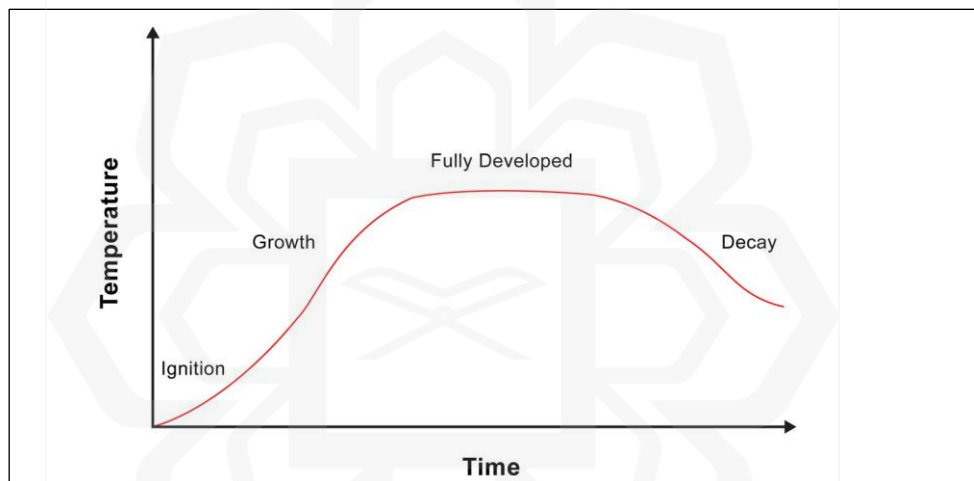


Figure 2.8 The Fire Curve
(Source: NIST, <https://www.nist.gov>)

2.3.2.2 The Ignition Stage

The ignition stage or inception is the process, fuel, oxygen and heat join together in a sustained chemical reaction. It marks the beginning of flame propagation where a material is heated to the point of spontaneous combustion. At this stage, the three (3) elements of fire: fuel, oxygen and heat are present and mixed in precise quantities to initiate ignition and sustain the chemical reaction.

2.3.2.3 The Growth Stage

The growth of fire is the phase that occurs after the ignition stage. It is a self-sustained chemical reaction where the initial flame becomes a heat source to ignite additional fuels nearby through convection, radiation and conduction. At this stage, a phenomenon called flashover takes place. Flashover occurs in an enclosed space when hot gases rise to the ceiling and spread across the walls. Heat radiates downwards and intensifies until all combustible items reach their ignition point and give off flammable gases or vapors that are hot enough to sustain combustion. The size of the fire increases and the smoke plume reaches the ceiling. Hot gases collecting at the ceiling transfer heat, allowing all fuels in a room to come closer to their ignition temperature at the same time (NFPA, 2022).

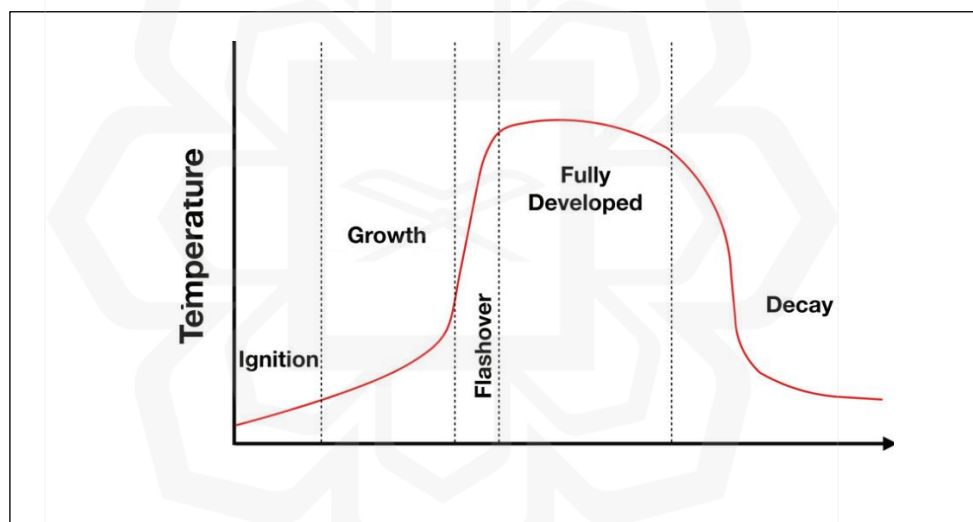


Figure 2.9 The Flashover Phenomenon
(Source: Cortés Blasco, et al.,2020)

2.3.2.4 The Fully Developed Stage

At this stage, the fire has reached its maximum intensity and temperature. Almost all available fuel has been consumed and oxygen is being rapidly used up. The temperature has reached its peak and the size of the fire depends on the availability of fuel and oxygen in the environment. Fire temperatures can reach as high as 1,000 degrees Celsius

and the resulting thermal expansion and degradation in material properties pose a serious threat to structural safety.

2.3.2.5 *The Decay Stage*

Decay or smoldering is the stage that follows the fully developed stage when all fuel or oxygen has been consumed. As the concentration of oxygen decreases and is converted to Carbon Dioxide (CO²) and Carbon Monoxide (CO), free burning is no longer supported. The flames and the fuel begin to glow. Smoldering can continue for hours before the fire is completely extinguished. Dangers during this stage include dangerous by-products and the occurrence of a hazard called backdraft. Backdraft occurs when oxygen is abruptly introduced into a compartmentalised smoldering fire and can result in an explosion in extreme cases.

2.3.3 The Concept of Fire Safety in Buildings

Most of the existing fire protection precaution provisions are prescribed in the Building and Fire Codes. There are four main strategies for fire safety measures, 1) Evacuation, providing a means of escape for occupants in the event of fire, 2) Passive containment, delays or stops the spread of fire and smoke within a building or between buildings, 3) Active intervention, involves detection and extinguishment of fire and 4) Access for fire fighting and rescue by providing the firefighters and rescue personnel to access and enter the burning building to carry out their duties. These provisions for fire safety measures are in line with the progression of fire development.

2.3.3.1 *Evacuation*

Evacuation refers to leaving a facility as quickly and safely as possible. Fire evacuation involves the process of removing people or occupants from an area in the event of a fire to a safe place, away from the burning building. When a fire is detected in the inception or growth stage of a fire development, building occupants are alerted via fire alarm

systems (manual or automated) and occupants are to exit away from the building safely through escape paths and staircases provided. In this inception stage, the fire could easily be contained, controlled and extinguished using fire extinguishers, while they still can.

2.3.3.2 *Passive Containment*

Structural fire protection is provided by building elements designed to maintain their load-bearing and separating functions during fire. Fire compartmentations prevent the spread of fire within or between buildings. Fire rarely spreads by burning through walls or floors but can spread through concealed spaces and openings. To ensure the integrity of a fire compartment, all openings must be protected to resist the spread of fire.

During this fully developed fire stage, the last defense for controlling fire is through passive fire protection involving compartmentation and structural stability. Passive fire protection includes; 1) adequate compartmentation to inhibit the spread of heat, smoke and gases: 2) limiting fire compartment size, 3) controlling the flammability of wall linings and fire stopping, 4) controlling the spread of smoke, 5) providing protected escape routes and 6) stability and structural performance. Passive fire protection systems (structural and non-structural building components) are designed to ensure structural stability during fire exposure and to contain fire spread.

During this stage, the main target of passive fire protection systems is to contain the spread of fire while ensuring structural stability. Therefore, all structural and non-structural members are required to satisfy the fire safety criteria for the required duration of fire exposure. These passive fire protection systems allow safe, 1) fire fighting operations, 2) safe evacuation operations and 3) mitigate property losses (Kodur, 2019).

The structural stability through the fire compartmentation is also crucial as a means to assist in, 1) localizing the fire, 2) allowing for a continuation of the fire fighter's fire staging area and rescue operations and 3) preventing property losses caused by complete structural collapse.

2.3.3.3 Active Intervention

Active fire protection systems, such as sprinklers, heat and smoke detectors, etc. or suppression systems are designed to detect and control or extinguish a fire in its initial stage and more importantly from life safety perspectives. Suppression systems involve manual or automated systems installed within the building used to control and limit the fire and are essential for early detection. Active fire protection measures include: 1) provisions of alarm systems - audible, visual, etc., 2) provision of automatic fire detectors, flame detectors, smoke detectors, 3) indication of the location of a fire on a visual display, mimic diagram, etc., 4) provision of smoke/heat venting and exhaust control systems to extend escape time, 5) closing of smoke dampers in ducts and closing of doors to create fire compartmentations, etc., 6) release of access control systems on doors, gates, turnstiles to facilitate escape and 7) provision of automatic suppression systems.

When a fire goes into a growth phase, the priority is to evacuate people out of the building as inhalation of toxic gases from the fire can be fatal within minutes (Alarie, 2002). In this stage, the fire management falls to automated or manual active fire protection systems.

2.3.3.4 Access for Fire Fighting and Rescue Intervention

Access for fire fighting and rescue refers to providing access to any premises or place or to any part thereof for the purpose of extinguishing, fighting, preventing or limiting a fire. If the fire is not extinguished through active fire protection systems, extinguishing or controlling fire as well as ensuring life safety comes down to the role of the fire fighting department. The time required by the fire fighting department to reach the site and begin fire fighting operations plays a key role in fire fighting and is known as response time. The fire fighting department is equipped with specialized equipment to provide alternate entries into a building and to perform rescue operations even in the most inaccessible places.

2.4 Regulatory Framework in Malaysia

The primary objective of fire safety and building regulations is to ensure the safety of life. Fire Services Act 1988 (Act 341) assigns the building owners and management responsibility of ensuring occupant safety, through a self-declared fire certificate. Malaysia's fire protection framework is primarily structured by the key legislations, which includes: 1) Fire Services Act 1988 (Act 341), 2) Street, Drainage and Building Act 1974 (Act 133), 3) Uniform Building By-Laws (UBBL) 1984 (Revision 2021) and 4) Malaysian Standard Fire Safety in the Design, Management and Use of Buildings (MS:1183). Table 2.2 shows the Fire Safety Regulatory in Malaysia.

Table 2.2 Overview of Malaysian Fire Safety Regulatory

Term	Nature	Scope	Document
Act	Law	Overall legal framework for fire safety in Malaysia	Fire Services Act 1988
Building Code	Technical Standards	Comprehensive Building Requirements	(UBBL) 1984 (Revision 2021) (SUBBL) 1986 (Revision 2012)
Fire Code	Technical Standards	Specific Fire Safety Requirements	PART VII and PART VIII in (UBBL) 1984 (Revision 2021) and (SUBBL) 1986 (Revision 2012)
Standards	Technical Specifications/ Guidelines	Detailed Technical Guidelines	Malaysian Standard Fire Safety in the Design, Management and Use of Buildings (MS:1183)
Circulars and Notices	Administrative Directives	Clarifications and Implementations	Circulars issued by the Fire and Rescue Department of Malaysia (FRDM) and Lembaga Arkitek Malaysia (LAM)
Guideline	Recommendation	Advisory, Best Practices	Guide to Fire Protection in Malaysia

It is significant to understand the interrelation of Malaysia fire safety Acts and regulations, between the Acts enacted by parliament and the state. The (UBBL) 1984 (Revision 2021) and (SUBBL) 1986 (Revision 2012) incorporate fire safety standards mandated by the Fire Services Act 1988. Additionally, the technical specifications outlined in MS:1183 complement this legal framework as standards and guidelines. Combined with supplementary circulars and guidelines, all these establish a comprehensive regulatory system for fire safety in Malaysia.

2.4.1 Fire Services Act 1988

The Laws of Malaysia (Act 341) Fire Services Act 1988 is the highest level of legislation and the foundation of fire safety legislation in Malaysia. The Act provides for the effectiveness and efficiency functionality of the Fire and Rescue Department of Malaysia (FRDM). The Act is divided into parts each dealing with different aspects of the fire services that outline the role administration of the Fire and Rescue Department of Malaysia (FRDM), general fire safety principles including requirements for obtaining fire certificates.

2.4.2 Uniform Building By-Laws (UBBL) 1984 (Revision 2021)

The Uniform Building (Amendment) By-Law 2021 had taken effect on December 31, 2021, as announced by the federal government. The (UBBL) 1984 (Revision 2021) was originally published and gazetted on September 12, 1985. Since then, the (UBBL) 1984 (Revision 2021) has undergone several revisions with the recent amendments made in 2021. Nevertheless, the State Authority has the jurisdiction to make and issue Building By-Laws under Section 133 of the Street, Drainage and Building Act (Act 133). Any state may choose or discard any By-Laws they think are fit and beneficial for their administration and to put these By-Laws into effect, the relevant states and federal territories, excluding Sarawak and Sabah, are required to announce these By-Laws prior to the implementation by the respective Local Authorities.

The (UBBL) 1984 (Revision 2021) is a set of rules or By-Laws that contribute to ensuring the safety and health of the public and the building users and occupants are being safeguarded. It describes a thorough framework for building development and upkeep and aids in ensuring all structures adhere to a set of minimal and quality requirements. Two out of the nine Parts of these By-Laws are dedicated to building fire protection provisions:

- 1) Part VII: Fire Requirements (Passive Fire Protection), and
- 2) Part VIII: Fire Detection, Fire Alarm and Fire Extinguishment (Active Fire Protection).

2.4.3 Selangor Uniform Building By-Laws (SUBBL) 1986 (Revision 2012)

While the (UBBL) 1984 (Revision 2021) is used as a national building code in Malaysia, individual states have the authority to establish their own specific building rules and regulations if required. The (SUBBL) 1986 (Revision 2012), is similar to (UBBL) 1984 (Revision 2021). However, (SUBBL) 1986 (Revision 2012) may differ from (UBBL) 1984 (Revision 2021) with its specified conditions and needs for legislation in the state of Selangor. Both the national building and fire code (UBBL) 1984 (Revision 2021) and state-level building and fire code (SUBBL) 1986 (Revision 2012) include regulations for fire safety: Part VII: Fire Requirements (Passive Fire Protection) and Part VIII: Fire Detection, Fire Alarm and Fire Extinguishment (Active Fire Protection).

2.4.4 Fire Safety in the Design, Management and Use of Buildings Malaysian Standard 1183 (MS:1183) 2015

The MS:1183 demonstrates the application of international standards being modified and adapted in the Malaysian local context. The enforcement of these standards is voluntary to be practiced (Department of Standards Malaysia, 2006). However, there are compulsory standards that need to be complied with, such as the standards concerning the process of fire certificate issuance which are considered mandatory by the Fire and Rescue Department of Malaysia (FRDM). The compulsory compliance is for fire safety components, such as; fire doors, fire dampers, bricks, “KELUAR” signs, emergency lights, smoke detectors, heat detectors, manual fire alarms, fire alarm panels, alarm bells, hose reels, smoke extraction system and fire extinguishers.

2.4.5 The Circulars

Circulars are administrative orders issued by the agency to streamline the prescriptive of fire safety standards and guidelines. In Malaysia, circulars are issued by the Fire and Rescue Department of Malaysia (FRDM) and Lembaga Arkitek Malaysia (LAM) as notices and directives concerning the (UBBL) 1984 (Revision 2021) or (SUBBL) 1986

(Revision 2012) as additional technical guidance documentation for clarification or reminders on implementation of rules and regulations to all industry stakeholders.

2.4.6 The Guideline for Fire Protection

The Guide to Fire Protection in Malaysia is a comprehensive guideline published with in-depth information incorporating diagrams and illustrations to clarify the By-Laws as prescribed in the (UBBL) 1984 (Revision 2021). The publication was edited by Dato' Hamzah Bin Abu Bakar (Director General Fire and Rescue Department of Malaysia) and is mainly used by professionals in the construction industry by translating the By-laws into easily understandable visual representations. It is published by the Institute of Fire Engineers (UK) Malaysia Branch (IFEM) in association with the Fire and Rescue Department of Malaysia (FRDM), Pertubuhan Arkitek Malaysia (PAM), Institute of Engineers Malaysia (IEM) and Association of Consulting Engineers Malaysia (ACEM).

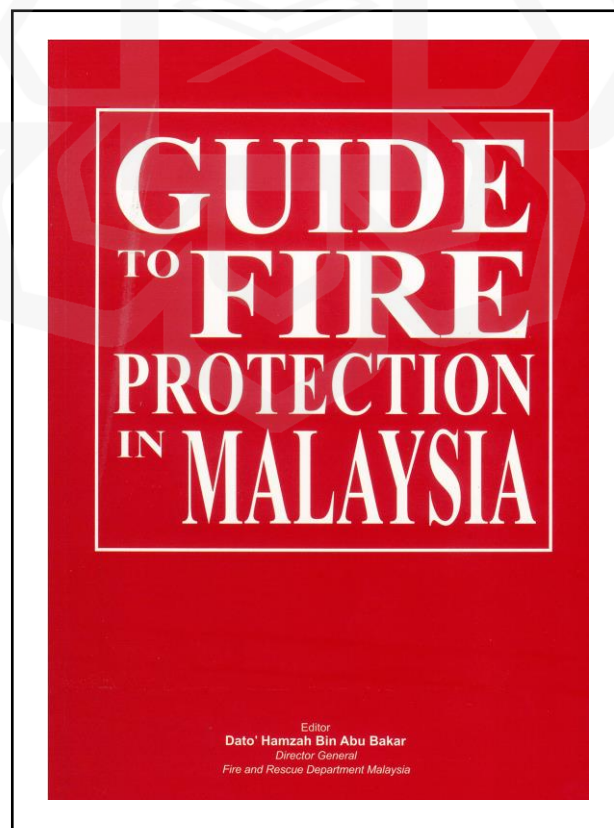


Figure 2.10 Guide to Fire Protection in Malaysia

2.4.7 Bodies and Agencies of Fire Protection in Malaysia

In Malaysia, several agencies are involved in fire safety and Fire and Rescue Department of Malaysia (FRDM) also known as BOMBA is a federal agency responsible for fire fighting and technical rescue operations. The Malaysian Fire Protection Association (MFPA) represents industry stakeholders, manufacturers, contractors and professionals in fire trades and promotes fire safety advancements. The Department of Standards Malaysia (DSM) is responsible for developing, promoting and implementing standards related to fire safety involving building construction, materials and equipment. MS:1183 is one standard that outlines building fire safety guidelines.

2.4.8 Selangor Uniform Building By-Laws (SUBBL) 1986 (Revision 2012):

Prescriptive By-laws

Fire safety in the state of Selangor is regulated by the prescriptive codes in the Selangor Uniform Building By-Laws (SUBBL) 1986 (Revision 2012). The fire safety provisions are prescribed in Part VII: Fire Requirements and Part VIII: Fire Alarms, Fire Detection, Fire Extinguishment and Fire Fighting Access.

2.4.8.1 PART VII: Fire Requirements (SUBBL) 1986 (Revision 2012)

Components and elements to be considered in the passive fire protection in connection with Part VII: Fire Requirements.

Table 2.3 Classification for Passive Fire Requirements

1) General and References
2) Containment and Protection
3) Exits and Evacuation
4) Rescue

(Source: Selangor Uniform Building By-Laws (SUBBL) 1986
(Revision 2012))

The related By-laws for each classification of passive fire requirements are specified in the tables based on the breakdown of topics below.

2.4.8.1.1 General and Reference By-laws (SUBBL) 1986 (Revision 2012)

Table 2.4 Classification for General and References By-laws

No.	By-law	Description
1	133	Interpretation
2	134	Designation of Purpose Groups profile of occupants, fire risk – escape, occupancy load, quantum of fire load
3	135	Rules of Measurement
4	209	Reference to buildings a) Reference to Fifth Schedule a) Purpose Group b) Limit of Compartmentation
5	215	Height of Building

(Source: Selangor Uniform Building By-Laws (SUBBL) 1986 (Revision 2012))

2.4.8.1.2 Containment and Protection By-laws (SUBBL) 1986 (Revision 2012)

Table 2.5 Classification for Containment and Protection By-laws

No.	By-law	Description
A. Compartmentation		
1	136	Provisions of compartment walls and compartment floors
2	137	Floor in building exceeding 30m in height to be constructed as compartment floors
3	138	Other walls and floors to be constructed as compartment walls or compartment floors
4	139	Separation of fire risk areas
5	148	Special requirements as to compartment walls and compartment floors

No.	By-law	Description
Lobbies		
33	196	Smoke lobbies
34	197A	Means of access and fire fighting in buildings over 18m
35	197B	Fire Fighting Access Lobby
36	197	Protected lobbies
Fire Stops		

6	220	Floor area and capacity of buildings and compartments	37	161	Fire stopping
B. Elements of Structure			Surface and Materials		
Separating Wall			38	203	Restriction of spread of flame
7	141	Separating walls	39	204	Classification of restriction of flame over surfaces of walls and ceilings
8	147	Construction of separating wall	40	205	Classification of interior finish materials
External Walls			41	206	Classification of surface of wall and ceiling
9	142	External walls	42	207	Exceptions relating to wall and ceiling
10	144	Cladding and External Wall	Roofing		
11	145	References to Sixth Schedule	43	208	Reference to roofs
12	146	Relevant Boundary	44	210	Construction of roofs
13	149	Horizontal and vertical barriers at the external walls	45	211	Roofing materials
Structure			46	211A	Construction materials
14	143	Beam and column	47	212	Category designation for the fire penetration and spread of flame on roof surface
Shaft			C. FIRE RESISTANCE		
15	150	Protected shafts	48	213	Fire resistance
16	151	Ventilation to lift shafts	49	214	Additional requirements
17	152	Openings in lift shafts	50	217	Fire resistance of structural
18	156	Protected shafts as ventilating duct	51	218	Compartment walls separating flats and maisonnette
19	157	Protected shafts consisting of staircase	52	219	Application of these By-laws to floors
Air Conditioning System			53	221	Test of fire resistance
20	160	Fire precaution in air-conditioning system	54	222	Fire resistance for walls
Doors			55	223	Fire resistance for floors above ground floor
21	162	Fire doors in compartment walls and separating walls	56	224	Fire resistance for any element of structure
22	163	Half hour and one hour door	D. DESIGNATED SPACE / SPECIAL PROVISION		
23	164	Door closers for fire doors	57	158	Stages in places of assembly
24	193	Power operated doors as means of egress	58	159	Open stages
Staircase			59	194	Building with single staircase
25	189	Enclosing means of escape in certain buildings	60	216	Single storey buildings
26	190	External staircase	Moving Walks		
27	191	Opening in adjacent walls not permitted	61	192	Moving walks
28	198	Ventilation of staircase enclosures			
29	199	Ventilation of staircase enclosures in buildings not exceeding 18 meters			
30	200	Ventilation of staircase enclosures in buildings exceeding 18 meters			
31	201	Staircase enclosure below ground			
32	202	Pressurized system for staircase			

(Source: Selangor Uniform Building By-Laws (SUBBL) 1986
(Revision 2012))

2.4.8.1.3 Exits and Evacuation By-laws (SUBBL) 1986 (Revision 2012)

Table 2.6 Classification for Exits and Evacuation By-laws

No.	By-law	Description
A. DETECTION AND FIRE MODE OPERATIONS		
1	153	Smoke detectors for lift lobbies
2	154	Emergency mode of operation in the event of mains power failure
3	155	Fire mode of operation
4	172	Emergency exit signs
5	187	Notice affixed to door or gate
B. EXITS CONSIDERATION		
6	165	Measurement of Travel Distances to Exits
7	166	Exits to be accessible at all times
8	167	Storey Exits
9	168	Staircases
10	169	Exit Routes
11	170	Egress through unenclosed openings
12	171	Horizontal exits
13	173	Exit doors
14	174	Arrangement of storey exits
15	178	Exits for institutional and other places of assembly
16	182	Rate of discharge
17	183	Exit details for places of assembly
18	184	Seating
19	185	Gangways in places of assembly
20	186	Exit doors in places of assembly
21	188	Travel distance in places of assembly
22	195	Staircases to reach roof level
C. CAPACITY EXITS AND OCCUPANCY LOAD		
23	175	Calculation of Occupant load
24	176	Computing storey exit width
25	177	Computing number of staircases and staircase width
26	179	Classification of places of assembly
27	180	Space standards for calculating occupancy load
28	181	Width of means of egress

(Source: Selangor Uniform Building By-Laws (SUBBL) 1986
(Revision 2012))

2.4.8.1.4 Rescue By-laws (SUBBL) 1986 (Revision 2012)

Table 2.7 Classification for Fire Rescue By-laws

No.	By-law	Description
1	140	Fire Appliance Access
2	197A	Means of Access and Fire Fighting in buildings over 18m
3	197B	Fire Fighting Access Lobby

(Source: Selangor Uniform Building By-Laws (SUBBL) 1986
(Revision 2012))

2.4.8.2 PART VIII: Fire Alarms, Fire Protection, Fire Extinguishment and Fire Fighting Access (SUBBL) 1986 (Revision 2012)

The main reasons for using an active fire protection system is to gain time for safe evacuation and to control or suppress a fire in order to minimise fire damage to contents and buildings. Active fire protection systems will include means of automatic fire detection systems as well as suppression extinguishing devices.

Table 2.8 Active Fire Requirements

No.	By-law	Description	No.	By-law	Description
1	225	Detecting and extinguishing fire	14	239	Voice communication system
2	226	Automatic system for hazardous	15	240	Electric isolation switch
3	226A	Hose reel	16	241	Special requirements for fire alarm systems
4	227	Portable extinguishers	17	243A	Emergency exit power failure
5	228	Sprinkler valves	18	245	Approval of D.G.F.S
6	229	Means of Access and Fire Fighting in buildings over 18,3m	19	248	Marking on Wet riser, etc.
7	230	Dry rising system	20	249	Smoke and heat venting
8	231	Wet rising system	21	250	Natural draught smoke vent
9	232	Wet and dry systems for buildings under construction	22	251	Smoke vents to prevent accumulation of smoke
10	235	Fixed Installations	23	252A	Atrium in building
11	236	Special Hazards	24	253	Emergency power system
12	237	Fire alarms	25	253A	Emergency light
13	238	Command and control centre			

(Source: Selangor Uniform Building By-Laws (SUBBL) 1986
(Revision 2012))

2.5 The Development of Fire Safety Standards and Regulations in Malaysia

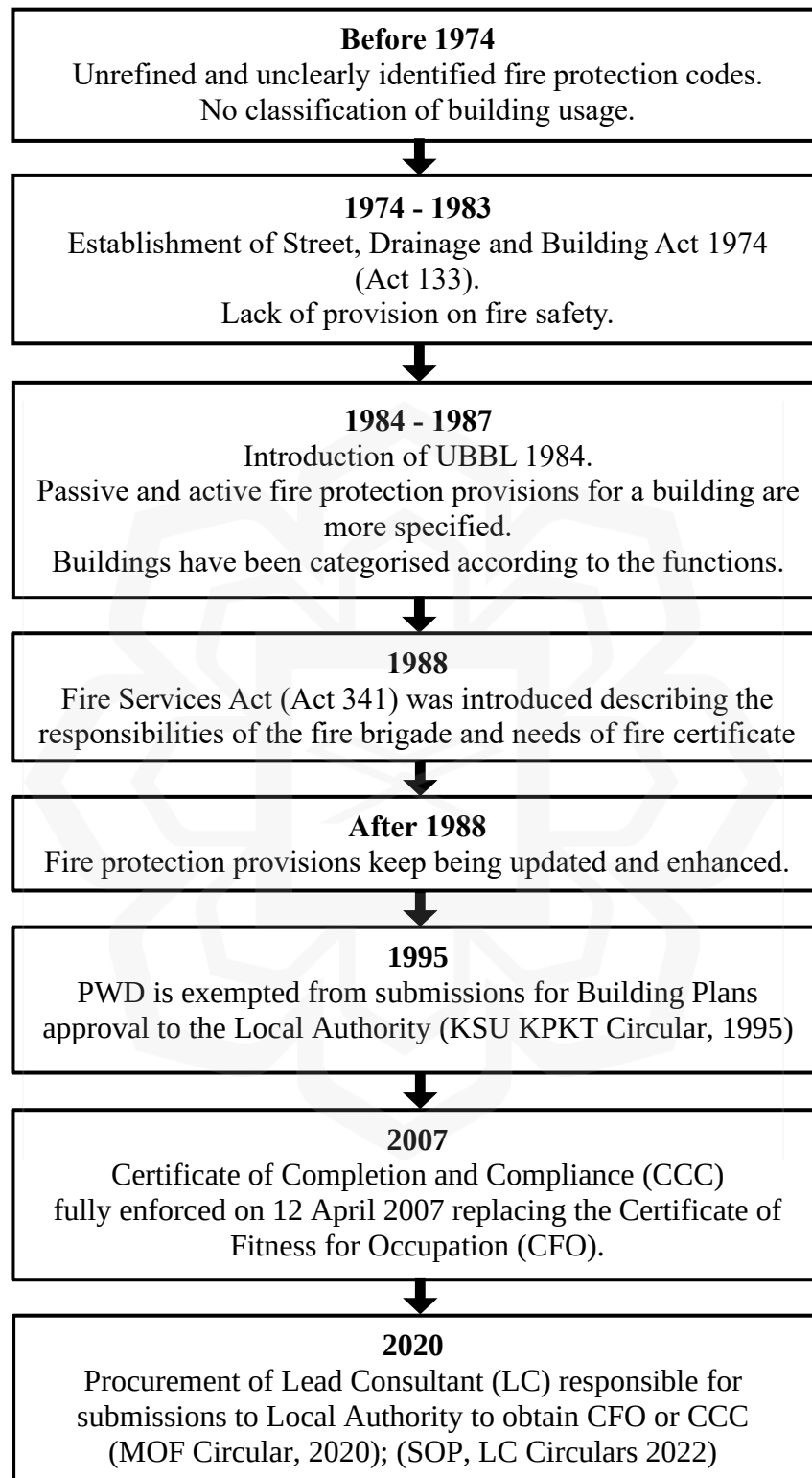


Figure 2.11 The Development of Fire Safety Standards and Regulations in Malaysia
(Adapted from Implementation of Fire Codes in Malaysia
(Akashah, Wan Teh & Baaki, 2016)

Figure 2.11 shows the development and implementation of fire safety standards and regulations in Malaysia. Prior to the year 1974, the Street Drainage and Building Act 1974 9 (Act 133) allowed for fire prevention and early warning measures, particularly regarding the clear marking of fire hydrants, installation of fire alarms and prevention of bush fires (Akashah, Wan Teh & Baaki, 2016). Uniform Building By-Laws 1984 was introduced in 1984 with passive and active fire protection provisions for a specified and categorised building type according to the functions (Akashah, Wan Teh & Baaki, 2016).

Fire Services Act (Act 341) was introduced in 1988 describing the responsibilities of the fire brigade and the need for a fire certificate. The Certificate of Completion and Compliance (CCC) has been fully enforced in Malaysia since 12 April 2007 replacing the Certificate of Fitness for Occupation (CFO) (mygovernment, 2022).

2.5.1 Work Implementation by The Public Works Department (PWD)

2.5.1.1 Prior to Implementation of Standard Operating Procedure (SOP) Procurement of Lead Consultant (LC)

Government projects are typically implemented in two (2) methods: 1) in-house execution by the Public Works Department (PWD) or 2) by appointing external consultants or Lead Consultant (LC) for planning, designing and supervising the project from commencement until completion (PWD, 2020). When a government project is executed in-house, the Public Works Department (PWD) being a government agency, acting as an executing agency is exempted from obtaining a Certificate of Fitness for Occupation (CFO) or Certificate of Completion and Compliance (CCC) (KSU KPKT Circulars, EPU Circular).

In accordance with the circular, Regulations on Federal Building Construction in Local Authority Areas (KSU KPKT Circulars issued on 15 August 1995) and a subsequent circular dated 14 June 1999 and EPU Circular dated 3 Jun 1999, all development proposals managed by the government executing agencies are exempted from obtaining a Certificate of Fitness for Occupation (CFO) or Certificate of

Completion and Compliance (CCC) (KPKT,1999). The circulars highlighted the Public Works Department (PWD) obligations for all government and federation building projects execution as stated below:

- 1) The Public Works Department (PWD) shall obtain approval from the Local Authority or Pihak Berkuasa Tempatan (PBT) for Planning Permission or Kebenaran Merancang (KM) or Development Order for Dewan Bandaraya Kuala Lumpur (DO-DBKL),
- 2) The Public Works Department (PWD) is exempted from submissions for Building Plans (BP) approval to the Local Authority or Pihak Berkuasa Tempatan (PBT). Drawings and documentation to be submitted for record-keeping purposes,
- 3) However, government or federation building projects which are built for sale purposes shall submit Building Plans (BP) for approval and to comply with (UBBL) 1984. This is to ensure compliance to the standard building plan approval process and finally obtain a Certificate of Fitness for Occupation (CFO) or Certificate of Completion and Compliance (CCC).

2.5.1.2 Implementation of Standard Operating Procedure (SOP) Procurement of Lead Consultant (LC)

Subsequently, the Public Works Department (PWD) has implemented the Procurement of the Lead Consultant (PK 3.11) procedure in relation to the circular issued by the Ministry of Finance (MOF) on June 5, 2020 (MOF Circular, 2020). This procedure outlines the process for appointing a Lead Consultant (LC) to oversee the planning, coordination and project management of the government and federation building projects. The Public Works Department (PWD) Standard Operating Procedures (SOP) for Lead Consultant (LC) Procurement, issued in 2022 are both aligned with the circular on PK 3.11 issued by the Ministry of Finance (MOF).

2.5.2 Lead Consultant (LC)

The implementation of the Lead Consultant (LC) Procurement shall require the HOPT (Head of Project Team) from the Public Works Department (PWD) to lead the procurement process. The HOPT (Head of Project Team) will identify the key appointed HODT (Head of Design Team) from the relevant fields within the Public Works Department (PWD): Architect, Mechanical Engineer, Electrical Engineer, Surveyor and Quantity Surveyor. The Lead Consultant (LC) shall also be a Principal Submitting Person (PSP) or a Submitting Person (SP) to oversee the planning, coordination and project management of the government and federation building projects. The Lead Consultant (LC) is responsible for drawings and documentation submission for approval to the Local Authority or Pihak Berkuasa Tempatan (PBT) to obtain a Certificate of Fitness for Occupation (CFO) or Certificate of Completion and Compliance (CCC).

2.5.3 Certificate of Completion and Compliance (CCC)

The Certificate of Completion and Compliance (CCC) was fully enforced in Malaysia on 12 April 2007, replacing the Certificate of Fitness for Occupation (CFO). The introduction of Completion and Compliance (CCC) is in parallel with the government's intentions to implement a self-certification and self-regulation approach in the construction industry. Certificate of Completion and Compliance (CCC) is aimed to further improve the efficiency of the project development service delivery system through efforts to reduce bureaucracy (JKR, 2021).

The Lead Consultant (LC) shall submit relevant drawings and documentation to the Local Authority's Internal Technical Agencies or Agensi Teknikal Dalaman (ATD) and Internal Technical Agencies or Agensi Teknikal Dalaman (ATD) for approval. Once all of the departments have approved with consensus, an official approval letter will be issued indicating compliance with all relevant regulations and By-Laws. Table 2.9 shows the list of the relevant External Technical Agencies or Agensi Teknikal Luaran (ATL) and Internal Technical Agencies or Agensi Teknikal Dalaman (ATD).

Table 2.9 List of External Technical Agencies or Agensi Teknikal Luaran (ATL) and Internal Technical Agencies or Agensi Teknikal Dalaman (ATD)

Internal Technical Agencies or Agensi Teknikal Dalaman (ATD)	1. Planning Department 2. Building Department 3. Engineering Department 4. Landscape Department 5. Other related departments in the Local Authority
External Technical Agencies or Agensi Teknikal Luaran (ATL)	1. Land and Mines Office 2. State Water Authority 3. Indah Water Consortium (IWK) 4. Irrigation and Drainage Department (JPS) 5. Fire and Rescue Department of Malaysia (FRDM) 6. Department of Environment (DOE) 7. Malaysian Communications and Multimedia Commission (SKMM) 8. Tenaga Nasional Berhad (TNB) 9. Public Works Department (PWD) 10. Department of Minerals and Geosciences (JMG) 11. Civil Aviation Authority of Malaysia (CAAM) 12. Town and Country Planning Department 13. Other related departments

(Source: mygovernment, 2024; Ang 2022)

2.5.4 Submission of Fire Protection Drawings to Fire and Rescue Department of Malaysia (FRDM)

Part of the submission shall include a full set of Fire Drawing Submissions to the Fire and Rescue Department of Malaysia (FRDM) for approval. Lai (2020) emphasized the crucial role of fire protection drawings in securing and obtaining approval from the Fire and Rescue Department of Malaysia (FRDM) for a building's Certificate of Completion and Compliance (CCC) or Fire Certificates. Fire protection in a building encompasses two (2) key strategies, Passive Fire Protection and Active Fire Protection. Both passive and active fire drawings shall indicate the elements and systems required to comply with the relevant By-laws, as prescribed in (UBBL) 1984 (Revision 2021) and (SUBBL) 1986 (Revision 2012).

2.5.4.1 Passive Fire Protection Drawings

In obtaining approval from Fire and Rescue Department of Malaysia (FRDM), passive fire protection is the sole responsibility of an Architect as the Principal Submitting Person (PSP). The submission drawings shall comply with Part VII: Fire Requirements as prescribed in Selangor Uniform Building By-Laws (SUBBL) 1986 (Revision 2012) by providing means of compartmentation and facilitating safe evacuation. The passive fire protection drawings shall clearly indicate the components and elements as shown in Table 2.10.

Table 2.10 Components and Elements to be Indicated and Shown
in the Passive Fire Protection Drawings

Internal Building (Floor plans)	1. Floor Area 2. Travel Distance and Dead Ends 3. Location of exits and staircases 4. Fire doors indication 5. Type of walls (brick wall thickness/ gypsum wall) 6. Type of structure with designated fire-rated hours 7. Fire breaks (compartmentation wall in red colour/ Party walls 8. Marking of areas requiring special fire suppression equipment, sprinklers, protected lobbies, fire dampers, heat and smoke detectors, pressurised systems, etc. 9. Marking areas of fixed extinguishing/ cleaning agents such as CO₂, FM200, Aerosol, etc. 10. Complete list of fire requirements to be described 11. Portable fire extinguishers 12. Emergency lights 13. Emergency exit signs 14. Breeching inlet location/ wet riser and dry riser location 15. Hose reel, break glass and alarm location 16. Fire intercom position 17. Fire lift
External Building (Site plan)	1. Fire hydrant indicated along fire appliance access road 2. Breeching inlet location (distance to nearest fire hydrant) 3. Ramp design shall comply with a minimum ratio of 1:12 (1:15 for Selangor) 4. Bomba road access (yellow colour)
General information	1. 'Kehendak-kehendak' Bomba including Architect's endorsement under 'Perakuan' stated 2. Occupancy load calculation schedule 3. Fire appliance access calculation

(Source: (SUBBL) 1986 (Revision 2012); Ang 2022)

2.5.4.2 Active Fire Protection Drawings

In obtaining approval from the Fire and Rescue Department of Malaysia (FRDM), active fire protection is the sole responsibility of the Mechanical Engineers as the Principal Submitting Person (PSP) concentrating on systems for fire detection, suppression and occupant alert. The submission drawings shall comply with Part VIII: Fire Detection, Fire Alarm and Fire Extinguishment as prescribed in Selangor Uniform Building By-Laws (SUBBL) 1986 (Revision 2012). The Mechanical Engineer will further submit drawings and other related documents subsequent to receiving the Bomba passive system approval from the Architect. The active fire protection drawings will incorporate additional components and elements into the already approved passive fire protection drawings. The active fire protection drawings shall clearly indicate the components and elements as shown in Table 2.11.

Table 2.11 Components and Elements to be Indicated and Shown
in the Active Fire Protection Drawings

Internal Building (Floor plans)	1. All indications same as included in the passive drawings (in black colour) and remove yellow colour from the road access 2. Pipe connection from the pump room and pressure valve to hose reel system and sprinkler system 3. Heat and smoke detectors (with exact location/ quantity) conduit connection 4. Sprinkler head (with exact location/ quantity) piping connection
External Building (Site plan)	1. All indications same as included in the passive drawings (in black colour) and remove yellow colour from the road access 2. External pipe connection layout from meter to sprinkler tank or fire hydrant tank to pump and to pressure valve 3. External pipe connection layout of fire hydrant system
Other drawings	1. Sprinkler, fire hydrant, hose reel schematic drawing with complete detailed specification schedule 2. Schematic diagram of fireman intercom panel 3. Schematic diagram of the main fire alarm control panel

(Source: (SUBBL) 1986 (Revision 2012); Ang 2022)

2.6 Fire Hazards and Risks

Hazards can be defined as any source of potential damage, harm or adverse health affecting something or someone (CCOHS, 2023). A hazard is a potential for harm or an adverse effect to people's health, to organizations as property or equipment losses or to the environment. Potential hazards may be caused by, 1) physical hazards, 2) chemical hazards, 3) biological hazards, 4) psycho-social hazards and 5) ergonomics hazards. Hazards means a source, situation or act with a potential for harm in terms of human injury or ill health and property damage (Guidelines on OSHMS, 2011).

Risk is defined as a combination of the likelihood of an occurrence of a hazardous event or exposure within a specified period or in specified circumstances and the severity of injury or damage to the health of people, property, environment or any combination of these caused by the event or exposure (Guidelines on OSHMS, 2011). Misnan (2013) defined risk as a combination of likelihood of occurrence and severity of injury or damage.

2.6.1 Fire Hazards in Schools

Fire hazards are defined as any actions, materials or conditions that might increase the size or severity of a fire or that might cause a fire to start (Introduction to Fire Inspection Principles and Practices Common Fire Hazards). Fire hazards in buildings is also defined as the potential of accidental or intentional fire causes that threaten life, structural and property safety in a building (Kodur et al. 2020). Fire incidents constitute a critical type of hazard in school facilities (Jonsson et al., 2016; Bhebehe et al., 2019). Schools are among the high-risk facilities for fire hazards, due to the presence of various types of combustible materials and sources of fire ignition (Hassanain et al., 2022). Statistics indicated that a significant number of fatalities and injuries, around the world have taken place in schools, due to fire accidents (Lambie et al., 2018).

Fire hazards in the United Kingdom were found to usually start inside a room (90% of school fires are limited to the item first ignited and/or the room of origin) (Fire Safety Design for Schools Building Bulletin 100 (revised) UK). Deliberate fires caused

by arson can be ignited anywhere from both inside or outside of buildings. In recent years, around 22% of school fires in the United Kingdom were classified as deliberately set.

In Sweden, almost every day one or two school fires occur in Sweden. In most cases, arson is the cause of the fire and it accounts for more than 40% of the annual 400-500 fires in Swedish school buildings (Swedish Fire Protection Association, 2010). The fire spread within a building is caused by exterior fires, which are initiated outside the building and then spread to the inside (Johansson, 2012), (Anderson, et al, 2011).

2.7 Chapter Summary

This chapter has presented a comprehensive overview of Malaysia's education system school design and the concept of fire safety. The fire science principles and the elaboration of relevant fire act, regulations and standards from the (UBBL) 1984 (Revision 2021), (SUBBL) 1986 (Revision 2012) and the MS:1183 have enhanced the researcher's understanding of the regulatory framework of fire strategy in Malaysia. This fundamental knowledge could be used to further understand the principle of passive compartmentation for passive fire design strategy which will be elaborated in the next chapter.

CHAPTER THREE

COMPARTMENTATION IN ROOF VOIDS FOR PASSIVE FIRE DESIGN STRATEGY

3.1 Introduction

This chapter explores the fundamentals of passive compartmentation as a passive fire design strategy and examines relevant fire codes and guidelines. This chapter discusses the current practices and provisions for national secondary school design to achieve fire safety on passive compartmentation at roof voids locally and internationally. Comparisons will also be made on fire safety practices in roof voids compartmentation in schools between Malaysia and other countries.

3.2 Containment Principle

According to Paul Stollard et al., 1999, fire containment safeguards both property protection and life safety. Passive fire protection ensures: 1) property protection through the limitation of fire spread and fire resistance provided to the elements of structure, 2) life safety through the limitation of smoke spread and through the provision of places of refuge within the building to which the occupants can retreat. The containment principle objectives is limiting of fire and all of its consequences to as small an area as possible.

This containment principle is accepted in designing for safe evacuation which means there will be “Only one fire at one location at a time”, while the main goal of compartmentation is ‘to contain the one fire within the one location at all times’ (Chong, 2012). In case of fire, it should be contained to control the spread of fire and smoke, ensuring that people can safely escape and evacuate from the burning building and that the structural fire will not cause the building to collapse.

International Fire Safety Standards-Common Principles (IFSS-CP) defined the containment principle as limiting fire and all of its consequences to as small an area as possible through different strategies including, 1) compartmentation, 2) smoke control, 3) fixed fire fighting systems, 4) structural integrity and 5) controlling the combustibility and smoke performance of materials used. A combination of these strategies are used as fire safety measures ensuring the containment principle is achieved.

3.3 Undivided Concealed Spaces

Johansson et al (2013) highlighted the fire separation in the roof voids or between the roof voids and the space below. Roof voids and ceiling voids shall be designed to ensure that the protection against fire spread between fire compartments is maintained. Passive compartmentation shall be considered for both within the roof voids (above the ceiling) and the area below the ceiling. Both shall be designed to ensure that the extensive spread of fire and smoke is limited through the provisions of maximum limit dimensions for undivided concealed spaces within a roof space (voids above the ceiling) and maximum limit of area (space below the ceiling). The maximum dimensions provisions may apply to both directions based on the layout plan (MS:1183; Fire Strategy Report UK, 2021; Building Bulletin 100 UK, 2021).

3.4 Compartmentation

Compartmentation means buildings can be subdivided to restrict the spread of fire by the use of walls and/or floors of fire-resisting construction. These walls and/or floors are provided to ensure effectiveness for the performance of compartmentation. The internal subdivision of a building into fire compartments influences the, 1) escape arrangements, 2) evacuation procedures and 3) the number of stairs and exits. Only the occupants and contents within the fire compartment are regarded as initially at risk from fire as described by Fire Safety in the Design, Management and Use of Buildings (MS:1183).

The size of a fire will depend on the building's compartmentation so that a fire may involve an entire compartment but will not spread to other compartments (Building Bulletin 100 UK, 2021). Properly designed passive compartmentation will help limit damage to the immediate area and prevent the spread of smoke and flames.

A fire occurring anywhere within a compartment of a building has to be regarded as presenting a hazard to all occupants within that compartment, even though in the initial stages of fire development it might be assumed the fire hazard is small and people are in no immediate danger. There is also likely to be a risk to persons in other parts of the building. In a compartmented building, all the occupants and contents of the building have to be considered at risk in the event of fire. Figure 3.1 shows the need for compartmentation between separate blocks and between internal spaces.

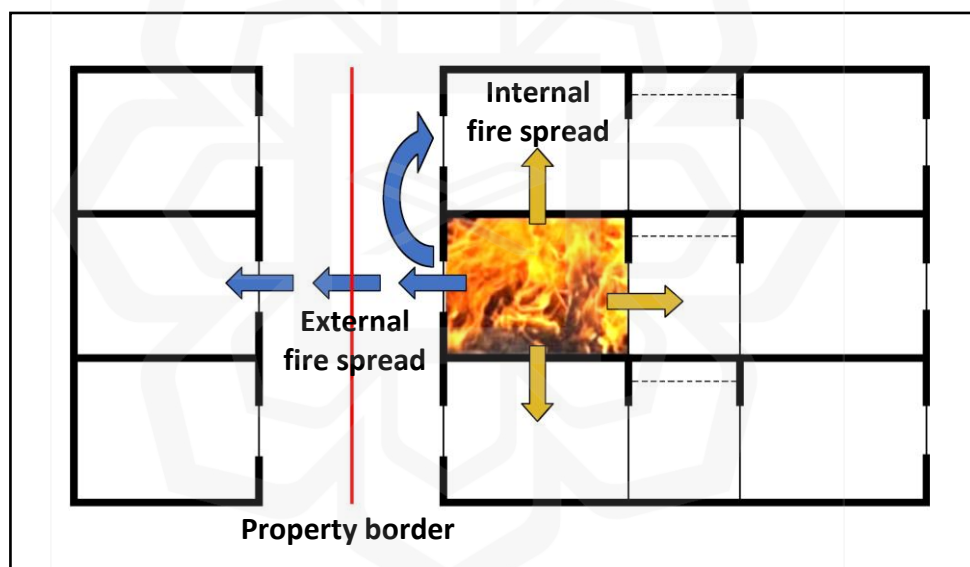


Figure 3.1 Fire Spread Internally and Externally

(Source: Entropic Ecology Indoors UK,

<https://entropic.ie/solutions/fire-safety/fire-compliance-survey-and-reports/>)

3.5 Concealed Roof Spaces (Voids and Cavities)

All buildings have voids, cavities and service and installation shafts as part of their construction. Fire can spread unnoticed in these spaces away from direct view, by penetrating through compartmentation and other fire safety measures within a building.

Concealed spaces or cavities are defined by International Fire Safety Standards - Common Principles (IFSS-CP) and Fire Safety in the Design, Management and Use of Buildings (MS:1183) as spaces enclosed by elements of a building (including a suspended ceiling) or contained within an element of the building.

Cavities in a building's construction can provide an easy path for the spread of smoke and flames. Hidden on invisible routes for the fire spread include concealed spaces above the suspended ceilings, so vertical separation must extend up to the underside of the soffit of the roof or extrude beyond the roof line to achieve compartmentation. Figure 3.2 and Figure 3.3 shows the need for compartmentation within the roof voids or cavities.

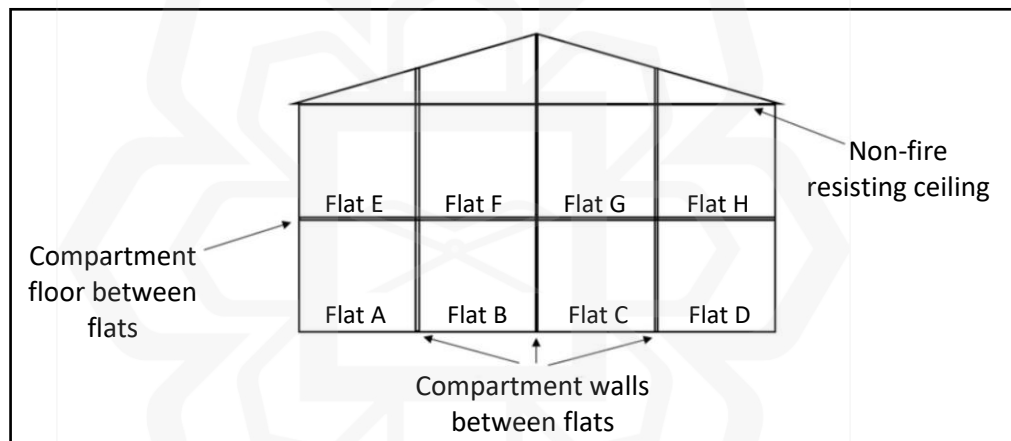


Figure 3.2 Compartmentation in Roof Voids
(Source: LIGTAS UK, <https://ligtas.co.uk>)

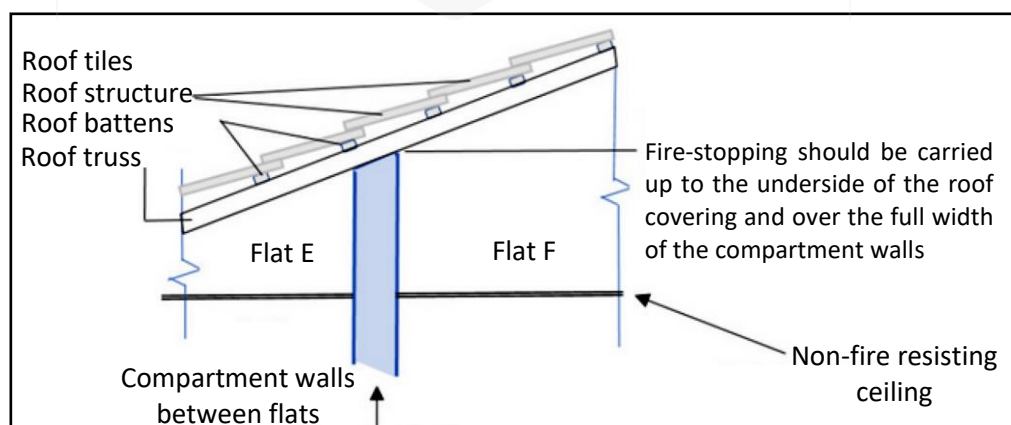


Figure 3.3 Compartmentation Walls
(Source: LIGTAS UK, <https://ligtas.co.uk>)

Insufficient compartmentation and cavities in building constructions may cause poor as unwanted air leakage (air permeability) causing heat loss, sound transmission and spread of smoke or fire (Littlewood, 2017). Insufficient compartmentation with a large cavity area could cause fire and smoke to spread through the entire elongated roof of the building (Johansson, 2012). This will give effect to the containment principle known as the ‘Safety Gap’ and will contribute to the overall performance of the building, known as the ‘Performance Gap’.

3.6 Performance Gap

A performance gap is the difference between current and desired performance levels. It highlights the discrepancies between how an element is performing in relation to the overall performance objectives of its purpose. Hidden cavities also have the potential to affect unwanted air leakages impacting sound pollution and heat loss (Littlewood, 2017). Littlewood (2017) examined the current approach towards achieving in-built performance of fire safety measures in buildings and the implications of potential failure of fire protection measures including compartmentation, which could also affect acoustics and thermal performance.

3.7 Safety Gap

One aspect of the safety gap is caused by potential defects in construction from incorrect installation, missing, inappropriate or defective components, that make up compartmentation, fire stoppings and workmanship errors, enabling rapid smoke spread across compartments (Littlewood, 2017). An investigation carried out by the United Kingdom’s Building Research Establishment (BRE) on fires in different types of buildings between 2003 and 2013 found that 32% of inspected fires had issues of fire spread due to either defects in compartment construction details or inadequate or poor condition of fire stoppings. The management of the uncontrolled spread of fire and smoke relies on the cavity barriers as fire stops.

3.8 Smoke and Fire Spread Within Concealed Roof Spaces (Voids and Cavities)

Fire can spread over the entire building rapidly due to the low height of the space and the availability of combustible materials if the roof space (voids or cavities) is not divided into fire compartments. If fire compartmentation is lacking or insufficient between the roof space and the space below, the fire will eventually spread into the spaces or rooms below. In the cases where there is no active detection system on the façade or in the roof space, the fire will first be detected when smoke reaches the classroom areas. This means that large parts of the school will be heavily damaged even before the fire service is alerted (Johansson et. al, 2013).

The main fire paths for fire and smoke to spread within a building are: 1) through separating elements, typically walls and floors of a building, 2) through joints between separating elements to adjacent compartments and associated construction tolerances, 3) through junctions between building parts or intersections, 4) through building penetrations and openings and 5) through concealed construction cavities (Johansson, 2012).

Even small defects and gaps in compartment construction contribute to the quick spread of smoke and fire (Cheung et al. 2006) demonstrated through numerical investigation that a gap of a few extra millimeters between fire rated walls or floor can lead to increased volume of hot smoke spread between compartments and the possibility of cold air re-entraining back into fire compartment. These fire spread paths must be considered and managed during design, installation and checked regularly during occupation of a building.

Studies carried out by Van Hees et al. (2010), Johansson (2012) and Johansson (2012) agreed that initial fires are allowed to grow and become severe and spread to the roof space or cavities due to the inadequacy and insufficiency of, 1) fire compartmentation separation, 2) fire stops, 3) construction quality or incorrect installation, 4) active detection system and automatic alarm system and 5) inadequate building code.

These findings of fire safety measures and considerations affect the design of the buildings to prevent fire and smoke spread via roof cavities. There are two (2) methods to overcome the spread of fire and smoke via roof cavities in buildings as illustrated in Figure 3.4: 1) compartment walls and 2) cavity barriers.

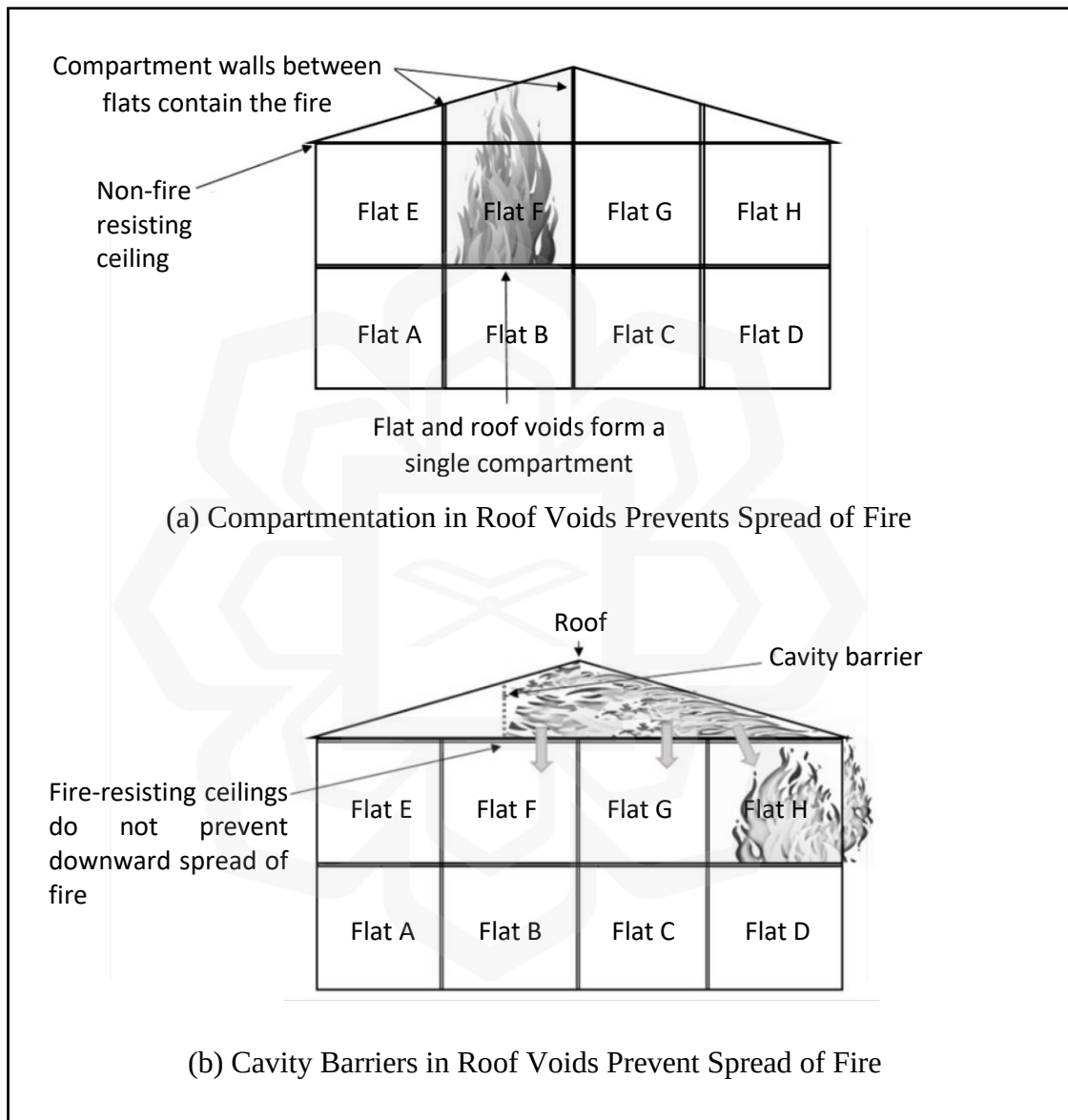


Figure 3.4 (a) and (b) The Use of Compartment Walls and Cavity Barriers as Methods to Overcome the Spread of Fire and Smoke within Roof Cavities in Buildings
(Source: LIGTAS UK, <https://ligtas.co.uk>)

3.9 Passive Compartmentation in School Roof Voids

3.9.1 Fire Code and Standards

The prescriptive fire codes or By-laws of Uniform Building By-Laws (UBBL) 1984 (Revision 2021) and Selangor Uniform Building By-Laws (SUBBL) 1986 (Revision 2012) are the primary reference for fire safety design in Malaysia and in the state of Selangor respectively. Both prescribe the By-laws related to passive compartmentation. These prescriptive codes or By-laws are deemed to be a set of rules forming the minimum standards and requirements for a building. Lilian & Hunt (2016) state that a building is considered safe if its design adheres to the prescriptive codes or By-laws. Whereas, Fire Safety in the Design, Management and Use of Buildings (MS:1183) is a set of guidelines that can be made mandatory by regulatory authorities through regulations and local by-laws. It is to be read in parallel as a voluntary document with the (UBBL) 1984 (Revision 2021) and (SUBBL) 1986 (Revision 2012) on fire safety measures.

3.9.2 Compartment Walls and Floors

Compartment walls are fire-resisting walls or floors used in the separation of one fire compartment from another MS:1183. It forms part of the element of structure. Every wall needed to subdivide the building is to observe the size limits on compartments in multi-storey buildings given in the Fifth Schedule of (SUBBL) 1986 (Revision 2012).

a) Fire wall Interpretation

By-Law 2 of (SUBBL) 1986 (Revision 2012) states:

“fire wall means any wall, not being an external wall, of materials having the fire resistance as required under Part VII, of these by-laws and either used or constructed to be used for the separation of adjoining buildings or the separation of parts of a building in such manner as to prevent or reduce the

spreading of fire from one building to another or from one part of a building to another part of that building and includes a proscenium wall, compartment wall, separating wall and a protecting structure” (SUBBL) 1986 (Revision 2012).

b) Special requirements as to compartment walls and compartment floors

By-Law 148 (3) of (SUBBL) 1986 (Revision 2012) states:

“Where any compartment wall forms a junction with a roof, such wall shall be carried to the under surface of the roof covering”.

The MS:1183 also accords on the importance of continuing any compartment wall up through a ceiling or roof cavity to maintain the standard of fire resistance. Therefore, compartment walls should be carried up full storey height to the underside of the roof as prescribed in By-Laws 148 (3). The (SUBBL) 1986 (Revision 2012) states that compartment walls form part of fire walls as prescribed in By-laws 2 Interpretation.

3.9.3 Maximum Limit Area (Below Ceiling) and Compartmentation

The Fifth Schedule of (SUBBL) 1986 (Revision 2012) prescribes the need for designated purpose group for which a building or compartments is intended to be used, as prescribed in By-Law 134 and By-Laws 138. It also states the dimensions of buildings and compartments, as prescribed in By-Law 136.

a) Designation of purpose groups

By-Laws 134 of (SUBBL) 1986 (Revision 2012) states:

“For the purpose of this Part every building or compartment shall be regarded according to its use or intended use as falling within one of the purpose groups

set out in the Fifth Schedule to these By-laws and, where a building is divided into compartments, used or intended to be used for different purposes, the purpose group of each compartment shall be determined separately: Provided that where the whole or part of a building or compartment, as the case may be, is used or intended to be used for more than one purpose, only the main purpose of use of that building or compartment shall be taken into account in determining into which purpose group it falls”.

b) Other walls and floors to be constructed as compartment walls or compartment floors

By-Law 138 of (SUBBL) 1986 (Revision 2012) states:

“The following walls and floors in buildings shall be constructed as compartment walls or compartment floors: (a) any floor in a building of Purpose Group II (Institutional)”.

c) Provisions of compartment walls and compartment floors

By-Law 136 of (SUBBL) 1986 (Revision 2012) states:

“Any building, other than a single storey building, of a purpose group specified in the Fifth Schedule to these By-laws and which has (a) any storey the floor area of which exceeds that specified as relevant to a building of that purpose group and height; or (b) a cubic capacity which exceeds that specified as so relevant shall be so divided into compartments, by means of compartment walls or compartment floors or both, that (i) no such compartment has any storey the floor area of which exceeds the area specified as relevant to that building and (ii) no such compartment has a cubic capacity which exceeds that specified as so relevant to that building”.

School buildings are designated Purpose Group II (Institutional), based on the Fifth Schedule of Selangor Uniform Buildings By-Laws (1986). School designs shall comply with the dimensions of buildings and compartments prescribed in By-Law 136. It states the permissible floor area of a storey in a building or a compartment, that shall be not more than 2,000 m². There are no limitations imposed on the height of the compartment and the volume of the compartment.

3.9.4 Maximum Limit for Undivided Concealed Spaces (Separation Intervals in Roof Voids)

Ceiling voids are cavities between a structural floor or roof and the suspended ceiling below, through which building services may pass. Concealed space or cavity is defined as space enclosed by elements of a building (including a suspended ceiling) or contained within an element, but not a room, cupboard, circulation space, protected shaft or space within a flue, chute, duct, pipe or conduit. The purpose of closing the cavity is to restrict airflow within the cavity (MS:1183).

It is also stated on the extensive cavities where cavity barriers should be used to subdivide any cavity, including any roof space so that the distance between cavity barriers does not exceed the required dimensions. The dimensions indicate the maximum dimensions of cavities (undivided concealed spaces) in non-domestic buildings. The maximum dimensions of cavities (between a roof and a ceiling) for non-domestic buildings shall be 20m (maximum dimensions in any direction) or a maximum of 400 m² in area (MS:1183).

3.9.5 Cavity Barriers

Cavity barriers are provided to close a concealed space against penetration of smoke or flame or to restrict the movement of smoke or flame within such a space (MS:1183).

3.10 Passive Compartmentation in School Roof Voids: Comparative Study

Each country has a regulatory framework to guide how to meet the legal requirements. Each country publishes and maintains a set of building and fire codes and standards for buildings used as a means to demonstrate compliance with the legal requirements by following the prescriptive guidance. Each country has a set of different but often similar requirements and guidance documents based on the concept of fire safety.

Building and fire codes and standards vary from country to country and a study was conducted to summarize the provisions for each country regarding passive compartmentation. The building and fire codes and standards included in the study are from the United Kingdom, Sweden and New Zealand. The building and fire codes and standards for these respective countries are listed in Table 3.1.

Table 3.1 Building and Fire Codes for Other Countries

Country	Building and Fire Code	Additional Standards/ Guidance
United Kingdom/ England	- Approved Document B (Fire safety) Volume 2 - Buildings other than dwelling houses, 2019 (2006 edition incorporating 2020 amendments) - The Regulatory Reform (Fire Safety) Order 2005	Fire Safety Risk Assessment: Educational Premises (Building Bulletin 100) 2021
Sweden	Boverket Building Regulations (BBR) National Board of Housing, Building and Planning's building code	Nil
New Zealand	The New Zealand <u>Building Act</u> 2004 (Version as at 24 August 2023)	Fire Safety Design Requirements in Schools (July 2008)

(Sources: The status and needs for implementation of Fire Safety Engineering approach in Europe (2023) and The Prevalence and Fire Safety Implications of Early Childhood Centres in Multi-Storey Buildings (Branz, 2015)

3.10.1 United Kingdom Fire and Building Codes

In the United Kingdom, fire safety for schools is regulated by the “Approved Document B (Fire Safety) Volume 2: Buildings other than dwelling houses, 2019 (2006 edition incorporating 2020 Amendments) and as stated in Item 0.14:

“The design of fire safety in schools is covered by Building Bulletin 100, which should be used. Building Bulletin 100 contains fire safety provisions that are outside the scope of the Building Regulations”.

Building Bulletin 100: Design for Fire Safety in Schools (BB100) is a guideline published by the UK Government that complements safety design in schools. It offers advice on how to meet the life safety requirements of the Building Regulations when designing a new school or an extension. The guide also covers the principles of fire safety management and outlines the fire protection measures that designers should consider. It emphasizes the importance of protecting both the fabric of schools and the continuity of education (Building Bulletin 100, BBR, Fire Safety Design Requirements in Schools).

3.10.2 Swedish Fire and Building Codes

In Sweden, fire safety for schools is governed by the Swedish National Board of Housing, Building and Planning's Building Code. Boverket Building Regulations (BBR) contain mandatory provisions and general recommendations on fire safety. The Swedish fire code has been performance-based since 1993 when the current Boverket Building Regulations were introduced (Mossberg, 2019).

3.10.3 New Zealand Fire and Building Codes

The New Zealand Building Act 2004 (Version as of 24 August 2023) sets out the rules for the construction, alteration, demolition and maintenance of new and existing buildings in New Zealand. Additional guideline applied is the Fire Safety Design Requirements in Schools (July 2008) outlining the mandatory requirements and providing best practice guidance on design requirements for new buildings or building alterations.

3.10.4 The Limits of Passive Compartmentation in School Roof Voids: A Comparative Study

Table 3.2 indicates the building and fire codes and standards comparison for significant countries: United Kingdom, Sweden, New Zealand and Malaysia. The key elements identified for investigation are: 1) compartmentation maximum limit, 2) compartment walls and floors, 3) undivided concealed spaces in roof voids, 4) cavity barriers and 5) fire detection provisions.

Table 3.2 Comparative Table on the Limits of Passive Compartmentation in Roof Voids Requirements for Different Countries

No.	Items	Malaysia	United Kingdom	Sweden	New Zealand
1	Compartment walls/ Fire Walls/ Vertical Fire Separators	carried up full storey height to the roof (through a ceiling void or roof cavity)			
2	Cavity Barriers	To be fitted in roof space (voids and cavities) in reference to Maximum Limit for Undivided Concealed Spaces (Separation Intervals in Roof Voids)			
3	Maximum Limit for Undivided Concealed Spaces (Separation Intervals in Roof Voids)	20 m in any direction (total of 400 m ²)	20 m in any direction (total of 400 m ²)	400 m ²	20 m in any direction (total of 400 m ²)
4	Maximum Limit Areas (Below ceiling) for Compartmentation/ Fire Cells	2,0000 m ²	Multi-storey school 2,000 m ² (without automatic suppression system)	<i>not available</i>	270 m ² maximum of three classrooms
			4,000 m ² (with automatic suppression system)		
			Single storey school No Limit		
5	(a) Active Fire Fighting Detection System	> 2,000 m ²	> 4,000 m ²	> 2,500 m ²	heat detector in roof voids and classroom
	(b) Active Fire Fighting Sprinkler System	> 2,000 m ²	> 4,000 m ²	> 5,000 m ²	new schools and school extension > 1,000 m ²

3.10.4.1 Compartment Walls (Fire Walls, Vertical Fire Separators)

In the United Kingdom, compartment walls, also known as “fire walls” in Sweden and “fire separators” in New Zealand are required to be carried up full storey height to a compartment floor or to the roof as appropriate (through a ceiling void or roof cavity) to maintain the standard of the fire separation. In the United Kingdom, requirements to provide a roof zone of 1500 mm wide on either side of the compartment walls covering at least 1.5m wide from the compartment walls (Building Bulletin 100, BBR, Fire Safety Design Requirements in Schools).

3.10.4.2 Maximum Limit Areas (Below Ceiling) and Compartmentation (Fire Cells)

Multi-storey schools in the United Kingdom require the maximum dimensions of compartmentations to be 2,000 m², without Automated Fire Suppression System (AFSS), while an area of 4,000 m² for schools equipped with AFSS. As for a single storey school building, there are no limitations on dimensions, with or without AFSS. In Sweden and New Zealand, fire compartmentations are known as Fire Cells. New Zealand’s Fire Cells comprise a maximum of three classrooms including associated corridor space. This will generally result in a maximum fire cell size of about 270 m² in area, except if sprinkled (Building Bulletin 100, BBR, Fire Safety Design Requirements in Schools).

3.10.4.3 Maximum Limit for Undivided Concealed Spaces (Separation Intervals in Roof Voids)

In the United Kingdom and New Zealand, the maximum dimensions of cavities (between a roof and a ceiling) shall be 20m, with maximum dimensions in any direction. Whereas, Swedish compartmentation requires roof void space to be divided into fire compartments of not more than 400 m² with fire compartment boundaries (Johansson et al., 2013).

3.10.4.4 Cavity Barriers

Cavity barriers are required for all countries and to be fitted in the roof space (voids and cavities) in compliance with the Maximum Limit for Undivided Concealed Spaces (Separation Intervals in Roof Voids) to reduce the potential for fire spread through dividing roof voids or cavities (MS:1183).

3.10.4.5 Active Fire Appliances

In the United Kingdom, active fire fighting, detection systems and sprinkler systems are required for compartment sizes exceeding 4,000 m². In Sweden, a sprinkler system is required for a compartment size larger than 5,000 m², while a detection system is required for a compartment size larger than 2,500 m² (Building Bulletin 100, BBR.).

Heat detectors located in the roof void space and in the classroom is a requirement in New Zealand. A classroom block that accommodates over 250 people would require a heat detection system, but if it were subdivided into fire cells where each has less than 250 people, only a manual system is required (Fire Safety Design Requirements in Schools).

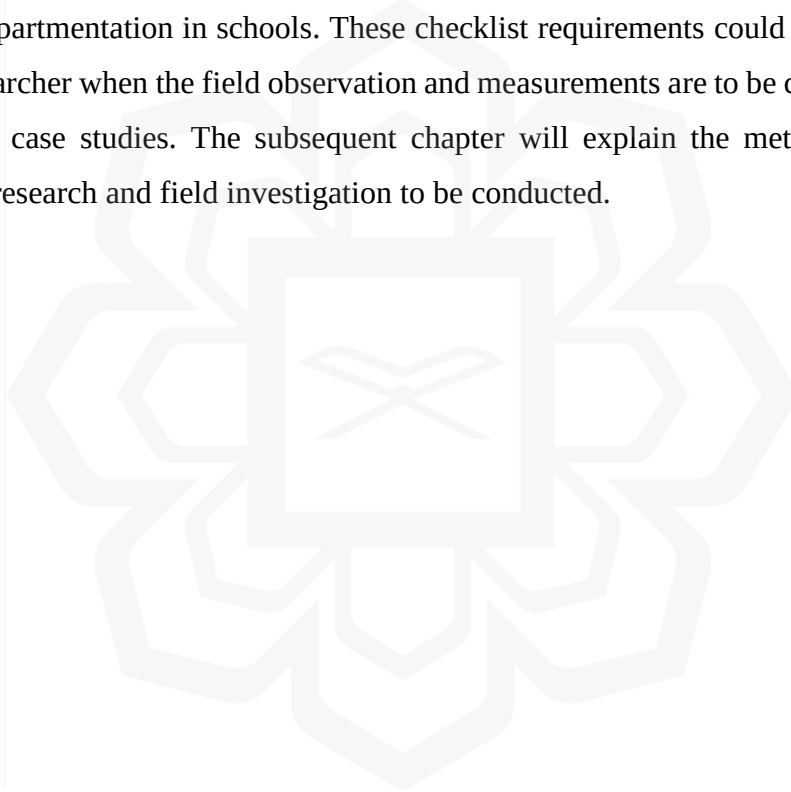
In New Zealand, sprinkler systems is compulsory to be equipped in the existing schools that undergo building extension in which the completed building will have a total floor area greater than 1000 m² or any extension to a school where the existing school is already installed with a sprinkler system. Additionally, the requirements for unsprinklered classroom blocks, with 250 occupants (about 7 classrooms) at two floors maximum in height shall be provided with a manual fire alarm system throughout the school facility (Fire Safety Design Requirements in Schools).

Automatic fire alarm system with heat detectors shall be provided for unsprinklered classroom blocks of between 250 and 500 occupants (ranging from 8 to 14 classrooms) at two floors maximum in height, while an automatic fire alarm system with smoke detectors for unsprinklered classroom blocks of over 500 occupants

(ranging 14 classrooms) at two floors maximum (Fire Safety Design Requirements in Schools).

3.11 Chapter Summary

A comprehensive analysis of the fundamentals of passive compartmentation in roof voids for passive fire design strategy focusing on Malaysian building and fire codes and standards as well as from other countries was elaborated in Chapter 3 including building and fire codes and standards that have provided the necessary checklist requirements for compartmentation in schools. These checklist requirements could be used to guide the researcher when the field observation and measurements are to be carried out on the selected case studies. The subsequent chapter will explain the methodology of the overall research and field investigation to be conducted.



CHAPTER FOUR

RESEARCH METHODOLOGY

4.1 Introduction

This chapter provides a detailed discussion of the methodology adopted to achieve the aim and objectives of the research. A mixed-method approach was adopted, integrating both qualitative and quantitative research techniques. This study incorporates primary on-site inspections (evidence-based research), questionnaire surveys (opinion base) combining literature reviews as secondary data. Procedures and techniques were carefully established and adopted in each method of data collection conducted. It is hoped that the methodology adopted and the established research framework would be able for the study to draw significant conclusions and provide recommendations.

4.2 Methodology

At the commencement, the focus was understanding the fire safety concepts through the building and fire codes in Malaysia and other significant countries to identify and examine the set requirements for the provisions of compartmentation to achieve fire safety in passive design strategy for school buildings, especially in the context of national secondary schools in Malaysia. The research then proceeded to inspect the applications of passive compartmentation in roof voids in schools. The literature review conducted in Chapters 2 and 3, through academic publications, research papers, dissertations, government statistics, building and fire codes, newspaper and web articles would provide sufficient background knowledge and understanding to evaluate the selected case studies of national secondary schools in the state of Selangor. Experts in the field of fire safety including school designers, professionals and technical persons are also captured through a questionnaire survey. Figure 4.1 illustrates the research framework of the study to be carried out based on the methodology adopted.

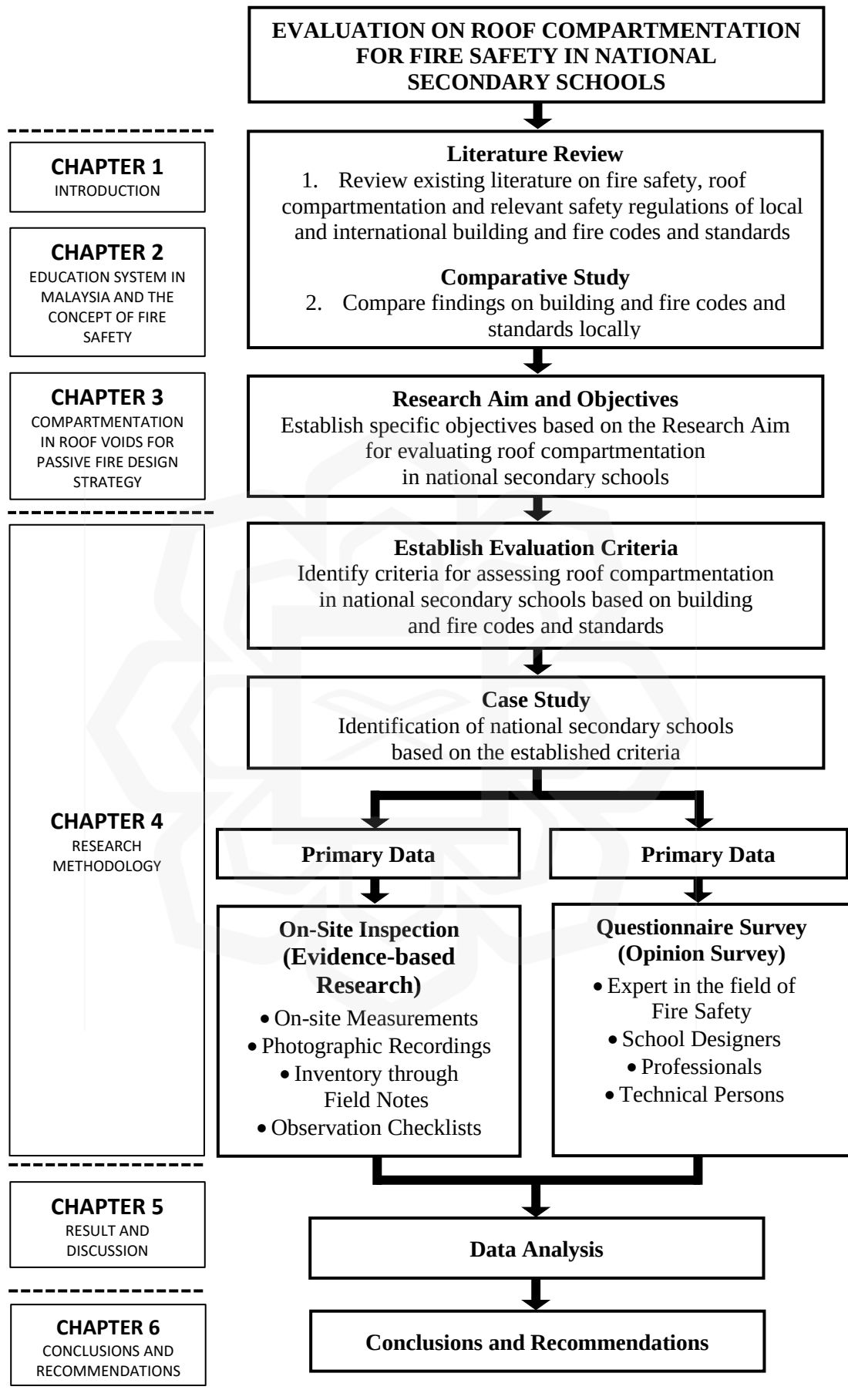


Figure 4.1 Research Framework of the Study

4.3 Research Techniques: Case Study

4.3.1 Introduction

This chapter will focus on identifying the existing provisions and current conditions of passive fire design strategy in compartmentation for national secondary schools. The case studies were selected to obtain primary data to achieve the objective: to identify and evaluate the existing conditions of fire safety design provision for passive compartmentation in particular vertical separation at roof voids in national secondary schools locally. Three (3) national secondary schools were chosen for this study:

- i. Sekolah Menengah Kebangsaan (SMK) Hulu Kelang, Selangor
- ii. Sekolah Menengah Kebangsaan (SMK) Taman Melawati, Selangor
- iii. Sekolah Menengah Kebangsaan (SMK) Sungai Pusu, Selangor

All three (3) schools are government educational institutions and share similar design layout configurations that are complexes of several building blocks with different functions within one site. Each block has its individual functional spaces.

4.3.2 Criteria Selection for Case Study

The purpose of this research is to evaluate the application of fire compartmentation (i.e. vertical separation) at roof voids of the existing school buildings. Three (3) national secondary schools in the state of Selangor were chosen based on the following rationale:

- i. Based on statistics, fire occurrence in national schools for both primary and secondary schools was recorded as being the highest from the year 2014 until the year 2019, in comparison to privatised primary and secondary schools. See statistics in Chapter 1 on page 4.
- ii. The block layout configurations and classroom layout arrangements for both primary and secondary schools adopted similar Public Works Department (PWD) module school designs with similar characteristics and derived from the

same project briefs. Thus, the properties for passive compartmentation provisions for roof voids are comparable in principles.

These three (3) selected national secondary schools were analysed based on the school design focusing on the classroom layouts and block layout configuration emphasizing the upper floor row classrooms and in connection with the longitudinal roof structure. This is essential to identify the passive fire design strategy in compartmentation, comprising these five (5) fire significant elements: -

- 1) vertical fire separators/ compartment walls/ fire walls,
- 2) cavity barriers,
- 3) maximum limit for undivided concealed spaces (separation intervals in roof voids),
- 4) maximum limit areas (below ceiling), and
- 5) fire detection (active fire detection).

For this study, two (2) block layout configurations from each respective school were chosen to be examined for further analysis on its application on compartmentation for passive fire design strategy. Table 4.1 shows detailed design characteristics of the selected national secondary schools as case studies. Based on the table, the order of the schools is not a significant factor in the study. All three (3) schools are under the jurisdiction of District Education Office Gombak (DEO Gombak). Permission to conduct field investigations on the schools was officially made through the headmasters and headmistress of the respective schools (See APPENDIX I on page 132).

Table 4.1 Characteristics of National Secondary Schools as Case Studies

No.	School	Code	Number of Class rooms	Number of Academic Blocks	Storey Height	Completion Date
1	SMK Hulu Kelang, Selangor	SMKHK	15	4 blocks	Ranging from 2 to 4 storeys	1967
2	SMK Taman Melawati, Selangor	SMKTM	36	4 blocks	4 storeys	1991
3	SMK Sungai Pusu, Selangor	SMKSP	36	4 blocks	3 storeys	1999

4.3.3 Case Study 1: SMK Hulu Kelang, Selangor

4.3.3.1 School Background



(a) School Location Plan

(b) School Site Plan

Figure 4.2 (a) and (b) SMK Hulu Kelang, Selangor: Location and Site Plan

Name	: Sekolah Menengah Kebangsaan Hulu Kelang (SMKHK)
Location	: KM 7, Jalan Hulu Kelang, Ampang, Selangor
School Type	: Sekolah Kurang Murid (SKM)

Figure 4.2 (a) and (b) show the location and site plan of SMK Hulu Kelang (SMKHK). SMKHK commenced its operations in 1967, initially known as Sekolah Menengah Hulu Kelang (SMHK). SMKHK is located in the district of Gombak known as a school with “Sekolah Kurang Murid” (SKM) since the year 2000, after newer secondary schools were built in most nearby residential areas in Taman Ahmad Razali, Pandan Indah, Pandan Jaya and Kosas Park. The school system operates with a single morning session.

SMKHK is a 15-classroom school with a total of 450 students and with 50 numbers of teachers. The school consists of 4 academic blocks, 1 canteen block, 2 workshop blocks and 1 administration office block. The three (3) academic blocks consist of Block A (2 storeys), Block B (2 storeys) and Block C (3 storeys) are meant for the use of mainstream students, while Block D (4 storeys), is used by form 6 students. The current headmistress is Puan Nik Nur Rahaya Binti Che Yahaya.

4.3.4 Case Study 2: SMK Taman Melawati, Selangor

4.3.4.1 School Background



(a) School Location Plan

(b) School Site Plan

Figure 4.3 (a) and (b) SMK Taman Melawati, Selangor: Location and Site Plan

Name : Sekolah Menengah Kebangsaan Taman Melawati (SMKTM)
Location : 31, Jalan Melawati 5, Taman Melawati, Selangor
School Type : Daily National Secondary School

Figure 4.3 (a) and (b) show the location plan and site plan of SMK Taman Melawati (SMKTM). The school was established in 1991 offering mainstream programs. SMKTM is a two (2) session school, with the first session running in the mornings (Forms 3,4 and 5), while the second session is in the afternoons (Forms 1 and 2). This is due to the large increase in number of students within the area and is due to space constraints.

SMKTM is a 36-classroom school with a total student body of approximately 2,636 students and 138 numbers of teachers. The school consists of 7 building blocks, 4 academic blocks with an administration office, 1 Canteen Block, 1 Workshop Block and 1 Surau. The current SMKTM headmaster, Mr. Jagdave Singh a/l Avtar Singh was awarded Anugerah Kepimpinan Menengah Negeri Selangor 2023 during his tenure as a headmaster in SMKTM since 13 September 2021.

4.3.5 Case Study 3: SMK Sungai Pusu, Selangor

4.3.5.1 School Background



(a) School Location Plan

(b) School Site Plan

Figure 4.4 (a) and (b) SMK Sungai Pusu: Location and Site Plan

Full Name : Sekolah Menengah Kebangsaan Sungai Pusu (SMKSP)
Location : KM 11, Jalan Gombak, Selangor
School Type : Secondary School with Daily Boarding Facilities

Figure 4.4 (a) and (b) show the location plan and site plan of SMK Sungai Pusu (SMKSP). The school was built in 1999 and is a daily boarding school accommodating students who excelled in Ujian Kemasukan Sekolah Khas (UKSK) from around the Gombak district and also admits day students from North Gombak and Sungai Pusu National School. This school was established as one of the Bestari Schools in the Bestari Schools Pilot Project by the Ministry of Education (MOE) and it is one out of a total of 88 Bestari schools nationwide.

It is a 36-classroom school with a total of 2,005 students and with 119 numbers of teachers. The school consists of 12 building blocks; 4 Academic Blocks with an Administration Office, 1 Laboratory Block, 1 Workshop Block, 1 Agricultural Block, 2 Dormitory Blocks, 1 Canteen Block, 1 Multipurpose Hall and 1 Surau. The school operates in two sessions, morning and afternoon. The current headmaster is En. Mohd. Rohan Bin Sidek.

4.3.6 Block Layout Configurations and Classroom Layout Arrangements

A total of six (6) academic blocks were identified and investigated for this research. Table 4.5 (a) and (b), 4.6 (a) and (b), 4.7 (a) and (b), 4.8 (a) and (b), 4.9 (a) and (b), 4.10 (a) and (b) illustrate the visual image of the physical block layout configurations with the classroom layout arrangements for the three (3) schools involved in the study. Two (2) academic blocks with different layout configurations, classroom layout arrangements and storey heights from each respective school were identified for further analysis.

The blocks involved in the investigation for fire safety compliance are:

- 1) academic blocks SMKHK-B1 and SMKHK-B2 for SMK Hulu Kelang,
- 2) academic blocks SMKTM-B1 and SMKTM-B2 for SMK Taman Melawati,
and
- 3) academic blocks SMKSP-B1 and SMKSP-B2 for SMK Sungai Pusu.

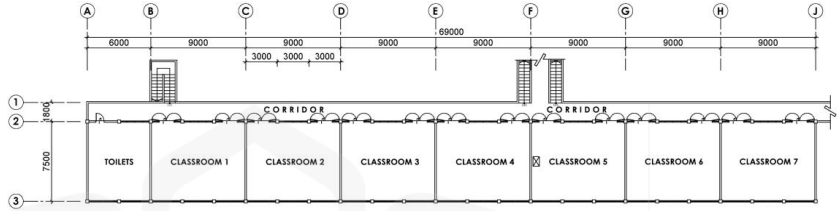
SMKHK-B1		
Academic Block	Figures	Descriptions
View of Academic Block 1	 Figure (a) View of Academic Block 1	The academic block has two (2) floors of classrooms. The overall dimension of the block is 69m in length. Seven (7) classrooms are located on every floor with a toilet connected through an open corridor and staircases.
Block Layout Configuration and Classroom Layout Arrangement of Academic Block 1	 Figure (b) Block Layout Configuration and Classroom Layout Arrangement	

Figure 4.5 (a) and (b) SMKHK-B1: View of Academic Block 1, Block Layout Configuration and Classroom Layout Arrangement

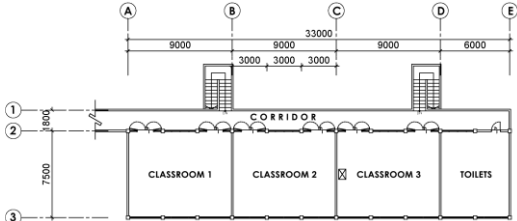
SMKHK-B2		
Academic Block	Figures	Descriptions
View of Academic Block 2	 Figure (a) View of Academic Block 2	The academic block has three (3) floors of classrooms. The overall dimension of the block is 33m in length. Three (3) classrooms are located on every floor with a toilet connected through an open corridor and staircases.
Block Layout Configuration and Classroom Layout Arrangement of Academic Block 2	 Figure (b) Block Layout Configuration and Classroom Layout Arrangement	

Figure 4.6 (a) and (b) SMKHK-B2: View of Academic Block 2, Block Layout Configuration and Classroom Layout Arrangement

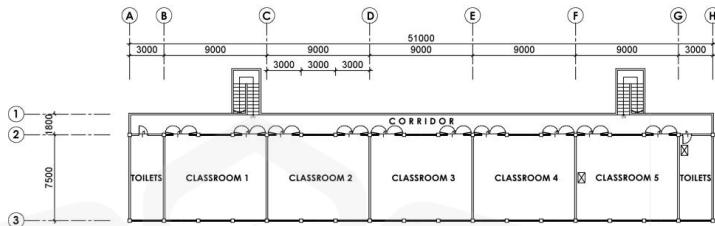
SMKTM-B1		
Academic Block	Figures	Descriptions
View of Academic Block 1	 Figure (a) View of Academic Block 1	The academic block has four (4) floors of classrooms. The overall dimension of the block is 51m in length. Five (5) classrooms are located on every floor with two (2) toilets connected through an open corridor and staircases.
Block Layout Configuration and Classroom Layout Arrangement of Academic Block 1	 Figure (b) Block Layout Configuration and Classroom Layout Arrangement	

Figure 4.7 (a) and (b) SMKTM-B1: View of Academic Block 1, Block Layout Configuration and Classroom Layout Arrangement

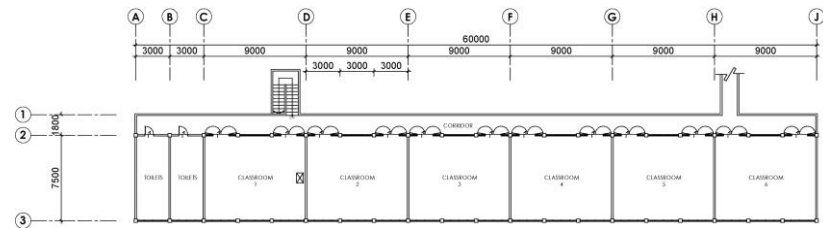
SMKTM-B2		
Academic Block	Figures	Descriptions
View of Academic Block 2	 Figure (a) View of Academic Block 2	The academic block has four (4) floors of classrooms. The overall dimension of the block is 60m in length. Six (6) classrooms are located on every floor with two (2) toilets connected through an open corridor and staircases.
Block Layout Configuration and Classroom Layout Arrangement of Academic Block 2	 Figure (b) Block Layout Configuration and Classroom Layout Arrangement	

Figure 4.8 (a) and (b) SMKTM-B2: View of Academic Block 2, Block Layout Configuration and Classroom Layout Arrangement

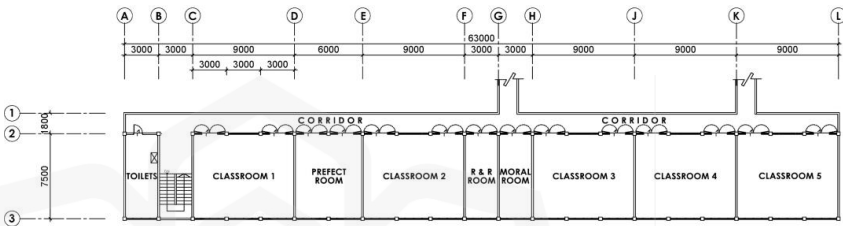
SMKSP-B1		
Academic Block	Figures	Descriptions
View of Academic Block 1	 Figure (a) View of Academic Block 1	The academic block has three (3) floors of classrooms. The overall dimension of the block is 63m in length. Five (5) classrooms are located on every floor with three (3) supportive rooms and a toilet connected through an open corridor and staircases
Block Layout Configuration and Classroom Layout Arrangement of Academic Block 1	 Figure (b) Block Layout Configuration and Classroom Layout Arrangement	

Figure 4.9 (a) and (b) SMKSP-B1: View of Academic Block 1, Block Layout Configuration and Classroom Layout Arrangement

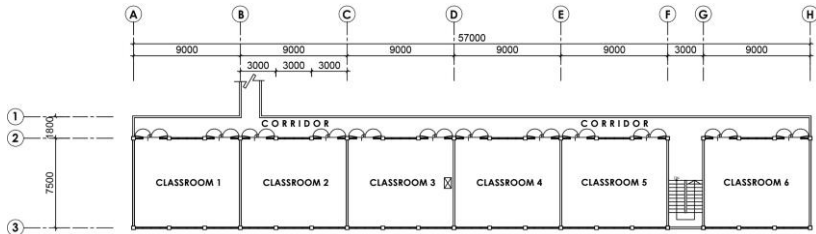
SMKSP-B2		
Academic Block	Figures	Descriptions
View of Academic Block 2	 Figure (a) View of Academic Block 2	The academic block has three (3) floors of classrooms. The overall dimension of the block is 57m in length. Six (6) classrooms are located on every floor with a toilet connected through an open corridor and staircases.
Block Layout Configuration and Classroom Layout Arrangement of Academic Block 2	 Figure (b) Block Layout Configuration and Classroom Layout Arrangement	

Figure 4.10 (a) and (b) SMKSP-B2: View of Academic Block 2, Block Layout Configuration and Classroom Layout Arrangement

4.4 On-Site Inspections (Observation)

4.4.1 Introduction

Observation skills is important to analyze the existing provisions and current conditions of passive fire design strategy in compartmentation for national secondary schools. Observation is based on the researcher's background knowledge of architecture to understand the context and the study area. Through on-site observations, the researcher was able to obtain firsthand insights into the current state of passive fire design.

4.4.2 On-Site Inspections

The data findings were obtained through direct observations and inspections conducted at the selected school buildings after obtaining permission from the school's management/ authority. This data-gathering technique was adopted by visiting the three (3) national secondary schools; observing, measuring, note-taking and photographic recording to identify the selected block layout configuration and classroom layout arrangements. This is intended to assess and understand the physical aspects of the existing conditions of passive roof compartmentation. The inspections focused on the upper floor row classrooms in connection with the longitudinal roof structure. During the field inspections, the passive compartmentation in particular vertical separation at roof voids was observed and documented to check their compliance. Table 4.2 shows the respective floors for the six (6) academic blocks involved in the inspection.

Table 4.2 Inspection Floors Involved in Investigation for Fire Safety Compliance

No.	Academic Block	Number of Storeys	Inspection Floor
1	SMKHK-B1	2 storeys	First floor
2	SMKHK-B2	3 storeys	Second floor
3	SMKTM-B1	4 storeys	Third floor
4	SMKTM-B2	4 storeys	Third floor
5	SMKSP-B1	3 storeys	Second floor
6	SMKSP-B2	3 storeys	Second floor

Appropriate tools were essential to be used during this inspection including a measurement tape, a digital laser measurement device, a digital camera, a light-emitting diode (LED) torchlight, a 6-tier and, an 8-tier ladder to reach the ceiling manhole hatch to assess the roof void area. The researcher's safety was considerably important during the entire inspection. The data collected from three (3) schools were subsequently transferred into Computer-Aided Design (CAD) drawings to produce layout plan drawings and section drawings of the academic block. The inspections conducted have provided the assessment of the performance of the roof compartmentation to be made. The process and contextual understanding are crucial for interpreting the effectiveness of these fire safety provisions in real-situation scenarios.

4.4.3 Preparation and Permissions

The preparation for the on-site inspections of the selected schools was planned ahead of time to ensure a thorough observation and inspection were conducted smoothly and ethically. Permissions were essential to obtain formal approval from the respective school management/ authority before any fieldwork was allowed to be undertaken. This includes preparing permission letters outlining the particulars of the research in securing permission to assess the case study buildings. Upon approval, the researcher was provided with schematic diagram layouts for the three (3) schools used as references during the site visits (See APPENDIX II on page 133).

4.4.4 Safety and Precaution

A pre-inspection was conducted prior to the actual inspection day for the three (3) selected schools. This was necessary to identify the ceiling manhole positions in order to gain visual access for observation to the roof space above the classrooms. The identification of locations of manholes that varied from one school block to another was intended to identify any potential hazards that might pose danger to the researcher during the actual on-site inspection day; loose ceilings, debris and wild animals. Obstruction caused by electrical wiring and water tanks positioned in the roof spaces was also observed and experienced.

Both the pre and actual on-site inspections were conducted during day time. For safety, particularly while using the ladder, the researcher was accompanied by a technical assistant throughout the entire process. An on-duty safety guard was also present as part of the school's procedure witnessing the activity conducted. Sufficient safety measures were exercised to prevent accidents and to ensure the documentation process did not pose any risk to the researcher and others.

4.4.5 On-Site Measurements

The classroom dimensions were determined by measuring the length, width and height of all floors of the six (6) academic blocks. The height of the roof space above the classroom was also measured to the underside of the roof ridge. The dimensions of the block layout configurations, the classroom layout arrangements and the roof space were measured and documented. All on-site information obtained was jotted down and noted in the field notes to ensure all relevant information was not missed and forgotten. This was to ensure all the required data was taken accurately and to prevent from any information being lost.

4.4.6 Photographic Recording

The photographs captured the overall design and physical condition of the classrooms and the roof compartmentation in each school. This included classrooms and the corresponding roof void spaces above. All photograph images were captured, categorized, labeled with the date, time, specific location and assigned a descriptive title. These procedures ensured the photographs could be retrieved easily during the analysis process. The photographic documentation became a valuable first-hand record that would enhance the analysis of the study.

4.4.7 Observation Checklists

An observation checklist was developed to identify all relevant information needed during the case study visits. The checklist included particulars of the compartmentation elements, signs of damage to compartment materials and improper installation of compartmentation. The researcher recorded the findings from the inspection based on the physical aspects of the existing conditions of passive roof compartmentation (See APPENDIX III on page 134).

4.4.8 Field Notes

The researcher utilized field notes documenting information retrieved on-site that complements other data sources such as measurements, photographs and observation checklists. During the case study visits to the selected schools, the relevant information such as the block layout configurations and classroom layout arrangements was captured and documented in the form of diagrams and sketches incorporating floor plans and section drawings of each respective school. The task was part of the documentation in producing diagrams and sketches of measurements and contextual information for the purpose of data analysis (See APPENDIX IV on page 136).

4.5 Key Informant Questionnaires

4.5.1 Introduction

The questionnaire for this research was formulated to gain professional insights to analyze the existing provisions and current conditions of passive fire design strategy in compartmentation for national secondary schools.

4.5.2 Questionnaire Survey

To understand the current state of passive compartmentation in national secondary schools, it is essential to gather the opinions of experts and professionals involved in

the design and construction of school buildings and fire safety. The key informants as respondents were from a diverse group of stakeholders selected for their professional knowledge due to their expertise and experience in fire safety. The questions addressed the current passive compartmentation for fire safety measures in school buildings and the respondents' views of the current existing passive compartmentation fire design strategies applied in these school buildings.

Questionnaire surveys were conducted based on the structured questions that included several sections:

- 1) Section 1: Background Information,
- 2) Section 2: School Design,
- 3) Section 3: Fire Safety in School Design,
- 4) Section 4: Passive Compartmentation at Roof Voids,
- 5) Section 5: Building and Fire Codes on Passive Compartmentation at Roof Voids, and
- 6) Section 6: Others.

The questionnaire comprised both close-ended (multiple-choice questions) and open-ended questions (See APPENDIX V on page 141).

4.5.3 Technique Employed for Questionnaire Survey

The questionnaire survey was executed using a distribution technique by hand to the key informants or expert panels as respondents. An appointment was made earlier prior to the handing over of the questionnaire survey. A total of thirty (30) questionnaires were distributed and collected within four (4) weeks. A total of twenty-two (22) respondents or 73.3% were received and responded. Their valuable responses were analysed quantitatively to understand the existing provisions and current conditions of passive fire design strategy in compartmentation for national secondary schools. This gave insights for providing recommendations on passive fire design strategy on compartmentation in roof voids implemented in national secondary schools in Malaysia to achieve fire safety.

4.5.4 Key Informants

Twenty-two (22) key informants as respondents participated in the questionnaire survey. The respondent's background was of professionals, school designers and technical persons. A detailed breakdown of the respondents: five (5) from the Fire and Rescue Department of Malaysia (FRDM), two (2) fire engineers, two (2) fire experts practicing Architects, six (6) practicing Architects, five (5) Design Architects from the Public Works Department (PWD) and two (2) Technical persons as listed in Table 4.2. The questionnaire aimed to gather opinions from the professionals who are specially involved and have experience in fire safety requirements in buildings (i.e. passive compartmentation fire design strategy).

Table 4.3 Background of Key Informants as Respondents

Key Informant Respondent No.	Expertise Field	Background
KI 01	Enforcement and Operations Fire and Rescue Department of Malaysia (FRDM)	Fireman
KI 02		Fireman
KI 03		Fireman
KI 04		Fireman
KI 05		Fireman
KI 06	Technical Design Fire Engineers	Fire Engineer
KI 07		Fire Engineer
KI 08	Technical Design Expert in Fire Safety	Architect
KI 09		Architect
KI 10	Technical Design Practicing Architects	Architect
KI 11		Architect
KI 12		Architect
KI 13		Architect
KI 14		Architect
KI 15		Architect
KI 16	Technical Design Architects from Public Works Department (PWD)	Design Architect
KI 17		Design Architect
KI 18		Design Architect
KI 19		Design Architect
KI 20		Design Architect
KI 21	Technical Design Technical person Architectural Consultation Practice	Technical Person
KI 22		Technical Person

4.6 Data Analysis: On-Site Inspections

4.6.1 Diagram Interpretation

No architectural building plans were provided for the inspections to be carried out. However, only schematic layout diagrams of the three (3) schools were provided for the basic arrangement of the academic, administration and other supporting spaces. These schematic layout diagrams were used as a reference during the case study visits for familiarization with the schools' physical conditions and block layout configurations.

4.6.2 Visual Content Analysis

This study involved systematically analysing visual materials, such as images and other non-textual data. It involves the process of deducing meaningful information from photographic recordings, sketches and diagrams captured, gathered and compiled during the observation. The field notes were later reviewed and organized, ensuring clarity in the images and handwriting. Recorded photographs were organized and labeled. Visual Content Analysis was carried out on the evidence gathered and was later used to corroborate the field observations made.

4.7 Data Analysis: Key Informant Questionnaires

The responses were analysed using Statistical Package for the Social Sciences (SPSS) Version 29. Frequency and means analysis was employed in analysing the responses of the respondents. A thematic analysis was applied to the responses to the open-ended questions.

4.7.1 Frequency Analysis

A frequency analysis is a statistical technique used to determine the occurrence pattern of values within the responses. It involves the number of times each value or item appears and the result is in the form of frequency distribution.

4.7.2 Means Analysis

Means analysis was deduced based on the overall score points calculated and the average point is taken to indicate the significance level of variables. Likert scales were adopted as rating scales. The higher average scores suggest greater significance.

4.7.3 Thematic Analysis

A thematic analysis method was used to identify, analyze and interpret patterns of shared meaning or themes within the open-ended responses in the questionnaire survey. This technique involves delving through a data set, identifying patterns, systematically coding, deriving themes and creating a narrative. It is a structured method to interpret qualitative information to reveal insights that may not be immediately apparent. This approach provided a clear framework for understanding respondents' insights based on their expertise and experience.

4.7.4 Integration of Data: Qualitative and Quantitative

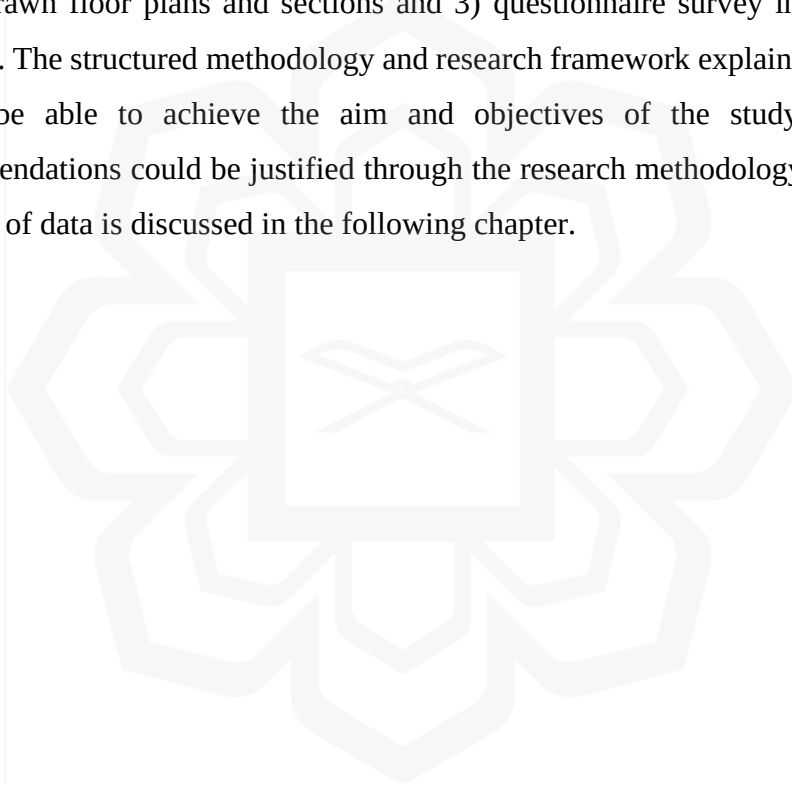
By employing these analysing techniques, data collected were able to be interpreted and integrated. Findings were then deduced from the triangulation method of data gathering:

- 1) Field observations and inspections,
- 2) Photographic, sketching and redrawn floor plans and sections, and
- 3) Questionnaire survey interpretation and analysis

This would assist the study in arriving at an appropriate conclusion and hence meeting the research aim and objectives. Recommendations would then be able to be made or established for future references by the stakeholders.

4.8 Chapter Summary

This chapter outlined the methodology of the research. Qualitative and quantitative approaches have been adopted in the research. Data were gathered through the triangulation method: 1) field observations and inspections, 2) photographic, sketching and redrawn floor plans and sections and 3) questionnaire survey interpretation and analysis. The structured methodology and research framework explained in Section 4.2 would be able to achieve the aim and objectives of the study. Findings and recommendations could be justified through the research methodology employed. The analysis of data is discussed in the following chapter.



CHAPTER FIVE

RESULT AND DISCUSSION

5.1 Introduction

This chapter presents the analysis of data collected from case study inspections and visits to the three (3) buildings and responses from the respondents based on the structured questionnaire survey. This analysis and findings are expected to be deduced and would meet the aim and objectives of the research. It is the aim of the study to evaluate the existing provisions of passive fire compartmentation in particular vertical separation at roof voids in national secondary schools locally.

5.2 Data Analysis: Evaluation of The Existing Conditions of Passive Fire Design Strategy in Compartmentation in Schools

The assessment of the existing conditions of passive fire design strategy in compartmentation in national secondary schools was made based on the selected three (3) case studies. Two (2) academic blocks from each respective school were identified to be analysed. The purpose is to assess the existing provisions of passive compartmentation in particular vertical separation at roof voids on the upper floor row classrooms which is in connection with the longitudinal roof structure as shown in Figures 5.1(c), 5.2(c), 5.3(c), 5.4(c), 5.5(c) and 5.6(c).

The floors involved in the investigation are: 1) the first floor of SMKHK-B1, the second floor of SMKHK-B2, the third floor of SMKTM-B1, the third floor of SMKTM-B2, the second floor for SMKSP-B1 and the second floor for SMKSP-B2. The visual field observations and inspections within the roof void were made through openable ceilings located at various rooms for each academic block shown in Figures 5.1(a) and (b), 5.2(a) and (b), 5.3(a) and (b), 5.4(a) and (b), 5.5(a) and (b), 5.6(a) and (b).

5.2.1 Case Study 1: SMK Hulu Kelang, Selangor

5.2.1.1 SMKHK-B1

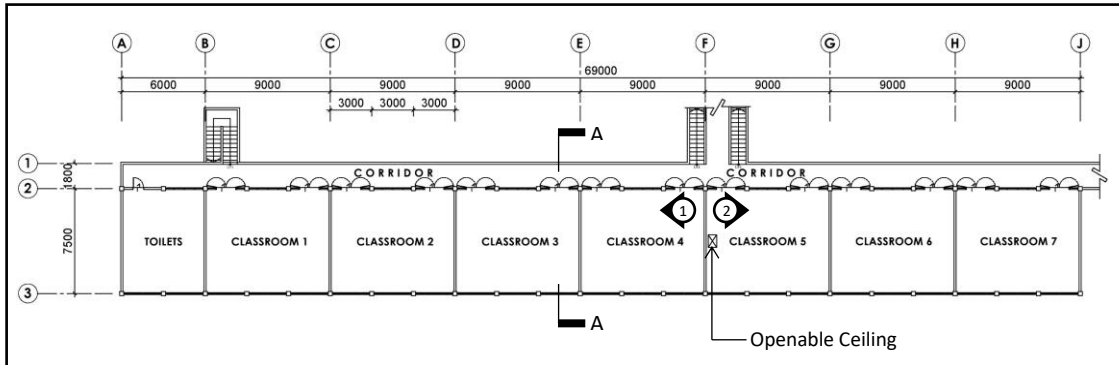


Figure 5.1 (a) SMKHK-B1: Location of Openable Ceiling



Figure 5.1 (b) SMKHK-B1:
Openable Ceiling

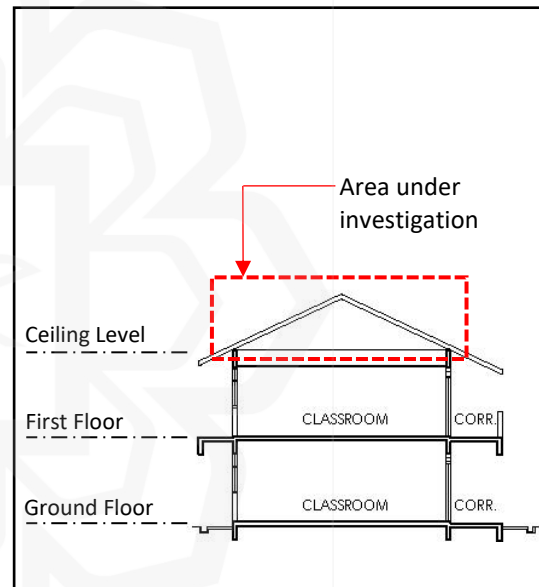


Figure 5.1 (c) SMKHK-B1:
Section A-A (2 Storeys Block)

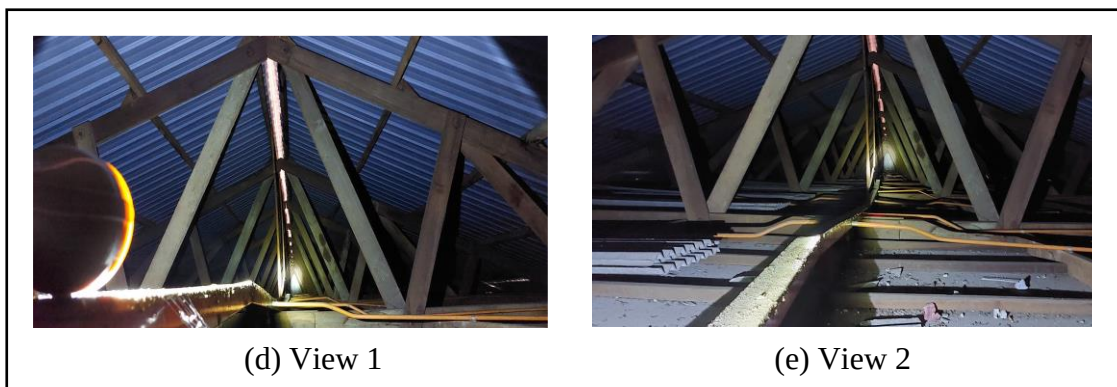


Figure 5.1 (d) and (e) SMKHK-B1: View 1 and View 2 Roof Space above Classrooms

5.2.1.2 SMKHK-B2

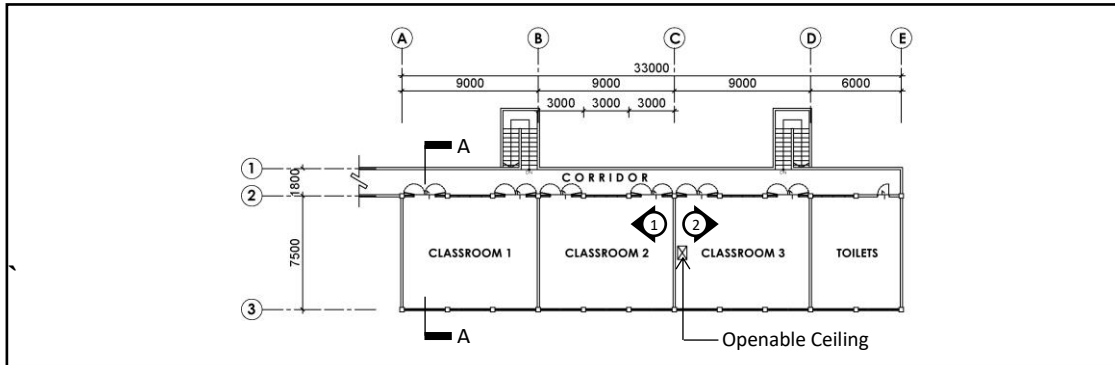


Figure 5.2 (a) SMKHK-B2: Location of Openable Ceiling



Figure 5.2 (b) SMKHK-B2:
Openable Ceiling

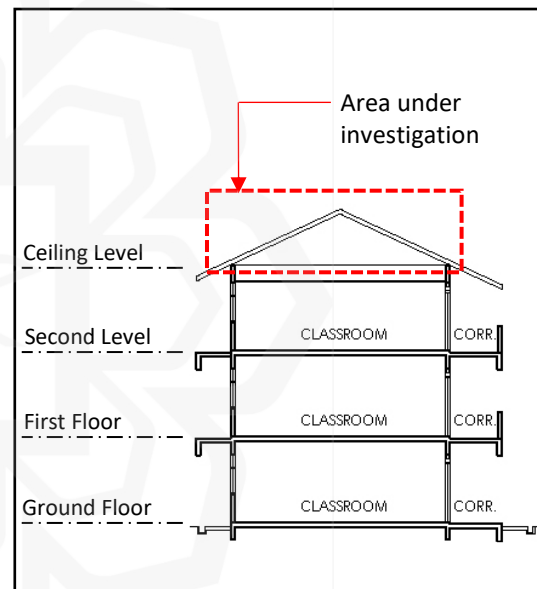


Figure 5.2 (c) SMKHK-B2:
Section A-A (3 Storeys Block)



Figure 5.2 (d) and (e) SMKHK-B2: View 1 and View 2 Roof Space above Classrooms

5.2.2 Case Study 2: SMK Taman Melawati, Selangor

5.2.2.1 SMKTM-B1

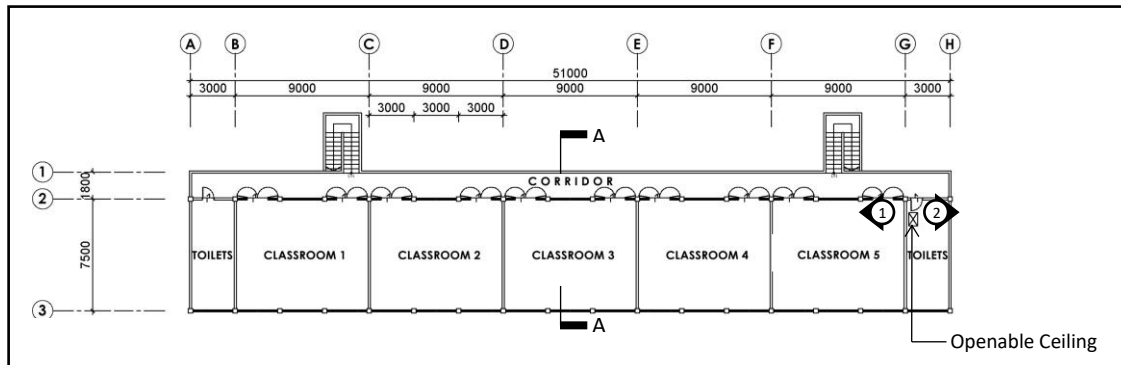


Figure 5.3 (a) SMKTM-B1: Location of Openable Ceiling

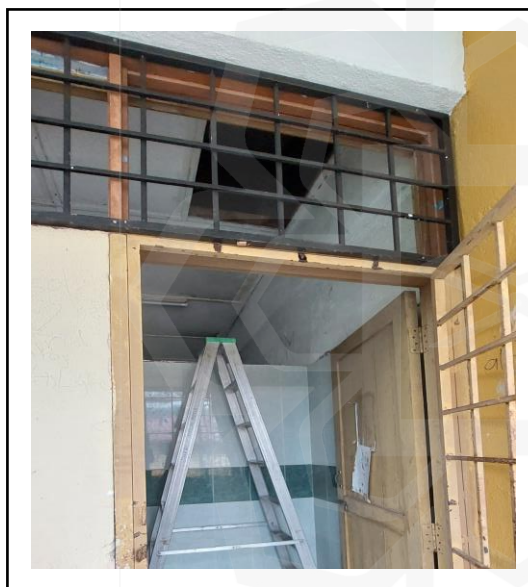


Figure 5.3 (b) SMKTM-B1:
Openable Ceiling

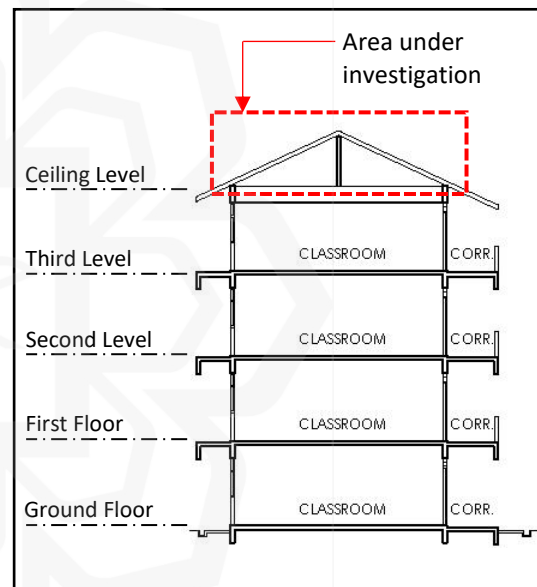


Figure 5.3 (c) SMKTM-B1:
Section A-A (4 Storeys Block)



Figure 5.3 (d) and (e) SMKTM-B1: View 1 and View 2 Roof Space above Classrooms

5.2.2.2 SMKTM-B2

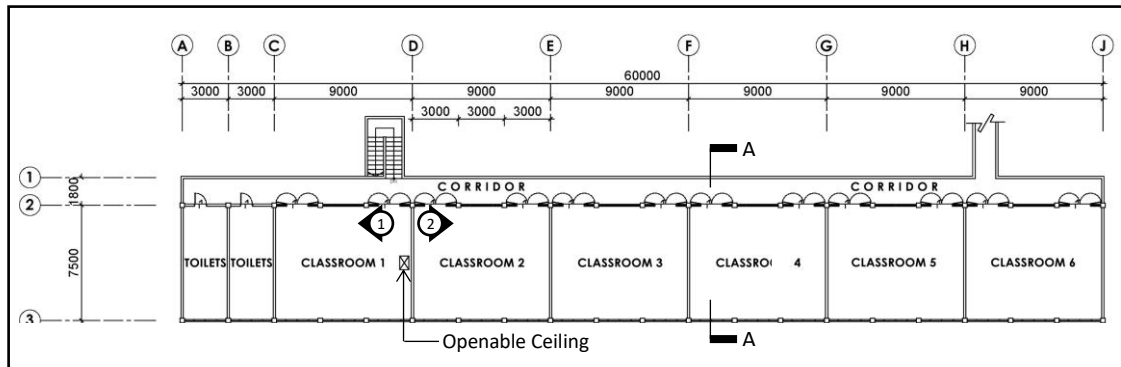


Figure 5.4 (a) SMKTM-B2: Location of Openable Ceiling



Figure 5.4 (b) SMKTM-B2:
Openable Ceiling

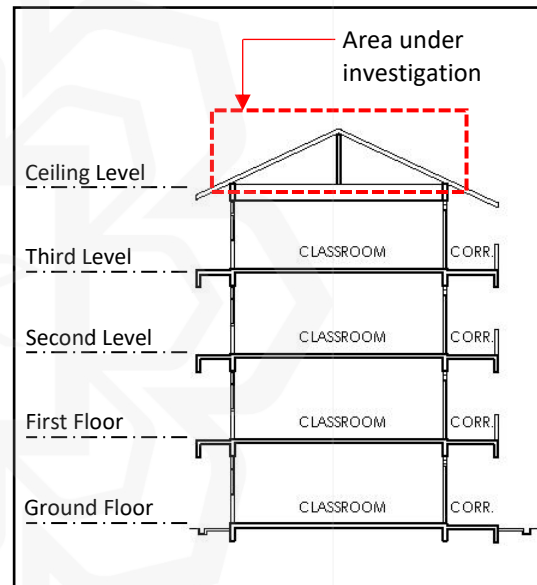


Figure 5.4 (c) SMKTM-B2:
Section A-A (4 Storeys Block)



Figure 5.4 (d) and (e) SMKTM-B2: View 1 and View 2 Roof Space above Classrooms

5.2.3 Case Study 3: SMK Sungai Pusu, Selangor

5.2.3.1 SMKSP-B1

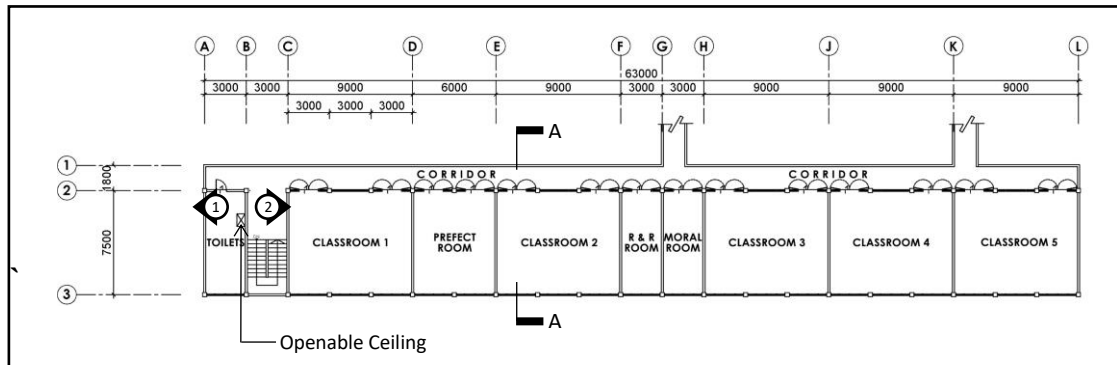


Figure 5.5 (a) SMKSP-B1: Location of Openable Ceiling

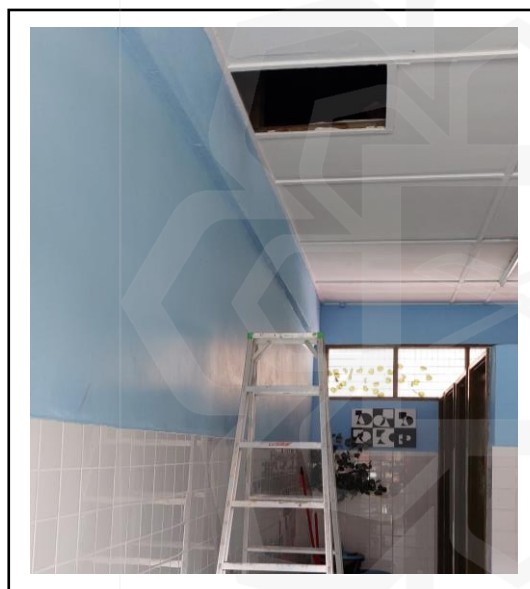


Figure 5.5 (b) SMKSP-B1:
Openable Ceiling

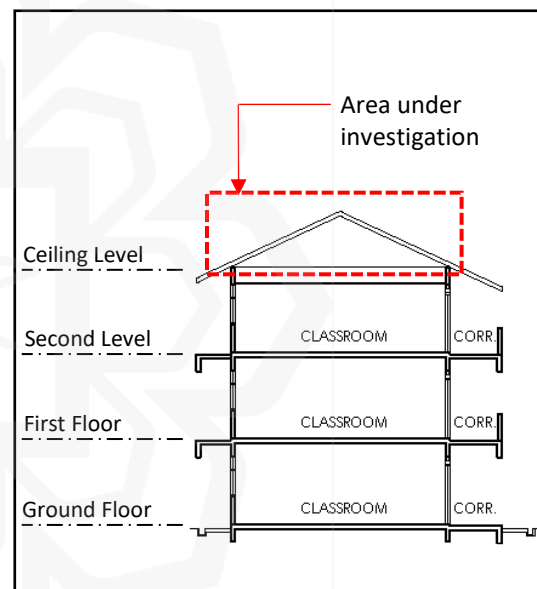


Figure 5.5 (c) SMKSP-B1:
Section A-A (3 Storeys Block)

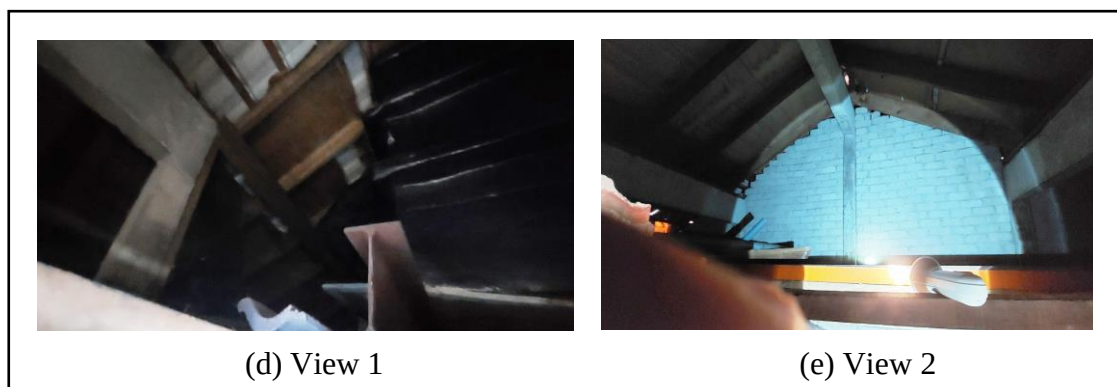


Figure 5.5 (d) and (e) SMKSP-B1: View 1 and View 2 Roof Space above Classrooms

5.2.3.2 SMKSP-B2

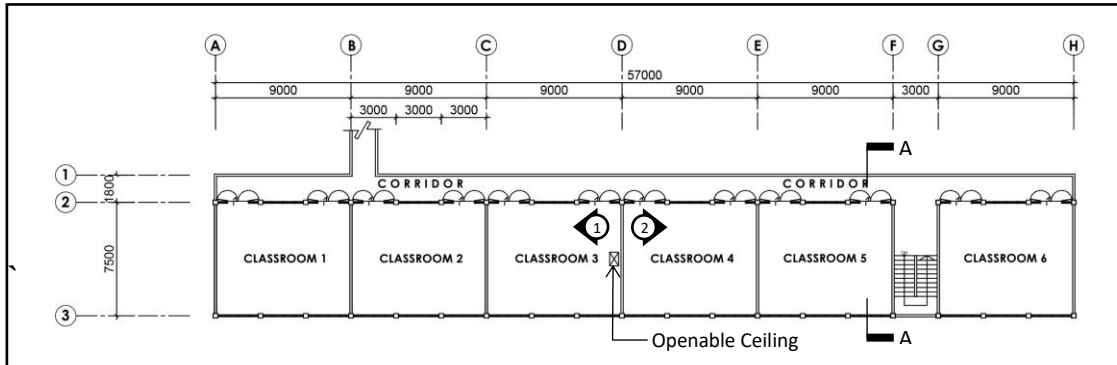


Figure 5.6 (a) SMKSP-B2: Location of Openable Ceiling



Figure 5.6 (b) SMKSP-B2:
Openable Ceiling

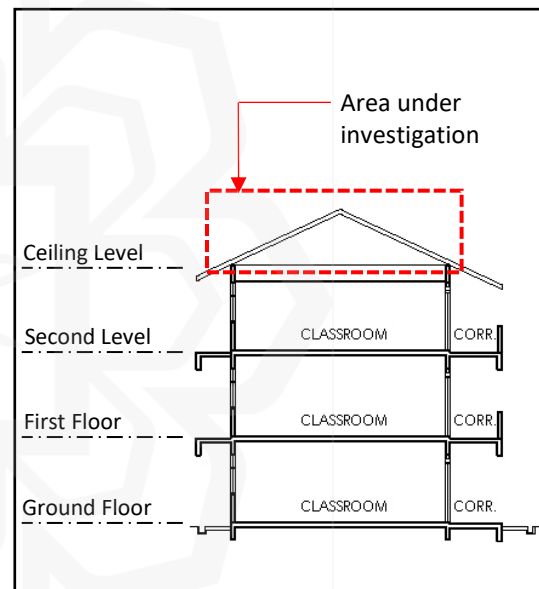


Figure 5.6 (c) SMKSP-B2:
Section A-A (3 Storeys Block)



Figure 5.6 (d) and (e) SMKSP-B2: View 1 and View 2 Roof Space above Classrooms

5.2.4 Classroom Layouts

Based on the field observations and inspections, it was found that all academic blocks ranged from two (2) to four (4) storeys high. All three (3) school complexes have similar planning block layout configurations adopted from the Malaysian Public Works Department (PWD) standard layout. It has been observed that all classrooms are in linear layout arrangement. On average, the typical classroom has a dimension of 9m in length and 7.5m in width which is equivalent to 67.5 m² or 726. 57 ft².

5.2.5 Block Layout Configurations

Based on the field observations and inspections, SMKHK-B1 has a two (2) storeys academic block. The overall block dimension is 69m in length. The first floor consists of seven (7) classrooms in a linear layout arrangement with a toilet connected through an open corridor and staircases (Figure 5.1(a)). Meanwhile, SMKHK-B2 has a three (3) storeys academic block. The overall block dimension is 33m in length. The second floor consists of three (3) classrooms in a linear layout arrangement with a toilet connected through an open corridor and staircases (Figure 5.2(a)).

As for blocks SMKTM-B1 and SMKTM-B2, both blocks are four (4) storeys academic blocks. Block SMKTM-B1 measures an overall block dimension of 51m in length. The third floor consists of five (5) classrooms in a linear layout arrangement with two (2) toilets connected through an open corridor and staircases (Figure 5.3(a)). Block SMKTM-B2 dimension is 60m in length. The third floor consists of six (6) classrooms with two (2) toilets connected through an open corridor and staircases (Figure 5.4(a)).

In addition, blocks SMKSP-B1 and SMKSP-B2 have three (3) storeys high academic blocks, with each block's dimension measuring 63m and 57m in length respectively (Figures 5.5(a) and 5.6(a)). The second floor of block SMKSP-B1 consists of five (5) classrooms, a 'Rehat dan Rawat' (R&R) room and a Moral Room in a linear layout arrangement with a toilet connected through an open corridor and staircases

(Figure 5.5(a)). The second floor of block SMKSP-B2 consists of six (6) classrooms in a linear layout arrangement with a toilet connected through an open corridor and staircases (Figure 5.6(a)).

5.2.6 Block Sections

Through visual field inspection, the physical conditions of the block sections for the six (6) academic blocks: SMKHK-B1 (Figure 5.1(c)), SMKHK-B2 (Figure 5.2(c)), SMKTM-B1 (Figure 5.3(c)), SMKTM-B2 (Figure 5.4(c)), SMKSP-B1 (Figure 5.5(c)) and SMKTM-B2 (Figure 5.6(c)) satisfy By-Laws 138 of Selangor Uniform Building By-Laws (SUBBL) 1986 (Revision 2012) that states:

a) Other walls and floors to be constructed as compartment walls or compartment floors

“The following walls and floors in buildings shall be constructed as compartment walls or compartment floors: (a) any floor in a building of Purpose Group II (Institutional)”.

b) Provisions of compartment walls and compartment floors

Based on field inspection, the academic blocks are designated as Purpose Group II (Institutional), based on the Fifth Schedule of (SUBBL) 1986 (Revision 2012). All blocks complied with the dimensions of buildings and compartments prescribed in By-Laws 136 of (SUBBL) 1986 (Revision 2012) which requires a permissible floor area of a storey in a building or a compartment, that shall be not more than 2,000 m². There is no limitation imposed on the height of the compartment and the volume of the compartment.

5.2.7 Roof Space (Voids and Cavities)

Based on the field inspection, it was found that cavity barriers were non-existence for all six (6) academic blocks: SMKHK-B1 (Figures 5.1 (d) and (e)), SMKHK-B2 (Figures 5.2 (d) and (e)), SMKTM-B1 (Figures 5.3 (d) and (e)), SMKTM-B2 (Figures 5.4 (d) and (e)), SMKSP-B1 (Figures 5.5 (d) and (e)) and SMKTM-B2 (Figures 5.6 (d) and (e)). It is significantly noted that this does not comply with Fire Safety in the Design, Management and Use of Buildings (MS:1183) which indicates the maximum dimensions of cavities (between a roof and a ceiling) for non-domestic buildings shall be 20m (maximum dimensions in any direction).

Cavity barriers should be used to subdivide any cavity, including any roof space so that the distance between cavity barriers does not exceed the required dimensions. In the absence of cavity barriers, the roof space above the classrooms forms a state of extensive cavities, which would allow the smoke and fire to potentially spread along the longitudinal roof structure.

Based on the roof void requirement checklist, Table 5.1 shows the findings of the non-existence of passive fire design safety provisions in the selected schools as case studies.

Table 5.1 The Findings of Non-Existence of Passive Fire Safety Design in Compartmentation in Roof Voids Requirements

Academic Blocks	Passive Compartmentation in Roof Voids Requirements			
	Compartment Walls/ Fire Walls/ Fire Separation	Cavity barriers	Maximum Limit for Undivided Concealed Spaces (Separation Intervals in Roof Voids)	Maximum Limit Areas (Below ceiling) and Compartmentation/ Fire Cells
SMKHK-B1	X	X	X	/
SMKHK-B2	X	X	X	/
SMKTM-B1	X	X	X	/
SMKTM-B2	X	X	X	/
SMKSP-B1	X	X	X	/
SMKSP-B2	X	X	X	/

5.2.8 Findings: On-Site Inspections

The primary data collected was mainly to obtain firsthand insights into the current state of passive fire design in schools. The findings were:

1. The roof compartmentation in all six (6) academic blocks of the national secondary school buildings was identified as having technical deficiencies.
2. Based on observation and field notes, one (1) element was identified in compliance with the (SUBBL) 1986 (Revision 2012), which is the Maximum Limit Areas (Below Ceiling) for compartmentation. The identified floor area was not exceeding 2,000 m².
3. The current conditions of the school's roof space above the classes were identified as being in an extensive cavity state with the non-existence of compartment walls nor any cavity barrier provisions.
4. The absence of these compartment walls (as prescribed in (SUBBL) 1986 (Revision 2012)) and cavity barriers (as described in MS:1183) would allow for smoke and fire to spread within the longitudinal roof space when a fire hazard occurs. This may lead to a catastrophic fire hazard caused by uncontrollable fire and smoke spread within the roof voids or cavities and subsequently spreading downward into the classrooms below.

The findings indicated the Maximum Limit Areas (Below Ceiling) for all schools do comply with the provisions of the (SUBBL) 1986 (Revision 2012). However, it was found that the other fire provisions; 1) vertical fire separators, compartment walls, fire walls, 2) cavity barriers and 3) maximum limit for undivided concealed spaces (separation intervals in roof voids) were non-existence or not provided.

5.3 Data Analysis: Key Informant Questionnaires

5.3.1 Respondents' Background Information

The respondents' background is from various fields of experts and basic questions were asked in the questionnaire survey. The respondents' professions were divided into Architect, Designer, Fire Engineer, Firemen and Others. Their qualifications and years of involvement were also captured to ensure that the participants met the respondents' criteria.

5.3.1.1 Profession Group

The total number of key informants as respondents is twenty-two (22). The respondents' professions involved in the survey were Architects (31.8%), Designers (27.3%), Firemen (22.7%), Fire Engineers (9.1%) and Others (9.1%) as illustrated in Table 5.2.

Table 5.2 Profession Groups of Key Informants

Profession Group	Frequency	Percent	Valid Percent	Cumulative Percent
Architect	7	31.8	31.8	31.8
Designer	6	27.3	27.3	59.1
Fire Engineer	2	9.1	9.1	68.2
Firemen	5	22.7	22.7	90.9
Others	2	9.1	9.1	100.0
Total	22	100.0	100.0	

5.3.1.2 Age Group

The majority of the respondents are between 31 to 45 years old, representing 72.7% of the total respondents. The second highest percentage of age participating in the survey is 18.2% with age below 30 years old, followed by 9.1% age above 56 years old. Table 5.3 shows the distribution of respondents' age group.

Table 5.3 Distribution of Age Groups of Key Informants

Distribution of Age Groups	Frequency	Percent	Valid Percent	Cumulative Percent
Below 30	4	18.2	18.2	18.2
31 to 45	16	72.7	72.7	90.9
Above 56	2	9.1	9.1	100.0
Total	22	100.0	100.0	

5.3.1.3 Qualification Group

The number of key informants who have qualifications with Master's Degree represents the highest number of ten (10) respondents with 45.5%. This is followed by a degree holder of 40.9%. The least number of respondents having Diploma qualification is two (2) respondents with 9.1%. Other qualifications show the lowest percentage with 4.5%. This indicates that the majority of the key informants are highly qualified and knowledgeable in the area of fire safety design.

Table 5.4 Qualification Groups of Key Informants

Qualification Groups	Frequency	Percent	Valid Percent	Cumulative Percent
Diploma	2	9.1	9.1	9.1
Degree	9	40.9	40.9	50.0
Masters	10	45.5	45.5	95.5
Others	1	4.5	4.5	100.0
Total	22	100.0	100.0	

5.3.1.4 Years of Involvement in School Design

The number of key informants who have 1 to 5 years of involvement in school design form the majority numbers at 77.3%, while 6 to 15 years represented 9.1% and above 16 years represented 4.5%. Meanwhile, 9.1% of respondents have no experience in school design. The findings show that all respondents are qualified and meet the criteria to be respondents.

Table 5.5 Years of Involvement in School Design

Years of Involvement in School Design	Frequency	Percent	Valid Percent	Cumulative Percent
0 Years	2	9.1	9.1	9.1
1 to 5 Years	17	77.3	77.3	86.4
6 to 15 Years	2	9.1	9.1	95.5
16 Years and above	1	4.5	4.5	100.0
Total	22	100.0	100.0	

5.3.2 Findings: Key Informant Questionnaire Results

5.3.2.1 School Design

The assessment required key respondents to indicate the most important aspects of the overall school and classroom design based on personal preferences and importance. Frequency analysis was conducted and the findings showed that Fire Safety Design is the most important aspect to be considered with a mean of 6.82, followed by Passive and Thermal Comfort Design with mean of 6.41 and 6.23 respectively. The findings indicate that respondents prioritise fire safety design above other considerations as indicated in Table 5.6.

Table 5.6 Priority of Considerations

Priority of Considerations	Minimum	Maximum	Mean	Std. Deviation
Fire Safety Design	6	7	6.82	0.395
Passive Design	5	7	6.41	0.854
Thermal Comfort Design	4	7	6.23	0.922
Mechanical and Electrical (M&E) Design	4	7	6.00	1.113
Building Structural Design	3	7	5.95	1.290
Universal Design (UD)	2	7	5.91	1.269
Classroom Environment Design	4	7	5.86	1.037
Acoustics Design	2	7	5.59	1.333
Aesthetics Design	1	7	4.36	1.620

5.3.2.2 Fire Safety in School Design

Statements on fire safety in school design and fire compartmentation were posed to the key informants or respondents and the frequency analysis shows that fire safety in school design (6.8) received the highest mean as shown in Table 5.7, followed by fire compartmentation (6.5). The findings show that the respondents come to an agreement that fire safety in school buildings is highly significant.

Table 5.7 Fire Safety in School Design and Fire Compartmentation

Fire Safety in School Design and Fire Compartmentation	Minimum	Maximum	Mean	Std. Deviation
Fire safety is crucial in school design	5.00	7.00	6.7727	0.61193
Fire compartmentation is essential in fire safety in school design	4.00	7.00	6.5000	0.85912

5.3.2.3 *Passive Compartmentation at Roof Voids*

The respondents were asked whether passive compartmentation in roof voids was considered when designing schools. Surprisingly, seventeen (17) respondents (77.3%) answered ‘NO’ and only 22.7% of respondents replied ‘YES’.

Table 5.8 Consideration of Passive Compartmentation in Roof Voids
when Designing Schools

Consideration of Passive Compartmentation in Roof Voids when Designing Schools	<i>Frequency</i>	<i>Percent</i>	<i>Valid Percent</i>	<i>Cumulative Percent</i>
Yes	5	22.7	22.7	22.7
No	17	77.3	77.3	100.0
Total	22	100.0	100.0	

A subsequent open-ended question was further responded by the seventeen (17) respondents who opted for the answer ‘NO’. This group of respondents does not consider passive compartmentation in roof voids when designing schools. Thematic analysis of their feedback revealed four (4) key points as shown in Table 5.9.

The first group of key informants with the highest percentage of 31.8% highlighted that the (SUBBL) 1986 (Revision 2012) is unclear and ineffectively implemented and enforced regarding passive compartmentation in roof void requirements. The second highest group of key informants at 22.7% stated their thoughts on passive compartmentation for classrooms was achieved by providing the minimum requirement based on Maximum Limit Areas (Below Ceiling), in this case, 2,000 m² for schools. It was made to understand that the whole upper floor row of classrooms and roof above are considered to be as one (1) big compartment.

Additionally, the third group forming 13.6% stated roof compartmentation is provided for the isolation of a particularly high-risk area above the classrooms. Otherwise, there is not a need to provide roof compartmentation. The fourth group of respondents with 9.1% clarified that the separator walls between the classrooms are not required to be designed as a vertical fire separators or compartment walls extended up to the roof for individual classroom compartmentation for the upper floor of classrooms.

Table 5.9 Open-Ended Responses on Considerations of Passive Compartmentation in Roof Voids in School Design

Open Ended Responses on Considerations of Passive Compartmentation in Roof Voids in School Design	Frequency	Percent	Valid Percent	Cumulative Percent
Not stated in (SUBBL) 1986	7	31.8	41.2	70.6
Achieved minimum requirement based on Volume in (SUBBL) 1986	5	22.7	29.4	29.4
High-risk area above the classrooms	3	13.6	17.6	100.0
Walls between the classroom is not designed as a party wall up to the roof for individual classroom compartmentation	2	9.1	11.8	82.4
Total	17	77.3	100.0	

The findings highlighted respondents who perceive the (SUBBL) 1986 (Revision 2012) as ambiguous regarding passive compartmentation in roof voids in school design. Respondents clarified that passive compartmentation for classrooms is achievable by adhering to the Maximum Limit Areas (Below Ceiling) and that the roof compartmentation and vertical fire separators extended to the roof are generally unnecessary to be provided unless isolating a high-risk area.

A more comprehensive approach needs to be taken to enrich knowledge and understanding of fire codes and standards. This is due to reasons respondents

demonstrated limited awareness knowledge on the passive compartmentation in roof voids requirements, leading to misinterpretation and misunderstanding on the provisions of passive compartmentation in roof voids in (SUBBL) 1986 (Revision 2012) and MS:1183.

The significant attention given to this issue highlights a critical deficiency in the current regulatory framework. The existing building and fire codes and standards are unclear and ineffectively implemented and enforced due to 1) inconsistent, disjointed and fragmented fire safety provisions in the building and fire codes and standards and 2) a knowledge gap in understanding the fire codes and standards as a whole.

5.3.2.4 Spread of Fire and Smoke Within Roof Space (Voids and Cavities)

The respondents were asked to evaluate the risks of insufficient passive compartmentation in large roof cavities, which could lead to potential smoke and fire spreading throughout the whole building. A significant majority (81.8%) agreed on the importance of proper and sufficient compartmentation. However, 18.2% of respondents considered less critical as indicated in Table 5.10 below.

Table 5.10 Spread of Fire and Smoke within Roof Space (Voids and Cavities)

Spread of Fire and Smoke Within Roof Space (Voids and Cavities)	Frequency	Percent	Valid Percent	Cumulative Percent
Most Important	9	40.9	40.9	40.9
Very Important	9	40.9	40.9	81.8
Moderately Important	3	13.7	13.7	95.5
Neutral	1	4.5	4.5	100.0

5.3.2.5 Downward Spread of Fire to Classrooms Below

When asked the question of the downward spread of fire that would eventually spread down into the spaces or classrooms below when there is insufficient fire passive compartmentation provided along the roof cavities, seventeen (17) respondents (77.3%) agreed to the statement. Five (5) respondents (22.7%) expressed their thoughts by opting for least importance and neutral., as indicated in Table 5.11.

Table 5.11 Downward Spread of Fire to Classrooms Below

Downward Spread of Fire to Classrooms Below	Frequency	Percent	Valid Percent	Cumulative Percent
Most Important	8	36.4	36.4	36.4
Very Important	9	40.9	40.9	77.3
Moderately Important	3	13.6	13.6	90.9
Neutral	2	9.1	9.1	100.0

5.3.2.6 Effective Passive Compartmentation in Roof Voids

Questions on passive compartmentation required the respondents to identify the most significant and effective passive compartmentation in roof voids. The respondents' judgments indicated the adoption of vertical fire separators/ compartment walls/ fire walls to be the most appropriate and effective passive compartmentation strategy with a mean of 6.4, while the Maximum Limit Area (Below Ceiling) with a mean of 6.31, ranked second. Cavity Barriers and Maximum Limit for Undivided Concealed Spaces (Separation Intervals in Roof Voids) were graded at third and fourth with a mean of 6.18 and 6.13 respectively. The least preferred was the Active fire detection at a mean of 5.8.

Table 5.12: Effective Passive Compartmentation in Roof Voids

Effective Passive Compartmentation in Roof Voids	N	Minimum	Maximum	Mean	Std. Deviation
Vertical Fire Separators/ Compartment Walls/ Fire Walls	22	5.00	7.00	6.4091	0.79637
Maximum Limit Areas (Below Ceiling)	22	5.00	7.00	6.3182	0.71623
Cavity Barriers	22	5.00	7.00	6.1818	0.90692
Maximum Limit for Undivided Concealed Spaces	22	4.00	7.00	6.1364	0.88884
Fire Detection (Active Fire	22	4.00	7.00	5.8636	1.03719

The findings indicated respondents are agreeable to the two (2) methods of adopting Vertical Fire Separators/ Compartment Walls/ Fire Walls and Maximum Limit Areas (Below Ceiling) as the most effective passive compartmentation in roof voids.

To meet passive compartmentation standards and provisions, most respondents typically adhere to the Maximum Limit Areas (Below Ceiling), in this case, 2,000 m² for schools. This approach considered the entire upper floor, including classrooms and the elongated roof structure (with extensive cavity state) above, as a single compartment and fire eventually spread within the roof space and downward to the spaces or classrooms below. Findings are consistent with on-site observation conducted.

Importantly, separator walls between classrooms are not required to be constructed as full height compartment walls for classrooms on the upper floor in connection to the elongated roof space. This means without the full height compartment walls, the entire upper classrooms and the roof space are one (1) big compartment. The Findings are also consistent with field observation conducted. Respondents also explained that the inclusion of separator walls for passive compartmentation in roof voids is only necessary whenever controlling potential risks associated with hazardous spaces located above the classrooms.

5.3.2.7 *Insufficient Fire Compartmentation Provisions*

The respondents are required to identify the most common technical deficiencies that may cause passive compartmentation in roof void to fail or give way during a fire outbreak. The analysis indicated Vertical Fire Separators/ Compartment Walls/ Fire Walls were the main cause with a mean of 5.8 and secondly, Maximum Limit Area (Below Ceiling) with a mean of 5.6. Maximum Limit for Undivided Concealed Spaces (Separation Intervals in Roof Voids) and Cavity Barriers were graded at third and fourth with means of 5.5 and 5.4 respectively. The least cause was the Active fire detection at 5.5.

Table 5.13: Insufficient Fire Compartmentation Provisions

Insufficient Fire Compartmentation Provisions	N	Minimum	Maximum	Mean	Std. Deviation
Vertical Fire Separators/ Compartment Walls/ Fire Walls	22	2.00	7.00	5.8182	1.43548
Maximum Limit Areas (Below Ceiling)	22	2.00	7.00	5.6364	1.17698
Maximum limit for Undivided concealed Spaces (Separation Intervals in Roof Voids)	22	2.00	7.00	5.5909	1.33306
Fire Detection Provision	22	3.00	7.00	5.5000	1.18523
Cavity Barriers	22	2.00	7.00	5.4091	1.22121
Valid N (listwise)	22				

Based on Table 5.12 and Table 5.13, the findings show consistency in respondents' consideration of Vertical Fire Separators/ Compartment Walls/ Fire Walls and Maximum Limit Areas (Below Ceiling) as the essential passive compartmentation measures in roof voids.

5.4 Discussions

5.4.1 Field Observations and Inspections on Selected Case Studies

Upon the establishment of the observation checklist, three (3) national secondary schools in the state of Selangor were selected as case studies to be evaluated and arrive at an evidence-based approach. The field observation and investigation conducted are to record and analyse data on the current approach application and implementation of the schools' passive compartmentation provisions against the building and fire codes and standards, Selangor Uniform Building By-Laws (SUBBL) 1986 (Revision 2012) and Fire Safety in the Design, Management and Use of Buildings (MS:1183).

The primary data was collected mainly to obtain firsthand insights into the current state of passive fire design in schools. The findings were:

1. The roof compartmentation in all six (6) academic blocks of the national secondary school buildings was identified as having technical deficiencies.
2. Based on observation and field notes, one (1) element was identified in compliance with the (SUBBL) 1986 (Revision 2012), which is the Maximum Limit Areas (Below Ceiling) for compartmentation. The identified floor area was not exceeding 2,000 m².
3. The current conditions of the school's roof space above the classes were identified as being in an extensive cavity state with the non-existence of compartment walls nor any cavity barrier provisions.
4. The absence of these compartment walls or fire barriers would allow for smoke and fire to spread within the longitudinal roof space when a fire hazard occurs. This may lead to a catastrophic fire hazard caused by uncontrollable fire and smoke spread within the roof voids or cavities and subsequently spreading downward into the classrooms below.

5.4.2 Questionnaire Survey

The key informant questionnaires were established and a distribution technique was employed to gather the opinions of experts and professionals involved in the design and construction of school buildings focusing on fire safety. Twenty-two (22) key informants from various fields of expertise participated as respondents. Based on the analysis of the questionnaire survey, the following findings were identified:

1. All twenty-two (22) respondents agreed fire safety is a critical component and passive compartmentation emerges as the fundamental consideration and strategy for safeguarding lives and property.
2. All twenty-two (22) respondents also confirmed that an effective school design is paramount in mitigating fire risks. Fire safety is crucial in school design indicating the significant risk of fire and smoke spreading through the roof voids or cavities.
3. Respondents indicated passive compartmentation in roof voids is essential for managing potential fire hazards. The majority of respondents (81.8%) identified vertical fire separators or compartmentation walls, as prescribed in (SUBBL) 1986 (Revision 2012) as the most effective strategy for passive compartmentation, as compared to cavity barriers (as described in MS:1183).
4. Seven (7) respondents (31/8%) indicated the (SUBBL) 1986 (Revision 2012) requirements for passive compartmentation in roof voids to be ambiguous or lacking in clarity, the reason being that requirements for cavity barriers and maximum limit for undivided concealed spaces (separation intervals in roof voids) are described in MS:1183, while no provisions for full height compartment walls in (SUBBL) 1986 (Revision 2012). This has led to the interpretation and understanding of:
 - a) To meet passive compartmentation standards and provisions, most respondents typically adhere to the Maximum Limit Areas (Below Ceiling), in this case, 2,000 m² for schools. This approach considered

the entire upper floor, including classrooms and the elongated roof structure (with extensive cavity state) above, as a single compartment and fire eventually spread within the roof space and downward to the spaces or classrooms below. Findings are consistent with on-site observation conducted.

- b) Importantly, separator walls between classrooms were not required to be constructed as full height compartment walls for classrooms on the upper floor in connection to the elongated roof space. This means without the full height compartment walls, the entire upper classrooms and the roof space are one (1) big compartment. The findings are also consistent with field observation conducted.
 - c) Four (4) respondents (18.1%) also explained that the inclusion of passive compartmentation in roof voids is only necessary whenever controlling potential risks associated with hazardous spaces located above the classrooms.
- 5. This amplifies the issue of schools having technical deficiencies in reference to both questionnaire surveys and visits to the three (3) national secondary schools.
 - 6. The roof space above the classrooms was identified as being in an extensive cavity state with the non-existence of compartment walls and any cavity barrier provisions.
 - 7. The proposed method as indicated by key informants is to treat the upper classrooms as individual compartments through the means of 1) continuing the compartment wall up to the underside of the roof or 2) through the roof extruding beyond the surface of the roof or by implementing 3) cavity barriers within the roof space to comply with Maximum Limit for Undivided Concealed Spaces (Separation Intervals in Roof Voids).
 - 8. These proposed methods could be applied to both new and existing school buildings through new construction and retrofitting methods. This will create a

more practical and effective approach to passive compartmentation for safeguarding lives, school property and operational efficiency.

9. Respondents limited understanding of passive compartmentation in roof voids, as highlighted in Figure 5.7, indicates a need for a comprehensive approach to improve knowledge and understanding of fire codes and standards, particularly the provisions of the (SUBBL) 1986 (Revision 2012) and the MS:1183.
10. The significant focus of the findings highlights a critical gap in the current regulatory framework. Respondents perceive the current building and fire codes and standards as inconsistent, fragmented and disjointed. A limited number of five (5) respondents (22.7%) from twenty-two (22) key informants were aware of the passive compartmentation in roof voids provision in schools in reference to both the (SUBBL) 1986 (Revision 2012) and Fire Safety in the Design, Management and Use of Buildings (MS:1183).

REQUIRMENT	FIRE SAFETY REGULATORY		COMPLIANCE
Mandatory to comply	Selangor Uniform Building By-Laws (SUBBL) 1986 (Revision 2012)		Individual classrooms on the upper floor lacked full height fire walls, resulting in extensive cavity state in roof space and considered as one big compartmentation
	Compartment Walls (Fire Walls, Fire Separation)	Maximum Limit Ares (Below Ceiling) and Compartmentation	
Voluntary to comply	Fire Safety in the Design, Management and Use of Buildings MS:1183		Non-Compliance
	Cavity Barriers	Maximum Limit for Undivided Concealed Spaces (Separation Intervals in Roof Voids)	
Mandatory to comply for schools above 2,000 m ²	Selangor Uniform Building By-Laws (SUBBL) 1986 (Revision 2012)		Not required (as schools below 2,000 m ²)
	Active Fire Appliances		

Figure 5.7 Current Regulatory Framework Requirements and Compliance for Passive Compartmentation Requirements for School Buildings

5.5 Chapter Summary

Overall, the chapter presented the result analysis for passive compartmentation in schools. The findings deduced from the results show fire safety design in school buildings is highly physical significant in school building typology. The findings of the case studies showed that the provisions of passive compartmentation were absent in the national secondary schools. Furthermore, a small number (22.7%) of key informants were aware of the passive compartmentation in roof voids provision in schools in reference to the (SUBBL) 1986 (Revision 2012) and Fire Safety in the Design, Management and Use of Buildings (MS:1183).



CHAPTER SIX

CONCLUSIONS AND RECOMMENDATIONS

6.1 Introduction

The conclusion and recommendations would be the final chapter of this study. It draws significant findings that would lead the researcher to make recommendations for future school designers. The aim of this study is to evaluate the existing provisions of compartmentation for fire safety in passive design strategy in national secondary schools in Malaysia. Discussions on whether the objectives of the study were met or not would be elaborated. The research experienced some limitations that need to be highlighted.

In this study, three (3) objectives were achieved. This section discusses the findings obtained from each objective to give a clear understanding of the passive compartmentation in roof voids or cavities in national secondary schools.

6.2 Conclusions

6.2.1 Objective 1: To identify the current practices and provisions for national secondary school design to achieve fire safety on passive compartmentation at roof voids locally and internationally.

Building and fire codes and standards were examined concerning passive compartmentation at roof voids in school buildings. By thoroughly understanding these regulations, key elements for further investigation were identified. Subsequently, a comparative study of the related building and fire codes was conducted from selected significant countries, such as the United Kingdom, Sweden and New Zealand, including Malaysia. This is to identify and highlight the similarities, differences and potential

gaps in passive compartmentation requirements for roof voids in national secondary schools in Malaysia. The key elements identified are:

- (i) compartmentation maximum limit,
- (ii) compartment walls and floors,
- (iii) undivided concealed spaces in roof voids,
- (iv) cavity barriers, and
- (v) fire detection provisions.

The comparative analysis study conducted between countries revealed commonalities in passive compartmentation requirements for roof voids for the three (3) key elements that have similar requirements. The study findings are:

- (i) compartment walls (fire walls or vertical fire separators),
- (ii) allowable maximum limit for undivided concealed spaces (separation intervals in roof voids), and
- (iii) cavity barriers.

However, differences in requirements were identified for the other two (2) key elements that showed variations in terms of required sizes and volumes:

- (i) Maximum Limit Areas (Below Ceiling) for compartmentation, and
- (ii) active fire-fighting system (detection and suppression system).

The data findings indicated the five (5) key elements are crucial in achieving fire safety in passive design strategy in schools. The performance of passive compartmentation at roof voids in schools is dependent on these key elements for fire safety design in schools.

6.2.2 Objective 2: To evaluate the existing conditions of fire safety design provision for passive compartmentation in particular vertical separation at roof voids in national secondary schools locally.

6.2.2.1 Field Observations

The field observation and investigation of the three (3) national secondary schools in the state of Selangor were conducted as an evidence-based approach. The findings revealed all six (6) academic blocks in the national secondary school buildings were found to have significant technical deficiencies in their roof compartmentation. The roof space was identified as being in an extensive cavity state with the non-existence of compartment walls nor any cavity barrier provisions, allowing for smoke and fire to spread within the longitudinal roof space when a fire hazard occurs.

6.2.2.2 Questionnaire Survey

A questionnaire survey was administered to a panel of twenty-two (22) key informants, comprising fire experts and professionals with specialized knowledge in school building design. The findings found that respondents found that the existing building and fire codes and standards are inconsistent and fragmented, where only 22.7% from twenty-two (22) key informants were aware of the passive compartmentation in roof voids provision in schools in reference to both the (SUBBL) 1986 (Revision 2012) and Fire Safety in the Design, Management and Use of Buildings (MS:1183).

6.2.2.3 Literature Review

A literature review was conducted on the building and fire codes and fire standards, with respective to the Selangor Uniform Building By-Laws (SUBBL) 1986 (Revision 2012) and the Fire Safety in the Design, Management and Use of Buildings (MS:1183).

The findings found that the fire requirements for the five (5) key elements for passive compartmentation requirements for roof voids were fragmented and disjointed.

As the literature review revealed the Selangor Uniform Building By-Laws (SUBBL) 1986 (Revision 2012) prescribes (i) Compartment Walls (Fire Walls or Vertical Fire Separators) and (ii) Maximum Limit Areas (Below Ceiling) for compartmentation. Whereas, the Fire Safety in the Design, Management and Use of Buildings (MS:1183) describes (i) the allowable maximum limit for undivided concealed spaces (separation intervals in roof voids) and (ii) cavity barriers. Active fire-fighting system (detection and suppression system) is mentioned in both as prescribed in (SUBBL) 1986 (Revision 2012) and as described in MS:1183.

Figure 5.7 (see page 110) illustrates the current regulatory framework for passive compartment requirements and compliance with the existing conditions of fire safety design provision for passive compartmentation at roof voids in national secondary schools in Malaysia as prescribed in (SUBBL) 1986 (Revision 2012) and as described in MS:1183.

Both the literature review and field observation also found that the case study schools: 1) Sekolah Menengah Kebangsaan (SMK) Hulu Kelang, Sekolah Menengah Kebangsaan (SMK) Taman Melawati and Sekolah Menengah Kebangsaan (SMK) Sungai Pusu were built between the years 1967 and 1999, prior to the implementation of Standard Operating Procedure (SOP) Procurement of Lead Consultant (LC). These schools are institutional buildings meant for educational purposes that are not meant for profit making by the government, permitting the Public Works Department (PWD) to be exempted from the standard building plan approval to submit drawings for approval to the Local Authority or Pihak Berkuasa Tempatan (PBT), Drawings and documentation are submitted solely for record-keeping purposes.

Based on the above, the study findings are:

- (i) inconsistent implemented enforcement of standard building plan approval process (prior to implementation of Standard Operating Procedure (SOP) Procurement of Lead Consultant (LC),
- (ii) fragmented and disjointed fire safety provisions in the building and fire codes and standards, and
- (iii) a knowledge gap in understanding the fire codes and standards.

6.3 Recommendations

6.3.1 Objective 3: **To provide recommendations on passive fire design strategy on compartmentation in roof voids implemented in national secondary schools in Malaysia for fire safety.**

Current regulations primarily concentrate on compartmentation within space below the ceiling, while emphasis is not given regarding compartmentalizing the voids and cavities in roofs for school buildings. To address this gap, stakeholders must enhance their understanding of relevant fire codes and standards. A holistic fire safety approach is achievable by fostering a comprehensive knowledge of passive compartmentation provisions outlined in (SUBBL) 1986 (Revision 2012) and MS:1183, from the initial stage of understanding fire concepts and containment principles through to building maintenance.

This section discusses the recommendations for a practical implementation from the view of 1) Building and Fire Codes and Standards, 2) compartmentation methods, 3) designers and experts, 4) building maintenance and 5) key suggestions for future improvements concerning passive compartmentation in roof voids.

6.3.1.1 Key Suggestions for Future Improvements

The respondents were finally asked an open-ended question regarding their thoughts on passive compartmentation in roof voids in school design and suggestions for further improvements. A thematic analysis was conducted for this question. The respondents' answers were analysed and interpreted as patterns of shared meaning or themes within the collected data from the questionnaire survey. This approach provided a clear framework for understanding respondents' insights based on their expertise and experience. The issues of concerns identified were 1) Policy and Regulations, 2) Design and Construction, 3) Education, 4) Cost and Feasibility, 5) Integrated Fire Safety System, 6) Human Factor, 7) Construction Quality and 8) Maintenance. Figure 6.1 shows the frequency of these themes generated using an Excel worksheet.

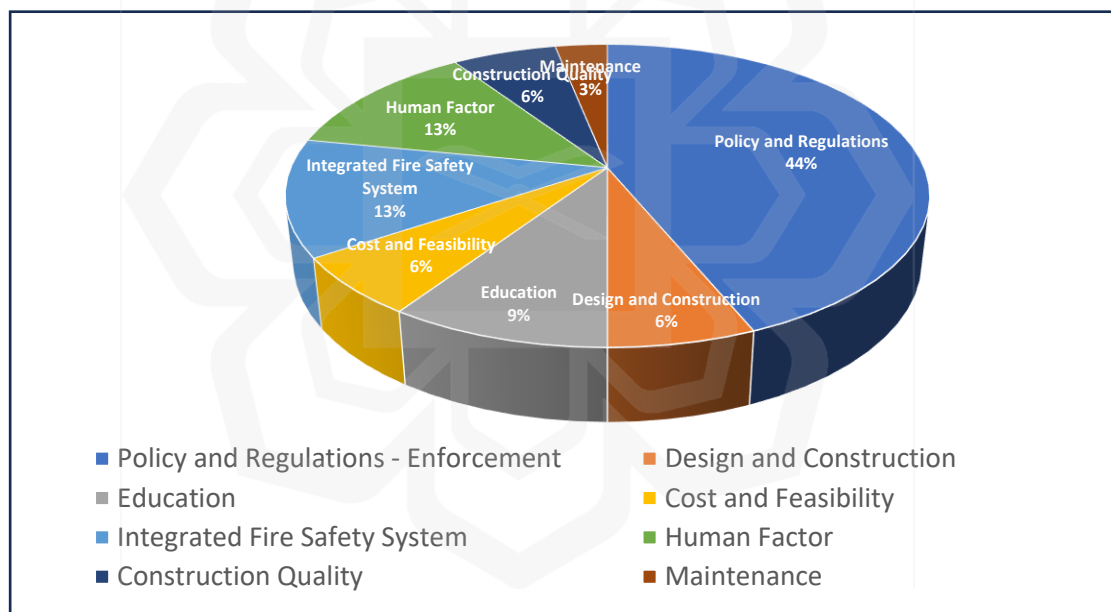


Figure 6.1 Key Suggestions for Future Improvements

There were thirty-two (32) feedbacks from the respondents on their insights. The analysis indicated the key suggestions based on the breakdown of 44% regarding policy and regulation, 13% integrated fire safety system, 13% human factor, 9% education, 6% design and construction, 6% construction quality, 6% cost and feasibility and 3% maintenance.

The findings of respondents' feedback on passive compartmentation in roof voids highlight the necessity for: 1) comprehensive Building and Fire Codes and Standards, 2) Integrated Fire System, 3) engagement of Designers and Experts and 4) persistent Building Maintenance.

6.3.1.2 Comprehensive Building and Fire Codes and Standards

A comprehensive regulatory framework is required to be implemented to ensure a more consistent and effective enforcement. The need for clear and comprehensive regulations addressing passive compartmentation at roof voids is to avoid misconception and misinterpretation. Aligning (SUBBL) 1986 (Revision 2012) with MS:1183 is crucial for consistency as an effective enforcement strategy as shown in Figure 6.2.

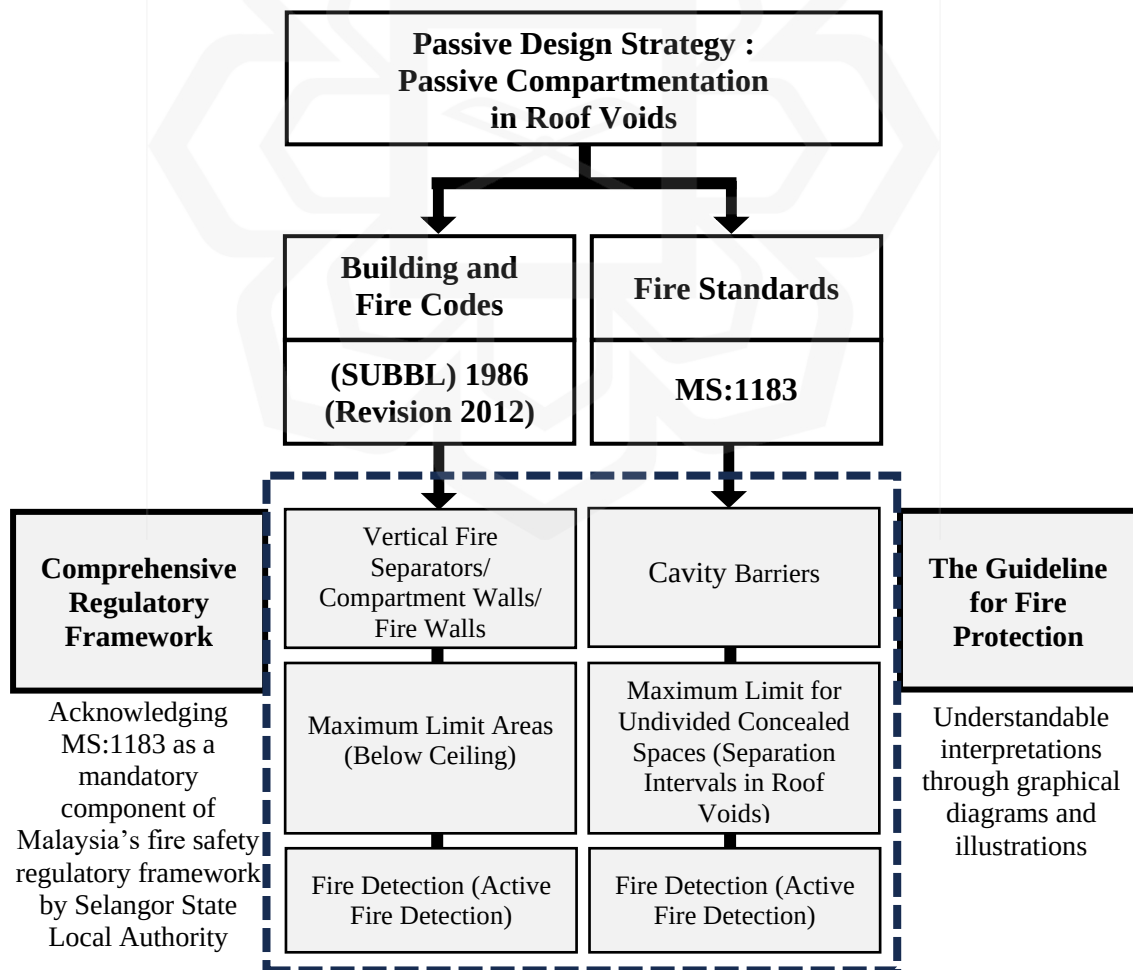


Figure 6.2 Conceptual Regulatory Framework of the Study

Acknowledging MS:1183 as a mandatory component of Malaysia's fire safety regulatory framework requirement instead of a voluntary guideline is essential to enforce compliance with the standards concerning passive compartmentation in roof voids in schools as shown in Figure 6.1. Selangor as a state has the authority to establish its own specific building rules and regulations prescribed in (SUBBL) 1986 (Revision 2012). Prioritizing both compartmentation below ceilings and compartmentation within the roof voids will provide a clear understanding of compartmentation for fire safety in passive design strategy in schools by including these relevant By-laws.

These attempts shall be in line by adopting international best practices incorporating proven compartmentation strategies from other countries, for instance, the United Kingdom, Sweden and New Zealand into Malaysian building and fire codes. Integrating active fire detection and suppression will enhance passive compartmentation in roof voids in schools as attempted by other countries.

Evidence-Based Decision making can significantly enhance the development of standards for passive compartmentation in fire safety. Understanding the containment principles and 'Performance Gap' and 'Safety Gap' guides policymakers in establishing standards enhancing the development of passive compartmentation in schools.

Additionally, efforts to break down complex fire safety regulations into understandable interpretations are desirable, for instance, the current Guide to Fire Protection in Malaysia is being used as a reference in the construction industry to understand the By-laws in Uniform Building By-Laws (UBBL) 1984 (Revision 2021) through diagrams and illustrations. The book is a compilation of graphical diagrams and interpretations from (UBBL) 1984 (Revision 2021) for easy understanding and application.

6.3.1.3 Integrated Fire Fighting System

Potential methods to enhance the passive compartmentation at roof voids in schools shall be treating the upper classrooms as individual compartments through means of 1) continuing the compartment walls up to the underside of the roof or 2) through the roof extruding beyond the surface of the roof or by implementing 3) cavity barriers within the roof space to comply with Maximum Limit for Undivided Concealed Spaces (Separation Intervals in Roof Voids) and 4) integrating active fire system.

A more integrated fire fighting safety system, combining both passive and active elements ensures enhanced fire safety and protection of life and property. Figure 6.3 shows the method of passive compartmentation integrated with active detection and suppression systems.

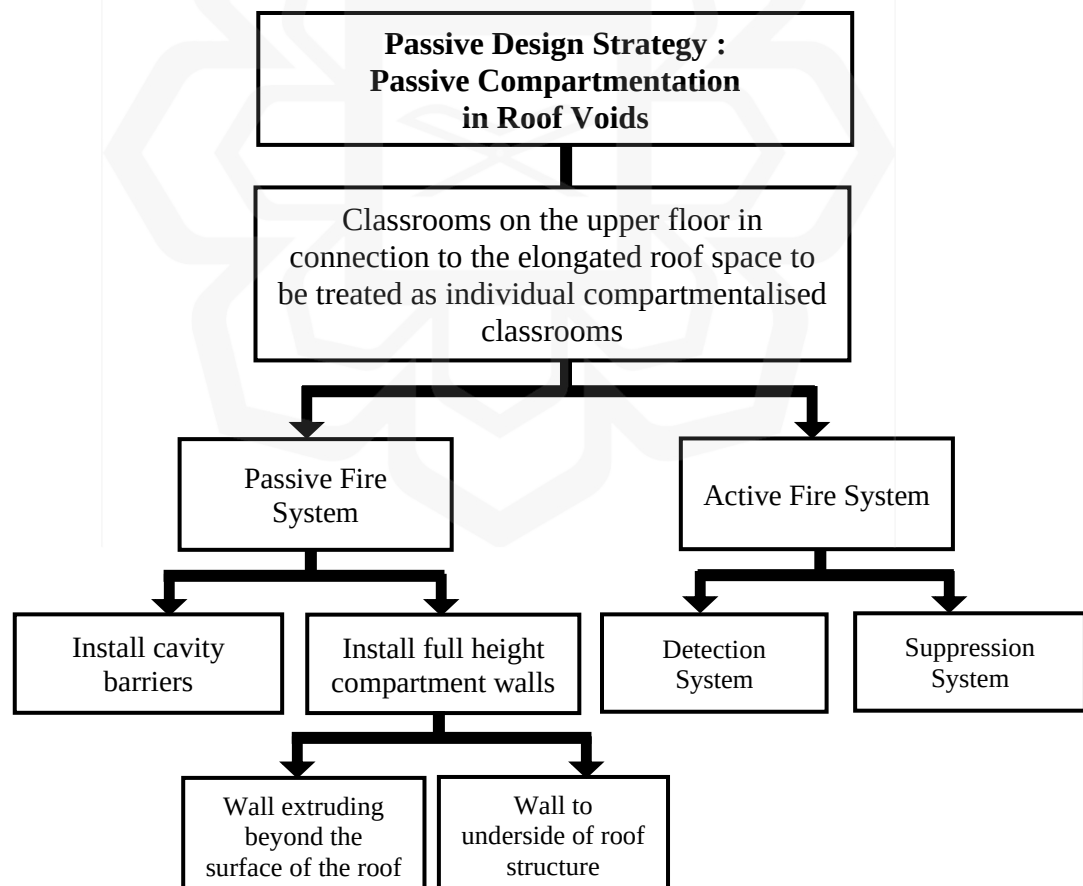


Figure 6.3 Integrated Fire Fighting System

6.3.1.4 Engagement of Designers and Experts

Collaboration among government agencies and stakeholders to facilitate a two-way dialogue on improving fire safety is vital. This collective effort promotes a comprehensive understanding of fire prevention and containment principles. A collaborative platform for the Fire Rescue Department of Malaysia (FRDM), Public Works Department (PWD), fire experts and school designers to foster the exchange of ideas, expertise and best practices to reinforce fire safety requirements and compliance.

6.3.1.5 Persistent Building Maintenance

A proper maintenance method for fire safety systems and building components is essential to ensure ongoing effectiveness from design inception through the construction and maintenance phase. Performance monitoring of passive compartmentation systems is crucial for identifying areas requiring improvements. Regular maintenance practices are vital for preserving the life cycle integrity of the roof structure, including passive compartmentation and active detection and suppression systems.

6.4 Limitation of Study

This study was subjected to some limitations:

1. A lack of references could be found regarding local research on passive fire safety strategies, specifically passive compartmentation in Malaysian roof voids and cavities, as there are very limited source of reference.
2. Limited time and resources to expand more complex issues regarding passive compartmentation in-depth.
3. As the roof voids require access and physical inspections by climbing with special tools, the researcher could only manage to carry out a visual inspection through photographic recording due to the lack of equipment and assistance provided.

6.5 Recommendation for Future Research

In order to provide a more comprehensive study on passive compartmentation in roof voids in schools, the following are recommendations to be considered:

1. To explore potential research gaps related to passive compartmentation in roof voids of different building typologies, and
2. A comprehensive study could be done in terms of Cost Benefit Analysis to evaluate the economic implications of implementing passive compartmentation measures for existing and newly constructed schools.

6.6 Chapter Summary

The investigation concerns the critical deficiency of passive compartmentation design in Malaysian national secondary schools. By reviewing existing research and conducting a comprehensive analysis, the study highlights the absence of compartment walls and cavity barriers in the case study schools. This is due to the exemption circulars enabling executing agencies, the Public Works Department (PWD) to be exempted from standard building plan submissions and from obtaining a Certificate of Fitness for Occupation (CFO) or Certificate of Completion and Compliance (CCC) from the Local Authority or Pihak Berkuasa Tempatan (PBT). This research found the absence of fire compartmentation in roof voids: 1) compartment walls and 2) cavity barriers, which are serious deficiencies in school designs. This is due to 1) inconsistent implemented enforcement of standard building plan approval process (prior to implementation of Standard Operating Procedure (SOP) Procurement of Lead Consultant (LC), 2) fragmented and disjointed fire safety provisions in the building and fire codes and standards and 3) a knowledge gap in understanding the fire codes and standards. Essentially, the findings highlight the urgent requirement for enhanced fire safety provisions in Malaysian schools by focusing on the importance of passive compartmentation, particularly roof voids. This research emphasizes the need for a more comprehensive regulatory framework 1) to promote a common understanding of the Building and Fire Codes and Standards among all stakeholders, 2) to enhance the implementation of an Integrated Fire Fighting System to improve fire safety

performance, 3) to foster engagement between Designers and Fire Experts and 4) to prioritise persistent building maintenance to ensure a more consistent and effective enforcement and understanding of fire safety design standards in schools for fire safety compliance. Thus, it is hoped that these research findings would make the relevant stakeholders aware and make amendments to the existing and future school designs.



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APPENDIX I: SAMPLE OF PERMISSION LETTER

 الجامعة الإسلامية العالمية ماليزيا INTERNATIONAL ISLAMIC UNIVERSITY MALAYSIA بُونَيَسْتِي اِسْلَامِيَّةٌ اِنْتَارَاغِيَّةٌ مِلِّيْسِيَا Garden of Knowledge and Virtue	LEADING THE WAY KHALIFAH • AMANAH • IQRA' • RAHMATAN LIL'ALAMIN SUSTAINABILITY INSTITUTION OF THE YEAR
Our Reference: IIUM/306/C/1/2	Date: 12 March 2024
Pn. Nik Nur Rahayu Binti Che Yahaya Pengetua, SMK Hulu Kelang KM 7, Jalan Hulu Kelang 68000 Ampang Selangor Darul Ehsan	
Assalamu'alaikum wrt. wbt. Dear Madam,	
REQUEST PERMISSION TO COLLECT DATA AND INTERVIEW FOR RESEARCH PURPOSES	
May this letter reach you while you are in the best of health by the grace of Allah S.W.T.	
This is to certify that the following student is a postgraduate student from Kulliyah of Architecture & Environmental Design (KAED) and he is currently carrying out his research work :-	
Name of Student	: Ar. Adli Hadi Abdul Hadi
Matric No/Programme	: G2210675 / Master of Science (Building Services, Asset and Facilities Management)
Email/HP No	: adlihadli@iium.edu.my / 0193644280
Title of Research	: Evaluation on Roof Compartmentation of National Secondary Public Schools in Fire Safety in Malaysia
We highly appreciate if your good office could provide assistance to the above student. The data collected by the student will be strictly confidential and used only for academic purposes. We look forward to your positive feedback.	
Your cooperation and consideration are highly appreciated.	
Thank you. Wassalam.	
 ASSOC. PROF. Ts. Dr. NURUL HAMIRUDDIN SALLEH Deputy Dean (Postgraduate, Responsible Research and Innovation) Kulliyah of Architecture & Environmental Design International Islamic University Malaysia	
c.c	: Asst. Prof. Ar. Dr. Srazali Aripin - Supervisor
NHS/snm	
KULLIYAH OF ARCHITECTURE AND ENVIRONMENTAL DESIGN (KAED) International Islamic University Malaysia, Gombak Campus, Jalan Gombak, 53100 Kuala Lumpur Mailing Address: Kulliyah of Architecture and Environmental Design, P.O. Box 10, 50728 Kuala Lumpur, Malaysia (Company No: 101067-F) Tel: +603 6421 5229 (Ext: 5234/5253/3765) Fax: +603 6421 4844 Email: kaed@iium.edu.my www.iium.edu.my/kaed	
	

[illegible]

APPENDIX III: SAMPLE OF OBSERVATION CHECKLIST

No.

OBSERVATION CHECKLIST

PART 1 : BUILDING INFORMATION

Name of National School: SMK HILLI KELANG

School Code: SMKHK

PART 2 : COMPARTMENTATION:

BLOCK NO. <u>1</u> (<u>2 storeys</u>)				
No.	Element	Presence	Absence	Remarks
1.	Vertical fire separation/ Compartment wall/Fire wall		<u>not extended to roof</u>	
2.	Cavity Barriers		<u>NOX</u>	
3.	Maximum Limit for Undivided Concealed Spaces (Separation Intervals in Roof Voids)		<u>NOX</u>	<u>absent</u>
4.	Maximum Limit Areas (Below Ceiling)	<u>Yes ✓</u>		<u>area 21000m² max.</u>
5.	Fire Detection (Active Fire Detection)		<u>No.</u>	<u>not provided</u>

PART 3 : SIGNS OF DAMAGE TO COMPARTMENT MATERIALS AND IMPROPER INSTALLATION OF COMPARTMENTATION

Nil - not applicable.

PART 2 : COMPARTMENTATION:

BLOCK NO. <u>2</u> (<u>3 storages</u>)				
No.	Element	Presence	Absence	Remarks
1.	Vertical fire separation/ Compartment wall/Fire wall		/	
2.	Cavity Barriers		/	
3.	Maximum Limit for Undivided Concealed Spaces (Separation Intervals in Roof Voids)		/	same as Block 1.
4.	Maximum Limit Areas (Below Ceiling)	/		
5.	Fire Detection (Active Fire Detection)		/	

**PART 3 : SIGNS OF DAMAGE TO COMPARTMENT MATERIALS
AND IMPROPER INSTALLATION OF COMPARTMENTATION**

Ditto

Pn. Nik Rahayu
Bt. Che Yahya.

Guard to assist

**APPENDIX IV:
SAMPLE OF FIELD NOTES**

No. /

FIELD NOTES

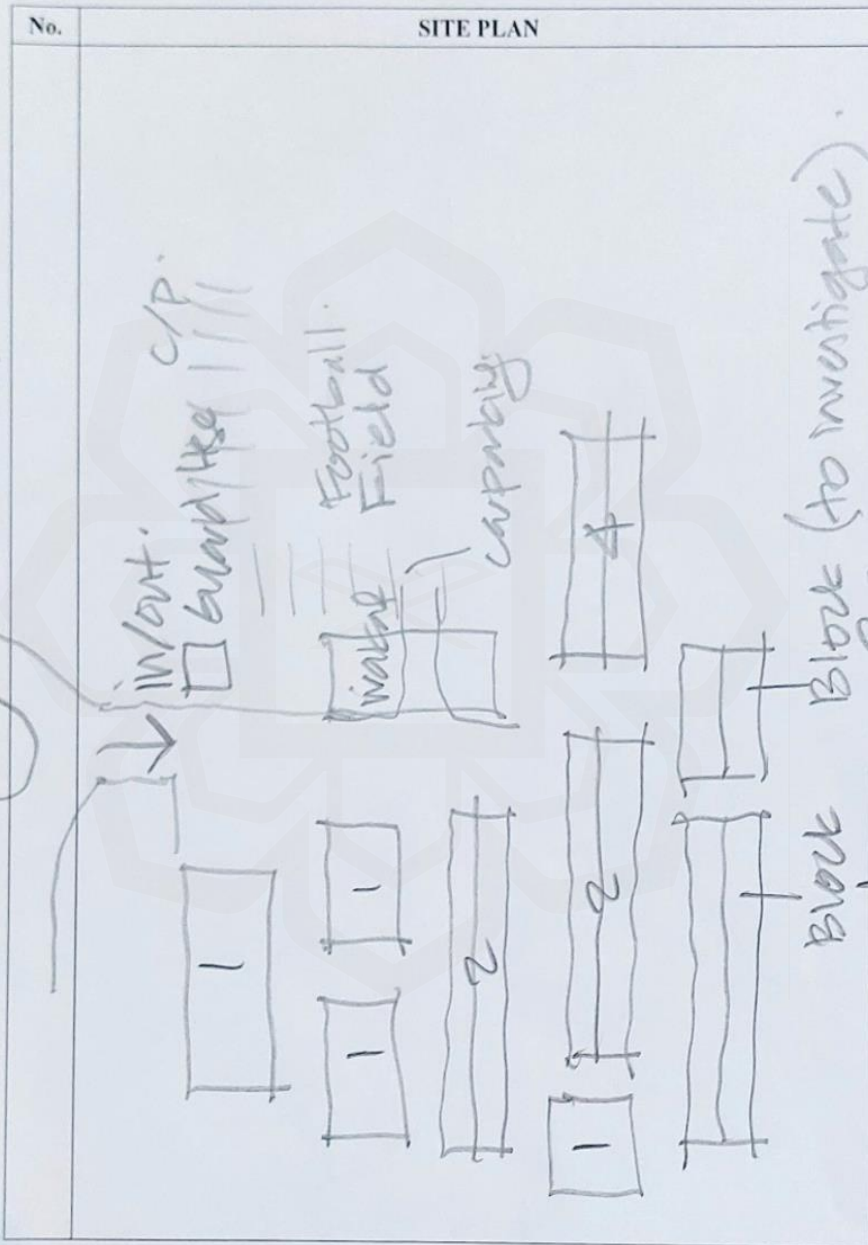
PART 1 : BUILDING INFORMATION

1. Name of National School: SMK HULU KELANG
2. School Code: SMKHK
3. Location/ Address: HULU KELANG, SELANGOR
4. Year Built: 1967
5. No. of Classrooms: 15 (to confirm).
6. No. of Blocks: 4 academic blocks.
7. Storey Height: 2 storeys to 4 storeys.

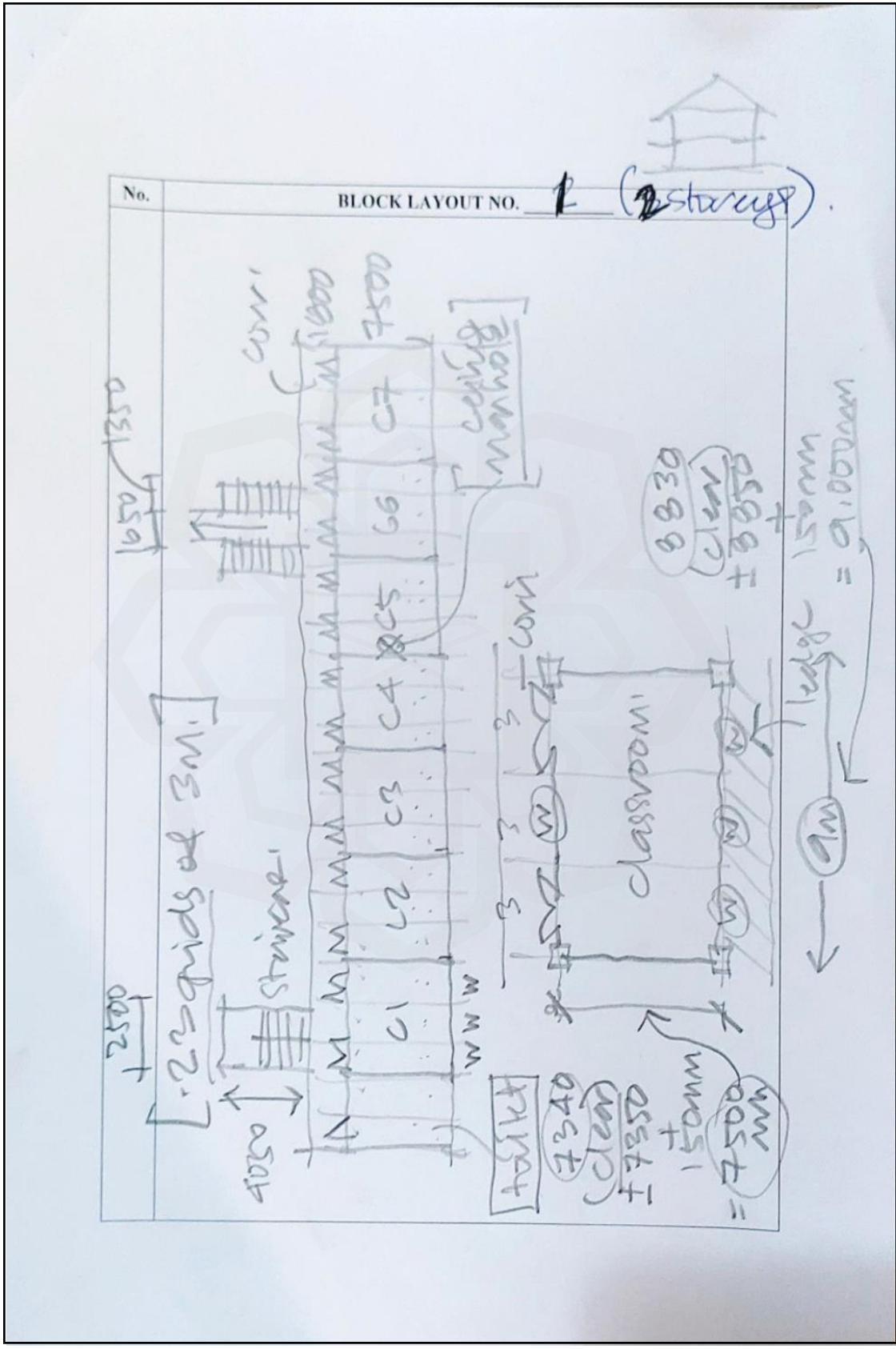
PART 2 : SITE VISIT INFORMATION

1. Date of Visits :
 - a) Pre-Visit: 18 May 2024
 - b) Actual Visit: 01 June 2024
2. Principle Name: Pn. Nik Rahayu Bt. Che Yahaya.
3. Date of Approval from School Administration: 16 May 2024

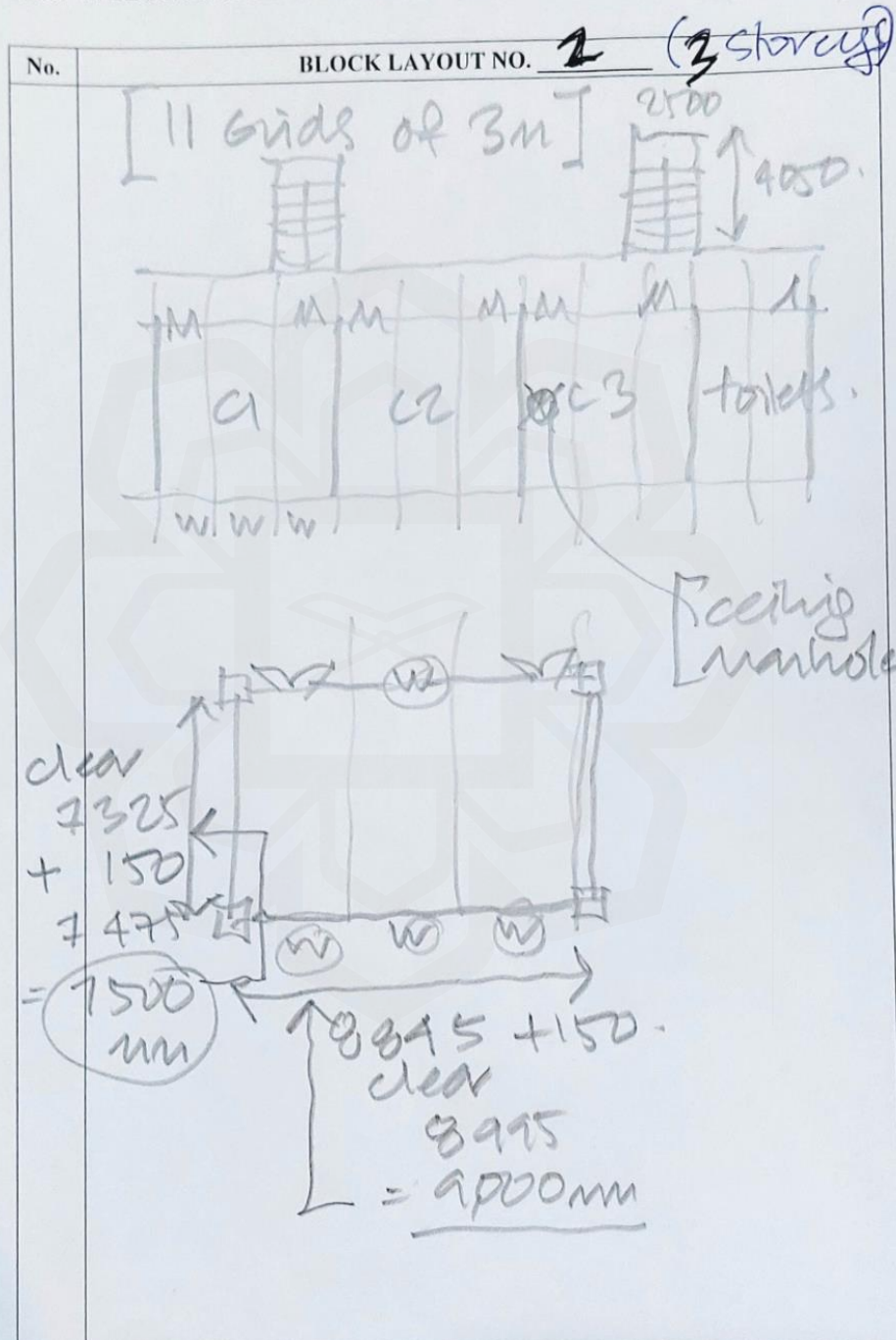
PART 3 : SITE PLAN



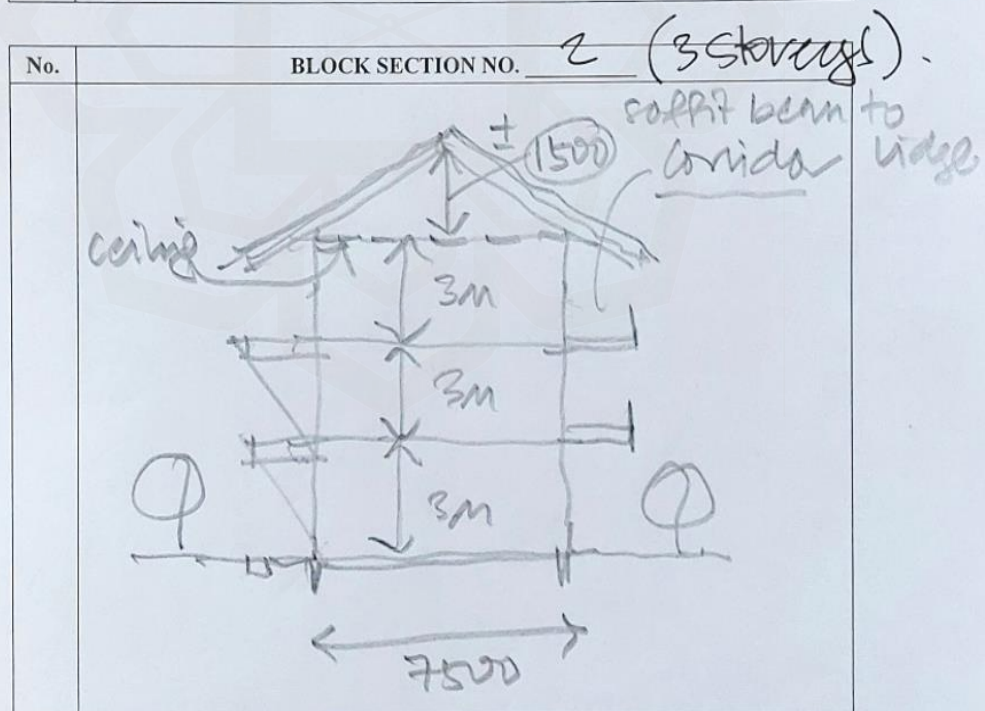
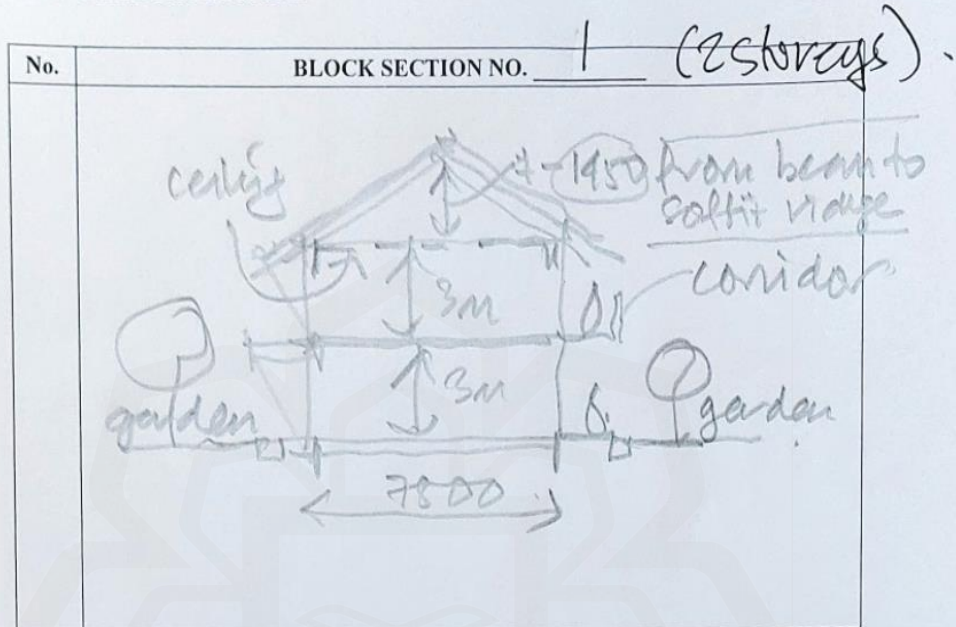
N
(to back)



PART 4 : BLOCK LAYOUT CONFIGURATIONS



PART 5: BLOCK SECTIONS



APPENDIX V: SAMPLE OF QUESTIONNAIRE

FIRE SAFETY DESIGN QUESTIONNAIRE SCHOOL DESIGNERS, PROFESSIONALS AND TECHNICAL PERSONS

Please tick your answer in the appropriate box

SECTION 1 : BACKGROUND INFORMATION

- 1.1 Profession
☒ Architect ☐ Designer ☐ Fire Engineer ☐ Firemen
☐ Other (Please specify) : _____
- 1.2 Gender
☒ Male ☐ Female
- 1.3 Age Group
☐ Below 30 ☐ 31 to 45 ☐ 46 to 55 ☒ Above 56
- 1.4 Years of involvement in school design
☐ 0 ☒ 1 to 5 ☐ 6 to 15 ☐ 16 and above
- 1.5 Type of school design involved (Secondary/Primary/Government school/Private school/Others)
PRIVATE SCHOOLS
- 1.6 Location of school/s (District/State)
SELANGOR, KUALA LUMPUR
- 1.7 Nos. of Classrooms (12/ 24/ 36 classrooms/ Others)
FROM 30 to 50
- 1.8 School completion year/s
ON-GOING PROJECT
- 1.9 What was the qualification you possessed when you participated in the school design process?
☐ Certificate ☐ Diploma ☒ Degree ☐ Master
☐ PhD ☐ Other (please specify) : _____
- 1.10 Please specify your role in the school design?
PRINCIPAL ARCHITECT
- 1.11 In your opinion, what knowledge or special skills are required to design a school?
PEOPLE MOVEMENT : PHYSICAL COMMUNICATION BETWEEN CLASSROOMS AND ALL OTHER SUPPORT AND ANCILLARY FACILITIES.

SECTION 2 : SCHOOL DESIGN

2.1 How important are these aspects to be considered in your overall school and classroom design based on your priority?

Please circle the most appropriate number next to each statement

	Least Important						Most Important
2.1.1 Aesthetics Design	1	2	3	4	5	6	7
2.1.2 Passive Design	1	2	3	4	5	6	7
2.1.3 Mechanical and Electrical (M&E) Design	1	2	3	4	5	6	7
2.1.4 Building Structural Design	1	2	3	4	5	6	7
2.1.5 Classroom Environment Design	1	2	3	4	5	6	7
2.1.6 Fire Safety Design	1	2	3	4	5	6	7
2.1.7 Thermal Comfort Design	1	2	3	4	5	6	7
2.1.8 Acoustics Design	1	2	3	4	5	6	7
2.1.9 Universal Design (UD)	1	2	3	4	5	6	7

2.2 How strongly do you agree/disagree with the statements below:-

Please circle the most appropriate number next to each statement

	Least Important						Most Important
2.2.1 Optimum Fire Design is significant to achieve a conducive learning environment that will influence the experiences of students	1	2	3	4	5	6	7

SECTION 3 : FIRE SAFETY IN SCHOOL DESIGN

3.1 How strongly do you agree/disagree with the statements below:-

Please circle the most appropriate number next to each statement

	Least Important						Most Important
3.1.1 Schools can pose a significant fire hazard if not designed effectively	1	2	3	4	5	6	7
3.1.2 Fire safety is crucial in school design	1	2	3	4	5	6	7
3.1.3 Fire compartmentation is essential in fire safety in school design	1	2	3	4	5	6	7

3.2 How would you describe or define an optimum fire compartmentation in fire safety for a school and classroom design?

FAST EVACUATION AND SMALL(ER)
FIRE COMPARTMENTS

SECTION 4 : PASSIVE COMPARTMENTATION AT ROOF VOIDS

4.1 Do you consider passive compartmentation in roof voids when designing a school?

☒ Yes

☐ No

(If NO, please specify)

4.2 Based on your professional opinion and experience, do you think passive compartmentation in roof voids have been sufficiently provided in school designs, in compliance to Uniform Building By-Law (UBBL)?

☐ Yes

☒ No

(If NO, please specify)

**NO COMPARTMENT UNITS SPECIFIED OR
FIRE SEPARATION OF INDIVIDUAL CLASSES**

4.3 How strongly do you agree/disagree with the statements below?

Please circle the most appropriate number next to each statement

		Least						Most
		Important						Important
		1	2	3	4	5	6	7
4.3.1	Catastrophic fire hazards that occur in school buildings may caused by uncontrollable fire and smoke spread in roof voids or cavities						6	
4.3.2	Cavities in a building's construction can provide an easy path for the spread of smoke and flames. Hidden or invisible routes for the fire spread include concealed spaces above the suspended ceilings						6	
4.3.3	Properly and sufficiently designed passive compartmentation will help limit damage to the affected area and immediate area and prevent the spread of smoke and flames						6	
4.3.4	Insufficient passive compartmentation in roof cavities in school building constructions may cause unwanted air leakage (air permeability) causing heat loss, sound transmission and spread of smoke or fire						6	
4.3.5	Insufficient passive compartmentation within a large roof cavity area may cause fire and smoke to spread through the entire elongated roof of the building						6	

4.3.6 If fire passive compartmentation is lacking or insufficiently provided along the roof cavities and the space below, the fire will eventually spread into the spaces or rooms below 1 2 3 4 5 **6** 7

4.3.7 Potential improvements could be achieved through specific initiatives and provisions to overcome these technical deficiencies, to provide an optimum passive compartmentation 1 2 3 4 5 **6** 7

SECTION 5 : BUILDING AND FIRE CODES ON PASSIVE COMPARTMENTATION AT ROOF VOIDS

5.1 How strongly do you agree/disagree with the statements below?
Please circle the most appropriate number next to each statement

5.1.1 Vertical fire separation/ Compartment wall/Fire wall
- Fire separators should be carried up full storey height to the underside of the roof
Least Important 1 2 3 4 5 **6** Most Important 7

5.1.2 Cavity Barriers
- Cavity Barriers should be provided to close and conceal, fitted to the underside between roof and compartment wall, preventing penetration of smoke or flame 1 2 3 4 5 **6** 7

5.1.3 Maximum Limit for Undivided Concealed Spaces (Separation Intervals in Roof Voids)
- Cavity barriers should be installed to subdivide any roof space, so that the distance between cavity barriers does not exceed the required dimensions 1 2 3 4 5 **6** 7

5.1.4 Maximum Limit Areas (Below Ceiling)
- The classroom shall be designed within the maximum allowable area for a compartmentation for classrooms 1 2 3 4 5 **6** 7

5.1.5 Fire Detection (Active Fire Detection) on school façades and within the roof voids and cavities
- The need for active detection System installation eg. heat detectors Installed along school façade and within roof voids and cavities, and smoke detectors in classrooms, and suppression system eg. Sprinkler System 1 2 3 4 5 **6** 7

5.2 Based on your experience, how do fire and smoke spread within a classroom during a fire hazard?
Please circle the most appropriate number next to each statement

	Least Important						Most Important
5.2.1	1	2	3	4	5	6	7
5.2.2	1	2	3	4	5	6	7
5.2.3	1	2	3	4	5	6	7
5.2.4	1	2	3	4	5	6	7
5.2.5	1	2	3	4	5	6	7
5.2.6	Others (please specify):-						

5.3 Based on your experience, what are the most common construction and technical deficiencies that may cause passive compartmentation in roof void to fail or give way during a fire outbreak?
Please circle the most appropriate number next to each statement

	Least Important						Most Important
5.3.1	Insufficient fire compartmentation separation provisions						
5.3.1.1	1	2	3	4	5	6	7
5.3.1.2	1	2	3	4	5	6	7
5.3.1.3	1	2	3	4	5	6	7
5.3.1.4	1	2	3	4	5	6	7
5.3.2	1	2	3	4	5	6	7
5.3.3	1	2	3	4	5	6	7
5.3.4	1	2	3	4	5	6	7
5.3.5	Others (Please specify):-						

SECTION 6 : OTHERS

- 1 Do you have any additional thoughts or other comments on the passive compartmentation in roof voids in school design?

PRIMARY ISSUE IS THE SPREAD OF FIRE FROM ONE CLASSROOM TO AN ADJACENT CLASSROOM OR AREA AND VICE-VERSA.

WE ~~ARE~~ SHOULD REGARD EACH CLASSROOM AS AN INDIVIDUAL ACCOMMODATION (E.G. FLATS, OR HOTEL ROOMS) TO BE FIRE SEPARATED FROM OTHER ADJACENT ACCOMMODATION

- 2 Any suggestion for further improvement?

LOWER THE THRESHOLD TO PRESCRIBE ACTIVE ALARM AND EXHAUSTION SYSTEMS (10th SCHEDULE)

THESE ARE WITH REFERENCES TO THE UBBL: AMENDMENTS TO A LAW WILL TAKE TIME AND INVOLVE MANY STAKEHOLDERS.

PERHAPS THESE SUGGESTIONS COULD BE ISSUED AS GUIDELINES OR DIRECTIVES BY THE MOE.

Name

Organization

Date

Time

18/6/24

830pm.

- Thank you -