AN EXPERIMENTAL INVESTIGATION ON PULL THROUGH FAILURE OF ROOF CLADDING TO PURLIN CONNECTION CONSIDERING OVERHANG ROOF

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By

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Date

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ABSTRAK

Kajian terhadap kesan ke atas beban angin ke sambungan kepingan bumbung dan purlin menjadi tumpuan kajian semasa. Kegagalan bumbung didapati bermula di bahagian juntaian bumbung disebabkan oleh pergolakan yang dihasilkan daripada angin yang kuat. Walau bagaimanapun, kajian terdahulu terhad kepada bangunan yang tidak berkejuruteraan tanpa juntaian bumbung terutamanya rumah luar bandar di kawasan utara Semenanjung Malaysia. Dalam kajian ini, ukuran panjang juntaian rumah diperoleh dari kaji selidik rumah luar bandar. Kajian eksperimen menggunakan ujian tarik untuk mensimulasikan kesan beban angin pada ciri rumah pedalaman terutamanya juntaian bumbung. Oleh itu, kajian ini dijalankan untuk mengkaji daya tarikan melalui kapasiti pada sambungan kepingan bumbung dan purlin. Ujian telah dijalankan pada dua jenis bumbung iaitu, bumbung beralur dan trapezoid. Kayu jenis Meranti Merah Tua yang diklasifikasikan di bawah kumpulan kekuatan 5 digunakan sebagai purlin dan beban angin dihasilkan melalui mesin hidraulik. Dalam hal jenis bumbung beralun, daya tarikan tertinggi melalui kapasiti dipamerkan dengan ketebalan 0.28 mm dengan 200 mm juntaian (1.534 kN) diikuti oleh ketebalan 0.28 mm dengan 300 mm juntaian (1.083 kN). Sementara itu, beban maksimum yang dipamerkan oleh ketebalan 0.28 mm dengan panjang 200 mm juntaian (3.391 kN) diikuti oleh ketebalan 0.28 mm dengan panjang juntaian 300 mm (2.830 kN). Dalam hal jenis bumbung trapezoid, ketebalan 0.35 mm bersama 300 mm juntaian menunjukkan maksimum kapasiti yang tinggi (1.153 kN) diikuti oleh tebal 0.35 mm bersama 200 mm juntaian (kN). Walau bagaimanapun, beban maksimum yang digunakan dipamerkan oleh ketebalan 0.35 mm dengan panjang juntaian 200 mm (3.738 kN) diikuti dengan ketebalan 0.35 mm dengan 300 mm juntaian (3.589 kN). Ia juga telah menyatakan bahawa semakin pendek juntaian menghasilkan sambungan kepingan bumbung dan purlin yang kuat. Sambungan yang paling berkesan

untuk sambungan kepingan bumbung dan purlin didapati bumbung beralun berketebalan 0.23 mm dengan panjang juntaian 200 mm.

ABSTRACK

The study of effects on wind loading to the roof cladding and purlin connection become the focus of the present study. It is found that the failure of roof cladding initiated at the overhang roof due to turbulence created form the strong wind. However, the previous studies are limited to the non-engineered building without overhang roof mainly the rural house in northern region of Peninsular Malaysia. In this study, the typical overhang roof length was obtained through rural house survey. The experimental study using simple pull through test was performed to simulate the wind loading effect on rural house features especially at overhang roof. Therefore, the study is conducted to investigate the pull through capacity on cladding to purlin connection of rural house. The tests were conducted on two types of claddings namely, corrugated and trapezoidal roof cladding. The purlin used timber type Dark Red Meranti which classified under strength group 5 and the wind loading was applied via hydraulic jack machine. In the case of corrugated roof cladding, the highest pull through capacity exhibited by 0.28 mm thickness with 200 overhang length (1.534 kN) followed by 0.28 mm thickness with 300 mm overhang length (1.083 kN). Meanwhile, the maximum applied load exhibited by 0.28 mm thickness with 200 mm overhang length (3.391 kN) followed by 0.28 mm thickness with 300 mm overhang length (2.830 kN). In the case of trapezoidal roof cladding, 0.35 mm thickness of 300 mm overhang exhibited the highest pull through capacity (1.153 kN) followed by 0.35 mm thickness of 200 mm overhang length (kN). However, the maximum applied load exhibited by 0.35 mm thickness with 200 mm overhang length (3.738 kN) followed by 0.35 mm thickness of 300 mm length of overhang (3.589 kN). It was noted that shorter length of overhang developed stronger roof cladding to purlin connection. The most efficient connection for roof cladding to

purlin connection was found to be 0.23 mm thickness of corrugated roof cladding with 200 mm overhang length.

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CHAPTER 1

INTRODUCTION

1.1 Background

Wind is caused by different atmospheric pressure where air is moves from higher to lower pressure resulting in winds of various speed. Malaysia experiences two monsoon seasons namely the southwest monsoon from late May to September and northeast monsoon from November to March where these seasons nominate wind and rainfall (Satari et al., 2015). According to Jayasinghe et al. (2018), the structural response due to fluctuating nature and spatial distribution of wind loads can cause large scale disaster across community. During high wind event, light-gauge steel roofing system are highly susceptible to premature failures (Sivapathasundaram and Mahendran, 2018). Roof is the part of house that is usually the most vulnerable when experiences such large wind loading. Mahaarachchi (2003) stated that interaction between wind flow and building surfaces will give a significant effect to wind loads of a roof of a low rise building. Figure 1.1 shows of an example severely damage roofing system in Malaysia.

Figure 1.1 Roof damage during strong wind event

1.2 Problem statement

Nowadays, there have been many cases of wind damage events frequently reported through mass media. These events have brought serious failure to the roof structure where it normally initiate at cladding and purlin connection. However, many research studies investigated the failure that occurred at purlin trusses connection. Recently, there is one case reported by Sinar Harian newspaper on 28th October 2018 involving windstorm event occurred at Bertam, Penang. About 18 houses and one institutional building (IPPT Bertam) were affected in 10 minutes' windstorm event. From initial investigation at IPPT Bertam, the main failure caused by weak cladding and purlin connection. Inadequate connection strength, insufficient strength of structural member and fluctuation of high wind speed can be the reasons that cause damage to the roof system.

In rural area, most of the houses consist of non-engineered low rise buildings. This type of house is easily damaged during strong wind event. Therefore, this issue should be study further especially at cladding and purlin connection.

1.3 Objectives

The experiment is intended to study the potential failure load capacity of simple cladding to purlin connection and is focused on the following objectives:

1) To determine the typical dimension of overhang roof of rural houses
2) To compare pull through capacity of roof cladding to purlin connections assembled from different cladding thickness, type, span and overhang length.

1.4 Scope of work

This study only emphasis on the experimental investigation pertaining to the pull through failure of roof cladding to purlin connection by considering the overhang roof part for rural houses in northern region of Peninsular Malaysia. Basically this study covers two main steps namely rural house survey and experimental work. The rural house survey will be conducted to collect information such as type of roof cladding, purlin spacing and length of overhang cladding. It covers the northern region of Peninsular Malaysia from three states namely Perak, Kedah and Penang. The information collected from the rural survey used to normalize the dimension of the specimen in the experimental work. The experimental work in this study use two types of roof cladding namely corrugated and trapezoidal which is cheaper and normally to be used as roof for rural houses in Malaysia. Each type of roof cladding consists of two different thickness. The corrugated steel cladding thickness will be 0.18 mm and 0.23 mm while trapezoidal zinc thickness will be 0.23 mm and 0.35 mm. The experimental work will use low strength group timber (SG5) for the purlin and it size will be fixed at 50.8 mm × 50.8 mm The experimental work is focus on the failure of the roof cladding to purlin connection.

Ideally, the wind pressure must be applied as a pressure that exerted on the connection. However, this type of experiment requires complex and intense laboratory set up and equipment such as wind tunnel and air box to run the test. Thus, the hydraulic jack testing machine will be used and associated steel frame assembly will be developed. A 5 kN load cell and six Lateral Vertical Displacement Transducer (LVDT) will be attached to the roof cladding to determine the actual fastener load at critical central support and measure the displacement of the cladding when subjected to loading

CHAPTER 2

LITERATURE REVIEW

2.1 Introduction

Recently, number of wind related disaster due to windstorm event had increased tremendously in Malaysia. According to Mahendran and Mahaarachchi (2002) low-rise buildings have higher tendency to damage caused by extreme wind events such as windstorm. Figure 2.1 shows, the housing in rural area in Malaysia which is particularly is non-engineered structures and low-rise buildings. This type of house is prone to destruction when subjected to high wind loading (Muhammad et al., 2015). This is because low rise buildings have low pitched roof and weak link of uplift load path (Mahendran, 1995). Such large number of non-engineered low rise buildings are not able to withstand high-wind events and this will contribute to an extremely large economic loss caused by damage to these buildings.

Figure 2.1 Typical house of rural area in Malaysia (Muhammad et al., 2015)

2.2 Roof structure element and connection

The main roof structure element comprises of roof sheeting or cladding, roof batten or purlin and rafter. Figure 2.2 shows that each element has their own role in providing both external and internal support to the roofing system. Uniquely in the

Northern region of Peninsular Malaysia , a study done by Majid et al. (2016) found that most of the rural houses are designated by having overhang roof. This part of roof located at the edge of the roof and protruding outwards where its function to protect the wall façade during heavy rain. However, Zaini et al. (2017) stated that due to inadequate support to hold the roofing system from uplift might initiate the damage at overhang especially during strong wind event. Figure 2.3 shows example of failure of roof that initiate that initiate at overhang roof of rural house in Penang.

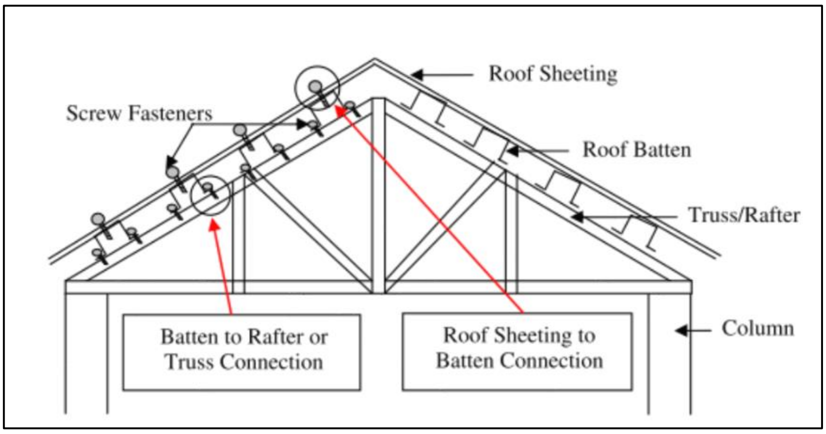


Figure 2.2 Roof structure component (Sivapathasundaram and Mahendran, 2016)

(a) (b)

Figure 2.3 Failure of roof that initiate at overhang roof of rural house in (a) Balik Pulau, Penang and (b) Kepala Batas, Penang (Majid et al., 2016)

2.3 Failure of roof connection

According to Chowdhury et al. (2012), extreme wind event can caused extensive damage to residential building due to failure of the roof connection. The worst failure of the roof connection occurred in roofing system might leads to accelerated damage to the whole building (Mahendran, 1995). Generally, the roof connection failure can be split into two types namely pull through failure and pull out failure. Sivapathasundaram and Mahendran (2016) stated that pull through failures occurred when the fastener head being pulled through the thin cladding and pull out failure occurred when the fastener pulled out from the purlin. Figure 2.4 shows the failure at roof cladding to purlin connection.

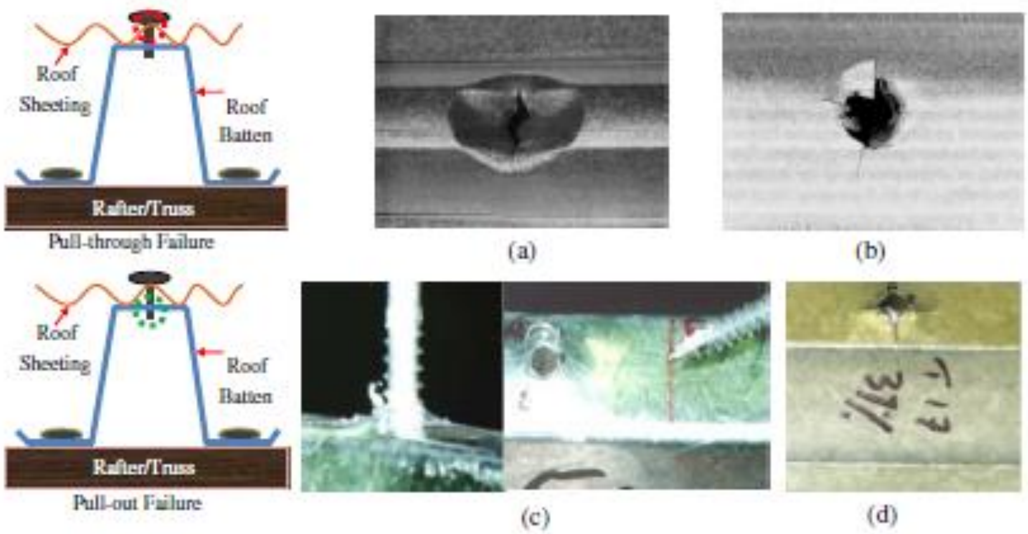


Figure 2.4 Roof purlin connection failures; (a) and (b) pull through failure; (c) and (d) pull out failure (Sivapathasundaram and Mahendran, 2016)

Based on a study done by Mahaarachchi and Mahendran (2009) found that the pull through of the roof cladding initiate by the presence of large stress concentration due to wind loading around the fastener hole. As the result, the cladding failed locally in the vicinity of the fastener thus forming a sizeable hole that allow the fastener to pull through the cladding (Yang and Bai, 2017).

2.4 Post Experimental Work

There are few experimental works conducted by previous researchers to simulate the wind uplift effect on the roof cladding. Kretzschmar (2011) used air bag as the loading to study the performance of roof cladding under uplift loading condition. The uniformly distributed load was simulated by applying pressured air bag directly to the bottom of the roof cladding. However, it is reported by (Stephen, 2013) that the air bag was found not to be fully capable of simulating actual uniformly distributed load pressure over entire of roof cladding.

Line load test method is conducted by Xu (1992) and Xu and Reardon (1993) to investigate the behaviour of roof cladding The method considered to be as cost effective testing method and easy to perform in the laboratory. The band pressure is used at the mid-span across the full length of the specimen to replace the uniformly distributed pressure acting on the roof cladding. Even though, the line load test method able to simulate the correct bending moment and reaction force at the central support but it is found that the method is embedded in the assumption that the test span length represents the design span length.

Mahaarachchi and Mahendran (2009) then performed air box test and he found that air box method is the most accurate laboratory testing for the roof cladding to simulate the wind loading. This is due to the ability of the air box to truly generate and distribute uniform pressure loading distribution over the entire roof cladding. Basically there are two different methods in applying pressure for the air box configuration. It can be done either by using vacuum chamber where the pressure is extracted until vacuum occurred in the box or applying the pressure directly to the roof cladding.

2.5 Post Computational Fluid Dynamic (CFD) Analysis

The Computational Fluid Dynamics (CFD) is also used as another method to study the behaviour of wind loading acting on the roof cladding. This method able to provide abundant information of wind-related problem at instant time (Deraman et al., 2018). The best part of CFD analysis is the ability of the method to predict the wind flow around the building under conditions of very close to actual state. However, Deraman et al. (2018) stated that the validation between experimental data and CFD can be very complex and tedious.

Irtaza et al. (2015) clearly expressed that the use of numerical solution such as CFD is relatively cheap but it has certain limitation that associated with it where the pressure taps are not easily to be placed at the sharp edges at the corner regions of the overhang parts. The mesh arrangement of the model in CFD analysis should be fine enough for the efficient computation since high meshing smoothness and fine quality meshing will give more accurate result for the simulation (Yahya et al.). The study of effects of overhang roof on rural houses done by Yahya et al. (2017) performed using ANSYS FLUENT 14 software found that the presence of overhang is more susceptible to cause damage on roof cladding. Hence, this study is carried out to investigate the wind uplift effect on overhang roof of rural house by using experimental work.

2.6 Summary of previous research

Table 2.1 shows previous research done by researchers regarding effect of strong wind on roof connection. The summary of the previous research explained well about the testing and the findings

Table 2.1 Summary of previous research

<table>
<tr><td rowspan="4">1.</td><td>Author, Year</td><td>M. Mahendran, 1994</td></tr>
<tr><td>Tittle</td><td>Behaviour and Design of Crest-Fixed Profiled Steel Roof under Wind Uplift</td></tr>
<tr><td>Testing</td><td>Finite Element Analysis and small scale test</td></tr>
<tr><td>Finding</td><td>• Strength of connection dependent on type of roofing, thickness, strength and ductility of steel, and type and size of fastener
• Behaviour of cladding much dependent on geometry of profile
• Thin cladding underwent large cross sectional distortion and localised deformation around fastener hole when subjected to wind uplift</td></tr>
<tr><td rowspan="4">2.</td><td>Author, Year</td><td>M. Mahendran, 1995</td></tr>
<tr><td>Tittle</td><td>Wind Resistant Low-Rise Buildings in the tropics</td></tr>
<tr><td>Testing</td><td>-</td></tr>
<tr><td>Finding</td><td>• Uplift load path often has the weakest links in form of connection
• Uplift loading causes fatigue failures of roofing to purlin connection
• Insufficient screws or nails make connection fail under high wind event</td></tr>
<tr><td rowspan="4">3.</td><td>Author, Year</td><td>M. Mahendran, D. Mahaarachchi, 2002</td></tr>
<tr><td>Tittle</td><td>Cyclic Pull-Out Strength of Screwed Connections in Steel Roof and Wall Cladding Systems using Thin Steel Batten</td></tr>
<tr><td>Testing</td><td>Small scale test</td></tr>
<tr><td>Finding</td><td>• Presence of fatigue effects as the pull out failures occurred after a few cycles of loading at much lower load levels than the static pull out failure loads
• Thicker batten produced small steel bending deformation around hole
• Presence of fatigue limit in the range of 25%-35% of static pull out failure load</td></tr>
</table>

4.	Author, Year	Harold w. Conner, David S. Gromala, Donald W. Burgess, 2012
	Tittle	Roof Connections in Houses: Key to Wind Resistance
	Testing	-
	Finding	• Strapping and clip angles were 15% and 36% stronger than conventional nail • Extra nailing with serrated nails doubles the strength of the connection • Conventional roof connections are generally adequate to resist extreme wind
5.	Author, Year	M. Sivapathasundaram, M. Mahendran, 2016
	Tittle	Development of Suitable Test Methods for Screw Connections in Cold-Formed Steel Roof Batten
	Testing	Air box testing
	Finding	• Short batten did not simulate bending moment as it not significantly effects the pull through failure • The use of special fastener arrangement allows accurate of actual screw fastener connection behaviour • Small scale testing result more conservative
6	Author	M. Sivapathasundaram, M. Mahendran, 2018
	Tittle	Development of Suitable Strengthening Methods for Thin Steel Roof Battens Subject to Pull Through Failure
	Testing	Lab
	Finding	• Roof batten with four screw fastener highlight shows slightly effect to the redistribution of applied load among screw fastener • High ductility roof improved the distribution of applied load compared to low ductility roof • Overlapping roof batten at connection will increase the pull through capacity and effect of higher bending moment at connection of batten

CHAPTER 3

METHODOLOGY

3.1 Introduction

The aim of this study is to determine pull through load capacity of various type of cladding with different thickness at overhang using pull through test. The study consists of two parts namely, rural house survey and experimental work. The rural house survey covers several districts in Kedah, Penang and Perak. Details of the site activities were presented accordingly in this chapter. Following this, the overview of the specimens' preparation, the test set up and the details on the procedure of pull through test are presented. The test was conducted at Heavy Structure Laboratory located at School of Civil Engineering, Universiti Sains Malaysia. The duration for conducting both rural house survey and experimental works took about 3 months starting from 1st December 2018 until 23rd April 2019. Figure 3.1 shows the flowchart of the overall methodology for rural house survey and experimental work. There are four steps involved in this study .

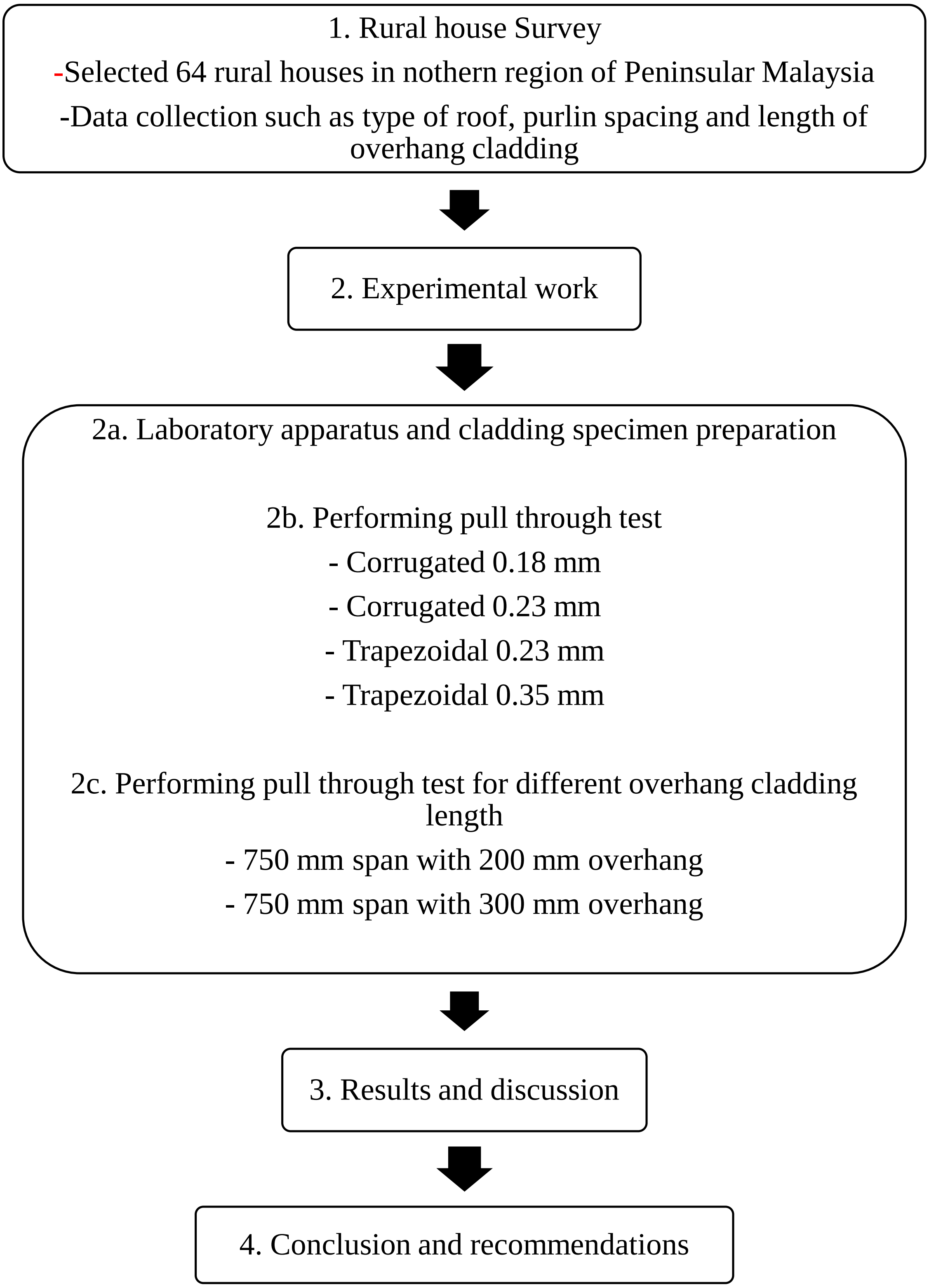


Figure 3.1 Flowchart of the study

3.2 Rural house survey

In this study, rural house survey was carried out to obtain useful information pertaining to the roof dimension especially on overhang roof part. This information is used in conducting experimental work. The roof dimension survey of house in rural area in northern region Peninsular Malaysia covered three states namely Penang, Kedah and Perak. This is because these three area have the highest number of damaged houses during high wind event (Wan Cik et al, 2014). The study area at three regions in northern region of Peninsular Malaysia is shown in Figure 3.2.

Figure 3.2 Study area located at Kedah, Penang and Perak

This survey initially being done to collect information regarding rural house roof dimension. The survey focused on non-engineered rural house where normally these type of house does not have specific measurement of roof especially at overhang part. The data was collected form 21st January 2019 until 3rd February 2019.

Various activities were involved during rural house survey like site visualisation, roof house measurement and interviewing the house owner as shown in Figure 3.3.

(a) (b)

Figure 3.3 Activities at site (a) measurement of roof overhang and (b) interview session with house owner

Rural house survey mainly being done to measure the roof part of house The measurement included dimension of roof especially on overhang roof and overhang zinc. The measuring tape and handled distance laser meter as shown in Figure 3.4.

(a) (b)

Figure 3.4 Measurement tool used in rural house survey (a) measuring tape an (b) handled distance laser met

In rural house survey, overhang roof is defined as combination of purlin spacing (PS) and overhang cladding (OC). Purlin spacing is a part of overhang roof from the end of the wall until the overhang cladding. Meanwhile, the roof part from the end of purlin until the overhang cladding is called overhang cladding. Figure 3.5 shows the part of overhang roof involved in rural house survey activities and schematic diagram of overhang roof is shown in Figure 3.6.

Figure 3.5 Part of overhang roof comprised of purlin spacing and overhang cladding

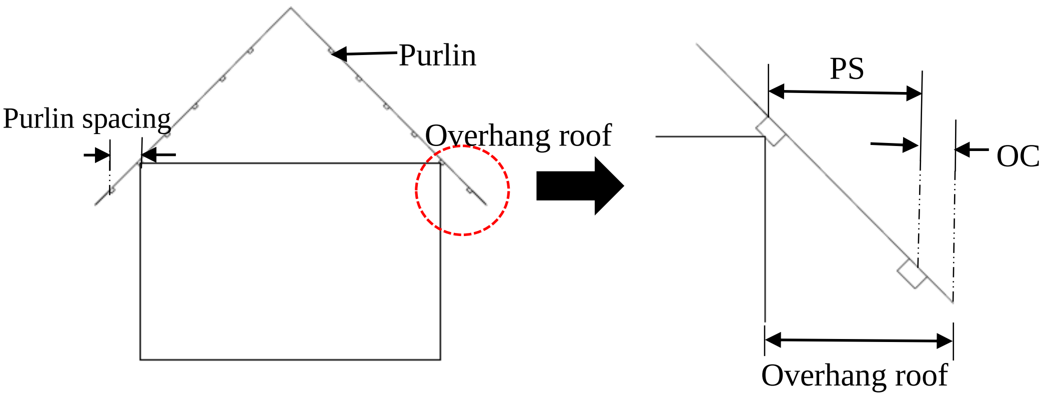


Figure 3.6 Schematic diagram of overhang roof

3.3 Experimental work

This section focuses on the experimental procedures of this study to investigate the pull through failure of roof cladding to purlin connection considering overhang roof. The details of the materials and apparatus used are presented in this section.

3.3.1 Materials and apparatus

All the testing specimens used in this experimental work are supplied by local supplier. The testing specimens includes roof cladding, timber purlin and fastener. The materials information as in Table 3.1.

Table 3.1 Material properties

No.	Material	Type	Dimension
1.	Roof cladding	Corrugated	Thickness: 0.18 mm, 0.23 mm
		Trapezoidal	Thickness: 0.23 mm, 0.35 mm
2.	Timber purlin	Dark Red Meranti (SG5)	50.8 mm × 50.8 mm × 914 mm
3.	Fastener	Umbrella head nail	Head diameter: 16 mm Shaft diameter: 3.90 mm

3.3.1.1 Roof cladding

Two types of roof cladding used in this experimental work are corrugated cladding and trapezoidal cladding. The roof dimension of corrugated cladding and trapezoidal cladding is 680 mm × 2137 mm and 850 mm × 2137 mm, respectively. However, the length of cladding is modified according to the length of overhang during the testing. These types of cladding are common in roof construction in the rural area because locally available and easy to be installed. Figure 3.7 shows two different types of cladding used in this experimental work. The corrugated cladding thickness of 0.18 mm and 0.23 mm while the trapezoidal cladding thickness are 0.23 mm and 0.35 mm are tested.

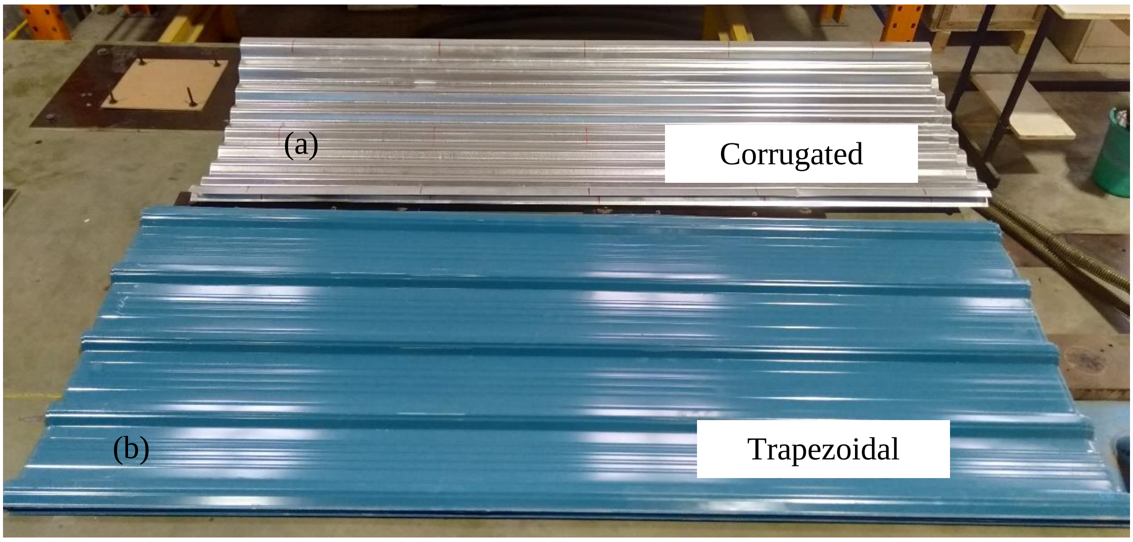


Figure 3.7 Two types of roof cladding namely (a) corrugated and (b) trapezoidal

3.3.1.2 Timber purlin

In this experimental work, timber from Strength Group 5 (SG5) namely Red Meranti is used as purlin. This type of wood commonly used in construction of roof truss of rural house due to it low cost (Humayunkabir, 2017). The dimension of purlin is to 50.8 mm × 50.8 mm and length was set to 914 mm in order to fit on the steel frame assembly as shown in Figure 3.8.

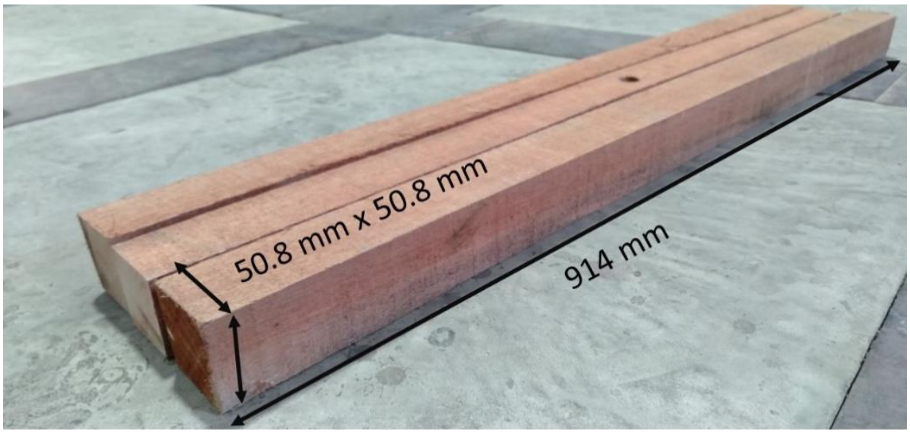


Figure 3.8 Dark Red Meranti was used as purlin

3.3.1.3 Fastener

The fastener used in this experimental work is umbrella head nail. Most of rural houses in Malaysia used umbrella head nail because it is easy to handle and give more strength to the connection. Figure 3.9 shows the types of fastener used to secure the connection between roof cladding and purlin namely umbrella head nail and modified umbrella head nail. The diameter of umbrella head nail is 16 mm and shaft diameter is 3.90 mm. The modified umbrella head nail has the same dimension with umbrella head but it has been modified by making a short thread on it so that it can be attached to the load cell.

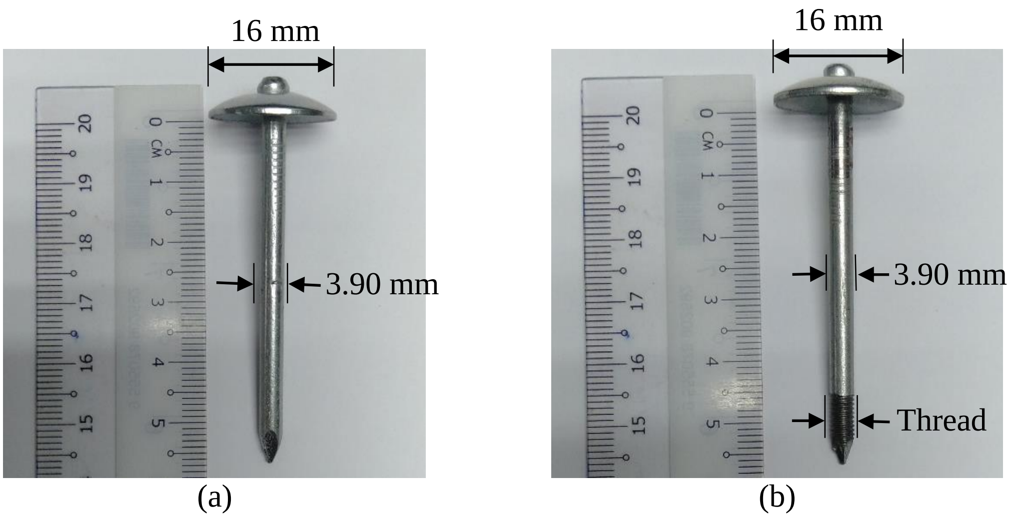


Figure 3.9 Types of fastener used in the study namely (a) umbrella head nail and (b) modified umbrella head nail

3.3.2 Preliminary test

A preliminary test was carried out to ensure the instrument and apparatus can produce the acceptable result before performing the experiment with the actual specimens. A two span cladding assembly with simply supported ends was tested under uniform wind uplift pressure using a hydraulic testing machine. The preliminary test called two span test because it used the same length for the both span. The crest of cladding and central support of purlin were predrilled for the insertion of modified nail fastener specially made with new thread before attached to the load cell.

Initial information of failure load will be generated from this test and it can be used as a benchmark when conducting the test on actual specimens. In this preliminary test, the grade of timber specimen is unknown since the test was conducted on readily available timber at Fabrication Laboratory. Figure 3.10 shows the full assembly of the preliminary test for corrugated zinc cladding of 750 mm spacing and shows the schematic diagram for the test.

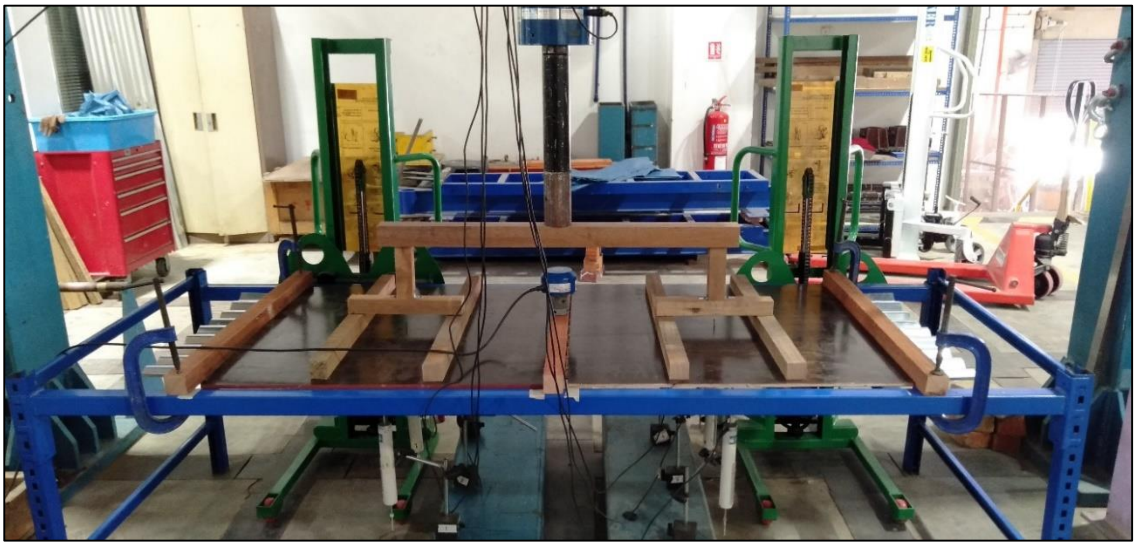


Figure 3.10 The preliminary test set up of 750 mm span

3.3.3 Pull through test

Table 3.2 shows the detail of the test matrix based on type of cladding, cladding thickness, span length and overhang length. All tests were conducted on three specimens and the average values were taken for discussion purposes. As such, a total of 20 tests were conducted in order to achieve the objectives.

Table 3.2 Test matrix

Type of Cladding	Cladding Thickness	Overhang Length	Specific Designation of specimen
Corrugated	0.18 mm	200 mm	C0.18-OV200
		300 mm	C0.18-OV300
	0.23 mm	200 mm	C0.23-OV200
		300 mm	C0.23-OV300
Trapezoidal	0.23 mm	200 mm	T0.23-OV200
		300 mm	T0.23-OV300
	0.35 mm	200 mm	T0.35-OV200
		300 mm	T0.35-OV300

3.3.3.1 Procedure of pull through test

In this experimental work, the roof cladding was installed similarly to the real roof construction. The roof cladding was fastened to the to 50.8 mm × 50.8 mm timber purlin at the crest of the cladding by nails. The roof cladding assembly then inversely set up to the steel frame. The details of the connections are explained below:

i. The cladding was measured and marked according to the span and overhang length. The midpoint of the span also was marked as a location of LVDT.

ii. The cladding was fastened at alternate crests of 320 mm spacing to the purlins at 750 mm spacing secured by nail for one span. The other span was fastened by nail at 200 mm spacing. The procedures were repeated for 300 mm spacing.

iii. The load cell was placed at the central support of the cladding by using modified nail fastener.

iv. A short steel section was placed on top of the load cell so that a gap between load cell and timber purlin can be created. This need to be done in order to avoid the reading of load cell affected when in contact with the purlin. The steel section also need to be clamped to the steel frame assembly.

v. Six LVDT's were placed on resting steel section at location as shown in Figure 3.11.

vi. The LVDT's need to be levelled 90^{o} vertically by using spirit level and plasticine was pasted at tip of each LVDT to ensure the LVDT's placed exactly on same location throughout the testing. This need to be done to get real reading of roof cladding displacement.

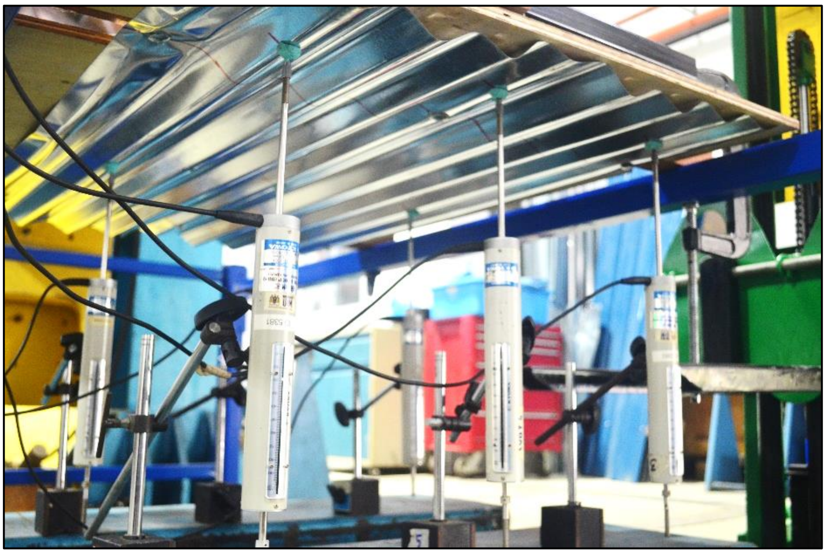


Figure 3.11 LVDT's set up on resting steel section

vii. Lastly, two stackers were placed at height of maximum LVDT's deflection to avoid roof cladding fall on it.

As the cladding was set up upside down on the steel frame assembly measuring 950 mm width × 2530 mm long × 710 mm height, the purlin need to be clamped on the steel frame assembly using G-clamp. The cladding was placed inversely on the steel frame assembly to simulate the uplift wind loading acting on it. There are three main components namely jointed loading pad, stacker, resting steel section as shown in Figure 3.12. The jointed loading pad designed to distribute load from the hydraulic testing machine to the cladding. The stacker was used to avoid the cladding from hit on the LVDT directly and resting steel section was placed to provide the base for LVDT to be installed. The schematic diagram for the pull through test are shown in Figure 3.13.

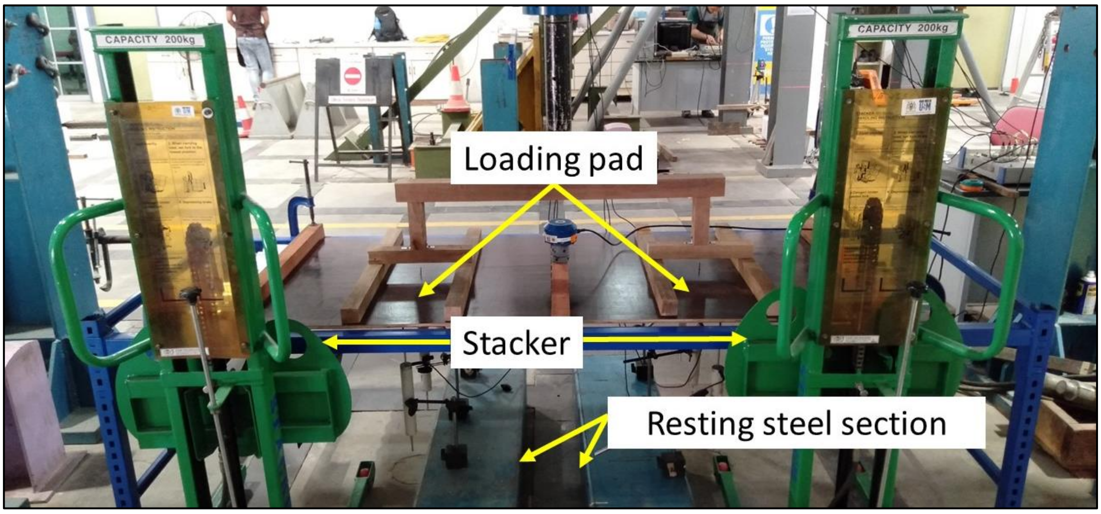
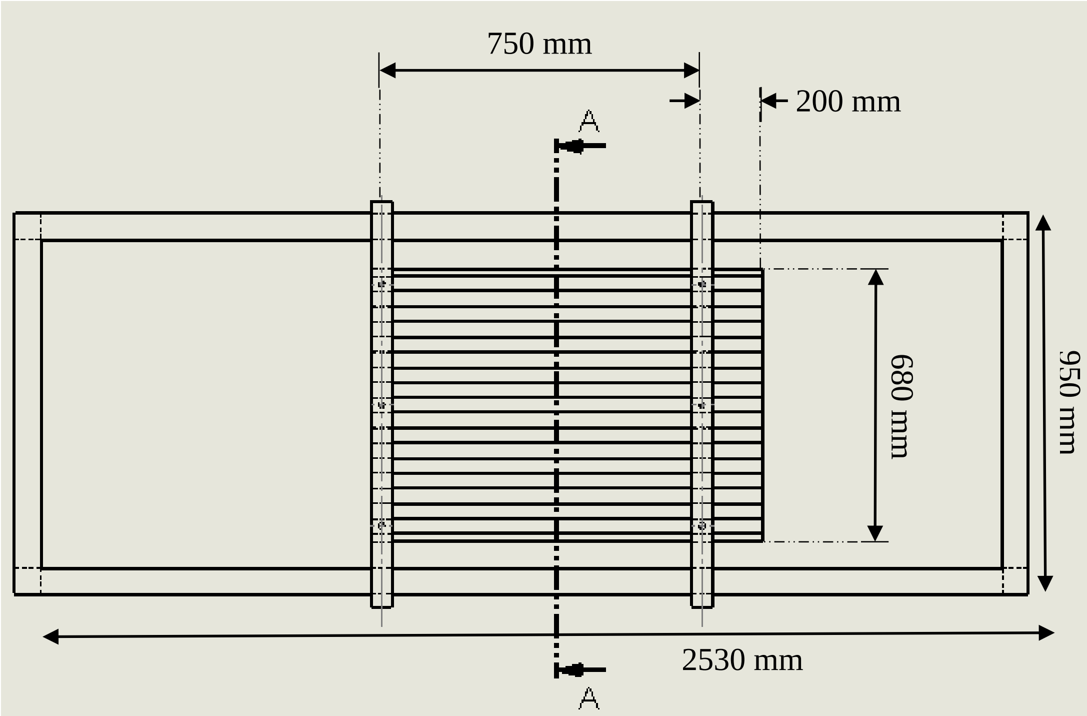
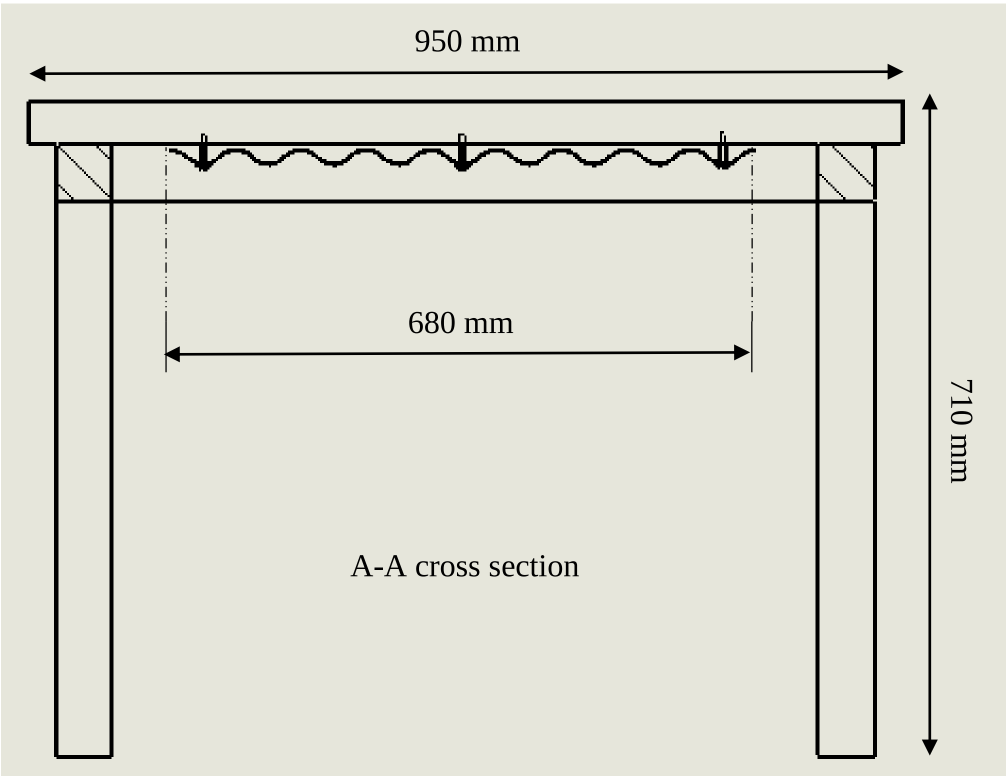


Figure 3.12 Main component in the experimental set up



(a) Top view



(b) Side view

Figure 3.13 Schematic diagram of pull through test (a) top view and (b) side view from A-A section

3.3.4 Measurement of reaction force

The reaction force of the central nail fastener is measured by the load cell that attached with the modified nail fastener.

3.3.4.1 Modified nail fastener

The experimental work used modified umbrella head nail to simulate the pull through capacity of the fastener. The modified nail fastener is attached to the load cell as shown in Figure 3.14.

Figure 3.14 Load cell of 5 kN load capacity with modified screw fastener

3.3.4.2 Load cell

A 5 kN load cell was placed on top of the central fastener head to measure the reaction. The modified nail fastener is attached into the load cell in order to obtain the pull through capacity. As such, the central fastener was not fastened to the timber purlin but it is fixed to the load cell. It is important to ensure the load cell not in contact with the timber purlin so that the real reading not affected.