CONCEPTUAL FRAMEWORK OF WIND DISASTER RISK MITIGATION FOR RURAL HOUSES IN NOTHERN PENINSULAR MALAYSIA

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by

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Hopefully, my research journey will not stop here and the completion of this thesis remarks a beginning to the next journey to explore the destiny and know the human creatures better.

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BBB	Build Back Better
BD	Southwest Penang Island
BEM	Board of Engineers Malaysia
CIDB	Construction Industry Development Board
CPC	Completion of Project Certificate
CPD	Continuous Professional Development
CREAM	Construction Research Institute of Malaysia
DDRC	The University of Delaware’s Disaster Research Centre
DRR	Disaster Risk Reduction
DV	Dependent Variables
DWF	Development Workshop France
ECO-AICCE	The Second Awam International Conference on Civil Engineering
EM-DAT	The International Disaster Database
HFA	Hyogo Framework for Action
IBM SPSS	IBM Statistical Package for Social Science
ICW	International Construction Week
IEM	Institute of Engineers Malaysia
JKM	Welfare Department of Malaysia
MET	Malaysia Meteorological Department

MNSC	Malaysia National Security Council
MOF	Ministry of Finance
MS1553:2002	Code of Practice on Wind Loading for Building Structure
NADMA	National Disaster Management Agency
NGO	Non-Government Organization
NSC	National Security Council
REHDA	Real Estate and Housing Development Board
RII	Relative Importance Index
SOP	Standard Operating Procedures
SPS	Southern Seberang Perai
SPT	Central Seberang Perai
SPU	Northern Seberang Perai
TDRM	Total Disaster Risk Management
TL	Northeast Penang Island
UN	United Nation
USM-JCI	Universiti Sains Malaysia in collaboration with the Japan Concrete Institute

KERANGKA KONSEP MITIGASI RISIKO ANGIN UNTUK RUMAH KAMPUNG DI UTARA SEMENANJUNG MALAYSIA

ABSTRAK

Kejadian angin ribut melanda beberapa bahagian di Malaysia terutamanya di rantau Utara telah memberi kesan buruk kepada manusia dan menyebabkan kerosakan kepada harta benda dan kematian. Usaha mitigasi risiko bencana perlu dilakukan untuk mengurangkan akibat angin ribut kepada sektor perumahan di kawasan luar bandar. Objektif utama kajian ini adalah untuk membangunkan rangka kerja konseptual pengurangan risiko angin untuk rumah kampung di Utara Semenanjung Malaysia. Kajian soal selidik menggunakan lima mata skala Likert telah diedarkan kepada dua kumpulan responden, iaitu kumpulan pakar dan komuniti di dalam kajian. Teknik pensampelan bukan probabilistik dipilih sebagai persampelan bertujuan dan dianalisis menggunakan statistik SPSS IBM versi 21. Data sekunder mengenai kajian pasca ribut angin menunjukkan kejadian angin ribut yang berlaku pada bulan April, Mei dan Oktober semasa tempoh inter-monsun di Utara Semenanjung Malaysia merosakkan bumbung rumah kampung, oleh itu penggantian diperlukan. Indeks kepentingan relatif diperkenalkan untuk menganalisis pengaruh yang signifikan terhadap faktor risiko yang telah dikenalpasti. Sementara itu, korelasi Spearman telah dilakukan untuk memastikan risiko dan ancaman di kalangan pembolehubah dalam mitigasi bahaya angin. Oleh itu, rangka kerja untuk mengurangkan risiko bencana angin untuk rumah kampung di Semenanjung Malaysia mendapat kedudukan pengenalan risiko, dan juga hierarki risiko dan ancaman berlaku dalam fasa mitigasi. Kedudukan pengenalan risiko menunjukkan pelaksanaan reka bentuk di sistem bumbung rumah kampung sebagai faktor risiko pra-dikenal pasti yang paling signifikan. Rangka kerja tersebut menunjukkan bahawa peranan kod pada pemuatan angin, peristiwa bencana angin dan

pelaksanaan reka bentuk sangat penting dalam risiko hierarki dan ancaman. Kitaran proses terlibat dalam fasa pembinaan semula untuk menghasilkan kualiti rumah kampung yang berkualiti. Cabaran-cabaran dan langkah-langkah pencegahan yang ditemui sepanjang proses ini perlu diambil kira untuk penambahbaikan yang berterusan dari semasa ke semasa. Akhir sekali, kajian ini akan memberi manfaat kepada pembuat dasar dan badan tadbir urus dalam membuat keputusan dan membangunkan garis panduan mengenai pengurangan risiko bencana angin.

CONCEPTUAL FRAMEWORK OF WIND DISASTER RISK MITIGATION FOR RURAL HOUSES IN NORTHERN PENINSULAR MALAYSIA

ABSTRACT

Windstorm event hit several parts of Malaysia particularly in the Northern region has severely affected humans and causing damage to the properties as well as fatality. Disaster risk mitigation efforts should be exerted to reduce the disastrous consequences of windstorm to the housing sector in rural area. The main objectives of the study are to develop conceptual framework of wind risk mitigation for rural houses in Northern Peninsular Malaysia. Questionnaire survey using five points Likert-scale was distributed to two groups of respondents, namely the expert and community group in the study. A non-probabilistic sampling technique was chosen as a purposive or judgmental sampling and analysed using IBM SPSS statistics version 21. The secondary data on post windstorm survey shows windstorm event predominantly occurs during the month of April, May and October during the inter-monsoon period in the Northern Peninsular Malaysia tremendously damage the rural houses roof cladding, hence, replacement is needed. The relative importance index was introduced to analyse significant influence on pre-identified risk factors. Meanwhile, Spearman's rho correlation was performed to ascertain the risk and threat among the variables in the wind hazard mitigation. Thus, framework on the wind disaster risk mitigation for rural houses in Northern Peninsular Malaysia derived risk identification rank, and also risk hierarchy and threats took place in mitigation phase. The risk identification rank showed implementation of design in rural roofing system as the most significant pre-identified risk factor. The framework indicated that roles of codes on wind loading, wind disaster event and design implementation are significantly important in risk hierarchical and threat. A process cycle involved during the reconstruction phase to

produce a good quality of rural houses. Challenges and preventive measures encountered throughout the process shall be taken into account required continuous improvement over time. Finally, this study shall benefit the policy maker and governance body in decision making and develop a guideline on the wind disaster risk mitigation.

CHAPTER ONE

INTRODUCTION

1.1 Background

In recent years, the increasing number of strong winds have caused extensive and serious damage on buildings. Yet, developing countries have lesser capacity to adapt to global climate change, therefore, facing the damages resulting in the increasing frequency, magnitude, and intensity of disasters (Gencer, 2013; Ahmed, 2011). In other words, the frequent occurrence of natural disasters has given severe impact to human life incurred direct and indirect cost to the local economy (Parwanto and Oyama, 2013).

According to the Census 2010 data produced by the Department of Statistics Malaysia, the total population of Malaysia in 2010 was 28.3 million compared to 23.3 million in 2000. This bounces an average annual population growth rate of 2.0 per cent throughout the period from 2000 to 2010. However, the rate was lower compared to that recorded from 1991 to 2000 (2.6 per cent). In 2010, the population density of Malaysia stood at 86 persons per square kilometre compared to 71 persons in 2000. The increasing pattern of human population support statement by Gencer (2013) that risks associate with natural hazards are expected to increase due to the continuous increasing of population.

Natural disasters have caused damages to the roofing systems and other components of buildings. Other impacts observes are the presence of flying debris, uprooted trees, power failure, and fatalities (Brazdil and Dobrovolny, 2003). These disasters have created casualties that contribute to damage, losses, and social problems.

As such, natural disasters give enormous socio-economic implications on the sustainability of human habitat and the built environment.

Recent newspaper articles have reported that windstorms hit the rural housing causing extensive damage and leading to the roofing system failure. The extensive damage involving the rural houses in the northern region of Malaysia are mainly caused by wind disaster. Thus, understanding the characteristics of rural housing may reduce the impact of post disaster on the properties and improve human life. This damages occurred in the Northern of Peninsular Malaysia were reported in the recent newspaper as example of cases involving rural houses as shown in Figure 1.1.

Baling storm rips off 24 roofs

By Safuri Kamarudin - September 6, 2017 @ 9:16pm

BALING: An evening storm wreaked havoc at four villages in Kuala Ketil here, ripping off roofs of at least 24 houses.

Fortunately, no injury was reported in the 6pm incident which was followed by rain.

Baling Welfare Department officer Shamsul Izrin Isahak said the worst affected was Kampung Carok Beras Sayak where 15 houses ere damaged, followed by Carok Beras Ulu and Islam Kembai with four houses each and one house in Kampung Banggol Serdang.

Shamsul said the department did not activate a relief centre as some of the affected families decided to remain at home while others were seeking shelter at their relatives' homes.

He said immediate disaster aid would be distributed to the victims tonight with assistance from Baling District Office, Baling member of Parliament service centre and Kuala Ketil coordinator office.

Figure 1.1: Newspaper articles on the roofing damages by windstorm (NST, 2017)

The rural houses are referring to the non-engineered buildings, were chosen as the subject matter for this study purpose. A non-engineered housing construction is defined as housing construction implemented via self-help or by informally organized construction sectors (abbreviated as informal construction sectors) and a non-engineered house is defined as a house built with non-engineered construction (Watanabe et al., 2013). The recurrence damage on rural houses show the importance of this study shall be conducted and understanding the rural housing characteristics may reduce the impact of post disaster on the properties and improve human life.

Roof is often the most expressive part of a house; it symbolizes a shelter and functionality, which are important to protect a house from deterioration. However, sometimes house owners tend to ignore the structure of a roof and focus on other structural members such as beams and columns. Some cases related to the failure of roof structures were due to the wind that blew during the rainstorm event.

1.2 Problem statement

Windstorm occurrence increases annually thus increasing the damage and loss to property, which in turn, causes disruptions to the local economy. Natural disaster is a global phenomenon. Figure 1.2 shows the total damage caused by natural disaster from 2012 to 2016 was the most severe occurred in Asian region compared to other regions in the world (Americas, Europe, Oceania, and Africa).

Correspondingly, the UN Economic and Social Commission stated that people living in Asia and the pacific region are (i) 25 times more likely to be affected by natural disasters than those living in Europe or North America, and (ii) 4 times more likely than those living in Africa (Cheng, 2009). According to Gencer (2013), hydro-meteorological hazards have been the dominant types of disasters affecting (i) Asia, mostly with tropical cyclone and floods; (ii) Africa, mostly with drought; and (iii) Europe, mostly with extreme temperature changes and heat waves. Table 1.1 by CRED (2009) lists the meteorological typologies of natural disasters by count, number of deaths, number of affected, and damage for five continents from the year 1900 to 2016.

Asian region experienced the highest storm event among all continents whereby, 1699 storm occurrence out of 1872 total natural disaster event count were recorded.

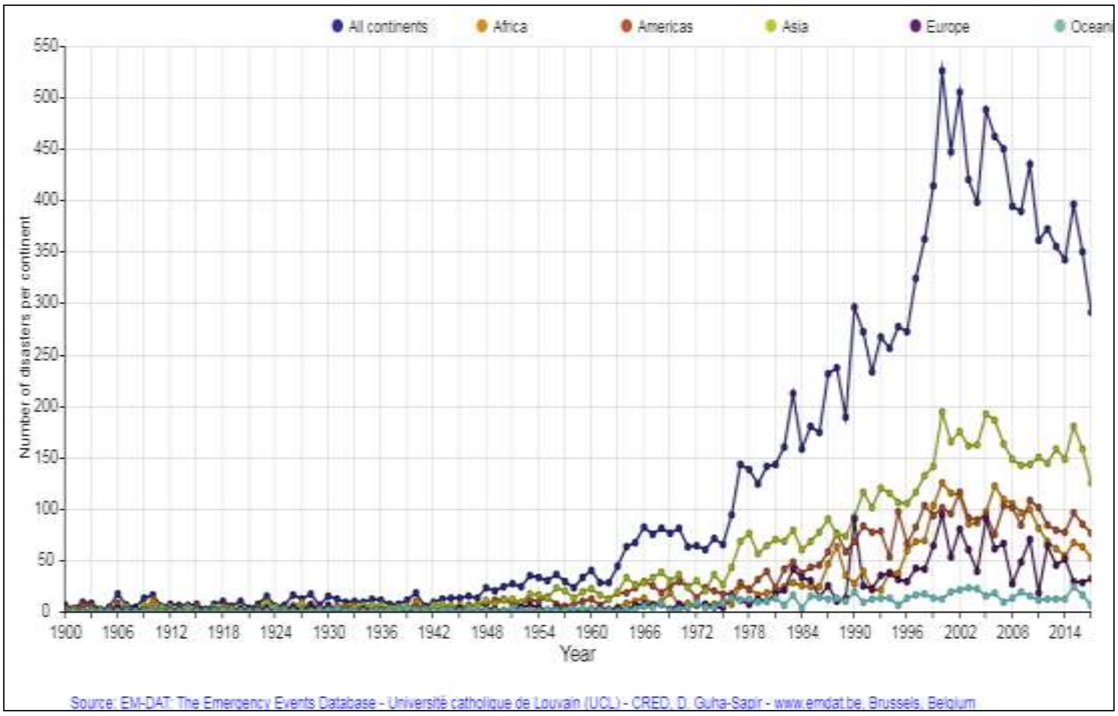

Figure 1.2: Natural disaster as per continent (CRED, 2009)

Table 1.1: Number of events, deaths, total damage caused by reported natural disaster on meteorological type 1990 to 2014 (Cred, 2009)

Continent	Disaster type	Disaster subtype	Events count	Total deaths	Total affected	Total damage ('000 US$)
Africa	Extreme temperature	Cold wave	10	73	3532605	47,000.00
Africa	Extreme temperature	Heat wave	8	291	86	809.00
Africa	Storm	--	54	581	95480	3,725.00
Africa	Storm	Convective storm	80	1396	620503	1,106,063.00
Africa	Storm	Tropical cyclone	123	4084	17116798	3,384,830.00
		Total	275	6425	21365472	4,542,427.00
Americas	Extreme temperature	Cold wave	66	3323	4645272	10,833,850.00
Americas	Extreme temperature	Heat wave	34	6107	20221	9,025,000.00
Americas	Extreme temperature	Severe winter conditions	13	112	1036364	1,400,000.00
Americas	Storm	--	242	7544	1246759	33,318,240.00
Americas	Storm	Convective storm	399	8428	86459271	190,761,430.00
Americas	Storm	Extra-tropical storm	10	610	2442039	16,200,000.00
Americas	Storm	Tropical cyclone	652	88691	62419871	593,905,784.00
		Total	1416	114815	158269797	855,444,304.00
Asia	Extreme temperature	Cold wave	83	8566	7073889	3,193,133.00
Asia	Extreme temperature	Heat wave	72	16057	212158	419,000.00
Asia	Extreme temperature	Severe winter conditions	18	2075	80472052	21,960,200.00
Asia	Storm	--	272	15319	52585450	4,970,956.00
Asia	Storm	Convective storm	281	8864	194315419	25,866,223.00
Asia	Storm	Tropical cyclone	1146	1251451	689893476	223,303,140.00
		Total	1872	1302332	1024552444	279,712,652.00
Europe	Extreme temperature	Cold wave	133	5405	964955	2,424,301.00
Europe	Extreme temperature	Heat wave	63	138544	2120	12,763,050.00
Europe	Extreme temperature	Severe winter conditions	43	1545	484857	1,000,000.00
Europe	Storm	--	202	5338	1508848	32,170,200.00
Europe	Storm	Convective storm	151	1474	3261758	19,847,746.00
Europe	Storm	Extra-tropical storm	101	448	3930635	49,594,139.00
Europe	Storm	Tropical cyclone	22	201	94682	1,817,360.00
		Total	715	152955	10247855	119,616,796.00
Oceania	Extreme temperature	Heat wave	7	509	4602784	200,000.00
Oceania	Storm	--	46	59	3538285	1,172,672.00
Oceania	Storm	Convective storm	38	302	480110	8,961,828.00
Oceania	Storm	Tropical cyclone	228	1839	3069486	16,612,164.00
		Total	319	2709	11690665	26,946,664.00

The data shown in the above Table 1.1 shows storm occurrence the lowest percentage count at 10.45% of compared to flood (53.73%) and epidemics (19.40%). The percentage shows that storm is one of the governing natural disasters despite of flood and epidemics in Malaysia.

A database is very crucial to provide information and better understanding about windstorm distribution and level of damage. However, no complete database has been gathered on previous wind storm occurrence in Malaysia to study the past trend of event. Previous related data were only collected from newspaper articles and published reports, and there is no particular study that emphasizes the occurrence of windstorm in the northern region and Malaysia in a broader view. This disaster database is needed to predict future event whilst analysing the losses and assessing the risk from previous natural hazard whereby the condition and trends are maintained (Velásquez et al., 2014). Meanwhile, Brazdil and Dobrovolny (2003) discovered that the descriptive data of historical climatology represents valuable source of information. The benefit from this research is to assist weather forecasters, state authorities, manufacturers, insurances and public towards wind disaster risk mitigation for rural houses in Northern Peninsular Malaysia.

Thus, mitigation measures are required in terms of post disaster assistance to ensure pre disaster readiness, which can reduce the damage resulting from wind occurrence. At the national level, the wind disaster management and implementation requires extra effort and participation from various stakeholders. For example, Cheng (2009), reported that the weaknesses of disaster management is in terms of the lack of effective manpower, strong international support, effective command control system, along with communication problem at the lower management lead the effective communication of public information. On the other hand, several aspects were identified to contribute to the success of a disaster risk management depends on clear objectives, commitment and support of the central and state government agencies, adequate training and realistic expectations of results (Metri, 2006). Thus, a study on the conceptual framework of wind risk mitigation is vital to reduce the wind disaster impact in terms of damage and losses to properties and human life.

1.3 Research questions

Based on the problem statement, it is clear that it serves as a foundation to develop the research question of this study. The research questions for this study are as follows:

i. Is the windstorm occurrence influenced by month and location?

ii. When is the highest frequency of windstorm throughout the years?

iii. Where is the most impacted location in Northern Peninsular Malaysia during the windstorm event?

iv. What are the influence factor contribute to damage on the rural houses in terms of structural impact due to windstorm?

v. What are the experts and community perceptions on wind disaster management towards risk reduction?

1.4 Research objectives

The followings are the objectives set out in this research from the problem statement:

i. To investigate windstorm occurrence trend in Northern Peninsular Malaysia.
ii. To identify post wind disaster structural impact on rural roofing system and wind prone area in Northern Peninsular Malaysia.
iii. To determine factors that influence wind disaster risk mitigation using primary data collected from a group of experts and community.
iv. To analyse how various influence factors have impacted wind risk mitigation from group of expert and community.
v. To develop a conceptual framework of wind risk mitigation for rural houses in Northern Peninsular Malaysia.

1.5 Scope of works and limitations

The work scope for this research involves data collection on the wind disaster research areas from local authorities and community experience in the windstorm which located in northern Peninsular Malaysia which are Kedah, Penang, and Perak.

Malaysia is situated in Southeast Asia and is divided by the South China Sea into Peninsular Malaysia and East Malaysia. Peninsular Malaysia shares a land and maritime border with Thailand and maritime borders with Thailand, Vietnam, and Indonesia. East Malaysia shares land and maritime borders with Brunei and Indonesia and a maritime border with the Philippines.

Figure 1.3 shows the northern region locate three (3) states involves in this research which are Kedah, Penang and Perak. Secondary data collection requires official permission from respective government agencies to meet the research objective set on the understanding of windstorm occurrence patterns for the research study areas. There are also limitation in data gathering information on type or parameter to be used in this research. This is due to data collection is handled at state level and not standardized among the authorities nationwide.

Figure 1.3: Malaysia map (Wonderful.com, 2017)

This research emphasizes the conceptual framework of wind disaster risk mitigation for the rural houses in the Northern Peninsular Malaysia. The case study is based on the key element of the study, which mostly focusing on the wind disaster risk mitigation subject matter, due to the following reasons.

i. The problem statement has highlighted that the Asian countries have experienced tremendous natural disasters which among others, were contributed by windstorm.

ii. Recurrence of the windstorm event and damaging the rural roofing housing system that needs particular attention in regard to damage impact on the post-disaster. Collection of secondary data on windstorm event from relevant agencies can facilitate better understanding of windstorm occurrence patterns for the research study areas.

iii. Wind disaster management shall be address to mitigate and minimize the effect of windstorm hence, in return, this will benefit the community and others.

This research is focusing on the non-engineered rural house which located in northern Peninsular Malaysia. The respondents involves the expert group from contractors, consultants, developers, home builders, and community who is residing within the study area limit.

1.6 Thesis organization

There are seven (7) main chapters that are outlined in this research on the conceptual framework of wind disaster risk mitigation for rural housing in Northern Peninsular Malaysia.

Chapter One: Introduction. This chapter emphasizes on the disaster statistical distribution for regional natural disaster specifically in Malaysia environment. This chapter highlights the problem statement, research questions, research objectives, scope of works and limitation, thesis organization and summary of achievement related to the research.

Chapter Two: Literature Review. This chapter reviews the literature on wind disaster event all around the world and the formation of thunderstorm, rural roofing system, wind loading consideration, wind hazard mitigation and the gap of the research. The wind hazard mitigation sub-divided into wind disaster, roles of wind codes on wind loading, rural roofing system, damage impact from disaster and the implementation of structural design.

Chapter Three: Theoretical framework. The disaster risk management discovered in the literature emphasizes on several sub-topics such as disaster management and risk reduction, theoretical disaster risk framework, post disaster housing reconstruction and reconstruction framework.

Chapter Four: Methodology. This chapter explains the research methodology adopted for this study which is design research approach, case study area, data collection method, windstorm occurrences in Northern Peninsular Malaysia, questionnaire design, description of participants, and reliability of data, research process and data analysis approach.

Chapter Five: Post Windstorm Evaluation on Rural Houses. This chapter presents and discusses on the rural housing characteristics, post disaster investigation, number of windstorm event and house damage on monthly frequency basis including Kedah, Penang and Perak state. Comparison of house damage within the study area and wind disaster distribution area was analyzed in this chapter. Furthermore, investigation on windstorm occurrence trend in Northern Peninsular Malaysia from the gathered data was also analyzed and discussed. Windstorm disaster distribution was tabulated in a mapping form based on location.

Chapter Six: Wind disaster mitigation perception among expert and community group. The analysis using relative importance index and rank, and spearman rho correlation between items were conducted to analyse how various influence factor have impacted wind risk mitigation among two focus groups i.e. expert and community group.

Chapter Seven: Development of framework. This chapter discusses on the conceptual framework of the wind risk mitigation for rural houses in Northern Peninsular Malaysia from the expert and community group perception.

Chapter Eight: Conclusion and Recommendations. This chapter summarised the whole research findings related to wind disaster risk management in Northern Peninsular Malaysia before the conclusions is drawn. Recommendation for future study also presented in this chapter.

The following research process is illustrated in below Figure 1.4 to capture the whole thesis organization in accordance to the research objective set.

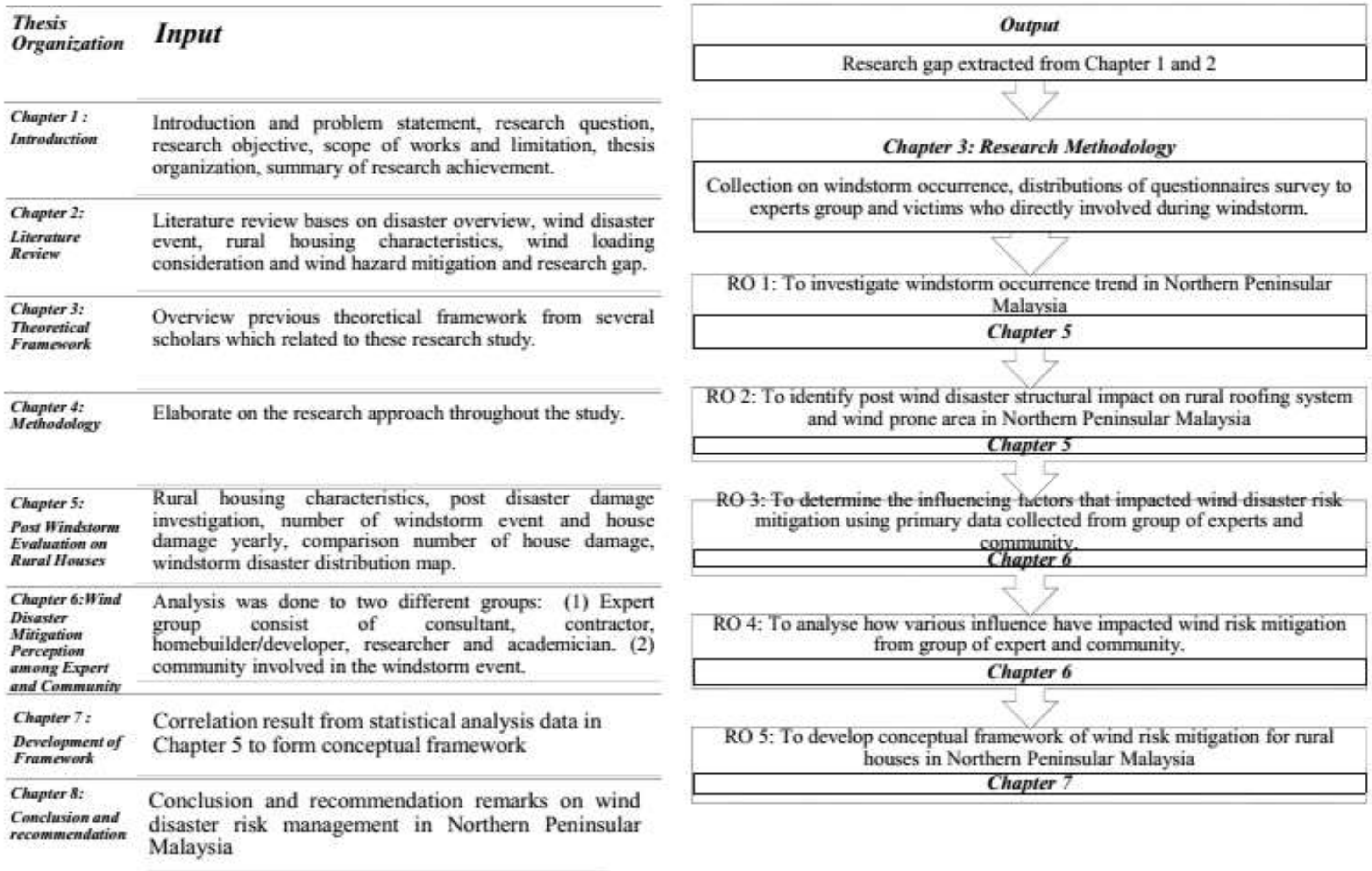

Figure 1.4: Thesis structure layout

CHAPTER TWO

LITERATURE REVIEW

2.1 Introduction

Subsection 2.2 defines disaster in broader view and its classification in brief. The subject matter of this research, windstorm, is related to natural disaster, therefore, the typology risk is related to the geophysical aspect. Due to the higher frequency of windstorm, its occurrence creates extensive damage to the housing sector.

This subsection highlights on the wind disaster events occurrence. The patterns of windstorm occurrence vary depending on several factors i.e. geographical factor due to terrain category, transition and months which are further discussed in subsection 2.3. Furthermore, the thunderstorm life cycle involve in the thunderstorm formation is presented in later subsection 2.3.1. Disaster risk management is very vital in handling the wind hazard. Thus, a balanced cycle of total disaster risk management shall be practiced. Thereby, rural housing characteristics are explored in subsection 2.4.

However, this research focuses on the disaster risk mitigation phase. Wind loading consideration in subsection 2.5 reviews acceptance of this criteria in the building design among the practitioners. Subsection 2.6 covers the wind disaster revelation, roles of wind codes on wind loading, rural roofing system, and damage impact from disaster and the implementation of structural design. In the subsection 2.7, the disaster risk management and risk reduction clarifies that the disaster management cycle, the disaster risk theoretical framework, post disaster housing reconstruction and reconstruction framework are related to resilient building. Subsection 2.8 discusses the research gap for this Chapter Two. The whole aspects discussed in this chapter is summarized in the subsection 2.9.

2.2 Disaster definition

Disaster is defined as a sudden event, such as an accident or natural catastrophe that causes great damage or loss of life. Kouroshi et al. (2008), defined disaster as a phenomenon that is relatively sudden, highly disruptive, and in most cases, time limited. In addition, the definition of disaster is highly related to the quantity and quality of its impact on human life, human society, economy and environment. Besides, poorly managed interactions between society and environment contribute to convert natural hazards into disasters (Kulatunga, 2010). A disaster is the occurrence of an extreme hazard event that impacts on vulnerable communities causing substantial damage, disruption and possible casualties, and leaving the affected communities unable to function normally without outside assistance (Benson and Twigg, 2007).

Another terminology on disaster by the UNDRR (2019) that disaster is:

"A serious disruption of the functioning of society, causing widespread human, material or environmental losses which exceed the ability of affected society to cope using only its own resources".

Disaster is also stated as an event that (i) involves more groups who normally do not need to interact in order to manage emergencies; (ii) requires involved parties to surrender the usual autonomy and freedom to special response measures and organizations; (iii) changes the usual performance measures; and requires closer operations between public and private organizations (DDRC).

In addition, Shaluf and Ahmadun (2006), discovered that disaster can be classified into three types namely, natural, man-made and subsequent disaster as summarized in Table 2.1. Natural disaster is also defined by Shaluf (2007) as an catastrophic event which is a by-product of natural hazards.

Table 2.1: Summary of disaster typology risk

Disaster	Typology risk		Description (Example)		
Natural Shaluf and Ahmadun, (2012)	Biological		Epidemics	Insect Invasion	
	Geophysical		Earthquake	Volcano eruption	Tsunami
	Hydrometeorological		Heat wave Wild fire	Flood Drought	Storm Hurricane
Man-made (Shaluf and Ahmadun, 2012)	Sudden	Technological	Due to operating major hazard installation (MHIs)	Fire/ explosion	Major emission
		Transportation	Major rail/highway accident	Disruption of vital transportation	Hazardous material incidents
		Public places failure	Collapse of stadia	Collapse of high rise buildings	Urban fires
		Production	Computer system breakdown	Production and distribution of defective product	
	Long-term	Warfare (Shaluf, 2007)	International conflict	National conflict	
Hybrid disaster Shaluf, (2007)	Continuation or mixture of the above disaster categories.				
Subsequent disaster (Shaluf and Ahmadun, 2012)	Not applicable		Haze	Forest fire	

Natural hazards resources are from internal, external, weather related and biological phenomenon. Internal resources are best described as source beneath the Earth’s surface while external is from topographical resources. In terms of weather-related phenomenon, natural disaster is referred to meteorological or hydrological typology risk. Biological disasters are caused by the spreading of diseases through bacteria. In the context of natural disaster, biological disasters can be categorized into three groups: geophysical disaster, hydro meteorological disaster, and biological disaster. In addition, Shaluf (2007) described man-made disaster are caused by human decision and can be considered as sudden or long-term disasters. These sudden man-made disasters also known as socio-technical disasters by Richardson (1994). Meanwhile, long term disaster is related to international and national conflict. A hybrid disaster is a disaster that occurs due to continuation or mixture of above category between natural and man-made disaster. Furthermore, Ramli et al. (2014) stated that man-made disaster is more complex among disaster typology due to unpredicted future technologies. It is important to note that due to a rise in severe windstorm events increases the damages and losses of life and property. Meanwhile, the subsequent disasters are those disasters, which resulted from natural and/or man-made disasters (Shaluf and Ahmadun, 2006). It was recorded that haze disasters encountered in Malaysia throughout year 1997 to 1998 such as haze, forest and peat fires.

2.3 Wind disaster event all around the world

Climate change induced the most anticipated risks which effect the sea level rise and other associated hazards on small island states and coastal cities. According to the IPPC, (2012), by year 2100, the global frequency of tropical cyclones will either decrease or remain unchanged. The likelihood of 90 – 99% increases in the average tropical cyclone maximum wind speed increase the heavy rainfalls associated with tropical cyclones (IPCC, 2012).

Wind disaster pattern varies for each location throughout the year. In central European country, the strong wind events in connection with convective summer which normally occur during summer half-year (April to September) and during winter half-year (October to March) (Brazdil and Dobrovolny, 2003).

There are three most active months for the five-year sample in Central-Eastern Mediterranean waterspouts which is August, September, and October with a percentage of 61.6% of the waterspout days and 72.8% of all waterspouts (Keul et al. 2009). It was observed that peak activity occur in September with 25.3% of the water-spout days and 36% of the total waterspout number recorded. Similarly, for the western Mediterranean Balearic Islands, the month of September was also recorded with the highest activity in tornado and waterspout occurrence (Gaya et al., 2001).

In Greece, both tornado and waterspout occurs in the autumn season. These may be influenced by the seasonal land or sea temperature lag, which can significantly contribute to the frequency of occurrence. One study traced that the month of November was discovered as to be the dominant month while April being the least dominant month (Gaya et al., 2001). For the month of December the number of cyclone-related windstorms is the greatest in Northwest United States. Other major windstorm months include November, January, and February, with reduced, but significant numbers of events noted in October and March (Mass and Dotson, 2010).

Windstorms in Malaysia must not be neglected because the occurrence has initiated damage and losses to structures and human life. It was reported that northern peninsular Malaysia experienced massive damage on the post windstorm observation caused structure failure to roof and truss (Majid et al., 2010). Located in the South-East Asia region, Malaysia is a country with a tropical climate whereby the coastal plains' average temperature is 28°C, the inland and mountain's average temperature is 26°C, and the higher mountain region's temperature is 23°C. In Malaysia, there are two monsoon seasons which are South East Monsoon and North East Monsoon. Heavy rain and windstorm take place during the monsoon season normally affect the East Coast of Peninsular Malaysia and East of Malaysia. The northeast monsoon observed as the major rainy season in the country commences in early November and ends in March. In contrast, the southwest monsoon is comparatively drier throughout the country except for the state of Sabah (East Malaysia) is usually established in later half of May or early June and ends in September. Malaysia Meteorological Department (MET) reported that windstorms are most likely to occur in the inter monsoon period from April to May and in October to November.

Mostly common influence factors discussed in the literature on the wind disaster occurrence are geographical factor due to terrain category and transition of season. According to Cochran (2012), the wind speeds are affected by elevation above ground, by the surrounding upwind terrain, and by local topography. Urban and rural communities on low islands or in unprotected, low- lying coastal areas or river floodplains are considered vulnerable to cyclones (Agarwal, 2007). Furthermore, the degree of exposure of land and buildings will affect the velocity of the cyclone wind at ground level, with open country, seashore areas and rolling plains being the most vulnerable. Meanwhile, Rosowsky and Schiff (2003) discovered that the highest wind speeds typically occur on the coast. However, inland structures may be more destructible due to direct impact of the wind occurrence sources from surrounding structures, other infrastructure components, and even trees (Kousky, 2013).

Thus, the following subsection discusses on the process of thunderstorm formation and the sequences.

2.3.1 Formation of thunderstorm

Several wind climates might result in monsoons, frontal depressions, tropical cyclones, gust fronts, downbursts, tornados, devils, katabatic winds, lee waves, and so on (Tamura et al., 2012). High wind event is referred to hurricane, cyclone or typhoon. Henderson and Ginger (2008) stated that windstorm can be broadly classified according to their meteorological parameter as tropical cyclone, thunderstorm, tornados, monsoons and gale.

Tropical cyclones have different appellations in different regions. They are known as typhoons in East Asia, cyclones in the region of Australia and the Indian Ocean, and hurricanes in North and Central America (Tamura et al., 2012). Tropical cyclones are intense cyclonic storms that occur over tropical oceans, mainly in summer and early autumn. The warmest ocean regions on either side of the equator most frequently suffer from hurricanes. Malaysia remains free from the hurricane due to the Coriolisis forces being weak in this area which located within the latitude of about 5° directly north and south of the equator. According to Yusoff (2005), the occurrence of windstorm in our country is in micro scale; it lasts from 15 to 30 minutes. These passive conditions produce hail, heavy rain, frequent lightning and strong gusty winds (Holmes, 2001).

Thunderstorm is defined as tall buoyant clouds of rising moist air. It generates lightning and thunder commonly with rain, gusty winds and sometimes hail (Abbott, 2008). Thunderstorms are caused by strong contrasting polar and subtropical air masses meet above. They are generally two types of thunderstorm: single-cell thunderstorm and supercell thunderstorm. The thunderstorm that occurs the most is the single-cell thunderstorm, which is also known as an air mass thunderstorm. This thunderstorm is formed in tropical locations around the world and is abundant all the year. The warm, moist air rises vertically, cools via adiabatic expansion, then rains. It often occurs during late afternoon when surface heating is significant. Meanwhile, the supercell thunderstorm encourages the development of tornadoes and produces flash flood and extreme winds, which last for many hours.

Tornadoes occur more frequently in the middle of the summer, and often in the late afternoon likewise to thunderstorm. Further elaboration can be referred to Figure 2.1 which illustrates the thunderstorm development. The thunderstorm development includes three stages which is developing stage, mature stage and dissipating stage as stated by Abbott (2008). In contrast, some studies refer to thunderstorm formation inclusive four stages of thunderstorm outflow. There are formative stage, early mature stage, late mature stage and dissipating stage.

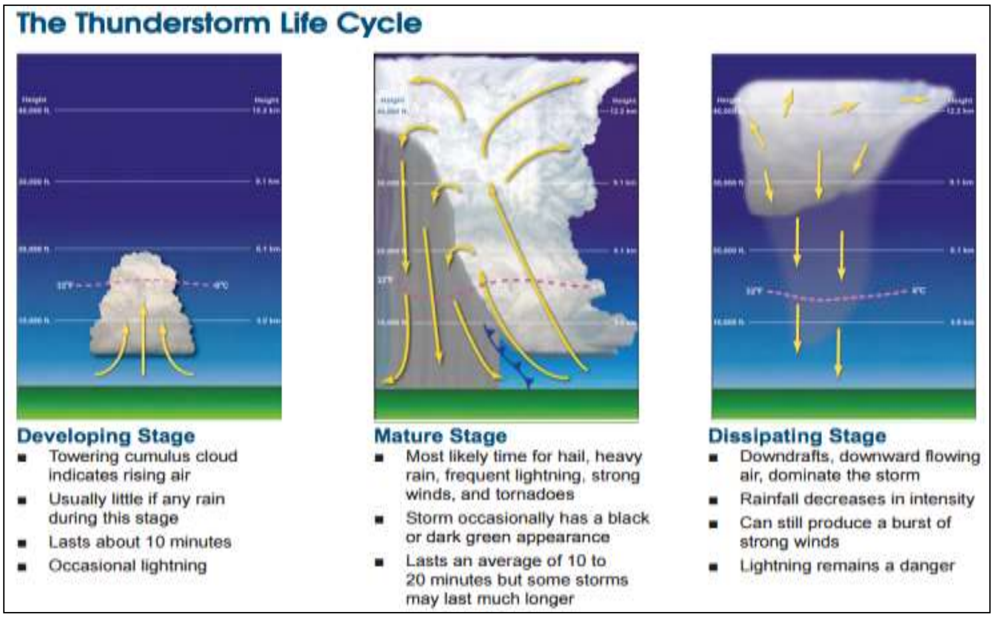

Figure 2.1: Thunderstorm life cycle (iAlert, 2018)

2.4 Rural roofing systems

Housing is usually the most valuable asset for people in developing countries (Ahmed, 2011). However, housing sector suffer the most extensive damaged or lost in the total impact of disaster on the national economy. Low-rise residential buildings have performed unsatisfactorily during past hurricane events (He et al., 2017). This creates the need to understand house characteristics and predict the potential damage of a wind disaster to house residents. In ASCE 7-10 (2010), low-rise residential buildings are defined as the facilities that have a mean roof height (h), less than or equal to 18m (60 ft.) and a height not exceeding the least horizontal dimension.

The rural houses in Malaysia are considered as non-engineered building built from timber or masonry or combination of both materials (Hanafi, 1994). The non-engineered house were built with a minimum or no structural engineering design compared to other buildings that use codes and standards. In terms of house setting, the Malaysian rural house may be low-set, double-storey, and a combination. A building with a mean roof height of less than 20 meters is categorized as low-rise. Allen et al. (2008) investigated in terms of roofing materials used in Malaysian houses and found the following composition. For example, semi-detached houses using (concrete tiles 20% and clay tiles 2.5%) of roofing materials; terrace apartments utilize (concrete tiles 45% and clay tiles 2.5%); whereby, bungalows using (concrete tiles 17.5%, clay tiles 5%, and metal deck 5%). The damage of a rural house usually begins at one of the components that form the building envelope (typically the roof), and when the damage progresses far enough, it can lead to the failure of the complete structure (Sid Hwa, 2008). Other rural house characteristics are their walls compose of different materials such as timber, brick, timber and brick, brick and concrete, precast concrete, steel stud and blockwork (Marsono and Balasbaneh, 2015).

The rural houses are constructed with low investment and local materials with the assistance of artisans or relatives, friends and neighbors who lack of sufficient knowledge about house construction (Alam et al., 2017). The similar approach also practice for vernacular houses stated by Alam et al., (2017) that house design is based on the local needs and availability of construction materials typically reflect the local traditions. Regarding to Hanafi (1994) the design of traditional houses was often the result of many years observation on the climate rhythms, variations, the awareness of the behaviors they could benefit from its advantages and method to overcome the disadvantage with the limited resources.

Different types of settlement patterns for traditional house was developed according to the topography, climatic conditions, ethnicity, sociocultural factors, occupation and status in the society (Tucker et al., 2014). With regards to the type of terrain and topography, buildings with various plan forms are constructed. Certain settlement patterns may create a funnel effect that increases the wind speed (Agarwal, 2007). In other point of view by Hanafi (1994), spacing of the traditional houses is largely governed by the need for occupant's privacy. It is also noted that the Malaysian rural houses are seldom sited on sloping ground above 15° due to structural constraints and accessibility rather than for the reason of solar exposure and lower air temperature.

The geometry and shape of the building and its roof specifically influence wind pressure coming into the particular building. In another view, Henderson (2008) and Taher, (2007) stated that the increase in internal pressure caused by the exterior opening can double the load on structure. As highlighted by Irtaza et al. (2015), the sharp edges and corners of buildings can induce sudden variation in wind pressure distribution and magnitude. Figure 2.2 is an example for rural typical traditional Malay house located in Penaga, Penang.

Figure 2.2: An example of a rural house in Northern Peninsular Malaysia located in Penaga, Penang

This typical Malay house characteristics comprise of several compartments with its own functionality. One of the features of the rural houses in Malaysia is the presence of large compartment of space known as core house or also known as (rumah ibu) and the extension house or kitchen house (rumah dapur) (Said, 2007). The most of the rural core house compartment functions are for family resting and relaxing, meanwhile, the extension house is occupied by kitchen and living room.

2.5 Wind loading consideration

Wind actions give guidance on the determination of natural wind actions for structural design (BS EN 1991-1-4:2005). The Code 2 is applicable to land structures with height up to 200m, bridges up to 200m spans require an availability of local data such as terrain type, wind speeds, building type and general structural configurations. On the other hand, according to MS1553:2002, the Malaysian Standard of Code of Practice on Wind loading for building structure sets out procedures for determining wind speeds and wind actions to be used in structural design. The standard applies to