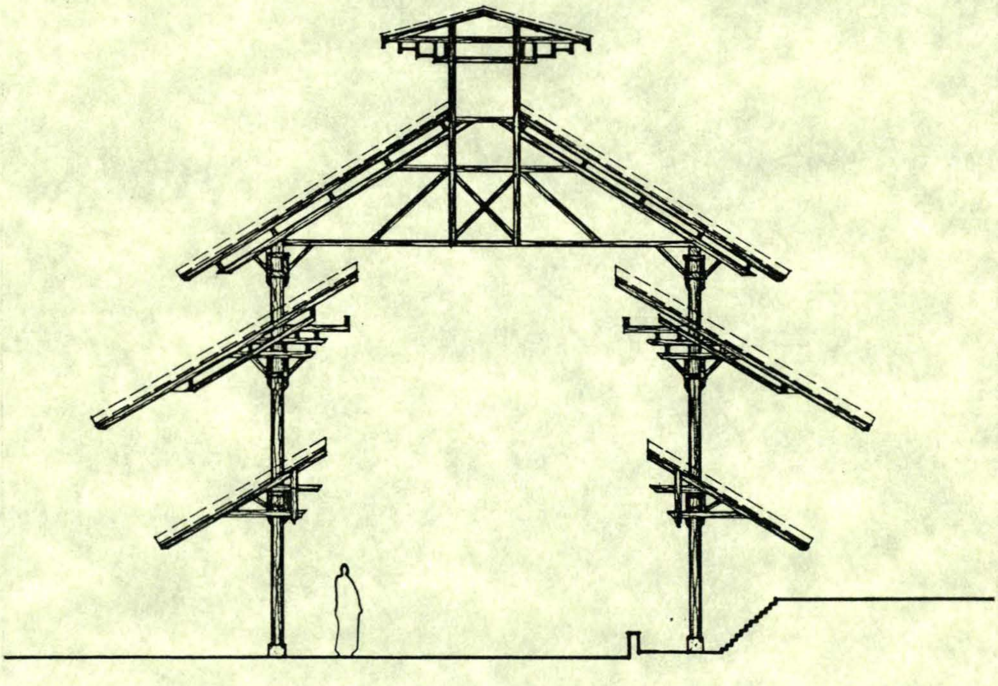
Timber Structures in Malaysian Architecture and Buildings



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Wai Sung Wong

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Finally, this work is dedicated to my beloved parents.

Abstract

Malaysia is endowed with rich timber resources. These have been used historically for building construction. However, the recording and documentation of the use of timber structures in architecture and building is a new field of study. The limited number of texts related to the use of timber in Malaysia are largely concerned with the design and construction of the traditional Malay house. The archival material related to the use of timber has been found to be very limited in scope and incomplete.

The primary aim of this study is to provide a broad overview of the influences that have shaped the structural use of timber in Malaysia from 15th century to the present day. It is hoped that this will provide the basis and inspiration for more specific detailed studies to be undertaken at a later date. Therefore, this is not seen as a definitive study but the beginning of a process which attempts to understand the use of this basic material, timber, in Malaysian architecture and building.

Chapter 1 of the thesis examines the cultural background of factors that have influenced the use of timber in structures on the Malaysian Peninsular. It traces the historical development of the use of timber as building material from the early indigenous timber structure to contemporary architecture. The detailing in timber jointing was different in each state due to the different cultural backgrounds of the local craftsman.

Chapter 2 explores the technological developments that have contributed the structural use of timber in Malaysia over the last 150 years. The evolution of timber technology has enabled the development in jointing capacity and the structural determination of various building forms. Eighteen case studies are examined for the comparison of their respective construction and structural systems with an overview of the technical influences on construction associated with connections and joints for structural timber.

Chapter 3 examines current issues in the application of structural timber technology at national and international level which might be applied in Malaysia. This chapters includes the discussion on current timber technology transfer from overseas and adoption to the local environment.

Chapter 4 concludes with the research findings and discusses the issues that have affected the use of timber in Malaysia and provides some suggestions for areas of further research. This research concludes with the difficulties of wider use of timber in Malaysia.

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Introduction

Background of the Study

Timber is one of the oldest construction materials that humankind has used (Law, 1985 : p. 2). Malaysia with its abundant of timber, 90 percent of which is hardwood (Tan, 1992 : p. 16), has relied upon timber for all types of structures, from the impressive and excellently crafted timber palaces for the Sultans (Lai, 1976 : p. 50) to the most humble, semi-permanent of structures. Although timber has many good qualities such as availability, strength and flexibility, it is subjected to fast decay due to environmental conditions and natural causes. Many timber buildings are also attacked by termites and destroyed by fire. It was only in the 20th century where this reliance on timber has given way to building materials such as reinforced concrete.

A recent study revealed that the total cost of timber used in construction is often only 15 percent of the total project cost (Medical and Health Department, 1993 : p. 5). Apart from non structural use in scaffolding and formwork, timber is only used in roof structures as a structural element and this can be found in government buildings such as offices, schools and hospitals.

Malay domestic architecture can be traced to distant origins in the islands of the Malay Archipelago where the West Malay Culture and Bornean culture are indigenous to the area. Elsewhere, indigenous Malay culture was strongly marked by influences from the Indian subcontinent, China, the Middle East, and Europe (See Figure I). These influences, and their affect on the use of timber in construction will be discussed in more detail in chapter 1 and 2.

Historically, the Malay house has been used as a model for design of palaces and religious buildings in Malaysia. (See Table i). Though it has undergone drastic changes over the years, the basic construction system and structural principles remained much unchanged. The variation in terms of building forms and spatial expression arise due to change in climatic and cultural factors.

Currently, there is a growing awareness of development in "Regionalism" architecture, several acclaimed architects in the country such as Ken Yeang, Jimmy Lim, Hijjas Kasturi and Harjeeder Majid, advocated the precedent as a possible inspiration model for future architectural development. The adapting and developing traditional forms using timber material to meet the demands of contemporary architecture will be discussed in more detail in Chapter 1. I hope that this study of timber architecture will inspire the intelligent use of a natural material which can provide buildings, both economically and ecologically sound to be constructed.

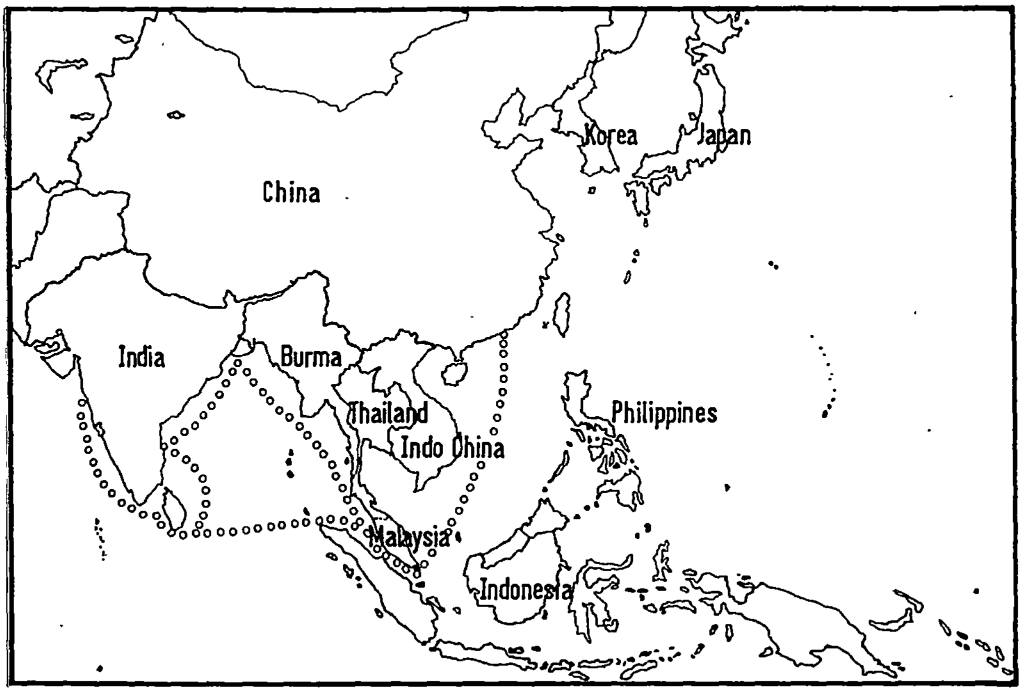


Figure i
The geographical location of the Malay Archipelago and Peninsular. Chinese and Indian came into Malaysia by trade of gold, tin teak and spices. This sea faring traders indirect brought with them their architectural principles which were later transformed and adapted into local building forms.

Aims and Objectives

The primary aim of this study is to analyse the evolution of timber buildings in Malaysia from indigenous shelters to contemporary architecture. Traditional architectural forms, regardless of their differences and complexity are based on a few basic structural principles and have relatively remained unchanged over time. In the field of traditional timber architecture, examples were found which indicated that a number of building forms, from a structural point of view, were originally influenced by the construction material available.

The aim of this research is to document the historical usage of timber in construction. Such information would provide practitioners with the knowledge to use timber as a natural resource in an appropriate manner so as to link our cultural, traditional and social values from the past to present. This research built up a structure database of existing timber structures which formed the basis for analysis. As far as can be acertained no such work has been attempted previously, except occasional fragments of architectural commentary that appear from time to time in journals and "Majallah Akitek". As such, this work can be claimed to be original, but no attempt has been made to go into historical or architectural details, for the intention has been to give a synoptic view of the development of timber Architecture in Malaysia. It must then be left to the future to go into the minutiae of elements unearthed so that a more comprehensive picture can be developed.

Table I : Chronological table of historical timber buildings in Malaysia

		1400	1500	1600	1700	1800	1900	2000
EARLY INDIGENOUS STRUCTURES	//////////	From 3rd century of Stone Age up to present →						
MALAY TIMBER ARCHITECTURE		From 1453 to present	. Malay House	. Palaces		. Mosques →		
			"Mohd. Natar", Malacca (1894)	- "Istana Ampang Tinggi", Negeri Sembilan (1861)		- "Masjid Kampung Laut", Kelantan (1743)		
			"Pak Ali", Kuala Lumpur (1917)	- "Istana Tengku Nik", Terengganu (1888)		- FRIM's Mosque, Selangor (1975)		
				- "Istana Sri Menanti", Negeri Sembilan (1902)		- ASPA Mosque, Pahang (1989)		
CHINESE TIMBER BUILDINGS				From 1600 up to 1980's on shophouses, temples and kongsi houses. →				
				- Cheng Hoon Teng Temple, Malacca (1624)				
				-"Teluk Intan Clock Tower", Perak (1855)				
				- Khoo Kongsi, Penang (1901)				
PORTUGUESE			From 1511 to 1641					
DUTCH				From 1641 to 1795 →				
				- Stadhuys Complex, Malacca (1641)				
				- Christ Church, Malacca (1753)				
BRITISH					From 1786 to 1942 →			
					"Gedung Raja Abdullah", Selangor (1894)			
					"Cargosa Sri Negara", Selangor (1897)			
					"Memorial Pengisthiharaan Kemerdekaan", Malacca (1911)			
JAPANESE							From 1942 to 1945	
CONTEMPORARY TIMBER ARCHITECTURE							From 1960 to present	
							. 1970's - Government's Buildings	
							. 1980's - Recreational/Clubs	
							- Hyatt Kuantan, Pahang (1979)	
							- "Tanjong Jara Resort", Terengganu (1983)	
							- Mediterranean Club, Terengganu. (1984)	
							- Pelangi Resort, Kedah (1988)	
							- Delima Langkawi, Kedah (1992)	
							- Datai Langkawi, Kedah (1993)	

Current technological principles used in timber construction and structural systems are investigated important issues of Malaysia's future development, including environmental implications of timber architecture are identify. Such a study will increase the understanding and appreciation of traditional forms as local design elements for contemporary timber architecture.

Limitations of the Study

The scope of archival material related to timber structures has been found to be very incomplete and limited. They are largely concerned with the design and construction of the traditional Malay house. Reliable architectural and historical documentation is notably lacking. Archaeological exploration has provided evidence of various Stone, Bronze and Iron Age civilisations in the Peninsular and the islands of the Malay Archipelago but no architectural remains dating from these periods have been found (Yeang : 1992, p. 15). Furthermore, the limited life span of timber as a building material, especially in the tropics, means that early examples of timber construction are no longer available for study. Termites and natural decay associated with a damp tropical climate have also resulted in the disappearance of many timber buildings. Many timber buildings, including palaces such as "Istana Seri Akar"in Kelantan had been demolished to give way to contemporary development. Therefore, the extent of this research is limited to the study timber of structures only, dating from 16th century to the present. The research findings outlined in this study represent only the first layer of possible information on the use of timber structures in traditional architecture in Malaysia. Therefore, the research findings are based on a pilot study and further research should be carried out and discussed in more details in Chapter 4

Previous Research

Information collection include measured drawings, slides and photographs, records of site inspections and interviews with local government officers and design professionals. (See Appendix A 1.1 for research methodology). Twenty weeks were spent doing library and archival research at the National Archive of Malaysia. The findings suggest that the research topic had been covered before. Furthermore, there has not been any comprehensive regional architecture histories cover this field. The most informative material written (Lim : 1987, Gibbs : 1987) covers traditional Malay house, giving details of the various house types, the construction system, the climatic design and the adaptations to the social and cultural requirements of the Malays. Other histories of parts of the study area are available, but they are less valuable as they do not privide the actual information required on the use and forms of timber construction.

The Heritage Council of Malaysia and National Museum Department provided a general description for many of the buildings that they have listed, and this description was used as a preliminary information for more detailed research. Other archival material which proved to be useful was the Journal of the Malayan Branch, Royal Asiatic Society articles and unpublished research notes of various individuals.

Valuable data was also collected directly from the Forest Department Headquarters. The Building Plans Approval Division kept drawings dating from 1960 to the present. This source provided information on industrial buildings, such as sawmills and timber products factories. (Refer to Table B : List of sawmills and forest products factory in Peninsular Malaysia).

CHAPTER 1

Malaysian Timber Construction and Structures

Chapter 1 Malaysian Timber Construction and Structures

"Where can one find a greater clarity of structure than in the timber construction of the ancients ?
Where else can one find such a great synthesis of material, construction and form ?
How beautiful and warm they are !
One could call them the echo of ancient songs.
What better examples could one find for young architects ?
(Mies van der Rohe) (Blaser, 1985 : p. 9)

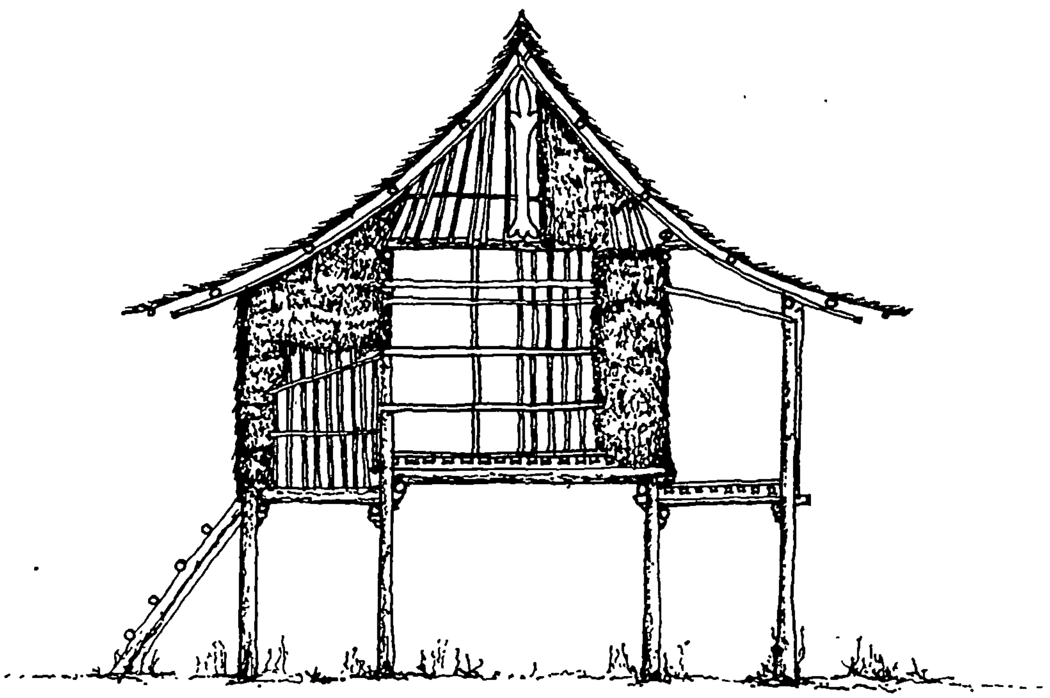


Figure 1.1
Perak Malay house built entirely with round timber.
Source : after Hilton, 1956 : p. 1

This chapter presents an overview of timber structures in Malaysia and describes the use of timber in simple buildings The basic structure of these buildings is the post and beam system Analysis is based on data collection, measured drawings, photographs illustration to describe the development of timber structures from beginning of traditional buildings to present day

1.1 Early Indigenous Timber Structures

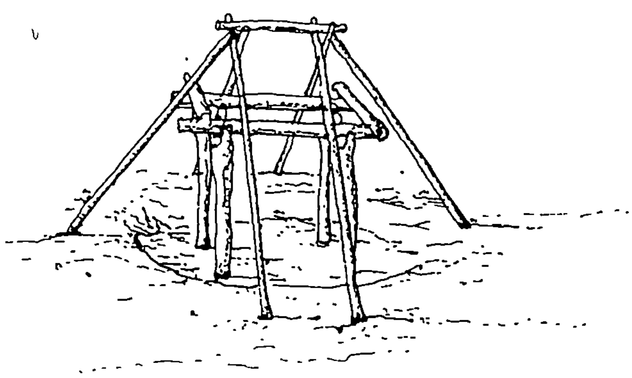
> "The true basis for the more serious study of the art of architecture lies with those more humble indigenous buildings everywhere. Functions are truthfully conceived and rendered invariably with natural feeling".
> (Frank Lloyd Wright) (Tan, 1994 · p. 17)

The tree has always been a symbol of shelter, an embodiment of security. According to Rykwert (1972 : p. 28), "anybody who makes a comparatives study of art on a geographical basis is practically driven to the conclusion that in the vast majority of countries wood was the original building material"

The earliest building materials used by the first inhabitants of Malaysia were the branches of trees, laid against each other and tied together to form free standing structures The roof of the building would have been covered by palm leaves. The headroom in such a primitive structure was limited by the length and straightness of the branches available. (See Figure 1.2).

The indigenous structures of Malaysia, using locally available material, have characteristic features in terms of construction; they are held together by means of a variety of jointing and mortising techniques, reinforced by pegging or wedging rather than nails. Timbers are simply lashed together using rattan or strips of bamboo. Built forms use the post and beam system of construction and structural members may be ingeniously shaped and notched to form a joint These time-proven shelters are invariably built by local craftsmen and reflect form, proportion and craftsmanship which have withstood the tests of time.

Figure 1.2
Early timber structure
Source : after Wolfram. G 1990 . p. 21.



Normally, diagonal bracing was not used in the vertical framework of this type of construction Tie beams were attached to posts with mortise and tenon joints and horizontal beams were set as high as possible to reinforce the building's resistance to horizontal stress from wind. However, this was effective only when the intersections of horizontal members and the posts were firmly fixed, and depended entirely on precise joinery and careful alignments

Shelter size and structural system were limited to short spans and appear to result from the cutting of timber in the forest to sizes that could be carried by men Various parts of the structure were prepared in the forest and assembled on site. Trimming the timber in the forest lightened the load for those who had to carry it to the building site.

The basic shelter was adapted to a wide range of physical, human and climatic conditions. The comfort and security of the shelter could be improved by raising the floor above the ground. Evidence for this can be seen among the "Orang Laut" (indigenous seafaring people) who live along the coast and build shelters supported by stilts, with walls and roofs of nipah leaves (Munan, 1990 · p 38)

"Orang Asli Shelters", Pahang

The Negritos of the Malay Peninsular live in simple huts, which are built entirely of fibrous material found in the surrounding area, such as bamboo leaves. The whole nature of the handiwork is rough and accuracy is not important. The quality of the finished product is very dependent on the local materials and skills available. No equipment is needed to construct this type of shelter. Only recently, corrugated iron has been introduced for roofing (Bier, 1991 · p 52) (See Figure 1.3).

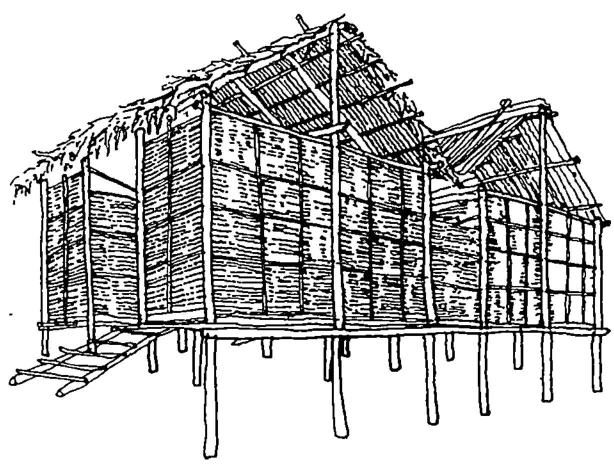


Figure 1.3
The "Negritos" of the Peninsular Malaysia build with timber, bamboo and palm leaves The hut shape is the prototype of the pitched roof It is the most economical roof form for the rapid discharge of rain water while at the same time giving enclosure.
Source after Bier, 1991 : p 52.

Iban Long House, Sarawak

The Iban long house is another example of the native dwelling, the most typical indigenous building type in Sabah and Sarawak (Sharp, 1991 · p 70) The long house is unique to the region of Sarawak and the building basically satisfies all the necessary functions of both public and private space within a single structure It also exemplifies indigenous construction in South-East Asia, such as Borneo, Mentawai and the highlands of Vietnam (Waterson, 1991 : p. 144). This type of shelter is 1.80 metres above the ground which provides sub-floor ventilation and shade spaces in hot, humid climates. The walls are made of bamboo lashed with rattan (See Figure 1.4).

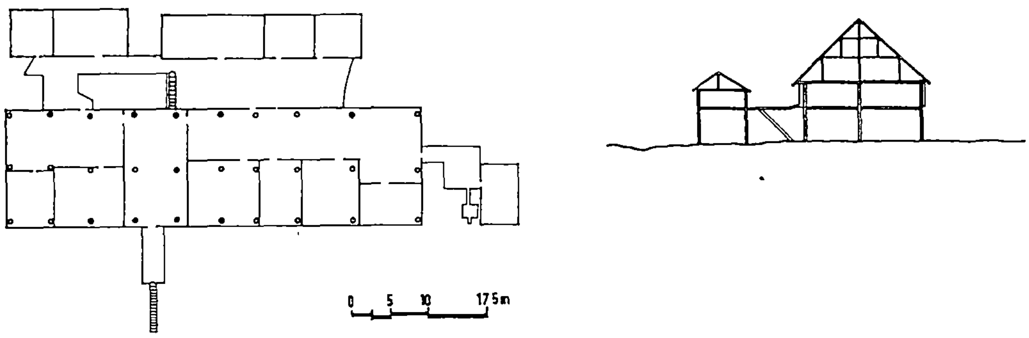


Figure 1.4
Plan and section of long house at Tumbang Gagu (Borneo). The floor construction was supported by thirty strong iron wood posts (Eusideroxylon zwageri)
Source · after Guidoni, 1978 : p. 112

Although the Ibans are becoming less reliant upon shifting cultivation and settling into urban areas, the traditional flavour of the long house has not gone; the commitment to the traditional form maintains the sense of belonging, continuity and identity (See Figure 1.5).

A long house is a temporary structure, to be dismantled if necessary. The form of the long house comes from a rectilinear structure which is derived from a simple technology but also includes aspects of social organisation The term "traditional building" refers to the act of building which is practised in societies of a simple technological and economic level. The traditional building reflects the diffusion of knowledge about the ways and means of building, influenced by belief, myths and religion. (See Plate 1.1 and Plate 1.2).

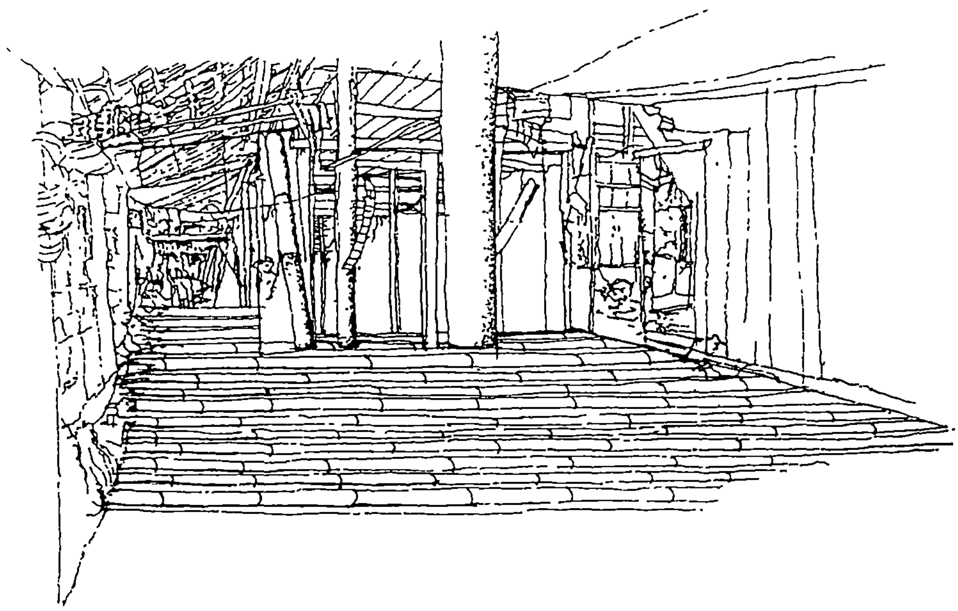


Figure 1 5
Internal spaces of the long house are generated by functional requirements.
Source : after Jin, 1989 . p 2

Construction System

The entire village lives in a rectangular timber and thatch structure which has been built on stilts up to 4.50 metres high (Jin, 1989 : p 2). The construction of the long house is lengthy, requiring skilled work and involving the whole community. Two large trees are felled and trimmed to the required height and these form the end supports for the central beam of the roof Later, the framework for the walls is built The roof and the floor are constructed using strong poles tied together with rattan The house is raised on 4.50 metres stilts, allowing for circulation of air. A gallery runs the entire length of the building with access ladders at both ends and the living quarters are divided into sections for each family.

Traditionally, construction did not require the use of nails; instead the timbers were lashed together with rattan rope (Bier, 1991 : p. 52) These techniques still exist, and by studying them, insight can be gained of the construction methods of the past The structural skeleton is formed by posts which are sunk into the ground and connected by purlins. Attap mats or sago palm leaf and hardwood shingles are used for roofing and split bamboo serve to cover the floor (Yeang, 1992 : p. 195). Bamboo boards are fixed to the posts to form walls Long self - supporting bamboos serve as rafters and roofing. The smallest purlin also acts as a gutter. On one side, the walls serve as doors and windows to provide ventilation. These bamboo huts are very simple but they provide maximum protection against sun, wind and heavy rain. Bamboo is the source for most of the building. The only vertical and horizontal forces acting on the structure are wind pressure, live loads and dead weight Each part of the building component is able to transfer axial and transverse forces to other members

Structural System

The framing system is a skeletal structure as a functional division between the carrying frame and the external envelope. The load bearing frame is determined by a simple arrangement of different parts to meet functional requirements. (See Plate 1 2)

The structural system, is built from large dimensional, naturally round timbers arranged in a linear grid. The span between the primary structures defines the position of the floor and floor planes. A light frame made of bamboo fills in the space between the floor and the roof, supporting the building skin. Flexibility of planning, form and structure within the space can be created from simple combination of bamboo partitions.

The spacing of the poles is one of the most important factors. The spacing must be the most efficient in terms of structural and space requirements. For example, the height of the floor must be accessible by people and create a semi-protected space underneath for storage as well as keeping domestic animals Poles are normally spaced at 3 0 - 4.0 metres apart. The poles have a significant structural capacity to accommodate vertical loads, and bearers resist lateral loads such as those imposed by wind. Therefore, the only structural system restrictions are the pole spacing and the selection of bearers with floor joists to accommodate these loads.

Roof Framing System

The building forms are determined by the layout of the floor and roof plane composed of the floor joists and rafters but restricted within the primary structural grid. The position and directions of the bearers dictate the span and direction of the floor joists. Similarly, the position and directions of the tie beams dictate the roof form and orientation of the ridge beams.

The roof frame is governed by the spacing of the supports and roof structure posts which are anchored in the ground. Solid types of roofs have rafters connected to their centre posts with tie beams acting as supports for the purlins The centre post is fixed by simple bracing. These triangular supports are the only transverse and rigid components. (See Plate 1 1).

Bracing is incorporated to strengthen the roof structure although long house construction was considered a temporary structure. Timber is a material that tends to be both strong and flexible compared to other materials, and because joints between timber members are not completely rigid. The structure of wood itself has adequate stiffness and strength, for this type of construction.

Plate 1.1
Long house at Mini Malaysia, Malacca. Post was recessed to support the circular tie beam.

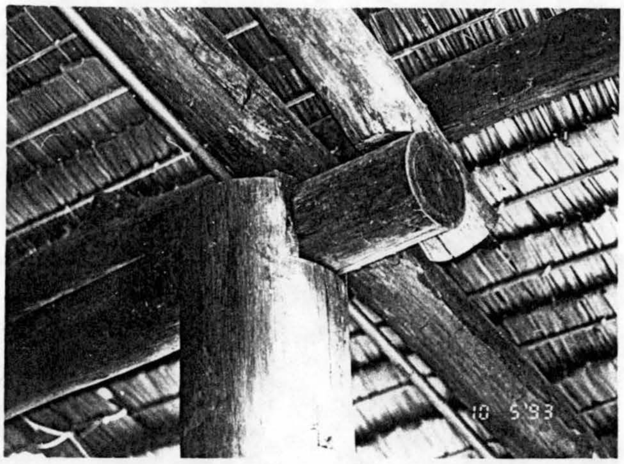
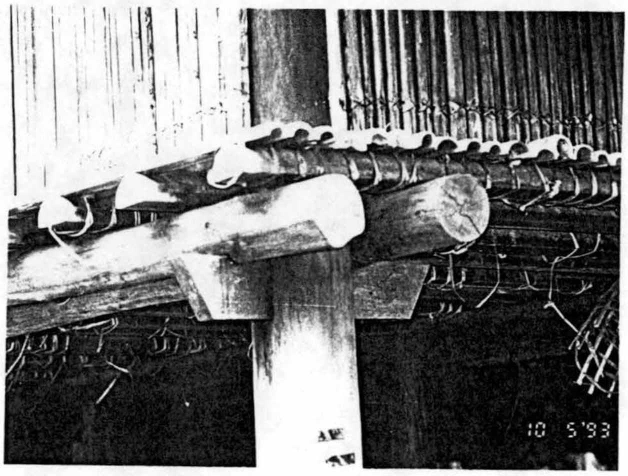


Plate 1.2
Long house at Mini Malaysia, Malacca. Details of floor construction based on twin girder to support the floor joists. Bearers are in the form of unsawn timber, and the nature of the poles usually leads to rougher detailing. Horizontal and vertical poles are considerably stronger than sawn material and very little energy and wastage is needed to form this type of shelter.



1.2 The Traditional Malay Timber Architecture

"We may use wood with intelligence only if we understand wood"
(Frank Lloyd Wright, 1928 p 481)

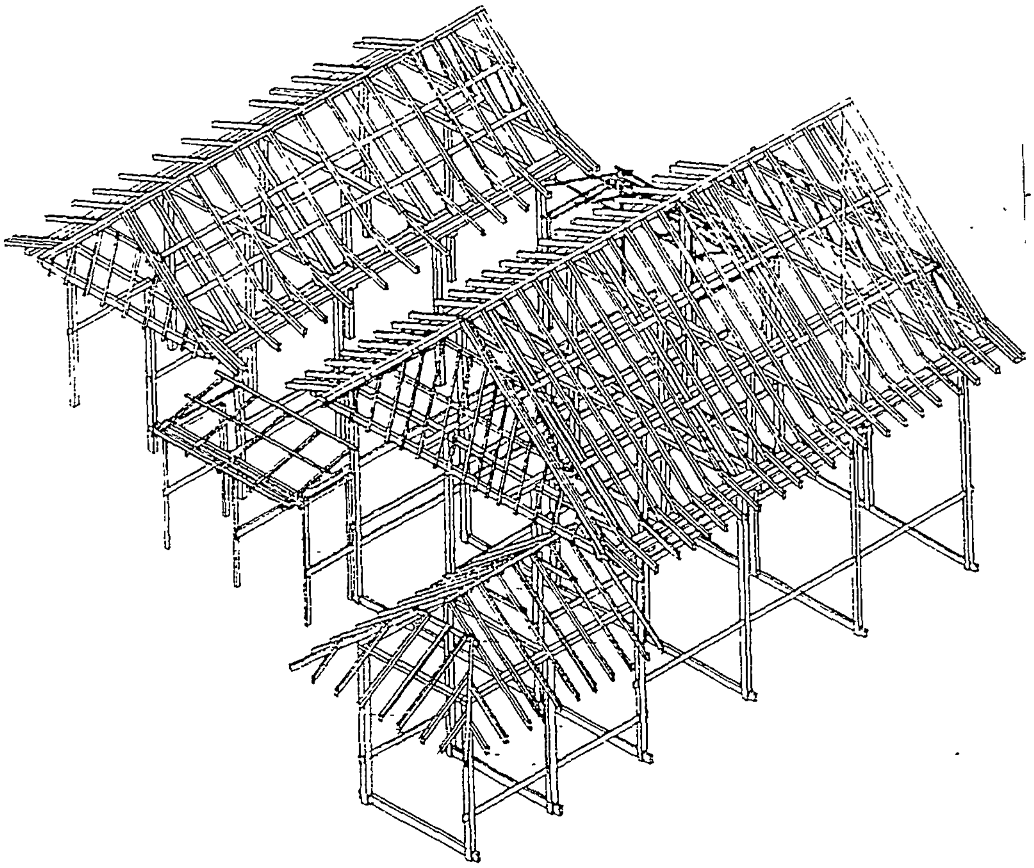


Figure 1.6
Traditional Malay house timber framing at Daeng Mat Diew, Parit Pecah, Johore. The traditional Malay house can be seen in the broad verandahs, steeply pitched roofs with wide eaves and deep overhangs for shade and cross ventilation, and the prevalent use of timber
Source Measured Drawing Studies, Department of Architecture, University of Technology Malaysia.

Malaysian timbers, either produced by local labour or commercially milled, are entirely hardwoods. The chengal species, being very strong, hard, heavy and relatively durable under exposure from sun and heavy rain, was the preferred species. The dense timber contains oil which makes structures resistant to termite attack. It is not difficult to work and shrinks less than other Malaysian timber and is therefore suitable for heavy structural work (Malaysian Timber Industry Board, 1986 . p. 50). "Merbau" is another common type which is strong, hard, heavy and resistant to termite attack. The "chengal" hardwood was selected for the first column to be raised on site and considered the essence of the whole construction of the traditional Malay house (Mokthar, 1992 : p 27)

In traditional building, the selection of timbers was very important and required expert local knowledge In fact, throughout the Archipelago, local taboos and superstitions influence almost all aspects of life, including the choice of materials, the actual construction process and detailing These taboos, rituals, ceremonies, and beliefs were seen as safeguards against the possible occurrence of fire, tragedies, sickness, evil spirits or other misfortunes (Gibbs, 1987 : p. 64; Waterson, 1991 · p. 118).

After felling, the logs were usually kept in water or mud for three months as it was considered that the timber would be more durable after the sapwood had been broken down by immersion. Later, the logs were exposed to sun for at least three years for seasoning to minimise dimensional changes in the wood and to enable the production of accurately shaped and sized components. Evidence for this can be found at "Rumah Pak Ali", Gombak at Kuala Lumpur which was constructed in 1917 and still exists today.

In his discussion of Malay house culture, Gibbs (1987, p 94 - 95), mentioned that the Malay follow a principle of "one house, one tree" in erecting traditional dwellings. The nine major posts must be cut from a single trunk which is shaped into a square section and then split into nine posts When the posts are positioned, they must maintain the same relationship to each other that they had before they were cut from the tree. The survival of many traditional buildings today is attributed to these traditional processing methods which ensured that the best possible materials were used.

The use of timber relies on an understanding of the material Evidence for this can be seen in Malay house construction using traditional timber framing. Ali (1991 · p. 10), argued that the traditional dwelling is a sophisticated system that had evolved with Malay culture over many centuries. The construction system incorporates the beliefs of the Malays and responds to the hot and humid tropical environment. Traditional Malay construction relied on post and beams as the primary load bearing elements, with wooden or bamboo walls and a thatch roof.

In the planning of a Malay house or mosque, the building faces the morning sun and is oriented towards the Qibla in Mecca. Although each regional house type has its own distinctive character, they all share several common features. The most significant architectural difference between Chinese and Malay culture is that Malay houses are always constructed on open stilts and have pitched roofs The logic of building on stilts has to do with health, comfort and aesthetics. It is also to avoid floods. The pitched roof is logical in the hot and wet climatic conditions The steep pitch permits rapid removal of rainwater and creates a high sloping ceiling ideal for ventilation in the tropical climate.

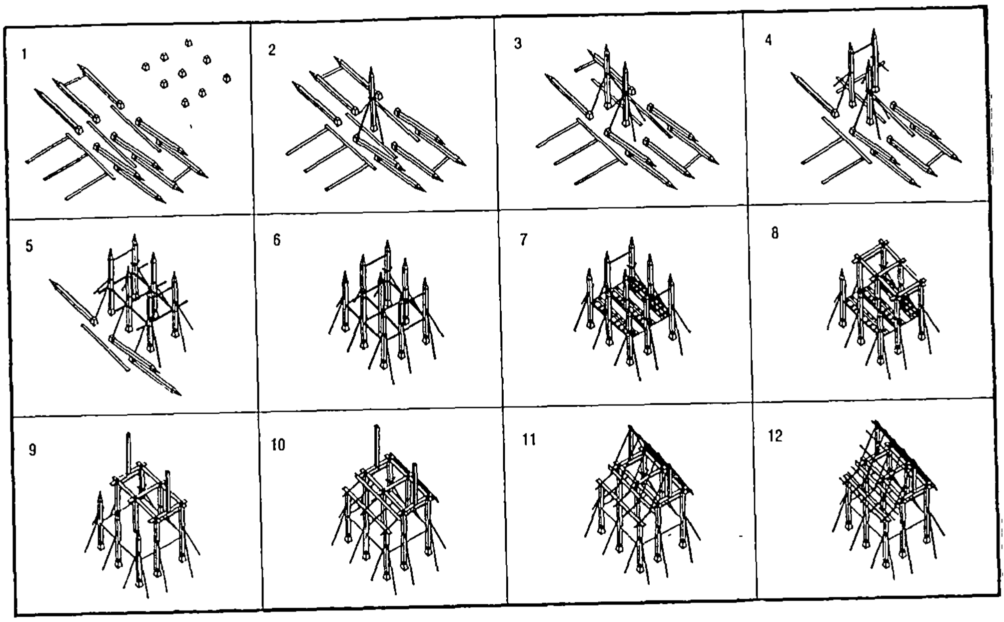


Figure 1 7
The process of construction of a Malay house.
Source after Gibbs, 1987 : p. 94 - 95.

1.2.1 The Malay House

According to Hilton (1956 : p. 134), the Malay house could have been derived from tree-dwellings constructed by many Malaysians, Melanesians and Polynesians. Hilton's analysis suggests that the distinctive style of the Malay dwellings developed partly as a result of technical limitations of construction knowledge of local craftsmen It is useful to compare the Malay house with the indigenous types as both are adapted to similar environments. They are both based on post and beam construction with slatted floors. The role of construction in Malay buildings throughout its evolution has preserved a unique balance between form, space and construction. Construction in the buildings is an essential component of space, as well as the major source of form. Architectural accentuation attained mainly through constructional means is derived from constructional device.

Traditional Malay houses are characterised by the shape of the roof which can be traced to the influences of various non-Malay people such as the Bugis, Minangkabau, Achehnese and Banjarese (Evan, 1948 : p. 211, Noone, 1948 : p 124). (See Figure 1.8). Noone (1948 . p. 124) described the Malay houses built by Malays of Patani descent living in Perak, but the broad principles apply to the whole of the Malaysian Peninsular The Malay house today has reached the peak of its evolution in terms of its structural system

Sheppard (1969 : p. 2 ; 1971 : p. 425) argued that the earliest roof forms in Terengganu and Kelantan originated in Khemer . The rectangular structural floor of the building was always raised high above the ground, evidence of which still can be seen in Thailand, Cambodia and Laos. The structural floors in Terengganu are raised as high as 2.40 metres from the ground for ventilation. Examples of this could be seen at "Istana Tengku Nik" which is preserved by the Terengganu State Museum ("Berita Warisan", 1989 : p. 7). (See Plate 1.3). This theory is supported by information recorded by Ma-Touan-Lin in the 13th century when he conducted a comprehensive survey of all the known countries in South East Asia (Raja Ahmad, 1988 : p. 16).

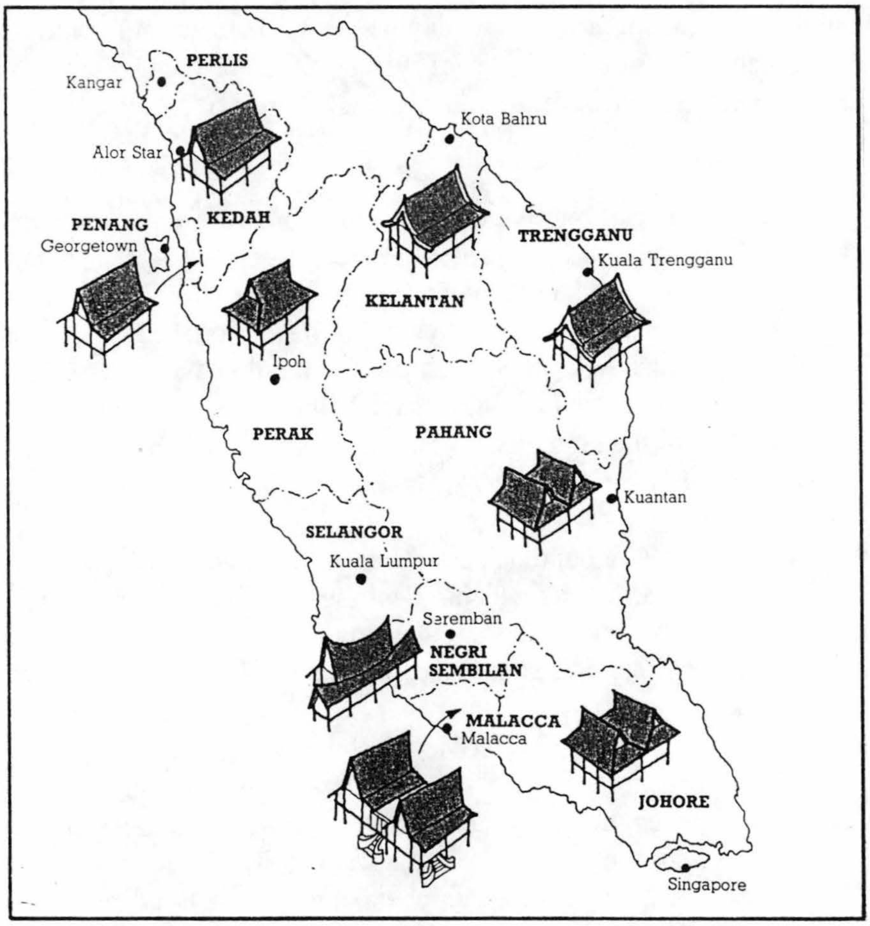
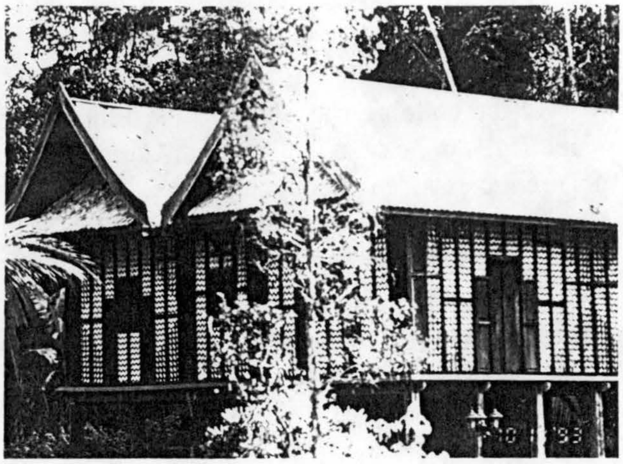


Figure 1.8
Common Malay house forms found in the Malaysian Peninsular.
Source : after Lim, 1987 : p. 27

Plate 1.3
"Istana Tengku Nik" at Kuala Terengganu. Structural timber columns 200 x 200 mm raised 2.40 metres above the ground.



Construction System

The traditional Malay house consists of two basic building units, the main house (rumah ibu) and the kitchen (rumah dapor). Both units are built with a rectangular frame and king post trussed roof system. The pre-formed timber structural components are assembled together using wedges or pegged mortise and tenons.

The main house is the larger of the two units, with three almost equally divided bays in cross section and three or four larger bays lengthwise. The central bay is spanned by the king post trussed roof with the side finished with a simple lean-to, giving a characteristic change of pitch on both sides of the ridge. This illustrates a traditional principle, as the Malay builders could have just as easily constructed a simple double pitched roof over the main unit. The smaller kitchen unit is similar with the king post trusses and lean-to roof, but has only two bays in cross section.

Variations in form and scale of buildings are achieved by different combinations or arrangements of these basic units which reflect the traditions of a particular region. The planning of the structural system is done by means of a linear grid. The advantage of timber skeleton structures planned on a grid is that it allows flexibility for internal structures to be added later, according to need. The additions can be attached without interference to the existing structure and can be dismantled without causing damage. The building depends for its strength on a complex jointing system made by the use of timber wedges. Once erected, if the wedges are removed, the building comes apart readily. In many instances, houses have been dismantled, shipped along the coast and reerected. Other houses, washed away by floods, have been traced, dismantled, taken back and reerected on their original sites. In some parts of the peninsular on the death of parents, the house was divided among the children, each child receiving one of the additional components. The sections were then dismantled and attached to their own house.

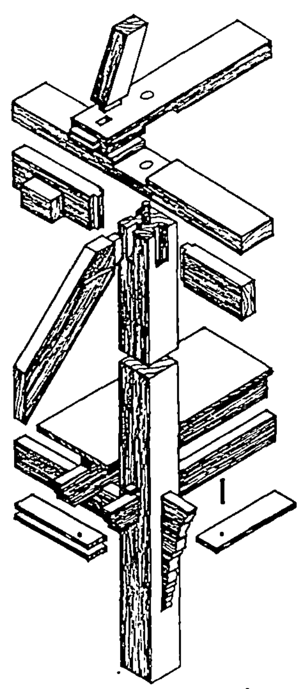
The foundation is laid out horizontally and vertically through the structural elements. Uprights are placed at regular intervals, the distance between any two plinths, corresponding to the span of the lowest horizontal beams, is 2.70 metres. Plinths was made of hardwood or concrete stumps to prevent them from sinking into the ground. (See Figure 1 7 for the process of construction of a Malay house)

The load of the timber house structure is transferred to the posts and rests on the plinths. The framework is erected as a whole and its uprights stand on the plinths. Peg and socket joints are not used between upright foundation stones. Two horizontal beam members are fixed to the main post (tiang seri). The lower bearer is 1.20 metres above the base of the post to support floor joists. The tie beam runs at a lower level and at right angles to the bearer, parallel with the floor joists. Wedges are driven into the mortise to prevent instability of the frame and to facilitate dismantling. (See Figure 1.9 and Plate 1.4).

The upper horizontal beam members consist of the wall plates of the outside wall and the tie beams running across the framework, which are joined end to end by a half lap joint through which a wooden peg is driven into the top of the post. The structural framework was extremely rigid, using mortise and tenon joints Tie beams have to resist the tendency of the roof to force the posts, which it ties, outwards. The weakness of the construction system is the lack of diagonal bracing in the structure. This causes the structure to move in instances of uneven loading when the joints are improperly made due to unskilled workmanship.

Figure 1.9
Floor construction detail.
The use of wedges (baji) to tighten mortise and tenon joints is an important feature of Malay timber architecture. This allows the joints to be easily taken apart and reassembled without damaging the building.

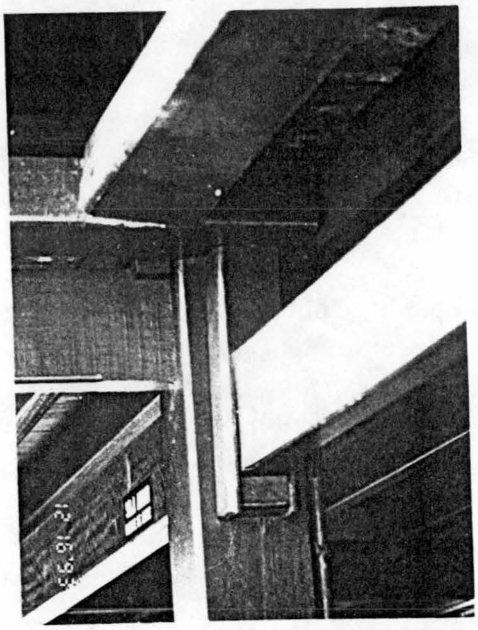
"Rumah Meleh", Tumpat, Kelantan.
Source : Measured Drawing Studies, Department of Architecture, University of Technology Malaysia.



Timber Floor (Lantai)

A suspended timber floor is constructed with a series of floor joists supported by bearers. The floor joists are exposed to the vertical stress of weight. The live and dead load of the house are transferred from the floor to the post and directly to the plinths. The floor is finished using 25 mm thick timber boards laid directly across floor joists. The advantages of the raised platform floor provides sub-floor ventilation and shaded spaces in hot, humid climates.

Plate 1.4
"Muzium Kebudayaan" at Malacca
Floor joists are inserted into a slot in the column to form a mortise and tenon joint.



Roof (Bumbung)

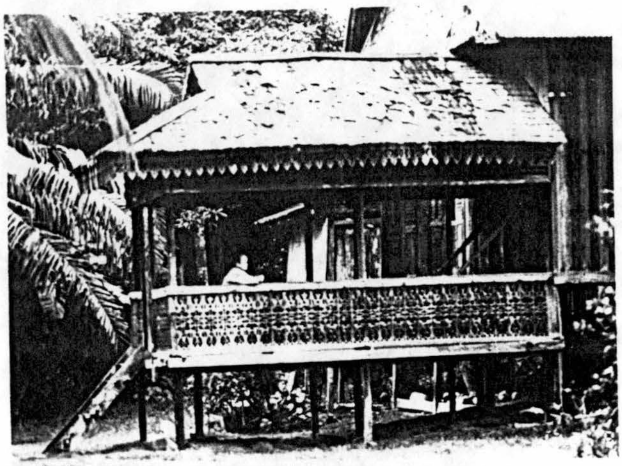
The system of framing the roof skeleton has advantages. Within the basic construction system, all different lengths can be spanned with equal sized members. The rafters may vary according to the depth of the building, but the size of the building does not affect the stress on any member and consequently does not require separate dimensioning for each structure.

The roof plates and tie-beams are fixed with roof trusses 600 mm apart. The trussed roof structure is sufficiently pitched with wide eaves and gable side overhangs to protect the timber walls from the weather. On the front house, which is the largest unit, the increased volume of rain water flow is countered by the change of pitch on each side of the ridge which helps to throw the water further away from the wall. The bigger the roof, the more often the pitch is changed, as for example in the roof design and construction of traditional mosques and palace halls.

Purlin members, supported by wooden wedges, run horizontally across the rafters. The common rafters (kasau betina) run vertically on top of the purlins to provide a framework to which the roofing material is fixed. The ridge member is supported by a beam lying within the crutch of the crossed rafters. The "tebar layar" is a triangular frame which provides both ventilation and protection from driving wind. In Malaccan houses, the "tebar layar" is elaborated to form a pair of large louvres to ventilate of the space under the roof (Roslan, 1981 : p. 62). The Malaccan house can be extended right across the roof space to form an attic (loteng) without obstructing the roof structures (MacDonald, 1934 : p. 22). This means the structural system allows for future extension.

Traditionally, Malay houses in Malacca, Negeri Sembilan and Johore use the same principle of structural system. These traditional dwellings indicate traces of the ancient tradition of the Malaccan civilisation which dominated the area in the 14th and 15th centuries. The most distinctive feature is the curved profile of the Negeri Sembilan roof which originated from the Sumatra Minangkabau style (Sherwin (b), 1979 : p. 52). Traces of Bugis influences are also to be found at the Daeng Mat Diew, Kampung Parit Pecah in Johore. (See Plate 1.5).

Plate 1.5
View of the porch of a Johore (Bugis) traditional house at Daeng Mat Diew, Kampung Parit Pecah in Johore.



1.2.2 The Malay Palace

Traditional methods of construction were not documented until the 15th century. The first detailed description available is of the 15th century Malaccan palace of Sultan Mansur Shah who ruled from 1457 - 1477. As described in Malay Annals (Sri Lanang, 1961 : p. 82), the palace had a raised seven-bay structure on wooden pillars with a seven tiered roof. This palace, like many others, was accidentally destroyed by fire.

The system of construction of domestic architecture is applied uniformly to palaces and mosques because Malay architecture represents a continuum of one basic construction system. Significant examples can be seen at the "Istana Tengku Nik" in Terengganu, "Istana Ampang Tinggi" in Negeri Sembilan and "Istana Kenangan" in Perak. (See Figure 1.10). In detail, Malay construction expresses high elaborateness and refinement that has reached perfection in method, economy and form (Sheppard, 1972 : p. 28; Ali, 1991 : p. 15). The basic construction systems directed the carpenters' imaginative spirit to develop details, provided for centuries gradual improvement. The refinement of constructional detail suggests that one was the logical consequence of the other.

In 1928, the last timber palace, the "Istana Kenangan", was built in Kuala Kangsar, Perak However, the construction of palaces has continued using other materials such as brick or concrete

The new reconstructed museum at Jalan Sungai Ujung, Seremban to replica traditional Malay palace is a fine example and demonstrates that there are still craftsmen able to build large timber structure

Figure 1 10
Location of palaces in Malaysian Peninsular.

"Istana Sri Menanti", Negeri Sembilan

The old Malay feudal system developed after the coming of Hinduism to the region in the 1st century A.D. At the top of the pyramidal structure of the ancient society were the state's rulers and court officials. Such a hierarchical structure of society is embodied in the structural planning of the traditional palaces, in the form of a hierarchy of floor level spaces. A good example of this can be found in one of the last Malay timber palaces to be built, "Istana Sri Menanti" in Negeri Sembilan, which has a three-tiered central structure rising from the main building. The bottom floor housed the audience hall, the second was for the ruler's family and the top two floors were the ruler's chamber and royal treasure house. (See Figure 1.12).

The plans for this Minangkabau-style building were drawn by the chief draftsman, Woodford, from Public Works Department in Seremban Construction of this palace commenced in 1902 and was completed in 1908. The main structure consists of four wooden pillars 19 5 metres high, which rise from the ground to the top of central tower. The pillars are constructed from hardwood "chengal" timber cut from a single tree The entire structural system with a total of 26 pillars was raised 1 5 metres above ground level. The traditional dowel jointing system was the only method of jointing used in construction. Wood joints such as mortise and tenon are capable of resisting and transferring tensile and compressive stresses. (See Plates 1.6 and 1.7).

The roof form is typical of the Sumatra Minangkabau style which is only found in Negeri Sembilan. According to Tun Sri Lanang, (cited in Sherwin 1979 : p. 52), in the Malay Annals, the earliest Minangkabau roof was brought to Malaya by settlers from across the Straits. Buildings in central Sumatra display this roof shape which derives from a stylistic representation of bull's horns.

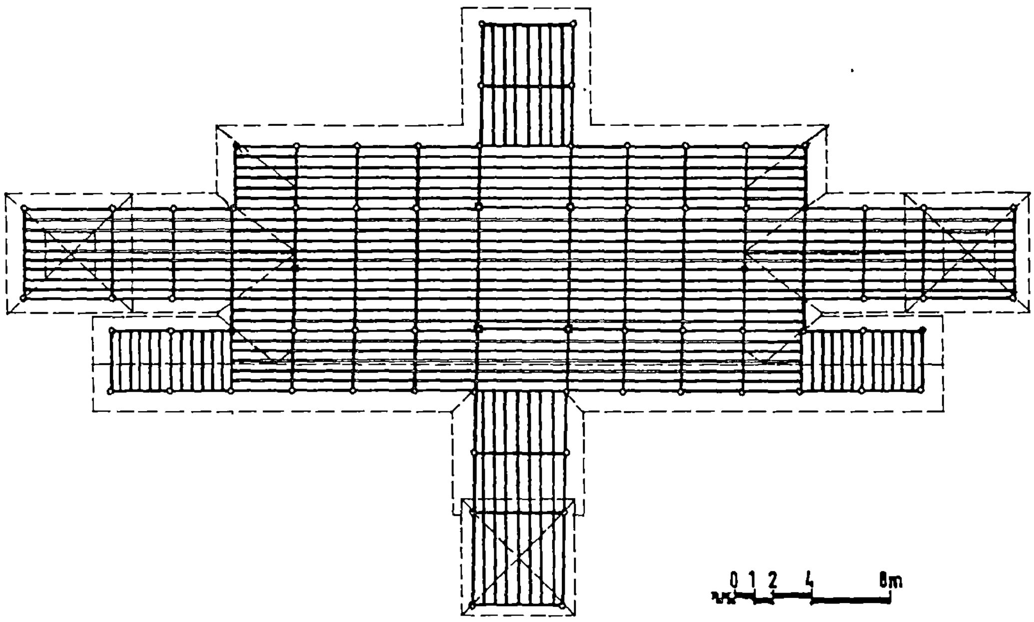


Figure 1 11
Floor framing plan of "Istana Seri Menanti"
Source . Measured Drawing Studies,
Department of Architecture, University of Technology Malaysia.

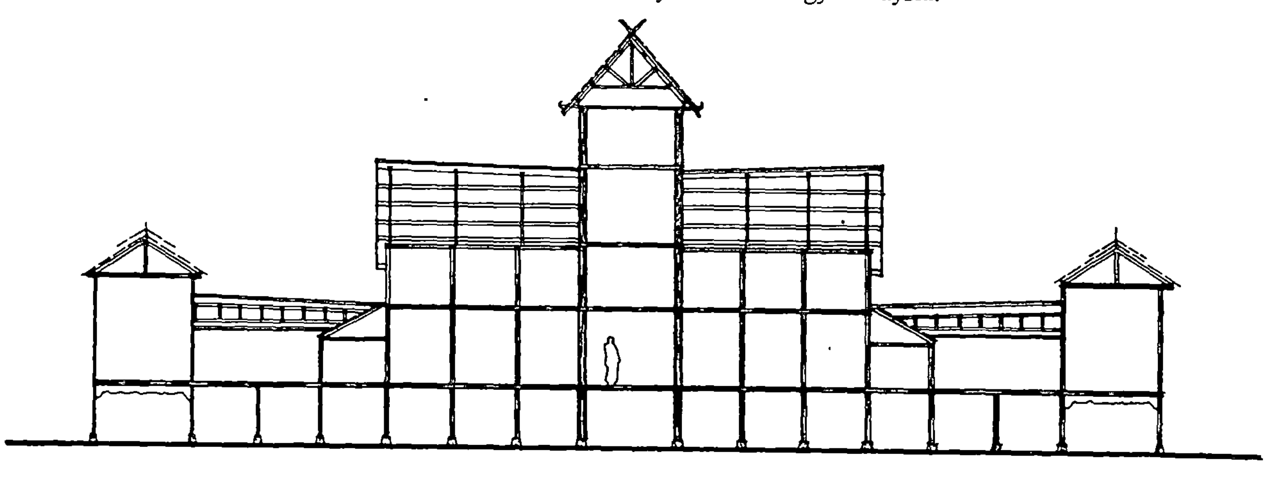


Figure 1 12
Section of "Istana Seri Menanti"
Source Measured Drawing Studies, Department of Architecture,
University of Technology Malaysia.

Plate 1.6
"Istana Sri Menanti", Negeri Sembilan.
The tallest timber palace in Malaysia, influenced by immigrants, adopted a Malay style of roof construction with a continuous ridge-piece and palm-leaf thatching prepared in rigid lengths fastened to battens. These methods were simpler and resulted in the roof having a much less pronounced curve than the original form.

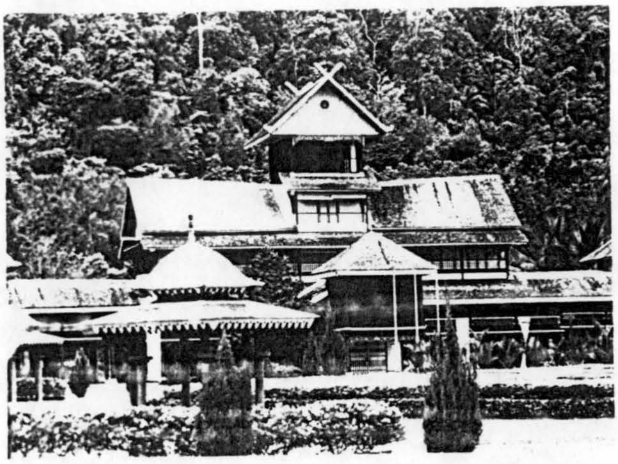


Plate 1.7
Detail showing junction of tie beam, column and joist. The floor joist is jointed to the column with a dowel.

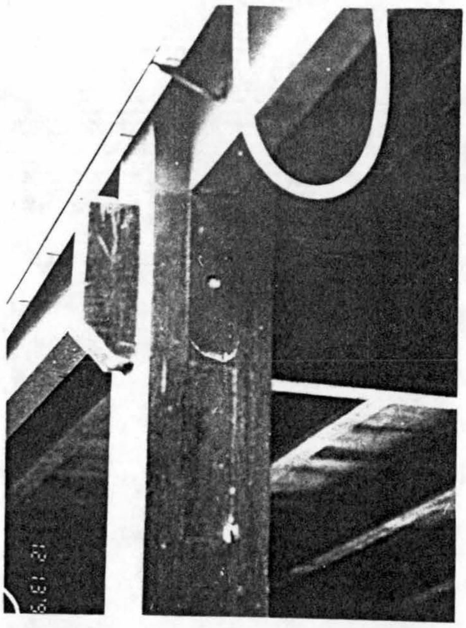
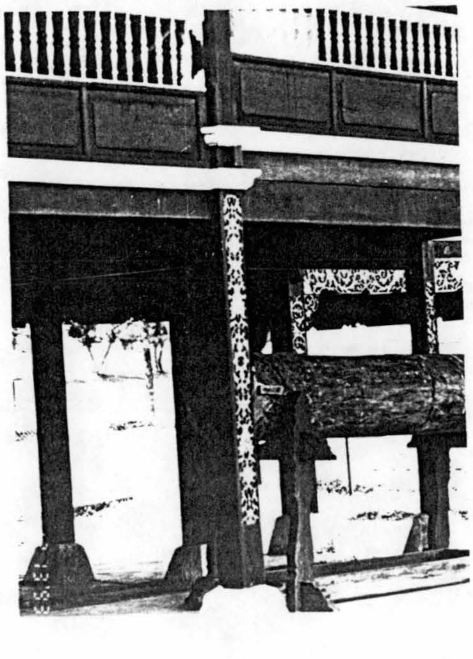


Plate 1.8
Hardwood timber post with floor resting on the junction. Embellishments are important status symbols in traditional Malay society.



"Istana Ampang Tinggi", Negeri Sembilan

The "Istana Ampang Tinggi" in Negeri Sembilan was constructed in 1861. (See Figure 1.13) This timber palace reveals elaborate craftsmanship in each part of the building. A variety of intricate jointing methods, which have been part of the Malay wood working tradition for centuries, create interlocking joints which allow larger span members to be formed without the use of secondary connectors. Skilfully made joints have positive resistance in compression, shear and racking. (See Plates 1.9, 1.10 and 1.11).

The curve of the roof, supported using "tunjuk langit", was originally designed with the ridge sagging . Sherwin (1979 : p. 52) suggests that the origin of the curved roof line might have been a response to climatic conditions, as it encourages ventilation towards the ends, warm air following the upswing through gaps in the roof. Alternatively, he suggests that a slope is more rigid than a straight ridge line because the three dimensions roof structure has advantages in terms of strength to weight ratio. The roof framing consists of cross beam 12 x 12 mm at the ends to form a very light-weight roof structure.

Wan Mahmood (1988 : p. 45) undertook full scale testing of a 5.50 metres span Minangkabau roof truss and found that the tested structure conformed with the requirement of clause 38 and acceptance clause British Standard 5268, Part 3, 1985 This proved that the traditional construction system used many centuries ago was structurally sound.

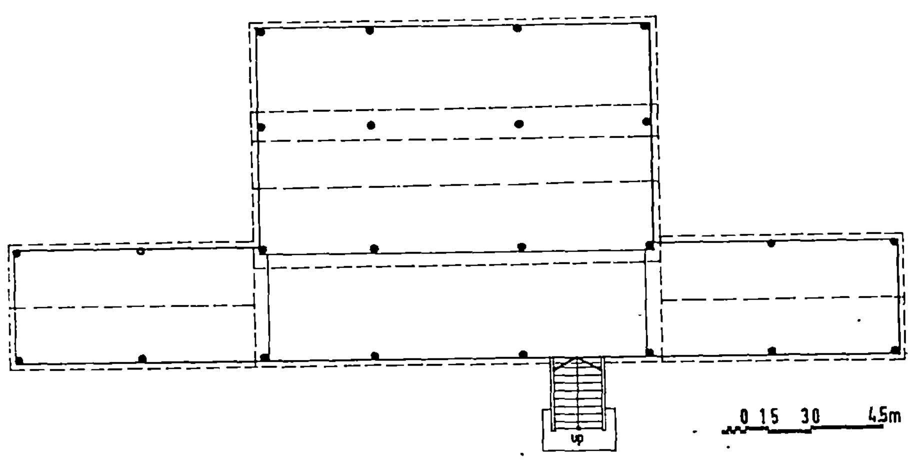


Figure 1.13
Plan of "Istana Ampang Tinggi"
Source : Measured Drawing Studies,
Department of Architecture, University of Technology Malaysia.

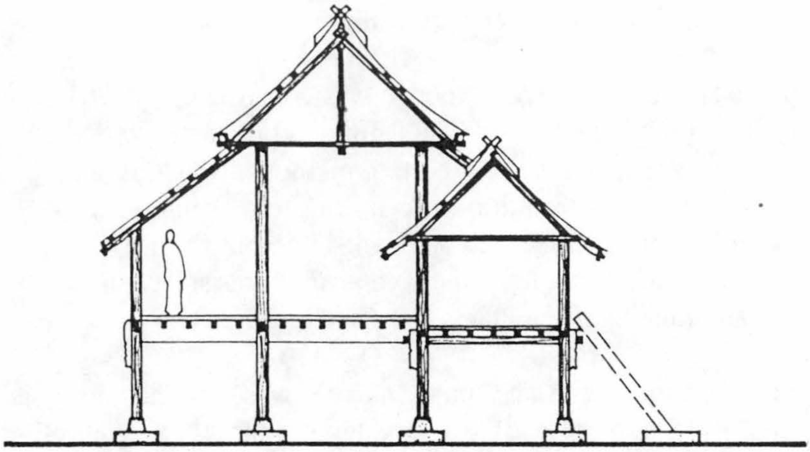


Figure 1.14
Section of "Istana Ampang Tinggi"
The adoption of the Malay roof form construction, with a continuous ridge-piece and vertical battens, were simpler to construct and resulted in the roof having a much less pronounced curve then the original form.
Source : Measured Drawing Studies, Department of Architecture, University of Technology Malaysia.

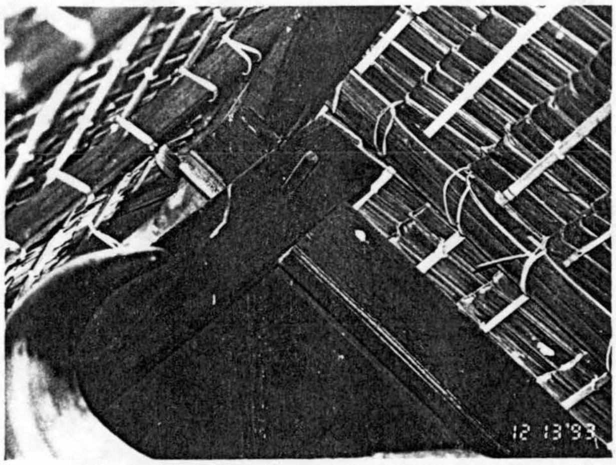


Plate 1.9
Trussed rafters are interlocked and fixed by wooden dowels. The dowel, as pin, is able to carry and transfer the shear load parallel to the side-grain member of the joint. The ridge beam was supported by rafters.

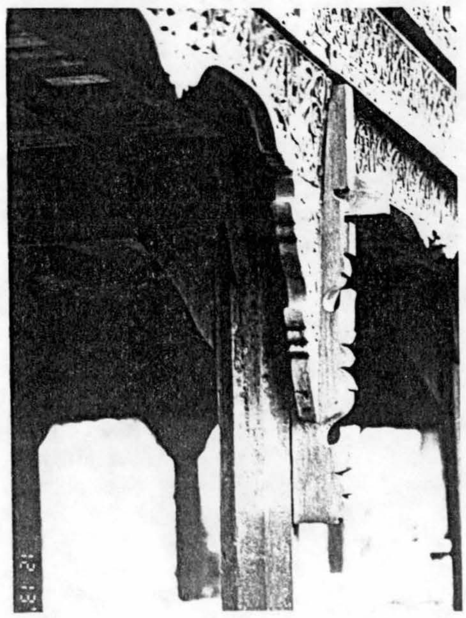
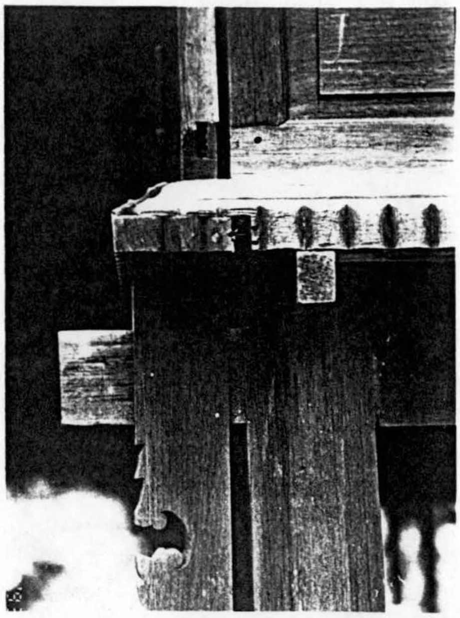


Plate 1.10
Intermediate post connected to bearers and floor joists. Wood carvings made of "chengal" hardwood were commonly used as architectural features. In traditional Malay wood carving, the decorative motif compositions found on eaves, fascia boards, architraves, railings and wall panels are guided by rules inherited by ethnic groups such as the Minangkabau, Bugis, Javanese and Achehnese.

Plate 1.11
Detail of the corner of the post. The joint has positive resistance to compression, shear and racking even without glue, but no resistance to tension.
All timber members could be dismantled and reerected.



"Istana Tengku Nik", Terengganu

A different characteristic element of the Terengganu palaces is that additional accommodation is housed in separate groups of pavilions which are linked by bridge-ways. At present, this type of building is the oldest surviving example of traditional East Coast timber structures. This traditional building form, from Malay palaces to old mosques with meru-tiered roof construction, is specifically found in the states of Kelantan and Terengganu (Sheppard, 1972 : p. 28).

A significant example is "Istana Tengku Nik", which was built in 1888 for Sultan Zainal Abidin III, and displays delicate carving skills in the form of wall ventilation. The form of the building was rectangular and raised 1.20 metres on wooden pillars from the ground. Structural connections consisted of joining two pieces of wood using the mortise and tenon method. The wooden tenon was fixed with wooden pins and nails for the transfer of forces at the jointing points. This palace was adapted from the Malay house form of the Riau which features a high gabled roof with a gable screen. (See Plate 1.12).

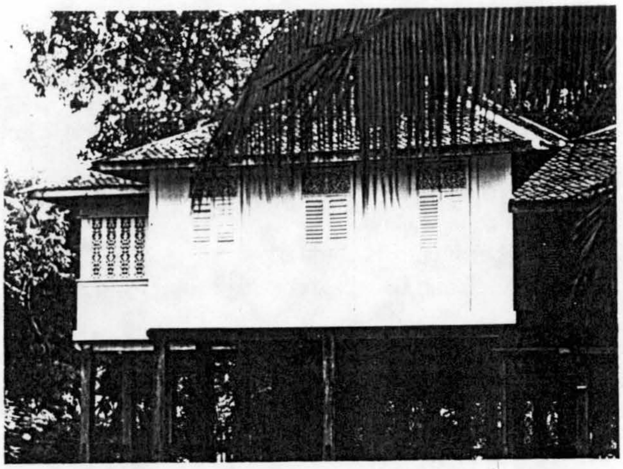


Plate 1.12
"Istana Tengku Nik", Terengganu.

"Istana Balai Besar", Kelantan

Another variation in traditional palaces was first pioneered by Sultan Muhammad II of Kelantan in 1842 for his new palace in Kota Bahru. "Istana Balai Besar" is the oldest surviving timber palace structure in Malaysia (Lai, 1976 : p. 50). (See Figure 1.15 and Plate 1.13). For structural reasons, the main hall, which was formed by a series of smaller halls, was built at ground level, marking a definite departure from traditional methods. Two other timber palaces, the "Istana Seri Akar" and "Istana Jahar", built in Kota Bahru have the typically raised floor.

Compared to the ordinary traditional dwelling construction, the flexibility of spaces created in the palaces is an exception rather than the rule. The formality of court life perhaps favoured the creation of rooms and areas for specialised functions. For example, the technique and method of construction of "Istana Tengku Long" in Besut is typical of the ordinary traditional dwellings.

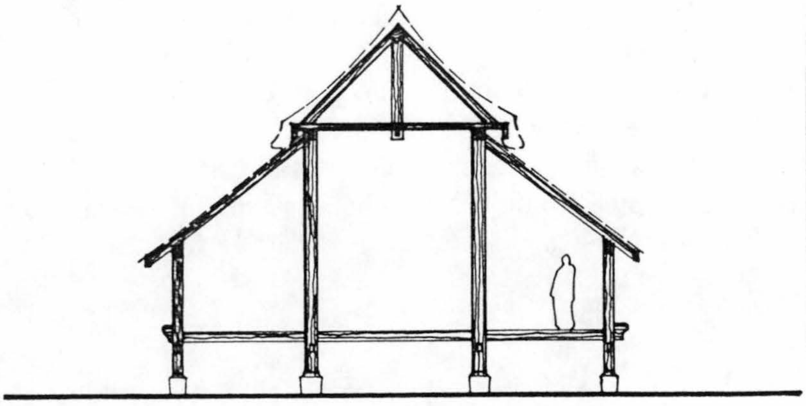


Figure 1.15
Section of "Istana Balai Besar", Kota Bahru, Kelantan.
Source : Measured Drawing Studies, Department of Architecture, University of Technology Malaysia.

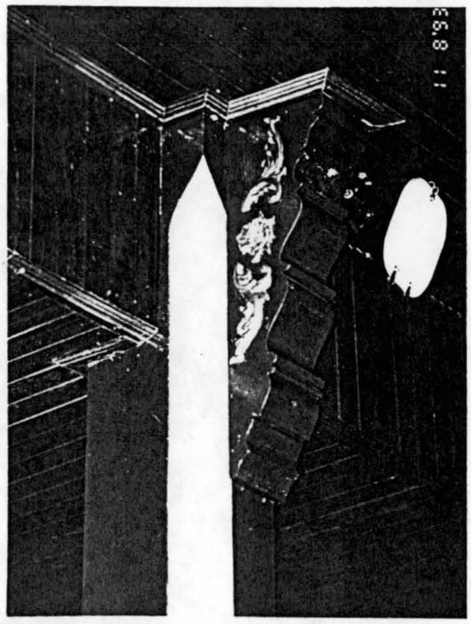


Plate 1.13
Detail of bracket.
The long bracket is provided to ensure more strength. The column is chamfered on the hall side to make it match the width of the bracket and make it look slender.

"Istana Kenangan", Perak

In the West Coast state of Perak, the only surviving timber palace is "Istana Kenangan" and was constructed in 1928 (Keromo, 1989 : p. vii). This palace is a temporary royal dwelling of modest scale which displays a magnificent example of local building skills in a unique external wall which has wicker work made up of an intricate bamboo network, created by a famous craftsman, Haji Suffian. Construction started in 1928 and was completed in 1931.

The palace was constructed, using 60 timber pillars raised 11.0 metres from the ground. The plan of the palace imitates the shape of a "keris", the traditional knife carried by sultans, which symbolised their power. (See Figure 1.16). It is also a fine example of the layout of a typical Perak roof form. (See Plates 1.14, 1.15, 1.16, 1.17 and 1.18).

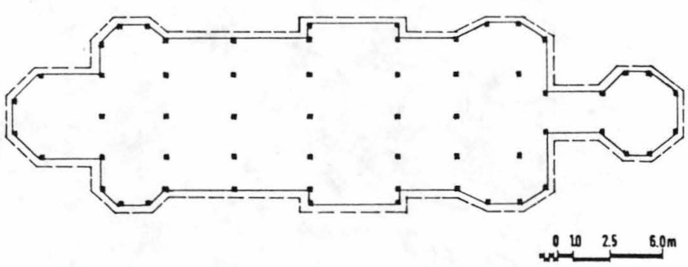


Figure 1.16
Plan of the "Istana Kenangan",
Kuala Kangsar, Perak.
Source : Keromo, 1989 : p.vii

Plate 1.14
"Istana Kenangan", Kuala Kangsar, Perak.

Plate 1.15
Detail of floor construction, view from below. Two floor beams resting on a corner post and support the floor members.

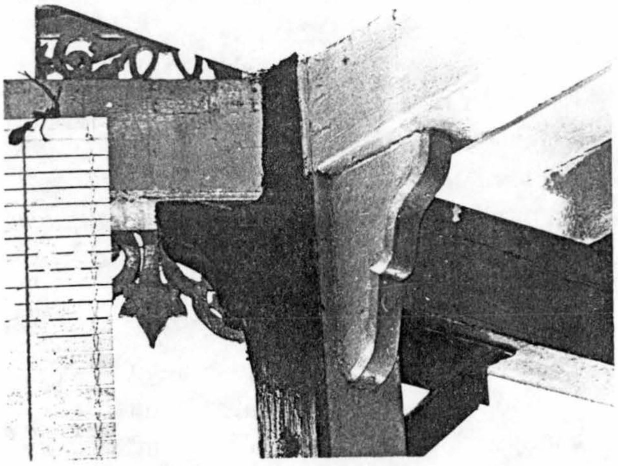


Plate 1.16
Detail of the post which supports the bearers.
Bracket to forms a rigid joint.

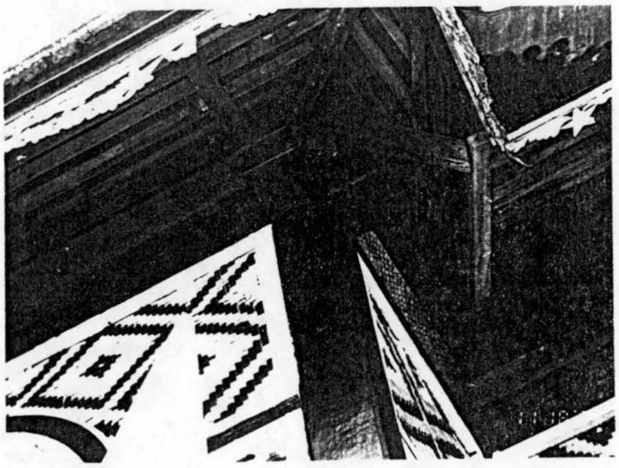


Plate 1.17
Detail of king post using bolts and nuts for connection. King post is in tension because its top is held by rafters and also receives loads from its braces.

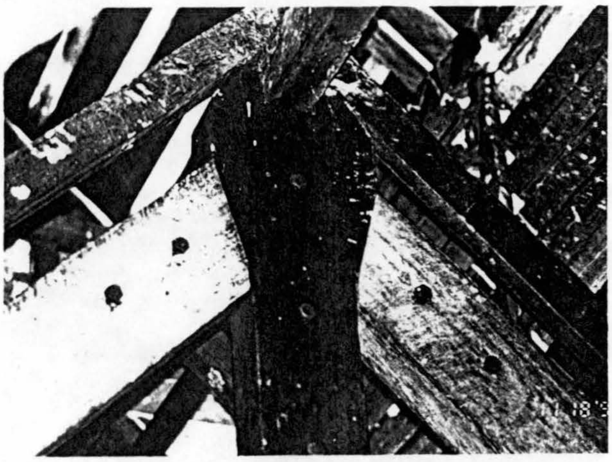
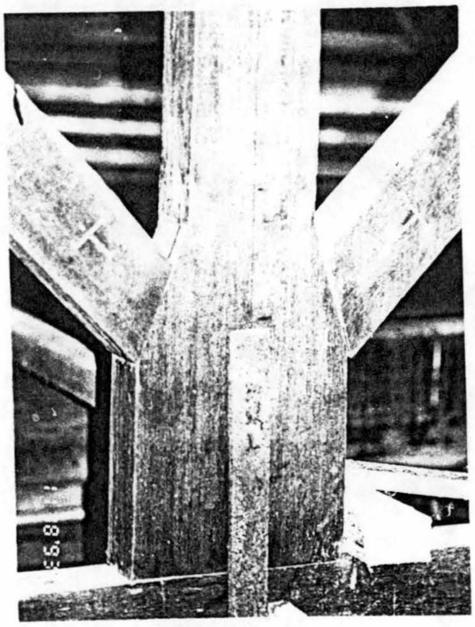


Plate 1.18
King post detail connection using a steel plate bolted to a tie beam.



1.2.3 Mosques

Timber mosques were first built on the Malaysian Peninsular with the introduction of Islam in the early 14th century. As in other parts of the Muslim world, the development of mosques in Malaysia was influenced by traditional and regional styles (Nasir, 1984 : p. 44). (See Figure 1.17). Orientated so that the qibla wall faces Mecca, traditional Malay timber mosques are built on square plans, with the main part of the building comprising an inner hall and a verandah.

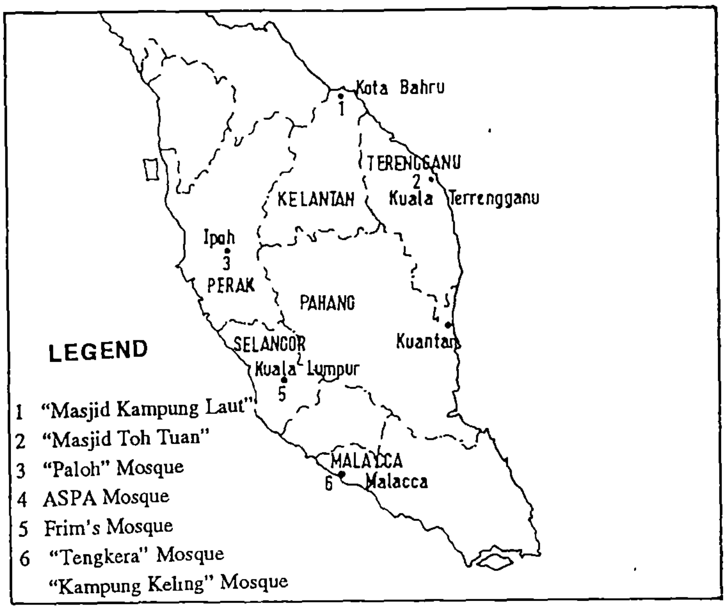
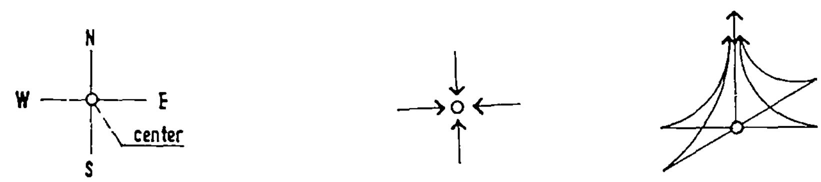


Figure 1 17
Location of timber mosques in Malaysia

The square floor plan of a mosque gives a strong sense of centrality which is manifested by a tiered roof form presenting a sense of centredness and verticality, its linearity focussed on the mihrab wall (Vlatseas 1990 : p. 40). (See Figure 1 18). It was one single space which expressed all Islamic ideas in its singularity of space The square plan generates four walls which symbolise the four fundamental elements of Creation (Mohamad Harun, 1979 : p. 72).



Five-fold division as the cardinal Points   The Center as Process   The Center as Manifestation

Figure 1.18
The tiered roof form generated from the sense of the centre based on cosmological constellations This tiered roof gives the sense of enclosing space, while its construction in timber expressed warmth and intimacy.
Source : after Prijotomo, 1988 p. 30

Traditional mosques have different roof forms which reflect the identity of a district or ethnic group within Malay society. The roof form was generated as a response to climate, topography and environment. For example, a steeply pitched roof is ideal in an area of heavy rain fall A hot, humid climate also requires ventilation and insulation, and a large overhang for protection from the rain Smaller mosques usually have roofs based on ordinary house construction, whereas larger mosques have roofs in the form of tiered pyramidal structures. Tiered roof forms were found to be more suitable to the climate in terms of ventilation When the sun is at its hottest, such a form will circulate the hot air within the building.

Adapting new roof forms and other building elements from abroad can be seen in the evolution of the Malaysian mosque. The oldest mosque on Malaysian Peninsular, the "Masjid Kampong Laut" in Kelantan, built in 1743 has similar timber pillar bases to Masjid Demak built in 1479 in Java. In addition, its meru roof shapè originated from Campa in Vietnam in the 16th century (Ambary, 1989 p 166). The original inspiration for the tiered form was the Indian stupa (Sherwin (a), 1981 p. 43)

The common use of wood in the construction of mosques has both an economic and aesthetic basis The ability to construct wood buildings with a minimal amount of equipment has kept the cost competitive with other types of construction. Timber is also preferable to concrete and steel for its greater aesthetic appeal allowing the architects more opportunity for expression in the building. Frank Lloyd Wright claimed that "(T)here is a need to bring forth the beauty of wood, the beauty being its intrinsic property" (Gotz, 1989 : p. 10). Architect Jimmy Lim recognised this when he used wood in a religious commission, saying that wood had a warmth and intimacy that was ideal in that situation (Lim . 1993). In both these observations, the warmth spoken of is a visual appreciation, derived from the colour and texture of the wood. The intimacy of wood is also a reflection of its acoustic properties, such as its ability to absorb sound. Wood architecture in Malaysia has served all functions, both sacred and secular "Chengal" hardwood, being a high quality timber, expresses monumentality and immortality.

Although few remain today, Malay timber mosques of great age are evidence of the unrivalled skill of the craftsmen and the versatility of timber as a constructional material. Basic forms of structure were used with an understanding of timber characteristics, and adopted to larger spans, different pitches, shapes of roofs and changes in construction detailing appropriate to Malaysia. The skill of Malaysian craftsman can be seen in their ability to integrate the functional with the symbolic. Many structural joints are decorated either by turning or carved relief work. Significant examples are found at "Masjid Kampung Laut", "Masjid Kampung Keling" and "Paloh" mosque. (See Plates 1.19, 1.21 and 1.23). Below are construction details of important examples of timber-built mosques in Malaysia.

"Masjid Kampung Laut", Kelantan

The "Masjid Kampung Laut", built in 1743 and moved to Nilam Puri, Kota Bahru and constructed from "chengal" hardwood, follows the original ancient mosque layout. The square in plan is 15.86 x 15.86 metres raised on concrete stumps with a three-tiered roof. (See Figure 1.20).

The central part of the inner hall consists of four columns supporting the roofing superstructure surrounded by outer columns. The four columns are bevelled and each was carved from a single tree. The structure is based on a beam grid system of beams intersecting at 90 degrees connected by mortise and tenon joints. These rigid joints create a indeterminate static system in which the loads are distributed in two directions. Secondary beams were constructed diagonally to form lateral wind bracing. (See Plate 1.19).

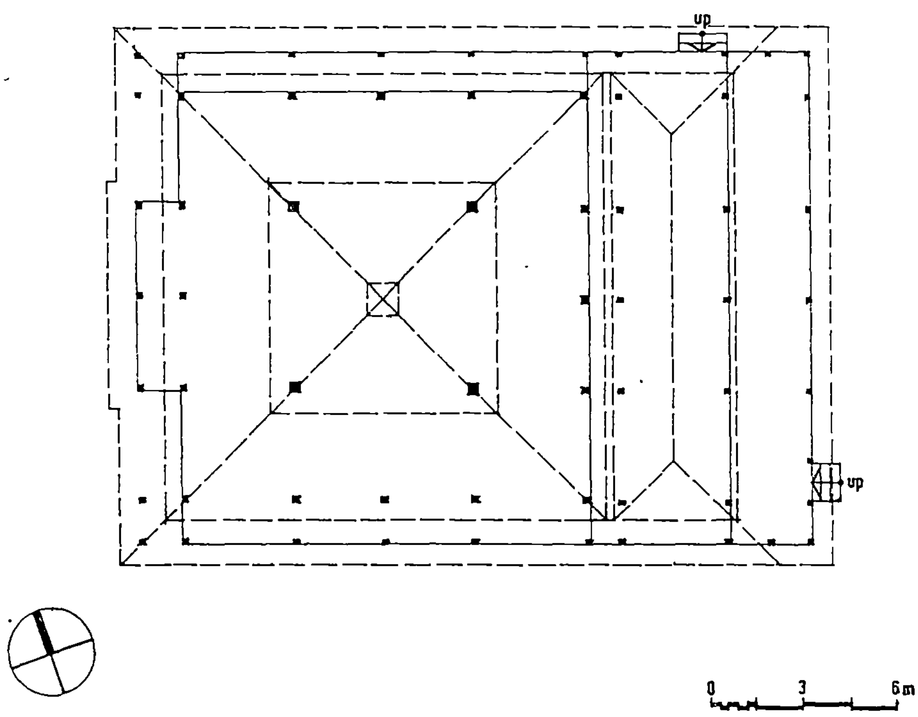


Figure 1.19
Floor plan of "Kampung Laut" mosque, Kota Bahru, Kelantan.
Source Measured Drawing Studies, Department of Architecture, University of Technology Malaysia.

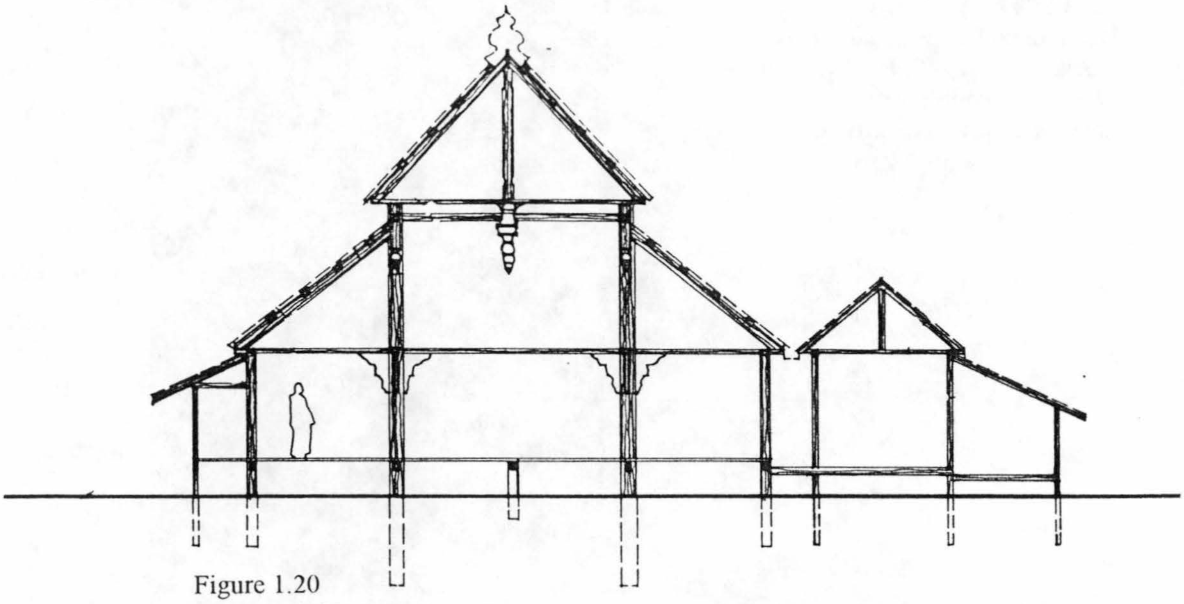


Figure 1.20
Section of "Kampung Laut"
Source : Measured Drawing Studies, Department of Architecture, University of Technology Malaysia.

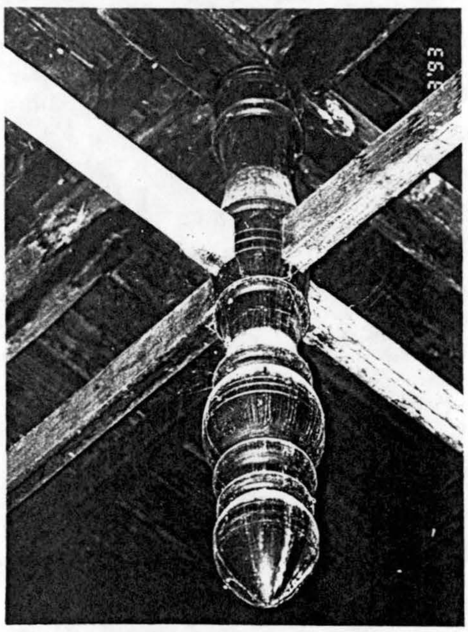


Plate 1.19
Detail of "buah butung" in the inner hall, constructed diagonally to provide lateral wind bracing.

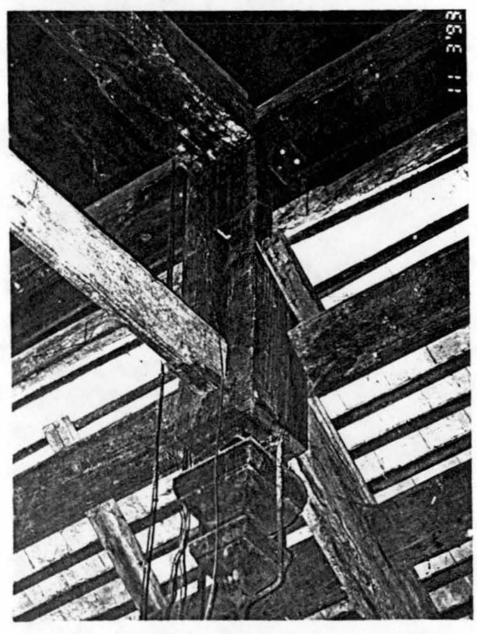
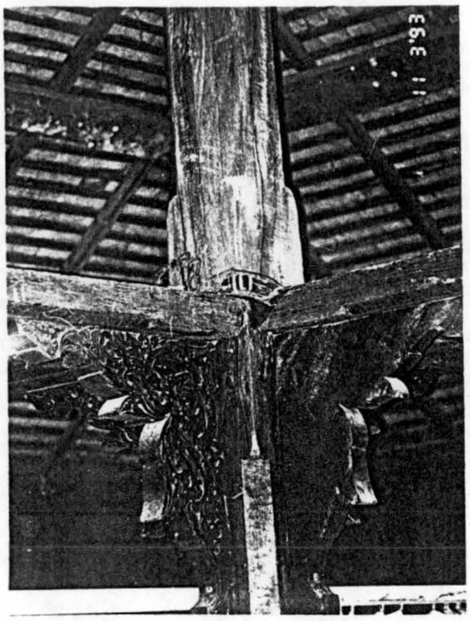


Plate 1.20
Detail of the corner roof beam using wooden dowels for construction. The end embellishment on this roof beam was roughed out with hand cuts and finished with a chisel and hand plane.

Plate 1.21
Detail of corner post using hardwood bracket carved with Islamic symbols.
The square columns supporting the roof are made of "chengal" hardwood and each is carved from a single tree.



"Toh Tuan" mosque, Terengganu

The "Toh Tuan" mosque in Terengganu was constructed in 1845 (Nasir, 1984 : p. 25). The mosque has a square plan, 8.38 x 8.38 metres with 20 pillars of "chengal" hardwood and a four-tiered roof as opposed to the three-tiered roof construction of "Kampung Laut". Although the basic construction details are the same, the additional roof tier reflects the development of structural understanding and is evidence for the process of technological change under way by the local craftsmen in the hundred years between the building of these two mosques.

"Tengkera" and "Kampung Keling" mosques, Malacca

The "Tengkera" mosque, constructed in 1728, is the second oldest in mosque in Malacca. The roof consists of a three-tiered roof form and is similar to the "Kampong Laut" mosque and the Great Mosque of Demak in Java. (See Figures 1.21 and 1.22).

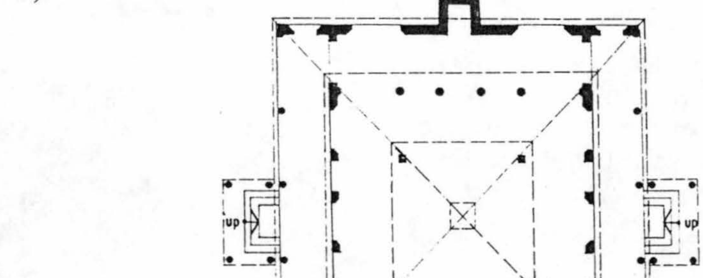


Figure 1.21
Floor plan of "Tengkera" mosque.
Source : Measured Drawing Studies,
Department of Architecture, University of Technology Malaysia.

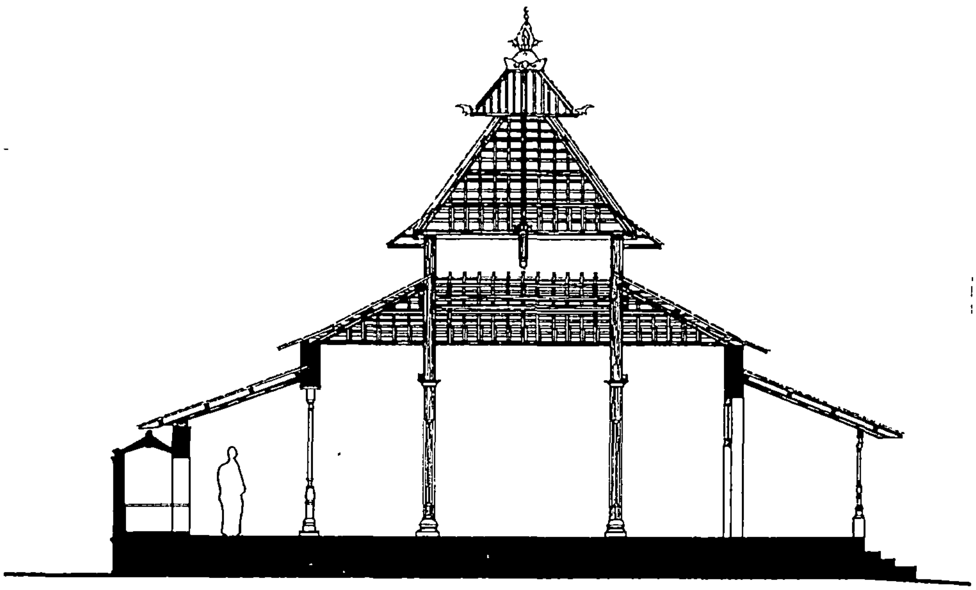


Figure 1.22
Section of "Tengkera" mosque.
Source : Measured Drawing Studies, Department of Architecture, University of Technology Malaysia.

The "Kampung Keling" mosque built in 1748 in timber was replaced with brick, a popular building material during the Dutch occupation in Malacca 1641 - 1795. The original roof, built of durable hardwood, remains today. (See Figures 1 23 and 1.24).

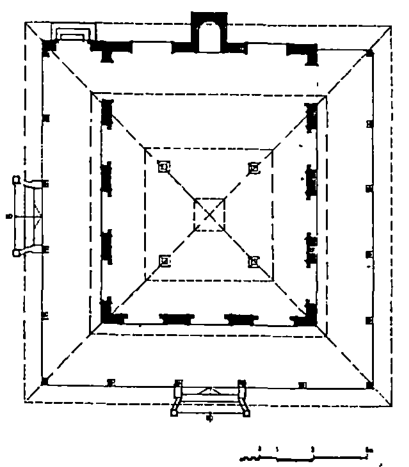


Figure 1.23
Floor plan of "Kampung Keling" mosque, Malacca.
Source : Measured Drawing Studies, Department of Architecture, University of Technology Malaysia.

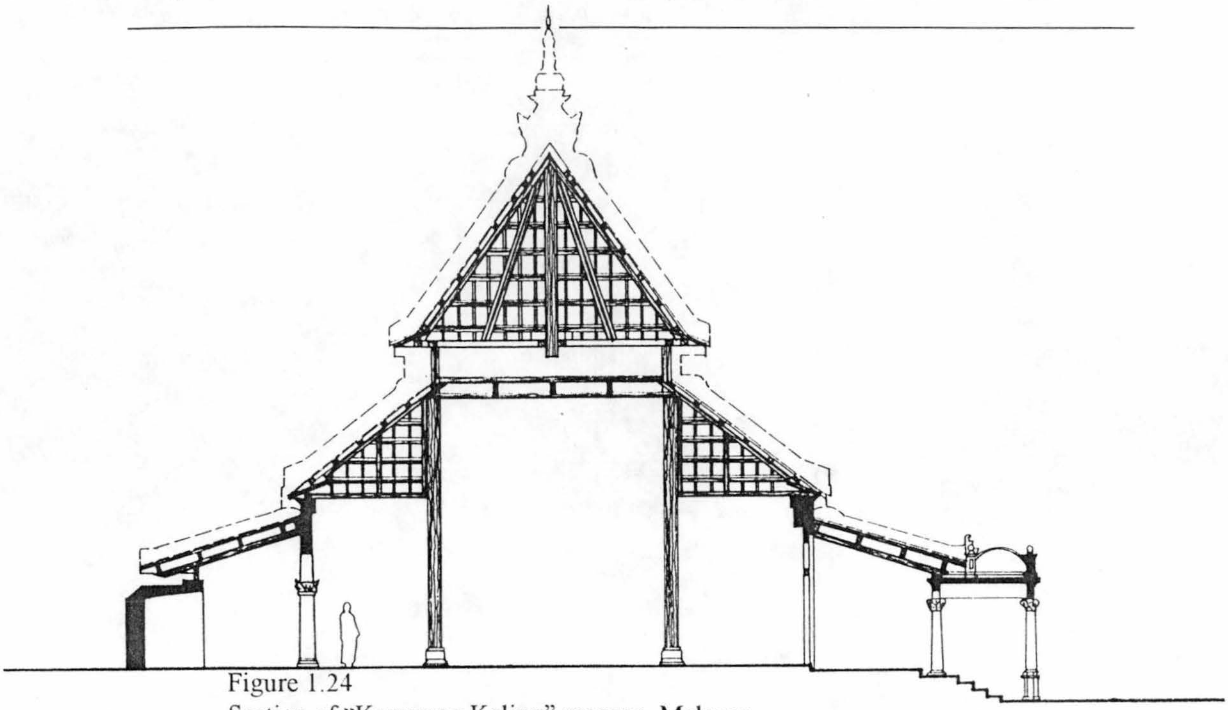


Figure 1.24
Section of "Kampung Keling" mosque, Malacca.
Source : Measured Drawing Studies, Department of Architecture, University of Technology Malaysia.

Plate 1.22
Detail of the corner post using hardwood timber.

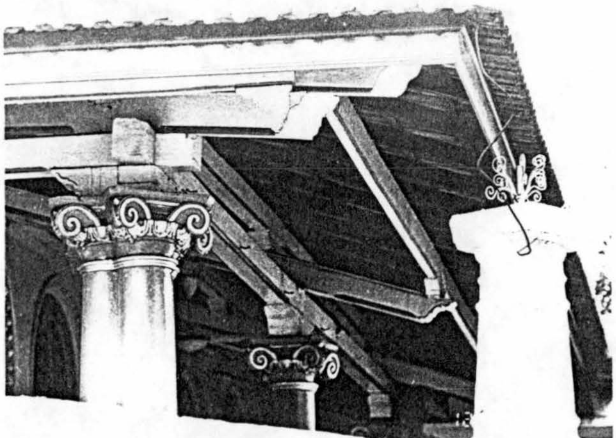
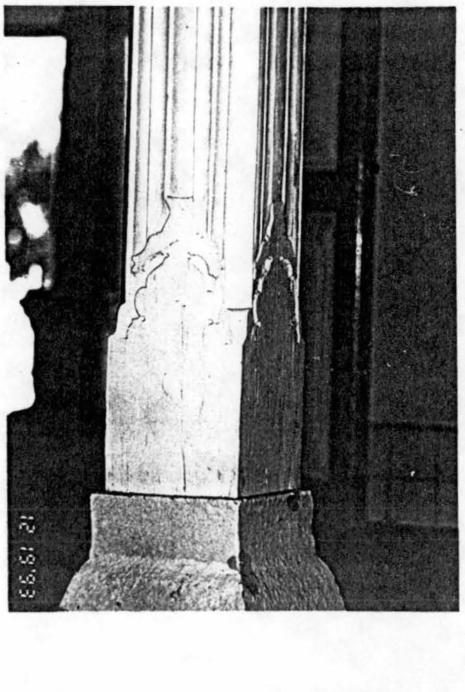
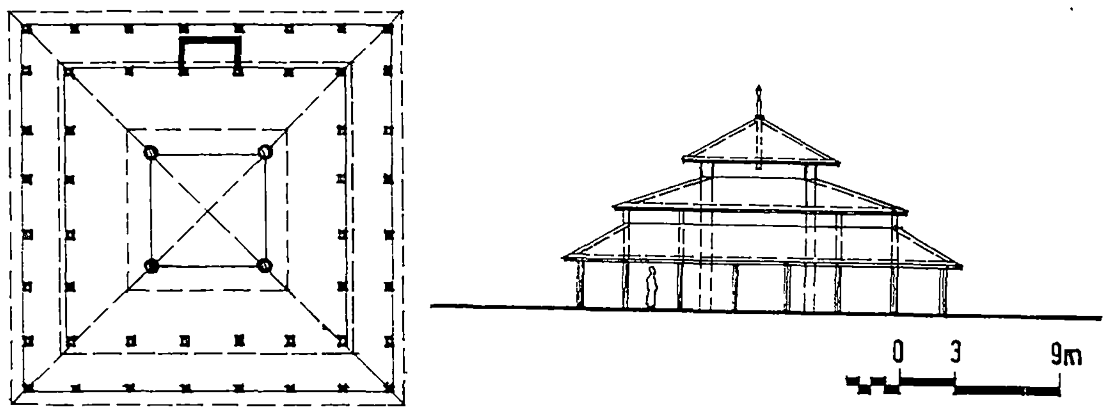


Plate 1.23
Internal timber column carved with Islamic motifs and supported by a concrete base.



"Paloh" mosque, Perak

The "Paloh" mosque at Ipoh in Perak was built in 1912. The square plan consists of four circular columns to support the main structure. It also has a three-tiered roof form, which followed the "Kampung Laut" mosque in Kelantan (See Figure 1 25).



See Figure 1.25
Floor plan and section of "Paloh" Mosque, Ipoh.
Source : Mosque of Peninsular Malaysia, 1984.

FRIM's Mosque, Selangor

The Forest Research Institute Malaysia carries out experiments and conducts tests to enhance and promote the use of timber products in the construction sector of the country. In 1975, glue laminated structural components were used to build a mosque within their complex at Kepong to test experimental methods of construction and structural form. The form of the mosque derived from the National mosque in Kuala Lumpur with an unusual fan shaped folded plate roof form which was influenced by recently built mosques in the Middle East (See Figures 1.26 and 1.27).

The glue laminated structure of the mosque was used to test and develop structural glue lamination technology in Malaysia (Tan, 1994 : p. 695). In addition, it uses innovative timber materials with the advantages of ease of construction and long span capabilities, which are different approaches to traditional mosque construction. Glued laminated timber arches were chosen because the members could be fabricated in a variety of sizes and shapes. The only limitation was the minimum radii of curvature for lamination and practical considerations concerning transportation, manufacturing and handling. Laminated glulam arches are supported at the apex and connected to the concrete base using galvanised welded steel shoes. (See Plates 1.24 and 1 25). The reinforced concrete base prevents frame action and provides the mass needed for overturning stability of the relatively high structure

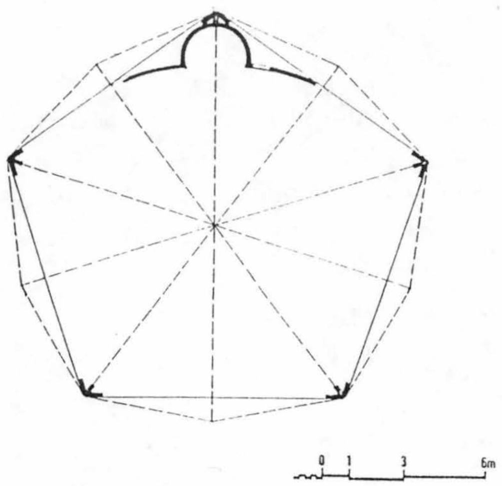


Figure 1.26
Plan of FRIM's mosque at Kepong, Selangor.
Source : Forest Products Division, Forest Research Institute Malaysia.

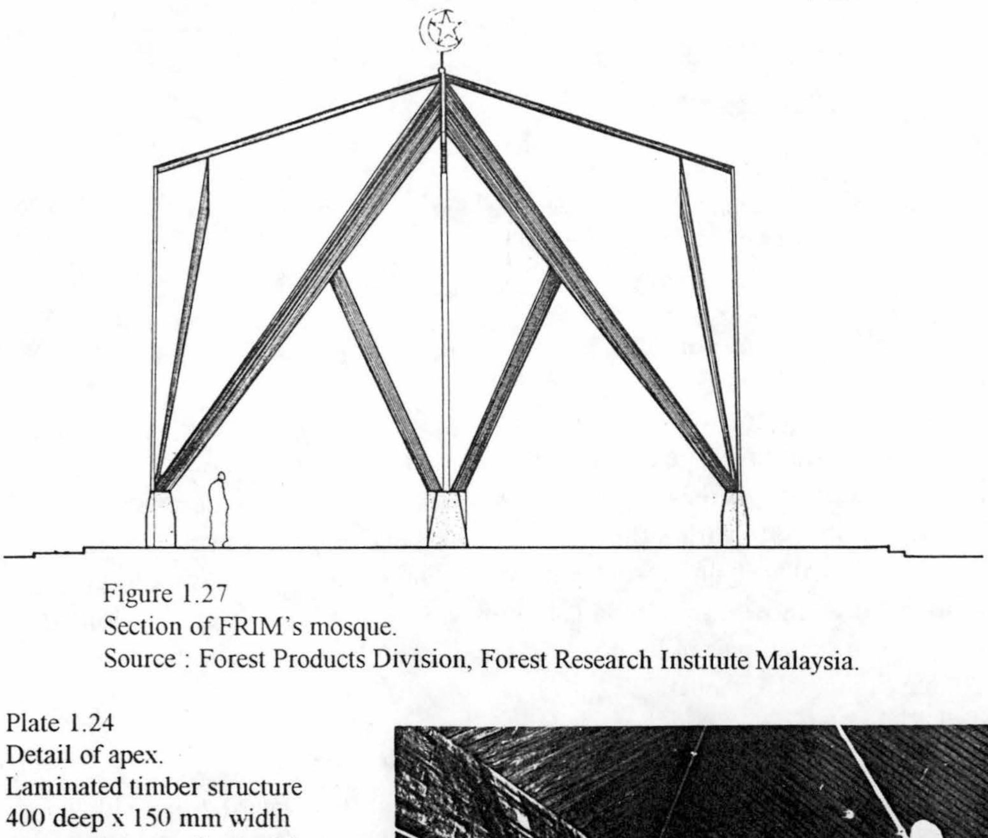
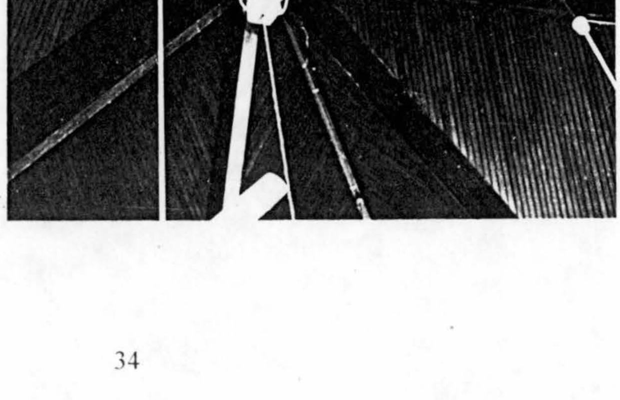


Figure 1.27
Section of FRIM's mosque.
Source : Forest Products Division, Forest Research Institute Malaysia.

Plate 1.24
Detail of apex.
Laminated timber structure 400 deep x 150 mm width meet at the apex fixed with 150 x 12 mm coach screw holding ridge connection plate to main frames.



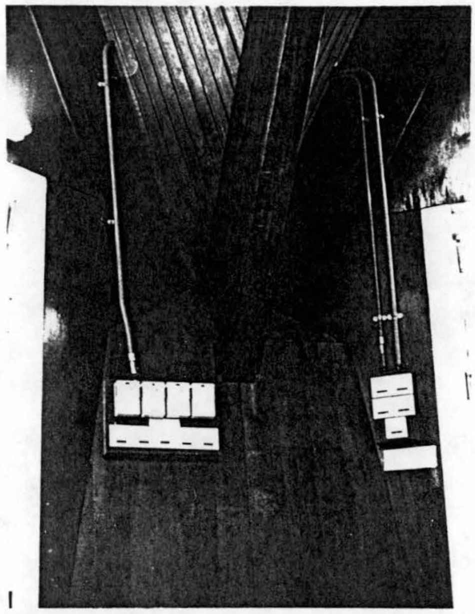


Plate 1.25
Base shoe detail.
Glue laminated timber rests on the concrete base, fixed with 4 high density bolts 25 x 375 mm long, 4 plate washers and 4100 x 12 x 100 mm bolts set in pockets.

ASPA mosque, Pahang

In 1989, the ASPA mosque in Pekan, Pahang was built. Designed by local architect Jimmy Lim, it explored the use of prefabricated components, in terms of speed of erection. (See Figure 1.28). The structural system based on post and beams integrated with standard basic components was utilised to ensure easy, economical and rapid construction. Wall and floor units in timber frame building systems can be highly standardised, but still easy to modify if needed. The units can be assembled on site using simple equipment or can be prefabricated at the building site. The floor structure is the most critical component. Besides carrying the working load, it must also transfer horizontal loads (by diaphragm action) to the stabilising walls to prevent deflection and vibration (Thelandersson, 1994 : p. 2). The limitations of this prefabrication method are that it requires allowance for tolerance and adjustment for jointing systems. (See Plates 1.26, 1.27 and 1.28).

The use of exposed timber framing in the inner hall has given warmth and intimacy to the religious significance of the mosque as a prayer room. The expression of structure continues through to the outside of the building, where wider eaves overhang up to 2.25 metres. The main structure is braced using steel tension rods to resist lateral wind forces. (See Plate 1.27).

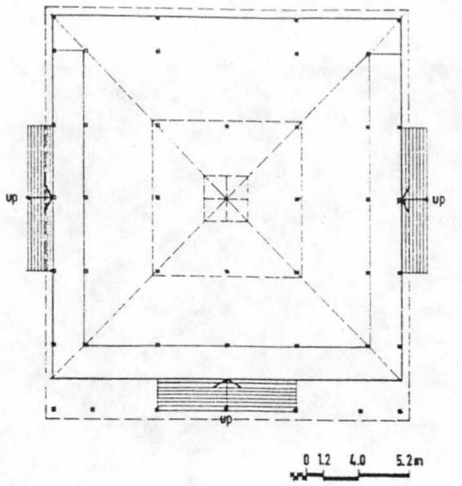


Figure 1.28
Floor plan of ASPA mosque in Pekan, Pahang.
Source : C.S.L. Associates.

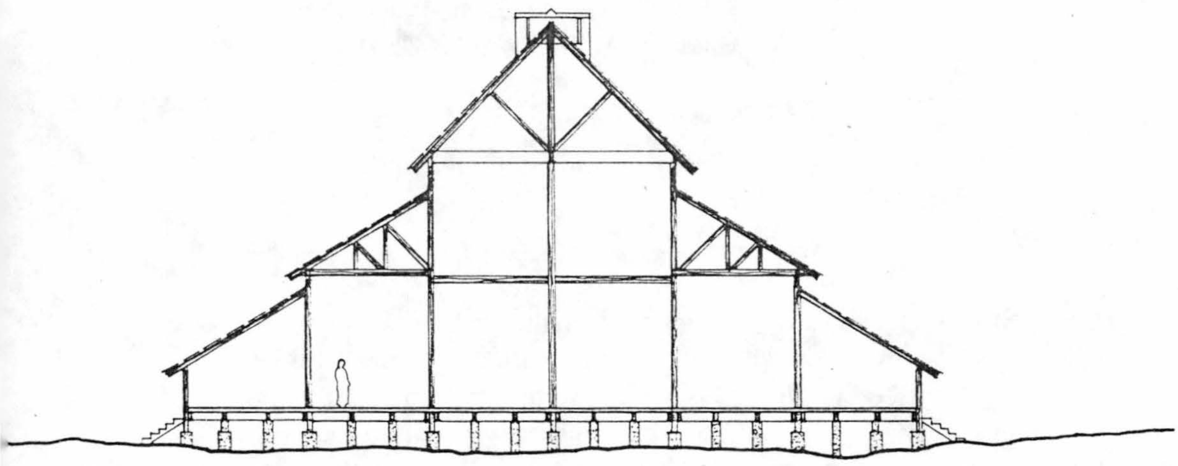


Figure 1.29
Section of ASPA mosque.
Source : C.S.L. Associates.

Plate 1.26
Tiered pyramidal roof form based on "Kampung Laut" mosque in Kelantan. The design basically comprises of a square plan, roofed over by a system of tiered pyramidal roofs with a ventilator at the apex.

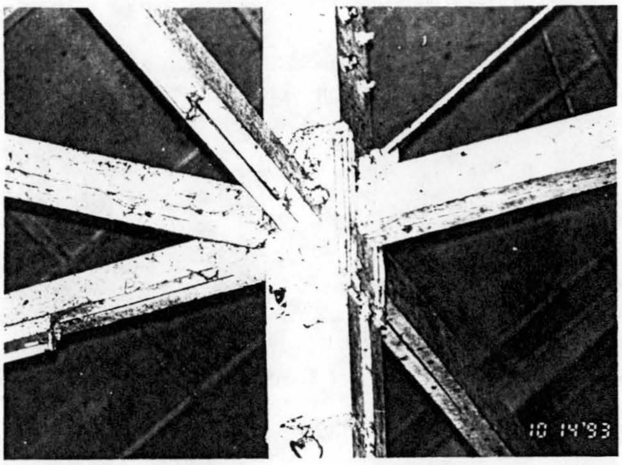


Plate 1.27
Corner post detail.
Steel tension rods were used to resist lateral wind bracing. A steel plate was inserted to connect the post and secondary beams to transfer load between members.

Plate 1.28
Corner post constructed with twin tie beam members fixed to verandah post. All structural members are "kempas" species.

1.3 The Chinese Timber Buildings : 16th to 19th Century

"The story of Chinese architecture is that of the development of bracket system for timber construction technique and its expressive elaboration in a traditional society"

(Preece, 1971 : p. 617)

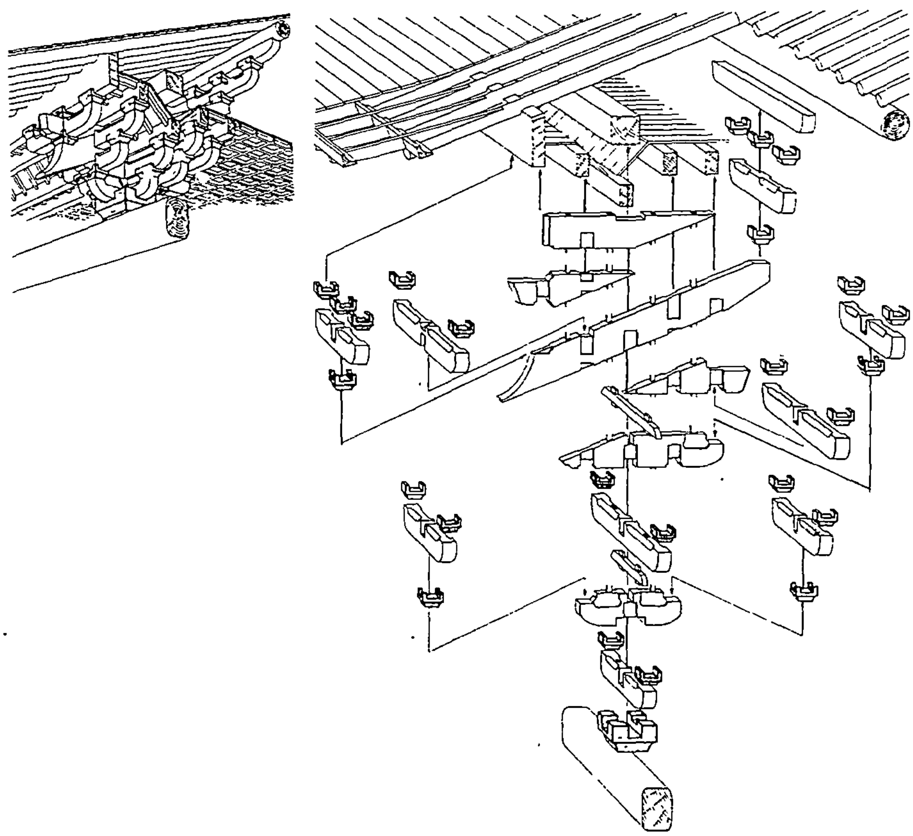


Figure 1 30
The cantilever bracket system, used to support the eaves overhang, underwent two thousand years of development to form a unique timber framing system for construction
Source : Wolfram, 1990 : p. 21

Chinese timber architecture was introduced to Malaysia by the migration of Chinese people of peasant background who were brought from China in the 16th century during the Straits Settlement. Chinese building is an organic structure because it is an indigenous growth that was conceived and born in the remote prehistoric past and developed until the Han dynasty, at approximately the beginning of the Christian era (Liang, 1984 : p. 3). Construction systems matured during the T'ang dynasty 7th and 8th century and the Sung dynasty (11th and 12th century). Information from literary and graphic sources testify to the fact that the Chinese have employed an indigenous system of construction which has retained its principal characteristic from prehistoric times through hundreds of years of evolution by way of trial and error to develop into a unique structural system for building (Jin, 1990 . p. 380) and it was this system that was brought into Malaysia in the 16th century.

Timber is the principal material in Chinese architecture and is described as being in a middle position between earth and heaven (Needham, 1971 p. 9). It is considered most suitable for the construction of columns, beams, brackets and eaves It was utilised as much as possible in its natural shape (Lin, 1977 p. 298.) Pillars, rafters and beams in roofs and walls are not hidden but are exposed and emphasised This means timber had become an important element not only in its structural form but also in its visual pattern as expressed in horizontal, vertical and curved shapes

In China, architecture historically was an art transmitted by literary tradition with few illustrated manuals. Buildings of the past and a few written works were the source for the Chinese designer. The major written works on architecture were composed during the Han Dynasty (260 B C. to 220 A.D.) and amended in 995 A.D. In 1100, Li Chieh , the Imperial Director of Building and Construction at the court of Emperor Hsui-tsung who ruled 1101 to 1125 of the Sung dynasty established "Ying-tsao-fa-shih" (Building Standards) of the Sung dynasty which were used to assist builders and architects. A better principle of architecture was improved after Tang's dynasty from 960 to 1279 and later the "Kung-ch'eng tso-fa tse-li" (Structural Regulations) was published in 1734 by Ministry of Construction of the Ch'ing dynasty who ruled from 1644 to 1912. This two technical manuals consist of all the technical terms that used to employ for comparative study of architecture of different period. Therefore, it is also one of the most distinguished characteristics of Chinese rationalism reflected construction systems which brought into Malaysia could be seen at Cheng Hoon Teng Temple in Malacca.

In examining religious structures of the Chinese, including temples, "kongsi" houses and pagodas in Malaysia, the building form expresses both the construction techniques and the structural system The basic characteristics of this system consist of a raised platform for a structure base with a timber post and beam to support a pitched roof with overhanging eaves. This construction allows for flexibility in walling by the simple adjustment of the proportion between walls and openings. Furthermore, the method of construction could be employed to build shelter wherever Chinese civilisation spread.

The process of refinement of architectural concepts and construction details has created the forms that can be found in the Federal Territory, Malacca and Penang. Two stages of this process exist. Firstly, where the requirement for larger internal spaces became evident, Chinese builders did not come to conclusions similar to those seen in Western construction techniques. The truss system was not explored, instead, more and more complex bracket systems were developed to deal with the evolution of building forms. This does not mean however that they did not know about truss systems. Secondly, a traditional belief, still existing today, that cross bracing or the use of diagonal structural elements, bring bad luck, justifies the use of beams (Bagenal and Meades, 1980 · p. 33)

The technology of construction understood by the Chinese has been adapted to suit the local climatic conditions and utilise the material available. As nails are rarely used because they tend to split the hardwood, rust, and cause wood decay, most jointing systems use the technique of mortising joints.

Roof Construction and Structural System

In the Encyclopaedia Britannica, Preece (1971 · p. 617) described that the story of Chinese architecture is described as the development of this timber construction technique and its expressive elaboration in a traditional society . The outstanding feature of Chinese monumental architecture is the curved roof with overhanging eaves, with different roof forms used according to the importance of the building. The most important Chinese buildings found in Malaysia, temples, have hipped roofs; less important buildings have hip and gable roofs.

The origin of the distinctive curve of the roof form which first appeared in China in about the 6th century A.D., was borrowed for purely aesthetic reasons from China's Southeast Asian neighbours (Hook, 1991 : p. 669). This roof type was covered by nipah palm leaves or split bamboo which tend to sag naturally and give a picturesque rather than structural effect. The corner eaves of the roof have a structural function in reducing the weight of the end points and transferring the load to the column and directly to the foundations.

The basic construction system is the post and beam. The structural system consists of a massive roof structure. This structure itself is a series of columns and defines the planes of enclosing walls. Wall beams and tie beams are tenoned into or through the upper ends of the columns. Roof trusses duplicate, on a smaller scale, the post and beam construction of the main support form while an internal arrangement of beams establishes the curvature and shape of the roof

Chinese roof systems are visually as well as structurally important both from inside and outside Chinese timber frame construction differs fundamentally from the conventional Western triangular roof trusses that dictate the rigidity of straight pitched roofs. The frame is instead flexible because the timber skeleton consists of post and cross beams rising towards the ridge in diminishing lengths. Purlins are positioned along the shoulders of the skeleton. Rafters are short, stretching down from purlin to purlin. (See Figure 1.31).

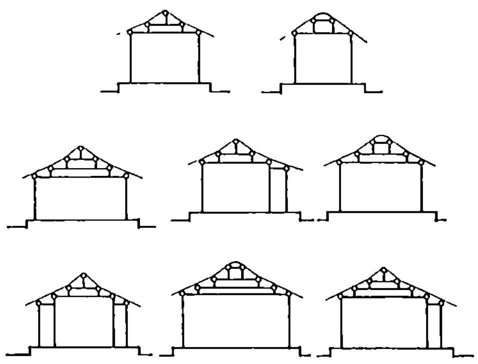


Figure 1 31
Flexibility of the beam system in determining the form of the Chinese roof. Curvilinear roof form negates the need for trusses in the roof system. Purlins are not on a single plane or of a constant shape. Roof beams give the flexibility to vary the line of purlins and to achieve the complete contour curve form.
Source Kohl, 1984 p. 35.

The climate of Malaysia required additional protection from sun and heavy rain Therefore, the roof projection became the accepted feature of Chinese building to provide shade for upper windows without obstructing sunlight. The extent of roof projection is important in sheltering the wooden structure from weather damage and to carry off water from the eaves, to be led away from the walls and foundations. The angle of intersection between the eaves and roof with a hollow curve makes the roof aesthetically pleasing as well as functional .

The detailing of the beams uses a socketed system to support an even shorter beam which is raised up until the required height of the roof at the king post position. Brackets are socketed into the column and rise in a sequence to increase the length of the topmost and longest brackets reaching the eaves level. The unity of structure and form which is different from Western Architecture using stone or concrete material. All construction members are dovetailed into each other and are important decorative elements. The construction members are painted for their own protection as well as for decorative and symbolic reasons, such as those found at Thean Hou Temple in Kuala Lumpur.

The ridge piece is an element of logical termination of the rising roof form. The ridge piece started from a simple constructional detail to conceal the waterproof joint between the two rows of tiles at the ridge. This arrangement was considered the basic standard unit repeated vertically to increase in length until the eave purlins were reached.

The lightness of the roof is effectively relieved by the complex lines of contours which give its characteristic form. The king post is fixed below the ridge beam in the centre of the upper most beam. Basically, some additional support to the roof framing is formed not only on a single plane of constant slope but also along the beam Roof purlin members fixed on the posts, which vary in height, can regulate the slope of the curve of the roof However, the deep overhang of the eaves is supported by extending the tie beams beyond the wall columns to support the eave purlins. Eave purlins are carried by an arrangement of cantilever and bracket systems from the columns.

The analysis of the Chinese order documented by Liang (1984 : p. 32) suggests that the most noticeable evolution is the gradual diminution of the "tou-kung" which were reduced from one third the height of the column to about one fourth by 1400 A.D. Intermediate sets became relatively larger in size and more complicated in combination with the introduction of the diagonal kung. This form of construction system supports was adapted and used at Cheng Hoon Teng Temple in Malacca, Khoo Kongsi and Cheah Kongsi, both in Penang.

Cheng Hoon Teng Temple, Malacca

The oldest Chinese timber structure is the Cheng Hoon Teng Temple or Temple of the Evergreen Clouds in Malacca. Built in 1645 by Kapitan China, Lee Wei King it is also the oldest functioning Chinese temple in the country. It was designed by a priest based on his memory of buildings in South China, traceable to Fukienese and Cantonese origins with reference to ChÕing Dynasty construction (Kohl, 1984 : p. 70). Its history reflects stages of construction typical of many Chinese temples in Malaysia.

The existing structure is single storeyed and employs the wooden frame system for beams and columns construction. The "Tai Liang" or raised beam construction is clearly used in the Cheng Hoon Teng Temple. (See Plate 1.29) Raised beam construction meant that the beams are placed on top of columns erected along the depth of a building. Shorter beams are placed over of the struts on the lower and larger beams. Through the diminishing length of the beams, a triangular wooden framework was erected. Purlins have been placed on top of struts on top of the beams to support the weight of rafters and the roofing.

The bracket system was incorporated with the "tai liang" system. These consist of a cluster of brackets used to support the roof on the inside of the building and the overhanging eaves outside the building. According to the building regulations of the Tang Dynasty, "tuo-gong" can only be used in palaces, temples and other important buildings (Liu, 1989 : p. 30).

The bracket system or "tou-gong" in Cheng Hoon Teng Temple is composed of two different types of structural elements. Firstly, a block placed on top of a column called "tou", which looks like a capital. Above it, and transverse to the direction of the depth of the building, are bow shaped elements called "gong" placed on smaller wooden blocks called "sheng". The timber technology used is conventional, using no nails or glue, as both "tou" and "gong" are assembled using mortise and tenon joints The "gong" was originally used to support the end of beams and eaves of purlins to reduce the shearing stress and to strengthen the joints (See Plates 1.30 and 1.31).

Plate 1.29
Cheng Hoon Teng, Malacca.
The structure was influenced by buildings of the Ch'ing Dynasty brought by immigrants from China about A.D. 1600. Structural timbers are "chengal" durable hardwood.

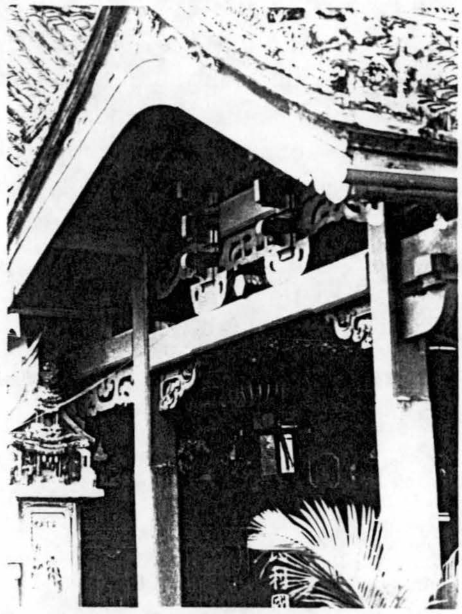


Plate 1.30
"Tou Kung" was used to support the eaves overhang.

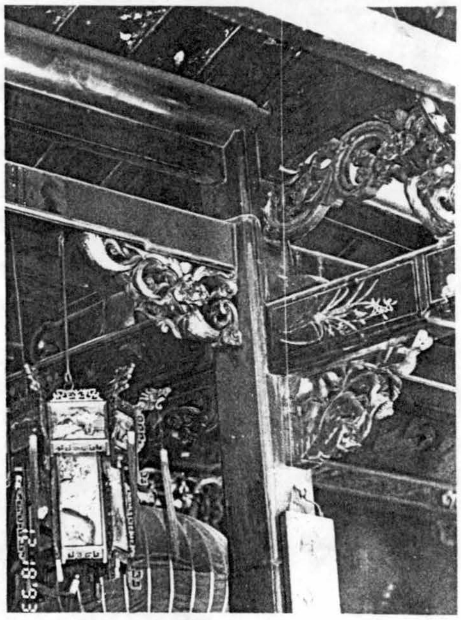
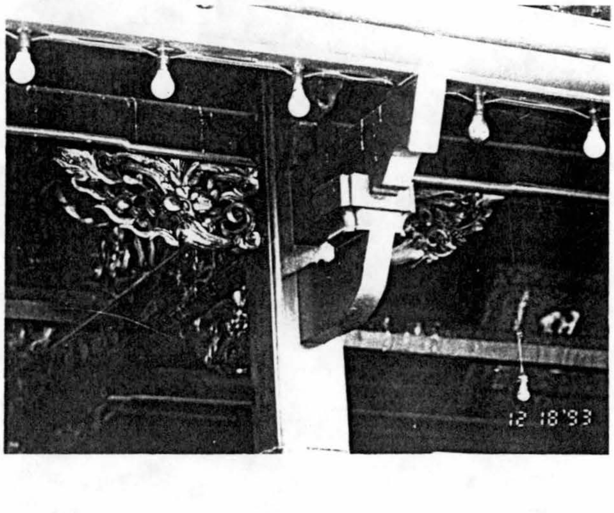


Plate 1.31
Detail of main hall.
"Tai Liang" and secondary structural members supported on carved wooden block. This block is cut in the form of lion heads or mythical winged figures as in Thian Hok Keng Temple in Teluk Ayer Street, Singapore.
(MacDonald, 1934 : p. 27)



Khoo Kongsi, Penang

The most unique adaption of traditional building structures is found in the form of the "kongsi" houses in Penang. "Kongsi" buildings and clan houses are modifications of the Chinese temple. Khoo Kongsi, built in 1901, with an elevated storey above the ground, was also influenced by traditional building practices through the use of timber piles.

The roof structure consists of vertical cross members laid over each other, resting on horizontal beams. Beams were notched into the columns to form a bracket system. Transverse beams, longitudinal beams and cantilevered brackets are carved with decorative elements. (See Plates 1.32, 1.33, 1.34 and 1.35).

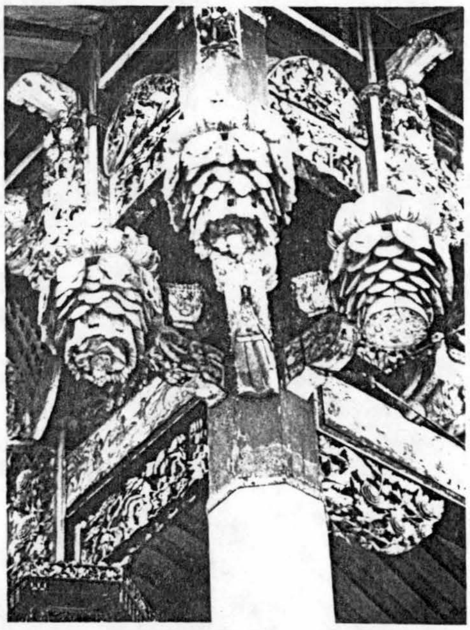


Plate 1.32
Khoo Kongsi, Penang.
Corner post detail. The bracket system was integrated with geometric carvings which symbolise of the positive "yang" principal. The use of wood is considered a "yang" element in Chinese building.

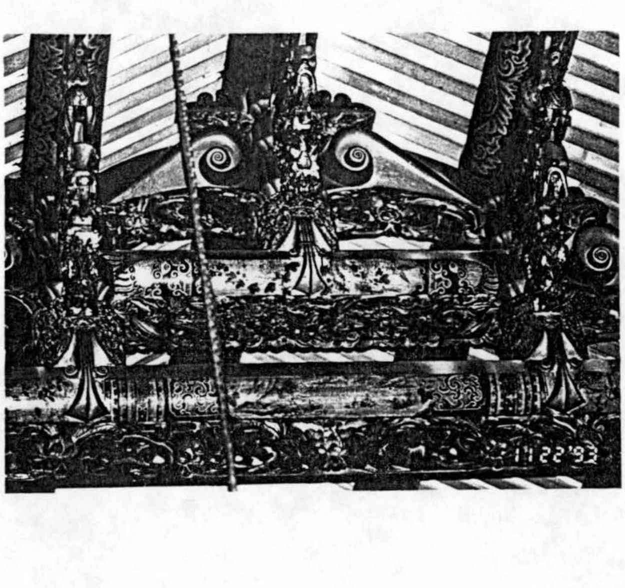


Plate 1.33
Main hall frame.
Queen post is seen resting on vertical members to transfer the load to the horizontal beam.

Plate 1.34
Theatrical stage corner post detail at the Khoo Kongsi in Penang. The origin comes from temporary or permanent stage platforms used in Southern China in the 19th century. The stage is constructed with durable hardwood structure elevated 1.20 metres above the ground.

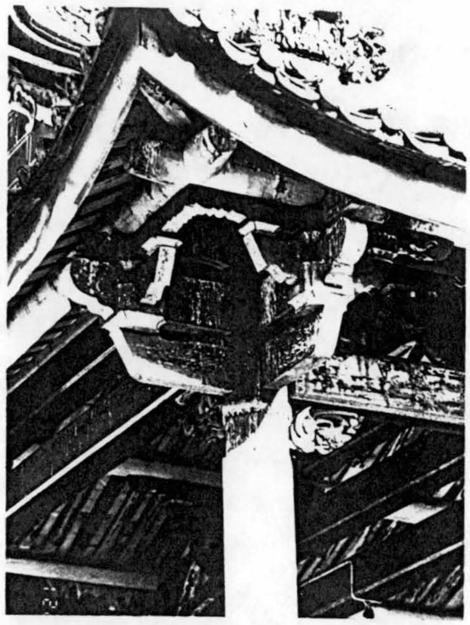
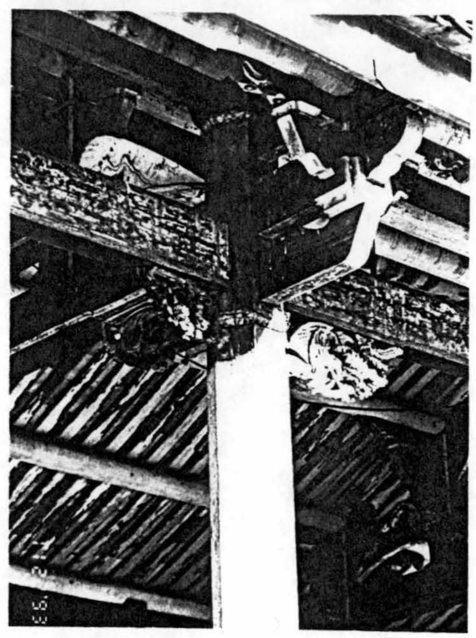


Plate 1.35
Intermediate post detail.
Brackets are used as a rigid joint to reduce the span of the beam. It is also carved with Chinese flora motifs for religious purposes.



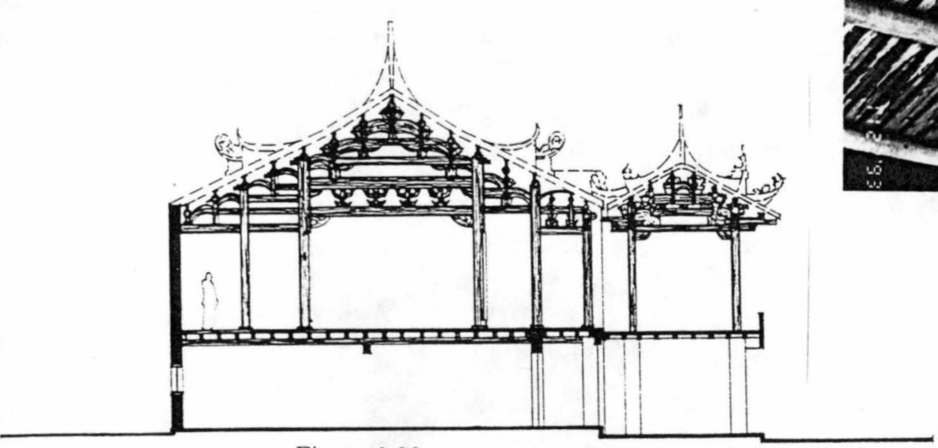


Figure 1.32
Section of Cheah Kongsi, Penang.
Source : Measured Drawing Studies,
Department of Architecture, University of Technology Malaysia.
The columns supporting the roof system are often round timber pillars, reflecting the influence of traditional Northern Chinese philosophy of construction. A good example is found at Cheah Kongsi in Penang which was built in 1890.

Clock Tower, Perak

The "Clock Tower of Teluk Intan" was constructed in 1885 by a Chinese businessman Mr. Leong Choon Cheong (Maniam, 1992 : p. 1). The tower is 25.50 metres tall, and houses a steel water tank to provide a water supply to the city.. The structure is octagonal in plan, influenced by the Chinese pagoda form. (See Plate 1.36). Western technology is reflected in the use of nails, bolts and nuts which were introduced by British in the 19th century.

The tower consists of three stories built of durable hardwood timber, and central core of brickwork. The timber flooring inside the main building, at plinth, first floor and second floor levels is supported directly by brick wall. Timber work in the corridor consists of columns and circular beams which act as ties for the columns.

A series of detached roofs, which indicate the external storeys, are supported by columns, 2.48 metres apart. The roofs are attached to the columns through brackets consisting of a tie and a strut. (See Plate 1.37). The main roof system rests on rafters which are supported by radial ties and timber resting on brickwork and columns.

The water tank is connected to the brickwork by bolts. Radial beams in the corridor are bolted to the brickwork and the bolts bear against steel plates. The brickwork and columns are held together by two radial beams of 230 x 75 mm which are connected at one end to the brickwork through a timber block 230 x 230 mm and bolt of 25 mm in diameter. These timber blocks are connected through another bolt 25 mm in diameter to the brickwork and the bolt bears against mild steel plate 10 mm thick.

Circular beams 230 x 100 mm provided along the periphery are connected to columns using nailed connections. (See Plate 1.38). These beams also serve to tie the columns to each other in the other direction. All the rafters of the main roof at the top are held together by tie rods which are connected to a central steel plate (See Plate 1.39). This connection provides wind bracing. (See Plate 1.40). The struts and ties of the detached roof are also bolted.

Plate 1.36
"Teluk Intan Clock Tower", Perak.
The tallest timber structure in Malaysia was influenced by the Chinese pagoda form. External form consists of seven storeys but internally has only three storeys.

Plate 1.37
Solid "chengal" hardwood timber roof overhang supports. The strut member is fixed to the column using a nailed connection.

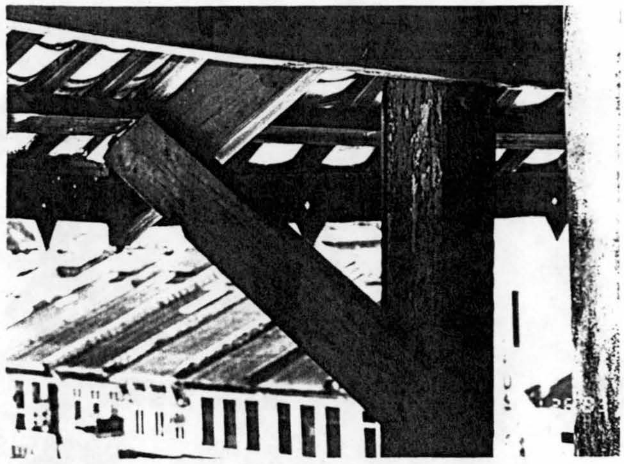


Plate 1.38
Details at the circular structural member 230 x 100 mm which acts as a ring beam connected to columns using bolt and nut connections.

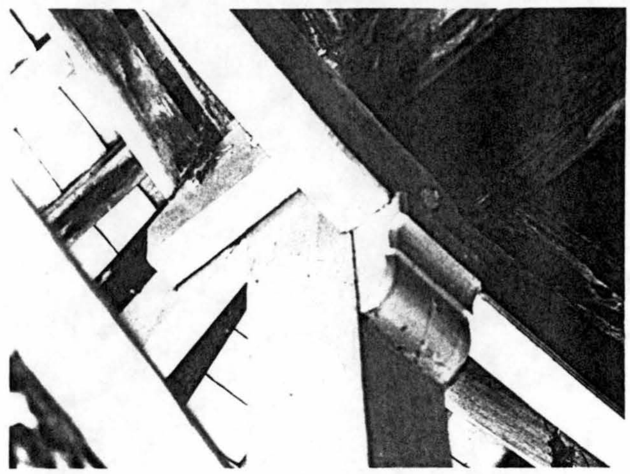


Plate 1.39
Apex detail.
All the rafters of the main roof at the top are held together by ties rods which are connected to a central piece.

Plate 1.40
Radial cross bracing is provided in the top two storeys where the water tank is situated.

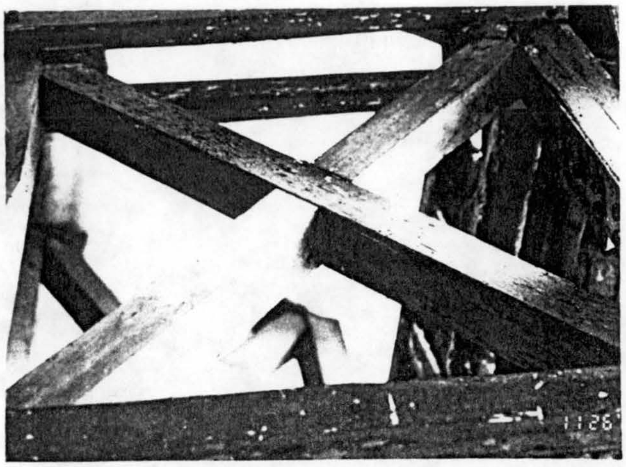
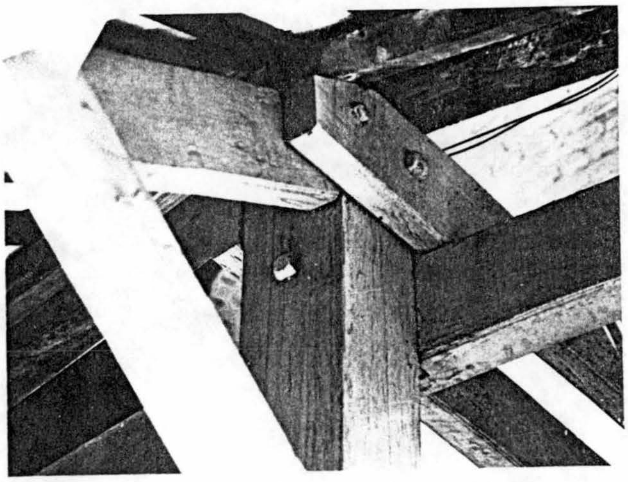


Plate 1.41
Detail at the intermediate column. This connection serves as a radial tie to transfer the load resting on brick wall to the centre core.



1.4 European Influenced Timber Technology : 18th to 19th Century

Dutch and British builders introduced European methods of timber construction to Malaysia, which greatly influenced ethnic structural concepts. The most significant was the introduction of larger spans in roof construction, by using nails, bolts and nuts which was a radical departure from traditional construction methods.

Bolted timber connections have widespread use throughout the world in a variety of forms, but it is in Europe in particular that high load capacity mechanical connections have been developed to a very high level of design sophistication. The use of bolts became widely accepted throughout Europe as a means of connection for moment resisting, particularly between columns and rafter in large free-spanning timber structures. This technological influence was introduced to Malaysia in the 19th century.

1.4.1 Dutch Influences

When the Dutch arrived in Malacca, they brought their own building designs but needed to change their building practices to adapt to local conditions. Dutch designers found that the timber buildings built by local craftsmen had problems with termites and fungal attack, thus reducing their strength and finally leading to building collapse (Killman, 1990 : p. 45). As a result, the Dutch built using stone for wall construction, and only used wood for the framework of the roof structure. (See Figure 1.33).

During the 16th century in Holland, a method of construction using a wooden framework supporting the weight of the building enabled the stone walls to be thinner and therefore less expensive. Thin stone walls were secured to the framework by means of iron wall ties. This method of construction can be found at Stadhuys and Christ Church building in Malacca. (See Plates 1.42 and 1.43).

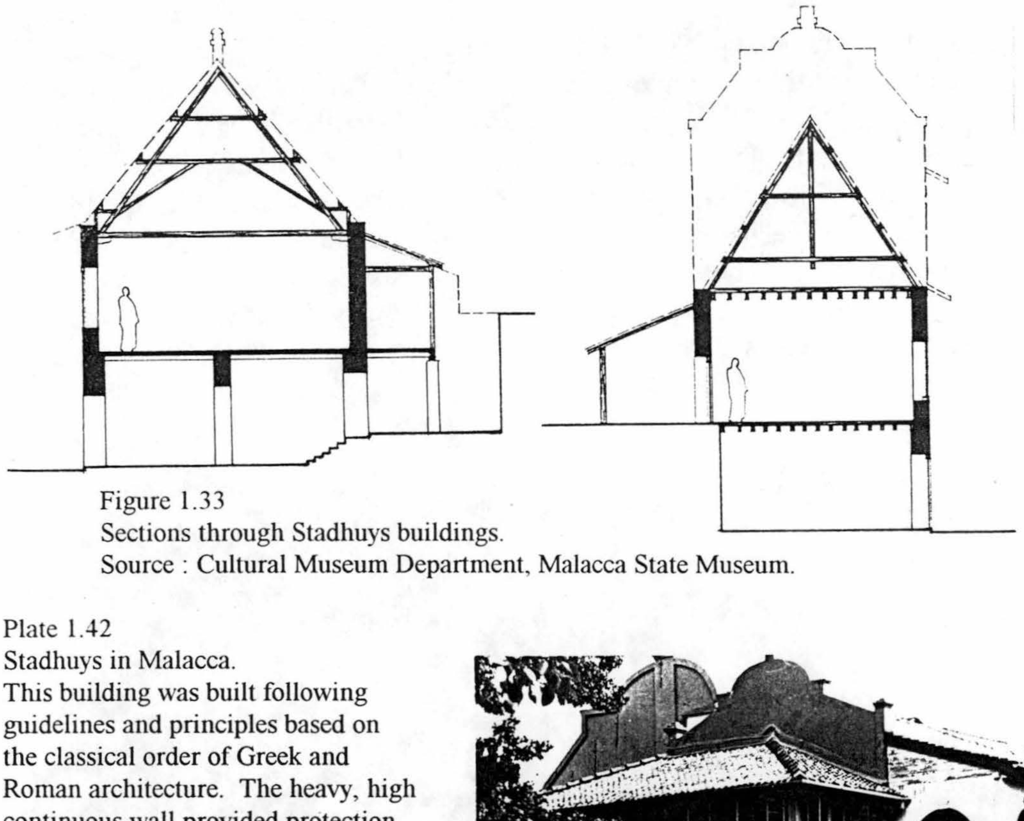


Figure 1.33
Sections through Stadhuys buildings.
Source : Cultural Museum Department, Malacca State Museum.

Plate 1.42
Stadhuys in Malacca.
This building was built following guidelines and principles based on the classical order of Greek and Roman architecture. The heavy, high continuous wall provided protection against fire and the upper floors have a wooden framework keeping the whole together.

Plate 1.43
Christ Church in Malacca.
The facade of the Christ Church
is expressed in a bottle neck gable.
It is built with a saddle roof, the most
common type of roof construction in
the Netherlands

Stadhuys, Malacca

The Stadhuys building built in 1641, at the beginning of the Dutch occupation, represents an important complex in Southeast Asia. (Lim, 1980 : p. 67). (See Plates 1.44 and 1.45). It consists of four storeys constructed mainly of straight lines with limited detailing and solid, massive and heavy walls. The roof is supported by massive transverse beams, 14.50 metres x 300 mm deep cut from a single tree. The ceilings are concealed where structural timber work is intentionally hidden. The ground floor beams consist of a number of cross beams placed one behind the other and connected by means of wall plates which are supported by the walls.

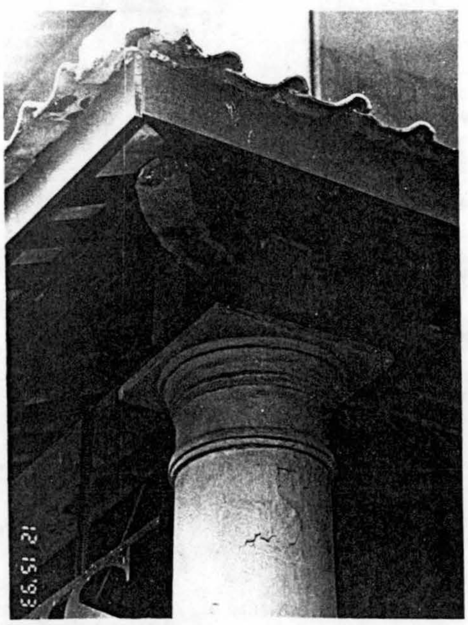
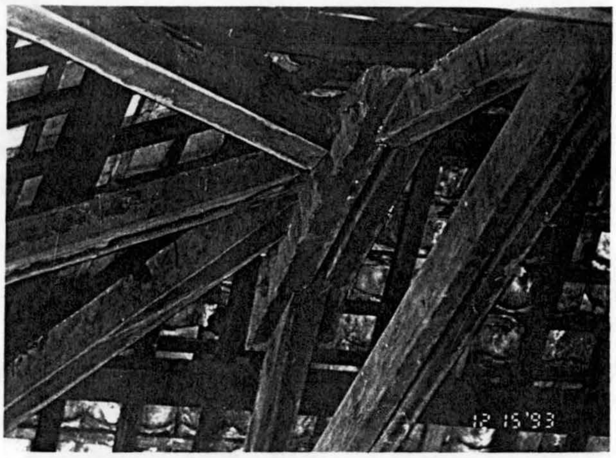


Plate 1.44
Detail of the main
entrance corner post.

Plate 1.45
Detail of the apex of the entrance porch. Twin girder tie beams are fixed to the concrete column using 150 mm long nails. A collar tie was provided to strengthen the truss system.



Christ Church, Malacca

Christ Church built in 1753, represents part of the elaborate system of Dutch government in which church organisation and functions were inseparable from the people. Christ Church has a rectangular plan of 24.60 x 12.60 metres, and a symmetrical front elevation of a massive, heavy and solid construction, similar to the Stadhuys building. (See Plate 1.46). This reflects its important position among the many fine Dutch buildings found in the Red Square of Malacca.

Each timber beam spanning the entire width of the building at 12.0 metres ceiling height is a continuous 12.60 metres x 300 mm. These beams were cut from a single tree. A total of sixteen such beams spanning the width of the church can be seen. (Plate 1.47). These are well preserved over the entire hall, leaving a spacious column-free volume internally. The jointing system used 150 mm long nails to connect the timber to the walls.

Plate 1.46
Detail of roof corner.
Massive durable hardwood projected from the eaves overhang.

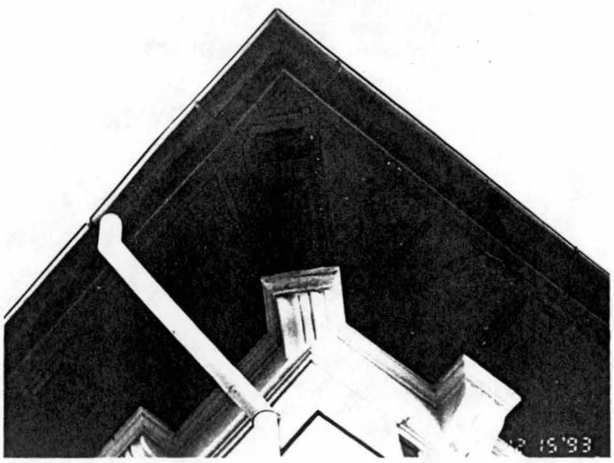
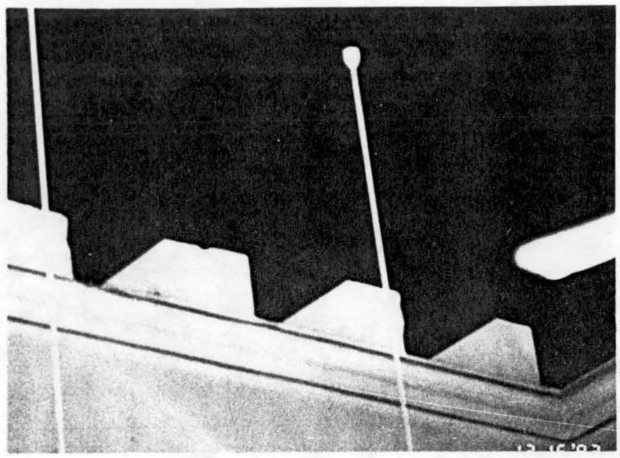


Plate 1.47
Detail of exposed ceiling.
12.0 metres x 300 mm exposed timber beams are supported on both sides by the massive solid walls.



1.4.2 British Influences

During the 19th century, a basis for the rational analysis of the principal structural form was established in Europe, in particular, methods of graphical analysis had been developed for statically determinate, more complex frameworks. The development in structural forms took place in a slow evolutionary manner and became more efficient towards simplication of construction using timber. This can be seen in many British colonial buildings where the bearing wall or the column and timber roof structures continue to be used.

The earliest form of construction used by English settlers in Malaysia was frame and half timber, where the spaces between the timbers were filled in with brick and plaster walls. The king post truss was a common structural element across Europe and in Britain. However, in the transfer of British building technology to Malaysia, the truss was abandoned in domestic construction.

The British adopted the traditional Malay house structural system but modified the construction and jointing system by using U-shaped metal straps, and bolts and nuts. The simplest form of roof was the king post truss. (See Figure 1.34). The form of the apex of this truss is notable in that the top of the rafter joint also carries a ridge piece to strengthen the apex support. These struts in compression are bolted into the lower portion of the king post which is in tension. This can be seen at the "Sentul Train Station", Kuala Lumpur.

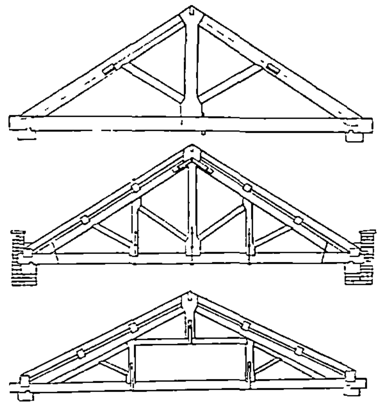


Figure 1.34
King post truss
In a king post roof, the principal rafters act together from the apex of where the post is suspended. The king post acts as a tie to support the centre of the beams, preventing them from sagging under the load of the ceiling. A U-shaped metal strap, which passes under the tie beam, is fixed to the bottom of the king post with bolts This beam in turn acts as a tie to restrain the ends of the principals, preventing the member from spreading.
Source . after Yeomans, 1992 : p. 27.

The frame system consists of the truss with its principal rafters, collar ties, a king post and horizontal tie beams and includes the ridge board and purlins. Ridge boards and the horizontal tie beam also connect with king post and are braced together with diagonal braces. This type of roof structure can be seen in colonial buildings such as "Gedung Raja Abdullah", in Selangor, "Bangunan Sultan Abdul Samad", Church of Saint Mary and "Carcosa Sri Negara" in Kuala Lumpur.

The system of central cross bracing is the characteristic difference between the king-post trusses common in English 19th century construction and traditional Malay roof construction. This bracing follows down the length of the roof and is always associated with horizontal ties, tenoned into the king post between the collar-tie. This feature is reminiscent of the collar purlin in the English mediaeval roof, which always passed directly over the collar.

The introduction of timber trusses into Malaysia involved a revolutionary change from the gradual evolution of traditional forms. This innovation was needed to provide the roofs of new kinds of building with larger spans, and became the widely adopted form because it provided advantages over the alternative traditional structures. Below are the construction details of important British examples which influenced Malaysian building techniques.

"Bangunan Sultan Abdul Samad" - Federal Territory

The building was designed by architect A.C Norman in 1904. It has become the major landmark of Kuala Lumpur with its 41 0 metres high clock tower. The purpose of the building was to house the offices of the Selangor State Secretariat Local hardwood timber was extensively used in the roof structure

(See Figure 1.35). The structure is based on a series of queen post trusses which occur at every third pair of principal rafters. The intention of the strutting was to assist the principal rafters and prevent their sagging under the load from the purlins and roof covering

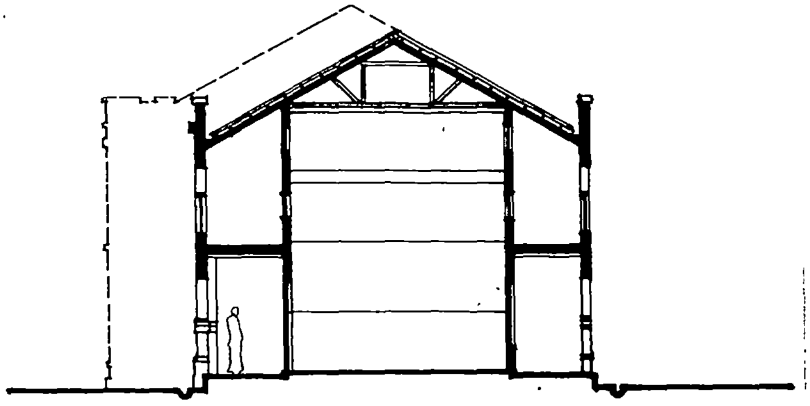


Figure 1.35
Section of "Bangunan Sultan Abdul Samad"
Source : after "Majallah Akitek", 1986 (March and April) : p. 34

Government Printing Office, Federal Territory

The two storey office building designed by A.C. Norman in 1909 stands out among the other government buildings constructed at the time in Kuala Lumpur (Yeo, 1986 : p. 17) The structure of the building has a load bearing brick wall along the perimeter with an internal grid of precast iron columns and beams together with tie members.

The roof structure is similar in construction to the "Bangunan Sultan Abdul Samad", employing a tie beam roof that carries two short, vertical struts connected by a cross beam about midway along the gable roof. This reflects the features described by Vitruvius as well as a roof type that gave inspiration to Greek post and beam construction. (See Figure 1.36).

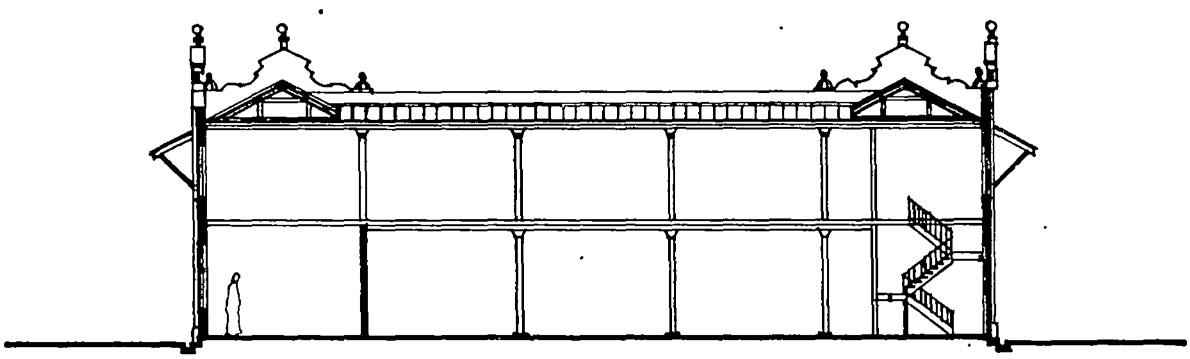


Figure 1.36
Section of Government Printing Office
Source : after "Majallah Akitek", 1986 (March and April) : p. 19

"Gedung Raja Abdullah", Selangor

Gedung Raja Abdullah, the oldest building in Selangor Darul Ehsan, was built by Raja Abdullah in 1857 and functioned as a ware house (Cheng, 1991 : p. 33). Presently, the building is preserved by the Selangor State Museum and used to display tin mine processes.

The roof structure consists of king and queen posts, and where they received loads from the tie beam, a tensile rod was needed. The tie beams carrying the ceiling load therefore required some intermediate support, to truss up the beam and rest on both sides of load bearing walls. Metal straps were used at the foot of the posts with U-shaped pieces of metal passed under the tie beams. The iron rod was a better tensile material because joints could be formed more easily, and timber used as a compression member ensures against buckling. (See Figure 1.37).

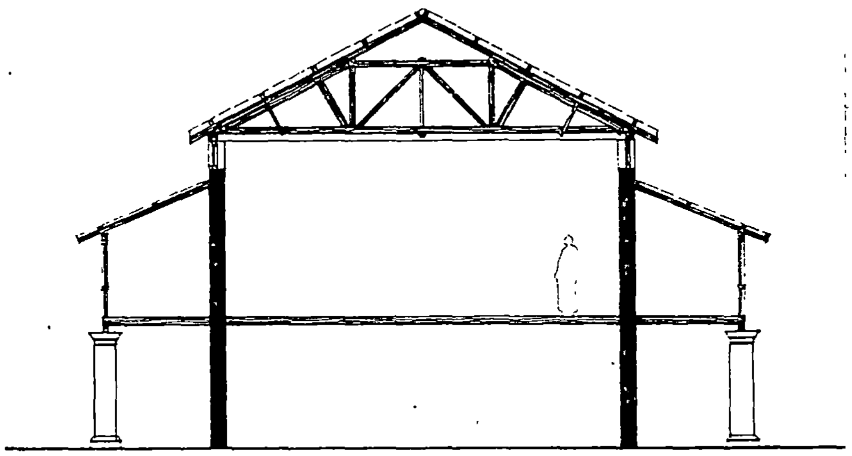


Figure 1.37
Section of "Gedung Raja Abdullah"
Source : Selangor State Museum, Selangor.

1.5 Contemporary Timber Architecture : 19th Century to the Present

Technological development never progresses in regular steps, often there is a long gap between the time when a new method is first introduced and the time it becomes universally accepted. For this reason, the development of timber framing in Malaysia can be seen in a technological rather than a chronological sequence.

Technological changes in construction techniques methods, pioneered in Europe and America, were introduced to Malaysia in the late 19th and early 20th centuries (Yeang, 1992 : p. 180). These principles, such as innovations in spanning techniques, were adopted and used in the construction of buildings in Malaysia. Previously, for example, the width of shophouses was restricted to the span of available timber beams but the new construction methods increased design opportunities

The technology of construction was introduced in the mid 20th century by a new generation of overseas graduate architects in Malaysia who brought with them contemporary ideas based on a strong sense of rationalism and functionalism adopted by the modernist movement.

During the 1960s, an emphasis on industry in Malaysia resulted in the construction of a wide range of processing and manufacturing mills using structural timber A comprehensive survey, on a technological level, by Ho (1988 : p.1) found that at present a total of 667 sawmills exist on the Malaysia Peninsular. These industrial buildings employ wooden truss systems because timber is economical and available in quantity.

In the 1970s, fabricated timber components were introduced by Malaysian architects who had trained abroad. These methods, such as Gang-nails and Pryda truss prefabricated systems are flexible to use and reduce in size timber members and labour, and increase speed of erection on site. The important structural advantage is that nail-plated trusses made with all the members in one plane can be erected more easily and forces are reduced in the bracing system (Ong, 1990 : p 111). This type of construction system has spread and been applied in housing, governmental offices and factories.

Tourism became a significant income generator for the Malaysian economy in the 1980s and the increasing number of foreign visitors to the country created the need for more hotels and holiday resorts. Tourist developments have provided employment and revitalised local building craft (Davey, 1983 : p. 101) Some of these resorts such as Club Mediterranean, "Tanjung Jara Hotel/Rantau Abang Visitor's Centre" and "Pelangi Beach Resort" were built entirely of timber structural components .

According to Medical Health Department (1993 : p. 9) cited from Statistics Department of Peninsular Malaysia stated that the total building material used in the construction industry indicated 15% consisted of timber, 31% of iron or steel, 19% of cement with concrete and 35% of other material. As stipulated in the 6th Malaysian Plan (1991 - 1995), the government has estimated amount of 1 3 billion worth of structural timber to be used. In fact, 312 blocks of class "G" quarters to be constructed costing about $312 million. Out of $312 million, 46 million was allocated for the cost of timber components which should be more encouraged to be used in construction sector. It is a renewable economic resource and can therefore continue to generate revenue, generation after generation. I would argued that more effort must be made to optimise its usage for constructional purpose.

Since 1960, the Forest Research Institute of Malaysia has carried out experiments and conducted tests into the effective use of timber in the building industry. The exploration of new building forms, the changing timber resource of shorts lengths and composite materials are all challenges yet to be explored in Malaysia. The use of structural timber such as glue-lamination technology is still at the experimental stage. In future if this structural glue-lamination is technology successful, it will replace existing building industry to produce any design shape of beams, portal frames, arches, grid frames and ring beams. Malaysia have the potential to enhance and promote the use of timber products in the construction sector in the country.

1.5.1 Resorts

A principal of resort buildings providing vacation accommodation, is to use materials and technology appropriate to a tropical climate. The successful design of these buildings using timber requires careful response to the climate, local values and heritage so as to minimise their impact on the environment (Lim, 1993 : p. 8).

Timber provides a useful material for these types of developments as it is durable in coastal climates and is environmentally sensitive (Guymer, 1994 : p 16). The selection of timber for resorts has been confined to their use in traditional construction methods either by replication of traditional buildings or rationalisation of traditional methods as can be seen at "Tanjung Jara Hotel/Rantau Abang Visitors' Centre", "Datai Kangkawi","Pelangi Beach Resort", "Sheraton Langkawi Resort" and "Hyatt Kuantan Hotel".

The interrelationship between forest resources and actual forms of timber construction for resorts is reflected in the resorts built in the late 1970s. The solid, heavy timber post and beam construction found in Malay palaces was modified in resort developments by reducing or eliminating the series of tall and heavy load-bearing posts. Trees of lesser length and section which are easier and faster to fell and transport could be used for roof trusses. This can be seen at "Impiana Resort", located at Kuantan, Pahang where all timber structural trusses were built out of smaller members bolted together.

Innovation in the use of timber has provided opportunities to build using steel and timber composites for beams and columns, as seen at "Hyatt Kuantan Hotel", "Awana Golf Course & Country Club", "Langkawi Island Resort", "Berjaya Langkawi Beach Resort" and "Bukit Kiarra Equestrian Resort"

Other methods used include on-site prefabrication systems, as at "Delima Resort Langkawi" Below are the construction details of important examples of timber-built resorts in Malaysia.

"Tanjung Jara Hotel/Rantau Abang Visitors Centre", Dungun, Terengganu

Tanjung Jara Hotel/Rantau Abang Visitors Centre was constructed in 1979 based on traditional 18th century Terengganu Malay palaces and made entirely of choice timber, mainly "kapor" species (Azali, 1993 : p. 1). The hotel, listed as one of the best hotels in the world, was designed by a team consisting of Wimberley, Whisenand, Allison, Too and Goo who won the Aga Khan Award for Excellence in Architecture in 1981 Commenting on the design, it was stated the award was given "for the courage to search out and successfully adapt and develop an otherwise rapidly disappearing traditional architecture and craft and at the same time meet the demands of contemporary architecture". (Hall, 1988 : p 31). Through the use of Malay house forms and timber material, this hotel has revived traditional craftsmanship and constructional skills. The adaption of traditional forms to new uses for resorts has generated an architecture that is in keeping with traditional values and compliments surviving examples

The entrance of the hotel was designed in a rectangular form where three hardwood posts 200 x 200 mm create a triangulated structure on each side of the entrance. (See Plates 1.48 and 1.49). Tie beams 250 x 150 mm slotted on top of the posts stiffen the entire structural frame layout.

Floor framing consists of a grid system layout. Bearers, 250 x 150 mm fixed to the corner posts raised 900 mm from ground level, rest on concrete stumps. Floor joists 200 x 75 mm spaced 1200 mm apart support 225 x 50 mm thick timber flooring boards.

The roof is pitched at 45 degrees to cope with the heavy rain on the East Coast. Gables have high pointed roofs with a single ridge-covering running the length of each building. Each gable is fitted with a gable screen which admits air but provides protection from driving rain. Hardwood rafters 150 x 150 mm are fixed on the 250 x 150 mm tie beams and rest on 250 x 200 mm wall plate.

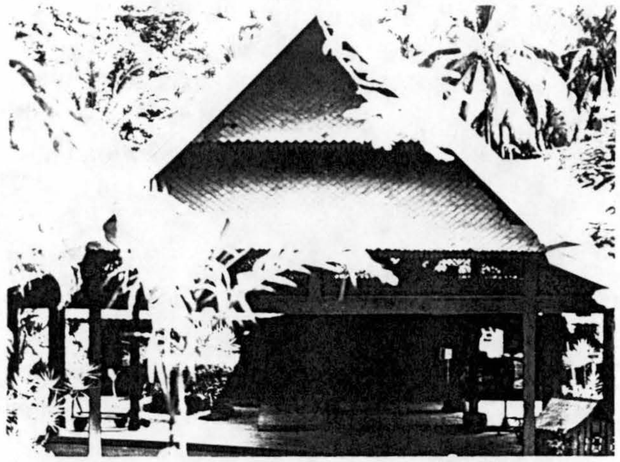


Plate 1.48
Entrance porch.
Each corner of the porch consist of hardwood posts 200 x 200 mm to form a triangulated structure to resist lateral load.

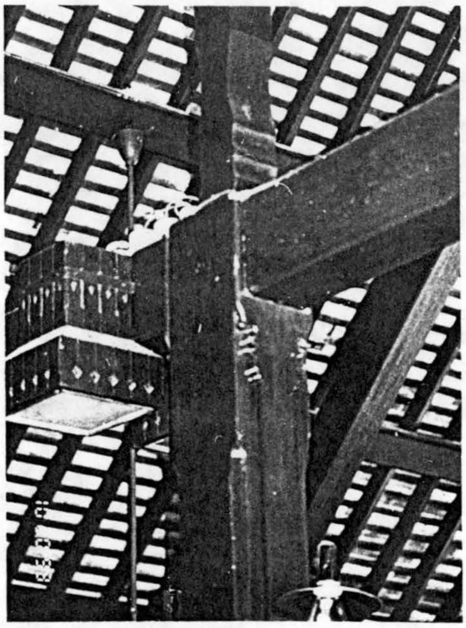


Plate 1.49
Detail of post at the entrance porch. Hardwood posts 200 x 200 mm were cut to recess 150 x 150 mm tie beam and provide a 1200 mm overhang on both sides.

Club Mediterranean Resort, Cherating, Pahang

The Club Mediterranean resort, located on the East Coast of the Malaysian Peninsular, was built in 1979. The resort, designed by Hijjas Kasturi Associates Architects, reflects the shapes and pitch of roof of Polynesian architecture (Baxendale, 1980 : p. 50). The whole village is built on a timber platform deck 3.0 metres above the ground. It is also the longest resort, stretching 1 km from Desaru in Johore to Kuala Terengganu in the north where the extensive use of timber as the main structural material has been successfully achieved. (See Plate 1.50).

Posts are the vertical members that transfer the weight of the roof, wall, floor and other parts of the building to the foundations. The structural floor system consists of twin girders framing 150 x 300 mm fixed to 200 x 200 mm hardwood timber columns. The layout of the columns with the grid system allows for possible future extension, an idea adapted from the traditional Malay house concept. Floor joist members 50 x 200 mm spaced at 600 mm apart rest on the 150 x 200 mm bearers. The columns are stiffened by lateral bracing which distributes loads in a balanced manner. All connections use 12 mm diameter bolts with washers attached to split rings on both sides to adjust themselves under movement due to load and according to moisture changes in the wood. (See Plates 1.51, 1.52, 1.53, 1.54 and 1.55).

The roof structure was constructed using a prefabricated Pratt truss system to span 13.0 metres. Tie beams consist of two members of 50 x 150 mm with 50 x 100 mm intermediate struts 2.0 metres apart. Principal rafters are built of two members 50 x 150 mm fixed at the apex using 6 mm thick mild steel plates. Connections are made by two 19 mm diameter bolts fixed with 6 mm thick mild steel plates. Bolts are used to resist load acting on the axis of the bolt in lateral loading and make the trusses more rigid. Furthermore, the trusses were braced between the principal rafters and roof beams to resist wind loading. (See Plates 1.56, 1.57 and 1.58).

The system was selected because it could provide maximum openness, a strong framework and maximum opportunity for wall openings. Though simple, this essential outline was a significant organisational force throughout the construction process for this building.

Plate 1.50
The building is a three storey unit raised 3.0 metres from the ground. The shape and pitch of the roof reflects Polynesian architecture.

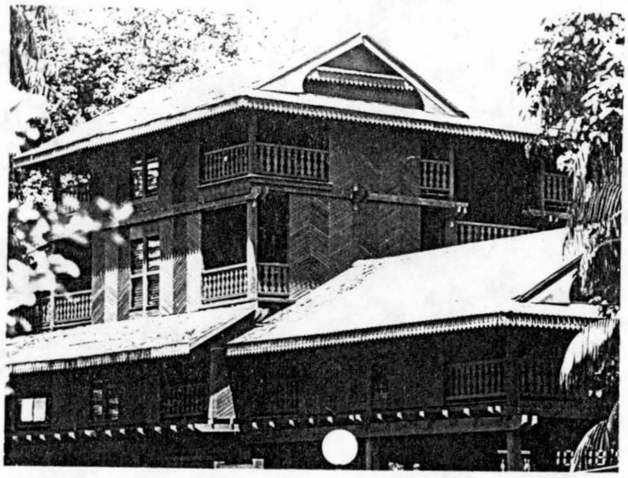


Plate 1.51
Detail of balcony.
Twin girder framing system with 75 x 300 mm fixed to 200 x 200 hardwood timber column.
All connections use M 12 bolts with washers attached to split rings on both sides.

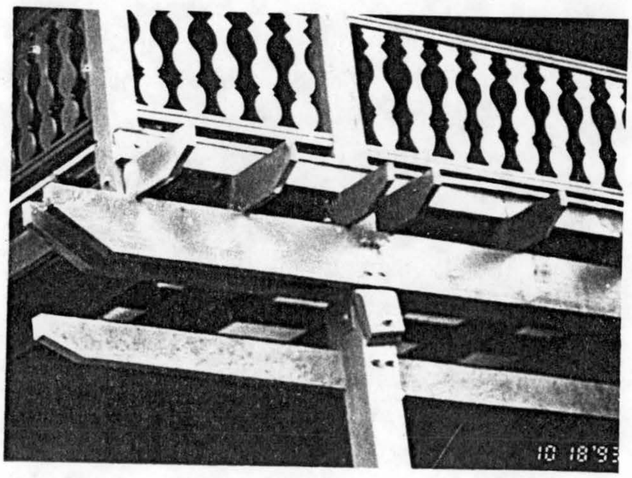


Plate 1.52
Detail of ground floor post.
Double floor joist 50 x 200 mm spaced at 600 mm apart rests on the 150 x 200 mm bearers.

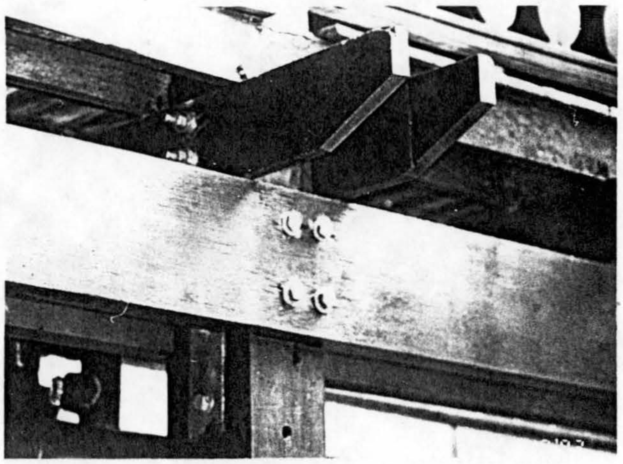


Plate 1.53
Detail of intermediate bearers.
Bearers are scarf jointed and stiffened, using 6 mm thick steel plate.

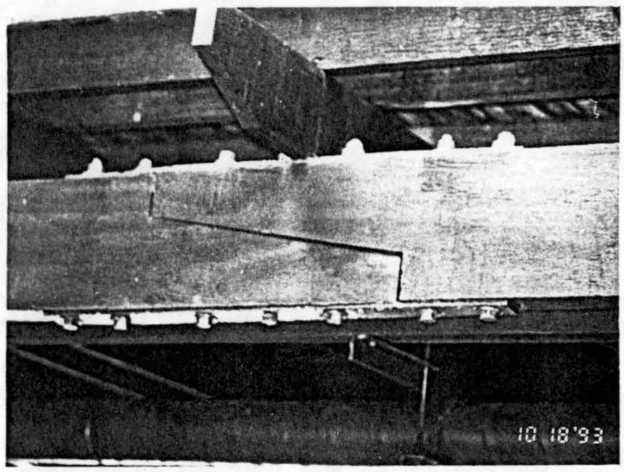


Plate 1.54
Detail of floor beam end joint.
Double bearers 50 x 200 mm recessed 50 mm deep fixed to 200 x 200 column and supported by 75 x 300 timber blocks on both sides.
Split rings were used on both sides of the connection.

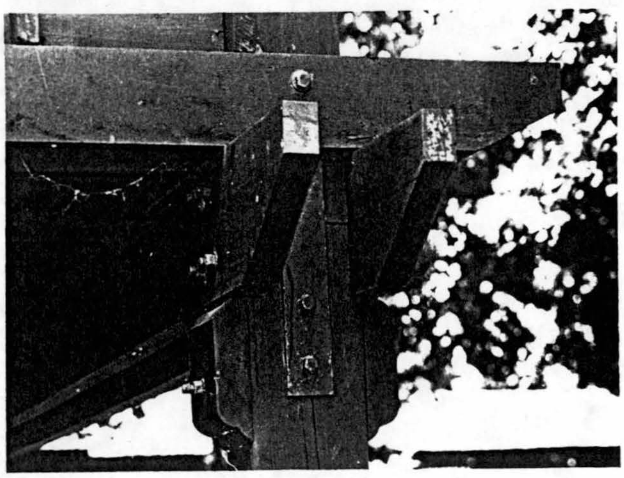


Plate 1.55
Detail of staircase.
Hardwood posts 200 x 200 mm rest on concrete stumps fixed with U-straps of 6 mm thick steel plate. 4 bolts were used to connect columns and stumps to transfer the loads of the building to the foundation.

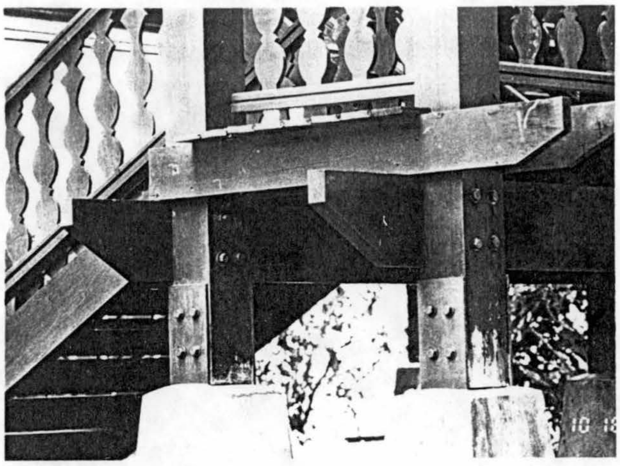


Plate 1.56
Detail of corner roof beam.
Two tie beams 50 x 150 mm rest on wall plates 50 x 150 mm and are fixed using bolts and nuts.

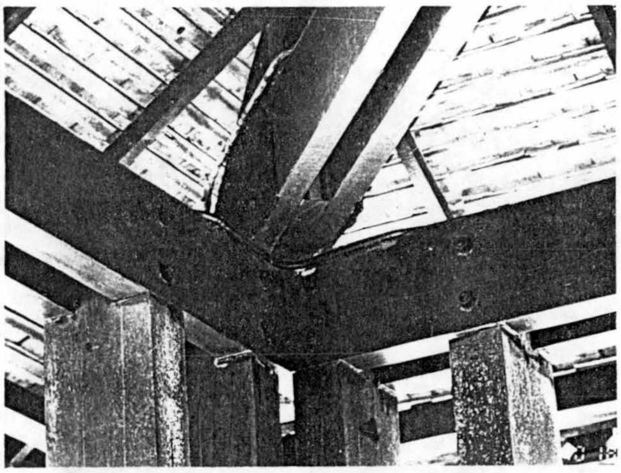
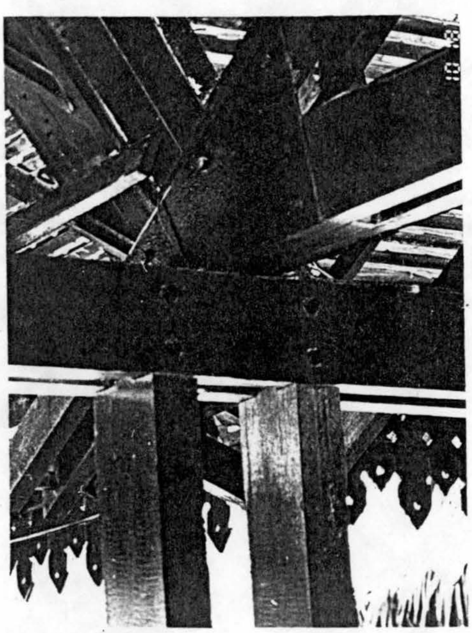


Plate 1.57
Detail of roof truss.
Two tie beams 50 x 150 mm rest on two wall plates 50 x 150 mm, connected to corner columns using 6 mm thick mild steel brackets .



"Pelangi Beach Resort", Langkawi

"Pelangi" Beach Resort designed by Unibina Architect, was built in 1988. The resort was designed to replicate traditional Malay houses but the final product is a delightful blend of Malaysian, Thai and Indonesia influences. It consists of chalet modules made of broad timber planks, held by timber frame construction and set in a random arrangement "to evoke a perception of "kampong" villages in a tropical paradise" (Loke, 1988 : p. 64).

The building was constructed using a variety of different wood species such as "chengal" and "kempas" for structural timber members. "Chengal" is used mainly for structural purposes, such as roof beams and trusses, using metal plates, brackets and bolts as connecting devices between members. (See Plate 1.58). Roofs are exposed internally as there are no ceilings, allowing for the dissipation of warm air naturally through the roof. The structural frame at the reception area was constructed of reinforced concrete and clad with timber to give an impression that the whole structure was constructed of timber. "Chengal" roof trusses with bolted connections between members are braced with steel rods. (See Plates 1.59, 1.60 and 1.61).

Outside the reception area, a pavilion was constructed using hardwood timber with a pyramidal roof with another roof stacked on it. Four valley double trusses support square ring double truss beams which in turn support the pyramidal roof lantern. The roof form traces its origins to the "meru" roof type, of which the earliest extant local example is that of "Masjid Kampung Laut" in Kelantan.

Plate 1.58
Detail of roof truss.
Gable end was designed with a rising sun symbol and provides cross ventilation to create a changing atmosphere. The sunlight filter through gable end, defining the hardwood roof structure and casting shadows that redefine the spaces throughout the day.

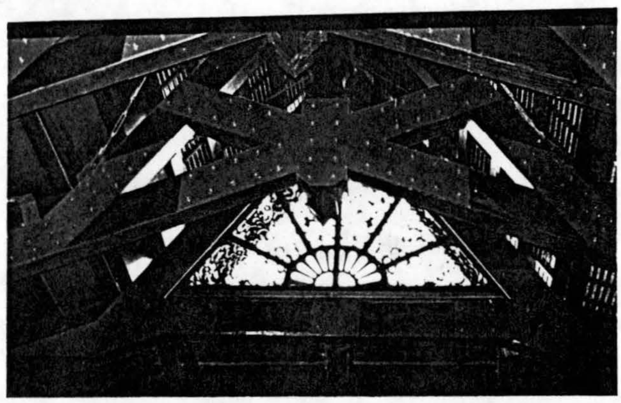


Plate 1.59
Detail of scissor truss.
The scissor truss was incorporated with king post member fixed with 6 mm thick mild steel plate and connected using bolts and nuts.

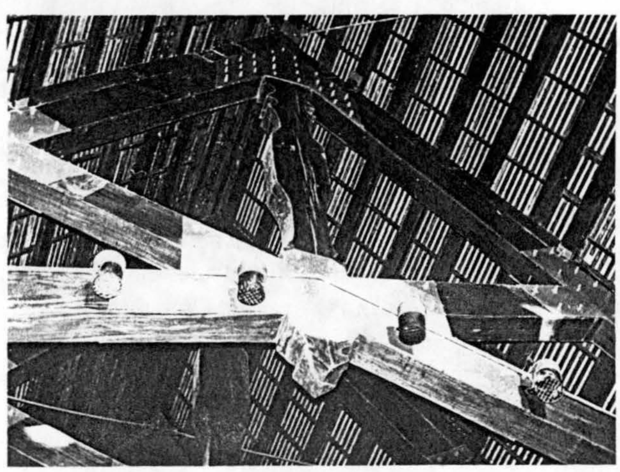


Plate 1.60
Detail of roof bracing.
The roof was braced using steel tension rods tied below the ceiling for lateral load bracing.

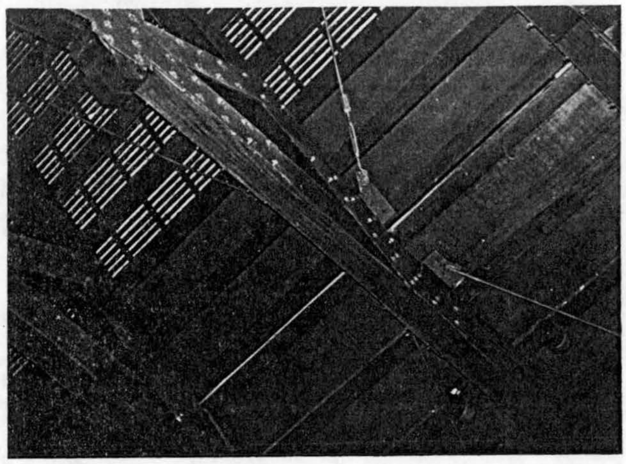
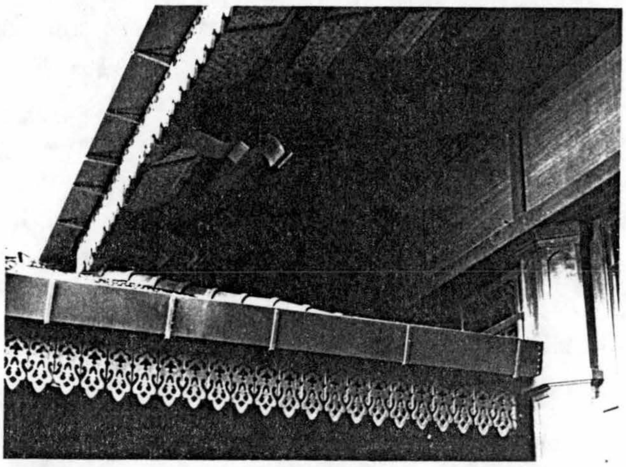


Plate 2.61
Detail of overhanging eaves.
The hardwood rafters were carved at the end, and overhang 900 mm to provide shade and deflect rain water.



Hyatt Hotel, Kuantan, Pahang

Hyatt Hotel, completed in 1980 was designed by Belt, Collins and Associates. The building form of this hotel was influenced by traditional Malay building principles of the East Coast and the open layout of the "kampong" (Wong, 1980 : p. 27).

The roof is timber framed but the essence of the timber house is reinterpreted here in concrete. The inspiration for the main pavilion was drawn from the two-storey wooden palaces of the early sultans of the region (Powell, 1989 (b) : p. 101). (See Plates 1.62, 1.63, 1.64 and 1.65). Vertical support for the roof structure is provided at intervals by concrete columns. Hardwood timber trusses are fixed on top the concrete ring beams attached at the four main columns. Steel brackets are used to connect timber trusses and are tied at the columns. Evenly distributed, omnidirectional lateral support is provided by rigid concrete joints.

Plate 1.62
Detail of the apex.
No ridge board was used in roof construction. Hardwood rafters were connected by 6 mm thick steel brackets with 4 mild steel bolts and washers.

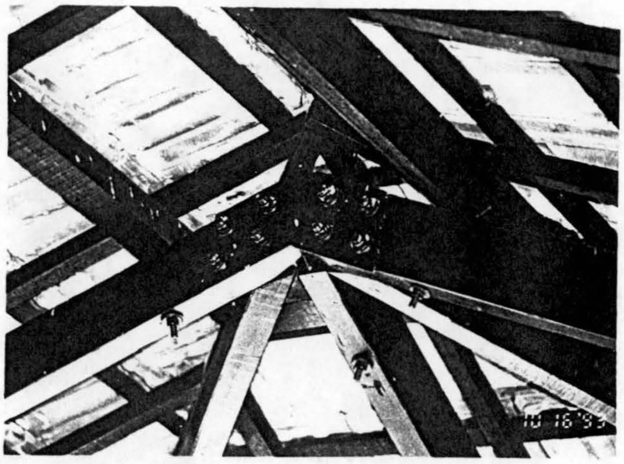


Plate 1.63
Detail of roof truss.
Two tie beams connected to strut members using mild steel bolts and nuts

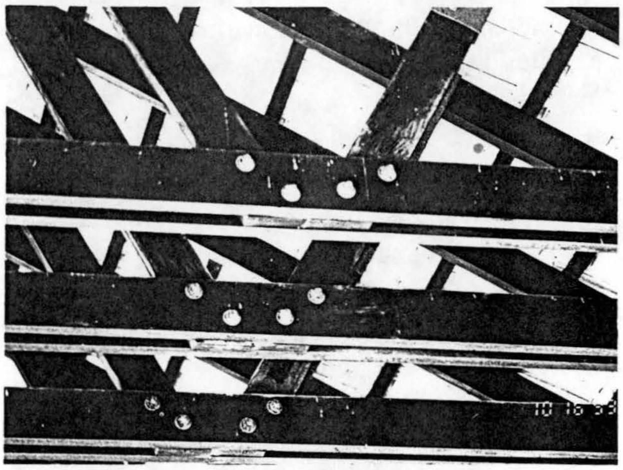
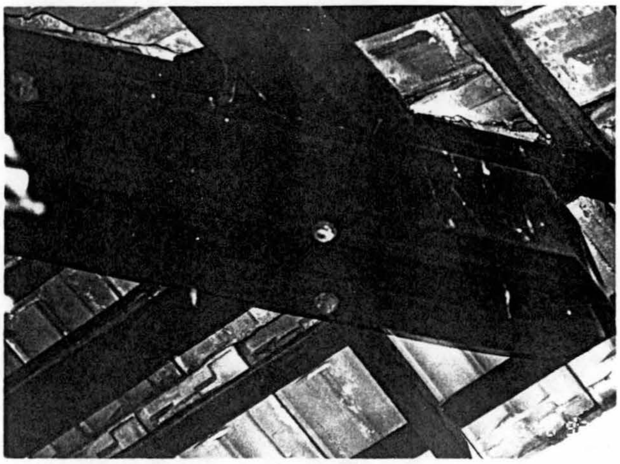


Plate 1.64
Detail of corner eaves.
Two rafter members overhang 900 mm from tie beams. Rafters are tied to the beams using bolts and nuts.



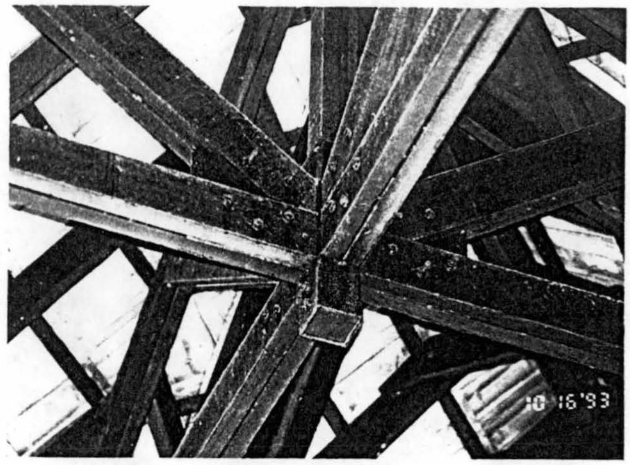


Plate 1.65
Detail of the watch tower pyramidal roof truss. Roof members meet at the centre, supported by a vertical tension member.

1.5.2 Industrial Buildings

The principal functions of an industrial building are to provide maximum volume for minimum cost and a flexible building form that can accommodate changes in production. The systems selected for industrial buildings use simple construction methods with clear spans for flexibility of movement within the building.

The development of these buildings has followed technological progress and started in the early 1950's in Malaysia. This was successful because with improvements in jointing techniques using long spanning trusses, computer structural analysis has made long span buildings cheaper and simpler to built. The buildings are generally long and narrow in shape, the width being dictated by natural day lighting requirements, with large overhangs on both sides to provide shade and keep rain water away. Floor plans are generally 15.0 - 20.0 metres wide and building height ranges from 5.0 - 6.0 metres for feasible movements of fork lifts or trucks within the building. Below are the construction details of important examples of timber-built industrial buildings in Malaysia.

Kayu Sedia Sdn. Bhd., Federal Territory

Timber industrial buildings for sawmills were constructed with simple, either pitched or curved, roofs. This can be seen at Kayu Sedia Sdn. Bhd., Kuala Lumpur which was built in 1954, with a curved roof form using the bowstring truss which is an attractive structural form, using small sections of material to achieve a long span structure. (See Plate 1.66).

The building is a simple industrial sawmill building consisting of six bays, each 2.40 metres long and 17.60 metres wide spanned by bowstring trusses. (See Plates 1.67 and 1.68). Hardwood columns 150 x 150 mm are rigidly connected to the trusses and their bases. This rigid frame transfers lateral wind forces.

Because glued laminated beams were not introduced in Malaysia until the 1960s (Tan, 1994 : p. 696), the bowstring curve roof was formed by nailing top chord members 20 x 100 mm into several layers to form segments. Purlin members 30 x 50 mm spaced 450 mm apart support the corrugated roof sheeting.

Plate 1.66
Kayu Sedia Sdn. Bhd.
Off Jalan Sungai Besi,
Kuala Lumpur. View of
main sawmill building.

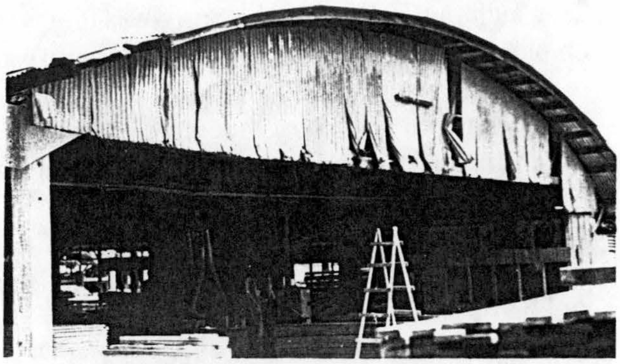


Plate 1.67
Detail of bowstring trusses.
Twin top chord members
20 x 100 mm are nailed
together in several layers
to form the segmental curve
of the truss.

Plate 1.68
Detail of bottom chords
connected to 50 x 150 mm
solid hardwood timber column.
To strengthen the jointing,
mild steel gusset plates 4 mm
thick connected using M 20
bolts are used.

General Lumber Fabricators and Builder Sdn. Bhd., Selangor

This building, designed by Yong Kee Hing, was constructed in 1989 and employed a prefabricated Gang-nails truss system. The floor plan consists of a rectangular shape, 18.20 x 6.0 metres with a grid system which used a butterfly roof form with a slope of 4 degrees. The structural system provides for expansion and additional space in the future if required. (See Plate 1.69).

All "kempas" hardwood columns consist of two members 400 x 200 mm to form spaced columns. The base of the columns are encased in a concrete pad and tied to the footings. The height of the columns reached to the level of the tie beams and roof truss at 6.0 metres for access of fork lifts and trucks within the building. (See Plate 1.70). The structural system consists of truss girders and knee braces to strengthen the columns with the roof framing. The roof framing has diagonal braced intervals on each bay for the stability of the whole structure. All the roof members were jointed using steel plates with nails spread evenly, allowing for distribution of the load over the area of the plate. (See Plates 1.71 and 1.72).

Plate 1.69
General Lumber Fabricators and Builders, Jalan Pandamaran, Selangor. View of the fabricator shed.The grid system used column 150 X 50 mm spaced by 200 x 50 mm timber blocks 1200 mm apart. They are connected using M12 bolts and nuts.

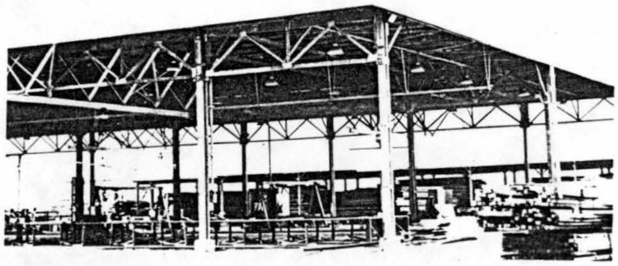
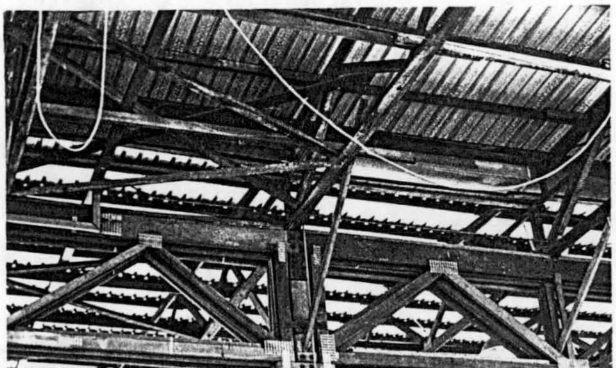


Plate 1.70
Detail of girders.
Girders are supported by timber blocks fixed to the columns, connected by 6 mm thick nail plate. All members consist of two smaller timbers for economical purposes.



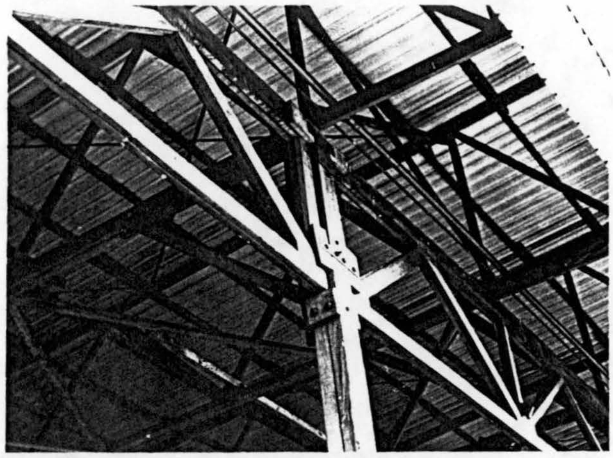


Plate 1.71
Detail of intermediate column. Two 150 x 50 mm hardwood timbers, spliced together to form a solid piece of column, are connected by M12 bolts and nuts. The roof was braced from lateral movement using tensile rods at each bay interval.

Plate 1.72
Detail of intermediate column. Two 150 x 50 mm hardwood columns support girders, connected using M 12 bolts and nuts.

FRIM's Experimental Space Frame Timber Structure, Selangor

The use of three-dimensional structural systems in building is a recent development which has derived from progress in jointing techniques. In conventional two-dimensional structures such as roof trusses or portal frames, the elements lie in the same plane and can only resist loads in that plane. With a three-dimensional structure, loads are spread in all directions and forces are balanced out. The peak loads diminish, therefore inner stresses are reduced and cross sections of compression and tension members are decreased. As a result, less material with less weight is required.

The development of this structural system can be seen at the Forest Research Institute of Malaysia where in 1989, an experimental shed for a motorbike parking space was built for this purpose. (See Plates 1.73 and 1.74). Space frame structures provide a more economic solution where reused off-cut timber can be used to construct roof members. This form of construction provides another feasible solution for long span structures and illustrates versatility, strength and potential for industrialised prefabrication.

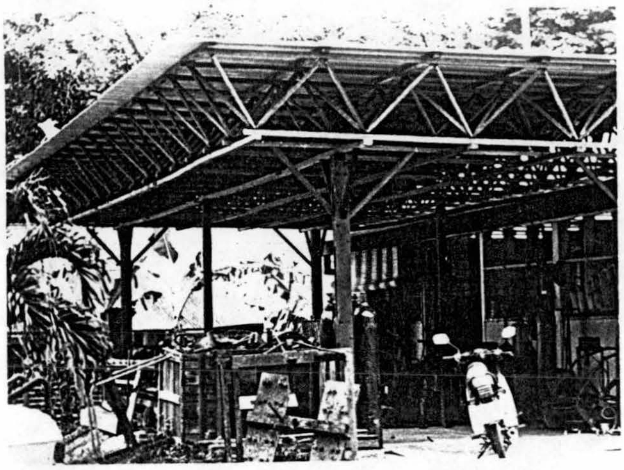


Plate 1.73
View of motorbike shed at Forest Research Institute of Malaysia.

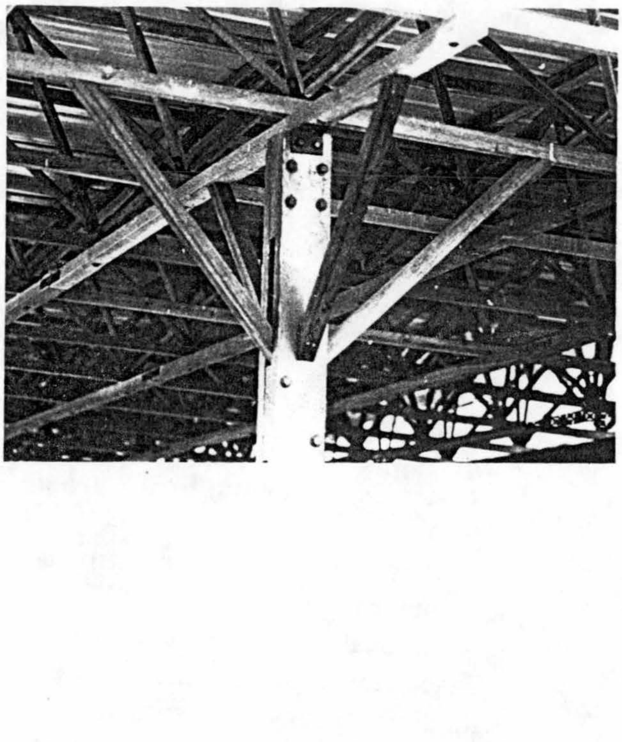


Plate 1.74
Detail of column.
The column consists of two timber members 150 x 50 mm spaced 600 mm apart by a timber block 100 x 50 mm and connected using M 12 bolts and nuts. The corner of the upper chords is supported by 50 x 50 mm knee braces in four directions, connected to the column.

CHAPTER 2

Technical Influences on the Construction of Malaysian Buildings

Chapter 2 Technical Influences on the Construction of Malaysian Buildings

The majority of the buildings discussed and illustrated in the previous chapter represent the various forms and manifestations of timber frame construction; predominantly post and beam construction. This chapter will discuss the relationship between construction and structural systems with an overview of the technical influences on construction associated with connections and joints for structural timber.

Eighteen case studies have been selected after the fieldwork completed to describe the comparison of their respective construction and structural system Each case study provides a description of architectural influences on the building construction, detailing and jointing systems.

2.1 History of Technological Changes in Timber Construction

The earliest evidence for human occupation on the Malaysian Peninsular dates to the Late Pleistocene, around 20,000 years ago (Tan , 1994 . p. 12; Loewenstein, 1956 . p 5). Undoubtedly, these early inhabitants created simple and crude shelters from the most available source, wood. However, such simple structures require little or no technology. The development of timber structures and construction is a direct result of the technological development of the relevant tools. While the refinement of stone tools allowed for the manufacture of other artifacts, it was not until the introduction of metal tools that the complex use of timber could be fully realised In the absence of timber structures, archaeologists deduce a knowledge and skill of timber construction techniques from the presence of tools associated with timber working.

The earliest evidence for the construction of shelters dates from the Bronze Age with the discovery of socketed bronze celts and adzes in Perak, Selangor, Negeri Sembilan and Kelantan (Loewenstein, 1956 · p. 5) (See Figure 2.1). Excavations in 1988 at Lenggong, Perak, uncovered pottery and a bronze axe, radio carbon dated to approximately 4920 years b.p., which also correspond to the early Bronze Age of Malaysia (Khoo, 1987 (c) : p. 41). At "Gua Cha", Kelantan, assemblages containing adzes have been found, dated to around 3000 years b p (Bellwood, 1992 : p. 101) The earliest stone tools were held in the hand but gradually ways of protecting the hand from sharp edges on the stone were introduced by wrapping one end with grass or using a wooden handle Bronze and iron adzes and celts were made to be halfted onto a wooden handle. Very little change has occurred in the form of the commoner tools; for example, hammers, axes and saws very similar to the ancient forms are in use today The axe has been, for a long time, the commonest cutting tool with a continuous history extending over 10,000 years and continues to be used, with minor improvements, by carpenters today (Goodman, 1978 . p 8) .

Sieveking (1956 · p 96) recorded that in Kelantan, East Coast, socketed axes were used in the Malayan Iron Age These tools are distinguished by their strength and heavy construction for cutting trees. (See Figure 2.2). The use of large trunks as uprights is found in the pole and frame construction of the long house in Sarawak (Freeman, 1970·: p.112).

Anthropologist Waterson's (1990 : p. 75) study of South East Asia indigenous societies has revealed that the existence of many forms of social structure is reflected directly in their buildings. For example, the techniques of the shipbuilder influenced houses, as the methods of building a wooden boat with different kinds of edge joining such as dowel, rebated, bevelled, mortise and tenon joints were adopted by carpenters for domestic architecture can be seen in traditional Malay jointing systems.

Gibbs (1987 : p. 22) described the analogies between Malay houses and boats, for example, the word for the posts of the house is "tiang", which is also the word for the mast of a boat. The word for flooring is "lantai", which is also used for the flooring at the bottom of boat.

In early times, timber would have been used only in log form but with the invention of tools logs were converted to useful forms and shapes. Timber is a comparatively soft material to work with and was used as a media for artistic expression Below are descriptions of different types of tools, some which have been found by archeologists, which are associated with carpentry or being used by carpenters

Figure 2 1 **Adze**
An axe-like tool used for rough-dressing wood, also used in ship building The slightly curved cutting blade is at right angles to the handle, and the tool is used by standing on the timber and swinging the tool down toward on to the top surface of the wood
Source : after Sieveking, 1956 : p. 106

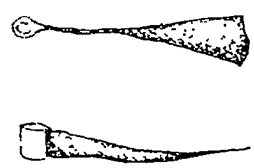


Figure 2.2 **Axe**
Axes were used in the Iron Age of Malaysia (Sieveking, 1956 : p. 99) for chopping, cleaning or splitting wood. This axe would have been useful to carpenters and shipwrights to trim mortises and edges of boards. Common types measure from 355 - 406 mm with 457 mm long and handles are 915 mm long.
Source . after Loewenstein , 1956 · p. 10

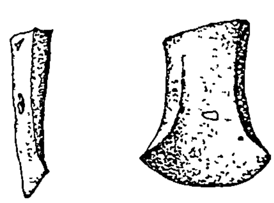


Figure 2 3 **Ink pot** .
Ink pot with inking line consisting of a piece of string up to 30 metres long wound around a spindle The spindle is mounted on a wooden container where the end string comes at the front of the instrument The string is dipped in a black ink and then extended between two points which indicate the distance to be measured so that it leaves a line mark
Source after Raja Ahmad Shah, 1988 p 43

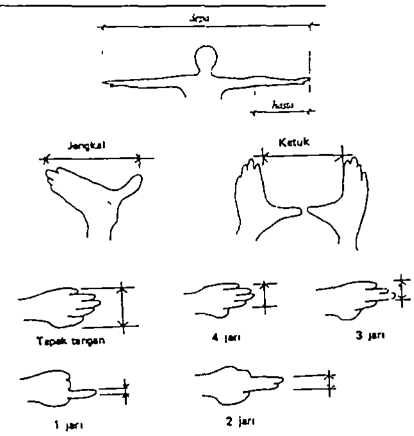


Figure 2 4 **Human proportions**
Human proportions acts as measures using fingers, palms and fore-arm. Basic dimensions are "depa", "hasta", "jengkal", "ketuk", "tapak tangan", "dua jari", "tiga jari" and "empat jari". (See Glossary). Using this system, the measurements are not standardised but changed from one person to another.
Source . after Raja Ahmad Shah, 1988 : p. 43

Figure 2 5 **Auger**
The oldest construction of the auger was used by shipwrights and is very commonly used in Malaysia A T-shaped long twist, hard-boring tool for drilling large holes. Normal length ranges from 508 - 635 mm, the cutting diameter being from 12 - 51 mm. The steel bit is driven into wood by slowly turning the handle at the top.
Source . after Gibbs, 1987 : p. 72

Figure 2.6 **Tenon-cutting or plug**
It is evident that plug bits were used as bits because the shanks are tapered to fit a brace. This tool has two metal cutters with the sharpened edges parallel to the opening and only cut with a clockwise motion. The bits cut wood to produce the round tenon or dowel.
Source · after Hummel, 1976 : p. 62

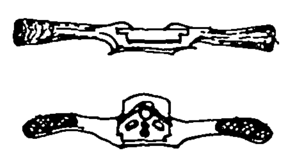


Figure 2.7 **Scraper**
Used by carpenters for cleaning wood with hard or soft grains. The thumbscrew at the back gives a slight bend to the blade so that the corners do not dig in, and at the same time gives support behind the cutting edge.
Source : after Taylor, 1990 : p. 124

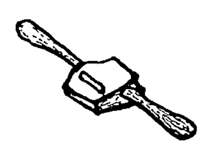


Figure 2.8 **Spoke shave**
A plane-like tool with a short bottom to permit planing of the edges of cut-out pieces of wood and also used to dress rounded pieces. It has two handles, one on either side of the cutting blade. The bottom is either flat for use on cut-out pieces with long sweeping curves, or convex for use on pieces with short sweeping curves.
Source : after Taylor, 1990 : p. 126

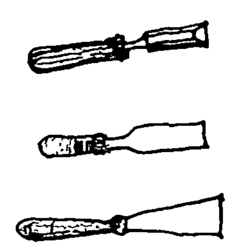


Figure 2.9 **Mortise chisels**
The earliest metal tools of copper and bronze had a similar form and were used without handles. The technique of casting socketed weapons and tools developed, and these methods were applied to chisels. The chisel is made in various forms which have flat blades with parallel sides. Butt chisels have shorter blades and are used for making mortises The hook shape mortise chisel has cutting edges for making a hole into a square Normally, mortises and haunches can be cut by reversing the wood and cutting from both sides. Mortise chisels cut rectangular holes into which tenons are fitted
Source after Hummel, 1976 · p. 67

Figure 2.10 **Files**
Files can have both concave and convex surfaces and are used to smooth rough surfaces. A riffler is used for acute concave shapes and holes.
Source : after Taylor, 1990 : p 66

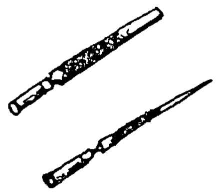


Figure 2.11 **Mortise gauge**
A tool having a steel cutter held with a wedge, used to make the marks for cutting thin wood. It is suitable for marking across the grain. In this manner, for example, a carpenter could insure the correct depth of cut for a dovetail joint.
Source : after Taylor, 1990 : p. 66

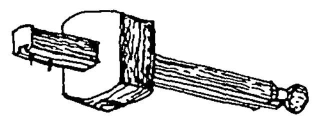


Figure 2.12 **Jack plane**
The development of the plane occurred during the 19th century after the double iron had been invented by an English carpenter. It was introduced to Malaysia and used by local carpenters. It is a portable smoothing tool for dressing rough timber, with a angled blade 50 mm wide which can be adjusted for cutting. This tool is used for smoothing rough surfaces, shaping, rebating, routing and grooving
Source . after Chinn, 1979 : p. 66

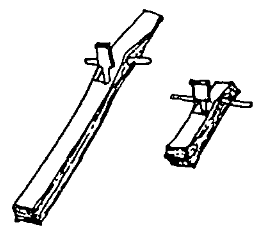


Figure 2.13 **Frame saw**
In the history of woodworking tools, Goodman (1978 : p. 10) suggested that the invention of saw dated right back to Neolithic times with the discovery of a number of flint tools with serrated edges in Palestine and Egypt. In Malaysia, the framed saw was introduced by the Dutch in the 16th century by shipwrights. The frame saw works with a reciprocating action and is used to cut board. It has a blade 508 x 38 mm wide held in tension in a frame similar to that of a bow saw
Source : after Goodman, 1978 · p. 127

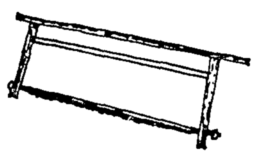


Figure 2.14 **Coping saw**
A form of fret saw in which the blade is held in tension by a metal frame. Used for cutting shapes in thin wood by turning the handle It can be held at angles in the frame enabling a cut to be made parallel with edge.
Source : after Taylor, 1990 : p 39

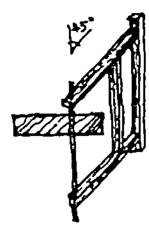
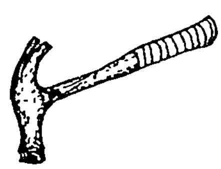


Figure 2.15 **Hammer**
Hammer is the most basic tool used by a carpenter working with wood. It has a head with a flat, round face at one end and a claw for pulling nails out at the other.
Source · after Sculler, 1973 : p. 68



2.2 Principles of Structural Systems

The principal function of the building structure is to transfer all the loads on it to the ground. The loads on the building can be split up into gravity loads, which act vertically, and lateral loads which act horizontally A structural system is created by the joint action of elements which consist of the main framework, secondary members, roof structure, stiffeners and foundations All these frameworks form a three-dimensional system to resist vertical and horizontal loads. If the structural system fails, the building will collapse The relationship between design system and the structural system is at the root of the construction's flexibility of planning, form and structure. The systems are independent in a structural sense but interdependent in a design sense as for example, option exists within each design system whatever the form of any given primary structural layout.

The indigenous and traditional Malay architecture is the post and beam structure and was based on the skeleton principle. A skeleton structure gives a clear distinction between statics and dynamics, between structure and design. The idea in such terms came naturally to the carpenters of earlier days since their minds were bound to the material, its possibilities and its limitations. Structural principles were dictated by the solid wood and gave rise to a system of infills.

The development of form from traditional buildings in Malaysia has not been one of progression Structural forms which became dominant for industrial buildings reflect changes in economic conditions. Pitched roofs using larger span trusses represent the majority of forms that have been used in Malaysian.

In timber construction, there is no arbitrary freedom of design (Nattered, 1989 : p. 79) because any natural curves or irregularities of height in the timber could be easily corrected by adjusting the purlins. Traditional built form illustrated that timber was used in simple and humble construction (Lim, 1994 : p. 4) Many of these timber buildings were outstanding in their manner of detail and structural form

A good architect depends on intuition regarding structural shapes under stress but also a rational approach to construction, regardless of the complexity of a structure. Mainstone (1983, p. 285) has suggested that there are three kinds of structural intuition : first "spatial intuition" which recognises the possibility of preventing an object from falling by means of some intervening structural member; second "muscular intuition" which draws analogies with our own sensations of pushing and pulling; and third "experiential intuition" which is based on an observation of the behaviour of materials or structures under loads He suggests that the first two of these, spatial and muscular intuition, are closely related to generated forms of trusses The third type of intuition, which depends upon experience of actual structures, is seen in the design of joints

2.3 Timber Construction Systems

Construction in building is both the act of building and the structural system, translating into reality ideas, concepts or design Construction in building is a means rather than an end. The choice of a structural system cannot be made without consideration to construction details

Construction in building is the materialisation of design which comprehends the total range of factors that determine the practical, technical, functional, environmental and spiritual design of architecture (Engel : 1989 : p. 101). If these details are compared with traditional timber construction methods used by local craftsmen, it becomes clear that major changes in technique in have been as a result of the development of steel in connections.

Construction also demonstrates architectural growth in its transformation and evolution. Architecture began as the purposeful construction of indigenous shelter and developed indirect interdependence with technical improvements For example, the Malay timber building in the past used rectangular or square sections connected by means of half lap joints, wooden pins, dovetail joints or mortise and tenon joints. The size of timbers was limited because tensile forces could be transmitted through the joint and because connections caused weakening of the timber. However, today it is possible to construct laminated beams, such as the 40 x 200 mm beams which were used to built a mosque at the Forest Research Institute Malaysia.

Framing Systems

All types of timber frames found in Malaysia are by their nature skeletal Skeletal structures are distinct in that there is a functional division between the carrying frame and other secondary finishes. The difference between masonry buildings or prefabricated reinforced concrete structures and timber frame constructions is the openness of the latter type of structure. Post and beam construction for instance creates highly open construction which is dependent on the spacing of the vertical structural members and size of the members

Both single and multistory buildings are feasible using timber skeleton framing construction where the cross sections and jointing of large timbers must be designed according to the principles of statics. Because of their general structural principles, skeletal structures are flexible in their application and forms, and with new connection techniques, have been widely used in new resort developments in Terengganu, Pahang, Perak and Kedah.

The traditional framing system based on Malay construction techniques are more economical in comparison to the contemporary approach. Traditional framing system consists of main timber members carry the roof and ceiling in bending requiring the use of big section timber. Rafters have to be closely spaced to avoid deflection or sagging. This time tested traditional Malay practices can be seen in the old mosque such as "Masjid Tua Kampung Laut", Kelantan On the other hand, the contemporary construction approach is more effective than traditional framing system For example, in examines the roof construction consist of an internally triangulated plane frame structure capable of clear span between external supports The roof and ceiling loads are converted into axial forces along the truss members, which the strength of the timber lies Therefore, in the fabrication of trusses, joint connection are very important as they must be sufficiently strong and stiff to withstand the forces in the different members meeting at the joint.

There are eight basic ways of constructing a timber frame building in Malaysia They differ in the spacing and arrangement of the load bearing members and the types of connections used. A structural system is defined by the way the horizontal, vertical or diagonal members are brought together at a point or node

Different types of timber frames offer different advantages and are very adaptable to special situations. For instance, they can be adapted to many different uses and are generally not difficult to enlarge or remodel. From the point of view of architecture, a timber frame can often express its own particular structure and retain the natural appearance of wood A special advantage such as precision assembly can be achieved by prefabricating widely used structural elements and components. The various framing systems are discussed below

Figure 2.16 **Traditional Frames**
The frame consists of columns (post, studs) and main beams. The entire building rest on concrete stumps to prevent the structure sinking into the ground. Columns are tenoned into mortises in the sills. The distance between the columns is kept as short as is necessary (not more than 3 metres apart) to carry loads. The weakening of members caused by mortises and notches is compensated for by larger solid cross section hardwood timber members. Traditional Malay building construction is a typical example using this method of framing system.

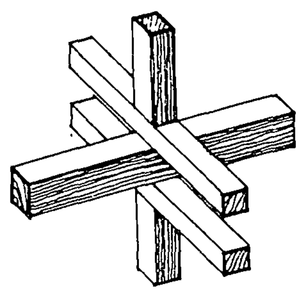


Figure 2.17 **Post and Beam, Single Storey**
The frame consists of posts on which rest parallel bearers; secondary bearers are placed on to them. If the bearing surface is not sufficient to transfer the load, bearing areas must be increased by means of steel plates or angles. An advantage of such a structure is the potential for longer spans by using trusses or larger bearers. This type of construction was used by designers of the "Tanjung Jara Hotel/Rantau Abang Visitors Centre" structure discussed earlier.

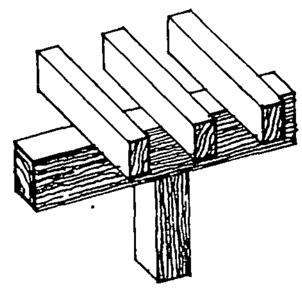


Figure 2.18 **Post and Beam, Two Storey**
Connection bearers rest on columns; columns are interrupted by the bearer; but are set up again on the next floor. Connection between bearers and columns can be made in various ways. Normally the load from the upper column is not transferred to the lower one through the bearer, because compression in the bearer might be exceeded. Again, it is necessary to use steel or timber gussets for this purpose, an example of which can be found in "Club Mediterranean Resort" structure

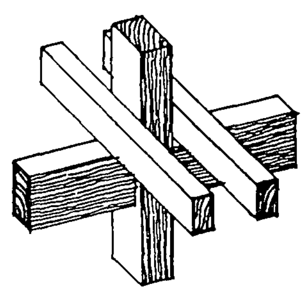
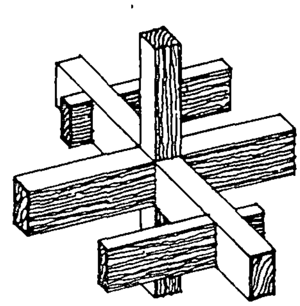


Figure 2 19 **Tie Beam Construction**
The bearers act as tie beams between the continuous posts with identical details in all directions. All interior and exterior connections occur on the same level. The joists in the adjacent floor panels span in alternate directions in such a way as to equally load the bearers. The disadvantage of this system is that it is not able to cantilever a structure away from the building Tie beam framing can accommodate prefabrication systems, therefore



it is economical for resort structures having a number of repeated units, such as those at "Delima Resort Langkawi" or "Langkawi Island Resort".

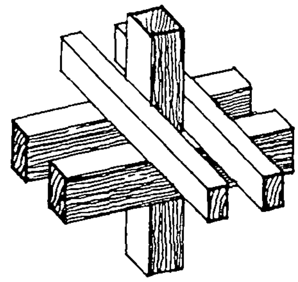


Figure 2.20 **Twin-Girder Framing**
Continuous twin bearers span between continuous columns and are attached to their sides, The advantage of this system is that both columns and bearers are continuous. A hallmark of this construction are the protruding ends of twin bearers, necessary in most cases due to the distance required between connections to the post and the end of bearers. This construction is the basis of pole frame construction for the long houses in Sarawak.

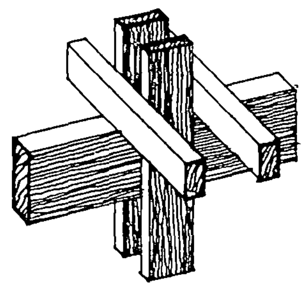


Figure 2.21 **Split Column Framing**
Continuous bearers are fixed between continuous split columns. Twin column structure layout is a reversal of twin girder framing type. Quadruple split columns allow a two-way layout of girders. Split columns are especially suitable for long span structures found in industrial building, such as the General Lumber Prefabrication and Builders Factory, Selangor.

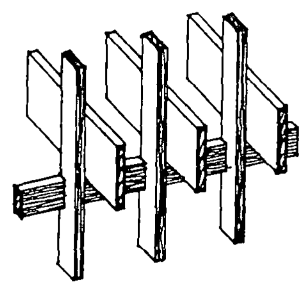
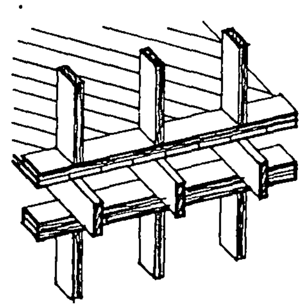


Figure 2.22 **Rib/Stud/Balloon or Platform Framing**
This type of construction is used in many parts of the world. The load carrying members generally consist of standard timber studs placed a relatively short distance apart. The studs carry sheathing on one or both sides, which takes some load and provides much of the stiffening. This framing system represents the transition between skeleton and panel framing.



In balloon construction. the wall studs continue through all the floors Uprights planks are cut into the studs as sills at every floor and the joists resting on them are nailed into the studs.

In platform construction. a continuous timber plate is fixed on top of the wall studs, the joists of the next floor rest on the plate and a deck is laid on the joists to form a new platform.

2.4 Connections and Joints

Developments in jointing capacity and the structural determination of various building forms reflect the technical innovations of timber as a building material. In Malaysia, the technology for the principal structural forms, arrived from overseas. Each form with its dependent jointing types, was adapted and modified to satisfy Malaysian timbers and conditions.

Timber jointing is the fastening together of two or more pieces of timber, using fasteners such as nails, bolts and connectors (Chu, 1987 : p. 1). These types of mechanical joints were introduced with European timber technology from the 16th century (Mettem and Richen, 1991 : p. 66). Other methods using structural glues as jointing media produce finger joints, scarf joints and lap joints, and are recent innovations

Traditionally, connections have consisted of a multitude of hand-cut details which have been developed by craftsmen through centuries of experience working with timber Throughout South East Asia in particular, these hand-cut details have been carefully adapted to the intricate characteristics of wood and reflect an understanding of wood technology and material behaviour

In traditional forms of timber joints, the performance of the connections normally relies upon bearing with occasional tie members being pegged or dowelled into place, usually with wooden dowels These traditional timber connections include, for example, notched joints which allow skewed connection members, lap joints which allow structural connection of timbers within the same plane, and mortise and tenon joints which serve to secure the adjacent faces of two timber members, such as to secure compression members against structural movement (Lim, 1994 . p 4.).

The jointing together of timber members plays a very important role in the construction of a timber in a building Joints and connections are usually required to transfer loads within a structure from one member to the other and then through the structure to the foundation. The load carrying capacity of any timber structure is controlled by the strength of the timber members and the strength of the fastener. Timber joints have very often been the weak point in timber construction, therefore careful consideration should be given to the design of joints to ensure the strength and stability of a structure. A structure also depends heavily on the fastening that fixes different parts together against rotation and vertical movement which exist between structural elements.

2.5 Case Studies of Malaysian Timber Architecture : A Comparison of Construction and Structural Systems

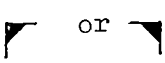
This section contains documentation of 18 wooden Malaysian buildings with a comparison of their respective construction and structural systems. Each case study provides a description of the building's structural behaviour with a load path diagram indicating the structural influence on architectural design. The ethnic influences of each individual period sources from published information and personal observation are analysed. The influence and general theoretical approach of each period, background and trends are also presented. Analysis was carried out based on the architectural characteristics of individual buildings which have a direct relevance to the specifically defined construction principles.

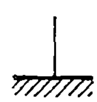
The subject of each case study was selected according to their different principal structural forms. Each building form is examined in its construction detailing and jointing systems. The buildings were selected based on the following criteria :

- Structures that were historically unique or had historical interest.
- Different structural technologies.
- Geographical locations of the structures.

The individual building analysis is presented in a short written form complemented by graphic presentation giving details of the dimensions, the principles of construction and the material used. The graphic presentation has allowed a reduction in the written analysis for the purposes of clarity.

Each case study is analyse with a load path diagram to give an understanding on structural form and structural behaviour It is important that structural understanding can play as an active influences in architectural design. The load path diagrame was represented by the following symbol .

Rigid frame 

Rigid joint 

Flexible joint O

Case Study 2.5.1

Name : Tungku's Longhouse, Sungai Tiau, Sarawak

Date Constructed : 1922

Influences : This longhouse, built on piles, is an ancient feature of Southeast Asian architecture, which has its cultural influences from the Austronesian (Bellwood, 1979 . p. 46). There is virtually no limit to the number of units and function dictated the spacing of the structural system. The structural frame consists of a solid piece of tree trunk, trimmed to the required height to support the central roof beam. Poles are erected from a simple arrangement of different parts for the needs of functional requirements. As wind load is negligible in this location and this is a temporary structure, diagonal bracing is not required.

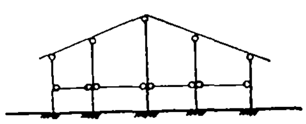
Structural System : Pole and frame

Analysis : The use of pole structure spaced at 4.0 metres centres each way with light wall and roof framing tied at the post using rattan. The poles are set in filled holes, which provide lateral resistance of the soil to resist lateral loads from the structure. Poles are extended up through the longhouse to support the roof directly. In this type of platform construction , the top of the poles are frequently notched to provide beam seats Horizontal beams are tied at the poles with rattan. Triangular or diagonal bracing is not used, so that structural stability depends entirely on precise joinery and careful alignment. Jointing system based on mortising and rebating with wooden wedges fit together. Therefore, the longhouse can be dismantled and resembled on new site

Sources :

- Freeman. 1970 . p. 3

Figure 2 23
Load path diagram



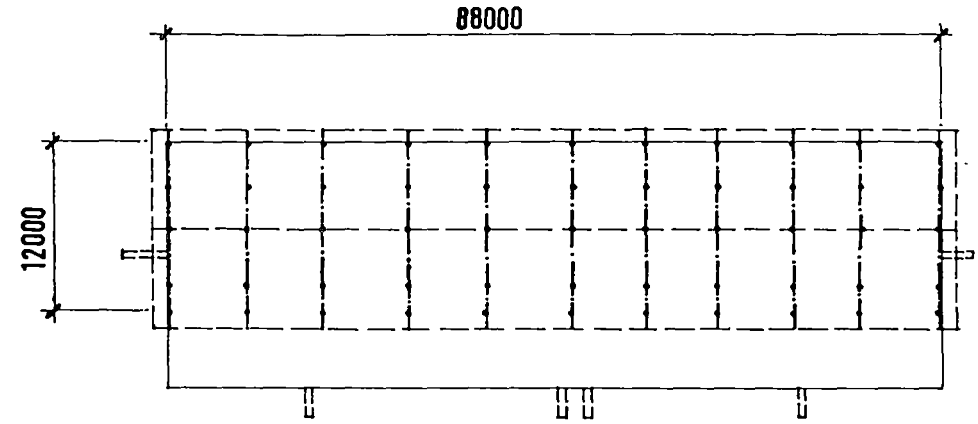


Figure 2.24
Floor framing plan

1	100 mm diameter hardwood purlin
2	120 mm diameter hardwood rafter
3	150 mm diameter hardwood tie beam
4	200 mm diameter hardwood post
5	half round bamboo floor tied with rattan into floor joists
6	100 mm diameter hardwood half round floor joists
7	150 mm diameter hardwood bearer
8	150 x 75 mm corbel

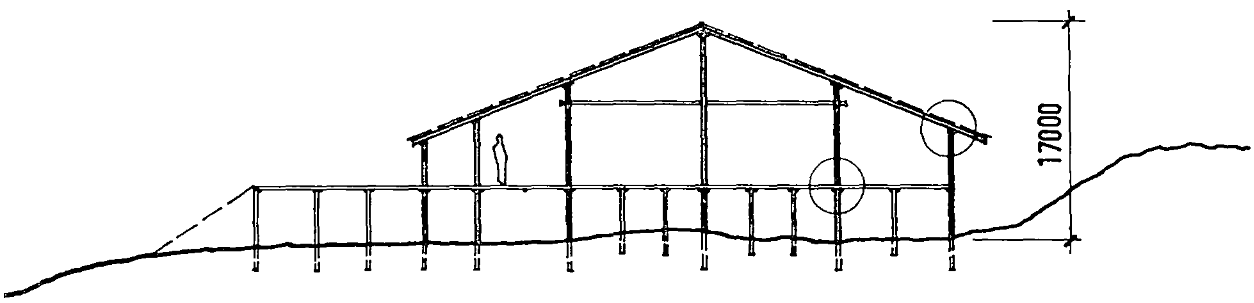


Figure 2 25
Section

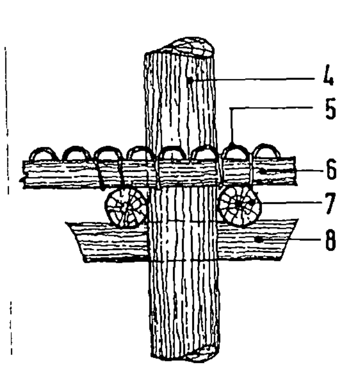


Figure 2 26
Detail of floor construction

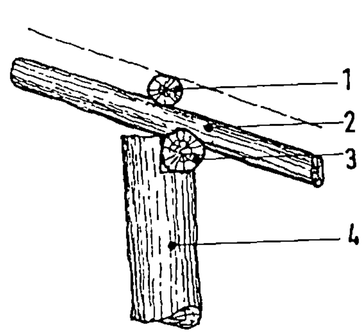


Figure 2.27
Detail of eaves

Case Study 2.5.2

Name : "Rumah Penghulu Mohamed Natar", Merlimau, Malacca

Builders : Manaf Bobeng, Mahmud Kelantan, Pendek Pendekar

Owner : Penghulu Mohamed Natar

Date Constructed : 1894

Influences : The design was based on old Malaccan traditional houses and showed considerable Chinese influence, both in terms of building form and use of colour. In this house, the extent of this influence was more than usual on account of the owner's partnership with a Chinese businessman. The main staircase was decorated with the richly coloured glazed tiles often found in Chinese architecture. Concrete entrance stairs have replaced the traditional timber steps. This Malaccan house contained a "short anjung" (reception area) and a "rumah induk" (main house) with two rooms, a "loteng" (attic) and a "rumah dapor" (kitchen) at the rear. A feature common to all Malaccan and Minangkabau houses of Negeri Sembilan is an attic in the roof space used for storage purposes. Both sides of the roof gable are closed by a "tebar layar" (fascia board). (See Plates 2.1 and 1.2.2). The houses usually follow a proportion of 1/2:1.1 between the raised portion on concrete stumps, the main body of the house and the roof respectively. The house was raised on concrete stumps at 1.20 metres high, to avoid water penetration and damage to the timber (See Plate 2.3).

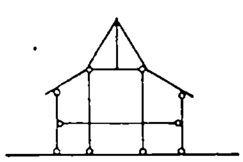
Structural System : Post and beam

Analysis : The design of this house is enhanced by simple construction, careful detailing and a spatial form determined by woodwork. Timber framing consists of 120 x 120 mm columns, 100 x 100 mm tie beams and 100 x 75 mm rafters, all made from "chengal" hardwood. Rafters rest on columns with span lengths of 2 30 metres. The king post acted as a tension member and supported tie beams

Source :

- Measured Drawing Studies, Department of Architecture, University of Technology Malaysia.

Figure 2.28
Load path diagram



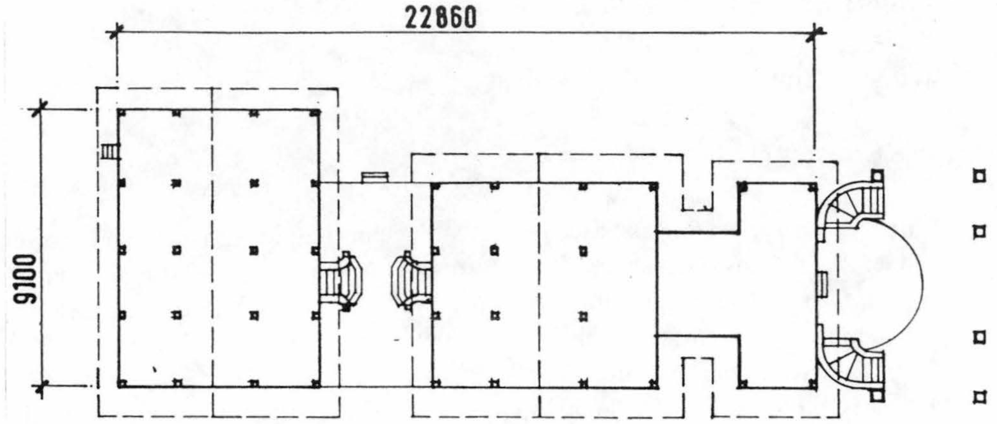


Figure 2.29
Floor plan of a Malacca House

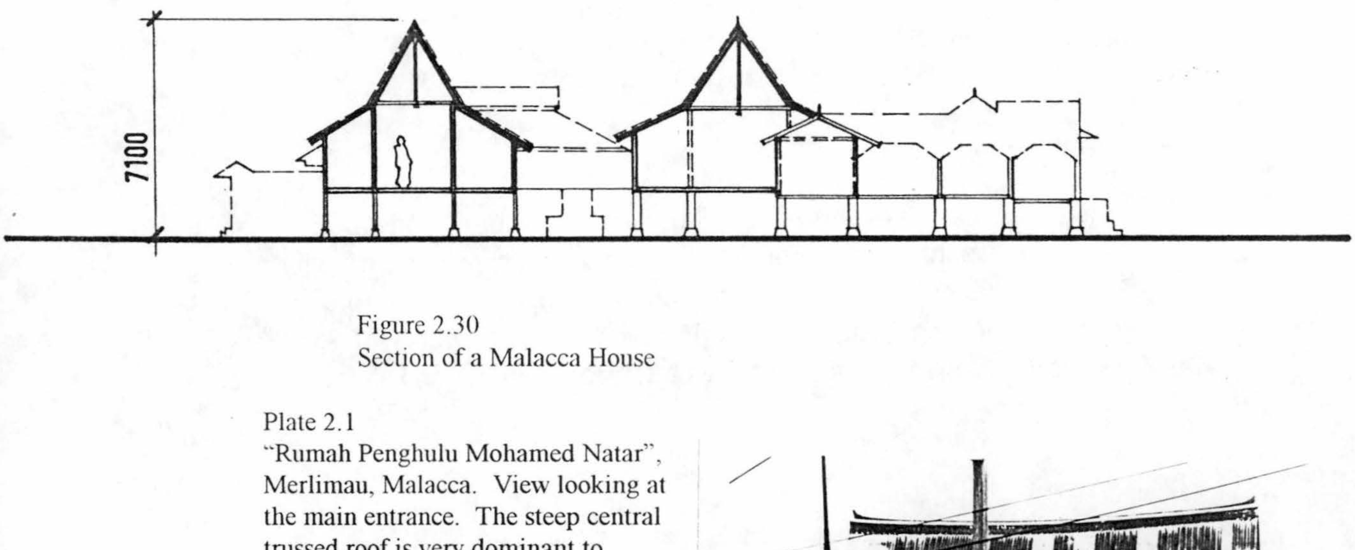


Figure 2.30
Section of a Malacca House

Plate 2.1
"Rumah Penghulu Mohamed Natar", Merlimau, Malacca. View looking at the main entrance. The steep central trussed roof is very dominant to accommodate attic space.

Plate 2.2
The gable of this type of roof often slants outwards at 600 mm from the walls. Ventilation holes in the gable-end will be small since they are protected from the rain by the overhang. There is a small gap between the timber and roof covering at the edges.

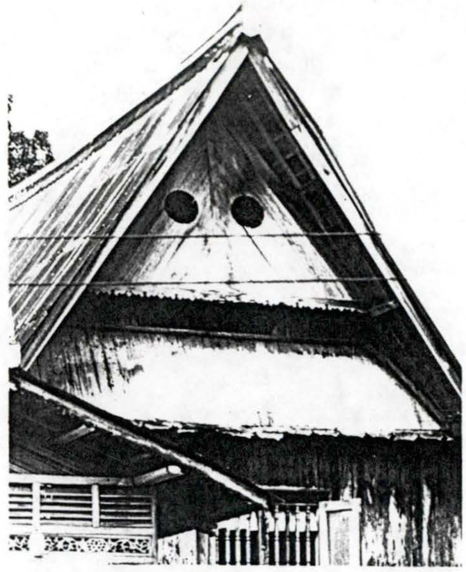


Plate 2.3
Detail of floor construction. The floor beams and corner post are inserted into place and rest on a concrete footing.

Plate 2.4
Detail of capital of the main column (tiang seri), the first column to be raised on the site, made of "chengal" hardwood. The capital was carved and painted with floral elements.

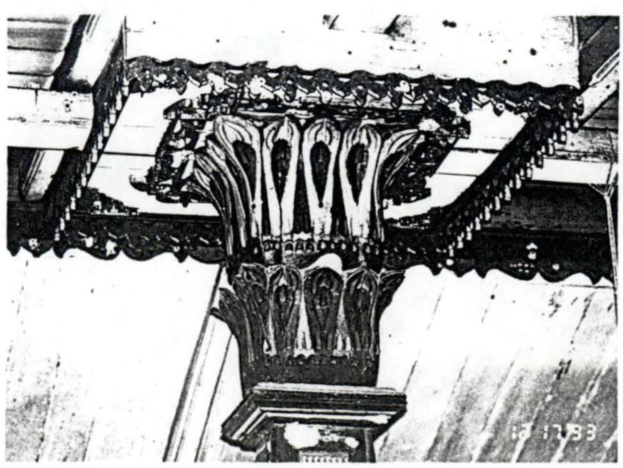


Plate 2.5
Detail of a corner column.
The structural column was carved at the capital with three layers of elements. There has been, for centuries, a tradition that Malay wood carvers used on building inspired by the pattern of leaves and branches of local trees.

Case Study 2.5.3

Name : Air Keroh Information Centre, Air Keroh, Malacca

Architect : "Cawangan Arkitek, Jabatan Kerja Raya", Malacca

Owner : Air Keroh Information Centre

Date Constructed : 1989

Influences : Traditional Malacca house with pointed high-pitched roof form which dictates the use of attic space under the roof. The building form has been developed from a simple king post to a scissor truss for the larger span

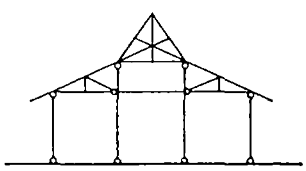
Structural System : Post and beam

Analysis : The frame consists of scissor trusses which rest on top of and are fixed to the columns by means of steel plates and bolts. Posts are erected from the footing, bearers and the floor joists are continuous. The floor joists 125 x 75 mm spaced at 600 mm centres are supported on the bearers 200 x 100 mm which rest on the posts. Framing connectors are nailed to the sides of the bearers and are designed to carry the floor joists Lateral bracing of the trusses is provided by internal walls. Wind loads and horizontal buckling loads from trusses are transferred to the posts and transmitted to the footings.

Source :

- "Cawangan Arkitek, Jabatan Kerja Raya", Malacca

Figure 2.31
Load path diagram



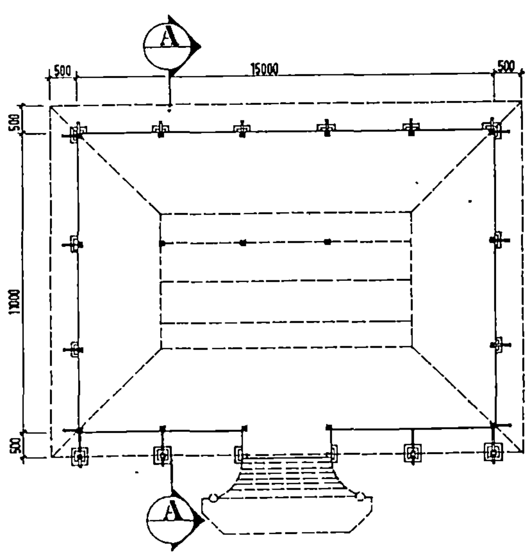


Figure 2.32
Floor plan

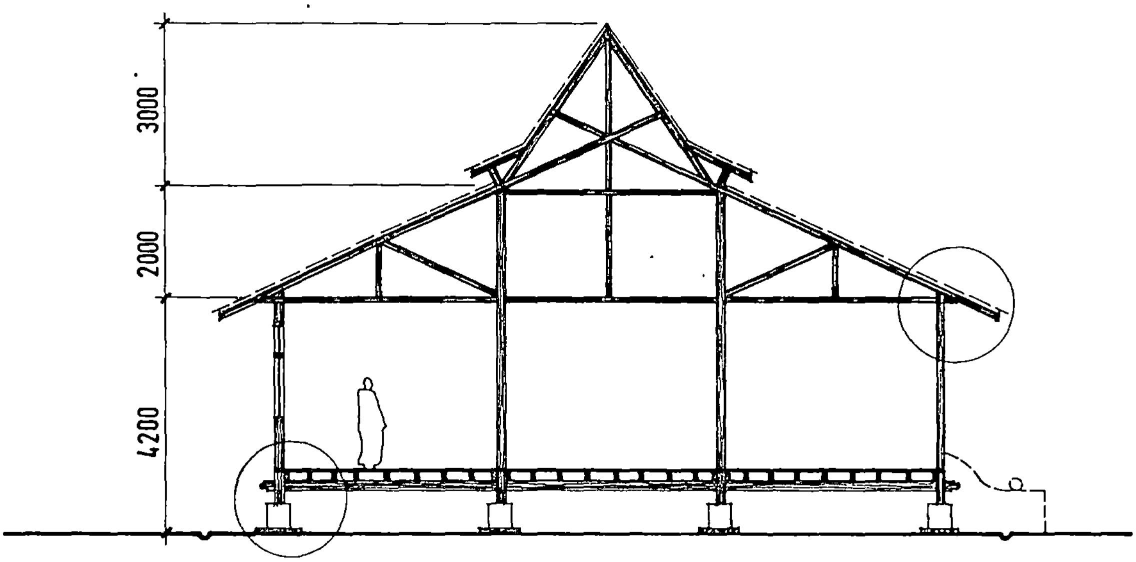


Figure 2 33
Section

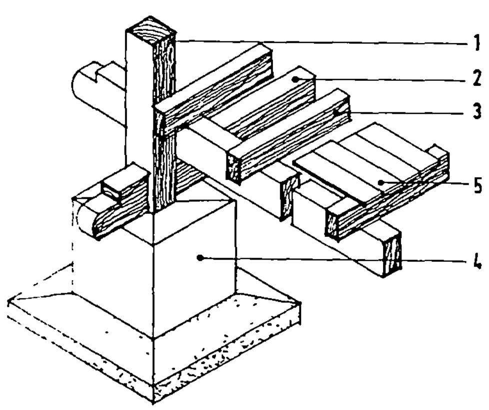


Figure 2.34
Detail of floor construction

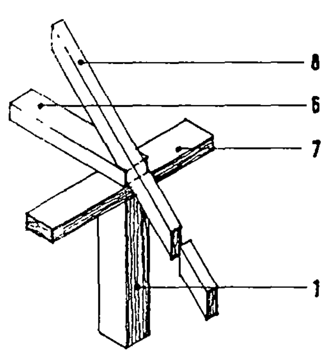


Figure 2 35
Detail of eaves

1	150 x 150 mm "chengal" hardwood post
2	200 x 100 mm hardwood bearer
3	125 x 75 mm hardwood floor joist at 600 mm centres
4	500 x 500 x 600 mm high pier rest on 900 x 900 x 100 mm thick concrete base
5	150 x 25 mm "resak" hardwood tongue and groove timber board
6	150 x 75 mm "resak" hardwood tie beam
7	150 x 50 mm "resak" hardwood wall plate
8	150 x 75 mm "resak" hardwood rafter at 1000 mm centre to centre

Case Study 2.5.4

Name : "Rumah Pak Ali", 61/4 Miles, Gombak, Kuala Lumpur

Owner : Mohd Ali and Hajjah Maimunah binti Haji Abbas

Date Constructed : 1917

Influences : A typical Malay house boasts a strong Minangkabau influence attained from the early settlers of Selangor district who were from Sumatra The unique roof of the house was constructed and derived from "bumbung panjang Minangkabau" (long Minangkabau roof), using "attap" tiles, in a terraced form to provide proper air circulation.

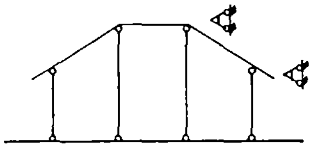
Structural System : Post and beam

Analysis : This traditional construction method requires a large amount of timber. Timber members are jointed by wooden pegs and mortise and tenon. The load bearing framework consists of square hardwood posts of 150 x 150 mm and bearers 120 x 75 mm. Posts are arranged in a grid system where bearers run in one direction between columns and are inserted into posts Posts rest on concrete stumps. Internal walls also act as secondary bracing.

Source :

- Measured Drawing Studies, Department of Architecture, University of Technology Malaysia

Figure 2.36
Load path diagram



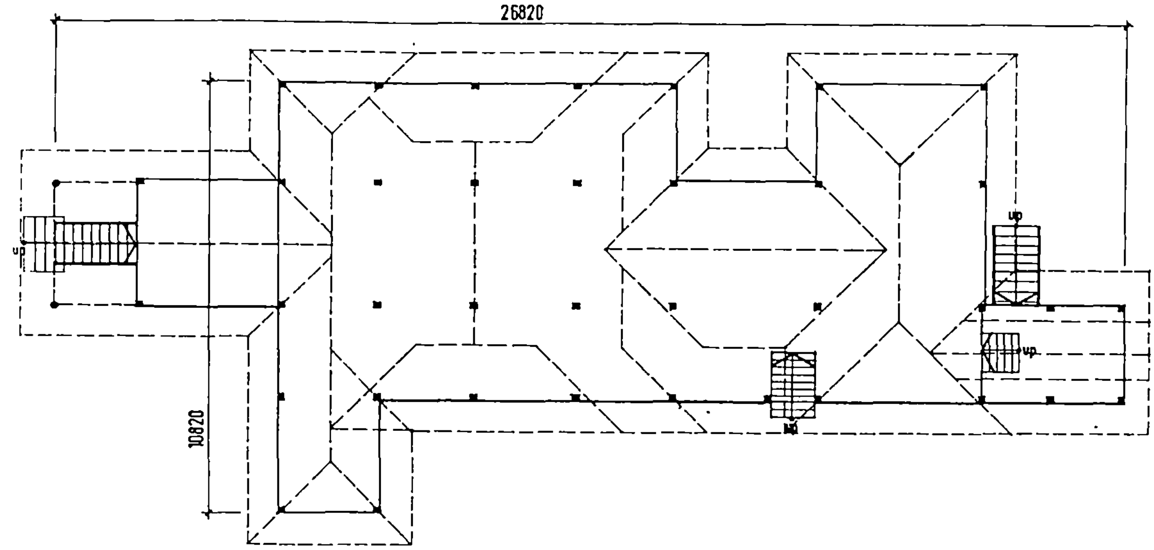


Figure 2.37
Floor plan

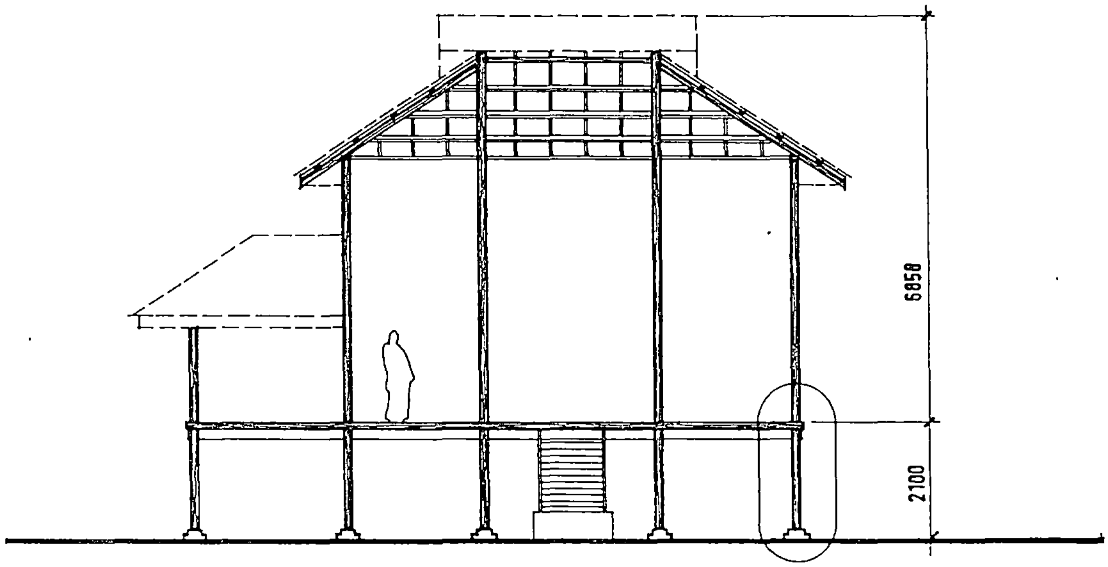
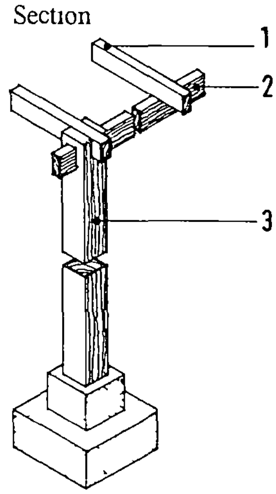


Figure 2 38
Section



1 90 x 75 mm "chengal" hardwood floor joist at 450 mm centres.
2 120 x 75 mm "chengal" hardwood bearers
3 150 x 150 mm "chengal" hardwood post
4 240 x 240 x 200 mm concrete base

Figure 2 39
Detail of floor construction

Case Study 2.5.5

Name : "Rumah Haji Su", Kampong Losong Haji Su, Kuala Terengganu

Owner : Haji Awang

Date Constructed : 1908

Influences : Stilt type houses were built in areas that were never flooded. They were found throughout the Malaysian peninsula, as well as Thailand and rural areas of Cambodia and Laos. They provided evidence for a theory that the traditional Malay house may be of Khmer origin.

Structural System : Post and Beam

Analysis : Timber frame consists of continuous posts of 150 x 150 mm "chengal" hardwood and floor joists of 90 x 75 mm spaced at 450 mm centre to centre. The posts are erected from the ground and transferal of forces occur through direct timber contact. The basic structural system consists of cross-shaped column nodes The floor joists are inserted into posts and tighten by wedges. Corrugated roof sheeting acts as roof bracing. Horizontal wind loads are transmitted to the foundations by means of internal wall panels.

Source :

- Measured Drawing Studies, Department of Architecture, University of Technology Malaysia

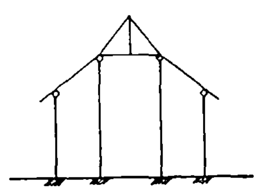


Figure 2.40
Load path diagram

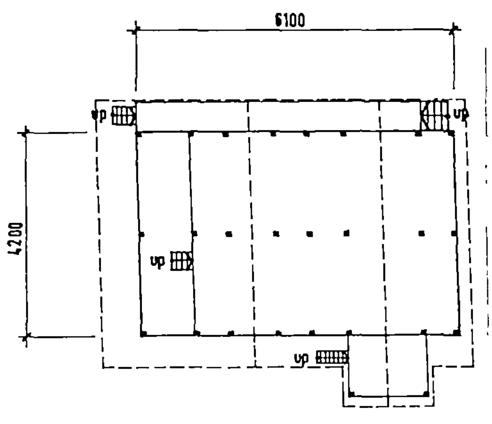


Figure 2 41
Floor plan

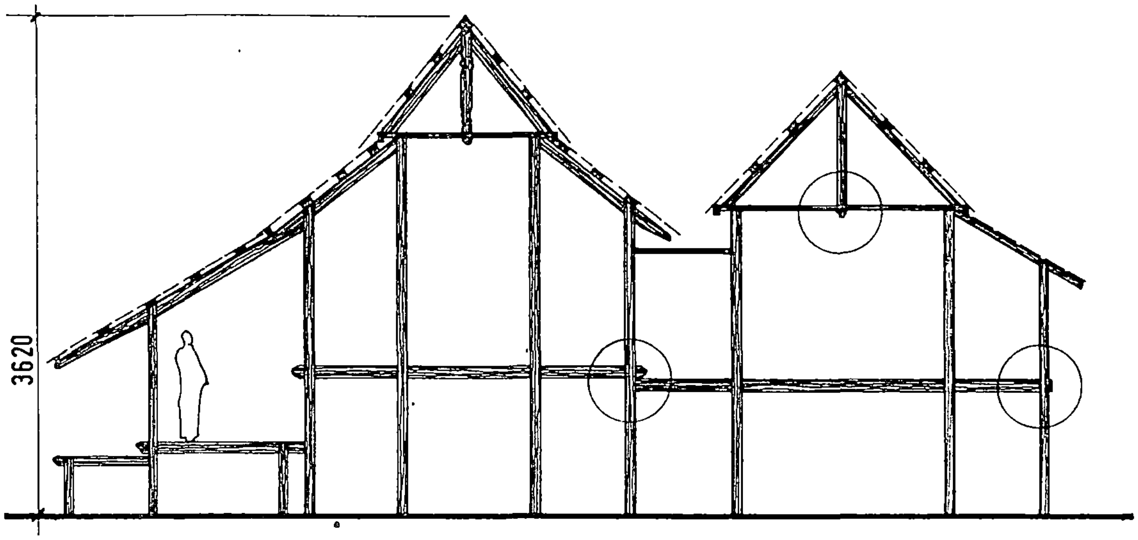


Figure 2 42
Section

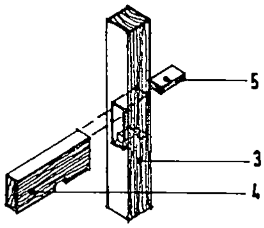


Figure 2 43
Detail of post connection

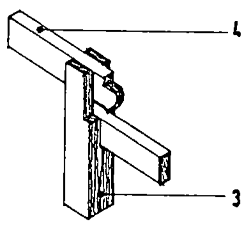


Figure 2.44
Detail of bearers connection

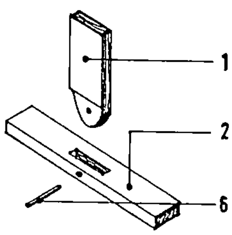


Figure 2 45
Detail of tie-beam

1 90 x 50 mm "chengal" hardwood king post
2 100 x 50 mm "chengal" hardwood tie beam
3 150 x 150 mm "chengal" hardwood post
4 90 x 75 mm "chengal" hardwood floor joist at 450 centres
5 wedges
6 wooden dowel

Case Study 2.5.6

Name : "Rumah Tele", Losong, Kuala Terengganu

Owner : "Muzium Negeri Terengganu"

Date Constructed : 1888

Influences : The building form and method of construction suggests influences from Thailand, Cambodia and Laos Many of these nations share a fairly common structural form, where timbers are selected for their durability. Timber, used for forming the wall framing, invariably continued into the ground to form the stumps.

Structural System : Post and Beam

Analysis : The framework of post and beam construction is arranged in a grid system. The "chengal" hardwood bearers of 195 x 70 mm are slotted into 160 x 160 mm posts to support the floor joists 195 x 70 mm tie-beams are used for connection at the top of the posts to prevent them from falling apart. The loads are transferred from the upper to lower column by means of a 160 x 160 mm "chengal" hardwood. Horizontal bracing is provided by internal wall panels.

Source :

- "Sembahrin Arkitek", Kuala Terengganu.

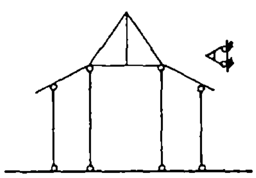


Figure 2.46
Load path diagram

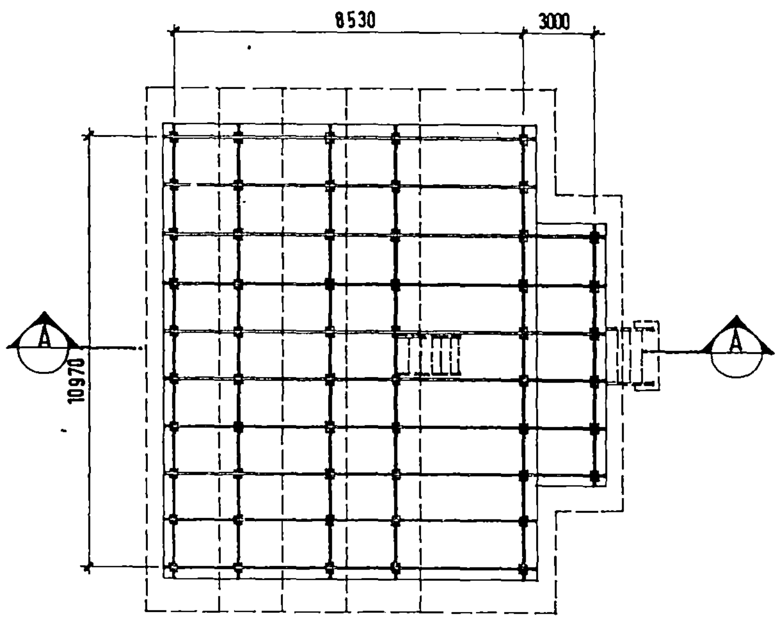


Figure 2 47
Floor framing plan

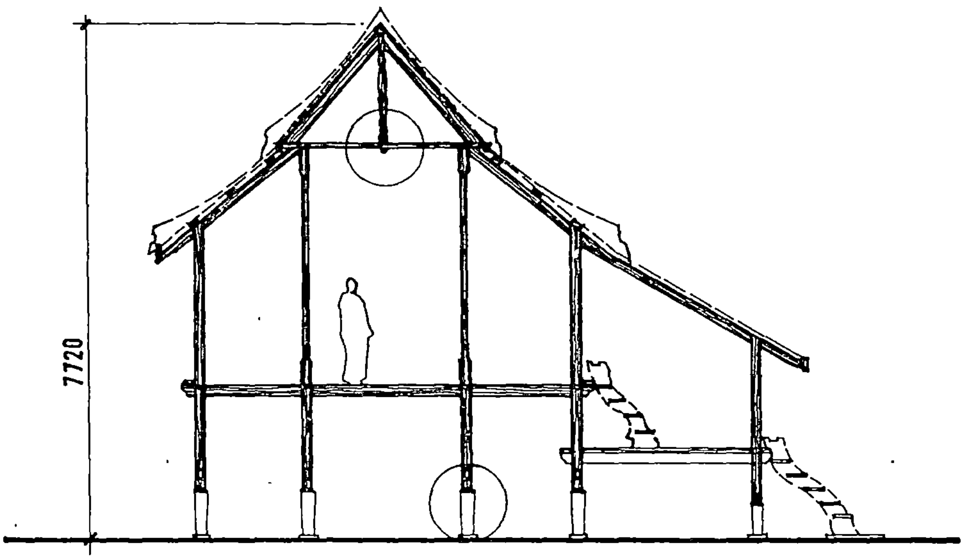


Figure 2 48
Section

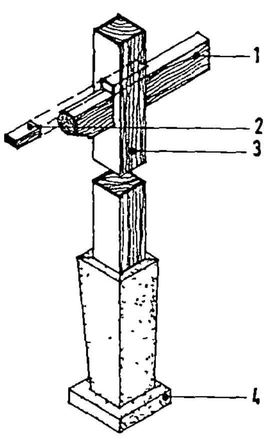


Figure 2.49
Detail of bearer and post connection
post jointing

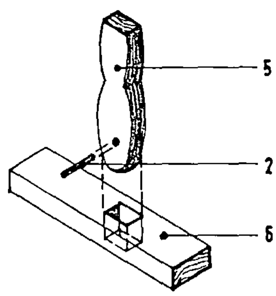


Figure 2.50
Detail of tie-beam and king

1	195 x 70 mm "chengal" hardwood tie beam
2	wedges
3	160 x 160 mm "chengal" hardwood post
4	310 x 310 mm stone base
5	195 x 95 mm "chengal" hardwood king post
6	160 x 75 mm "chengal" hardwood tie beam

Case Study 2.5.7

Name : "Rumah Tiang Enam", Losong, Kuala Terengganu

Owner : "Muzium Negeri Terengganu"

Date Constructed : 1914

Influences : This type of building tradition is regarded as a continuation of the old Patani influences. The most significant and distinctive features are the wide roof fascia boards that decorated each gable end in the form of two wide arcs to a sharp apex. There are two types of layout for these houses; the simplest is "rumah bujang" (six pillared type) and "rumah tiang dua belas" (twelve pillared type). The house structure is different because of the wide bay spans which require additional intermediate rows of stumps to support the floor.

Structural System : Post and Beam

Analysis : The basic plan is a rectangular form of 7.60 x 3.0 metres, consisting of single square hardwood posts of 225 x 225 mm resting on stone bases The hardwood ridge beam 175 x 175 mm slots into the king post, 150 x 150 mm, slanted at 45 degrees. The tie-beam is connected to post and roof members to provide additional strength. Horizontal bracing is provided by external wall panels

Source :

- Raja Ahmad Shah, 1988 : p. 51

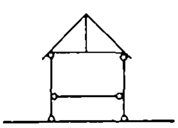


Figure 2.51
Load path diagram

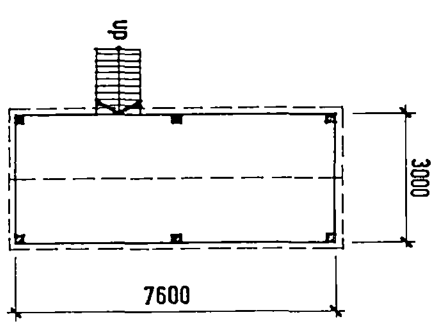


Figure 2.52
Floor plan

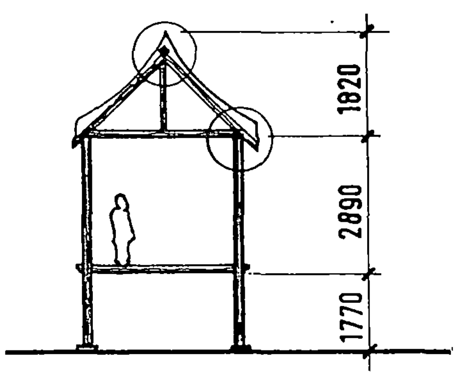


Figure 2.53
Section

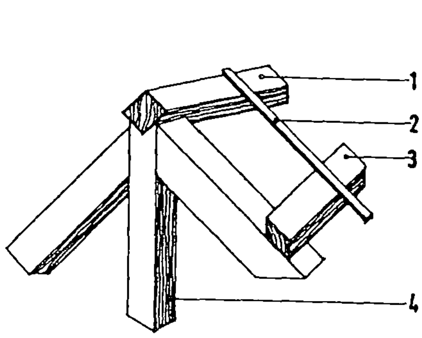


Figure 2 54
Detail of ridge

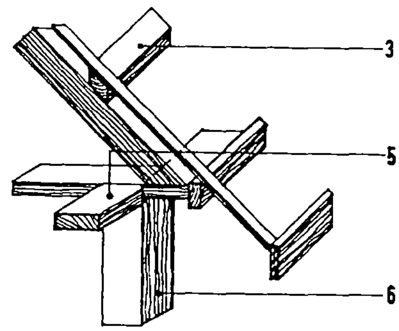


Figure 2.55
Detail of eaves

1	175 x 175 mm hardwood ridge beam
2	25 x 25 mm hardwood batten
3	75 x 190 mm hardwood purlin
4	150 x 150 mm hardwood king post
5	200 x 90 mm hardwood tie beam
6	225 x 225 mm hardwood post

Case Study 2.5.8

Name : "Rumah Kutai", Perak

Date Constructed : 1902

Influences : "Rumah Kutai" are commonly found in settlements along the North Perak River The most significant feature of this building form is the extensive use of open plan concept where the "serambi" is defined by a short bay-space on the same floor level as the main house. "Rumah Kutai" are mainly found in the Northern states of Kedah, Perlis, Penang and Perak, where "bumbung lima" roofs are used with the "anjung" projected at the front of the house On the outside, the house is easily recognised by it steep roof shape. The roof is continuous and gradually changes pitch merging the two roofs together

Structural System : Post and Beam

Analysis : The timber frame consists of continuous square hardwood posts of 150 x 150 mm resting on concrete stumps Posts are erected from the concrete stumps and connected with hardwood tie-beams of 150 x 150 mm. This system provides an economical frame that can be fabricated and adopted to buildings of various uses, sizes, layout and roof shapes This is not a prefabricated system but an incentive as a model to design and build a timber frame building.

Source :

- Hilton, 1956 . p. 153

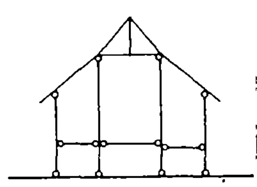


Figure 2 56
Load path diagram

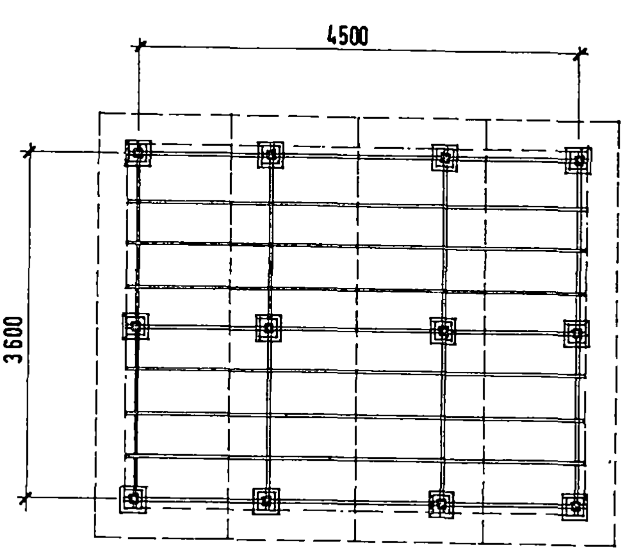
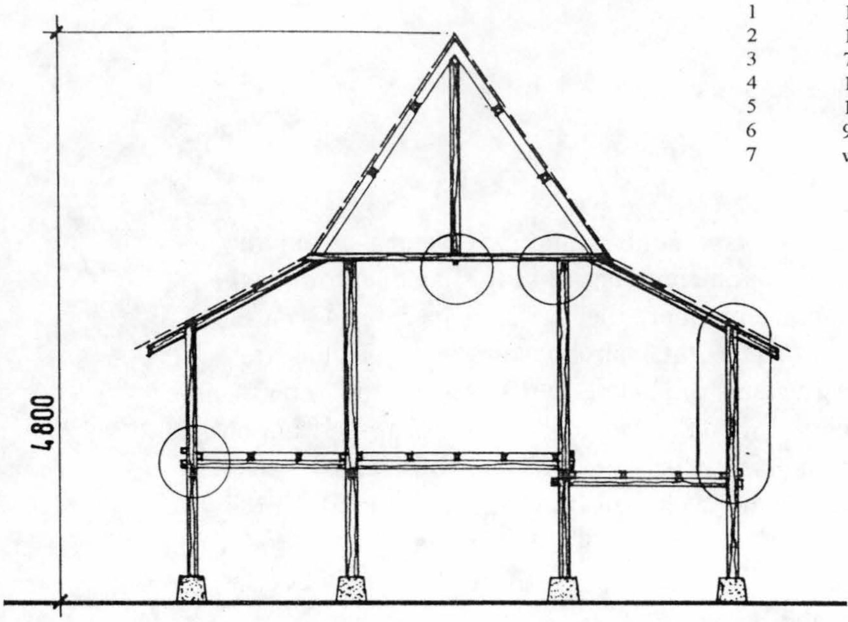


Figure 2 57
Floor framing plan



1 150 x 150 mm hardwood post
2 120 x 50 mm hardwood bearer
3 75 x 50 mm hardwood floor joist
4 150 x 50 mm hardwood tie beam
5 120 x 75 mm hardwood wall plate
6 90 x 50 mm hardwood king post
7 wooden dowel

Figure 2.58
Section

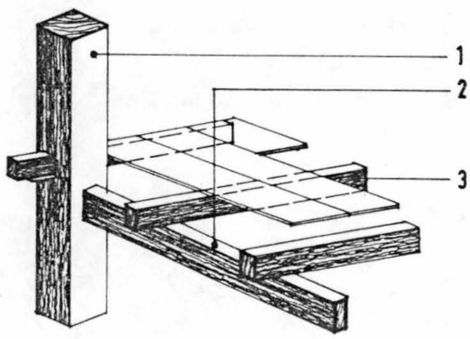


Figure 2.59
Detail of floor construction

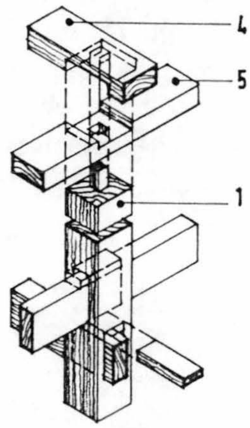


Figure 2.60
Detail of post jointing system

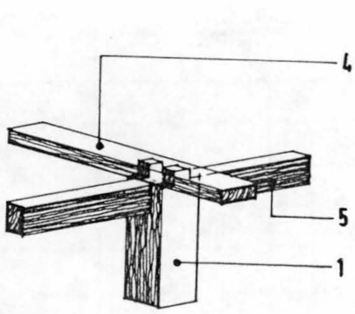


Figure 2.61
Detail of wall plate and tie-beam joint into post

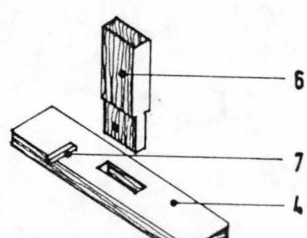


Figure 2.62
Detail of king post slotted into tie-beam

Case Study 2.5.9

Name : Walian House, Jalan Nusa, Kuala Lumpur

Architect : CSL Associates

Engineers : Perunding Bersama Sdn Bhd.

Builders : Miles Reality

Owner : Mr and Mrs. Lim C W.

Date Constructed : 1980

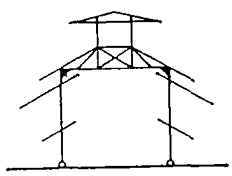
Influences : The architectural expression for this house has many traditional elements of detailing reminiscent of the Chinese bracket system, with modifications using connections of bolts and nuts. The building form is inspired by industrial smoke sheds and adapted as a residence. The designers have a thorough understanding of the use of recycled timber that can be structurally sound. Using recycled timber not only utilises what would have become waste, it is also a way of obtaining some of the older types of timber that are not readily available today and reduces the need to cut down trees

Structural System : Post and Beam

Analysis : The roof structure is built up of timber trusses braced, bracketed, and bolted to heavy chengal beams to create suspended layered roofs. Rigid joints are formed by the bracket system. Timber frame consists of single piece cross sections and 150 x 75 mm "chengal" tie beams are continuous. The 200 x 200 mm columns are erected from the ground rest on square concrete stumps.

Source :

- Lim. 1984 · p. 32
- Houses - 7 KL Architects, 1985 : p. 26
- Lim. 1988 (c) : p. 13
- Lim 1990 (b) p 85



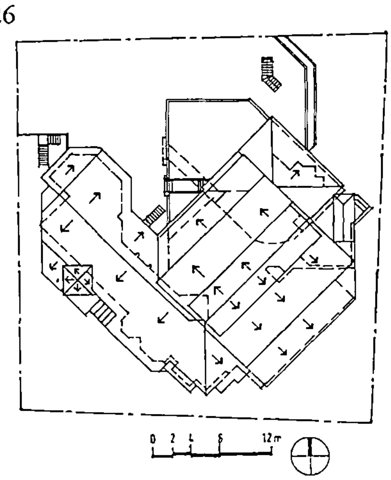


Figure 2 63
Load path diagram and roof plan

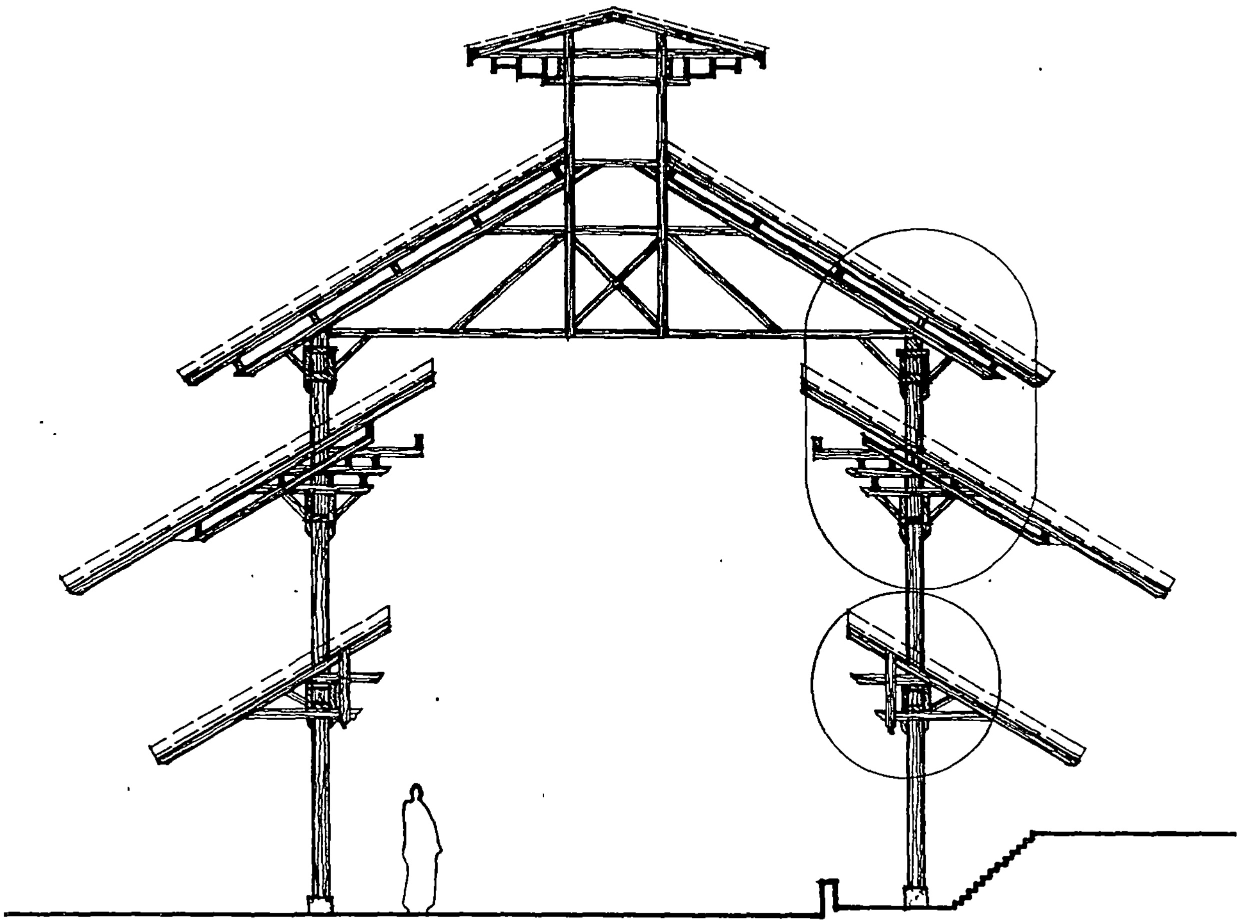


Figure 2.64
Section

2	100 x 50 mm "chengal" hardwood purlin
4	200 x 200 mm "chengal" hardwood column
6	150 x 75 mm "chengal" hardwood rafters at 600 mm centres

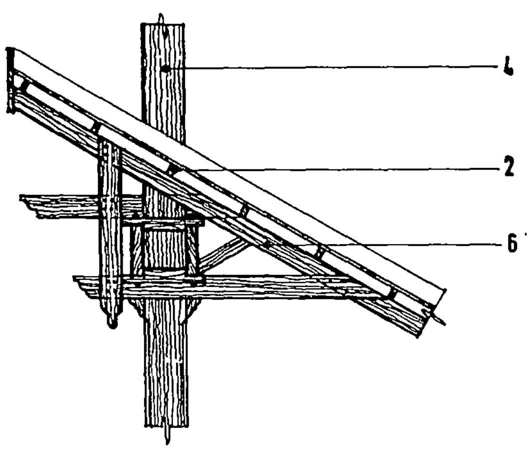


Figure 2 65
Detail of bracket support roof overhang

1	50 x 25 mm "chengal" hardwood battens at 250 centres
2	100 x 50 mm "chengal" hardwood purlin
3	150 x 75 mm "chengal" hardwood rafter at 600 centres
4	200 x 200 mm "chengal" hardwood column
5	250 x 75 mm "chengal" hardwood beam
6	150 x 75 mm "chengal" hardwood rafters at 600 centres

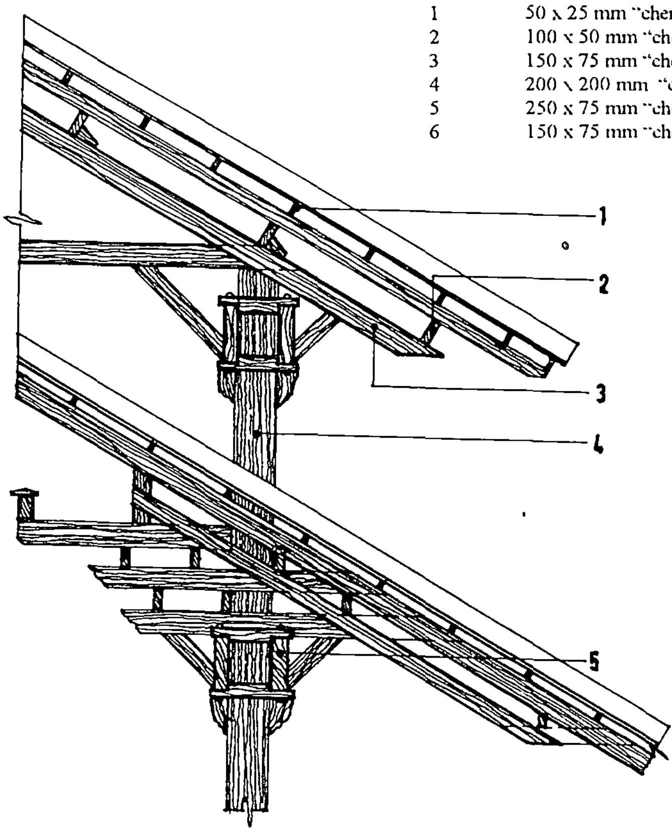


Figure 2 66
Detail of bracket connected to post

Case Study 2.5.10

Name : "Masjid Tua Kampung Laut", Kota Bahru, Kelantan

Owner : "Yayasan Islam Negeri Kelantan"

Date Constructed : 1874

Influences : The "Kampong Laut" Mosque is linked to "Masjid Agung Demak" in Jawa, built in approximately 1479 with the growth and spread of Islam in Jawa. The three-tiered roof form is similar to the roof of Kampung Laut Mosque

Structural System : Post and Beam

Analysis : The central part of the inner hall consists of four square hardwood columns of 200 x 200 mm supporting the roofing superstructures. The structure is based on post and beam intersecting at 90 degrees, connected by mortise and tenon joints. The jointing method for the columns 200 x 200 mm is based on the form of post-head and tying joints for the beams 150 x 75 mm The posts have refined tenon frontal upstand, the upstand stub-tenoning into the tie beam. (See Figure 2.71 and Plate 2.6). The weakness of this assembly is that decay of any of the three timber members causes total collapse. Secondary beams are constructed diagonally to form lateral wind bracing. Horizontal stiffening is provided by external walls which act as secondary wind bracing

Source :

- Measured Drawing Studies, Department of Architecture, University of Technology Malaysia
- Ruslan, 1980, p. 40.
- Nasir, 1984 · p 45.
- Valatsea, 1990, 9. 43

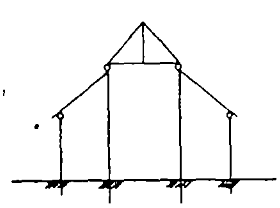


Figure 2 67
Load path diagram

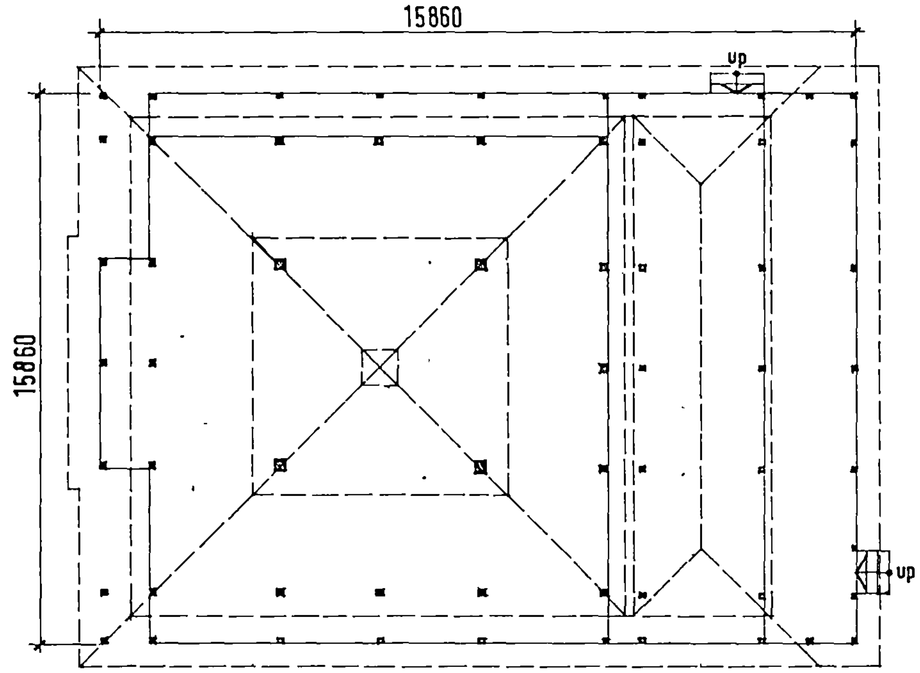


Figure 2.68
Plan

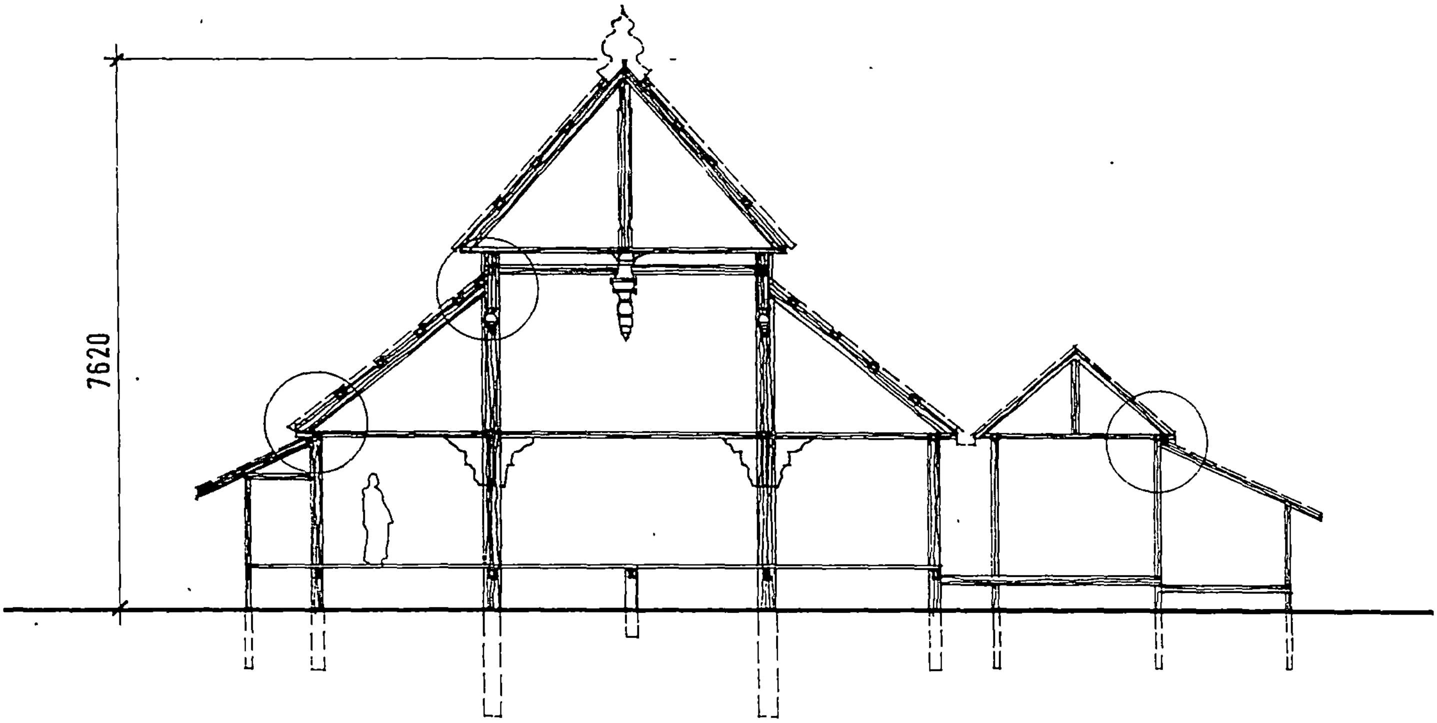


Figure 2.69
Section

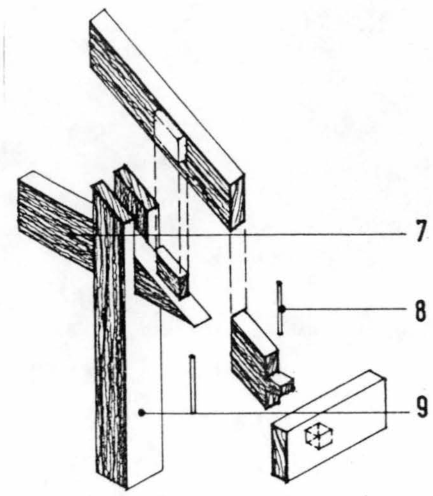


Figure 2.70
Detail of corner post

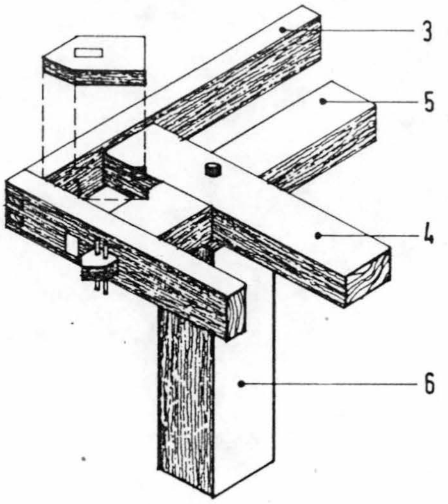


Figure 2.71
Detail of tie-beam jointed with roof beam

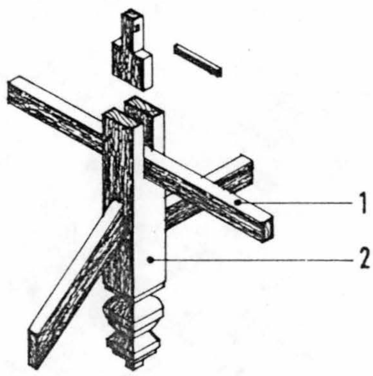
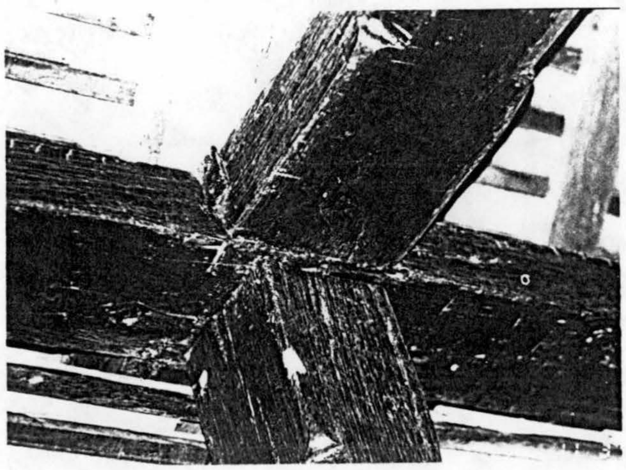


Figure 2.72
Detail of hanging beam

1	75 x 75 mm "chengal" hardwood bracing
2	150 x 150 mm "chengal" hardwood hanging beam
3	120 x 75 mm "chengal" hardwood ring beam
4	150 x 75 mm "chengal" hardwood tie beam
5	150 x 75 mm "chengal" hardwood wall plate
6	200 x 200 mm "chengal" hardwood post
7	100 x 50 mm "chengal" hardwood tie beam
8	dowel
9	300 x 300 mm "chengal" hardwood post

Plate 2.6
Detail of tie beam connection.
Tie beam of 150 x 75 mm "chengal" hardwood inserted into wall plate of 150 x 75 mm "chengal" hardwood and resting on 150 x 150 post.



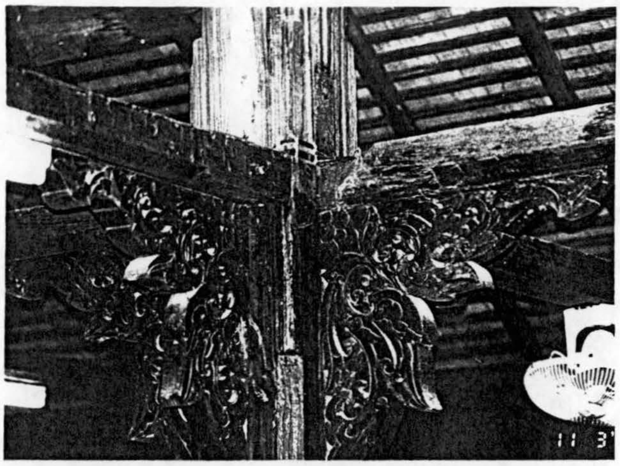


Plate 2.7
Detail of corner post in inner hall. Decorated hardwood "chengal" bracket. carved with floral motifs, stiffens the stability of the inner four post structure.

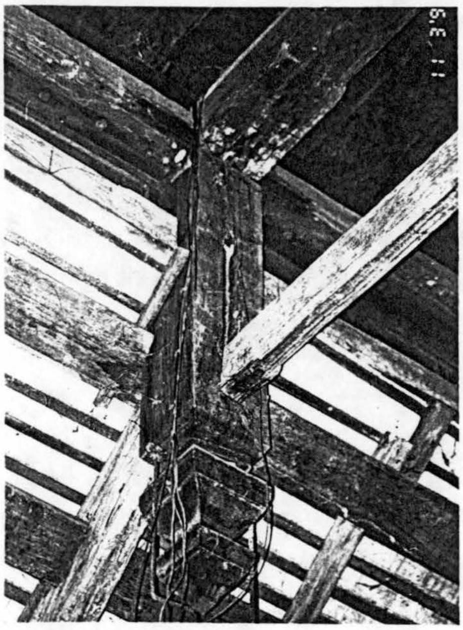


Plate 2.8
Detail of hanging beam. Hanging beam 150 x 150 mm carved at the bottom with Islamic symbols.

Case Study 2.5.11

Name : Forest Research Institute's Mosque, Kepong, Selangor

Engineers : Lew Wing Hing

Owner : Forest Research Institute of Malaysia

Date Constructed : 1975

Influences : The multi fold umbrella-like roof form is inspired by the National Mosque which was influenced by the post-independence mosque builders from Middle East. It is the first mosque in Malaysia to explore laminated timber beams The pentagon floor plan is based on an Islamic symbols.

Structural System : Hinged Frames.

Analysis : Roof is divided into 10 segments to create multifolded roof. Five radially arranged glued-laminated beams form the multi-folded roof at a height of 15.0 metres. Three hinged laminated wood frames are statically determinate, therefore the loads are carried through bending and shear stresses in frame bent and legs. The bases of beams are embedded in concrete footings at 2.89 metres high and are secured against lateral movement by 4 x 25 x 375 mm high density bolts. At the apex, beams are joined by 150 x 120 mm coach screws

Source .

- Forest Products Division, Forest Research Institute of Malaysia

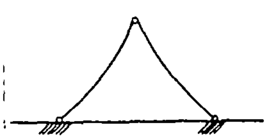


Figure 2 73
Load path diagram

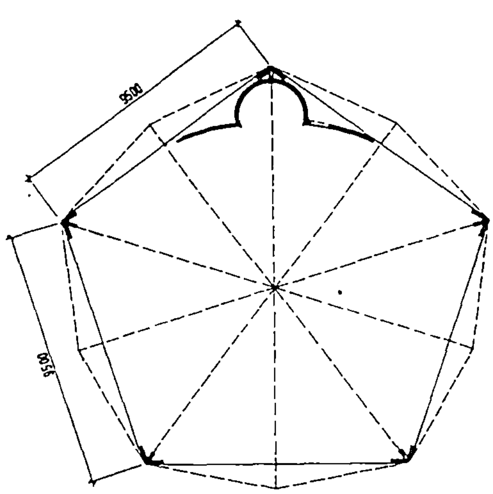


Figure 2 74
Plan

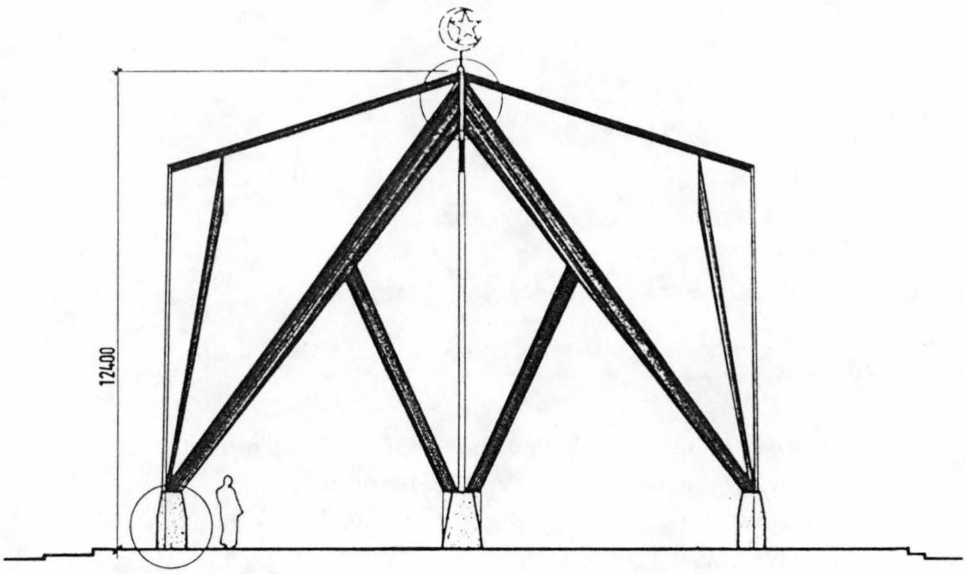


Figure 2.75
Section

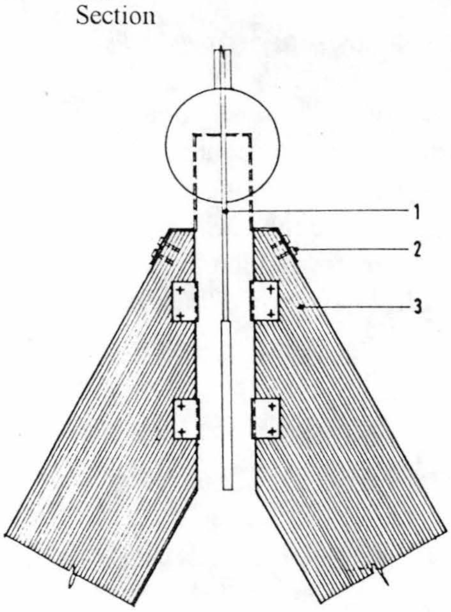


Figure 2.76
Detail of apex

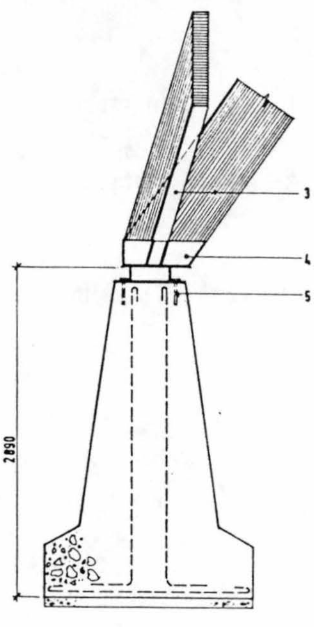


Figure 2.77
Detail of base

1	25 mm diameter vane rod
2	150 x 120 mm coach screws
3	glue laminated beam
4	galvanised welded mild steel base shoe
5	4 x 25 x 375 mm high density bolts
6	M 20 bolt
7	20 mm thick mild steel plate

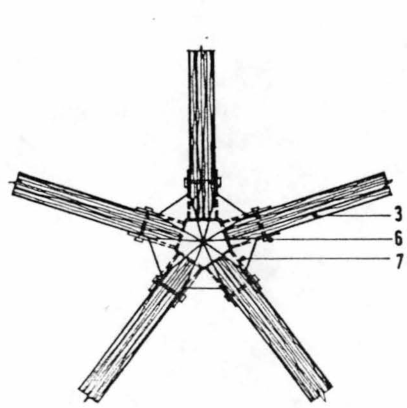


Figure 2.78
Detail of apex

Case Study 2.5.12

Name : "Teluk Intan Clock Tower"

Builder : Leong Choon Choong

Owner : "Majlis Daerah Hilir Perak", Teluk Intan, Perak

Date Constructed : 1885

Influences : Building form imitates the Chinese pagoda and was influenced by European timber technology and jointing systems. The principal innovation in the detailing during this period was the introduction of metalwork as an integral part of the structure. This was used not simply to reinforced joints but as the principal means of transmitting load from one timber to another.

Structural System : Timber framed suspended of a solid masonry core.

Analysis : The timber connection used bolts and nuts and solid timber ring beams of 200 x 200 mm, which were curved by heating using traditional methods Horizontal stiffening is provided in floors and roof by connecting piece 300 x 90 x 8 mm tied with hardwood rafters of 230 x 90 mm Cross bracing is provided above the solid masonry core to eliminate buckling under service loads. The tension stability transferred the multi-layered roof load back to the solid core.

Source :

- Civil Engineering Department, University Science of Malaysia.
- Maniam, 1992 . p 1
- Khoo, 1991 p. 8

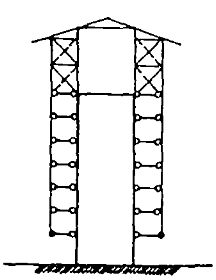


Figure 2 79
Load path diagram

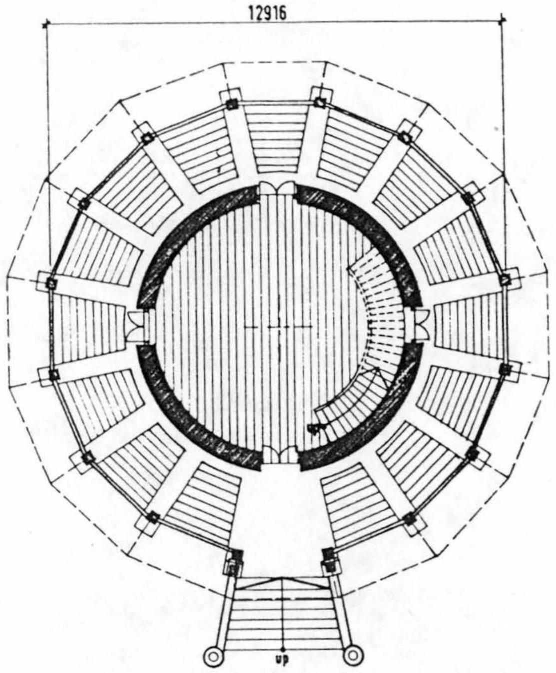


Figure 2.80
Plan

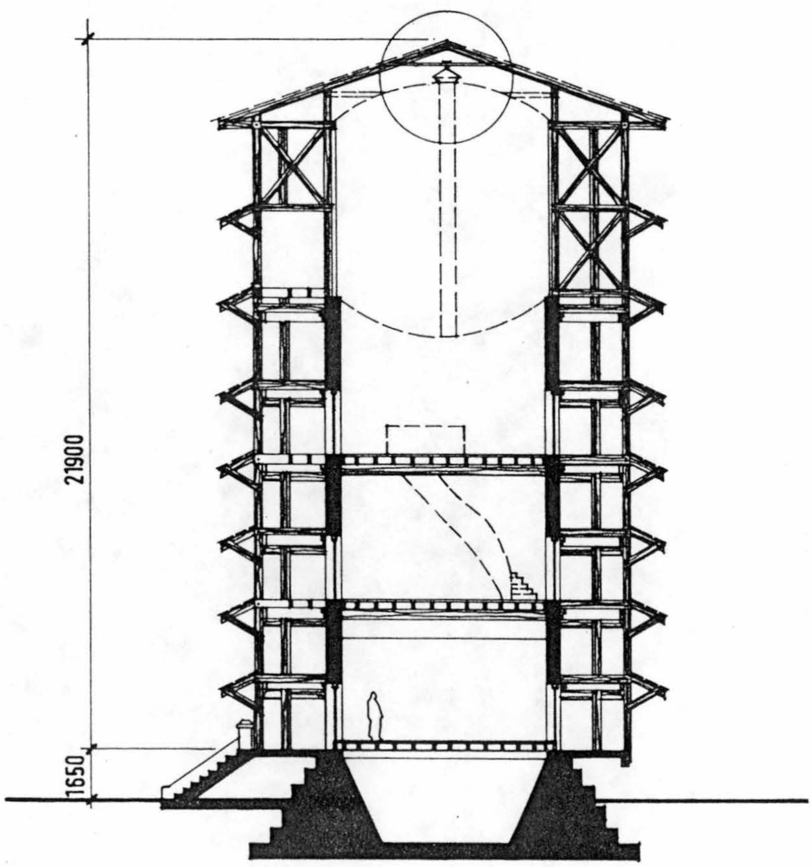
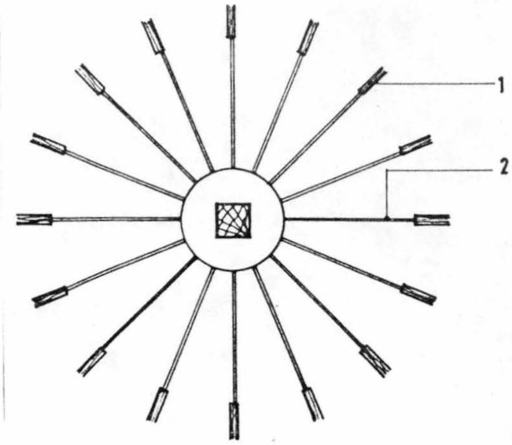


Figure 2.81
Section



1 connecting piece 300 x 90 x 8 mm for rafter
2 18.75 mm steel tie
3 300 x 300 x 750 mm hardwood timber
4 connector assembly

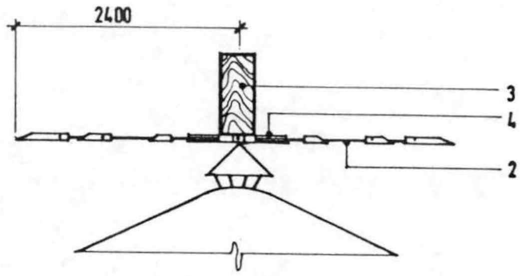


Figure 2.82
Plan view of tie rod connection

Figure 2.83
Elevation of tie rod detailing

Plate 2.9
Detail of floor joists supported on 724 mm thick brick wall all around the building. Floor joists of 230 x 75 mm are recessed and rest on the brick wall to support timber boards.

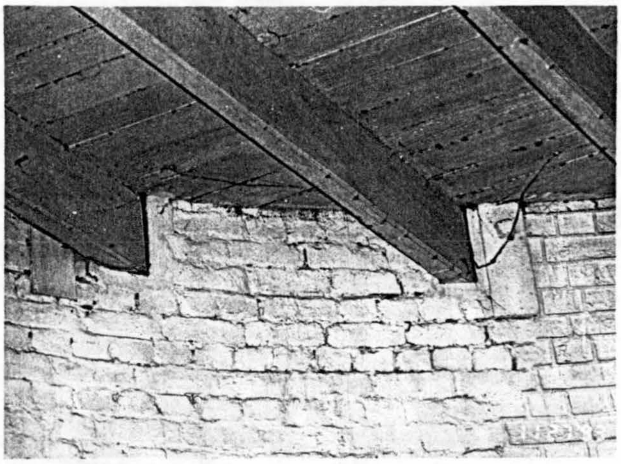


Plate 2.10
Detail of intermediate post. Hardwood ring beams of 240 x 100 mm are recessed 40 mm deep and bolted to the post of 230 x 230 mm. A timber block of 150 x 100 mm is used to strengthen the ring beam's connection.

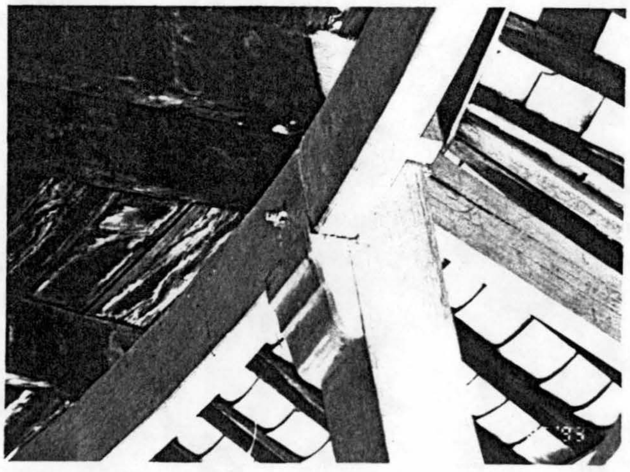


Plate 2.11
Detail of roof connecting piece. Connecting piece of 300 x 90 x 8 mm tied with hardwood rafters of 230 x 90 mm.

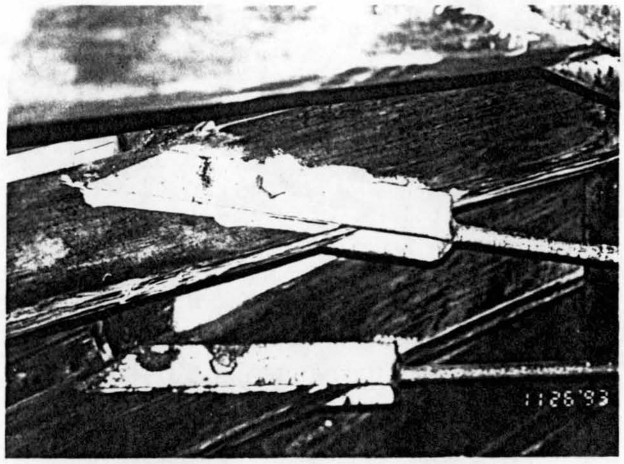
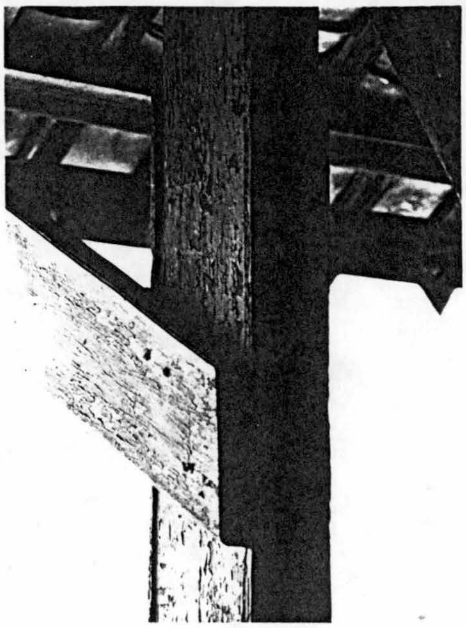


Plate 2.12
Detail of overhang roof structure. Struts of 230 x 80 mm support overhanging roof and are fixed by nails into posts of 230 x 230 mm. The posts were stiffened by 6 mm thick steel plates, bolted on both sides.



Case Study 2.5.13

Name : Club Mediterranean Resort, Kuantan, Pahang

Architect : C.V Z Paterne, Paris (Local Consultant - Hijjas Kasturi Associates)

Engineers : Angkasa Jurutera Perunding Sdn. Bhd.

Owner : SEDC Pahang Holiday Villages of Malaysia Club Mediterranean, Paris

Date Constructed : 1980

Influences : The village was influenced of Polynesian and East Coast traditional building principles in modern architecture using timber material. The design and construction of the building also to develop a responsive related to Malaysia's climate and at the same time expressive of national and regional ideals (Yeang, 1993 : p. 327).

Structural System : Post and Beam

Analysis : The timber framework consists of tie beams and columns where the basic structural feature is the cross-shaped column node Floor joists are cantilevered at 300 mm on each side, shear connectors used between the plate and column transfer the load through the plate directly from the upper to the lower column. Floor beam connections are bolted to columns. The roof structure rests on roof beams and columns and is stiffened by steel brackets and diagonal bracing

Source :

- Baxendale, 1980 · p 50

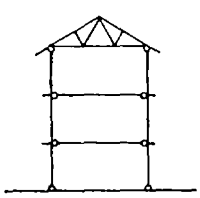


Figure 2 84
Load path diagram

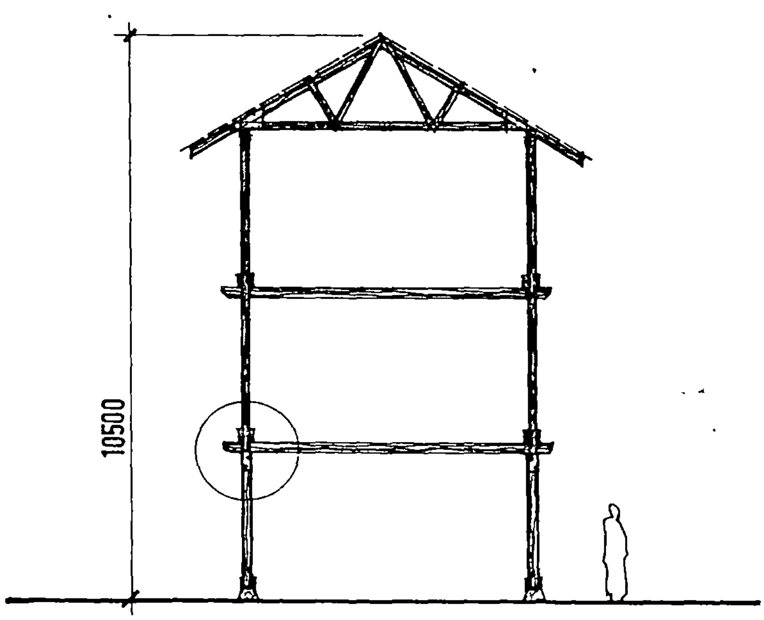


Figure 2.85
Section

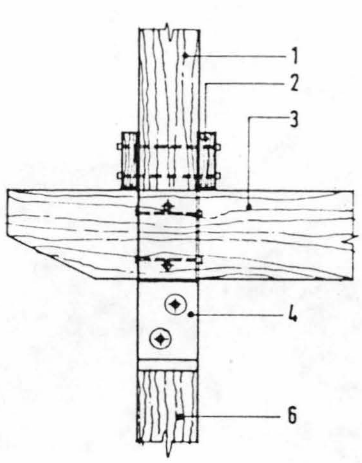


Figure 2.86
Detail of floor beam end joint

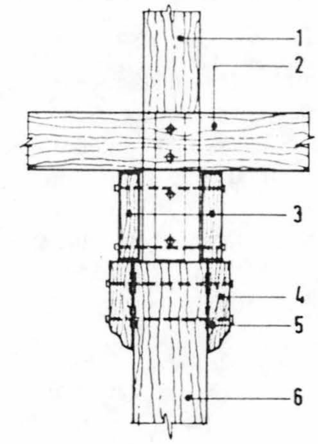


Figure 2.87
Elevation of floor beam detail

1	200 x 200 mm hardwood column
2	200 x 150 mm floor beam
3	300 x 150 floor beam
4	300 x 150 mm timber blocks
5	split rings
6	200 x 250 mm hardwood column

Plate 2.13
Detail of the covered walkway.
Hardwood columns 150 x 100 mm are braced to resist lateral movement. Bracing is fixed together with 150 x 75 mm bearers, using M 12 bolts

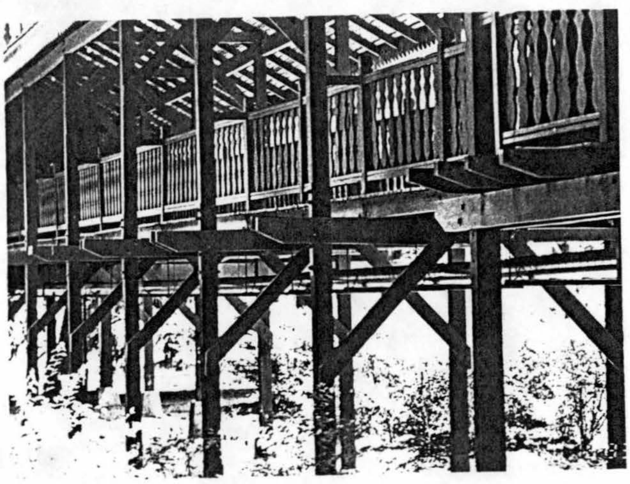


Plate 2.14
Detail of first floor beam at cafeteria. Two floor beams of 50 x 150 mm with staircase component bolted for stability. M 20 bolts are used for jointing between members.

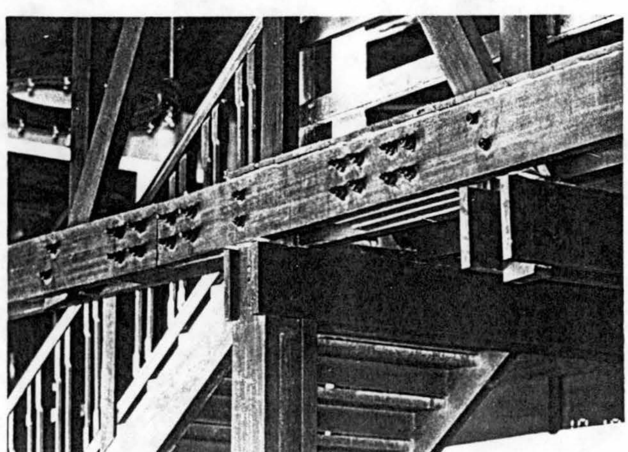


Plate 2.15
Detail of bearers and floor joists
Twin bearers of 50 x 200 mm recessed at 50 mm deep are fixed to 200 x 200 mm columns and supported by 75 x 300 mm timber blocks on both sides. Floor joists of 50 x 150 mm are scarf jointed and bolted to the columns, using M 20 bolts. Steel plates are used to prevent the joint from splitting.

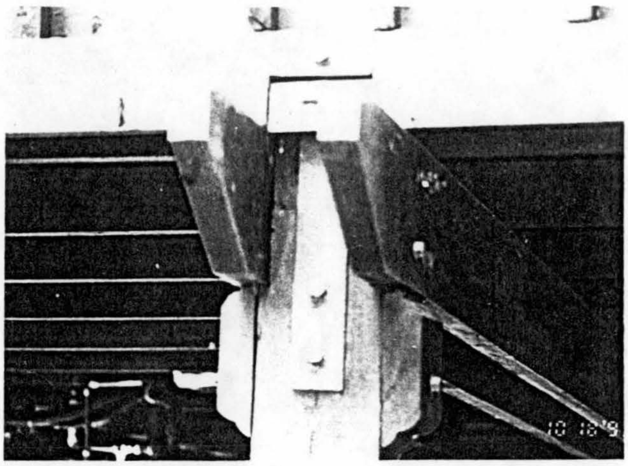


Plate 2.16
Detail of the eaves overhang.
Twin rafters of 50 x 150 mm rest on the tie beam of 75 x 200 mm and are fixed to columns using mild steel brackets.

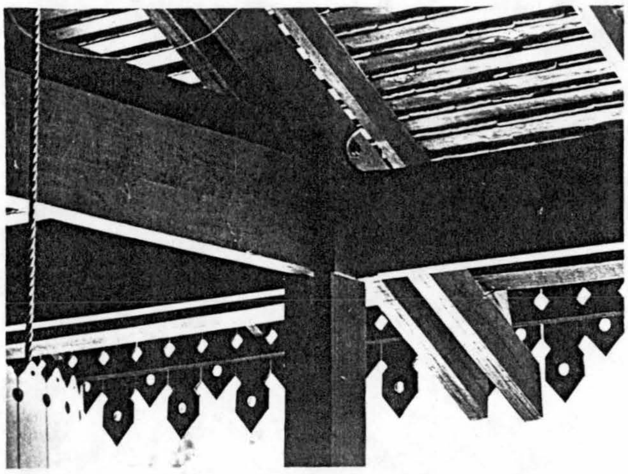
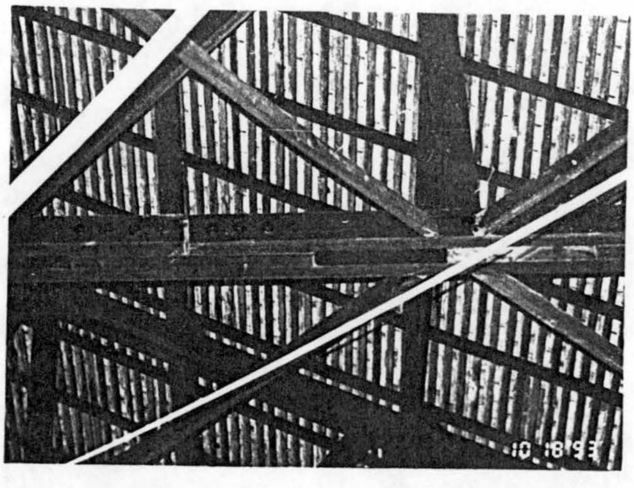


Plate 2.17
Detail of tie-beam at foyer.
Tie-beam of 50 x 150 mm is braced and bolted with M 20 at interval bay to prevent lateral movement. A timber block is inserted between the tie-beam members to connect the joint.



Case Study 2.5.14
Name : Kayu Sedia Sdn. Bhd , Off Jalan Sungai Besi, Kuala Lumpur

Owner : Kayu Sedia Sdn Bhd

Date Constructed : 1950

Influences : This is a simple curved top chord truss The substantial gussets at knee-joints provide frame action for lateral loads and truss action for vertical loads

Structural System : Bowstring truss

Analysis : The structure is a large curved roof truss. It is 17 60 x 27.40 metres long with 150 x 150 mm solid hardwood columns. It used the bowstring truss to provide an alternative type of roof truss system for a large span industrial building The roof trusses have twin top and bottom chords to form a segmented curve. Trusses are nailed together in several layers, bolted and strengthened with gusset plates. The building has a series of longitudinal bracing trusses, formed around the main transverse truss members and fully braced truss and column bays.

Source :

- Tottenham, 1958 : p 25
- Jaap, 1975 : p. 7

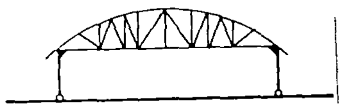


Figure 2 88
Load path diagram

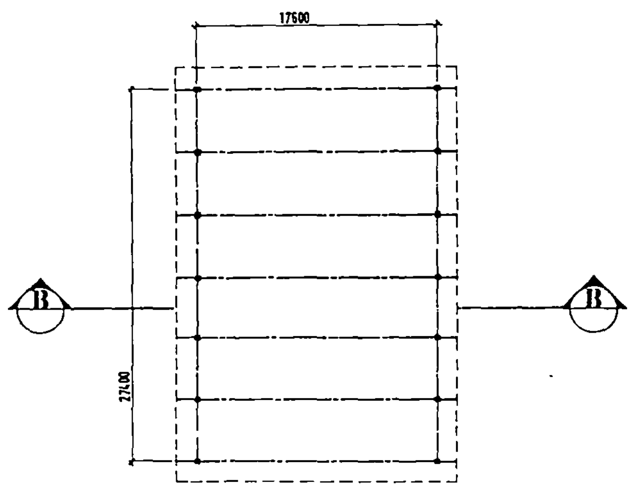


Figure 2.89
Roof trusses layout plan

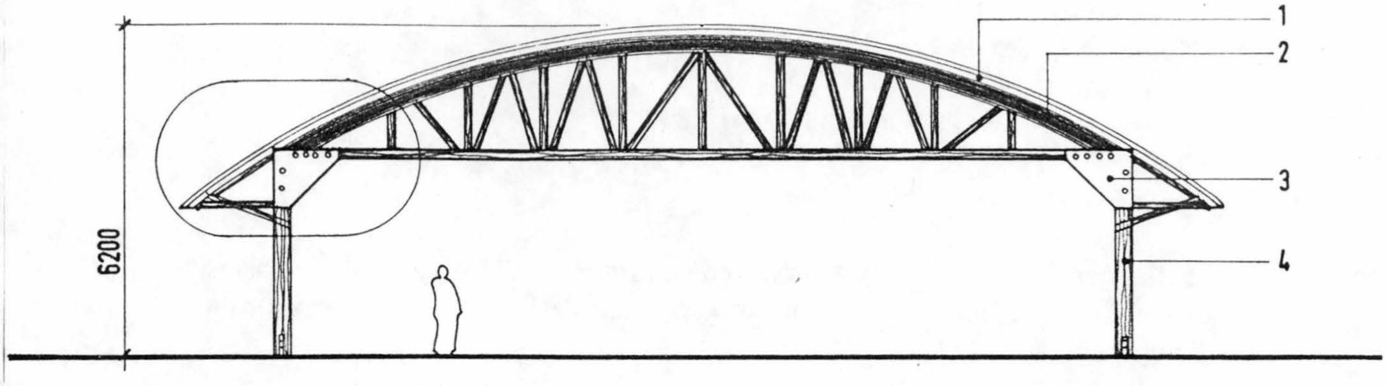


Figure 2.90
Section

Figure 2.91
Detail of roof overhang

1	30 x 50 mm hardwood purlin at 450 mm
2	2 x 20 x 100 mm top cord nailed in 5 layers
3	4 mm thick gusset plate
4	M 20 bolts
5	2 x 40 x 75 mm hardwood support
6	150 x 150 mm hardwood column

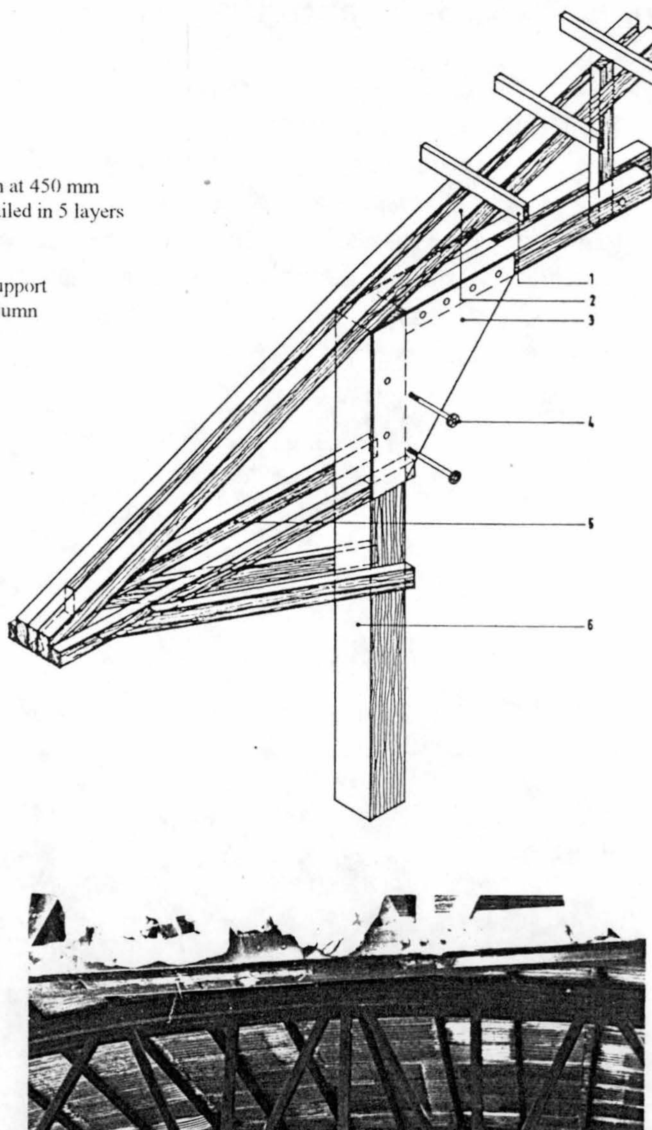


Plate 2.18
Detail of bowstring truss. Segmental upper chord member was formed using several layers of smaller timber joined together with nails.

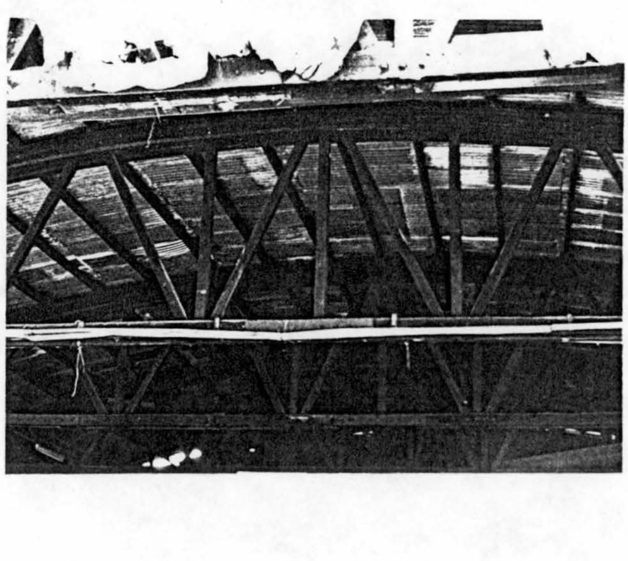


Plate 2.19
Detail of the bottom chord. The chord consists of two members sandwiched together with an intermediate web member bolted using M 16 bolts.

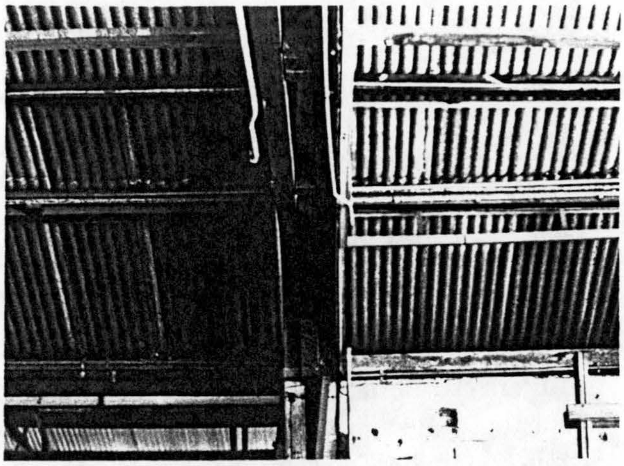
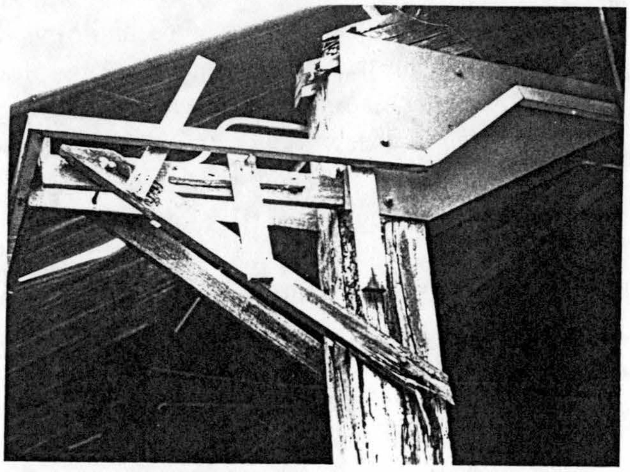


Plate 2.20
Detail of roof overhang. Segmented curve has collapsed due to exposure to weather. The overhanging eaves provided are too shallow to prevent rain water entering the roof members.



Case Study 2.5.15

Name : Fire Resistant Shed, Forest Research Institute Malaysia, Selangor

Engineers : Lew Wing Hing

Owner : Forest Research Institute of Malaysia

Date Constructed : 1982

Influences : Portal frames are most commonly used in commercial and industrial buildings which have no historical inspiration. Structural glued laminated timber (gluelam) has been used in engineering structures in the United States since 1935. The technology for these buildings was derived from international influences. They were made possible by the use of glued-laminated timber or multiple nail technology. The rigid-joint of the portal frame was connected by nails on site using plywood gusset plates It does not have rotational restraint because it can easily be given stiffness on its own plane to resist any tendency to sway sideways under the action of a horizontal load Wind bracing and stiffening in both directions of such rigid connections are provided by nailing end purlins to the frame.

Structural System : Portal frames

Analysis : Another structural form which has been used successfully is portal framing which provides rigid joints at junction and roof to transfer wind load movement to the walls. An example of this form can be found at the Forest Research Institute of Malaysia at Selangor where the Fire Resistant Laboratory was constructed in 1984

The plan is rectangular in form, 15 0 x 40 8 metres with a 20 degree pitched roof. The main structural system consists of 9 portal frames and each bay is 6.0 metres long. Laminated columns 350 x 150 mm are supported on concrete bases 300 x 150 mm. The bases of the columns are connected to concrete footings and are secured against lateral movement by steel plates. The reinforced concrete footing closed the frame action and provided the mass needed for overturning stability of the relatively high and very light structure. The stability of the portal frame is supported by knee braced trusses to form a triangulated frame structure Side plates of 25 mm thick plywood on both sides were used to connect columns and beams in frame. All connections used nails to form a pattern (See Figures 2.95 and 2.96; Plate 2.21). Longitudinal bracing was provided by timber bracing in the roof plane at intermediate and the end bays. The apex of the portal frame was stiffened using plywood gussets on both sides. In addition, diagonal bracing is formed with purlins as struts to resist wind forces. (See Plate 2.22).

Source :

- Forest Products Division, Forest Research Institute of Malaysia.
- Tan, 1988 (a) : p. 1
- Tan, 1992 : p. 16
- Zoe, 1992 : p. 1

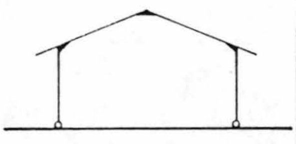


Figure 2.92
Load path diagram

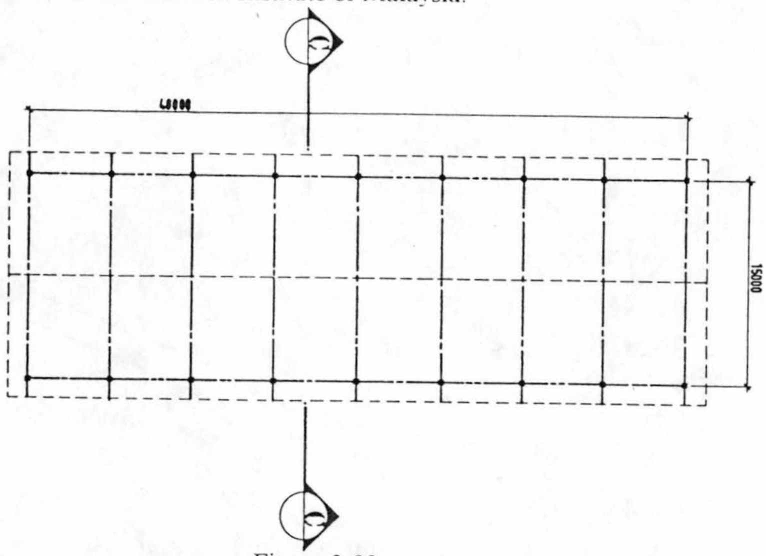


Figure 2.93
Roof layout plan

1 50 x 100 mm purlins at 600 centres
2 25 mm thick plywood gusset plate
3 150 x 350 mm column
4 300 x 500 mm concrete base

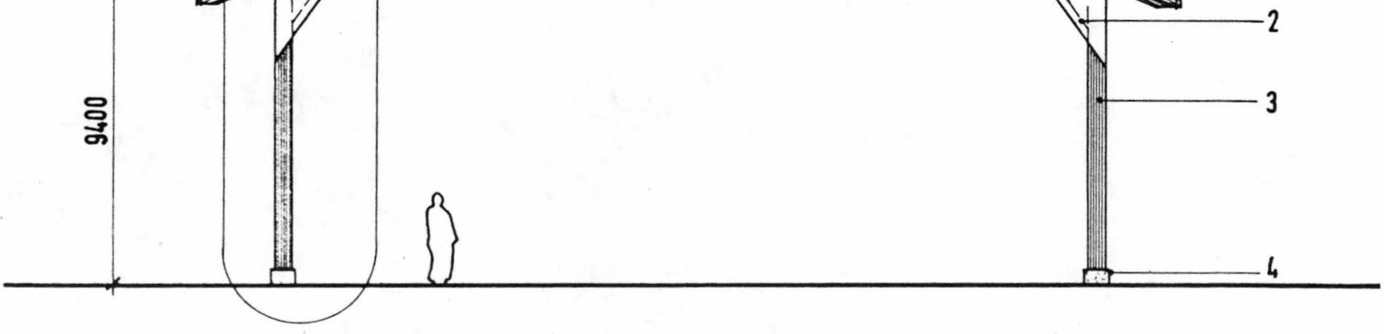


Figure 2.94
Section

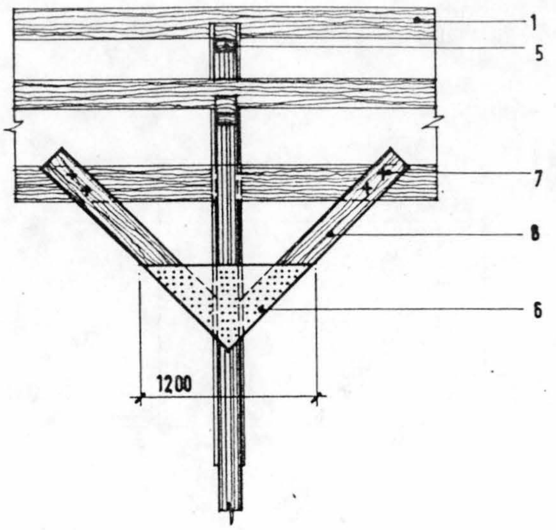


Figure 2.95
Detail of intermediate post with knee brace support

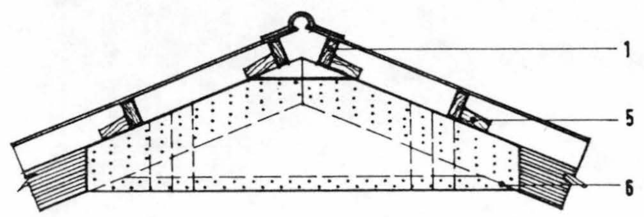


Figure 2.96
Detail of apex

1	50 x 100 mm purlins at 600 centres
2	25 mm thick plywood gusset plate
3	150 x 350 mm column
4	300 x 500 mm concrete base
5	100 x 150 x 225 mm cleat
6	150 x 300 mm glulam rafter
7	2 x M 16 bolts
8	75 x 200 mm knee brace

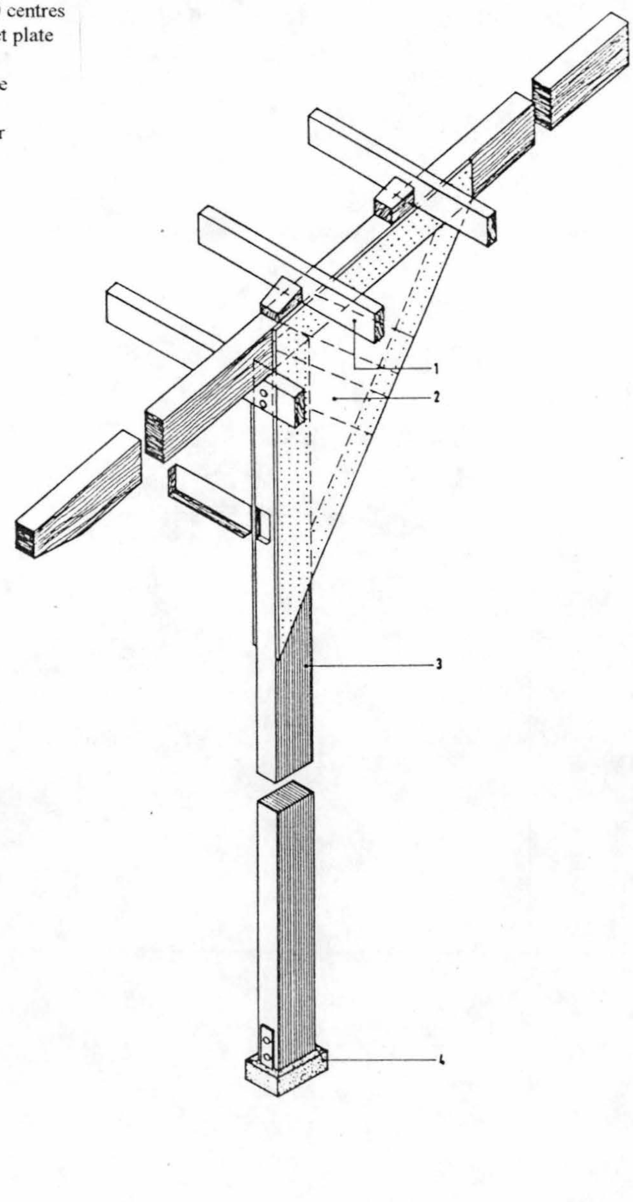


Figure 2.97
Detail of column connection

Plate 2.21
Detail of apex.
25 mm thick plywood gusset plates nailed on both sides of the portal frame. Roof was braced with purlins as struts to resist wind forces.

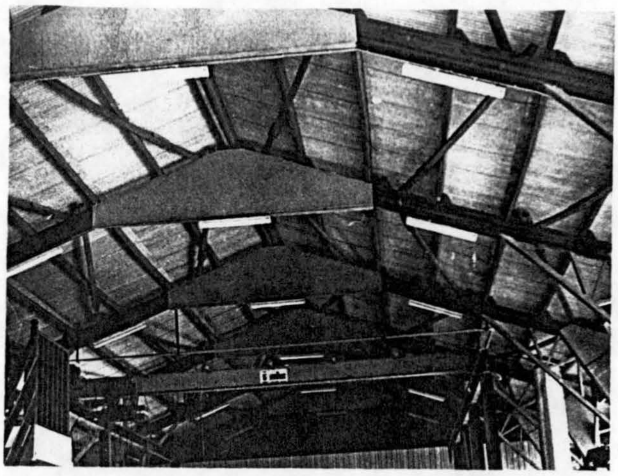
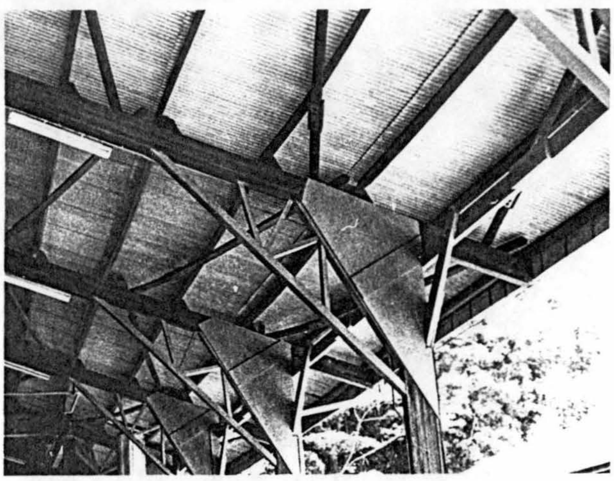


Plate 2.22
Detail of knee brace.
25 mm thick waterproof plywood gusset fixed with 70 mm s.w.g. nails. Knee brace 150 x 200 mm used to strengthen lateral movement. The portal frame is efficient structurally, this loads to savings in the timber.



Case Study 2.5.16

Name : General Lumber (Holdings) Bhd , Kelang, Selangor

Engineers : Y Wong Dan Sekutu

Owner : General Lumber (Holdings) Bhd

Date Constructed : 1973

Influences : In the past two decades, trussed roof construction has become dominant, beginning with traditional patterns of Fink, Howe, King Post and minor modifications of these types. The basic method of roof framing is the roof truss using the Gang-nail prefabricated system. The truss was assembled with a multitude of connection systems including metal plates and bolts and nuts. Individual truss members are designed to restrain the corresponding forces in tension or compression forces. Prefabricated timber trusses are highly efficient in the utilisation of timber and they form an economical roofing system Saving in fabrication and erection costs can be achieved if the designer has an intimate knowledge, not only of the materials, but also of the fabrication process. Properly designed, manufactured and erected timber trusses will perform satisfactory to support the specified roof without sagging or leaking

Structural System : Double Howe truss

Analysis : The building encloses an open plan area of 48.0 x 18.20 metres for a timber store. The columns are spaced 12.0 metres apart with 75 x 50 mm purlins and girts spaced at 1.20 metres in between. The spliced columns consist of 2 x 50 x 100 mm pieces of "kempas" species laced together, making the overall section size nominally 100 mm wide and 200 mm deep. The structural system is based on "portal" action with solid posts. Rafters are braced with 48 x 75 mm timbers at the columns together with the roof structure. Horizontal bracing is provided in the roof structure for stability

Source :

- Building Plan Approval Department, Forestry Department Headquarters, Kuala Lumpur.
- Ong, 1990 p. 111
- Yong, 1992, p 54

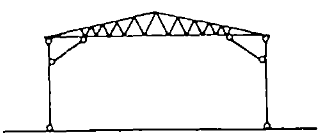


Figure 2 98
Load path diagram

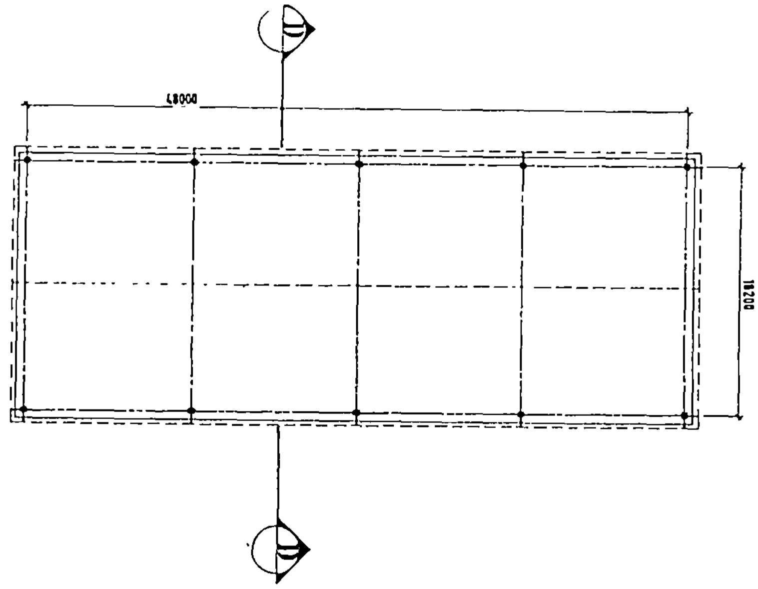


Figure 2 99
Roof trusses layout plan

1 2 x 50 x 100 mm hardwood column
2 25 x 60 mm truss members
4 50 x 150 x 6 mm thick mild steel plate

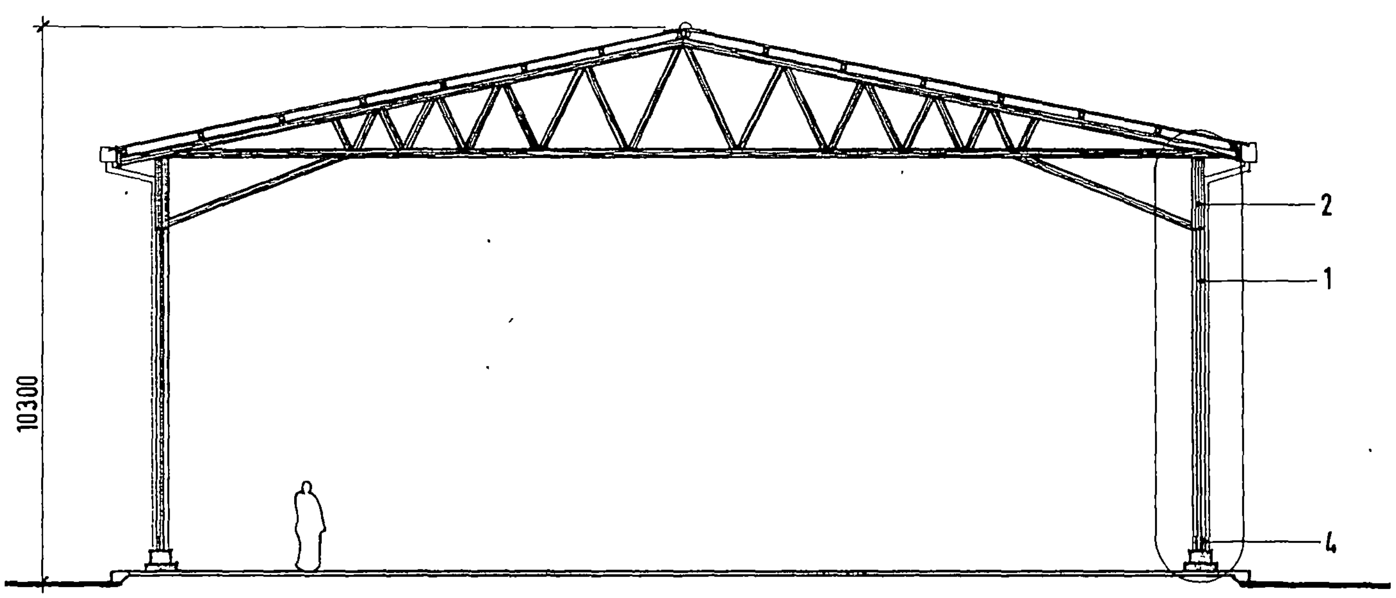


Figure 2 100
Section

1 2 x 50 x 100 mm hardwood column
2 25 x 60 mm truss members
3 50 x 50 mm intermediate spliced column
4 50 x 150 x 6 mm thick mild steel plate

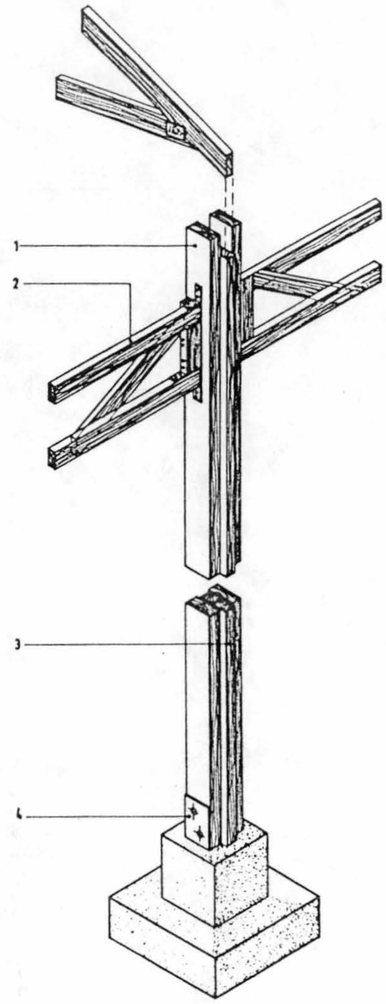


Figure 2.101
Detail of column connection

Plate 2.23
Detail of intermediate column. Truss plate connectors used the connecting members of roof trusses to transmit tensile forces to hardwood "kempas" column

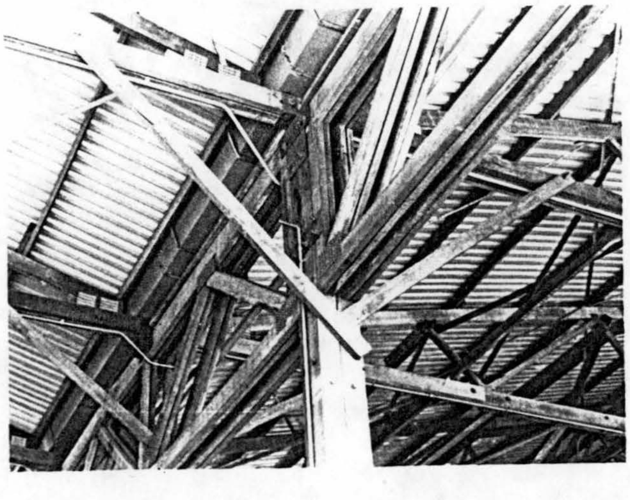
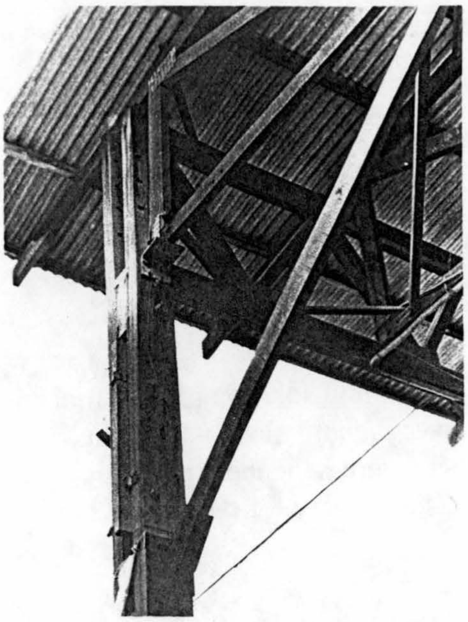


Plate 2.24
Detail of corner column.
Columns consist of
2 x 50 x 100 mm with a
75 x 50 mm knee brace to
resist lateral movement.



Case Study 2.5.17

Name : Kim Chin Hoe Sawmill Sdn Bhd , Jalan Kapar, Kelang, Selangor

Engineers : Yap Chin Tian

Owner : Kim Chin Hoe Sawmill Sdn. Bhd.

Date Constructed : 1972

Influences : A common solution of industrial building with a jack roof structure for natural ventilation and lighting The wood trusses used bolts and nuts for fasteners were dependent primarily on skilful carpentry to obtain the well-fitted joints necessary for the transferred of both compression and tension stresses

Structural System : Pratt Truss

Analysis : The building is a simple pitched roof shelter with a rectangular plan of 30.0 x 22.40 metres. The shelter consists of six bays and each bay is 4.28 metres long. The columns support the trusses which cantilever 5 0 metres on both sides. (See Plate 1.75). The base of each "kempas" hardwood square timber post 300 x 300 mm is covered with circular 6 mm thick steel plate to height of 900 mm. They serve to protect against damage from fork lifts and the heavy concrete base tied to the footing gives stability to the structure and prevents it from over turning The columns were stiffened using 125 x 125 mm web members acting as knee braces. A knee brace creates some fixity, resulting in a shorter effective column length which permits the column to support a larger load. This bracing method is a practical means of transferring loads to column members to minimise the column's instability.

The roof structure is a Pratt truss system, consisting of two 150 x 50 mm tie beams using M 20 bolts, bolted at the column. Rafter members are also two pieces of timber 150 x 150 mm with the intermediate connection at 600 mm, overlapped using M 12 mm bolts. The apex detail, strengthened by 6 mm thick gussets plates on both sides and struts members, was braced with a 150 x 150 mm collar tie The roof was braced with timber members 125 x 50 mm at bay intervals to prevent lateral movement The corrugated roof sheeting also acts as a secondary structural bracing for stability of the structure.

The disadvantage of this type of construction is that bolting is concentrated at a few positions Therefore, spacing between bolts, as well as edge distance, is critical in design. For example, bolted trusses are kept closely spaced to minimise the number of bolts required at the joints Mistakes very commonly spotted on bolted trusses include over-sized bolt holes, missing washers, nuts not properly tightened and wrong bolt locations which will often deflect problems to truss members

Source :

- Building Plan Approval Department. Forestry Department Headquarters, Kuala Lumpur
- Kim Chin Hoe Sawmill Sdn Bhd
- Atwell, 1979 p 6
- Hoyle et al. 1989 p 299

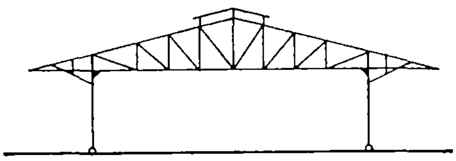


Figure 2.102
Load path diagram

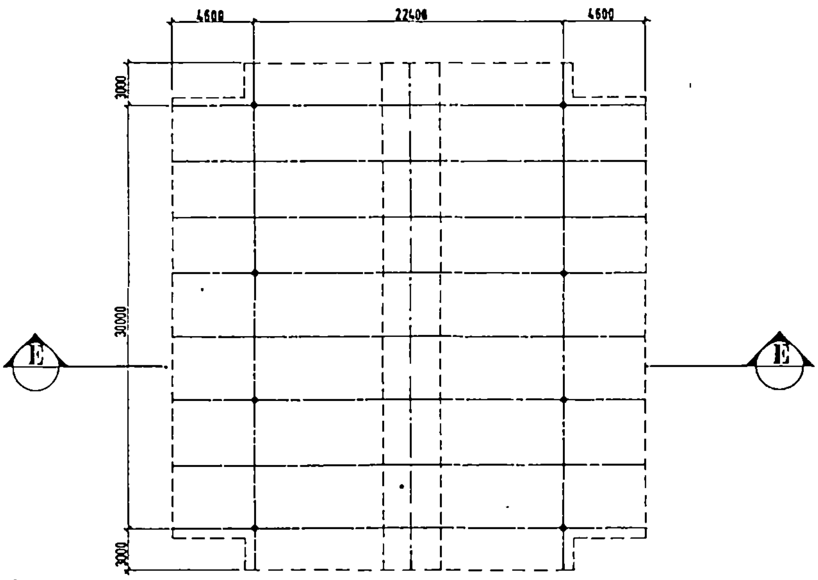


Figure 2.103
Roof trusses layout plan

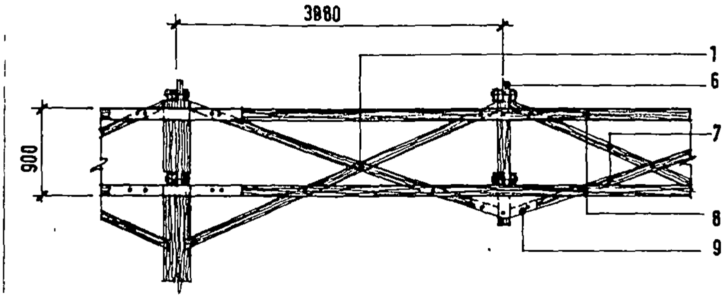
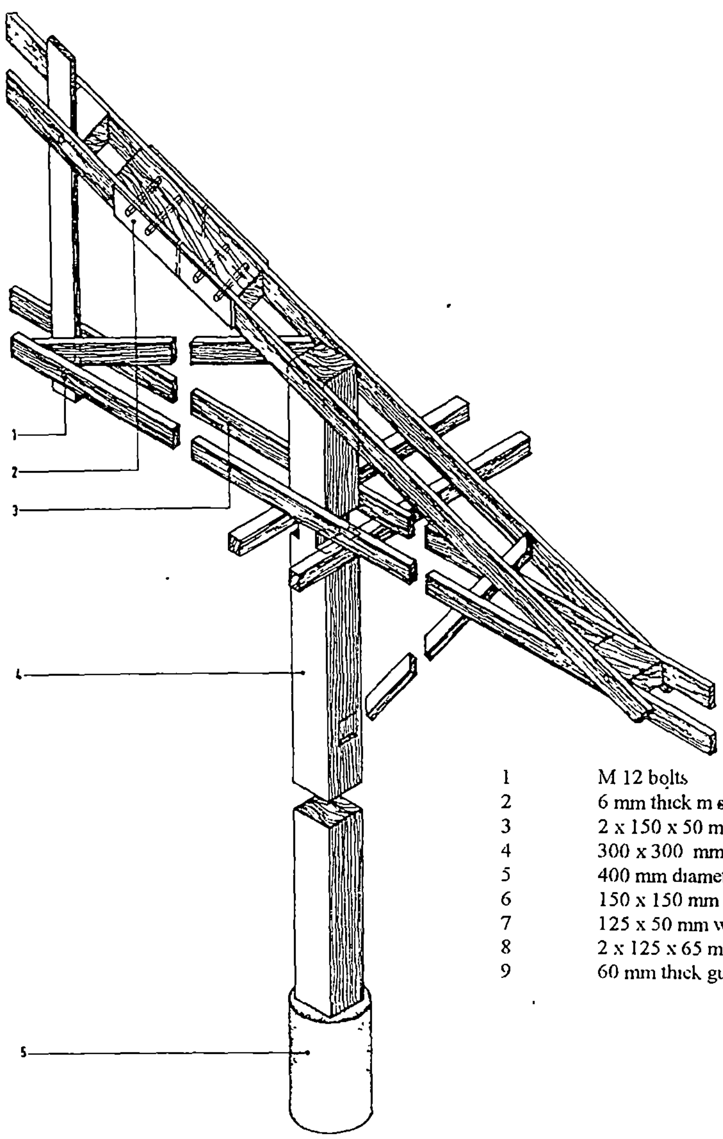


Figure 2.105
Detail of intermediate post with bracing



1 M 12 bolts
2 6 mm thick m s. gusset plate
3 2 x 150 x 50 mm "kempas" tie beams
4 300 x 300 mm hardwood "kempas" column
5 400 mm diameters concrete base at 900 mm high
6 150 x 150 mm hardwood "kempas" roof beam
7 125 x 50 mm web members
8 2 x 125 x 65 mm upper and lower chords
9 60 mm thick gussets plate

Figure 2 106
Detail of column connection

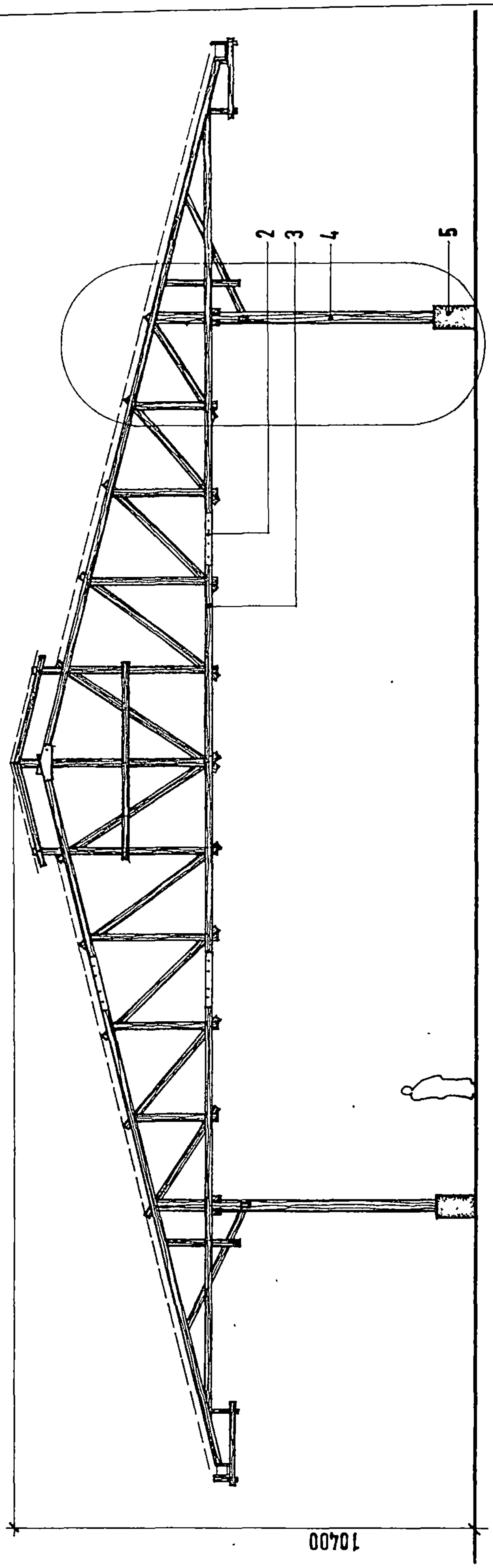


Figure 2.104
Section

Plate 2.25
Detail of truss with knee braced support. Lateral movement was strengthen by 125 x 125 mm knee braced support at the column, connected using M 12 bolts and nuts. Because it was difficult to obtain timbers of sufficient length for the tie beam, this member was formed in two lengths.

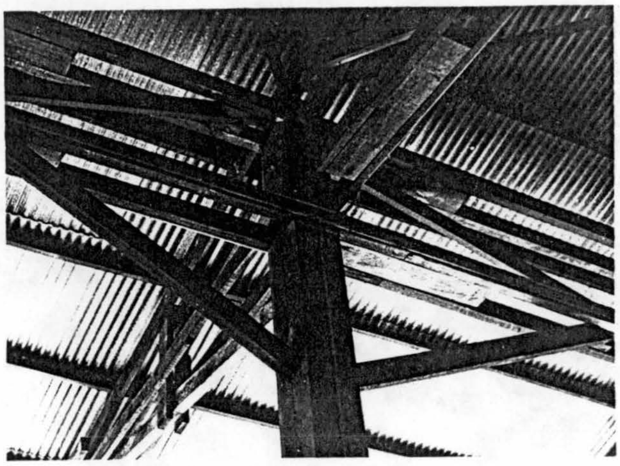


Plate 2.26
Detail of roof bracing.
Diagonal bracing is provided to prevent the roof structures from lateral movement.

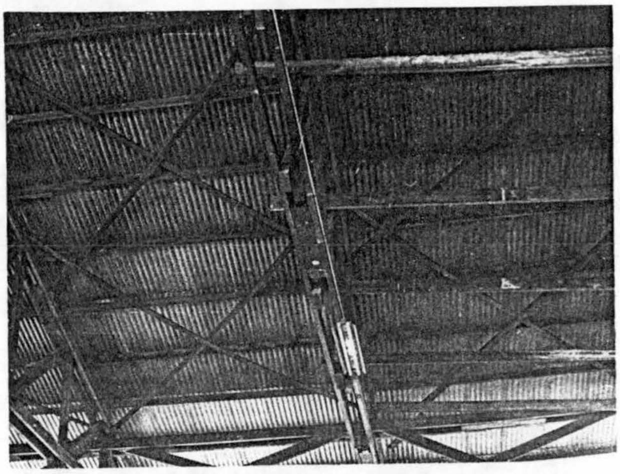
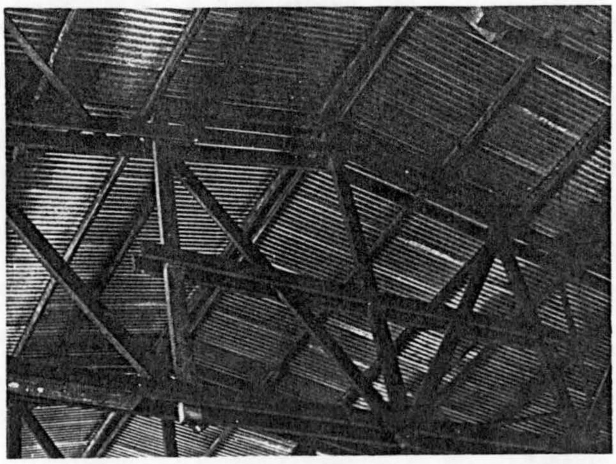


Plate 2.27
Detail of truss.
Twin collar tie is used to brace at the centres of the webs members.



Case Study 2.5.18

Name : Space Frame Experimental Structure

Engineers : Low Kow Sai

Owner : Forest Research Institute of Malaysia, Kepong, Selangor

Date Constructed : 1989

Influences : Space frame is a 20th century structural innovation using computer calculations to analyse the structural behaviour of roof members Timber space frame could be adopted for more efficient and economical reasons, compared to steel structures. Space frame structure has the advantages of cost efficiency and structural lightness for larger span buildings Although wood has a high strength to weight ratio, it is governed by the efficiency of the jointing system, especially the joints in tension state. Essentially this efficiency derives from the elimination of bending or direct axial forces in individual members. Lower chord joints are bolted into the spaced column with bolts. The bending moment governing the webs and connections is decomposed into shears and axial forces in upper and lower chords Because the cost of space frame depends primarily on the number of joints, it is economical to use large grid module. However, a disadvantage is that larger grids increase the connection forces.

Structural System : Flat plate

Analysis : Roof is a partially cantilevered truss grid resting on corner columns spaced at 2 50 x 1.60 metres. Truss cantilevers sides at 1.50 metres and truss depth is 600 mm. Upper and lower chords 50 x 50 mm are single member Lower chord joints are jointed with steel plates with M 20 bolts and nuts Columns are built up of 2 x 50 x 50 mm "kempas" hardwood. The end columns is braced with 50 x 50 mm hardwood knee brace in four directions to give stability of the entire structure.

Source :

- Forest Products Division, Forest Research Institute of Malaysia.

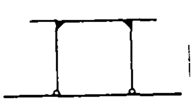


Figure 2 107
Load path diagram

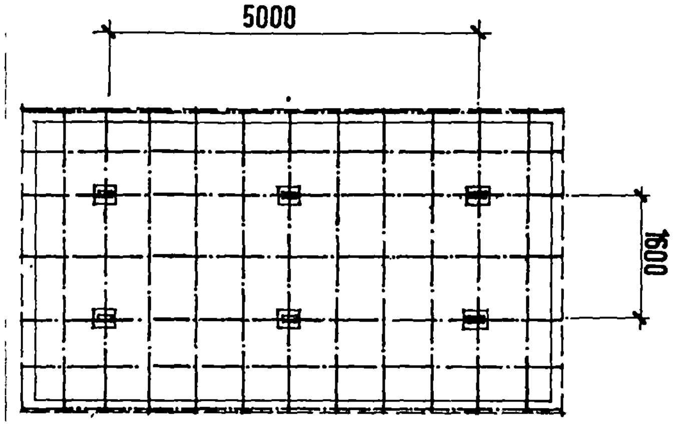


Figure 2.108
Roof framing plan

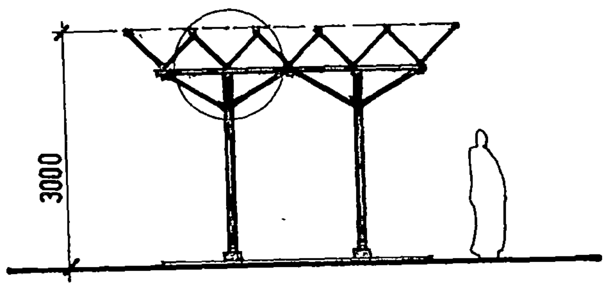


Figure 2.109
Section

1 50 x 50 mm hardwood purlin
2 25 x 25 mm strut member
3 M 20 bolt
4 50 x 50 mm hardwood knee braced
5 2 x 50 x 50 mm hardwood post
6 150 x 200 mm hardwood timber block

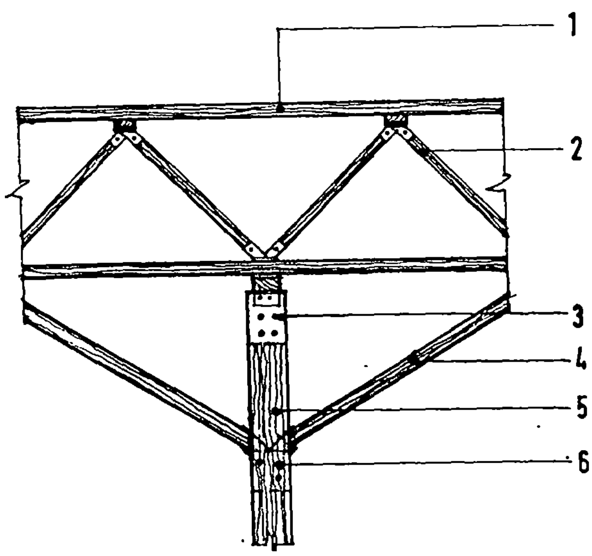


Figure 2 110
Detail of roof connection

Plate 2.28
Detail of intermediate post.
Hardwood knee brace
50 x 50 mm braced in four
directions to give stability
to the roof structure and transfer
loads to spaced columns
50 x 100 mm.

Plate 2.29
Detail at the top of a spaced column.
Space frame roof structure is
designed in a modular system
using mild steel plates to connect
the roof to the columns using bolts
and nuts.

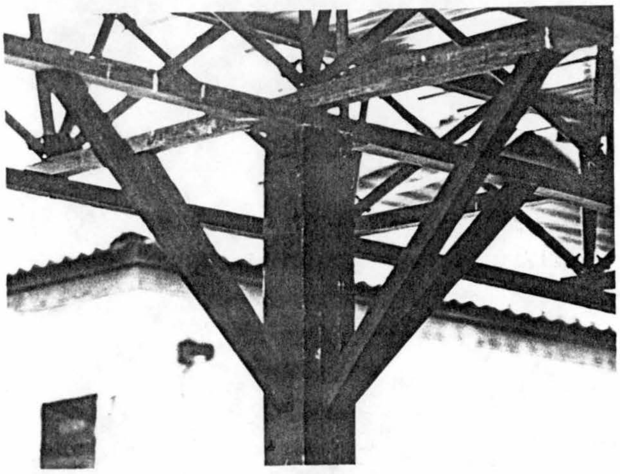
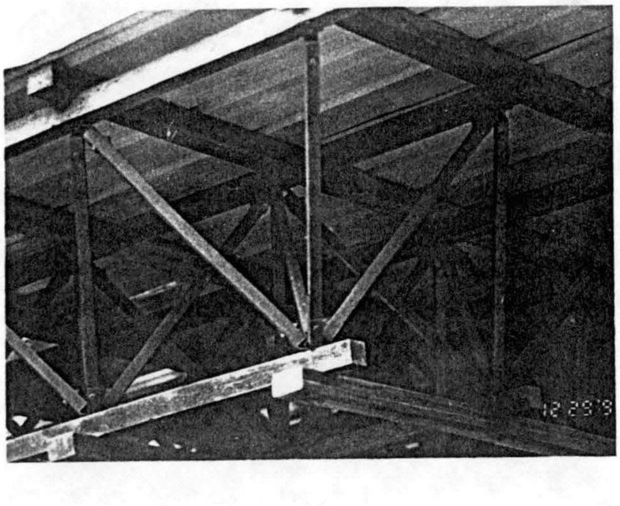


Plate 2.30
Detail at the corner of the
cantilevered roof structure.
Space frame member
50 x 50 mm cantilevered
out 1.50 metres from support
which transmits load to column.



CHAPTER 3

Case Studies of International Wood Architecture

Chapter 3 Case Studies of International Wood Architecture

This section contains five case studies, three Australian, one from Norway and another from Switzerland. These examples of wooden structures illustrate the practical use of structural timber, and suggest future directions for value adding to forest-based resource which might applicable to Malaysia situation. Although, these examples are from overseas, the integration of timber technology use in their construction, has potential for the construction of timber structures in the Malaysian context.

These structures have been selected as they represent unique structural forms, with the common characteristic of long span capabilities, over 19.50 metres Such structures, which require a high level of technical competence from designers, are the product of different structural technologies and will be examined in terms of construction and structural systems

Lew (1992 : p. 72), has stated that the Asean Timber Technology Centre, of which he is the director, will continue to play a catalytic role focussing specifically on appropriate technology transfer based on research and development, to achieve a rapid development for timber use locally.

Wong (198 : p. 3), has mentioned that Malysian experiance in techno-transfer process does not always end with success. The development of new technologies and the translation of new technologies into commercial application involve extensive research and development, incurring considerable time, efford and money. In the course of industralization, the Malaysian timber sector has brought in various technologies from overseas and has been exposed to some of the indigeneous technologies which are mostly adaption of technologies developed in oyher research laboratories It is a complex process particularly in developing countries which have different cultures and needs to be adapted

The resposibility of carrying out research and development activities rests with Forest Research Institute of Malaysian (FRIM), the Forest Research Centre of the Forest Department Sabah, the Timber Research and Technical Training Centre of the Forest Department Sarawak and the institutions of higher learning, particularly the Forestry Faculty of the Agriculture University Malaysia (UPM) and University Technology Malaysia (UTM). The promotion of research on timber engineering for a greater use of timber for structural purpose should be collective and coperative efforts between the researchers in the ASEAN region.

1 Naval Stores, New South Wales, Australia

The first example examines a clear large span triangular timber truss building constructed in 1943 in New South Wales, Australia (See Figure 3 1) The construction system explored the use of small built-up timber members nailed together to form boxed trussed arches which span 32.0 metres. This has obvious advantages to the use of timber in a resource rich country, which is concerned about the depletion of this valuable resource. Properly designed structural timber components can also make effective use of cheaper, locally available wood species of short lengths from off-cuts or forest thinning.

2 Devonport War Memorial Swimming Centre, Tasmania, Australia

The second example explored the use of timber to create built-up space frame trusses, which is a recent innovation with the aid of advancements in computer software to calculate its structural behaviour (See Figure 3.7). The space frame supports a metal deck roof made up of saw textured Tasmanian hardwood members joined by 50 mm steel bolt connections. The structure is designed on a 1220 mm grid and is seated on 12 RHS columns An experimental shed constructed by the Forest Research Institute of Malaysia at Kepong has proven that smaller off-cut timber members can be successfully adopted and applied for larger span building. The efficiency of this type of system which is supported along it edges, rather than by columns, has effectively reduced the span. Further more, space frame is much more efficient than a two-way truss system because the diagonal members are at an angle so that they give torsional stiffness and the ability to distribute load.

3 Tradesman's Entrance Hardware Store, Victoria, Australia

The third example used plywood box beams which have considerable structural depth and saving of material in the less heavily stressed webs. (See Figure 3 10). This building demonstrates an understanding of the use of different timber materials in a variety of structural forms and jointing techniques For example, solid timber was used as bolted columns and trusses, while plywood was used in diaphragms, shear walls, webs in beams, nailed gusset plates and as external cladding Glued-laminated timber was used to form the main portal frame structure and laminated veneer lumber was used as members in the bolted and nailed trusses.

4 Hamar Olympic Stadium, Norway

The fourth example used a glue-laminated timber construction to achieve an alternative solution for a large span structure. (See Figure 3.13). Glued-laminated technology arrived in Malaysia in the 1960's, and has been used to construct an experimental laminated bridge structure and later a mosque at Forest Research Institute Malaysia (Tan, 1987 (a) : p. 1). This method uses smaller pieces of "Light Red Meranti" timber glued together to form individual members which in turn are glued together to form large cross sections for beams or columns In the field of glue-laminated timber construction, the development of different techniques has created a virtually unlimited range of possibilities to adopting the shape of members to structural or aesthetic requirements They are suitable for industrial and commercial buildings appropriate for Malaysia.

5 Wohlein High School, Switzerland

The fifth example explored the possibilities of using plywood material in building. Because of its shear values combined with flexural rigidity and light weight, it can be fully exploited as sheathing for framed buildings, gussets for timber trusses, I-webs, box beams and folded plate roofs (See Figure 3.15) Plywood has a very light strength to weight ratio because its structure can resist high concentrated loads. It has a low coefficient of expansion and moves very little with changes in moisture. In 1992, Malaysia exported 1.92 million cubic metres plywood, which is now Malaysia's largest export product. However, very little use is made of plywood locally. Development overseas in the use of plywood for structural components have potential applications in Malaysia and such local use of plywood should be encouraged

Case Study 3.1

Name : Naval Stores

Designer : Allied Works Council (AWL)

Owner : The Royal Australian Navy

Builders : Civil Construction Corporation

Date Constructed : 1943

Location : Spurway St. Ermington, New South Wales, Australia

Structural System : Three pin trussed arches - foundation

Sources

- Department of Works & Housing, 1946, A Report on the Structural Soundness of Unseasoned Timbers Used in Structures Erected for War Purposes, Department of Works & Housing, Melbourne.
- Nolan, G., 1994 (b) : pp. 269 - 278

Description : In 1943, the threat of Japanese invasion of Australia created the need for rapidly constructed military buildings. The design of naval store at Ermington, New South Wales, was derived from steel hanger in the U.S. A., and adapted for construction as a segmented curved roof structure built from unseasoned Australian hardwood instead of steel (Nolan, 1994 (b) : p 272) This building explored every possible timber construction nail joint technology introduced by the United States military which was available at that time These structures are unique as they are the first long span trusses recorded that use timber as tension web members and remain the longest clear span triangular timber truss buildings in Australia.

The complex consists of seven 125.0 x 32.0 metres wide buildings (See Figure 3 3). Each store is roofed by 32 three pin trussed arches in 31 off 4.02 metres bays Each arch is a boxed trussed member 600 mm wide and 950 mm high at the centre, and tapering in height to each end. (See Figure 3. 1). The arches are constructed from green hardwood and were nailed on site. The diagonal web members run past the arch chords, giving enough space end grain distance to control end splitting (See Figure 3. 2) Two bays at each end are braced. Purlins 100 x 50 mm are spaced at 1000 mm centres are simply supported by green hardwood running over the top of the arches, supporting a curved sheet metal roof (See Figures 3 4 and 3.5) The roof structure is strutted off the arches at the apex to provide a ridge Arches are supported off concrete base pads for stability and tied down by two bolts at each foundation point.

Plate 3.1
The arches being constructed by local carpenter in 1943.
Source : Australian Archive

Plate 3.2
View looking at the arches. The arches are constructed of lattice nailed light hardwood members.

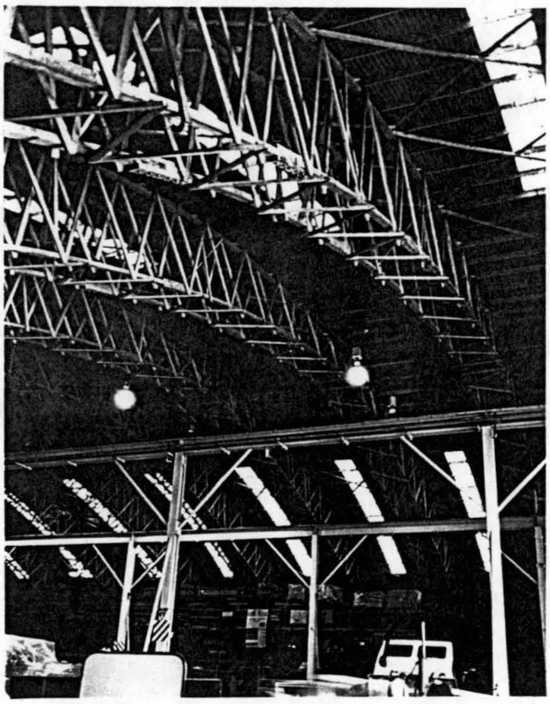


Plate 3.3
Detail of arches.
A section of the box arch showing four layers of vertical webs and two layer of horizontal weds framing the arch chords.

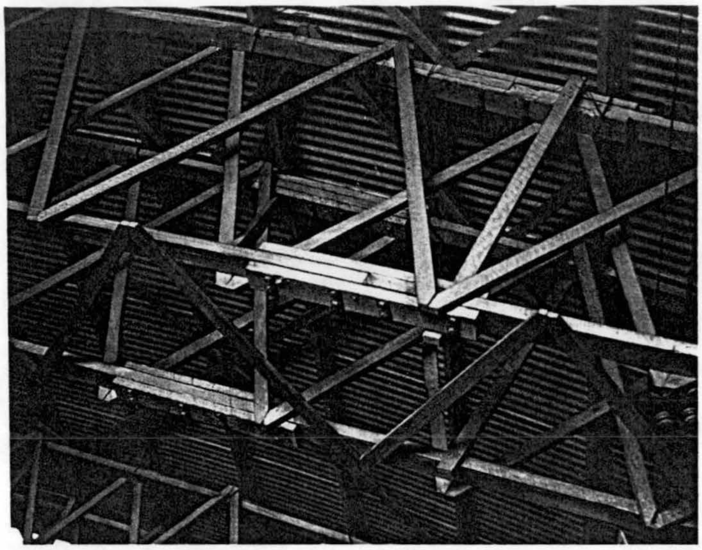


Plate 3.3
Detail of arches.
Timber of 125 x 63 mm arch chords is used.

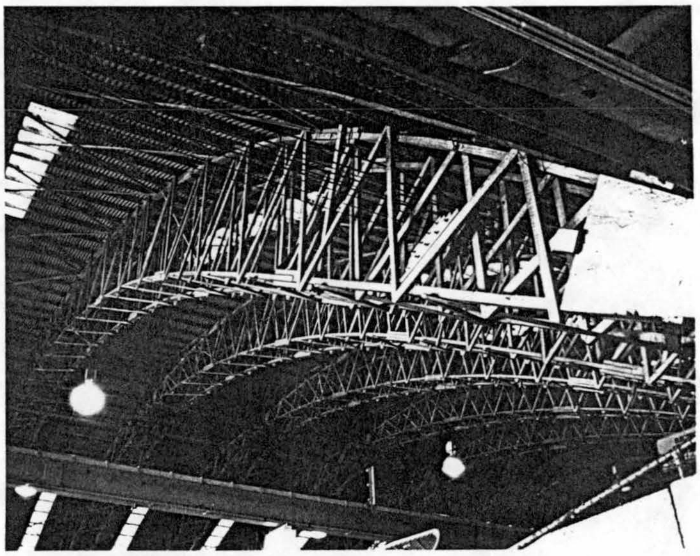


Plate 3.5
The base connection of arches consisted of two tie down bolts and a hardwood pin. Base pin to the arches is sited on the buttress frame.

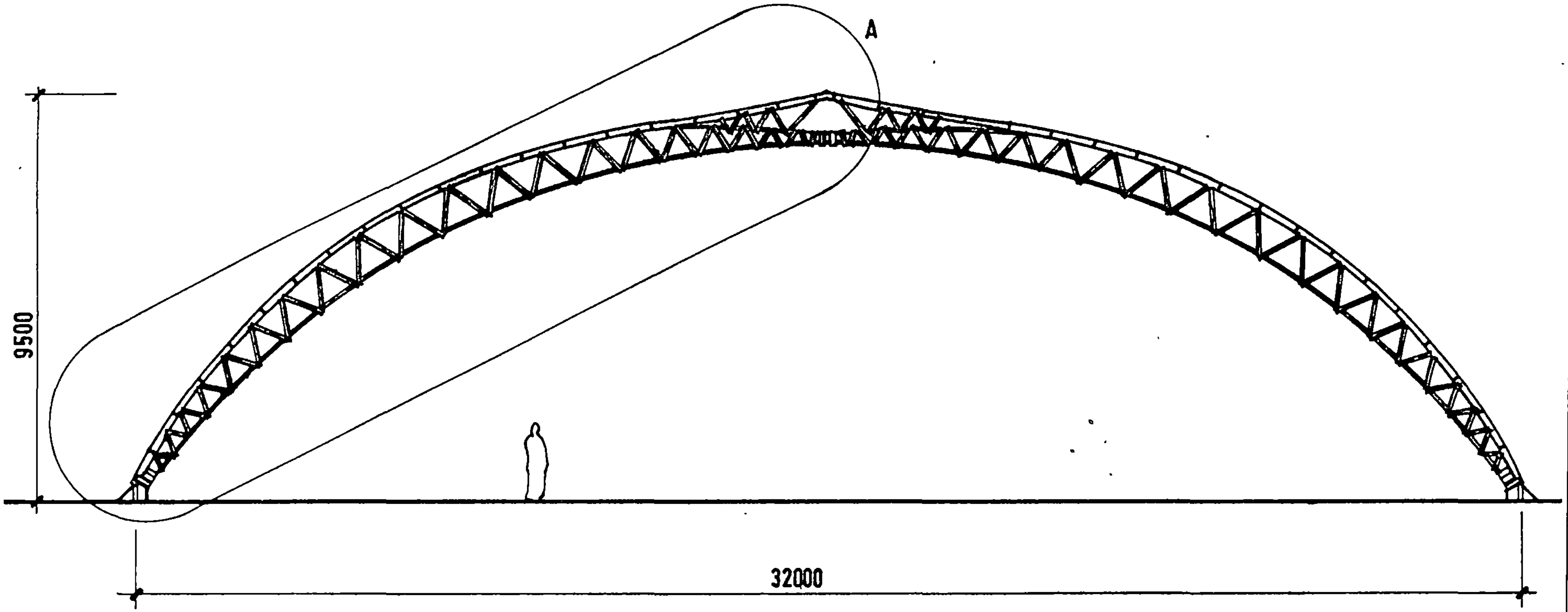
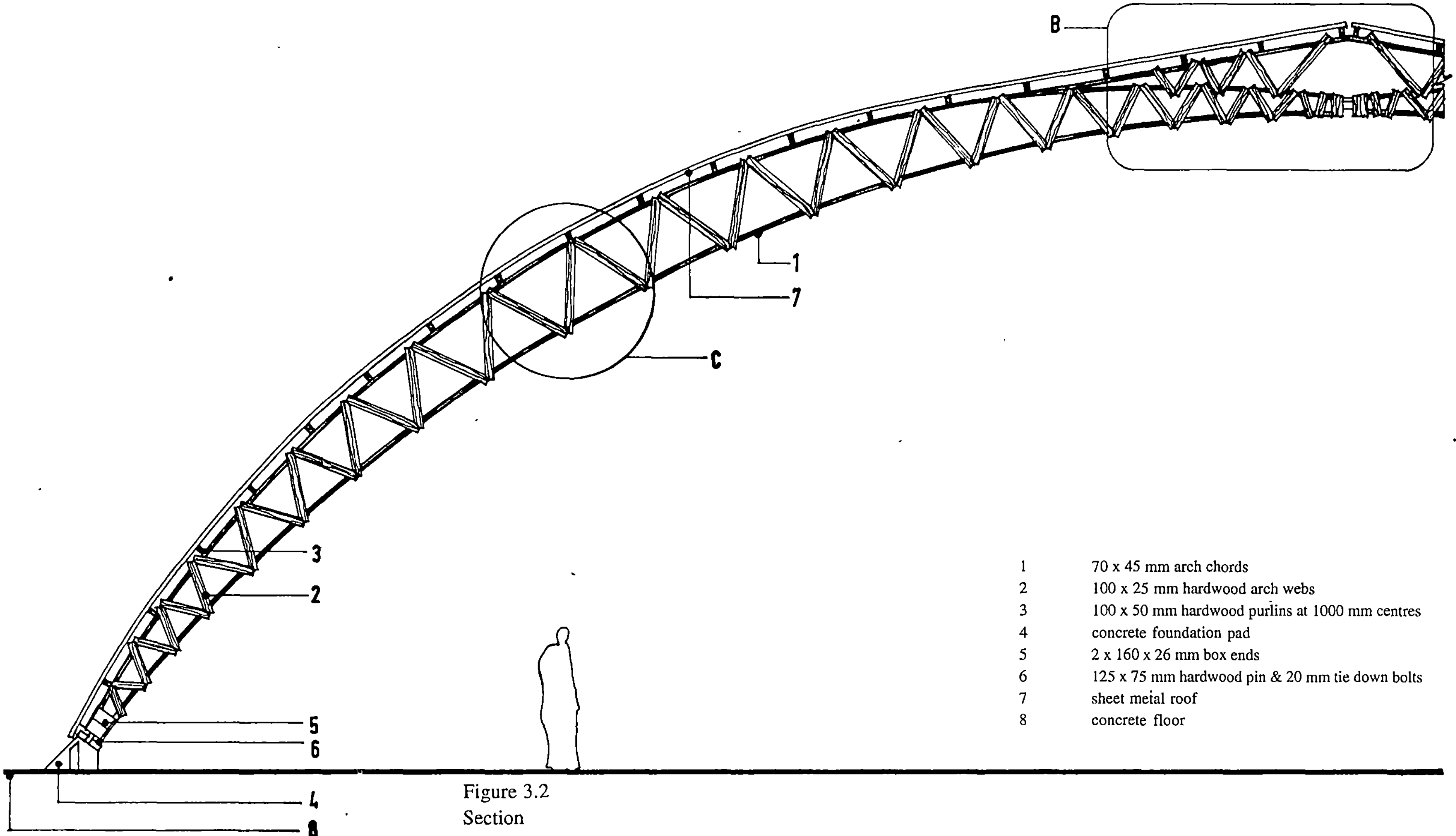


Figure 3.1
Section
Source : after Nolan, 1993 : p. 202



1	70 x 45 mm arch chords
2	100 x 25 mm hardwood arch webs
3	100 x 50 mm hardwood purlins at 1000 mm centres
4	concrete foundation pad
5	2 x 160 x 26 mm box ends
6	125 x 75 mm hardwood pin & 20 mm tie down bolts
7	sheet metal roof
8	concrete floor

Figure 3.2
Section
Source : after Nolan, 1994 : p. 203

1	70 x 45 mm arch chords
2	100 x 25 mm hardwood arch webs
3	100 x 50 mm hardwood purlins at 1000 mm centres
4	concrete foundation pad
5	2 x 160 x 26 mm box ends
6	125 x 75 mm hardwood pin & 20 mm tie down bolts
7	sheet metal roof
8	concrete floor
9	100 x 25 mm hardwood arch chords to top & bottom faces
10	75 x 35 mm hardwood internal braces
11	150 x 75 mm hardwood pin & steel tie rod
12	4 x 65 mm nails to each web joint
13	hardwood roof bracing
14	box arches

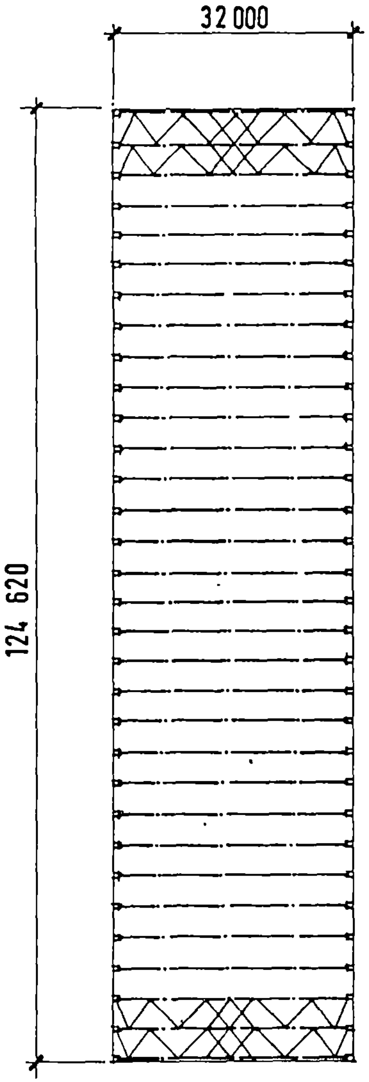


Figure 3.3
Plan
Source · after Nolan, 1994 : p. 204

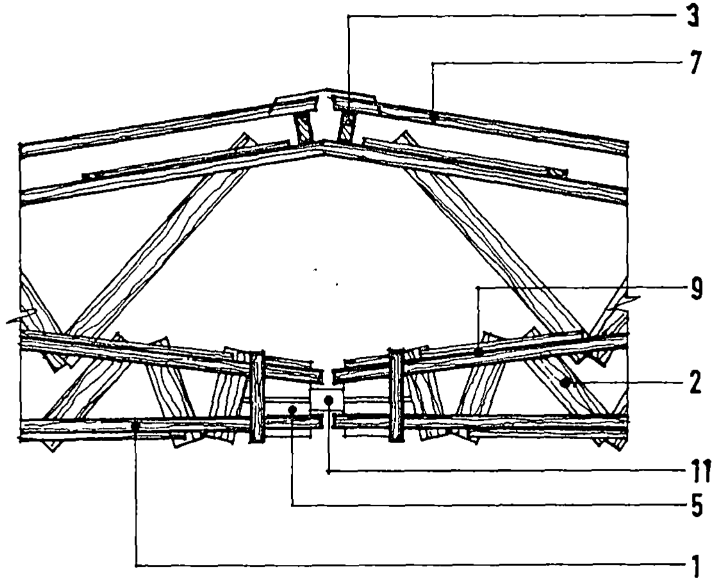


Figure 3.4
Detail A

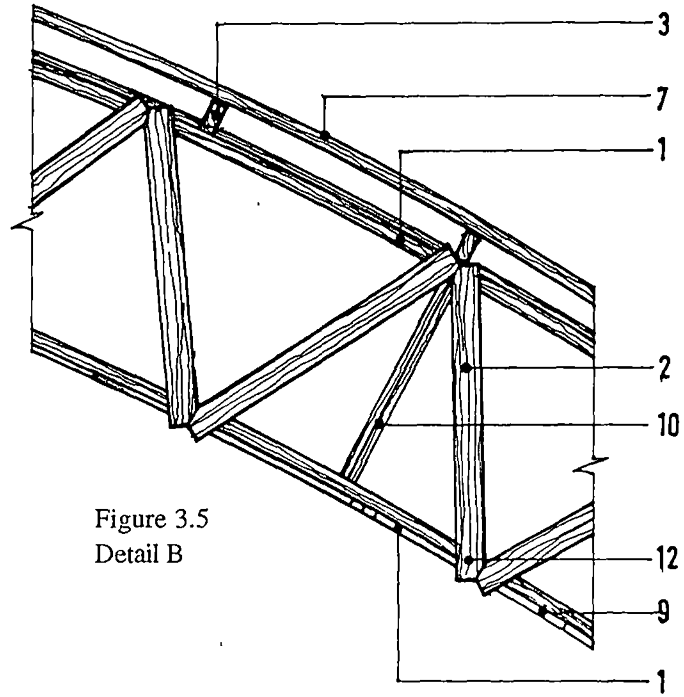


Figure 3.5
Detail B

Case Study 3.2

Name : Devonport War Memorial Swimming Centre

Architect : Albert A. Freak

Engineer : Pit and Sherry Consulting Engineers

Owner : The City of Devonport

Builders : Civil Construction Groups

Date Constructed : 1974

Location : Steele Street, Devonport, Tasmania, Australia

Structural System : A grillage of intersecting sawn hardwood trusses

Sources

- Devonport Municipal Council
- Wood World, 1974, "Devonport Swimming Centre", Wood World, Vol. 8, No 1.

Description : The building consists of three 14.60 metres square units of intersecting trusses to a support metal roof. (See Figure 3 7). Each unit is supported on four steel knee bracing resting on concrete supports. Each truss in the unit is a parallel chord Warren truss system fabricated from seasoned hardwood. Truss is built up with pairs of members for the top chord 127 x 38 mm and bottom chord 100 x 38 mm, and single web members 100 x 38 mm. The trusses are designed to pass through each other on a regular grid, and the chords are tied together with a M 20 bolts as they cross. To resist the increased shear around the supports, the webs were designed in the four perimeter lines of trusses which vary from a normal truss layout. The two outside trusses on each face of the grid use a 100 x 38 mm web, reinforced with additional members over the columns. The next two trusses are 76 x 51 mm webs and the remaining trusses used are 76 x 38 mm. Truss joints are bolted with 50 x 50 mm washers. (See Figure 3.8 and 3.9).

Plate 3.6
Detail of the corner of truss support on four steel RHS 102 x 102 mm.

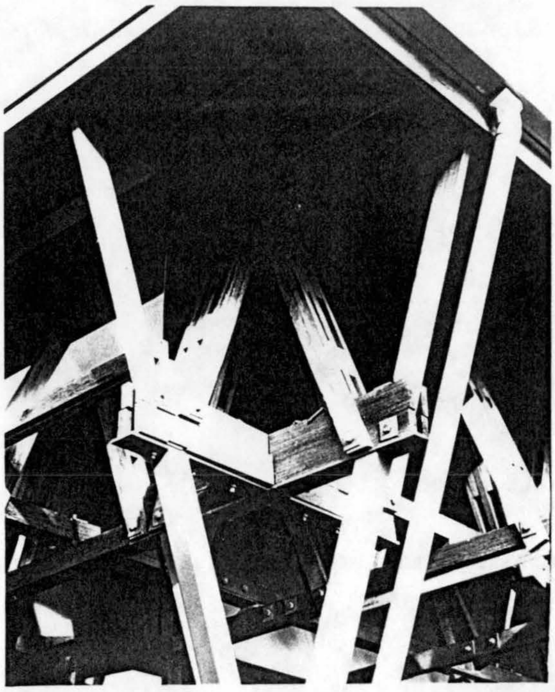


Plate 3.7
Detail at intermediate support. A cross shape steel plate used as a base connector between bottom chord and steel RHS using bolts and nuts.

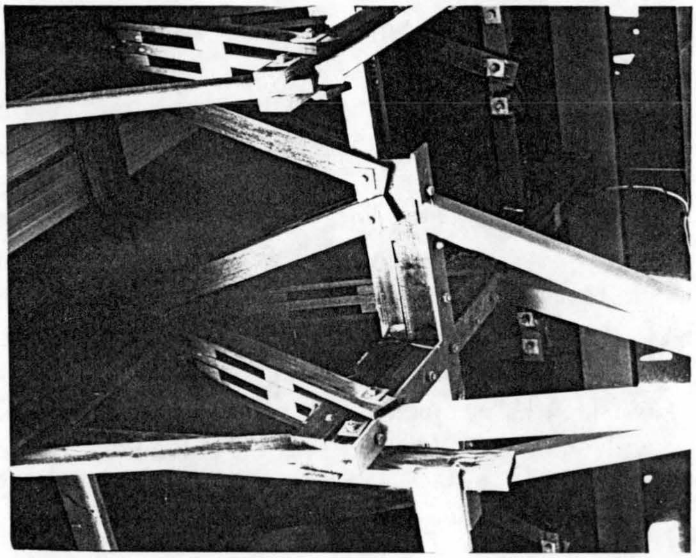
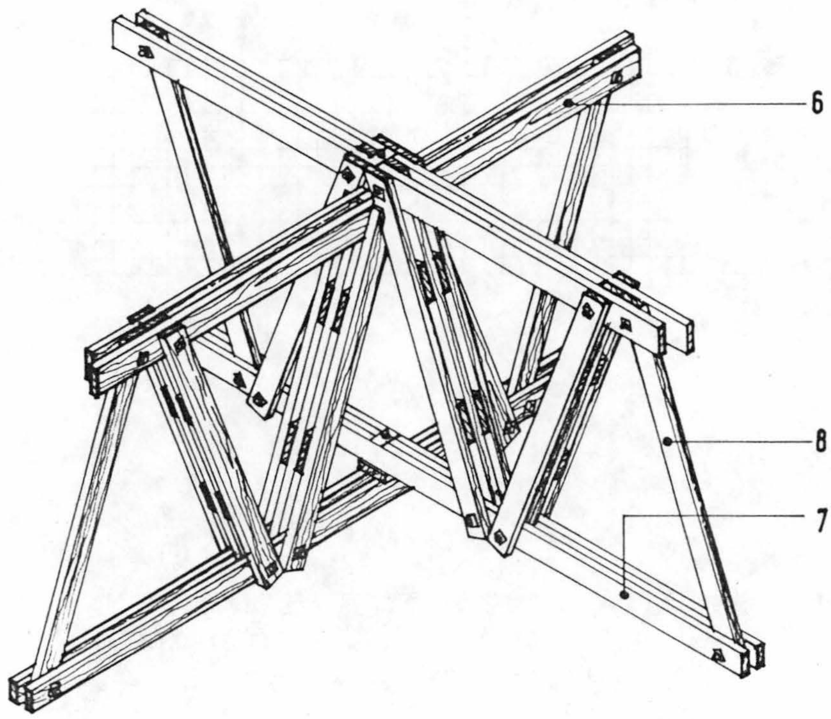


Figure 3.6
Trussed beam grid detail

6	top chords 2 x 127 x 38 mm
7	bottom chords 2 x 100 x 38 mm
8	web 75 x 38 mm



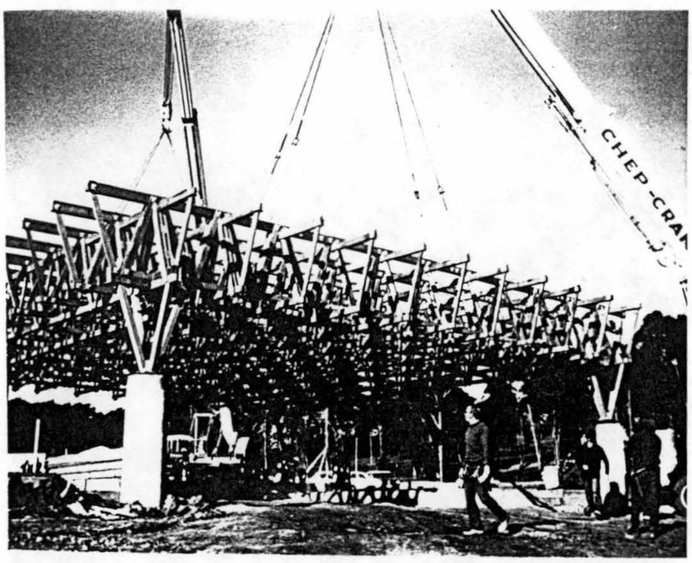


Plate 3.8
The transverse trusses were prefabricated, assembled and spaced on-site before the precut members of longitudinal trusses were assembled and connected. The finishes roof units were craned onto their support.
Source : Devonport City Council

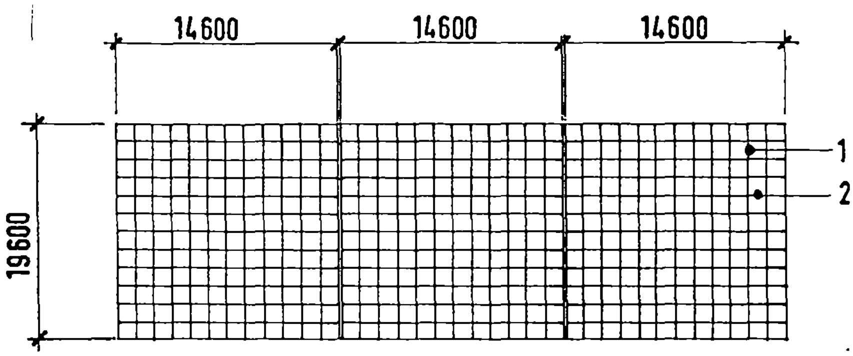


Figure 3.7
Plan

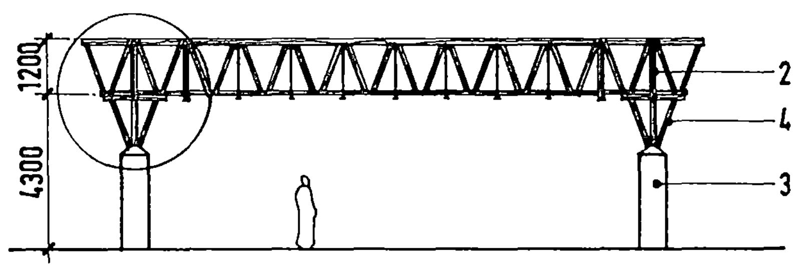
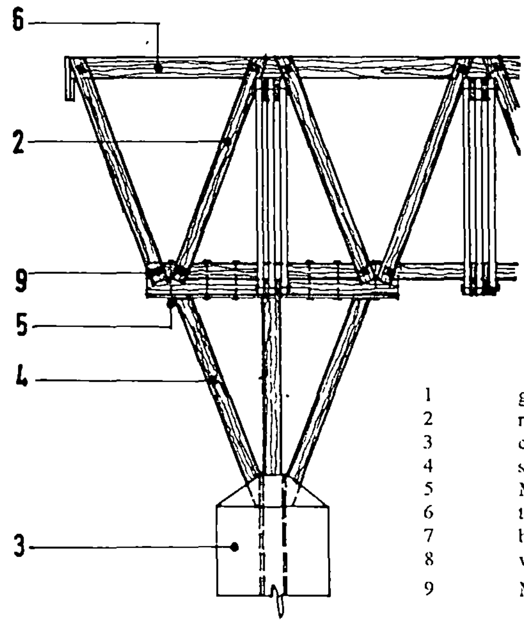


Figure 3.8
Section



1 grillage truss
2 reinforced web 3/100 x 38 mm
3 concrete column, 610 mm diameter
4 steel RHS support 102 x 102 mm
5 M 20 bolt
6 top chords 2 x 127 x 38 mm
7 bottom chords 2 x 100 x 38 mm
8 web 75 x 38 mm
9 M 16 bolt

Figure 3.9
Detail A

Case Study 3.3

Name : Tradesman's Entrance Hardware Store

Architect : S Sokolski Co Design

Engineer : P.J Yttrup and Associates

Operator : BBC Hardware

Builder : S C. Project Management

Location : Mickleham Road, Tullamarine, Victoria, Australia

Date Constructed : 1987

Structural System : Plywood box beams

Sources

- Australian Forest Industries Journal, 1987, "Structural Timber Smorgasboard", July, pp 36 - 38
- Australian Forest Industries Journal, 1987, "Tradesman"s Entrance Showpiece Sales Centre, July.
- Nolan, G., 1994 (b) : p. 269.

Description : The Tradesman's Entrance Hardware store at Tullamarine, Victoria was designed by S Sokolski in 1987 and consists of two wings, each constructed from different structural systems. The timber warehouse was built with double Oregon columns supporting 30 0 metres laminated veneer lumber (LVL) box beams (See Figures 3.19 and 3 20). Each beam consists of eleven 1200 mm deep tapered box section fabricated from 240 x 63 mm L.V L., sawn timber stiffeners and 15 mm plywood as webs. Twin 350 x 75 mm F7 Oregon folding columns were attached to the box beams on the ground, with 200 x 75 mm F7 knee braces connected after erection to reduce the effective height. A plywood diaphragm runs the length of the building in the roof plan. Purlins and girt cleats were built from 200 x 50 mm F7 Oregon. This building uses a variety of structural techniques and materials including glue laminated pine, ply and laminated veneer lumber, and bolted and nailed parallel chord trusses. The principle structural form of this wing complex comprises twin bay portal frames spanning at 15.0 metres each and are on a 12.0 metres grid. The central column of these frames carries 4.80 metres deep parallel chord trusses which support secondary transverse portal frames at mid span The parallel chord truss was designed to support clerestory trusses for natural lighting.

Plate 3.9
The 1200 x 260 mm plywood box beam spaced at 6.0 metres at the timber warehouse.

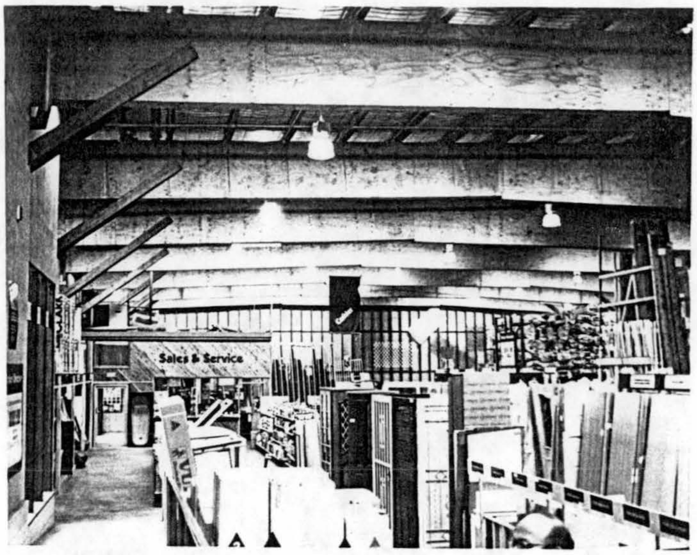


Plate 3.10
4.80 metres high laminated veneer lumber trusses running through glu-laminated twin portal frames in the hardware wing.

Plate 3.11
200 x 50 mm F 7 purlins run over in the plywood box beam in the timber warehouse. Purlins members of 200 x 50 mm F 7 spaced at 1200 mm centre rest on the plywood box beam.

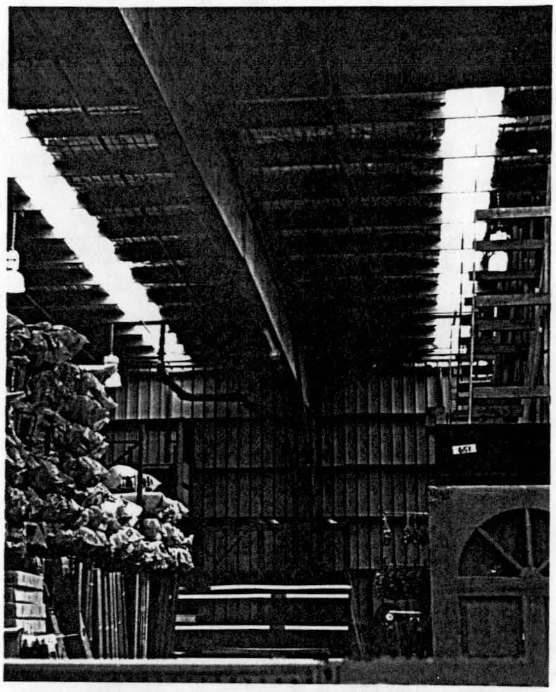
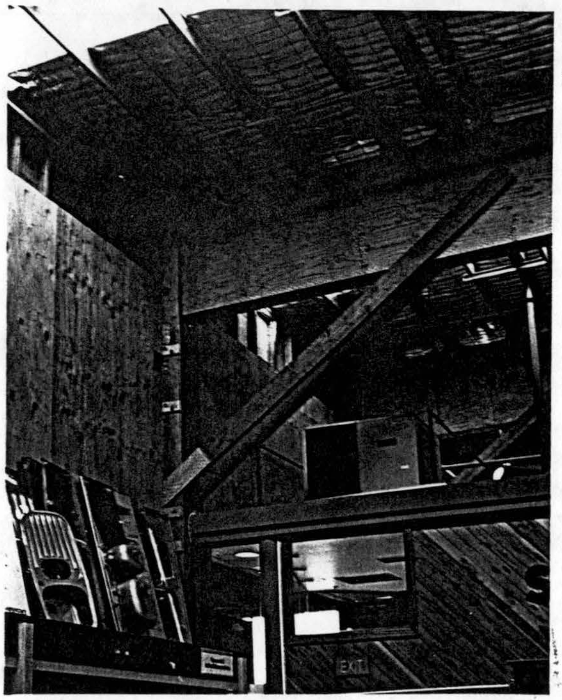


Plate 3.12
Knee braces of 200 x 75 mm used to stiffen the spaced twin 300 x 75 mm columns.



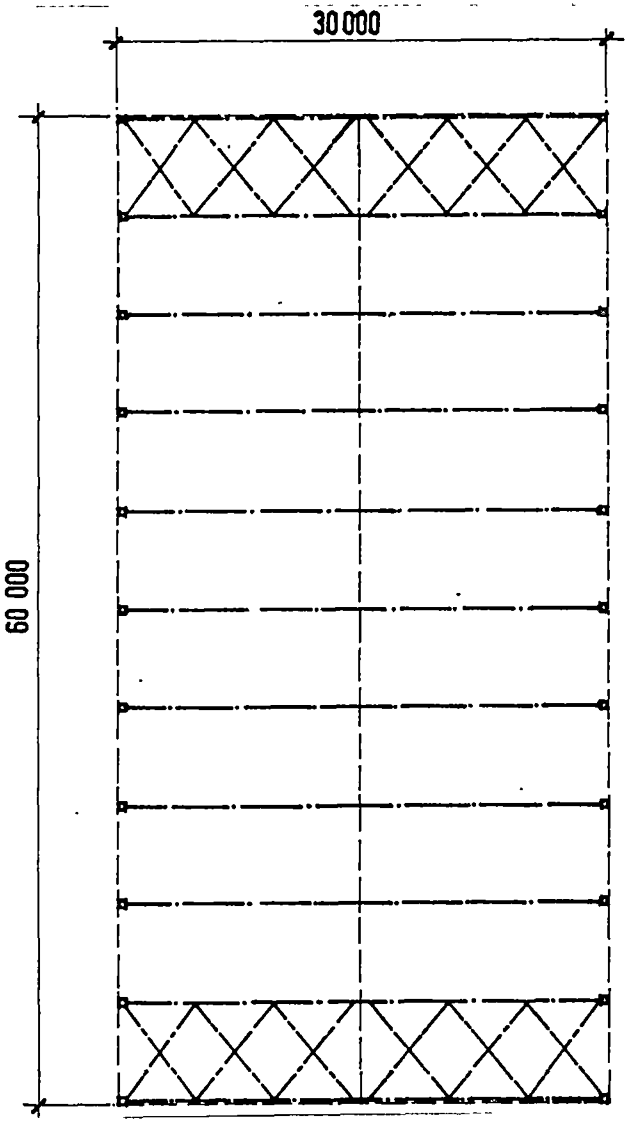


Figure 3.10
Plan
Source : after Nolan, 1993 : p. 97

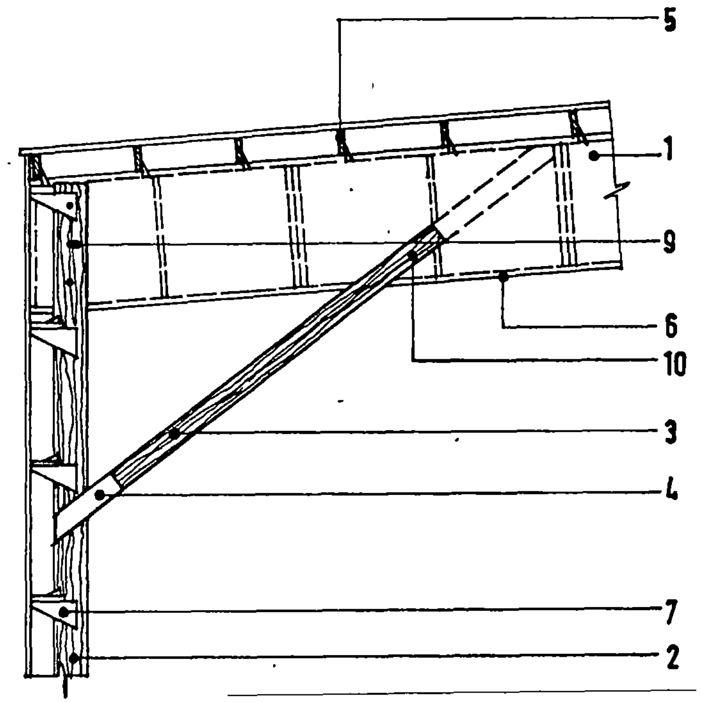


Figure 3.11
Detail A

1	1 x 200 x 270 mm plywood box beam
2	2 x 300 x 75 mm F 7 columns
3	2 x 200 x 75 mm F 7 knee braced
4	15 mm plywood nail gussets
5	200 x 50 mm F 7 purlin at 1200 centres
6	240 x 63 mm LVL frame
7	15 mm ply girt cleat
8	15 mm ply shear skin bracing
9	3 x M 20 bolts
10	Nail group

1	1 x 200 x 270 mm plywood box beam
2	2 x 300 x 75 mm F 7 columns
3	2 x 200 x 75 mm F 7 knee braced
5	200 x 50 mm F 7 purlin at 1200 centres
8	15 mm ply shear skin bracing

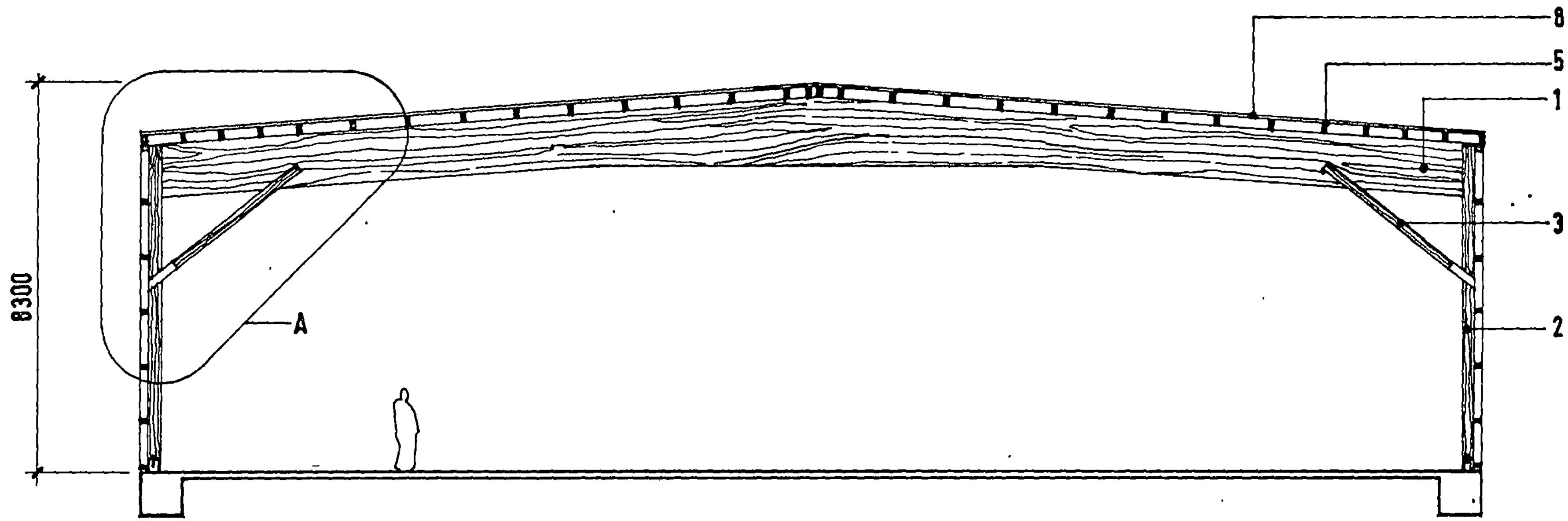


Figure 3.12
Plan
Source : after Nolan, 1993 : p. 98

Case Study 3.4

Name : Hamar Olympic Stadium

Architect : Biong & Biong/Niels Torp A.S.

Contractor : Ole K. Karlsen A.S.

Location : Lillehamar, Norway

Date Constructed : 1994

Structural System : Glue-laminated trusses

Sources

- Aasheim, E., 1994, "Glulam Trusses for the 1994 Winter Olympics". In Proceeding of Pacific Timber Engineerıng Conference, Vol. 1, p. 381.
- Holmestad, A. 1994, "The use of Wood and Glulam in the XVII Olympic Winter Games". In Proceedings of the Vision Eureka - Lillehammer Õ94, 13th - 16th June, 1994, Norway, pp. 1 - 3.
- Sund, B. and Hovedflyplass, O. 1994, "General use of Wood in connection with the XVII Olympic Winter Games". In Proceedings of the Vision Eureka - Lillehammer '94, 13th - 16th June, 1994, Norway, pp. 1 - 3.

Description : In 1994, the Hamar Olympic Stadium was built for the Winter Olympic Games which were held in Lillerhamer, Norway. (See Figure 3.14). Glulam trusses were chosen as the principal load-carrying elements. For glulam, the arch is particularly favourable because the cost of producing large curved glulam beams is particularly the same as for the production of straight beams. The jointing system used 12 mm steel dowels of high grade steel and slotted-in with 8 mm steel plates. The construction system is developed based on such factors as the effective use of timber, flexibility in design, prefabrication of components, ease of handling, transport and installation. The main structure consists of arched trusses with spans varying between 30.0 metres and 96.40 metres, spaced 12.0 metres apart. (See Figure 3.13). The roof construction consists of corrugated steel with insulation and roofing felt covering, supported by glulam purlins. The stadium has an inside length of 260.0 metres, width of 96.0 metres and a highest point of 35.0 metres.

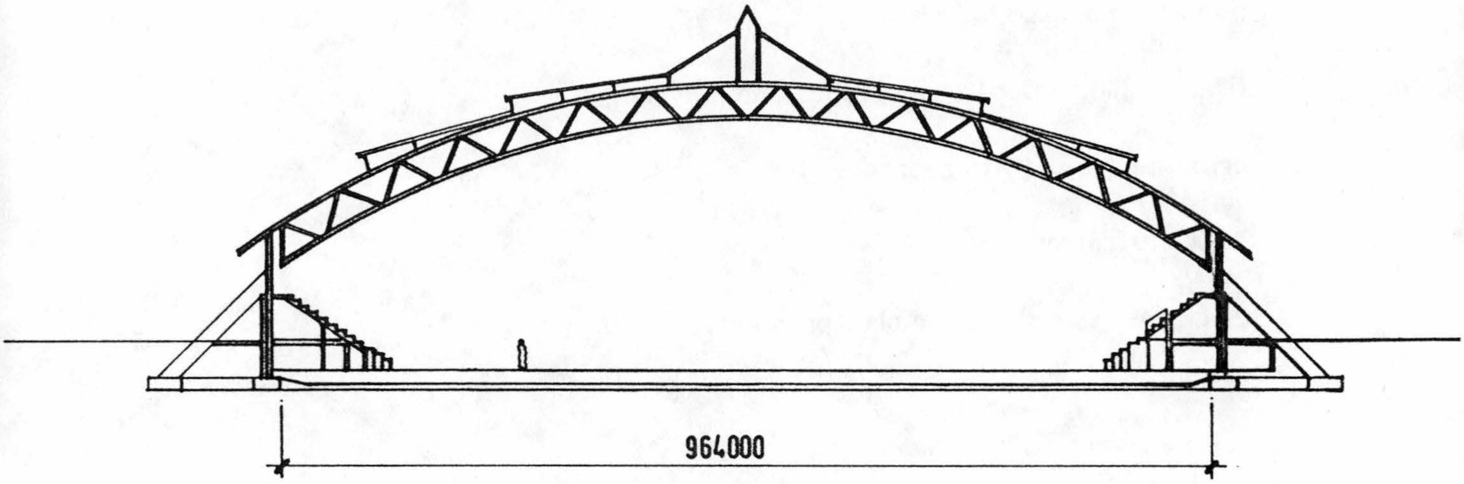


Figure 3.13
Cross section of Hamar Olympic Stadium
The architectural form was inspired by an upturned Viking ship. It is also defined as adaption to the landscape, plain volume compositions, use of natural materials, stone and wood. The stadium has the capacity to accommodate between 10,000 to 20,000 spectators.
Source : after Aasheim, E. p. 381

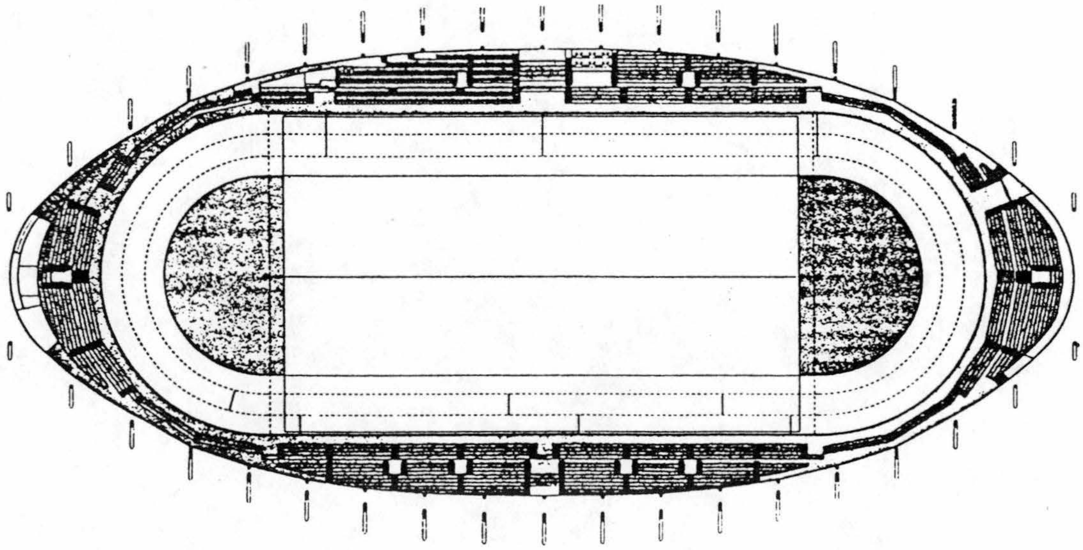


Figure 3.14
Plan of Hamar Olympic Stadium
Source : after Aasheim, E. p. 381

Case Study 3.5

Name : Wohlein High School

Architect : Burkhard, Meyer, Steiger, Baden

Engineer : Santiago Calatrava

Client : Building Department of the Canton of Aargau

Location : Aargau, Switzerland

Date Constructed : 1987

Structural System : Folded plate plywood

Sources

- Natterer at al, 1991, *Holzbau Atlas*, p. 251
- Davey, P. (edi.), 1991, "Burkhard Meyer Steiger", p 36.
- Blazer, W. (edi.), 1990, Santiago Calatrava, Birkhauser Verlag Basel, p. 40

Description : The entrance hall, 13.0 metres in diameter, is roofed by twenty manufactured V-formed elements. (See Figures 3.15 and 3.16). These are connected on one central steel ring fixed in a position which lay on a metal support anchored in a concrete beam. A series of folded plate plywood is held together by steel tension rods. Double cone wood pieces provide the tension for the box profile and are made from steel tubes on the lower edge of the BHS disk fastener. The stiffening of the roof surface is provided by the above panelling.

1 10 x 16 mm pressure beam
2 steel ring 70 mm diameter
3 cladding bound together with V-shaped beams
4 steel square
5 rod BSH 60 mm
6 pulling bend BSH 50 - 180 mm
7 tension metal support
8 pull anchored 3 x 10 x 40 mm

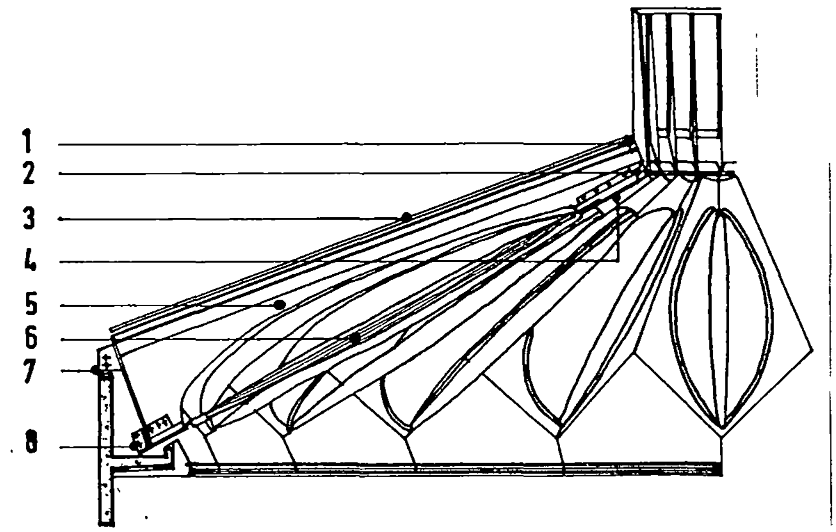


Figure 3.15
Partially section of cupola

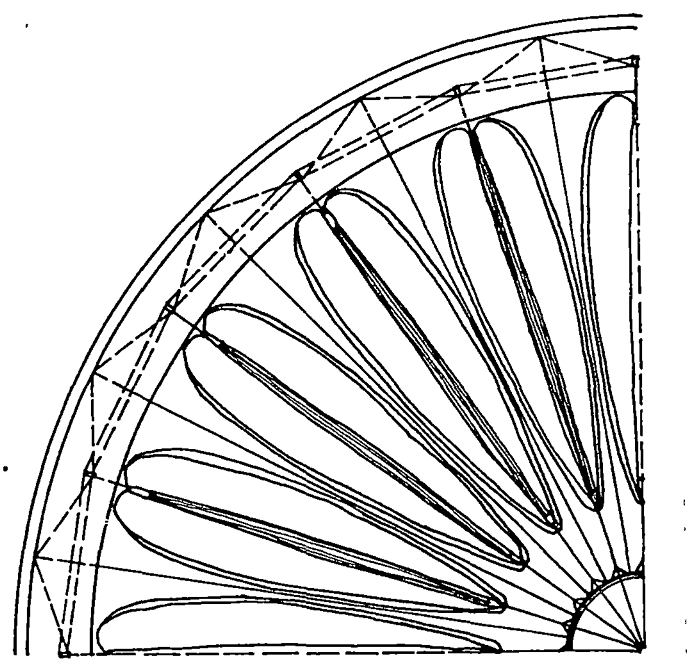


Figure 3.16
Partially plan of cupola

CHAPTER 4

Conclusions

Chapter 4 Conclusions

At the commencement of this research, the expectation was that in a rich timber resource country such as Malaysia, many examples would be found of the development and use of timber as building material. The tropical rain forest in Malaysia contains a heterogeneous mixture of tree species which constitute suitable commercial hardwood timber appropriate for building structures.

However, fieldwork conducted in Malaysia suggested that at present timber is under utilised in construction as structural elements. The development of form and detail in timber building in Malaysia has not progressed. Various issues related to legislation, technical problems, standards and social economy are responsible for the lack of use of timber in the construction sector. The sawmilling industry is currently export-orientated (Ho, 1988 : p. 1). This is because of high market demand and the quality of Malaysian timber. Its export has reduced the availability of better quality timber for local consumption. Ideally, timber should be processed in the country and as much of the timber produced possible should be used domestically in construction sectors.

The *Uniform Building By-Laws, 1984* restrict in the use of timber in terms of fire regulations and requirements. The use of timber for party walls in the construction of terrace type houses is prohibited as it does not meet the requirements stipulated in the *Uniform Building By-Laws*, which requires party walls to be made of a non-combustible material or class O-rated materials. Timber is rated as class 3 or 4 in its natural form and as class 1 or 2 if it is impregnated with flame retardants. Although the *Uniform Building By-Laws* allow the use of timber in construction of up to 18.0 metres in height, it is impossible to satisfy the stringent requirements of class O fire rating for surface flame spread. This regulation would naturally be the most deterrent to the use of timber in building construction. Furthermore, building regulations confine the use of timber and wood panel structural elements to buildings severely restricted in flooor area and height to urban area. Yet, technically sound ways of protecting timber from being damaged by fire have available for many years.

Uniform Building By-Laws also state that timber is regarded as a temporary material that is not allowed for permanent structures in which brick, concrete or steel is used. In addition, the current fire safety regulations are still material-based instead of performance-rated, and as a result prejudices the use of timber as a structural element in urban development (Shamsuddin, 1985 : p. 6657). Timber, although combustible, has a low ignitability. This characteristic renders it stable in a fire. It is well known that timber structural components of a sufficiently large cross section do not buckle or crumble like steel and concrete which are non-combustible material under intense heat.

There is no authority or legislation to check and ensure quality control over the processing and treatment of timber, and timber-based components for use as building materials. Quality control is necessary to assure practitioners that the material supplied meets the standards necessary for its satisfactory performance in use. For wood, this is especially important because of the variety species available, grades and suppliers.

Wood is an organic material. In Malaysia, there are 3000 native timbers available but only 100 species are better known and utilized (Thang, 1991 : p. 1). Each has different physical properties which are currently being researched by the Forest Research Institute of Malaysia. For some species, this process is still incomplete and their characteristics are unknown. Each species has a variety of grades that must be defined before the individual pieces can be graded and sorted visually or mechanically. The characteristics of a piece of wood is potentially made up of hundreds of different possible sets of characteristics. This is unlike steel or concrete where more limited and easily manipulated options are available. As a result, the variability of timber is one of the major reasons why professionals are reluctant to use timber in non-domestic structural work.

Timber structures are considered as inferior, low cost, difficult to maintain and unsafe, and therefore are often used by lower status people. Timber is only treated as worthy for temporary structures and only used to build traditional Malay houses. The poor design and low quality of timber used in construction and leads to sub-standard buildings and this indirectly cause a status conscious public to shy away from timber buildings.

Timber is also assumed to have a short life span. This is not true, as a sound knowledge of the properties of timber would help in the right choice of species for particular purposes as treatment, proper detailing and maintaining would ensure that timber attains the status of permanent structure material. Timber could be treated with Copper Chrome Arsenic (CCA) preservative to extend its resistance to attack by the weather and insects. On the other hand, this treatment will add to the cost thus making it less favourable to the public compared to other construction materials such as bricks and mortar.

The notion that timber is a temporary or semi permanent building material has been disproved by the numerous old structures found in Malaysia. Timber technology is so advanced that as timber processing and treatment is properly and regular controlled, timber can be efficient and durable. The psychological attitudes towards the use of timber can be corrected through organised promotional companies.

There are many factors that cause timber to be unpredictable which are detrimental to its structural properties, such as insect attacks, knots and grains. Timber technology has advanced in the treatment of timber, therefore only the additional cost remains a deterrent factor

At present, the code of practice, Malaysia Standard 544, 1989, is being reviewed and revised by incorporating some of the existing information, with some additional tests of appropriate design standards to comply with the development of timber technology today (Tan, Y.E. 1994 : p. 698). The

Standard has not included the design specification for calculating the fire resistance of timber members (Abdul Malek, 1989 : p. 1).

The lack of a central source of information detailing wood design considerations and analysis has caused design professionals to choose other materials rather than timber. Architects' or engineers' lack knowledge of wood types and confidence in the use of timber in building construction. For example, few understand that the nature of wood available in this country is rather different from those obtained from overseas.

Designing with wood requires an understanding of the material, properties for efficient utilisation and the available sizes and shapes. The designers and specifiers are rather reluctant to specify and design timber structures in this country mainly due to the lack of exposure to timber designs during early training and the prevalence of inconsistent quality of timber products.

Legislation is needed to control the quality and treatment of timber to maintain its standard. Contractors often dipped timber for construction in black or diesel oil instead of in creosote thereby cheating the ignorant public. The incentive to cheat is great because treated timber would cost approximately $40-00 more per ton than untreated timber (Wee, 1976 : p. 58). There is a justification for legislation to protect the consumers.

The Forest Research Institute of Malaysia conducts research and disseminates information on forest products utilisation. Presently, there is a lack of researchers and development for the promotion of structural timber products in construction by other government bodies and wood industry and a lack of information about timber properties being disseminated to professional engineers requiring data for calculating loading in structure.

The timber industry employs professionals to promote their product but these professionals are generally trained in institutions where timber construction technology is ignored. As a result, their effectiveness as researchers for timber is limited by the available descriptions and their own experience.

There is also the negative attitude of insurance companies towards the use of timber as a building material. Timber is combustible, which is a bad feature from the underwriter's viewpoint. Although combustible, timber is a safer material in fire than any other non-combustible material because of its thermal conductivity, self insulation and predictability (Hashim, 1988 : p. 2). Apparently, this bias against timber buildings has somehow enhanced and indirectly reinforced the unfavourable reference to the use of timber in the local building by-laws or building codes.

Financial institutions are not willing to grant loans in respect of timber building. An extremely high premium for insurance towards timber building is charged and is prejudiced by the fact that timber buildings are considered a fire risk. According to Lew (1992 : p. 85), in Scandinavia, the insurance premiums imposed on buildings with timber structures are in fact lower than those using steel. There is abundant evidence that timber structures perform well in fires. Nevertheless the message has yet to filter through the regulatory authorities in ASEAN.

There are many existing systems of mass producing timber houses and other structures. However, such systems are limited in Malaysia to the production of brick and concrete structures, as there is a lack of creativeness in timber designing and promoting the appropriateness of timber as a building material. Timber components can be designed sufficiently small enough to be manageable for easy handling and fabrication. House components, appropriately designed for transportation and speedy erection, will further contribute towards cost effectiveness. The current lack of market acceptability of timber mass-produced houses may be attributed to the lack of resourcefulness of the manufacturers. Inconsistencies in the supply and availability of particular types of timber species means that contractors view timber unfavourably as a building material. Similarly, the lack of a standardised grading system in the timber industry further discourages those involved in the building industry.

The art of building in wood is lost to a large extent because over the past fifty years the design of timber structures has fallen into disuse as brick and concrete became more widely used (Wee, 1976 : p. 58). Other construction materials such as steel and concrete compete with timber in terms of price. Wood can be considered a viable material if the wood industry demands, and educational institutions develop, designs and tools for it.

Timber construction is more difficult and requires more supervision during construction in terms of quality, supply, grading, selection and pricing. If the corner and sharp surfaces are damaged more effort is needed to rectify the problem. Skilled carpenters are difficult to find and traditional craftsmen are few. Further more, new apprentices coming into the industry are very few.

This research documents historic construction ideas on the use of structural timber which may be precedents for today's designers. It will provide future directions for the design of new building forms. This is the central theme for the future developments in Malaysia. Past experiences give guidance on how to avoid repetition of past failures. Similarly, Philip Cox (1988 : p. 1) an Australian architect stated that any development should start from the beginning, in the desire that discovery may be made of trends and directions for the future form origins. I would like to think the above theme could be applied to many current proposed developments in Malaysia, one of which is a golf club comprising of 1,500 high density low rise condominium and 463 bungalows in Ulu Yam District, Selangor. These proposals aim to use large span timber structures which can contribute to a sustainable architecture based on renewable resources of Malaysia and beyond. The intelligent use of timber in construction is beginning to be observed in other countries, for example Eurocodes, the changes to the Australian building regulations to allow three storey construction, and the development of engineered wood products in the United States of America such as Parallel Lumber (PSL), Laminated Veneer

(LVL), Oriented Strand Board (OBS), Structural Particle Board, Structural Wafer Board, Structural Medium Density Fibreboard (MDF) and Wisawood.

4.1 Areas for Further Research

Technical innovation in the development of jointing capacity and structural determination of various building forms has not been fully explored. Timber jointing systems need to be further examined in terms of detailing and connections. An investigation conducted by Halperin (1994 : p. 28) stated that 90 percent of the structural failures experienced in wood frame buildings originated at connection points. Throughout the history of wood construction, a number of types of fasteners have been developed for use with wood, ranging from wooden dowels to steel connectors. Currently, the most common connections include nails, screws, bolts and nuts, and special connectors such as split rings, shear plates and truss plates. Each type needs to be thoroughly explored for their appropriateness in Malaysian timber conditions

Further research should be carried out in the field of structural glue-lamination for its efficiency in material utilisation, aesthetic value, excellent fire performance and use of renewable resources. Although, glue-lamination technique is well established in advanced countries of North America, Scandinavia, Australia and New Zealand, Malaysia faces various challenges in overcoming the existing prejudices against the use of timber member components. Glue-lamination technique is suitable for use in the construction of both indoor and outdoor structures such as sports complexes, recreational centres and industrial buildings.

Historically, large structures such as palaces, mosques and temples made use of heavy hardwood timber columns. Roof structures of these buildings were also built from hardwood timber which was joined with rather elaborate systems of mortises, tenons and dowels. These buildings were not even designed or checked by engineers but still exist today. The limited types of timber species for structural use in construction need to be identified for further application in building structures. This will give designers confidence to choose appropriate timber species and in the future, develop timber as a low-energy, environmentally friendly building material.

As timber is a complex and still not well understood material, it is possible for architects to propose structural forms and details which may not fit into any of the engineer's preconceived notions, both theoretical and practical. I believed we are still unable to cope fully with the complexity and variability of natural timber. As this research suggests, there remains a distinctive aesthetic value of timber construction which is challenging for designers. It will require the development of a radically new way of thinking about structures to allow for the use of non-homogeneity natural timber. In terms of structural form, aesthetic of lightness and elegance could be developed.

i) Aims of the Practitioner Survey and Entries to the Practitioner Index Database

A list of buildings which were considered as significant regarding the use of timber was compiled. Significance was defined as meaning that timber was used as a major structural component or as the dominant material of the building. The survey and documentation of timber structures provided an evaluative overview of timber construction and structural systems in buildings in Malaysia from the 16th century to the present.

A total of 936 questionnaires were sent out on the 30th of April, 1993 to practising architects, engineers, timber industry representatives and academics throughout Malaysia. Unfortunately, only 28 replies to the questionnaires were received. A total of 654 copies of reminder letters were sent out again on 5th July, 1993 for them to return the questionnaires. The time allocated to this research was lengthened due to the poor response to the questionnaires. Originally three months had been allowed, but another five months was added to get more responses from practitioners.

Two sets of questionnaires was sent out for this survey. The first questionnaire asked each recipient to nominate three buildings which they considered to be important timber structures constructed in Malaysia either during the historical period or in recent times. In addition to this information, the name of the owner of the building was significant for documentation purposes. (Refer to Appendix A. 2.1).

The building's significance might refer to the historical connection that may be made between the site and known events or persons. An example would be where a house was known to have been lived in or built by an historical figure. This historical significance may represent older types of technology or ways of life which have long passed and this will add to their significance.

The current use of the building also requires determining what type of functions it has been used for since its construction. However, it is very important to record the innovative use of timber for constructional purposes. The respondent was also requested to supply any additional information about the building which included photographs, building plans and drawings, if they had any, and literature references. Respondents were required to write their personal details in case of further inquiries.

The second questionnaire sought to identify individuals involved with timber design in Malaysia during that same period. The designers could be traced back from the contribution to the development of timber usage in building, either as architects, engineers, or builders. Further research was carried out after the information provided by respondents became the primary sources for a detailed interview between the researcher and practitioners. (Refer to Appendix A. 2.4). Table A gives the list of organisations or individuals to whom the questionnaires were sent.

Even though this survey was considered at national level, the number of respondents for these questionnaires was disappointing. The Malaysian Institute of Architects published an article in "Berita Akitek" July, 1993 edition concerning primarily research findings and requested architects to respond to the questionnaires. The Institute of Engineers Malaysia has also published this in the October issue of their bulletin for a similar response to the questionnaires. (Refer to Appendix A. 2.2).

At the end of December 1993, the response to the questionnaires from practising architects, engineers, manufacturers and academics was considered poor. Of the total number of questionnaires sent out, only 10.1% (92 copies out of 936) had been returned. The main conclusion for the poor response is attributed to a lack of expertise and interest in timber technology in Malaysia. The results of the questionnaire are indicated in Table A.

Table A : Comparison of individuals/organisations to whom the questionnaires have sent and the number of responses

	Sent out	Received
Architects	730	50
ASEAN Timber Technology Centre	1	0
Bank Negara	1	0
Dewan Bandaraya Kuala Lumpur	1	0
Engineers	61	16
Forest Research Institute Malaysia	9	4
General Contractors	77	7
Heritage Council of Malaysia	1	0
Institute Technology Mara	15	2
Jabatan Kerja Raya	10	2
Lembaga Kemajuan Bintulu	1	1
Malaysia Timber Industry Board	4	3
Manufacturers	12	6
University Malaya	3	0
University Pertaniaan Malaysia	5	1
University Technology Malaysia	4	0
Urban Development Authority	1	0
Total	**936**	**92**

From the 92 respondents, a plan for the field work was drawn up. The majority of the information received from the questionnaires related to palaces, mosques, club houses or resorts, Malay houses and state museums. Out of 92 respondents, 53.4 percent of them are practising architects who have been involved in the design of 167 timber buildings. Most of the timber buildings are based upon residential concepts, resorts and clubhouses. A total of 17.3 percent are consultant engineers working on industrial and commercial projects. Another 7.6 percent are general contractors who are owner builders involved in design and construction. The remainder of the respondents are from academic institutions, government departments and research institutions.

At an early stage of the research, it was decided to explore timber buildings with a span of more than 10 metres dating from 1900 to the present. However, research indicated that this was not feasible within the Malaysian context, as the majority of large span timber structures occurred in industrial buildings which were constructed from 1960 up to the present. The primary function of these industrial building types are sawmills or timber products factories. (Refer to Table B). A further discussion in detail will follow in chapter 2.

Table B : List of sawmills and forest products factories in Peninsular Malaysia.

STATE	TYPES OF INDUSTRIALS BUILDING				
	Sawmill	Plywood	Furniture	Kumai	Rubber
Johore	84	9	425	9	16
Kedah	35	2	260	0	20
Kelantan	68	5	253	3	10
Malacca	19	1	160	0	16
Negeri Sembilan	48	2	144	18	14
Pahang	124	8	157	18	5
Perak	98	8	367	1	15
Perlis	3	0	24	0	0
Pulau Pinang	41	2	250	21	4
Selangor	62	1	295	18	6
Terengganu	80	3	213	5	2
Wilayah Persekutuan	34	3	39	4	0
Peninsular Malaysia	**696**	**44**	**2857**	**97**	**108**

Sources : Forestry Department Headquarter Peninsular Malaysia, Kuala Lumpur - 1984

ii) Building Database

The information collected from various resources will be entered into three computer databases which are linked together for quick reference. The timber construction is characterised by a large amount of options solution but this variety is not exploited due to lack of well designed examples. The system will enable the user to locate information on timber structural systems and details.

The three databases are as follows :

- 1. Timber Structures Database
- 2. Timber Practitioner Database
- 3. Timber Literature References Database

The first database describes timber structures in detail, the names and addresses of the buildings, descriptions of their construction, names of the owners and relevant literature references. A total number of 2,074 timber structures were identified. This database could help designers to analyse types of timber buildings which have been constructed in different periods. It also could be used to analyse different types of timber technology that have been explored by designers and suggest appropriate structural systems commonly being used. (Refer to Appendix A. 1.2).

The information from the timber structure database suggests that the majority of the data available refers to industrial type buildings and was kept by the Forestry Headquarters Peninsular Malaysia. Other classifications of building types such as government, recreational, religious and residential have limited data due to a lack of documentation or recording having been carried out. (See Table C).

Table C : List of timber structure database

	Classification of buildings and structures				
	Government	**Industrials**	**Recreational**	**Religions**	**Residentials**
Army Camp	1				
Hospital	1				
Office	7				
Prison	1				
Museums	3				
Factories		19			
Furniture Workshops		472			
Sawmills		472			
Timber Stores		991			
Club Houses		5			
Pavilion			1		
Resorts			13		
Sport Centres			3		
Church				1	
Mosques				17	
Temples				8	
Palaces					22
Residential					37
Total	13	1954	17	26	59

iii) Timber Practitioner Database

The second database records timber practitioners who have been involved in design or who have designed with timber. The philosophy of the designer could be traced from the technology used at a particular period. It also suggests to the user what type of structural system is being commonly used by designers. At present, a total of 193 databases have been entered. (Refer to Appendix A. 1.1).

The data showed that the majority of the timber structures were designed and constructed by registered draughtsmen or carpenters. Architects and engineers were not employed by clients to design timber structures unless the projects were beyond the capacity of a registered draughtsman. This is the main reason why not many timber structures have the thought of construction applied in the built form. (See Table D).

Table D : List of timber practitioners in Peninsular Malaysia

States	Architects	Engineers	Others	Subtotal
Federal Territory	7	0	0	7
Johore	15	3	11	29
Kedah	5	2	6	13
Kelantan	8	2	11	21
Negeri Sembilan	7	0	16	23
Pahang	8	4	14	26
Perak	6	2	11	19
Pulau Pinang	3	0	2	5
Selangor	10	7	5	22
Terengganu	9	0	19	28
Total	18	20	95	193

iv) Literature References Database

The third database consists of general literature references or descriptions for a particular timber building. The information was drawn from notes on practitioner knowledge or from interviews. This database consists of information which enables the user to search for the related information required. A description of the text was given for each of the literature references. If any key word is known by the user, the system itself can find many articles for further references. A total of 248 literature reference databases was recorded. (Refer to Appendix A. 1.3).

v) Collection of Measured Drawings

Only a few drawings on Malay timber palaces are available for viewing at the National Archives and there are very poorly drawn. For example, in the working drawing of the Malacca Malay Palace, the construction details are completely missing. The sketches are often not to the right scale and structural elements were inaccurately presented. Scale and dimensions are vaguely given. Many building plans of Malay palaces and houses are missing.

For the above reasons, it was necessary to make a thorough study of timber buildings in Malaysia so that the historical background could be established. The construction and structural system of timber buildings could be properly documented.

The Department of Architecture, University Technology Malaysia, and the Department of Housing, Building and Planning, University Science Malaysia were contacted to provide measured drawings of the buildings documented. The measured drawings have been made out by architectural students. Measurement on site would be carried out on those buildings where measured drawings are not available. The measured drawings were useful for comparative analysis of buildings of different types of construction and their application in each case study in Chapter 2. (Refer to Appendix A. 2.5).

vi) Slides and Photographs

The documentation included the taking of photographs and slides for recording purposes. The black and white photographs will be used to illustrate the development of different types of timber construction and detailing in Malaysia. In addition, photographs provide an accurate image of the structure as it was when it was studied for the purpose of this research. This collection should serves a useful purpose to later users. Refer to Appendix A. 2.3 for the schedule of work which was carried out between September 1993 to January 1994.

vii) Site Inspections and Interviews

Before the site visits and surveys were carried out, an inquiry was made concerning the literature available on timber buildings in Malaysia. It was discovered that written materials are few and far in between. Materials written in English and Malay language are just as scarce. Material available were considered insufficient. Generally, in existing articles, books or publications on timber building in Malaysia, little attention is paid to timber architecture. They were written by journalists or writer rather than by architects. Some did not approach the subject matter in a thorough and academic manner, and many of the finished products are in the form of tourist guides rather than academic treatises.

Field trips were made to all states in Peninsula Malaysia from 6th of September 1993 to 15th of January 1994. Originally, it was proposed that a study of as many timber buildings as possible within the time available should be made. Therefore, a list of timber buildings was prepared initially from information obtained form daily visits to sites. During these site inspections, over 136 sites and structures were visited. Brief visits were initially during which appointments were made for subsequent visits. Subsequent visits were made to those caretakers were willing to co-operate by answering questions and to permit photographs to be taken. The majority of the structures were photographed and slides were taken for documentation. State museum curators were contacted to assist in identifying and obtaining the historical background of timber structures before carrying out any documentation work. Relevant information on the historical background, construction system, structure, decorative motifs and details was recorded. If no drawing was available, a detailed measured drawing was carried out..

These field visits were extremely useful in order to gain an understanding of the nature of the physical remains of the timber structures for furthering an understanding of the past. Each building was chosen as the most interesting structure system for site investigation. All the buildings in each state were grouped and visited together rather than visiting them individually.

A tape recorder was used at each interview with practitioners. Perhaps the biggest advantage of using the oral information provided by practitioners was to know more detail about their own approach to design applied in structural systems. The material collected was not only recorded but was also ccompanied by notes and observations which could be useful to later users. It was planned to conduct at least 100 interviews but due to time constraints, only a total of 73 interviews were undertaken with practitioners or timber industry representatives. Admittedly, this number may not be considered sufficient for vigorous analysis. However, the data should be sufficiently for general conclusions to be drawn. Refer to Appendix A. 2.4 for the list of interviewees.

To establish sources of influences, correspondence was entered into with overseas professors in China, United Kingdom and Netherlands. This correspondence, as well as lengthy discussions, proved to be helpful and enlightening. In summary, the procedure is as follows :

a). To study the principle use of timber in Malaysian architecture and buildings b). To establish the relationship and connection the use of timber in Malaysia and those in overseas.

c). To analyse examples of the older timber building in Malaysia in terms of construction and structural concepts, so that a more comprehensive comparison could be made between different types of timber structures from different influences.

d). To trace the evolution of timber buildings from 15th century to the present time and to establish their sources of influences.

NAME	STATE	PRACTITIONER TYPE
	Federal Territory	
Alias Salleh	FederalTerritory	Architect
Dato I Hisham Albakri	Federal Territory	Architect
Jimmy Tham Chee Ming	Federal Territory	Architect
Lim Cheok Siang	Federal Territory	Architect
Tan Kok Wan	Federal Territory	Architect
Wong Kin Men	Federal Territory	Architect
Wong Tow Cheong	Federal Territory	Architect
	Johore	
Abdul Rahman Ahmad	Johore	Architect
Ahmad Ariffin	Johore	Architect
Chiang Seng Leng	Johore	Architect
Cheng Kwong Teik	Johore	Engineer
Kam Chong Ming	Johore	Architect
Kua Chong Beng	Johore	Architect
Lee Ah Seng	Johore	Architect
Lip Y. K. Francis	Johore	Architect
Ong Gim Tin	Johore	Architect
Tay Y.H. Johny	Johore	Architect
Teoh Seng Choon	Johore	Architect
Wong Kin Leong	Johore	Architect
Wong Kok Yan	Johore	Architect
Wong Ton	Johore	Engineer
Ya'akob Hj. Ja'afar	Johore	Architect
Yap Chin Leong	Johore	Engineer
Yap Tet Fah	Johore	Architect
Yeo Soo Wee	Johore	Architect
	Kedah	
Chor Kai Guan	Kedah	Architect
Hew Hoi Lam	Kedah	Architect
Hiroshi Kobayashi	Kedah	Architect
Hj.Mohd Sa'aud Yussof	Kedah	Architect
Khoo Kooi Siang	Kedah	Engineer
Kassim Ahmad	Kedah	Architect
Malik Waheed Ahmad	Kedah	Engineer
	Kelantan	
Ismail Sa'ad	Kelantan	Engineer
Khor Ping Cheong	Kelantan	Engineer
Kua Chong Beng	Kelantan	Architect
Mohamed Abdullah	Kelantan	Architect
Mohd Ghani	Kelantan	Architect
Ng Keng Lim Bernard	Kelantan	Architect
Ngan K.E. Joseph	Kelantan	Architect
Salahuddin Abdullah	Kelantan	Architect
Teoh Seng Choon	Kelantan	Architect
Yeoh Hoon Theng	Kelantan	Architect
	Negeri Sembilan	
Lee Y. Vincent	Negeri Sembilan	Architect
Leong Tud Seng	Negeri Sembilan	Architect
Lim E.H.	Negeri Sembilan	Architect
Liong Richard	Negeri Sembilan	Architect
Ong Kim Leong	Negeri Sembilan	Architect

NAME	STATE	PRACTITIONER TYPE
Tan Siang Wee	Negeri Sembilan	Architect
Yuen Shiu Kee	Negeri Sembilan	Architect
	Pahang	
Chen Soo Soon	Pahang	Engineer
Chik Martin	Pahang	Architect
Kam Chong Ming	Pahang	Architect
Kat Gregory	Pahang	Engineer
Liew Hon Fong	Pahang	Architect
Ross J.B.	Pahang	Engineer
Soon Yih Sin	Pahang	Engineer
Wong Piang Yoon	Pahang	Architect
Wong Toon Cheng	Pahang	Architect
Yeoh Meow Shih Antrick	Pahang	Architect
Yong Antrick	Pahang	Architect
Yuen Peng Cheng	Pahang	Architect
	Penang	
Chong Kum Kwan	Penang	Architect
Derrick E. David	Penang	Architect
Fang Ting Yik	Penang	Architect
	Perak	
Choy Kee Fong	Perak	Architect
Chin Kang Sin	Perak	Engineer
Kong Peng Cheong	Perak	Architect
Leong Kum Choy	Perak	Engineer
Low S.N.	Perak	Architect
Saw Eng Chee	Perak	Architect
Tan Kok Wan	Perak	Architect
Yeoh Kok Leong	Perak	Architect
	Selangor	
Hijjas Kasturi	Selangor	Architect
Chin Kai Wah	Selangor	Engineer
Lew Wing Hing	Selangor	Engineer
Lum Chong Lin	Selangor	Architect
Ong Guan Teck	Selangor	Architect
Ong Kim Teck	Selangor	Engineer
Shaharun Dato Harun	Selangor	Architect
Tee Ching Huat	Selangor	Architect
Teh Keng Seng	Selangor	Architect
Tong Kok Mau	Selangor	Architect
Woo Hin Wai	Selangor	Engineer
Voon K.S.	Selangor	Architect
Voon K.S.	Selangor	Engineer
Wan Mohamed	Selangor	Engineer
Yang Ah Lak	Selangor	Architect
Yap Chin Tian	Selangor	Engineer
Yee Poo Soon	Selangor	Architect
	Terengganu	
Abdul Jalil Haji Embi	Terengganu	Architect
Ahmad Muda	Terengganu	Architect
Foo Y.S. Paul	Terengganu	Architect
Handan Othman	Terengganu	Architect

NAME	STATE	PRACTITIONER TYPE
Lee Siang Hing Alvin	Terengganu	Architect
Liew Hoo Fong	Terengganu	Architect
Md. Idras Sumari	Terengganu	Architect
Wee Beng Teck Maurice	Terengganu	Architect
Wong Pian Yoon	Terengganu	Architect

File Name Structure

Army Camp : Perak
AC12001 Bangunan Markas Regimen 503 (P.S.T.D.), Ipoh.

Assembly Area : Pahang
AA12101 Syarikat Kilang Papan Baharuddin Abu Bakar, Raub.

Balai Besar (Great Hall) : Kedah
IS12201 Istana Balai Besar, Alor Setar.

Bamboo Shed : Kedah
BS12301 Koperasi FELCRA, Sik.
BS12302 Lembaga Kemajuan Wilayah Kedah (KEDAH), Kubang Pasu.

Basketball Court : Pahang
BC12401 MCA Stadium, Raub.

Bend Saw Shed : Terengganu
BA12501 Syarikat Shukur Jaya, Dungun.

Boiler Shed : Johore
BS12601 Sindora Wood Product Sdn Bhd, Bandar Tenggara.

Box Making Factory : Selangor
BM12701 Tee Sheng Hot @ Teh Cheng Chuen, Kelang.

Cane Factory : Perak
CF12801 Hua Seng Cane Manufacture, Taiping.

Carpentry Section : Perak
CS12901 Kilang Papan Lee Kim Weng, Grik.

Church : Malacca
CA13001 Christ Church, Malacca.

Club House : Malacca
CM13101 Memorial Pengistiharaan Kemerdekaan, Malacca.

Club House : Pahang
CP13201 Pahang Club House, Kuala Lipis.
CP13202 Awana Golf Course & Country Club, Genting Highland.
CP13203 Club Mediterranean, Kuantan.

Club House : Perak
CP13401 Bangunan Kelab Ipoh, Ipoh.

Drying Kiln Shed : Pahang
DS13601 Institut Kemahiran Mara, Pekan.
DS13602 Kilang Papan Yong Yin Kwee Sdn Bhd, Kuantan.

Drying Kiln : Perak
DP13701 Kilang Papan Lee Kim Weng, Grik.

Drying Kiln : Kedah
DK13801 Syarikat Process, Jabi.

Dust Shed : Kelantan
DS14001 Mohamed & Daham Sawmill Sdn Bhd, Kota Bahru.

File Name Structure

Engine Shed : Federal Territory
ES14101 Tiong Kiat Company Sdn Bhd, Kuala Lumpur.

Excise Control Area : Negeri Sembilan
EN14201 Yoong Leok Kee Corporation Sdn Bhd, Seremban.

Factory : Selangor
FS14301 General Lumber (Holdings) Bhd, Kelang.

Factory : Kedah
FK14401 Kilang Proses Serbok Kayu Luen Seng, Daerah Baling.

Factory : Perak
FP14501 Musical Products Sdn Bhd, Ipoh.

Furniture Factory : Negeri Sembilan
FN14601 Intan Woodcraft Sdn Bhd, Seremban.

Furniture Factory : Perak
FP14701 Lintang Industries Sdn Bhd, Taiping.

Furniture Factory : Terengganu
FP14801 Ishak b. Salleh, Kuala Terengganu.
FP14802 Jabir b. Mohd Shah, Besut.
FP14803 Kilang Kayu Perabut Kg. Bahru, Besut.
FP14804 Mamat b. Kassim & Nik Awang b. Jusoh, Kuala Terengganu.
FP14805 Manaf b. Awang Hamat, Daerah Besut.
FP14806 Mat Amin b. Zainal, Kuala Terengganu.
FP14807 Mat Khalid b. Abdullah & Ngah B. Sulong, Daerah Kuala Terengganu.
FP14808 Mat Rani b. Said, Kuala Terengganu.
FP14809 Mohamad b. Awang, Seberang Marang.
FP14810 Mohd Yassin b. Hj. Mamat, Besut.
FP14811 Muda b. Ahmad, Besut.
FP14812 Muhamad b. Mahmud, Besut.
FP14813 Syarikat Perusahaan Perabut Jaya Sepakat, Besut.
FP14814 Syarikat Perusahaan Perabut Jaya Sepakat, Kemaman.

Furniture Shed : Johore
FJ14901 Syarikat Kayu Wangi Sdn Bhd, Batu Pahat.
FJ14902 Syarikat Gunung Timor Sdn Bhd, Johore Bahru..
FJ14903 Syarikat Subari Pembinaan Perniagaan Sdn Bhd, Johore Bahru.
FJ14904 Veteran Industries Sdn Bhd, Yong Peng.

Furniture Shed : Kedah
FK15001 Khor Chu Ping, Daerah Kota Setar.
FK15002 Kilang Kerjakayu Sun Kee Beng, Kulim.
FK15003 Kilang Papan Bangunan Huat (Kedah) Sdn Bhd, Daerah Kuala Muda.
FK15004 Nyioh Hai Chau, Sungai Patani.
FK15005 Perabut Sin Kong Min, Kulim.
FK15006 Soon Hing, Alor Setar.
FK15007 Soon Seng Huat Kilang Perabut, Daerah Pendang Kedah.
FK15008 Syarikat Process, Jabi.
FK15009 Viki Enterprise, Alor Setar.
FK15010 Wah Lim Trading Co., Sungai Patani.

Furniture Shed : Kelantan
FE15101 Kilang Papan Kwangli Sdn Bhd, Hulu Kelantan.
FE15102 Rumus Sidique b. Sidek, Kuala Krai.
FE15103 Syarikat Kilang Kayu Pekan Jeli Sdn Bhd, Jeli.

File Name Structure

FE15104 Syarikat Kilang Kerjakayu Kawanku, Gua Musang.

Furniture Shed : Negeri Sembilan

FN15201 Perusahaan Sri Simpang Pertang Sdn Bhd, Daerah Jelebu.
FN15202 Syarikat Anika Trading Co. Bhd, Kuala Pilah.

Furniture Shed : Pahang

FP15401 Kilang Papan WMP Sdn Bhd, Pekan.
FP15402 Syarikat Perabot Weng Cheong, Kuantan.

Furniture Shed : Penang

FA15301 Hup Heng Sdn Bhd, Butterworth.
FA15302 Kee Neng Wood Working Factory, Butterworth.

Furniture Shed : Selangor

FP15501 Kilang Membuat Perkakas Rumah Mesin Letrik Sdn Bhd, Kelang.
FP15502 Lee Ah Sai Construction, Port Kelang.
FP15503 Syarikat Jasa Bakti Enterprise, Kuala Langat.

Furniture Shed : Terengganu

FT15601 Abd. Hamid b. Taib, Besut.
FT15602 Abdul Wahab Tawang, Kemaman.
FT15603 Abdullah b. Hamid, Mukim Bukit Payong.
FT15604 Abdullah b. Yusof & Ahmad b. Embong, Daerah Ulu Terengganu.
FT15605 Agra Dungun Sdn Bhd, Dungun Terengganu.
FT15606 Ali b. Salleh, Dungun.
FT15607 Aliz Supplies, Kuala Terengganu.
FT15608 Baya's Maju Enterprise, Kuala Terengganu.
FT15609 En. Wan Da b. Ahmad, Ulu Terengganu.
FT15610 Geliga Besar Perabut, Kemaman.
FT15611 Haji Mohd b. Abdullah, Dungun.
FT15612 Hamzah b. Awang, Kuala Terengganu.
FT15613 Ibrahim b. Abas, Jajahan Kuala Terengganu.
FT15614 Kilang Papan Desa Medang Sdn Bhd, Kuala Terengganu.
FT15615 Kilang Papan Syarikat Miro, Besut.
FT15616 Kilang Perabut Abdullah b. Awang, Kuala Terengganu.
FT15617 Kilang Perabut Ahmad @ Zahid b. Daud, Pengkalan Nangka.
FT15618 Kilang Perabut Awang b. Hj. Mohamed, Kemaman.
FT15619 Kilang Perabut Ghazali Ahmad, Kuala Terengganu.
FT15620 Kilang Perabut Haji Ismail b. Abd. Rahman, Kemaman.
FT15621 Kilang Perabut Mat Ali b. Idris, Kuala Terengganu.
FT15622 Kilang Perabut Osman b. Abu Bakar, Kuala Terengganu.
FT15623 Kilang Perabut Syarikat Sri Dungun, Kuala Dungun.
FT15624 Kilang Perabut Tengku Lela Segara, Kuala Terengganu.
FT15625 Megat Sulong b. Ahmad, Kuala Terengganu.
FT15626 Mohamad b. Said, Kuala Terengganu.
FT15627 Nawi b. Ismail, Besut.
FT15628 Omar b. Muda, Kuala Terengganu.
FT15629 Perabot Maju Bena, Besut.
FT15630 Salim b. Mohamad, Kuala Terengganu.
FT15631 Saling b. Jusoh, Kemaman.
FT15632 Salleh Ali, Hulu Terengganu.
FT15633 Salleh b. Ali, Hulu Terengganu.
FT15634 Syarikat Adek Beradek Abdul Manan Sdn Bhd, Daerah Kuala Terengganu.
FT15635 Syarikat Arif Ahmad Kamal, Mukim Jeragau.
FT15636 Syarikat Bumi Maju, Kemaman.
FT15637 Syarikat Kayu Wangi Sdn Bhd, Batu Pahat.
FT15638 Syarikat Salis Enterprise, Kemaman.
FT15639 Syarikat Zamri, Kuala Berang.

File Name Structure

FT15640 Tai Huat Timber, Besut..
FT15641 Tan Chin Keong Perabot, Ulu Terengganu.
FT15642 Tengku Sulaiman b. Tengku Halim, Kuala Terengganu.
FT15643 Usaha Bersama Terengganu Sdn Bhd, Kuala Terengganu.
FT15644 Wan Abu Bakar Wan Endut, Daerah Kuala Terengganu.
FT15645 Wan Hassan & Sons Furniture, Jerteh.
FT15646 Wan Mohd (Haniff) b. Wan Yahya, Kemaman.
FT15647 Wan Musa b. Wan Yusof, Besut.
FT15648 Yaha Enterprise, Kuala Terengganu.
FT15649 Zakaria b. Ibrahim, Kuala Terengganu.

Furniture Store : Johore
FJ15701 Syarikat Maywood Industries Sdn Bhd, Labis.

Furniture Store : Terengganu
FS15801 Kilang Papan Sri Tengkawang Sdn Bhd, Daerah Ulu Terengganu.
FS15802 Syarikat Mustapha Said & Anak-anak, Kuala Terengganu.
FS15802 Perusahaan Cheneh Baru Sdn Bhd, Daerah Kemaman.

Furniture Store : Pahang
FP15901 Syarikat Perusahaan Chini (M) Sdn Bhd, Rompin.

Furniture Workshop : Kelantan
FK16001 Abdul Ghani Awang, Machang.

Furniture Workshop : Malacca
FM16101 T.T. Enterprise Sdn Bhd, Daerah Melaka Tengah.

Furniture Workshop : Perak
FP16201 Yip Choy & Sons Sawmill, Menglembu.
FP16202 Perabut Sekusa Sdn Bhd, Chemor.

Furniture Workshop : Terengganu
FT16401 Cahaya Perabut Sdn Bhd, Daerah Dungun.
FT16402 Pelangi Perabut Sdn Bhd, Besut.
FT16403 Usaha Bersama Terengganu Sdn Bhd, Kuala Terengganu.

Game Court : Negeri Sembilan
GN16501 Gelanggang Gasing, Seremban.

General Assembly Shed : Kelantan
GK16601 Syarikat Kilang Kayu Pekan Jeli Sdn Bhd, Jeli.

Generator Room : Federal Territory
GF16701 Kuala Lumpur Timber Sdn Bhd, Kuala Lumpur.

Godown : Selangor
GS16801 M/S Astraco Sdn Bhd, Pelabuhan Kelang.

Godown : Federal Territory
GG16901 Tiong Kiat Company Sdn Bhd, Kuala Lumpur.

Grading Shed : Kelantan
GK17001 Kilang Papan A. Abdullah (G.M.) Sdn Bhd, Gua Musang.
GK17002 Wong Vot Sawmill Co. Sdn Bhd, Kota Bahru.

Green Seasoning Chamber : Negeri Sembilan
GS17101 Bina Gemencheh Sdn Bhd, Batang Melaka.

File Name Structure

Hospital : Kedah
HK17201 Hospital Daerah, Kuala Nerang.

Hotel : Terengganu
HT17301 Tanjong Jara Beach Hotel, Dungun.

Impregnation Plant Shed : Johore
IJ17401 Southern Sawmill Sdn Bhd, Kluang.

Impregnation Tanks Shed : Selangor
IS17501 Kim Chin Hoe Sawmills Sdn Bhd, Kelang.

Institution (College) : Perak
IP17601 Maktab Melayu Kuala Kangsar, Kuala Kangsar.

Joinery Shed : Pahang
JP17701 K.C. Cheah Sawmills (Pahang) Sdn Bhd, Temerloh.
JP17702 Kilang Papan Kemuning, Temerloh.

Joinery Shed : Negeri Sembilan
JN17801 Syarikat Sri Palong Bhd, Seremban.

Joinery Store : Selangor
JS17901 Midah Joinery Sdn Bhd, Sungai Buloh.
JS17902 Wood & Allied Industries Holding Sdn Bhd, Kajang.

Kiln Drying Shed : Federal Territory
KF18001 Finewood Products Corporation Sdn Bhd, Pelabuhan Kelang.
KF18002 Kuala Lumpur Timber Sdn Bhd, Kuala Lumpur.
KF18003 Syarikat Nam Lee Trading Sdn Bhd, Kuala Lumpur.

Kiln Drying Plant : Negeri Sembilan
KN19001 Syarikat Everprime Timber Industries Products Sdn Bhd, Gemas.

Kiln Drying Shed : Terengganu
KT191001 Eng Hong Lee Timber Industries Sdn Bhd, Kuala Terengganu.
KT191002 Besut Tsuda Industries Sdn Bhd, Besut.

Laminating Factory : Federal Territory
LF19201 Kian Leong Sawmills Sdn Bhd, Kuala Lumpur.
LF19202 Ong Kian Teck Wood Preservation Sdn Bhd, Kuala Lumpur.

Log Shed : Selangor
LS19301 Syarikat Kilang Papan Economy Baru Sdn Bhd, Kuala Selangor.

Machinery Shed : Pahang
MP19401 Syarikat Kilang Papan Baharuddin b. Abu Bakar, Raub.

Machinery Shed : Johore
MJ19501 Kilang Papan Kemajuan (J) Sdn Bhd, Kluang.
MJ1950 Kilang Papan Simca Sdn Bhd, Masai.

Machinery Shed : Kedah
MK19601 Amirwood Sdn Bhd, Kulim.
MK19602 Kilang Papan Ahmad Othman, Langkawi.
MK19603 Kilang Papan Kuala Muda, Sungai Petani.
MK19604 Syarikat Amiruddin Dan Anak-anak, Kulim.

File Name Structure

Machinery Shed : Kelantan
MS19701 Syarikat Abdul Rahman Sdn Bhd, Kota Bahru.
MS19702 Syarikat Perusahaan Kilang Papan Kuala Krai Sdn Bhd, Kuala Krai.
MS19703 Syarikat Wan Mamat b. Wan Sulong Kilang Kayu Sdn Bhd, Jajahan Krai.

Machinery Shed : Malacca
MN19801 Wah Heng Sdn Bhd, Mukim Bukit Rampai.

Machinery Shed : Negeri Sembilan
MN19901 Kilang Papan Murad Sdn Bhd.
MN19902 Kilang Papan Yoong Yew Loong Sdn Bhd, Gemas.

Machinery Shed : Pahang
MP12001 Kilang Papan Kian Seng Huat, Kuala Lipis.
MP12002 Kilang Papan Ani Sdn Bhd, Temerloh.
MP12003 Ong Kian Teck Sawmill Sdn Bhd, Kuantan.
MP12004 Syarikat Kilang Papan Kecil Sri Pekan, Pekan.
MP12005 Syarikat Kilang Papan Semangat Apollo Sdn Bhd, Mukim Karatong.

Machinery Shed : Perak
MS12101 Van Sen Sawmill, Ipoh.

Machinery Shed : Penang
MM12201 Keaw Seng Sawmill Sdn Bhd, Seberang Prai

Machinery Shed : Selangor
MA12301 Kilang Balak Kecil Textwood (M) Sdn Bhd, Kelang.

Machinery Shed : Terengganu
MT12401 Abdullah b. Hamid, Mukim Bukit Payong.
MT12402 Abu bakar b. Semaun, Dungun.
MT12403 Aziz Ahmad Perabot, Kuala Terengganu.
MT12404 Cahaya Perabut Sdn Bhd, Daerah Dungun.
MT12405 Haji Abd Aziz b. Abd Rahman, Kuala Terengganu.
MT12406 Hassan b. Kassim Perusahaan Perabut & Alat-alat Binaan, Besut.
MT12407 Hussin b. Mohamad, Besut.
MT12408 Ibrahim b. Abas, Jajahan Kuala Terengganu.
MT12409 Ibrahim Jusoh, Dungun.
MT12410 Ishak b. Salleh, Kuala Terengganu.
MT12411 Kayu Kayan Sesama Sdn Bhd, Dungun.
MT12412 Kilang Balak Kecil Yaakub b. Hj. Daud, Dungun.
MT12413 Kilang Kayu Perabut Kg. Bahru, Besut.
MT12414 Kilang Papan Sri Tengkawang Sdn Bhd, Daerah Ulu Terengganu.
MT12415 Kilang Perabut Awang b. Hj. Mohamed, Kemaman.
MT12416 Kilang Perabut Ghazali Ahmad, Kuala Terengganu.
MT12417 Kilang Perabut Haji Ismail b. Abdul Rahman, Kemaman.
MT12418 Kilang Perabut Syarikat Sri Dungun, Kuala Dungun.
MT12419 Mat Rani b. Said, Kuala Terengganu.
MT12420 Megat Sulong b. Ahmad, Kuala Terengganu.
MT12421 Mohamad b. Said, Kuala Terengganu.
MT12422 Muhamad b. Mahmud, Besut.
MT12423 Mustaffa b. Abdullah, Marang.
MT12424 Perabot Maju Bena, Besut.
MT12425 Salim b. Mohamad, Kuala Terengganu.
MT12426 Sasali b. Ibrahim (Perusahaan Alatan Rotan), Paka.
MT12427 Syarikat Adek Beradek Abdul Manan Sdn Bhd, Daerah Kuala Terengganu.
MT12428 Syarikat Isof, Kuala Terengganu.
MT12429 Syarikat Berkat Usaha, Kamaman.
MT12430 Syarikat Din b. Ahmad Dan Anak-anak, Mukim Kuala Dungun.

File Name Structure

MT12431 Syarikat Din Traders, Kuala Berang.
MT12432 Syarikat Haji Ismail Jaya, Daerah Kuala Terengganu.
MT12433 Syarikat M.M.I Sawmill Sdn Bhd, Besut.
MT12434 Syarikat Mohamad Sham, Besut.
MT12435 Syarikat Sri Damai Development Sdn Bhd, Kuala Terengganu.
MT12436 Tan Chin Keong Perabot, Ulu Terengganu.
MT12437 Yaakob Perabut Sdn Bhd, Besut.

Main Sawmill Building : Pahang
MP12501 Rimba Jaya Sawmill, Jajahan Marang.

Magistrate Court : Perak
MC12601 Bangunan Makamah Lama Teluk Intan, Teluk Intan.

Mosque : Perak
MP12701 Bangunan Masjid Lama, Taiping.

Mosque : Johore
MJ12801 Masjid Jamek Air Baloi, Pontian.
MJ12802 Masjid Pasir Pelangi, Johore Bahru.
MJ12803 Masjid Parit Bakar, Muar.
MJ12804 Masjid Sungai Dinar, Pontian.

Mosque : Kelantan
MK12901 Masjid Langgar, Kota Bahru.
MK12902 Masjid Tua Kampung Laut, Nilam Puri.

Mosque : Malacca
MM13001 Masjid Jamik Duyung Malacca, Malacca.
MM13002 Masjid Kampung Hulu, Malacca.
MM13003 Masjid Kampung Keling, Malacca.
MM13004 Masjid Peringgit, Malacca.
MM13005 Masjid Tengkera, Malacca.

Mosque : Pahang
MO13101 ASPA Mosque, Pekan.
MO13102 Masjid Mat Kilau, Jerantut.

Mosque : Perak
MS13201 Bangunan Masjid Jamek (Dato' Panglima Kinta), Ipoh.
MS13202 Bangunan Masjid Kampong Paloh, Ipoh.
MS13203 Bangunan Masjid Tengku Menteri, Matang.

Moulding Factory : Federal Territory
MF13301 Kuala Lumpur Timber Sdn Bhd, Kuala Lumpur.
MF13302 Kian Leong Sawmills Sdn Bhd, Kuala Lumpur.
MF13303 Ong Kian Teck Wood Preservation Sdn Bhd, Kuala Lumpur.

Moulding Factory : Pahang
MF13401 Suria Bee Leong Timber Industries. Sdn Bhd, Kuantan.

Moulding Factory : Selangor
MS13501 Bortim Wood Processing Sdn Bhd, Pelabuhan Kelang.
MS13502 Nymeriwood Industries Sdn Bhd, Pelabuhan Kelang.

Moulding Factory : Terengganu
MT13601 Mustaffa Sutim Sdn Bhd, Kuala Terengganu.

File Name Structure

Moulding Plant : Johore
MJ13701 Sindora Wood Product Sdn Bhd, Tenggara.

Moulding Plant : Kedah
MK13801 Leong Yee Brothers Timber Industries Sdn Bhd, Kulim.

Moulding Plant : Kelantan
MO13901 Kilang Papan Galas (Kelantan) Sdn Bhd, Gua Musang.

Moulding Plant : Pahang
MP14001 Hong Moh Sawmill Limited, Mentakap.
MP14002 Syarikat Sum Thai Trading Sdn Bhd, Jerantut.

Moulding Plant : Selangor
MS14101 Beh Timber Co Sdn Bhd, Pelabuhan Kelang.

Moulding Plant : Perak
MP14201 Wing Ying Sawmill & Plywood Bhd, Chemor.

Moulding Shed : Johore
MJ14301 Johore Timber Industries Sdn Bhd, Lapis.
MJ14302 Kilang Papan Kemajuan (J) Sdn Bhd, Kluang.

Moulding Shed : Kelantan
MK14401 Mohamed & Daham Sawmill Sdn Bhd, Kota Bahru.

Moulding Shed : Negeri Sembilan
MN14501 Syarikat Everprime Timber Industries Products Sdn Bhd, Gemas.
MN14502 Kilang Papan Murad Sdn Bhd, Seremban.

Moulding Shed : Selangor
MS14601 Kilang Kerjakayu Kenwood (M), Kelang.

Moulding Shed : Terengganu
MT14701 Besut Tsuda Industries Sdn Bhd, Besut.
MT14702 Indahya Corporation Sdn Bhd, Daerah Ulu Terengganu.
MT14703 Dasar Bahagia Sdn Bhd, Daerah Besut.

Museum : Malacca
MM14801 Istana Kesultanan Melaka (Muzium Budaya), Malacca.

Museum : Perak
MP14901 Bangunan Muzium Darul Ridzuan, Ipoh.
MP14902 Muzium Negeri Perak, Taiping.

Office : Malacca
OM15001 Bangunan Mahkamah Majistret, Malacca, Malacca.
OM15002 Bangunan Stadthuys, Malacca.
OM15003 Majlis Daerah Alor Gajah, Alor Gajah.
OM15004 Muzium Daerah Jasin, Jasin.
OM15005 Muzium Lama Malacca, Malacca.
OM15006 Pejabat Daerah dan Majlis Daerah Jasin, Jasin.

Office : Perak
OP15101 Bangunan JKR (Lama), Taiping.
OP15102 Bangunan Pejabat Daerah & Tanah, Ipoh.
OP15103 Bangunan Pejabat Pos, Taiping.
OP15104 Bangunan Pejabat Pos, Teluk Intan.
OP15105 Bangunan Majlis Perbandaran Taiping (Lama), Taiping.

File Name Structure

Open Shed : Pahang
OP15201 Lee See Sawmill Sdn Bhd, District of Termeloh.

Open Shed : Negeri Sembilan
ON15301 Syarikat Kilang Papan Gemas Sdn Bhd, Gemas.
ON15302 Yee Woh Chan Sawmill (Bentong) Sdn Bhd, Bentong.

Open Shed : Pulau Pinang
OS15401 Hup Seng Huat Sdn Bhd, Bukit Mertajam.

Open Shed : Negeri Sembilan
ON15501 Syarikat Sri Palong Bhd, Seremban.

Palace : Kelantan
PK15601 Balai Tengku Besar Indera Diraja, Kota Bahru.
PK15602 Bangunan Istana Balai Besar, Kota Bahru.
PK15603 Istana Jahar, Kota Bahru.
PK15604 Istana Seri Akar, Kota Bahru.
PK15605 Istana Tengku Mahmud, Kota Bahru.

Palace : Negeri Sembilan
PN16401 Istana Ampang Tinggi, Seremban.
PN16402 Istana Lama Sri Menanti, Kuala Pilah.
PN16403 Istana Negeri Sembilan, Seremban.

Palace : Pahang
PP16501 Istana Leban Tunggal, Pekan.
PP16502 Istana Mangga Tunggal, Pekan.
PP16503 Istana Seri Melati, Pekan.

Palace : Perak
PP16601 Istana Kenangan, Kuala Kangsar.
PP16602 Istana Raja Muda, Teluk Intan .
PP16603 Istana Raja Bilah, Pusing.
PP16604 Istana Perak, Perak.

Palace : Terengganu
PT16701 Istana Kampung Raja Besut, Besut.
PT16702 Istana Maziah, Kuala Terengganu.
PT16703 Istana Tengku Abdullah, Besut.
PT16704 Istana Tengku Anjang, Besut.
PT16705 Istana Tengku Long Besut, Besut.
PT16706 Istana Tengku Puteri, Besut.
PT16707 Rumah Bujang, Kuala Terengganu.

Pavilion : Kedah
PK16801 Balai Nobat, Alor Setar.

Planning Shed : Pahang
PS16901 Kilang Papan Yin Woh Sdn Bhd, Raub.
PS16902 K.C. Cheah Sawmills (Pahang) Sdn Bhd, Temerloh.

Plywood Factory : Pahang
PF17001 Sin Cheong Hin Plywood Sdn Bhd, District of Jerantut.

Plywood Factory : Perak
PP17101 Perak United Sdn Bhd, Taiping.

File Name Structure

Plywood Workshop : Federal Territory
PF17201 Tiong Kiat Company Sdn Bhd, Kuala Lumpur.

Plywood Workshop : Perak
PP17301 Yip Choy & Sons Sawmill, Menglembu.

Predrying Shed : Pahang
PS17401 Lutz - Aspa Handles Sdn Bhd, Maran.

Predrying Shed : Selangor
PR17501 General Lumber (Holding) Bhd, Klang.

Preservation Plant : Pahang
PP17601 Guan Huat Sawmill, Temerloh.
PP17602 Hong Moh Sawmill Limited, Mentakap.
PP17603 K.C. Cheah Sawmills (Pahang) Sdn Bhd, Temerloh.

Pressure Treatment Plant : Negeri Sembilan
PN17701 Syarikat Perusahaan Kayuan Medan Jaya Sdn Bhd, Gemas.
PN17702 Kilang Papan Murad Sdn Bhd, Seremban.

Prison : Perak
PP17801 Bangunan Kompleks Sejarah Perak (Rumah Ngah Ibrahim), Matang.

Public Gathering Building : Kedah
PK17901 Bangunan Balai Besar, Alor Setar.

Queen's Palace : Terengganu
QT18001 Istana Tengku Nik, Kuala Terengganu.

Recovery Band Sawmill : Negeri Sembilan
RN18101 Syarikat Kilang Papan Gemas Sdn Bhd, Gemas.

Recovery Band Sawmill : Pahang
RP18201 Perkayuan Pahang (Temerloh) Sdn Bhd, Pekan.
RP18202 Lesong Forest Products Sdn Bhd, Kuala Rompin.

Residence : Federal Territory
RF18301 L & F Residence, Kuala Lumpur.
RF18302 Mr. Jimmy Lim, Kuala Lumpur.
RF18303 Peter Eu House - 1st House, Damansara.
RF18304 Peter Eu House - 2nd House, Damansara.
RF18305 Precima House, Bangsar.
RF18306 Quah House, Sungai Buloh.
RF18307 Rolf Schnyder House, Kuala Lumpur.
RF18308 Walian House, Bangsar.
RF18309 WP Residence House, Kuala Lumpur.

Residence : Johore
RJ18401 Bangunan Datuk Jaafar, Johore Bahru.
RJ18402 House at Johore Bahru, Johore Bahru.
RJ18403 Mawar Heritage Centre, Mukim Bandar
RJ18404 Rumah Daeng Mat Diew, Muar.

Residential : Kelantan
RK18501 Pusat Asihan & Bimbingan Kanak-kanak Islam, Kota Bahru.
RK18502 Rumah Meleh Hajjah Wan Mek, Tumpat.
RK18503 Rumah Puan Wee Mek Kian, Kota Bahru.
RK18504 Rumah Tok Yakup, Bachok.

File Name Structure

RK18505 Rumah Traditional Melayu Kelantan, Kota Bahru.

Residence : Malacca

RM18601 Rumah Baba, Malacca, Residential.
RM18602 Rumah Melaka, Malacca.
RM18603 Rumah Melayu Bandar Hilir, Bandar Hilir.
RM18604 Rumah Penghulu Mohd. Natar, Merlimau.
RM18605 Rumah T.Y.T .Yang Dipertua Negeri Malacca, Malacca.

Residence : Negeri Sembilan

RNI8701 Rumah Contoh Minangkabau, Seremban.
RNI8702 Residential, Pahang.
RNI8703 Rumah Tempat Lahir Tun Abdul Razak, Pekan.

Residence : Perak

RP18801 Rumah Baitul Rahmah; Kuala Kangsar.
RP18802 Rumah Melayu, Pasir Salak.

Residence : Selangor

RS18901 Kampung Tuanku House, Petaling Jaya.
RS18902 Nilly House, Petaling Jaya.
RS18903 Salinger House, Bangi.
RS18904 Rumah Pak Ali, Sabak Bernam.

Residence : Terengganu

RT19001 Rumah Haji Abdul Rahim, Kuala Terengganu.
RT19002 Rumah Haji Su, Kuala Terengganu.
RT19003 Rumah Haji Tahir b. Yusof, Kemaman.
RT19004 Rumah Hajjah Mariam, Kuala Terengganu.
RT19005 Rumah Melayu, Besut.
RT19006 Rumah Melayu, Kuala Terengganu.
RT19007 Rumah Tok Ku Paloh, Kuala Terengganu.

Residence/Mosque : Kedah

RK19101 Madrasah dan Rumah Tok Janggut - Langgar, Alor Setar.

Resort : Federal Territory

RF19201 Bukit Kiara International Equestrian & Country Resort, Kuala Lumpur.

Resort : Johore

RJ19301 Ponderosa Golf & Country Resort, Johore Bahru.

Resort : Kedah

RK19401 Berjaya Langkawi Beach Resort, Pulau Langkawi.
RK19402 DeLima Resort, Pulau Langkawi.
RK19403 Pelangi Beach Hotel Resort, Pulau Langkawi.
RK19404 Sheraton Langkawi Resort, Pulau Langkawi.
RK19405 The Datai, Pulau Langkawi.
RK19406 Langkawi Island Resort, Pulau Langkawi

Resort : Malacca

RM19501 Air Keroh Country Resort, Malacca.

Resort : Pahang

RP19601 Genting Staff Resort, Kuantan.
RP19602 Hyatt Kuantan, Kuantan.
RP19603 Impiana Resort, Kuantan.

File Name Structure

Resort : Perak

RE19701 Banding Island Resort, Grik.

Rest House : Pahang

RH19801 Chief Rest House, Pekan.
RH19802 Rest House, Kuala Lipis.
RH19803 Rest House, Pekan.
RH19804 Pahang Rest House, Pekan.

Rest House : Perak

RT19901 Bangunan Rumah Rehat Bandar, Taiping.

Sawmill : Federal Territory

SF20001 Aik Bee Sawmill Sdn Bhd, Petaling.
SF20002 Aik Joo Bee Sawmill, Kajang.
SF20003 Chon Joo Sawmill, Kuala Lumpur.
SF20004 Fook Soon Hin Sawmill Sdn Bhd, Kuala Lumpur.
SF20005 Hin Kee Sawmill, Cheras.
SF20006 Hong Lim Sawmill, Kuala Lumpur.
SF20007 Hua Fuat Machine Joinery Enterprise Sdn Bhd, Kuala Lumpur.
SF20008 Kayu Sedia Sdn. Bhd, Kuala Lumpur.
SF20009 Kian Leong Sawmills Sdn Bhd, Kuala Lumpur.
SF20010 Kilang Papan Kwong Lee Chin, Kuala Lumpur.
SF20011 Kimma Industries Sdn Bhd, Cheras.
SF20012 Kuala Lumpur Timber Sdn Bhd, Kuala Lumpur.
SF20013 Kwong Kee Cheong Sawmill Sdn Bhd, Kuala Lumpur.
SF20014 Leong Moh Sawmill Sdn Bhd, Kuala Lumpur.
SF20015 Ong Kian Teck Wood Preservation Sdn Bhd, Kuala Lumpur.
SF20016 Sem Siong Industries Sdn Bhd, Kuala Lumpur.
SF20017 Sin Joo Kee Sawmill, Kuala Lumpur.
SF20018 Syarikat Kilang Kerjakayu Rawang, Kuala Lumpur.
SF20019 Syarikat Kilang Papan Abdul Aziz Sdn Bhd, Kuala Lumpur.
SF20020 Syarikat Kilang Papan Abdul Aziz Sdn Bhd, Sungai Besi.
SF20021 Syarikat Kotakualiti, Kuala Lumpur.
SF20022 Syarikat Nam Lee Trading Sdn Bhd, Kuala Lumpur.
SF20023 Syarikat Tenaga Shah Sdn Bhd, Kuala Lumpur.
SF20024 Tan Nam Sawmills (M) Kuala Lumpur.
SF20025 Tiong Kiat Company Sdn Bhd, Kuala Lumpur.

Sawmill : Johore

SJ20101 Ayer Hitam Sawmill Co. Sdn Bhd, Ayer Hitam.
SJ20102 Ban Hoe Sawmill Co. Ltd, Kluang.
SJ20103 Bee Chai Co. Sdn Bhd, Batu Pahat.
SJ20104 Bee Seng Sawmill (J) Sdn Bhd, Yong Peng.
SJ20105 Cha'ah Sawmill Sdn Bhd, Segamat.
SJ20106 Chong Lim Sawmill Sdn Bhd, Muar.
SJ20107 Hock Leong Timber Trading Sdn Bhd, Johore Bahru.
SJ20108 Hong Lim Sawmill Sdn Bhd, Muar.
SJ20109 Johore Lumbering Sdn Bhd, Kluang.
SJ20110 Johore Sawmill Sdn Bhd, Kota Tinggi.
SJ20111 Johore Timber Industries Sdn Bhd, Lapis.
SJ20112 Kayuasli Industries (M) Sdn Bhd, Kluang.
SJ20113 Kilang Papan Hock Seng Teck, Kota Tinggi.
SJ20114 Kilang Papan Johore Tenggara Sdn Bhd, Daerah Ulu Lebir.
SJ20115 Kilang Papan Kemajuan (J) Sdn Bhd, Kluang.
SJ20116 Kilang Papan Kwong Maw Co. Ltd, Johore Bahru.
SJ20117 Kilang Papan Mas Sdn Bhd, Kota Tinggi.
SJ20118 Kilang Papan Rimba Timor (Johore) Sdn Bhd, Johore Bahru.
SJ20119 Kilang Papan Selatan Malaysia Sdn Bhd, Kota Tinggi.

File Name	Structure
SJ20120	Kilang Papan Simca Sdn Bhd, Masai.
SJ20121	Kilang Papan Tan Choon Seng Sdn Bhd, Segamat.
SJ20122	Kim Hiap Lee Sdn Bhd, Benut..
SJ20123	Kim Thye Sawmill, Kluang.
SJ20124	Kong Loon Sawmill Sdn Bhd, Kluang.
SJ20125	Kwong Hock Leong Sawmill Sdn Bhd, Kluang.
SJ20126	Labis Batu Bata Sdn Bhd, Labis.
SJ20127	Labis Industries, Labis.
SJ20128	Lee Hin Sawmill Co. Sdn Bhd, Muar.
SJ20129	Lee Hing Sawmills Co. Sdn Bhd, Muar.
SJ20130	Lien Hoe Sawmill Co.Sdn Bhd, Johore Bahru.
SJ20131	Lian Pang Sawmill (M) Sdn Bhd, Kluang.
SJ20132	Malaysian Forest Industries Sdn Bhd, Labis.
SJ20133	Mini Sawmill Sdn Bhd, Kota Tinggi.
SJ20134	Ng Yew Chai Sawmill Sdn Bhd, Renggam.
SJ20135	Ong Kian Teck Sawmills (Sdn) Berhad, Johore Bahru.
SJ20136	Perusahaan Kayu Kayan (Kluang) Sdn Bhd, Mukim of Mersing.
SJ20137	Perusahaan Kilang Papan & Perabut Sim Seng Sdn Bhd, Durian Tunggal.
SJ20138	Sharikat Kilang Papan Johore Tenggara Sdn Bhd, Johore Bahru.
SJ20139	Sindora Wood Product Sdn Bhd, Bandar Tenggara.
SJ20140	Southern Sawmill Sdn Bhd, Kluang.
SJ20141	Syarikat Berkerjasama Permodalan Melayu Negeri Johor, Segamat.
SJ20142	Syarikat Kayu Wangi Sdn Bhd, Batu Pahat.
SJ20143	Syarikat Kemajuan Tanahan Sdn Bhd, Daerah Kota Tinggi.
SJ20144	Syarikat Kilang Papan Gerak Maju Sdn Bhd, Segamat.
SJ20145	Syarikat Kilang Papan Seri Bukit Kepong Sdn Bhd, Muar.
SJ20146	Syarikat Kilang Papan Tai Cheong (Sdn) Bhd, Mersing.
SJ20147	Syarikat Maywood Industries Sdn Bhd, Labis.
SJ20148	Syarikat Mini Mill Sdn Bhd, Ayer Hitam.
SJ20149	Syarikat Peridi Sdn Bhd, Labis.
SJ20150	Syarikat Perniagaan dan Perusahaan Melayu Muar Berhad, Muar.
SJ20151	Syarikat Perusahaan Kilang Papan CIM Sdn Bhd, Johore Bahru.
SJ20152	Syarikat Subari Pembinaan Perniagaan Sdn Bhd, Johore Bahru.
SJ20153	Syarikat Subari Pembinaan Sdn Bhd, Johore Bahru.
SJ20154	Umac Sawmill Sdn Bhd, Mersing.
SJ20155	Veteran Industries Sdn Bhd, Yong Peng.
SJ20156	Yong Huat Sawmill & Co., Yong Peng.

Sawmill : Kedah

SK20201	Chop Hai Huat, Sungai Patani.
SK20202	Eng Hong Kuan Sawmill, Kuala Muda.
SK20203	Guan Soon Huat Sawmill, Alor Setar.
SK20204	Guar Chempedak Sawmill, Guar Chempedak.
SK20205	Kilang Kayu Hoe Hup Sdn Bhd, Daerah Kuala Muda.
SK20206	Kilang Papan Bangunan Huat (Kedah) Sdn Bhd, Daerah Kuala Muda.
SK20207	Kilang Papan Kecil Chin Chun Swee & Rodzi B.Ahmad, Kulim.
SK20208	Kilang Papan Kedah Sdn Bhd, Daerah Kota Setar.
SK20209	Kilang Papan Kee Leong Sdn Bhd, Gurun.
SK20210	Kilang Papan Teik Hong (Kota Setar) Sdn Bhd, Kota Setar.
SK20211	Leong Yee Brothers Timber Industries Sdn Bhd, Kulim.
SK20212	Padang Serai Kelang Kayu Sdn Bhd, Kulim.
SK20213	Swee Yuen & Co., Changloon.
SK20214	Swee Yuen Sawmill Sdn Bhd, Kubang Pasu.
SK20215	Syarikat Amiruddin Dan Anak-anak, Kulim.
SK20216	Syarikat Kayu Kayan Kedah Sdn Bhd, Sungai Patani.
SK20217	Tai Sun Electric Sawmills Sdn Bhd, Kulim.
SK20218	Tai Sun Sawmills Ltd., Kulim.
SK20219	Yeoh Hup Bee Sdn Bhd, Mukim Sala Besar.

File Name Structure

Sawmill : Kelantan

SA20301 Emasasli (Kilang Papan Kecil), Bukit Merah.
SA20302 Fajar Sawmill Sdn Bhd, Tanah Merah.
SA20303 Great Bonanza Timber Sdn Bhd, Mukim Manjor.
SA20304 Hussein b. Musa Sawmill, Kota Bahru.
SA20305 Jaya Sawmill Co. Sdn Bhd, Ulu Kelantan.
SA20306 Keltra Timber Complex, Machang.
SA20307 Kesedar Sawmill Sdn Bhd, Gua Musang.
SA20308 Kesedar Sawmill Sdn Bhd, Ulu Kelantan.
SA20309 Kilang Papan A. Abdullah (G.M.) Sdn Bhd, Gua Musang.
SA20310 Kilang Papan A. Abdullah (G.M.) Sdn Bhd, Kota Bahru.
SA20311 Kilang Papan Bakti Bachok, Bachok.
SA20312 Kilang Papan Bakti, Bachok.
SA20313 Kilang Papan Datuk Ong Kian Seng, Ulu Kelantan.
SA20314 Kilang Papan Galas (Kelantan) Sdn Bhd, Gua Musang.
SA20315 Kilang Papan Ketereh Kelantan, Kota Bahru.
SA20316 Kilang Papan Kwangli Sdn Bhd, Hulu Kelantan.
SA20317 Kilang Papan Tengku Jaafar Sdn Bhd, Machang.
SA20318 Kilang Papan Tengku Yaakob b. Tengku Salleh, Kelantan.
SA20319 Kilang Papan Wong Vot, Kota Bahru.
SA20320 Kuala Krai Sawmill Co., Kuala Krai.
SA20321 Mohamed & Daham Sawmill Sdn Bhd, Kota Bahru.
SA20322 Nestra Sdn Bhd, Mukim Manjor.
SA20323 Pasir Mas Sawmill Sdn Bhd, Gua Musang.
SA20324 Perusahaan Kayu Melayu Kelantan, Pasir Puteh.
SA20325 Perusahaan Kayu Melayu Sawmill, Kota Bahru.
SA20326 Perusahaan Kilang Papan Kuala Krai, Machang.
SA20327 Sri Wangsa Selatan Timber Sdn Bhd, Gua Musang.
SA20328 Sungai Rek Pembangunan Sdn Bhd, Kuala Krai.
SA20329 Syarikat Abdul Rahman Sdn Bhd, Kota Bahru.
SA20330 Syarikat Adam Sawmill, Pasir Putih.
SA20331 Syarikat Binaan Budi Sawmill Sdn Bhd, Ulu Kelantan.
SA20332 Syarikat Bumiair Timber Industries Sdn Bhd, Tanah Merah.
SA20333 Syarikat Great Bonanza Timbers Sdn Bhd, Kuala Krai.
SA20334 Syarikat Jaya Raya Kuala Krai Sawmill (Sdn) Bhd, Kuala Krai.
SA20335 Syarikat Kemajuan Timbermine Sdn. Bhd, Gua Musang.
SA20336 Syarikat Kilang Kayu Pekan Jeli Sdn Bhd, Jeli.
SA20337 Syarikat Kilang Papan Bumi Sdn Bhd, Kelantan.
SA20338 Syarikat Kilang Papan Kecil (Mini Sawmill), Machang.
SA20339 Syarikat Kilang Papan Limbongan Sdn Bhd, Tanah Merah.
SA20340 Syarikat LLK Latib Perak Sdn Bhd, Jajahan Ulu Kelantan.
SA20341 Syarikat LLK Latib Perak Sdn Bhd, Ulu Kelantan.
SA20342 Syarikat Maju Lembah Pergau, Kuala Krai.
SA20343 Syarikat Pembinaan Kg. Cermin Sdn Bhd, Jajahan Tanah Merah.
SA20344 Syarikat Perusahaan Kilang Papan Kuala Krai Sdn Bhd, Kuala Krai.
SA20345 Syarikat Perusahaan Perabut Ipar, Jajahan Pasir Mas.
SA20346 Syarikat Tiga Antara, Machang.
SA20347 Syarikat Usahasama Gua Musang, Jajahan Ulu Kelantan.
SA20348 Timber mine Development Corporation Sdn Bhd, Gua Musang.
SA20349 Tong Lam Sawmill Co., Tanah Merah.
SA20350 Wong Vot Sawmill Co. Sdn Bhd, Kota Bahru.
SA20351 Zam Zam Sawmill Sdn Bhd, Melor.

Sawmill : Malacca

SM20401 Abdul Hadi Sdn Bhd, Bukit Rambai.
SM20402 Bina Gemencheh Sdn Bhd, Batang Melaka.
SM20403 Focus Malaysian Woods Sdn Bhd, Melaka Tengah.
SM20404 Harga Sawmill & Timber Products Sdn Bhd, Telok Mas.
SM20405 Kilang Papan Harga Industries Sdn Bhd, Telok Mas.

File Name	Structure
SM20406	Kilang Papan Letrik Melaka Sdn. Bhd, Malacca.
SM20407	Kilang Papan Pulau Sebang Sdn Bhd, Aloh Gajah.
SM20408	Sing Foh Sawmill Sdn Bhd, Malacca.
SM20409	Syarikat Kilang Papan Empat Sejaras, Mukim Merlimau.
SM20410	Syarikat Kilang Shim Foh Sdn Bhd, Melaka Tengah.
SM20411	T.T. Enterprise Sdn Bhd, Daerah Melaka Tengah.
SM20412	Tan Kai Liat Sawmill Sdn Bhd, Bukit Rambai.
SM20413	Tee Siong Sawmill Co. Sdn Bhd, Malacca.
Sawmill : Negeri Sembilan	
SN20501	Belantara Enterprise Sdn Bhd, Gemas.
SN20502	Chin Fatt Kee Sdn Bhd, Seremban.
SN20503	Chok Ley Ngioh Trading Co, Daerah Port Dickson.
SN20504	Eng Hong Lee Timber Industries Sdn Bhd, Tampin.
SN20505	Hup Seng Sawmill Co., Bahau.
SN20506	Jaya Furniture Industries Sdn Bhd, Kuala Pilah.
SN20507	Kilang Balak Kecil Mok Sum Construction Sdn Bhd, Seremban.
SN20508	Kilang Papan Hang Tuah, Ayer Hitam.
SN20509	Kilang Papan Kota Sdn Bhd, Kota.
SN20510	Kilang Papan Murad Sdn Bhd, Seremban.
SN20511	Kilang Papan Seri Serting, Kuala Pilah.
SN20512	Kilang Papan Sim Fatt, Rembau.
SN20513	Kilang Papan Sri Gadut, Seremban.
SN20514	Kilang Papan Syarikat Kam-Yusof, Kuala Pilah.
SN20515	Kilang Papan United Sdn Bhd, Tampin.
SN20516	Kilang Papan Yoong Yew Loong Sdn Bhd, Gemas.
SN20517	Kwong Onn Sawmill (Sdn) Bhd, Mantin.
SN20518	Lee Wah Sawmill Sdn Bhd, Gemas.
SN20519	Lian Pong Timber Industries Sdn Bhd, Tampin.
SN20520	Loong Fatt Company, Seremban.
SN20521	Mah Fah Timber Industries Sdn Bhd, Seremban.
SN20522	Modern Wood Products Sdn Bhd, Seremban.
SN20523	Murad Construction, Seremban.
SN20524	Nam Seng Hong Sawmill, Kuala Pilah.
SN20525	Nam Seng Sawmill Sdn Bhd, Kuala Pilah.
SN20526	Nestin Sdn Bhd, Seremban.
SN20527	Rimba Muda Co.Sdn Bhd, Batu Kikir.
SN20528	Sem Joo & Co. Sawmill, Seremban.
SN20529	Sembilan Electric Sawmill Sdn Bhd, Seremban.
SN20530	Seong Fatt Sawmill Sdn Bhd, Seremban.
SN20531	Sim Sim Sawmill Sdn Bhd, Kuala Pilah.
SN20532	Sin Hup Seng Sawmill Sdn Bhd, Seremban.
SN20533	Siong Moh Sawmill, Tampin.
SN20534	Soo Kee Sawmill Co, Seremban.
SN20535	Soo Kee Sawmill, Seremban.
SN20536	Sum Hup Sawmill, Bahau.
SN20537	Syarikat Everprime Timber Industries Products Sdn Bhd, Gemas.
SN20538	Syarikat Guan Seng Timber Products, Seremban.
SN20539	Syarikat Johore Sdn Bhd, Seremban.
SN20540	Syarikat Kemajuan Jaya, Gemas.
SN20541	Syarikat Kilang Papan Gemas Sdn Bhd, Gemas.
SN20542	Syarikat Kilang Papan Gemas, Seremban.
SN20543	Syarikat Kilang Papan Kelemah Sdn Bhd, Mukim Bahau.
SN20544	Syarikat Kilang Papan Kim Mah Sdn Bhd, Tampin.
SN20545	Syarikat Malaysia Kilang Papan Sdn Bhd, Tampin.
SN20546	Syarikat Perabut Dan Kerja Perkayuan Fan Yong, Seremban.
SN20547	Syarikat Perusahaan Kayuan Medan Jaya Sdn Bhd, Gemas.
SN20548	Syarikat Sri Palong Bhd, Seremban.
SN20549	Syarikat U Lian, Seremban.

File Name Structure

SN20550 Syarikat Usaha Murni, Jelebu.
SN20551 Tampin Sawmill & Co, Tampin.
SN20552 Tan Kai Liat Sawmill Sdn Bhd, Daerah Tampin.
SN20553 Tong Kwee Sawmill, Seremban.
SN20554 Wan Leong Timber Trading, Seremban.
SN20555 Wee Hin Sawmill Sdn Bhd, Seremban.
SN20556 Wee Hing Sawmill Sdn Bhd, Mantin.
SN20557 Yoong Leok Kee Corporation Sdn Bhd, Seremban.

Sawmill : Kedah

SK20601 Alliance Enterprise Co, Seberang Prai.
SK20602 Lim Chin Joo Sawmills, Seberang Prai.
SK20603 Lucky Woodwork Engineering Centre, Bukit Mertajam.
SK20604 Syarikat Kilang Papan Bersatu, Bukit Mertajam.

Sawmill : Pahang

SP20701 Asia Sungei Yu Sawmill Sdn Bhd, Kuala Lipis.
SP20702 Bok Kee Teak Wood Co. Sdn Bhd, Bukit Tinggi.
SP20703 Bukit Goh Sawmill Sdn Bhd, Kuantan.
SP20704 Bukit Senorang Lumber Industries Sdn. Bhd, Mentakap.
SP20705 Chan Kok Choon, Temerloh.
SP20706 Cheng Cheok Bee Sawmill Sdn Bhd, Pekan.
SP20707 Cheng Cheok Bee Sawmill Sdn Bhd, Temerloh.
SP20708 Cheong Kai Lam Sawmill, Kuantan.
SP20709 Cheong Sawmills Sdn Bhd, Bentong.
SP20710 Continental Sawmill, Veneer & Plywood Sdn Bhd, Kuantan.
SP20711 East Union Timber Industries Sdn Bhd, Mentakap.
SP20712 Federal Sawmill Gambang (1965) Sdn Bhd, Gambang.
SP20713 Gee Seng Sawmill, Kuantan.
SP20714 Guan Huat Sawmill, Temerloh.
SP20715 Hean Lee Sawmill & Trading Co. Sdn Bhd, Jerantut.
SP20716 Hin Lee Sawmill Sdn Bhd, Kuantan.
SP20717 Hong Bee Sawmill Co, Kuantan.
SP20718 Hong Huat Sdn Bhd, Kuantan.
SP20719 Hong Leong Co. Sdn Bhd, Bentong.
SP20720 Hong Moh Sawmill Limited, Mentakap.
SP20721 Institut Kemahiran Mara, Pekan.
SP20722 Jaya Muda Sdn Bhd, Temerloh.
SP20723 Jusoh Sawmill Co., Kuantan.
SP20724 K.C. Cheah Sawmills (Pahang) Sdn Bhd, Temerloh.
SP20725 Khoo Chee Seng Sawmill, Maran.
SP20726 Kilang Papan (MC), Jerantut.
SP20727 Kilang Papan Ali Baba, Temerloh.
SP20728 Kilang Papan Amalgamated Lumber (M) Sdn Bhd, Kuantan.
SP20729 Kilang Papan Berkas Perajurit Malaysia Barat, Mentakap.
SP20730 Kilang Papan Bukit Emas Sdn Bhd, Raub.
SP20731 Kilang Papan Bukit Godam Sdn Bhd, Temerloh.
SP20732 Kilang Papan Haji Arshad b. Hj. Taib, Sementan.
SP20733 Kilang Papan Kecil Alias, Temerloh.
SP20734 Kilang Papan Kemuning, Temerloh.
SP20735 Kilang Papan Kian Seng Huat, Kuala Lipis.
SP20736 Kilang Papan Land Development Corporation Ltd, Rompin.
SP20737 Kilang Papan Maran Sin Hin Sdn Bhd, Maran.
SP20738 Kilang Papan Maran Sin Hin Sdn Bhd, Temerloh.
SP20739 Kilang Papan Mohd Said b. Singah & Soh Yong Seng, Mentakap.
SP20740 Kilang Papan Ng Hock Seng, Raub.
SP20741 Kilang Papan Pekan Sdn Bhd, Kuantan.
SP20742 Kilang Papan Pekan Sdn Bhd, Pekan.
SP20743 Kilang Papan Poh Soo Trading, Temerloh.

File Name	Structure
SP20744	Kilang Papan Rompin Trading Sdn Bhd, Rompin.
SP20745	Kilang Papan Semantan, Kuantan.
SP20746	Kilang Papan Sophia Industries, Benta.
SP20747	Kilang Papan Syarikat Sophia Industries, Benta.,
SP20748	Kilang Papan Wan Abdullah, Kuantan.
SP20749	Kilang Papan Wan Ahmad Sdn Bhd, Lipis.
SP20750	Kilang Papan WMP Sdn Bhd, Pekan.
SP20751	Kilang Papan Yin Woh Sdn Bhd, Raub.
SP20752	Kilang Papan Yong Yin Kwee Sdn Bhd, Kuantan.
SP20753	Kilang papan Selamat Sentosa (Keratong-Pahang) Sdn Bhd,Pekan.
SP20754	Kim Teck Leong Sawmills Sdn Bhd, Karak.
SP20755	Kimyu Kilang Papan dan Plywood Sdn.Bhd, Temerloh.
SP20756	Kimyu Sawmill & Plywood Company Limited, Temerloh.
SP20757	Kit Ming Sawmill Sdn Bhd, Raub.
SP20758	Kuantan Sawmill, Kuantan.
SP20759	Lee See Sawmill Sdn Bhd, Termeloh.
SP20760	Lee Tee Kit Sawmill, Mentakap.
SP20761	Lee Wan Sin & Mey Sawmill, Kuantan.
SP20762	Malatab Industries Sdn Bhd, Kuantan.
SP20763	Maran Road Sawmill Sdn Bhd, Temerloh.
SP20764	Modal Moulding Sdn Bhd, Kuantan.
SP20765	Moh Lim Sawmill Sdn Bhd, Temerloh
SP20766	Mohd Sood b. Abdul Hamid, Pekan.
SP20767	Nam Yit Developments (M) Sdn Bhd, Pekan.
SP20768	Nam Yit Developments (M) Sdn Bhd, Ulu Keratong.
SP20769	Nenasi Sawmill Sdn Bhd, Pekan.
SP20770	Ng Tiong Kiat Sawmill (Triang) Sdn Bhd, Jerantut.
SP20771	Ong Kian Teck Sawmill Sdn Bhd, Kuantan.
SP20772	Pahang Sawmills, Temerloh.
SP20773	Pan Malaysia Industries Sdn Bhd, Mukim of Keratong.
SP20774	Perkayuan Pahang (Pekan/Kuantan) Sdn Bhd, Kuantan.
SP20775	Perkayuan Pahang (Temerloh) Sdn Bhd, Pekan.
SP20776	Poh Chan Hup Seng Sawmill Sdn Bhd, Raub.
SP20777	Raub Sawmill, Raub.
SP20778	Rimba Jaya Sawmill, Jajahan Marang.
SP20779	Rompin Sawmill Sdn Bhd, Kuala Rompin.
SP20780	Seng Peng Sawmills Sdn Bhd, Gambang.
SP20781	Sharikat Jiwa Mentakap Sdn Bhd, Mentakap.
SP20782	Sharikat Sungei Belat Sdn Bhd, Kuantan.
SP20783	Sim Guan Sawmill & Co., Pahang, Mukim Sabai.
SP20784	Sim Hoe wood & Sawmills Sdn Bhd, Kuantan.
SP20785	Syarikat Sum Thai Trading Sdn Bhd, Jerantut.
SP20786	Sungai Charu Sawmill & Company, Kuantan.
SP20787	Southern Sawmill, Lipis.
SP20788	Suria Bee Leong Timber Industries. Sdn Bhd, Kuantan.
SP20789	Syarikat Al-Hadi (Sdn) Bhd, Temerloh.
SP20790	Syarikat Hong Lim Kilang Papan Sdn Bhd, Mentakap.
SP20791	Syarikat Ihsan Sdn Bhd, Temerloh.
SP20792	Syarikat Jengka Sdn Bhd, Jengka.
SP20793	Syarikat Kemajuan Pembalak Pahang, Temerloh.
SP20794	Syarikat Kembar Sebati (Sdn) Bhd, Kuantan.
SP20795	Syarikat Kilang Papan Chin Guan Sdn Bhd, Mentakap.
SP20796	Syarikat Kilang Papan Kecil Kampong Jambu Rias, Karak.
SP20797	Syarikat Kilang Papan Kecil Sri Pekan, Pekan.
SP20798	Syarikat Kilang Papan Semangat Apollo Sdn Bhd, Mukim Karatong.
SP20199	Syarikat Kilang Papan Sri Pahang, Raub.
SP20100	Syarikat Kilang Papan Timber Merchants Co., Temerloh.
SP20101	Syarikat Membalak Gerak Maju Sdn Bhd, Temerloh.
SP20102	Syarikat Ong Kian Teck Sawmill Sdn Bhd, Maran.

File Name	Structure
SP20103	Syarikat Permodalan Dan Perusahaan Pahang Bhd, Kuantan.
SP20104	Syarikat Perniagaan Gelanggi, Jerantut.
SP20105	Syarikat Perusahaan Chini (M) Sdn Bhd, Rompin.
SP20106	Syarikat Perusahaan Kayu Bentong, Bentong.
SP20107	Syarikat Perusahaan Pahang Timor, Kuantan.
SP20108	Syarikat Perusahan Chini (M) Sdn Bhd, Pekan.
SP20109	Syarikat Sri Wangsa Sawmill Sdn Bhd, Benta.
SP20110	Syarikat Sungai Batu (M) Sdn Bhd, Kuantan.
SP20111	Syarikat Tenaga Desa Pahang, Jerantut.
SP20112	Tekun Jaya (Teja), Kuantan.
SP20113	Telemong Tong Leong Sdn Bhd, Bentong.
SP20114	Temerloh District Timber Trading Co. Sdn Bhd, Mentakap.
SP20115	Temerloh Sawmill Co. Sdn Bhd, Temerloh.
SP20116	Thye Hing Sawmill Sdn Bhd, Temerloh.
SP20117	Tioman Sendirian Berhad, Pahang.
SP20118	Tong Kwee Sawmill, Seremban.
SP20119	Union Bestwood Sdn Bhd, Maran.
SP20120	United Furniture International Sdn Bhd, Temerloh.
SP20121	United Trading Sawmill Sdn Bhd, Kuantan.
SP20122	Yap Timber Trading Sdn Bhd, Kuala Lipis.
SP20123	Yee Hup Sawmill, Maran.
SP20124	Yee Woh Chan Sawmill (Bentong) Sdn Bhd, Bentong.

Sawmill : Penang

SA20801	Ban Guan Thye Sawmill Ltd, Butterworth.
SA20802	Hup Seng Huat Sdn Bhd, Bukit Mertajam.
SA20803	Kilang Papan Woodwell Sdn Bhd, Seberang Prai.
SA20804	Syarikat Ah Pong Kilang Papan, Nibong Tebal.
SA20805	Teong Lee Sawmill & Hardware Sdn Bhd, Seberang Prai.
SA20806	Yeoh Kok Eng, Province Wellesly.

Sawmill : Perak

SP20901	Au Chong Mun Sawmill Sdn Bhd, Slim River.
SP20902	Bee Choon Sawmill Company, Ipoh.
SP20903	Bidor Sawmill Sdn Bhd, Bidor.
SP20904	Boon Hock Sawmill Sdn Bhd, Taiping.
SP20905	Chong Mah Wooden Boxes Factory, Tanjong Malim.
SP20906	Chop Sin Hin Chong Khai Chen & Brother Sawmill, Ipoh.
SP20907	Dr Kok Chee Min Sawmill, Ipoh.
SP20908	Eng Joo Enterprise Sdn Bhd, Taiping.
SP20909	Guan Hin Sawmill & Hardware Sdn Bhd, Taiping.
SP20910	Heap Moh Sawmill Sdn Bhd, Sitiawan.
SP20911	Hock Wah Seng Timber Products Sdn Bhd, Tanjong Rambutan.
SP20912	Hong Seong Sawmills Ltd, Tanjong Malim.
SP20913	Ikatan Syarikat Pembalak-pembalak Perak Bhd, Grik.
SP20914	Kilang Papan Aziz b. Kulup Ahmad, Daerah Batang Padang.
SP20915	Kilang Papan Chop Yeap Yuen Kee Sdn Bhd, Simpang Pulai.
SP20916	Kilang Papan Chun Lee, Padang Rengas.
SP20917	Kilang Papan Dr. Kok Chee Min, Sungei Siput.
SP20918	Kilang Papan Grik, Hulu Perak.
SP20919	Kilang Papan Kuala Kangsar Sdn Bhd, Kuala Kangsar.
SP20920	Kilang Papan Lee Kim Weng, Grik.
SP20921	Kilang Papan Perbadanan Kemajuan Negeri Perak, Ipoh.
SP20922	Kilang Papan Seraya Sdn Bhd, Ipoh.
SP20923	Kilang Papan Slim River Sdn Bhd, Slim River.
SP20924	Kilang Papan Thong Mee Ching Kee Sdn Bhd, Ipoh.
SP20925	Kilang Papan Tuan Haji Ahmad Sapawi b. Kulop Lela, Ipoh.
SP20926	Kilang Papan Weng Lee, Bruas.
SP20927	Kilang Papan Zainuddin Hj. Aris Sdn Bhd, Bidor.

File Name	Structure
SP20928	Kwong Luen Foong Sawmill Company, Ipoh.
SP20929	Kwong Yuen Sang Sawmill, Batang Padang.
SP20930	Lee Sang Loong Sawmill, Ipoh.
SP20931	Nam Fong Sawmill, Ipoh.
SP20932	Nam Seng Sawmill Sdn Bhd, Parit Buntar.
SP20933	Perak Simpang Timber Sdn Bhd, Taiping.
SP20934	Perbadanan Kemajuan Negeri Perak, Ipoh.
SP20935	Pintu Gerbang Perpaduan Kilang Papan Sdn Bhd,Ipoh.
SP20936	Santary Sdn Bhd, Ipoh.
SP20937	Seng Fatt Sawmill, Bidor.
SP20938	Simpang Wood Works Sdn Bhd, Taiping.
SP20939	Sin Hin Sawmill (Chong Khai Chen & Brother Sdn Bhd), Ipoh.
SP20940	Sin Hin Sawmill (Chong Khai Chen) Sdn Bhd, Ipoh.
SP20941	Song Seng Sawmill, Taiping.
SP20942	Sun Nam Lee Sawmill Sdn Bhd, Kampar.
SP20943	Syarikat H.M. Radzi Sdn Bhd, Ulu Kinta.
SP20944	Syarikat Kwong Fook Hing Sdn Bhd, Bidor.
SP20945	Syarikat Kwong Fook Hing Sdn Bhd, Tapah.
SP20946	Syarikat Meranti Sdn Bhd, Ipoh.
SP20947	Syarikat Salamah (Perak) Sdn Bhd, Kuala Kangsar.
SP20948	Syarikat Sun Ngoon Sawmill (M) Sdn Bhd, Teluk Anson.
SP20949	Tan Chee Seng Sawmill Sdn Bhd, Ipoh.
SP20950	Tat Meng Sawmill and Furniture, Mukim Ulu Kinta.
SP20951	Thong Fatt Timber Sdn Bhd, Sungai Siput..
SP20952	Tong Fong Plywood Factory Sdn Bhd, Ipoh.
SP20953	Tong Hing Sawmill, Temoh.
SP20954	Wing Ying Sawmill & Plywood Bhd, Chemor.
SP20955	Woh Hup Kee Sdn Bhd, Ipoh.
SP20956	Yip Choy & Sons Sawmill, Menglembu.
SP20957	Yip Yoon Kee Sawmill, Simpang Pulai.
Sawmill : Selangor	
SS21001	F.H. Chai Sawmill, Petaling.
SS21002	General Lumber (Holdings) Bhd, Petaling Jaya.
SS21003	Goodwill Veneer And Plywood Products (M) Sdn Bhd, Klang.
SS21004	Guan Guan Timber Industries Sdn Bhd, Kajang.
SS21005	Ho Guan Sawmill Sdn Bhd, Batu Caves.
SS21006	Hong Seng Sawmill & Co, Ulu Selangor.
SS21007	Hu Sang Sawmill, Rawang.
SS21008	Jinjang Sawmill Sdn Bhd, Batu Caves.
SS21009	Kekal Kayu Sdn Bhd, Klang.
SS21010	Keong Kee Sawmill Sdn Bh, Kuala Selangor.
SS21011	Kian Ann (Seng Kee) Sawmill, Kajang.
SS21012	Kian Kee Sawmills (M) Sdn Bhd, Batang Berjuntai.
SS21013	Kilang Balak Kecil Textwood (M) Sdn Bhd, Kelang.
SS21014	Kilang Balak Kecil Yeoh Teong Lin, Kelang.
SS21015	Kilang Kerja Kayu Hoe Leong Timber, Kelang.
SS21016	Kilang Kerja Kayu Sungei Pelek, Sepang.
SS21017	Kilang Papan Balak Kecil Yap Soon Huat, Mukim Sepang.
SS21018	Kilang Papan Chan Fook, Mukim of Petaling.
SS21019	Kilang Papan Ekonomi Baru Sdn Bhd, Kuala Selangor.
SS21020	Kilang Papan Goodwood, Ulu Selangor.
SS21021	Kilang Papan Kian Ann (Seng Kee), Kajang.
SS21022	Kilang Papan Mohd Nazir Sdn Bhd, Ulu Langat.
SS21023	Kim Hock Timber Sawmill, Daerah Kuala Langat.
SS21024	Kim Hoe Seng Timber Merchant, Kuala Langat.
SS21025	Kim Lian Huat Sawmill Sdn Bhd, Tanjung Karang.
SS21026	Leong Moh Sawmill Sdn Bhd, Kepong.
SS21027	Mattaku Sdn Bhd, Kuala Selangor.

File Name	Structure
SS21028	Ong Kian Teck Plywood Sdn Bhd, Kepong.
SS21029	Ong Kian Teck Wood Preservation Sdn Bhd, Kepong.
SS21030	Rawang Sawmill, Rawang.
SS21031	Salak Sawmill, Sepang.
SS21032	Sharikat Kilang Papan Hock Guan Sdn Bhd, Kajang.
SS21033	Sin Yew Huat (Timber Merchants), Kuala Langat.
SS21034	Siong Hoe Sawmill, Kajang.
SS21035	Sri Ledang Sdn Bhd, Klang.
SS21036	Syarikat Hassan And Sons Sawmill Sdn Bhd, Sekinchan.
SS21037	Syarikat Jasa Bakti Enterprise, Kuala Langat.
SS21038	Syarikat Jaya Sahabat, Daerah Kuala Selangor.
SS21039	Syarikat Kilang Papan Economy Baru Sdn Bhd, Kuala Selangor.
SS21040	Syarikat Kilang Papan Kim Guan Huat Sdn Bhd, Kelang.
SS21041	Syarikat Kilang Papan Rasa, Hulu Selangor.
SS21042	Syarikat Kilang Papan Sdn Bhd, Kelang.
SS21043	Syarikat Kilang Papan Sim Mok, Kajang.
SS21044	Syarikat Lucky Timber, Kepong.
SS21045	Syarikat Perniagaan Ketua Kampong Kuala Selangor, Kuala Selangor.
SS21046	Syarikat Sebati Sdn Bhd, Ulu Selangor.
SS21047	Syarikat Tenaga Shah Sdn Bhd, Ulu Selangor.
SS21048	Syarikat Usahajaya, Kuala Selangor.
SS21049	Wandex Sdn Bhd, Sungai Buloh.
SS21050	Wood & Allied Industries Holding Sdn Bhd, Kajang.
SS21051	Yee Woh Chan Sawmill, Mukim of Petaling.

Sawmill : Terengganu

ST21101	Abdullah @ Awang b. Ismail, Kuala Terengganu.
ST21102	Abdullah b. Yusof & Ahmad b. Embong, Daerah Ulu Terengganu.
ST21103	Agra Dungun Sdn Bhd, Dungun.
ST21104	Ahmad Zaki Sdn Bhd, Terengganu.
ST21105	Asrama Raya Sdn Bhd, Jerangau.
ST21106	Bakti Malaysia Sdn Bhd, Kuala Terengganu.
ST21107	Berjaya Sawmill Co, Mukim Bukit Payong.
ST21108	Bersama Timber Corporation Sdn Bhd, Kemaman.
ST21109	Besut Tsuda Industries Sdn Bhd, Besut.
ST21110	C.W. Abdul Hamid Sdn Bhd, Kemaman.
ST21111	Chee Fook Lian Sawmill, Ulu Terengganu.
ST21112	Chye Hin Sdn Bhd, Kemaman.
ST21113	Dasar Bahagia Sdn Bhd, Daerah Besut.
ST21114	Eastern Sawmills & Co. Sdn Bhd, Kuala Terengganu.
ST21115	Eng Song Timber Trading, Kuala Terengganu.
ST21116	Hussin b. Mohamad, Besut.
ST21117	Indahya Corporation Sdn Bhd, Daerah Ulu Terengganu.
ST21118	Jerangau Sawmill Sdn Bhd, Dungun.
ST21119	Jusoh Sawmill Co., Besut.
ST21120	Kapur Sawmill Sdn Bhd, Kerteh.
ST21121	Kilang Balak Kecil Musa b. Muda, Kemaman.
ST21122	Kilang Dungun Lumber Co. Sdn Bhd, Dungun.
ST21123	Kilang Papan Chendana Sdn Bhd, Kuala Terengganu.
ST21124	Kilang Papan Desa Medang Sdn Bhd, Kuala Terengganu.
ST21125	Kilang Papan Leung Huat Sawmill Sdn Bhd, Dungun.
ST21126	Kilang Papan Malay Sino (Terengganu) Sdn Bhd, Kuala Terengganu.
ST21127	Kilang Papan Pengkalan Nangka, Besut.
ST21128	Kilang Papan Syarikat Lam Sim Sdn Bhd, Jerteh.
ST21129	Kilang Papan Syarikat Miro, Besut.
ST21130	Kilang Papan Syed Yusof Bersaudara, Ulu Terengganu.
ST21131	Kilang Papan Ulu Terengganu Sdn Bhd, Kuala Berang.
ST21132	Kilang Papan Ulu Terengganu Sdn Bhd, Ulu Terengganu.
ST21133	Kilang Papan Wakaf Tapai Sdn Bhd, Kuala Terengganu.

File Name Structure

ST21134 Megat Yahya b. Megat Osman, Kuala Terengganu.
ST21135 Mohd Amin Store & Housemaker, Mukim Kuala Nerus.
ST21136 Mohd Arifin b. Jabir, Besut.
ST21137 Mustaffa Sutim Sdn Bhd, Kuala Terengganu.
ST21138 Ong Kian Teck Sawmills Sdn Bhd, Paka.
ST21139 Paka Kerteh Sawmill Sdn Bhd, Dungun.
ST21140 Perusahaan Cheneh Baru Sdn Bhd, Daerah Kemaman.
ST21141 Perusahaan Kayu Kayan Lim Choo Fong Sdn Bhd, Marang.
ST21142 Perusahaan Kayu Kayan Sri Terengganu, Kuala Berang.
ST21143 Perusahaan Kayu Kayan Sri Terengganu, Ulu Terengganu.
ST21144 Perusahaan Seberang Baroh Sdn Bhd, Daerah Kuala Terengganu.
ST21145 Sekawan Enterprise, Besut.
ST21146 SPPK Woodworking Complex Sdn Bhd, Kemaman.
ST21147 Syarikat Batu Rakit Sawmill Terengganu, Batu Rakit.
ST21148 Syarikat Berkat Usaha, Kamaman.
ST21149 Syarikat Dasar Timur Sdn Bhd, Daerah Kuala Terengganu.
ST21150 Syarikat Din b. Ahmad Dan Anak-anak, Mukim Kuala Dungun.
ST21151 Syarikat Eng San Sawmill Sdn Bhd, Besut.
ST21152 Syarikat Jaya Seberang Takir Sdn Bhd, Kemaman.
ST21153 Syarikat Keruak Sawmill Sdn Bhd, Besut.
ST21154 Syarikat Kilang Papan Bina Bot & Perniagaan Bina Bot,Terengganu.
ST21155 Syarikat Kilang Papan Bintang Timor, Besut.
ST21156 Syarikat Kilang Papan Ismail Omar, Besut.
ST21157 Syarikat Kilang Papan Pinang Dungun Terengganu Sdn Bhd, Dungun.
ST21158 Syarikat Kilang Papan Sino Malay Sdn Bhd, Kuala Terengganu.
ST21159 Syarikat Kilang Perabut Kiat Huat, Mukim Seraya.
ST21160 Syarikat Mustapha Said & Anak-anak, Kuala Terengganu.
ST21161 Syarikat Persahabatan Maju, Kemaman.
ST21162 Syarikat Perusahaan Dan Pemborong Kemaman Sdn Bhd, Kemaman.
ST21163 Syarikat Perusahaan Putra Terengganu (Sdn) Bhd, Ulu Terengganu.
ST21164 Syarikat Seri Serangkai Sdn Bhd, Kuala Terengganu.
ST21165 Syarikat Shukur Jaya, Dungun Terengganu.
ST21166 Syarikat Sri Langkap, Setiu.
ST21167 Syarikat Usaha Jaya, Kemaman.
ST21168 Syarikat Usaha Murni, Daerah Kemaman.
ST21169 Syarikat Zaiya, Dungun.
ST21170 Tai Huat Timber, Besut.
ST21171 Tam Enterprises Sdn Bhd, Daerah Kemaman.
ST21172 Tan Ah Tong Sdn Bhd, Kemaman.
ST21173 Tan Seng Sawmill Co, Kuala Terengganu.
ST21174 Terengganu Sawmills & Co, Kuala Terengganu.
ST21175 Tuan Hj. Abd. Hamid b. Yaakob, Kemaman.
ST21176 Usaha Bersama Terengganu Sdn Bhd, Kuala Terengganu.
ST21177 Usahasama Tenaga Wan, Besut.
ST21178 Uzir b. Mahmood, Kemaman.
ST21179 Wan Yusof b. Abu Bakar, Besut.
ST21180 Wong Fong Sawmill, Dungun.
ST21181 Zakaria b. Ibrahim, Kuala Terengganu.

Sawn Timber Shed : Perak

SP21201 Song Seng Sawmill, Taiping.

Seasoning Shed : Federal Territory

SF21301 Kwong Kee Cheong Sawmill Sdn Bhd.

Seasoning Shed : Johore

SJ21401 Chung Hwa National Type Primary School, Muar.
SJ21402 Ng Yew Chai Sawmill Sdn Bhd, Renggam.
SJ21403 Sindora Wood Product Sdn Bhd, Bandar Tenggara.

File Name Structure

SJ21404 Syarikat Beruntung Sdn Bhd, Segamat.
SJ21405 Syarikat Subari Pembinaan Perniagaan Sdn Bhd, Johore Bahru.
SJ21406 Syarikat Subari Pembinaan Perniagaan Sdn Bhd, Renggam.

Seasoning Shed : Kelantan

SK21501 Kilang Papan Wong Vot, Kota Bahru.
SK21502 Mohamed & Daham Sawmill Sdn Bhd, Kota Bahru.
SK21503 Perusahaan Kayu Melayu Kelantan, Pasir Puteh.
SK21504 Syarikat Bumiair Timber Industries Sdn Bhd, Tanah Merah.
SK21505 Wong Vot Sawmill Co. Sdn Bhd, Kota Bahru.

Seasoning Shed : Malacca

SM21601 Sing Foh Sawmill Sdn Bhd, Malacca.

Seasoning Shed : Negeri Sembilan

SS21701 Mah Fah Timber Industries Sdn Bhd, Seremban.
SS21702 Syarikat Kilang Papan Gemas, Seremban.
SS21703 Kilang Papan Syarikat Kam-Yusof, Kuala Pilah.

Seasoning Shed : Pahang

SP21801 Cheng Cheok Bee Sawmill Sdn Bhd, Pekan.
SP21802 Moh Lim Sawmill Sdn Bhd, Temerloh.
SP21803 Pan Malaysia Industries Sdn Bhd, Mukim of Keratong.
SP21804 Rimba Jaya Sawmill, Jajahan Marang.
SP21805 Sim Hoe wood & Sawmills Sdn Bhd, Kuantan.
SP21806 Syarikat Hong Lim Kilang Papan Sdn Bhd, Mentakap.

Seasoning Shed : Penang

SP21901 Ban Guan Thye Sawmill Ltd, Butterworth.

Seasoning Shed : Perak

SE22001 Kilang Papan Chun Lee, Padang Rengas.
SE22002 Keow Seng Sawmill Sdn Bhd, Nibong Tebal.
SE22003 Syarikat Perindustrian Kayu Sungai Ketyoh, Batang Padang.

Seasoning Shed : Terengganu

ST22101 Ahmad Zaki Sdn Bhd, Terengganu.
ST22102 Bersama Timber Corporation Sdn Bhd, Kemaman.
ST22103 Chye Hin Sdn Bhd, Kemaman.
ST22104 Kilang Dungun Lumber Co.Sdn Bhd, Dungun.
ST22105 Syarikat Kilang Papan Sino Malay Sdn Bhd, Kuala Terengganu.
ST22106 Kilang Papan Ulu Terengganu Sdn Bhd, Ulu Terengganu.
ST22107 Kilang Perabut Haji Ismail B. Abd. Rahman, Kemaman.
ST22108 Kilang Perabut Mat Ali B.Idris, Kuala Terengganu.
ST22109 Perusahaan Kayu Kayan Sri Terengganu, Ulu Terengganu.
ST22110 Syarikat Persahabatan Maju, Kemaman.
ST22111 Tan Seng Sawmill Co, Kuala Terengganu.

Shed : Perak

SP22201 Bengkel Kejuruteraan, Ipoh.

Shed : Terengganu

ST22301 Pesaka Terengganu Berhad, Dungun.
ST22302 Syarikat Kilang Papan Pinang Dungun Terengganu Sdn Bhd, Dungun.

Stacking Shed : Johore

SJ22401 Malaya Steam Sawmill, Labis.

File Name Structure

Stacking Shed : Terengganu
ST22501 Pesaka Terengganu Berhad, Dungun.

Store : Pahang
SP22601 Guan Huat Sawmill, Temerloh.
SP22602 Khoo Chee Seng Sawmill, Maran.
SP22603 Kilang Papan Kian Seng Huat, Kuala Lipis.
SP22604 Kilang papan Selamat Sentosa Sdn Bhd, Pekan.
SP22605 Nam Yit Developments (M) Sdn Bhd, Kuantan.
SP22606 Perkayuan Pahang (Temerluh) Sdn Bhd, Kemayan.
SP22607 Temeloh Sawmill Co. Sdn Bhd, Temerloh.

Store : Perak
SP22701 Syarikat Salamah (Perak) Sdn Bhd, Kuala Kangsar.

Store : Selangor
SS22801 Gedong Raja Abdullah, Kelang.
SS22802 Guan Guan Timber Industries Sdn Bhd, Kajang.

Store : Terengganu
ST22901 Berjaya Sawmill Co, Mukim Bukit Payong.
ST22902 Kilang Papan Syarikat Lam Sim Sdn Bhd, Jerteh.

Store : Negeri Sembilan
SN23001 Kilang Papan Murad Sdn Bhd, Seremban.

Store : Pahang
SP23101 Gee Seng Sawmill, Kuantan.
SP23102 Kilang Papan Syarikat Sophia Industries, Benta.

Store : Perak
ST23201 Tan Chee Seng Sawmill Sdn Bhd, Ipoh.
ST23202 Syarikat H.M. Radzi Sdn Bhd, Ulu Kinta.

Surau (Prayer Room) : Pahang
SP23301 Surau Engku Dato, Pekan.

Tanalising Plant : Pahang
TP23401 Hin Lee Sawmill Sdn Bhd, Kuantan.

Tanalising Plant : Perak
TA23501 Kilang Papan Lee Kim Weng, Grik.
TA23502 Kilang Papan Grik, Hulu Perak.
TA23503 Syarikat H.M. Radzi Sdn Bhd, Ulu Kinta.

Tanalising Plant : Terengganu
TT23601 Cahaya Perabut Sdn Bhd, Daerah Dungun.
TT23602 Ibrahim b. Abas, Kuala Terengganu.
TT23603 Tai Huat Timber, Besut.
TT23604 Tan Seng Sawmill Co., Kuala Terengganu.

Tanalising Plant : Federal Territory
TF23701 Hua Fuat Machine Joinery Enterprise Sdn Bhd, Kuala Lumpur.

Tanalising Plant : Johore
TJ23801 Syarikat Subari Pembinaan Sdn Bhd, Johore Bahru.

Tanalising Plant : Kelantan
TK23901 Kesedar Sawmill Sdn Bhd, Gua Musang.

File Name Structure

TK23902 Syarikat Perusahaan Kilang Papan Kuala Krai Sdn Bhd, Kuala Krai.
TK23903 Yunus Sawmill (M) Sdn Bhd, Kota Bahru.

Tanalising Plant : Negeri Sembilan
TN24001 Syarikat Kemajuan Jaya, Gemas.
TN24002 Syarikat Everprime Timber Industries Products Sdn Bhd, Gemas.

Tanalising Plant : Penang
TP24101 Alliance Enterprise Co., Seberang Prai.
TP24102 Ban Guan Thye Sawmill Sdn Bhd, Butterworth.

Temple : Federal Territory
TF24201 Thean Hou Temple, Kuala Lumpur.

Temple : Malacca
TM24301 Tokong Cina, Malacca.
TM24302 Tokong Cheng Hoon Teng, Malacca.

Temple : Penang
TP24401 Kuil Cina Kongsi Cheah, Pulau Pinang.
TP24402 Snake Temple, Bayan Lepas.
TP24403 Tokong Khoo Kongsi, George Town.

Temple : Perak
TE24501 Bangunan Tokong China Matang, Matang.

Timber Depot : Perak
TI24601 Seng Fatt Sawmill, Bidor.

Timber Drying Kiln : Selangor
TS24701 Kim Chin Hoe Sawmills Sdn Bhd, Kelang.

Timber Factory : Penang
TP24801 Lam Tatt Electrical Furnishing Sdn Bhd, Seberang Prai.

Timber Factory : Negeri Sembilan
TN24901 Syarikat Perniagaan Chuan Sin, Daerah Jelebu.

Timber Impregnation Plant : Pahang
TP25001 Malatab Industries Sdn Bhd, Kuantan.
TP25002 Syarikat Kilang Papan Kecil Sinar Pahang, Kuala Lipis.

Timber Mouding Workshop : Johore
TJ25101 Syarikat Kayu Wangi Sdn Bhd, Batu Pahat.

Timber Moulding : Negeri Sembilan
TM25201 Syarikat Everprime Timber Industries Products Sdn Bhd, Gemas.

Timber Moulding Factory : Pahang
TP25301 Gim Heng Enterprise Sdn Bhd, Kuantan.
TP25302 Kuantan Moulding (M) Sdn Bhd, Kuantan.

Timber Office : Selangor
TS25401 Ho Guan Sawmill Sdn Bhd, Batu Caves.

Timber Preservative Shed : Federal Territory
RF25501 Syarikat Hock Seng Timber Preservers Sdn Bhd, Kuala Lumpur.

File Name Structure

Timber Seasoning Shed : Perak
TP25601 Kilang Papan Lee Kim Weng, Grik.

Timber Seasoning Shed : Selangor
TI25701 Kilang Papan Chan Fook, Mukim of Petaling.

Timber Seasoning Shed : Terengganu
TT25801 Abdullah @ Awang b. Ismail, Kuala Terengganu.

Timber Seasoning Shed : Negeri Sembilan
TS25901 Bina Gemencheh Sdn Bhd, Batang Melaka.

Timber Seasoning Shed : Pahang
TP26001 Lee Wan Sin & Mey Sawmill, Kuantan.

Timber Seasoning Shed : Johore
TJ26101 Bee Seng Sawmill (J) Sdn Bhd, Yong Peng.
TJ26102 Hong Bee Sawmill Co., Kuantan.
TJ26103 Malatab Industries Sdn Bhd, Kuantan.
TJ26104 Syarikat Kilang Reja Kayu Bukit Batu Sdn Bhd, Simpang Regam.
TJ26105 Veteran Industries Sdn Bhd, Yong Peng.

Timber Shed : Kelantan
TK26101 Keltra Timber Complex, Machang.
TK26102 Syarikat Abdul Rahman Sdn Bhd, Kota Bahru.
TK26103 Syarikat Tiga Antara, Machang.

Timber Shed : Negeri Sembilan
TN26201 Belantara Enterprise Sdn Bhd, Gemas.
TN26202 Syarikat Everprime Timber Industries Products Sdn Bhd, Gemas.
TN26203 Syarikat Sri Palong, Seremban.
TN26204 Syarikat Perusahaan Kayuan Medan Jaya Sdn Bhd, Gemas.

Timber Shed : Pahang
TP26301 Kilang Papan Kian Seng Huat, Kuala Lipis.
TP26302 Lesong Forest Products Sdn Bhd, Kuala Rompin.
TP26303 Syarikat Kilang Papan Baharuddin b. Abu Bakar, Raub.
TP26304 Syarikat Kilang Papan Kecil Sinar Pahang, Kuala Lipis.
TP26305 Syarikat Perniagaan Gelanggi, Jerantut.

Timber Shed : Selangor
TS26401 Kilang Balak Kecil Textwood (M) Sdn Bhd, Kelang.

Timber Shed : Terengganu
TT26501 Mustaffa Sutim Sdn Bhd, Kuala Terengganu.
TT26502 Syarikat Din b. Ahmad Dan Anak-anak, Mukim Kuala Dungun.
TT26503 Usaha Bersama Terengganu Sdn Bhd, Kuala Terengganu.

Timber Shed : Johore
TJ26601 Far East Plywood Bhd, Johore Bahru.

Timber Shed : Malacca
TM26701 Harga Sawmill & Timber Products Sdn Bhd, Telok Mas.
TM26702 Kilang Papan Harga Industries Sdn Bhd, Telok Mas.

Timber Shed : Negeri Sembilan
TN26801 Belantara Enterprise Sdn Bhd, Gemas.
TN26802 Bina Gemencheh Sdn Bhd, Batang Melaka.
TN26803 Sembilan Electric Sawmill Sdn Bhd, Seremban.

File Name Structure

TN26804 Syarikat Perusahaan Kayuan Medan Jaya Sdn Bhd, Gemas.

Timber Shed : Pahang.

TP26901 Khoo Chee Seng Sawmill, Maran.
TP26902 Kimyu Kilang Papan dan Plywood Sdn. Bhd, Temerloh.
TP26903 Lee See Sawmill Sdn Bhd, District of Termeloh.

Timber Shed : Perak

TP27001 Dr. Kok Chee Min Sawmill, Ipoh.
TP27002 Kilang Papan Dr. Kok Chee Min, Sungai Siput.

Timber Stacking Shed : Selangor

TI27101 Kim Chin Hoe Sawmills Sdn Bhd, Kelang.

Timber Store : Federal Territory

TF27201 Aik Joo Bee Sawmill, Kajang.
TF27202 Fook Soon Hin Sawmill Sdn Bhd, Kuala Lumpur.
TF27203 Hong Lim Sawmill, Kuala Lumpur.
TF27204 Kuala Lumpur Timber Sdn Bhd, Kuala Lumpur.
TF27205 Reamer & Spindle Industries Sdn Bhd, Cheras.
TF27206 Syarikat Hock Seng Timber Preservers Sdn Bhd, Kuala Lumpur.
TF27207 Syarikat Kilang Kerjakayu Rawang, Kuala Lumpur.
TF27208 Syarikat Kilang Papan Abdul Aziz Sdn Bhd, Sungai Besi.
TF27209 Syarikat Tenaga Shah Sdn Bhd, Kuala Lumpur.
TF27210 Kwong Kee Cheong Sawmill Sdn Bhd, Kuala Lumpur.
TF27211 Sin Joo Kee Sawmill, Kuala Lumpur.
TF27212 Syarikat Kotakualiti, Kuala Lumpur.
TF27213 Syarikat Nam Lee Trading Sdn Bhd, Kuala Lumpur.
TF27214 Tan Nam Sawmills (M), Kuala Lumpur.

Timber Store : Johor

TJ27301 Ayer Hitam Sawmill Co. Sdn Bhd, Ayer Hitam.
TJ27302 Cha'ah Sawmill Sdn Bhd, Segamat.
TJ27303 Chong Lim Sawmill Sdn Bhd, Muar.
TJ27304 Hock Leong Timber Trading Sdn Bhd, Johore Bahru.
TJ27305 Johore Sawmill Sdn Bhd, Kota Tinggi.
TJ27306 Johore Timber Industries Sdn Bhd, Lapis.
TJ27307 Kilang Papan Hock Seng Teck, Kota Tinggi.
TJ27308 Kilang Papan Kemajuan (Johore) Sdn Bhd, Kluang.
TJ27309 Kilang Papan Mas Sdn Bhd, Kota Tinggi.
TJ27310 Kilang Papan Rimba Timor (Johore) Sdn Bhd, Johore Bahru.
TJ27311 Kilang Papan Selatan Malaysia Sdn Bhd, Kota Tinggi.
TJ27312 Kilang Papan Simca Sdn Bhd, Masai.
TJ27313 Kilang Papan Tan Choon Seng Sdn Bhd, Segamat.
TJ27314 Kim Chin Hoe Sawmills Sdn Bhd, Johore Bahru.
TJ27315 Kong Loon Sawmill Sdn Bhd, Kluang.
TJ27316 Kwong Hock Leong Sawmill Sdn Bhd, Kluang.
TJ27317 Labis Industries, Labis.
TJ27318 Malaya Steam Sawmill, Labis.
TJ27319 Malaysian Forest Industries Sdn Bhd, Labis.
TJ27320 Mini Sawmill Sdn Bhd, Kota Tinggi.
TJ27321 Perusahaan Kayu Kayan (Kluang) Sdn Bhd, Mukim of Mersing.
TJ27322 Perusahaan Kilang Papan Letrik Sim Seng Sdn Bhd, Durian Tunggal.
TJ27323 Sharikat Kilang Papan Johore Tenggara Sdn Bhd, Johore Bahru.
TJ27324 Sharikat Kilang Papan Seri Bukit Kepong Sdn Bhd, Muar.
TJ27325 Lian Pang Sawmill (M) Sdn Bhd, Kluang.
TJ27326 Sharikat Kilang Papan Seri Bukit Kepong Sdn Bhd, Muar.
TJ27327 Sindora Wood Product Sdn Bhd, Bandar Tenggara.
TJ27328 Sin Cheong Loong Sawmill, Kulai.

File Name Structure

TJ27329 Southern Sawmill Sdn Bhd, Kluang.
TJ27330 Syarikat Gunung Timor Sdn Bhd, Johore Bahru.
TJ27331 Syarikat Kayu Wangi Sdn Bhd, Batu Pahat.
TJ27332 Syarikat Kemajuan Tanahan Sdn Bhd, Daerah Kota Tinggi.
TJ27333 Syarikat Kilang Papan Gerak Maju Sdn Bhd, Segamat.
TJ27334 Syarikat Kilang Papan Tai Cheong (Sdn) Bhd, Mersing.
TJ27335 Syarikat Maywood Industries Sdn Bhd, Labis.
TJ27336 Syarikat Mini Mill Sdn Bhd, Ayer Hitam.
TJ27337 Syarikat Peridi Sdn Bhd, Johore Bahru.
TJ27338 Syarikat Perusahaan Kilang Papan CIM Sdn Bhd, Johore Bahru.
TJ27339 Syarikat Subari Pembinaan Sdn Bhd, Johore Bahru.
TJ27340 Umac Sawmill Sdn Bhd, Mersing.

Timber Store : Kedah

TK27401 Hock Seng Sawmill, Baling.
TK27402 Kang Eng Aun Sdn Bhd, Kota Setar.
TK27403 Kilang Papan Teik Hong (Kota Setar) Sdn Bhd, Kota Setar.
TK27404 Lunas Industries Sdn Bhd, Kulim.
TK27405 Sin Wooi Guan Sawmill, Baling.
TK27406 Soon Seng Huat Kilang Perabut, Daerah Pendang.
TK27407 Swee Yuen & Co, Changloon.
TK27408 Swee Yuen Sawmill Sdn Bhd, Kubang Pasu.

Timber Store : Kelantan

TS27501 Kuala Krai Sawmill Co, Kuala Krai.
TS27502 Kilang Papan Ketereh Kelantan, Kota Bahru.
TS27503 Syarikat Perusahaan Kilang Papan Kuala Krai Sdn Bhd, Kuala Krai.
TS27504 Syarikat Great Bonanza Timbers Sdn Bhd, Kuala Krai.
TS27505 Syarikat Maju Lembah Pergau, Kuala Krai.
TS27506 Syarikat Adam Sawmill, Pasir Putih.
TS27507 Syarikat Perusahaan Perabut Ipar, Jajahan Pasir Mas.
TS27508 Syarikat Kilang Papan Kecil (Mini Sawmill), Machang.
TS27509 Syarikat Usahasama Gua Musang, Jajahan Ulu Kelantan.
TS27510 Syarikat Pembinaan Kg. Cermin Sdn Bhd, Jajahan Tanah Merah.
TS27511 Syarikat Wan Mamat b. Wan Sulon Kilang Kayu Sdn Bhd, Jajahan Krai.
TS27512 Syarikat Perusahaan Kilang Papan Kuala Krai Sdn Bhd, Kuala Krai.
TS27513 Syarikat Perusahaan Kilang Papan Kuala Krai Sdn Bhd, Kuala Krai
TS27514 Kesedar Sawmill Sdn Bhd, Gua Musang.
TS27515 Syarikat Usahasama Gua Musang, Jajahan Ulu Kelantan.
TS27516 Sri Wangsa Selatan Timber Sdn Bhd, Gua Musang.
TS27517 Syarikat Pembinaan Kg. Cermin Sdn Bhd, Jajahan Tanah Merah.
TS27518 Syarikat Perusahaan Kilang Papan Kuala Krai Sdn Bhd, Kuala Krai.
TS27519 Pasir Mas Sawmill Sdn Bhd, Gua Musang.
TS27520 Syarikat Kilang Papan H.I. Mohd Salleh Sdn Bhd, Pasir Mas.
TS27521 Syarikat Seri Bintang Sdn Bhd, Kuala Krai.
TS27522 Emasasli (Kilang Papan Kecil), Bukit Merah.
TS27523 Fajar Sawmill Sdn Bhd, Tanah Merah.
TS27524 Guan Ann Sawmill Sdn Bhd, Ulu Kelantan.
TS27525 Kelantan Lumber Product Great Eastern Mill Sdn Bhd, Kuala Krai.
TS27526 Kilang Papan A. Abdullah (G.M.) Sdn Bhd, Kota Bahru.
TS27527 Kilang Papan Bakti Bachok, Bachok.
TS27528 Kilang Papan Datuk Ong Kian Seng, Ulu Kelantan.
TS27529 Kilang Papan Galas (Kelantan) Sdn Bhd, Gua Musang.
TS27530 Kilang Papan Kwangli Sdn Bhd, Hulu Kelantan.
TS27531 Kilang Papan Limah bt. Awang, Ulu Kelantan.
TS27532 Kilang Papan Tengku Jaafar Sdn Bhd, Machang.
TS27533 Kilang Papan Tengku Yaakob b. Tengku Salleh, Kelantan.
TS27534 Kuala Krai Sawmill Co, Kuala Krai.
TS27535 Murni Sawmill Sdn Bhd, Kuala Krai.

File Name Structure

TS27536 Pasir Mas Sawmill Sdn Bhd, Gua Musang.
TS27537 Perusahaan Kilang Papan Kuala Krai, Machang.
TS27538 Sharikat Kilang Papan Bakti, Tanah Merah.
TS27539 Sri Lakota Sdn Bhd, Jeli.
TS27540 Sungai Rek Pembangunan Sdn Bhd, Kuala Krai.
TS27541 Syarikat Binaan Budi Sawmill Sdn Bhd, Ulu Kelantan.
TS27542 Syarikat Kilang Kayu Haji Hassan Isa (M) Sdn Bhd, Tanah Merah.
TS27543 Syarikat Kilang Kayu Pekan Jeli Sdn Bhd, Jeli.
TS27544 Kilang Papan H.I. Mohd Salleh Sdn Bhd, Pasir Mas.
TS27545 Syarikat Kilang Papan Limbongan Sdn Bhd, Tanah Merah.
TS27546 Syarikat LLK Latib Perak Sdn Bhd, Ulu Kelantan.
TS27547 Syarikat Perusahaan Kilang Papan Kuala Krai Sdn. Bhd, Machang.
TS27549 Timbermine Development Corporation Sdn Bhd, Gua Musang.
TS27550 Tong Lam Sawmill Co., Tanah Merah.
TS27551 Wong Vot Sawmill Co., Sdn Bhd, Kota Bahru.

Timber Store : Malacca

TM27601 Kilang Papan Letrik Melaka Sdn. Bhd, Malacca.
TM27602 Kilang Papan Pulau Sebang Sdn Bhd, Aloh Gajah.
TM27603 Syarikat Kilang Shim Foh Sdn Bhd, Melaka Tengah.
TM27604 T.T. Enterprise Sdn Bhd, Daerah Melaka Tengah.
TM27605 Tan Kai Liat Sawmill Sdn Bhd, Bukit Rambai.
TM27606 Tee Siong Sawmill Co. Sdn Bhd, Malacca.
TM27607 Wah Heng Sdn Bhd,Mukim Bukit Rampai.

Timber Store : Negeri Sembilan

TN27701 Eng Hong Lee Timber Industries Sdn Bhd, Tampin.
TN27702 Firama Jaya Sdn Bhd, Seremban.
TN27703 Kilang Papan Kota Sdn Bhd, Kota.
TN27704 Kilang Papan United Sdn Bhd, Tampin.
TN27705 Kilang Papan/Perabut Ban Lee Co., Daerah Tampin.
TN27706 Modern Wood Products Sdn Bhd, Seremban.
TN27707 Murad Construction, Seremban.
TN27708 Nam Seng Sawmill Sdn Bhd, Kuala Pilah.
TN27709 Sem Joo & Co. Sawmill, Seremban.
TN27710 Syarikat Ahlan, Batu Kelikir.
TN27711 Syarikat Everprime Timber Industries Products Sdn Bhd, Gemas.
TN27712 Syarikat Kemajuan Jaya, Gemas.
TN27713 Syarikat Kilang Papan Kim Mah Sdn Bhd, Tampin.
TN27714 Syarikat Kin Yip, Tampin.
TN27715 Syarikat Perabut Dan Kerja Perkayuan Fan Yong, Seremban.
TN27716 Syarikat Perabut dan Kerja Perkayuan Seng Chow, Seremban.
TN27717 Syarikat U Lian, Seremban.
TN27718 Syarikat Usaha Murni, Jelebu.
TN27719 Tan Kai Liat Sawmill Sdn Bhd, Daerah Tampin.
TN27720 Tong Kwee Sawmill, Seremban.
TN27721 Wee Hin Sawmill Sdn Bhd, Seremban.
TN27722 Chin Fatt Kee Sdn Bhd, Seremban.
TN27723 Hup Seng Sawmill Co, Bahau.
TN27724 Kilang Papan Hang Tuah, Ayer Hitam.
TN27725 Kilang Papan Seri Serting, Kuala Pilah.
TN27726 Kwong Onn Sawmill (Sdn) Bhd, Mantin.
TN27727 Lian Pong Timber Industries Sdn Bhd, Tampin.
TN27728 Ng Teong Kiat Sawmills Ltd, Gemas.
TN27729 Rimba Muda Co.Sdn Bhd, Batu Kikir.
TN27730 Sembilan Electric Sawmill Sdn Bhd, Seremban.
TN27731 Sim Sim Sawmill Sdn Bhd, Kuala Pilah.
TN27732 Syarikat Johore Sdn Bhd, Seremban.
TN27733 Syarikat Malaysia Kilang Papan Sdn Bhd, Gemas.

File Name	Structure
TN27734	Syarikat Malaysia Kilang Papan Sdn Bhd, Tampin.
TN27735	Tampin Sawmill & Co, Tampin.
TN27736	Wan Leong Timber Trading, Seremban.
TN27737	Yoong Leok Kee Corporation Sdn Bhd, Seremban.
TN27738	Yoong Leok Kee Corporation Sdn Bhd, Tampin.

Timber Store : Pahang

TP27801	Abu Hassan Sdn Bhd, Lanchang.
TP27802	Bukit Goh Sawmill Sdn Bhd, Kuantan.
TP27803	Cheng Cheok Bee Sawmill Sdn Bhd, Temerloh.
TP27804	Federal Sawmill Gambang (1965) Sdn Bhd, Gambang.
TP27805	Gee Seng Sawmill, Kuantan.
TP27806	Jaya Muda Sdn Bhd, Temerloh.
TP27807	Kilang Papan Bukit Godam Sdn Bhd, Temerloh.
TP27808	Telemong Tong Leong Sdn Bhd, Bentong.
TP27809	Temerloh District Timber Trading Co. Sdn Bhd, Mentakap.
TP27810	Thye Hing Sawmill Sdn Bhd, Mengkuang.
TP27811	Kilang Papan Leong Seng Sdn Bhd, Kuantan.
TP27812	Kilang Papan Pekan Sdn Bhd, Pekan.
TP27813	Kilang Papan Wan Ahmad Sdn Bhd, Lipis.
TP27814	Kilang Papan WMP Sdn Bhd, Pekan.
TP27815	Kit Ming Sawmill Sdn Bhd, Raub.
TP27816	Kuantan Sawmill, Kuantan.
TP27817	Nenasi Sawmill Sdn Bhd, Pekan.
TP27818	Nyee Woh Sawmills Limited,.Jerantut.
TP27819	Ong Kian Teck Sawmills (Sdn) Bhd, Rompin.
TP27820	Pahang Sawmills, Temerloh.
TP27821	Pan Soo Meng Sawmill, Raub.
TP27822	Perkayuan Pahang (Temerloh) Sdn Bhd, Pekan.
TP27823	Perniagaan Bukit Damai, Daerah Lipis.
TP27824	Seng Peng Sawmills Sdn Bhd, Gambang.
TP27825	Sim Guan Sawmill & Co. Pahang, Mukim Sabai.
TP27826	Southern Sawmill, Lipis.
TP27827	Syarikat Al-Hadi (Sdn) Bhd, Temerloh.
TP27828	Syarikat Kilang Papan Kecil Sri Pekan, Pekan.
TP27829	Syarikat Kilang Papan Semangat Apollo Sdn Bhd, Mukim Karatong.
TP27830	Syarikat Kilang Papan Timber Merchants Co., Temerloh.
TP27831	Syarikat Kuantan Lumber Sdn Bhd, Kuantan.
TP27832	Syarikat Kuantan Lumber Sdn Bhd, Kuantan.
TP27833	Syarikat Tenaga Desa Pahang, Jerantut.
TP27834	Tekun Jaya (Teja), Kuantan.
TP27835	Temerloh District Timber Trading Co. Sdn Bhd, Mentakap.
TP27836	Union Bestwood Sdn Bhd, Maran.
TP27837	Wan Foo Sawmill Sdn Bhd, Jerantut.
TP27838	Yap Timber Trading Sdn Bhd, Kuala Lipis.
TP27839	Asia Sungei Yu Sawmill Sdn Bhd, Kuala Lipis.
TP27840	Cheong Sawmills Sdn Bhd, Bentong.
TP27841	Continental Sawmill, Veneer & Plywood Sdn Bhd, Kuantan.
TP27842	East Union Timber Industries Sdn Bhd, Mentakap.
TP27843	Guan Huat Sawmill, Temerloh.
TP27844	Hean Lee Sawmill & Trading Co. Sdn Bhd, Jerantut.
TP27845	Hong Bee Sawmill Co., Kuantan.
TP27846	Hong Huat Sdn Bhd, Kuantan.
TP27847	Hong Moh Sawmill Limited, Mentakap.
TP27848	K.C. Cheah Sawmills (Pahang) Sdn Bhd, Temerloh.
TP27849	Kilang Papan (MC), Jerantut.
TP27850	Kilang Papan Ani Sdn Bhd, Temerloh.
TP27851	Kilang Papan Berkas Perajurit Malaysia Barat, Mentakap.
TP27852	Kilang Papan Bukit Emas Sdn Bhd, Raub.

File Name Structure

TP27853 Kilang Papan Kecil Alias, Temerloh.
TP27854 Kilang Papan Kemuning, Temerloh.
TP27855 Kilang Papan Leong Seng Sdn Bhd, Kuantan.
TP27856 Kilang Papan Maran Sin Hin Sdn Bhd, Temerloh.
TP27857 Kilang Papan Ng Hock Seng, Raub.
TP27858 Kilang Papan Poh Soo Trading, Temerloh.
TP27859 Kilang Papan Semantan, Kuantan.
TP27860 Kilang Papan Sophia Industries, Benta.
TP27861 Kilang Papan Yin Woh Sdn Bhd, Raub.
TP27862 Kim Teck Leong Sawmills Sdn Bhd, Karak.
TP27863 Kimyu Sawmill & Plywood Company Limited, Temerloh.
TP27864 Modal Moulding Sdn Bhd, Kuantan.
TP27865 Ng Tiong Kiat Sawmill (Triang) Sdn Bhd, Jerantut.
TP27866 Perkayuan Pahang (Pekan/Kuantan) Sdn Bhd, Kuantan.
TP27867 Perkayuan Pahang (Temerloh) Sdn Bhd, Pekan.
TP27868 Poh Chan Hup Seng Sawmill Sdn Bhd, Raub.
TP27869 Rompin Sawmill Sdn Bhd, Rompin.
TP27870 Sharikat Sungei Belat Sdn Bhd, Kuantan.
TP27871 Simpang Woodworking Sdn Bhd, Pekan.
TP27872 Suria Bee Leong Timber Industries. Sdn Bhd, Kuantan.
TP27873 Syarikat Ihsan Sdn Bhd, Temerloh.
TP27874 Syarikat Kemajuan Pembalak Pahang, Temerloh.
TP27875 Syarikat Kilang Papan Chin Guan Sdn Bhd, Mentakap.
TP27876 Syarikat Kilang Papan Kecil Sri Pekan, Pekan.
TP27877 Syarikat Kilang Papan Semangat Apollo Sdn Bhd, Mukim Karatong.
TP27878 Syarikat Kilang Papan Sri Pahang, Raub.
TP27879 Syarikat Membalak Gerak Maju Sdn Bhd, Temerloh.
TP27880 Syarikat Ong Kian Teck Sawmill Sdn Bhd, Maran.
TP27881 Syarikat Permodalan Dan Perusahaan Pahang Bhd, Kuantan.
TP27882 Syarikat Perusahaan Chini (M) Sdn Bhd, Rompin.
TP27883 Syarikat Sum Thai Trading Sdn Bhd, Jerantut.
TP27884 TAB Timber Traders Sdn. Bhd, Pekan.
TP27885 Telemong Tong Leong Sdn Bhd, Bentong.
TP27886 Temerloh District Timber Trading Co. Sdn Bhd, Mentakap.
TP27887 Thye Hing Sawmill Sdn Bhd, Mengkuang.
TP27888 Thye Hing Sawmill Sdn Bhd, Temerloh.
TP27889 Ulu Gali Sawmill & Co, Raub.
TP27890 United Trading Sawmill Sdn Bhd, Kuantan.
TP27891 Yee Hup Sawmill, Maran.

Timber Store : Penang

TS27901 Keaw Seng Sawmill Sdn Bhd, Seberang Prai.
TS27902 Keow Seng Sawmill Sdn Bhd, Nibong Tebal.
TS27903 Teong Lee Sawmill & Hardware Sdn Bhd, Seberang Prai.

Timber Store : Perak

TP28001 Bee Choon Sawmill Company, Ipoh.
TP28002 Chong Mah Wooden Boxes Factory, Tanjong Malim.
TP28003 Chop Sin Hin Chong Khai Chen & Brother Sawmill, Ipoh.
TP28004 Eng Joo Enterprise Sdn Bhd, Taiping.
TP28005 Hock Wah Seng Timber Products Sdn Bhd, Tanjong Rambutan.
TP28006 Hong Seong Sawmills Ltd, Tanjong Malim.
TP28007 Ikatan Syarikat Pembalak-pembalak Perak Bhd, Grik.
TP28008 Kilang Papan Aziz b. Kulup Ahmad, Daerah Batang Padang.
TP28009 Kilang Papan Chop Yeap Yuen Kee Sdn Bhd, Simpang Pulai.
TP28010 Kilang Papan Kuala Kangsar Sdn Bhd, Kuala Kangsar.
TP28011 Kilang Papan Nam Loong, Menglembu.
TP28012 Kilang Papan Seraya Sdn Bhd, Ipoh.
TP28013 Kilang Papan Slim River Sdn Bhd, Slim River.

File Name	Structure
TP28014	Kilang Papan Tuan Haji Ahmad Sapawi b. Kulop Lela, Ipoh.
TP28015	Kilang Papan Zainuddin Hj. Aris Sdn Bhd, Bidor.
TP28016	Kwong Yuen Sang Sawmill, Batang Padang.
TP28017	Lee Sang Loong Sawmill, Ipoh.
TP28018	Nam Fong Sawmill, Ipoh.
TP28019	Perak Simpang Timber Sdn Bhd, Taiping.
TP28020	Perbadanan Kemajuan Negeri Perak, Ipoh.
TP28021	Santary Sdn Bhd, Ipoh.
TP28022	Saw Lee Sawmill Sdn Bhd, Sitiawan.
TP28023	Sin Hin Sawmill (Chong Khai Chen & Brother Sdn Bhd), Ipoh.
TP28024	Syarikat Kwong Fook Hing Sdn Bhd, Bidor.
TP28025	Sun Nam Lee Sawmill Sdn Bhd, Kampar.
TP28026	Syarikat H.M. Radzi Sdn Bhd, Ulu Kinta.
TP28027	Syarikat Kwong Fook Hing Sdn Bhd, Tapah.
TP28028	Syarikat Salamah (Perak) Sdn Bhd, Kuala Kangsar.
TP28029	Syarikat Sun Ngoon Sawmill (M) Sdn Bhd, Teluk Anson.
TP28030	Tan Chee Seng Sawmill Sdn Bhd, Ipoh.
TP28031	Thong Fatt Timber Sdn Bhd, Sungai Siput.
TP28032	Wing Ying Sawmill & Plywood Bhd, Chemor.
TP28033	Yip Yoon Kee Sawmill, Simpang Pulai.

Timber Store : Selangor

TS28101	Finewood Products Corporation Sdn Bhd, Pelabuhan Kelang.
TS28102	General Lumber (Holdings) Bhd, Petaling Jaya.
TS28103	Guan Guan Timber Industries Sdn Bhd, Kajang.
TS28104	Hills Wood Processing Plant Sdn Bhd, Kelang.
TS28105	Ho Guan Sawmill Sdn Bhd, Batu Caves.
TS28106	Hong Seng Sawmill & Co, Ulu Selangor.
TS28107	Hu Sang Sawmill, Rawang.
TS28108	Kekal Kayu Sdn Bhd, Klang.
TS28109	Kian Ann (Seng Kee) Sawmill, Kajang.
TS28110	Kian Kee Sawmills (M) Sdn Bhd, Batang Berjuntai.
TS28111	Kilang Balak Kecil Yeoh Teong Lin, Kelang.
TS28112	Kilang Kerja Kayu, Sungei Pelek Sepang.
TS28113	Kilang Kilns & Processing Sdn Bhd, Kelang.
TS28114	Kilang Papan Balak Kecil Yap Soon Huat, Selangor.
TS28115	Kilang Papan Ekonomi Baru Sdn Bhd, Kuala Selangor.
TS28116	Kilang Papan Goodwood, Ulu Selangor.
TS28117	Kilang Papan Kian Ann (Seng Kee), Kajang.
TS28118	Kilang Papan Lim Ah Soon Sdn Bhd, Mukim Beranang.
TS28119	Kilang Papan Mohd Nazir Sdn Bhd, Ulu Langat.
TS28120	Kim Hock Timber Sawmill, Daerah Kuala Langat.
TS28121	Kim Lian Huat Sawmill Sdn Bhd, Tanjung Karang.
TS28122	Lawang Tin Industry Sdn Bhd, Rawang.
TS28123	Mattaku Sdn Bhd, Kuala Selangor.
TS28124	Salak Sawmill, Sepang.
TS28125	Sharikat Kilang Papan Hock Guan Sdn Bhd, Kajang.
TS28126	Shintar Enterprise Sdn Bhd, Kelang.
TS28127	Sin Chuan Aik Sdn Bhd, Kajang.
TS28128	Successwood Products Sdn Bhd, Klang.
TS28129	Syarikat Hassan And Sons Sawmill Sdn Bhd, Sekinchan.
TS28130	Syarikat Jaya Sahabat, Daerah Kuala Selangor.
TS28131	Syarikat Kilang Papan Kim Guan Huat Sdn Bhd, Kelang.
TS28132	Syarikat Kilang Papan Rasa Sdn Bhd, Hulu Selangor.
TS28133	Syarikat Kilang Papan Sdn Bhd, Kelang.
TS28134	Syarikat Kilang Papan Sim Mok, Kajang.
TS28135	Syarikat Lucky Timber, Kepong.
TS28136	Syarikat Perdagangan Dan Perindustrian Yee Woh, Kajang.
TS28137	Syarikat Sebati Sdn Bhd, Ulu Selangor.

File Name Structure

TS28138 Syarikat Tenaga Shah Sdn Bhd, Ulu Selangor.
TS28139 Tee Sheng Hot @ Teh Cheng Chuen, Kelang.
TS28140 Wood & Allied Industries Holding Sdn Bhd, Kajang.
TS28141 Yee Woh Chan Sawmill, Mukim of Petaling.

Timber Store : Terengganu

TT28201 Abdullah @ Awang b. Ismail, Kuala Terengganu.
TT28202 Abdullah b. Yusof & Ahmad b. Embong, Daerah Ulu Terengganu.
TT28203 Ali b. Salleh, Dungun.
TT28204 Aziz Ahmad Perabot, Kuala Terengganu.
TT28205 Bakti Malaysia Sdn Bhd, Kuala Terengganu.
TT28207 Bersama Timber Corporation Sdn Bhd, Kemaman.
TT28208 Besut Tsuda Industries Sdn Bhd, Besut.
TT28209 Cahaya Perabut Sdn Bhd, Daerah Dungun.
TT28210 Chee Fook Lian Sawmill, Ulu Terengganu.
TT28211 Dewan Enterprise, Besut.
TT28212 En. Wan Da b. Ahmad, Ulu Terengganu.
TT28213 Hamzah b. Awang, Kuala Terengganu.
TT28214 Huat Timber, Besut.
TT28215 Hussin b. Mohamad, Besut.
TT28216 Ibrahim b. Abas, Kuala Terengganu.
TT28217 Indahya Corporation Sdn Bhd, Daerah Ulu Terengganu.
TT28218 Jabir b. Mohd Shah, Besut.
TT28219 Jerangau Sawmill Sdn Bhd, Dungun.
TT28220 Jusoh Sawmill Co., Besut.
TT28221 Kapur Sawmill Sdn Bhd, Kerteh.
TT28222 Kapur Sawmill Sdn Bhd, Kuala Berang.
TT28223 Kayu Kayan Sesama Sdn Bhd, Dungun.
TT28224 Kilang Balak Kecil Musa B.Muda, Kemaman.
TT28225 Kilang Dungun Lumber Co.Sdn Bhd, Dungun.
TT28226 Kilang Papan Caca Paka Sdn Bhd, Paka.
TT28227 Kilang Papan Chendana Sdn Bhd, Kuala Terengganu.
TT28228 Kilang Papan Desa Medang Sdn Bhd, Kuala Terengganu.
TT28229 Kilang Papan Malay Sino (Terengganu) Sdn Bhd, Kuala Terengganu.
TT28230 Kilang Papan Pesaka Terengganu Berhad, Kuala Terengganu.
TT28231 Kilang Papan Musa Co. (M) Sdn, Jajahan Kemaman.
TT28232 Kilang Papan Sri Tengkawang Sdn Bhd, Daerah Ulu Terengganu.
TT28233 Kilang Papan Syarikat Miro, Besut.
TT28234 Kilang Papan Syed Yusof Bersaudara, Ulu Terengganu.
TT28235 Kilang Papan Wakaf Tapai Sdn Bhd, Kuala Terengganu.
TT28236 Kilang Perabut Abdullah b. Awang, Kuala Terengganu.
TT28237 Kilang Perabut Osman b. Abu Bakar, Kuala Terengganu.
TT28238 Mohd Amin Store & Housemaker, Mukim Kuala Nerus.
TT28239 Mohd Yassin b. Hj. Mamat, Besut.
TT28240 Mohd Yusof b. Abd Manaf, Kuala Terengganu.
TT28241 Mustaffa b. Abdullah, Marang.
TT28242 Nawi b. Ismail, Besut.
TT28243 Ong Kian Teck Sawmills Sdn Bhd, Paka.
TT28244 Paka Kerteh Sawmill Sdn Bhd, Dungun.
TT28245 Pelangi Perabut Sdn Bhd, Besut.
TT28246 Perabot Maju Bena, Besut.
TT28247 Perusahaan Cheneh Baru Sdn Bhd, Daerah Kemaman.
TT28248 Perusahaan Kayu Kayan Sri Terengganu, Kuala Berang.
TT28249 Perusahaan Seberang Baroh Sdn Bhd, Daerah Kuala Terengganu.
TT28250 Pesaka Terengganu Berhad, Dungun.
TT28251 Salim b. Mohamad, Kuala Terengganu.
TT28252 Sekawan Enterprise, Besut.
TT28253 Syarikat Isof, Kuala Terengganu.
TT28254 Syarikat Adek Beradek Abdul Manan Sdn Bhd, Daerah Kuala Terengganu.

File Name	Structure
TT28255	Syarikat Anika Bakti Sdn Bhd, Kemaman.
TT28256	Syarikat Batu Rakit Sawmill Terengganu, Batu Rakit.
TT28257	Syarikat Berkat Usaha, Kamaman.
TT28258	Syarikat Dasar Timur Sdn Bhd, Daerah Kuala Terengganu.
TT28259	Syarikat Jaya Seberang Takir Sdn Bhd, Kemaman.
TT28260	Syarikat Keruak Sawmill Sdn Bhd, Besut.
TT28261	Syarikat Kilang Papan Pinang Dungun Terengganu Sdn Bhd, Dungun.
TT28262	Syarikat Kilang Perabut Kiat Huat, Mukim Seraya.
TT28263	Syarikat M.M.I Sawmill Sdn Bhd, Besut.
TT28264	Syarikat Mohamad Sham, Besut.
TT28265	Syarikat Mustapha Said & Anak-anak, Kuala Terengganu.
TT28266	Syarikat Perusahaan Dan Pemborong Kemaman Sdn Bhd, Kemaman.
TT28267	Syarikat Perusahaan Kilang Papan Haji Ibrahim, Daerah Kemaman.
TT28268	Syarikat Perusahaan Perabut Jaya Sepakat, Kemaman.
TT28269	Syarikat Seri Serangkai Sdn Bhd, Kuala Terengganu.
TT28270	Syarikat Sri Langkap, Setiu.
TT28271	Syarikat Usaha Jaya, Kemaman.
TT28272	Syarikat Usaha Murni, Daerah Kemaman.
TT28273	Syarikat Zaiya, Dungun.
TT28274	Tam Enterprises Sdn Bhd, Daerah Kemaman.
TT28275	Tan Ah Tong Sdn Bhd, Kemaman.
TT28276	Tan Seng Sawmill Co, Kuala Terengganu.
TT28277	Terengganu Sawmills & Co, Kuala Terengganu.
TT28278	Tuan Hj. Abd. Hamid b. Yaakob, Kemaman.
TT28279	Usaha Bersama Terengganu Sdn Bhd, Kuala Terengganu.
TT28280	Usahasama Tenaga Wan, Besut.
TT28281	Uzir b. Mahmood, Kemaman.
TT28282	Wong Fong Sawmill, Dungun.
TT28283	Yaha Enterprise, Kuala Terengganu.

Timber Store and Kiln Dry : Selangor

TS28301 Keong Kee Sawmill Sdn Bhd, Kuala Selangor.
TS28302 Kilang Papan Rompin Trading Sdn Bhd, Rompin.

Timber Workshop : Johore

TJ28401 Sin Cheong Loong Sawmill, Kulai.

Timber Treatment Plant : Johore

TP28501 Syarikat Subari Pembinaan Perniagaan Sdn Bhd, Johore Bahru.
TP28502 Veteran Industries Sdn Bhd, Yong Peng.

Timber Workshop : Kelantan

TK28601 Kilang Papan A. Abdullah (G.M.) Sdn Bhd, Kota Bahru.

Timber Workshop : Negeri Sembilan

TS28701 Loh Kwong Leong, Port Dickson.
TS28702 Syarikat Perabut dan Kerja Perkayuan Seng Chow, Seremban.
TS28703 Syarikat Perniagaan Chong, Kuala Pilah.
TS28704 Syarikat Semangat Baru, Tampin.
TS28705 Syarikat Yong-yong Trading, Daerah Jelebu.

Timber Workshop : Penang

TP28801 Lim Chin Joo Sawmills, Seberang Prai.

Timber Workshop : Pahang

TW28901 Simpang Woodworking Sdn Bhd, Pekan.

Timber Workshop : Perak

TI29001 Woh Hup Kee Sdn Bhd, Ipoh.

File Name Structure

Timber Workshop : Terengganu

TT29101 Kilang Balak Kecil Yaakub b. Hj. Daud, Dungun.
TT29102 Kuala Brang Sawmill, Ulu Terengganu.
TT29103 Mohd Amin Store & Housemaker, Mukim Kuala Nerus.
TT29104 Syarikat Din Traders, Kuala Berang.
TT29105 Syarikat Zamn, Kuala Berang.

Timber Yard : Pahang

TY29201 Nam Yit Developments (M) Sdn Bhd, Ulu Keratong.

Traditional Malay House : Perak

TP29301 Rumah Alma Baker, Batu Gajah.
TP29302 Rumah Kuning, Batu Gajah.

Treatment Plant : Johore

TJ29401 Kilang Papan Kemajuan (J) Sdn Bhd, Kluang.
TJ29402 Sharikat Kilang Papan Seri Bukit Kepong Sdn Bhd, Muar.

Treatment Plant : Terengganu

TT29501 Perusahaan Kayu Kayan Lim Choo Fong Sdn Bhd, Marang.

Treatment Plant : Pahang

TP29601 Maran Road Sawmill Sdn Bhd, Temerloh.

Treatment Plant : Kelantan

TK29701 Keltra Timber Complex, Machang.

Veneer Factory : Terengganu

VT29801 Leung Huat Sawmills (Pty) Bhd, Dungun.

Warehouse : Selangor

WS29901 General Lumber (Holdings) Bhd, Kelang.

Water Storage Tower : Perak

WP30001 Bangunan Menara Jam Besar, Teluk Intan.

Wood Machinery Shed : Federal Territory

WF30101 Boon Kee Teak Wood Factory Sdn Bhd, Kuala Lumpur.

Wood Working Mill : Pahang

WP30201 Maran Road Sawmill Sdn Bhd, Temerloh.
WP30202 Rompin Sawmill Sdn Bhd, Kuala Rompin.
WP30203 Syarikat Ong Kian Teck Sawmill Sdn Bhd, Maran.
WP30204 Syarikat Sungai Batu (M) Sdn Bhd, Kuantan.

Wood Working Mill : Perak

WW30301 Kilang Papan Nam Loong, Menglembu.
WW30302 Chong Mah Wooden Boxes Factory, Tanjong Malim.
WW30303 Saw Lee Sawmill Sdn Bhd, Sitiawan.

Wood Working Mill : Selangor

WS30401 Hills Wood Processing Plant Sdn Bhd, Kelang.
WS30402 Kian Ann (Seng Kee) Sawmill, Kajang.
WS30403 Kilang Balak Kecil Textwood (M) Sdn Bhd, Kelang.
WS30404 Liaw Ting Huat Timber Trading, Kelang.

Wood Working Mill : Kelantan

WK30501 Keltra Timber Complex, Machang.

File Name Structure

Wood Working Mill : Kedah
WM30601 Kee Leong Sawmill Sdn Bhd, Gurun.

Wood Working Mill : Johore
WJ30701 Syarikat Gunung Timor Sdn Bhd, Johore Bahru.

Wood Work Training Shed : Kedah
WT30801 Lembaga Kemajuan Wilayah Kedah (KEDAH), Jitra.

Wood Working Shed : Terengganu
WT31001 Tan Seng Sawmill Co, Kuala Terengganu.

Workshop : Pahang
WP31102 K.C. Cheah Sawmills (Pahang) Sdn Bhd, Temerloh.

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Name	:	ASPA Mosque
Address	:	Jalan Pekan
Town	:	Pekan
State	:	Pahang
Access Descriptors	:	Post and Beam Structure
Designed Function	:	Mosque
Present Function	:	Mosque
History Of Use	:	Mosque
Date Constructed	:	1989
Designed By	:	CSL Associates
Designer Address	:	No 8 Jalan Scott
Engineered By	:	Ranhill Bersekutu Sdn. Bhd.
Engineer's Address	:	6th Floor, Wisma Central, Jalan Ampang, Kuala Lumpur.
Constructed For	:	Amanah Saham Pahang Berhad
Constructed By	:	Mentiga Corporation Bhd.
Construction Cost	:	
Construction Method	:	Post and Beam
Floor System	:	Prefabricated
External Wall System	:	Prefabricated
Internal Wall System	:	
Ceiling System	:	Exposed structures
Roofing System	:	Corrugated sheeting
Author	:	Cheah, F.(ed.)
Title	:	ASPA Mosque, Pahang Darul Makmul
Publisher	:	Pertubuhan Akitek Malaysia
Date	:	Nov. 1991
ISBN	:	PP 69/11/89
Text	:	"The purpose of this project is to present a prototype Mosque design for the State of Pahang Darul Makmur. It also emphasised the use of timber as the prime prefabricated material used".

Design Concept

The main concept in the design of the mosque is to provide a space which complies with the requirements and basic essential need of prayer, capable of being erected easily, economically and rapidly. Spiritually, the space designed will convey the feeling of spaciousness and volume, conducive to religious congregation. Total flexibility is also incorporated into the design so that if the need arises, the mosque can be extended and utilised for other activities such as "kenduri", kindergarten or an Islamic study centre.

Architectural Treatment

The overall architectural expression is in timber with traditional concrete stairs and deep profiled "V" shaped, metal sheet roofing being the other two secondary materials utilised. Consideration of the local climatic and site conditions were also accounted for and in the following context.

Ventilation

Three feet louvred wall panels and ventilating shutters located between roof layers allow for unimpeded air flow and cross ventilation, both horizontally and vertically. This will prevent air from being trapped in the building. The floor level is raised to improved ventilation as wind velocity increases with altitude. Large overhangs (about seven feet six inches) are used as means to direct air flow into the building.

Sun/RainControl

Large overhangs (extending seven feet six inches from the building) provide shade when sunny and shelter when rainy. In addition, they also help reduce glare and provide indirect lighting which is comfortable and psychologically cooling to the occupant.

Construction System

The construction system is based on a simple timber post and beam prefabricated system. In adopting this system, standard basic components were utilised to ensure easy, economical and rapid construction. All standard components of the building were fabricated off-site, transported to the site and erected as scheduled.

Critique

The ASPA (Amanah Saham Pahang Berhad) mosque, being a prototype design, is a result of certain factors taken into consideration for a simple design, an easy construction system and the speed of erection without compromising on the religious significance of a mosque as a prayer house.

As such, the familiar "dome" component which is largely symbolic than structural in nature, has been left out in view of economy and the limitations of timber as a structural material. The ASPA mosque design has been stripped of the frills one would associate with a mosque, leaving only the essential "space" for the praying congregation and a niche for the "imam".

The design basically comprises of a square plan, roofed over by a system of tiered pyramidal roofs with a ventilator at the apex. The design is variable to accommodate a range of congregation capacity of 300, 400 and 500 persons.

Externally, the design does not have any reference to its genre, except if one recollects the shape of Masjid Kampung Laut in Kelantan, the oldest mosque built on the Malaysian Peninsular. It has a similar hierarchical form, devoid of the more familiar Arabesque features found in other bigger or royal mosques. The ASPA mosque is also designed for a rural context, and as such, it has to blend in with the similarly-built vernacular timber village houses. Islam has been a way of life for every Muslim and religion has been a base for social activities, particularly in the rural sectors. The blending in of the mosque design with the village structures is a response to enhancing the role of religion in every villager's life. While the Malay village house has demonstrated its suitability in the climatic context, it is only natural that the village mosque follow an architectural and construction system that has been the practice of local carpenters and has proved to be compatible all this time.

Extras	:	Plans, section and details
Author	:	Lim, C.S.
Title	:	Architecture and Tropical Timbers
Publisher	:	2nd CIB/W18B International Conference on Tropical Hardwood Timber Structures
Date	:	1992
ISBN	:	
Text	:	
Current Owner	:	Amanah Saham Pahang Berhad
Contact Person	:	
Phone Number	:	
Postal Address	:	
Reference Person	:	

Name	:	Jimmy Lim Cheok Siang
Address	:	No 8 Jalan Scott
Town	:	Kuala Lumpur
State	:	Federal Territory
Field of Practice	:	Architecture
Practising	:	Yes
Qualifications	:	B.Arch
From	:	University of New South Wales
Date of Birth	:	
Date of Death	:	
Building Reference	:	MO13101
Building Name	:	Peter Eu's House
Location	:	Kuala Lumpur
Function	:	Residence
Date Constructed	:	1989
Other Involved	:	
Construction Notes	:	
Design Notes	:	The use of timber in the building helps to promote the image of the past to the present.
Author	:	Cheah, F. (ed.)
Title	:	House for Peter Eu - Kuala Lumpur
Publisher	:	Pertubuhan Akitek Malaysia
Date	:	1989
ISBN	:	PP 84/11/88
Text	:	Interesting use of prefabricated system for mosque construction.
Professional Notes	:	
Reference Person	:	Tan, Y.E.
Organisation	:	Forest Research Institute of Malaysia
Phone Number	:	03 - 634 2633
Postal Address	:	52109, Kepong, Kuala Lumpur

INSTITUT PENYELIDIKAN PERHUTANAN MALAYSIA
Forest Research Institute Malaysia
Kepong, 52109 Kuala Lumpur
Tel: 03-6342633 Telex: FRIM-MA-27007 Fax: 603-6367753

Ruj. Kami/*Our Ref:* **FRIM 394/KH 665/3/1 Kh 3 (44)** Tarikh/*Date:* **30th April 1993**
Ruj. Tuan/*Your Ref:*

Dear Sir/Madam,

The Department of Architecture of the University of Tasmania, Australia has funds from the Federal & Tasmanian Governments to develop a specialist programme in Building in Wood. As part of this development, I am undertaking a Master of Architecture degree by research with the Department. This research is carried out with support from the Forest Research Institute Malaysia (FRIM), Kepong and the Department of Architecture of the University of Tasmania, Australia. Its purpose is to develop an evaluative overview of timber usage and jointing in buildings in Malaysia from 1900 to the present. The first step in achieving this is to compile a list of those buildings which are regarded as important in their use of timber. Importance means that timber is used as a major structural component or as the dominant material of the building. The findings will form a series of valuable educational and informational tools concerning the economic, technological, intellectual and cultural validity of using timber as a main-stream engineering material.

May I ask you for your support and other members of your organisation to share your experience and knowledge on this topic.

Please find enclosed copies of two different questionnaires which require your valuable inputs.

In the first questionnaire, please name three buildings in Malaysia that, in your opinion, have extensive or innovative use of timber. The buildings can be from any period to the present but must be constructed in Malaysia.

Please complete one copy of the questionnaire for each building with as much information as you could readily supply.

If you wish to include more than three buildings, please do so.

In the second questionnaire, please think of one person who has made a major contribution to the development of timber usage in buildings, either as an architect, engineer, or builder.

Again, please complete the second questionnaire with as much information as you can readily supply. If you wish to include more than one practitioner, please feel free to do so.

Please return the completed questionnaires in the envelope provided to the above address if possible by 28th May 1993. If you wish to suggest additional participants to this survey from your organisation, please include their names and I shall contact them.

I believe your assistance in this research will contribute to the increased appreciation of the true value of timber in Malaysia. It is hoped that results will be published early next year.

I greatly appreciate your co-operation in this important survey which will benefit Malaysia.

Yours sincerely,

Wong Wai Sung
BA Env. Des., B. Arch (Hons)
(Assistant Research Officer)

P.S. If you have any queries on how to complete the questionnaires or about the research topic in general, please call (03) 6342633 ext. 463.

INSTITUT PENYELIDIKAN PERHUTANAN MALAYSIA
Forest Research Institute Malaysia
Kepong, 52109 Kuala Lumpur
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Ruj. Kami/*Our Ref:* FRIM 394/KH 665/3/1 Kh 3 (44) Tarikh/*Date:* 30th April 1993
Ruj. Tuan/*Your Ref:*

Timber Building Questionnaire 1

Please fill in as many sections as you can.

The Building
Building Name : ....
Address : ....
.... Postcode ....

Why should it be included ?

Historical Interest ☐ Building Form ☐
Structurally sound ☐ Aesthetic ☐
Construction ☐ Detailing ☐

Others, please specify ....

Who Owns the Building ?

Original Owner ☐ Current Owner ☐
Tenanted ☐ others, please specify ....

Additional Information ?
Is there any additional information you can supply about the building : photos, plan, literature references, etc.? Please list what you have available or know is available from others.

....
....

Your Details
Name : ....
Organisation : ....
Address : ....
....
Phone No. : (....)......................................
Fax No. : (....)......................................

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Ruj. Kami/*Our Ref:* FRIM 394/KH 665/3/1 Kh 3 (44)
Ruj. Tuan/*Your Ref:*

Tarikh/*Date:* 30th April 1993

Timber Practitioner Questionnaire 2

Please complete this section if you are a designer or you know a person who has made a major contribution to the development of timber usage in buildings, either as an architect, engineer, or builder.

Designer Name : ....

Profession : architect ☐ engineer ☐
builder ☐ others ☐

Why should it be included ?

Historical Interest ☐ Building Form ☐
Structurally sound ☐ Aesthetic ☐
Construction ☐ Detailing ☐

Others, please specify ....

Important Building Works ?
Include buildings or structures you believe of note.

Building Name : ....
Address : ....
.... Postcode : ....

Function / Usage : residential ☐ mosque ☐
warehouse ☐ palaces ☐
factory ☐ office ☐
others, please specify ....

Your Details

Name : ....
Organisation : ....
Address : ....
....

Phone No. : (....)................. Fax No.: (....).................

COMPUTERS AND TALL BUILDINGS

The Council on Tall Buildings and Urban Habitat, an international activity sponsored by engineering, architectural and planning professionals, was established to study and report on all aspects of the planning, design, construction and operation of tall buildings.

The conference on "Computers and Tall Buildings" will be held from 25 to 27 April 1994 in Bahrin. The Council is organising this conference with the objective of bringing together the various groups invovled in the design, construction and maintenance of tall buildings to realize the full potential of the advances in computer technology in all aspects of tall buildings.

The conference programme will cover computer applications as they relate to tall buildings and the urban habitat which they create, by a selection of internationala experts on computers and tall buildigns.

Subjects planned for the formal conference sessions will include:

- Integration of Design, Fabrication and Construction
- Automation in Construction and Robots
- High-Tech Buildings: Design, Operationa and management
- Knowledge Bases, Knowledge Systems
- Impact Studies (virtual reality):
  - Visual Impact, skylines, streetscapes
  - Interior design and space cognition
  - Transportation interfaces
  - Waste disposal and service systems
- The Role of the Computer in Decentralisation

<u>Call for Papers</u>

Those interested should submit an abstract of the proposed paper in English. The abstract should not exceed 250 words and should state clearly the objectives, subject matter and conclusions to be presented in the full paper.

<u>Schedule for Papers</u>

15 September 1993
Deadline for receipt of abstracts

30 September 1993
Notification of acceptance of abstracts sent to authors

31 December 1993
Deadline for submission of final papers in prescribed form

PAM TENNIS COMPETITION 1993

We are pleased to inform members that the PAM Tennis Competition 1993 will be held from 7 to 10 October 1993 at the National Tennis Centre, Jalan Duta, Kuala Lumpur.

Registration is now open and any member who is interested to participate in this year's tennis competition is to contact the PAM Secretariat for the registration form. The last date for registration is 24 September 1993.

The registration fee is RM10 per person (singles)
RM15 for a pair (doubles)

As usual, Sissons Paints (M) Sdn Bhd is the sponsor for the PAM Tennis Competition for 1993.

SURVEY ON TIMBER STRUCTURES

A survey and documentation of timber structures was carried out by the Forest Research Institute Malaysia. Its purpose is to develop an evaluative overview of timber usage and jointing in buildings in Malaysia from 1900 to the present. The first step in achieving this is to compile a list of those buildings which are regarded as important in their use of timber. Importance means that timber is used as a major structural component or as the dominant material of the buildings The findings will form a series of valuable educational and informational tools concerning the economics, technological, intellectual and cultural validity of using timber as a main stream engineering material.

A total of 936 questionnaires was sent to PAM members on 30 April 1993 but he response has been very poor. Those who have not returned the questionnaires are strongly urged to do so. If you have any queries on how to complete the questionnaire or about the research topic, please contact the following:

Mr Wong Wai Sung
Assistant Research officer
Forest Products Division
Forest Research Institute Malaysia
Kepong
521089 Kuala Lumpur
Tel: 03-6342633 Extn 463
Fax: 03-6367753

DATO' IR. LEE YEE CHEONG ELECTED CHAIRMAN OF COMMONWEALTH ENGINEERS COUNCIL

Dato' Ir. Lee Yee Cheong, Past President of the Institution of Engineers, Malaysia (IEM) has been elected Chairman of the Commonwealth Engineers Council (CEC). The CEC is the umbrella organisation for all the National Institutions of Engineers in Commonwealth Countries. He will take over from Sir Robert Telford of the Institution of Electrical Engineers, United Kingdom in the forthcoming CEC assembly in Kingston, Jamaica in November 1993. Dato' Ir. Lee, currently Executive Committee member of CEC, will be CEC Chairman for 4 years. Dato' Ir. Lee is also an Honorary Fellow of the Institution of Engineers, Malaysia, the Institution of Engineers, Australia and the Institution of Engineers, Mauritius.

The Commonwealth Engineers Council was established in 1946 by the National Institutions of Engineers in Commonwealth Countries to increase the collaboration and co-operation amongst them. The founding member countries were Britain, Australia, New Zealand, Canada, India and South Africa. Membership has since grown to 29 countries divided into seven geographic regions : Africa, Asia, Caribbean, Europe, North America, South East Asia and South Pacific.

CEC's present aims and objectives include:-

a) foster co-operation and the exchange of information among members and other cognate organisations.

b) support the development of indigenous engineering institutions in all member countries and associated states in the Commonwealth.

c) foster the education, training and professional development of engineers at all levels of professional and technical competence.

d) encourage and facilitate the transfer of technology between Commonwealth Countries.

Malaysia through the Institution of Engineers, Malaysia has been co-ordinating the CEC Continuing Engineering Education Workshop Programme under which experts from Australia, UK, Hong Kong and Trinidad had conducted or are scheduled to conduct courses in Kuala Lumpur, Kota Kinabalu, Kuching, Bandar Seri Begawan, Singapore, Hong Kong and Papua New Guinea. Two Malaysian specialist engineers recently conducted a training course on the rehabilitation of structures in Mauritius, Harare and Nairobi.

SURVEY AND DOCUMENTATION OF TIMBER STRUCTURES

A survey and documentation of timber structure was carried out by the Forest Research Institute Malaysia. Its purpose is to develop an evaluative overview of timber usage and jointing in buildings in Malaysia from 1900 to the present. The first step in achieving this is to compile a list of those building which are regarded as important in their use of timber. Importance means that timber is used as a major structural component or as the dominant material of the building. The findings will form a series of valuable educational and informational tools concerning the economics technological, intellectual and cultural validity of using timber as a main stream engineering material.

A total of 936 questionnaires was sent out on 30 of April 1993 but the response was very poor. I strongly urge those who have not returned the questionnaires, to do so as soon as possible.

If you have any queries on how to complete the questionnaires or about this survey, please contact the following:-

Mr. Wong Wai Sung
Assistant Research Officer,
Forest Products Division,
Forest Research Institute Malaysia,
Kepong,
52109 Kuala Lumpur.

Tel: 03-6342633 Extn: 463
Fax: 603-6367753

Editor's Note : Members interested in obtaining the questionnaires on this survey could also contact Mr. Wong Wai Sung at the above address.

Appendix A. 2.3 *Scheduled of Work for Site Inspection and Interviews Completed Between September 1993 and January 1994*

	Date	Site	Function	Remarks
	September 1993			
1	9/6/93	**Kim Chin Hoe Sawmill Sdn. Bhd.**	Sawmill	Measured drawings
		1 3/4 mile, Jalan Kapar, Klang,		Photographs & slides
		Selangor.		
2	9/7/93	**General Lumber Fabricators & Builders**	Sawmill	Measured drawings
		Jalan Pendamar, Pelabuhan Kelang,		Photographs & slides
		Selangor.		
3	9/8/93	**Gedong Raja Abdullah**	Tin Mine	Photographs & slides
		Kelang,	Museum	
		Selangor.		
4	9/9/93	**General Lumber (holding) Bhd.**	Sawmill	Photographs & slides
		Jalan Kapar, Klang,		
		Selangor.		
5	13/9/93	**Kayu Sedia Sdn. Bhd.**	Sawmill	Measured drawings
		Jalan Satu, Off Jalan Sungai Besi,		Photographs & slides
		Kuala Lumpur.		
6	15/9/93	**Bukit Kiara International Equestrian**	Resort	Photographs & slides
		& Country Resort, Kuala Lumpur.		
		Jalan Bukit Kiara, Off Jalan Damansara.		
		Kuala Lumpur.		
7	16/9/93	**Thean Hou Temple**	Temple	Slides
		65, Persiaran Endah, Off Jalan Syed Putra,		
		Kuala Lumpur.		
8	20/9/93	**Laminated footbridge**	Bridge	Photographs & slides
		Forest Research Institute Malaysia,		
		Selangor.		
9	20/9/93	**Fire resistant shed**	Shed	Measured drawings
		Forest Research Institute Malaysia,		Photographs & slides
		Selangor.		
10	20/9/93	**Bamboo shed**	Shed	Photographs & slides
		Forest Research Institute Malaysia,		
		Selangor.		
11	20/9/93	**Mosque FRIM**	Mosque	Photographs & slides
		Forest Research Institute Malaysia,		
		Selangor.		
12	20/9/93	**Experimental Space Frame building**	Shed	Photographs & slides
		Forest Research Institute Malaysia,		
		Selangor.		
13	20/9/93	**Prototype Low-cost Houses**	Residence	Photographs & slides
		Forest Research Institute Malaysia,		
		Selangor.		
14	21/9/93	**Shah Alam Gateway**	Gateway	Photographs
		Istana Kayangan, Shah Alam,		
		Selangor.		
15	21/9/93	**Bungalow house**	Residence	Photographs & slides
		Istana Kayangan, Shah Alam,		
		Selangor.		

16	22/9/93	**Rumah Pak Ali**	Residence	Photographs & slides
		Gombak,		
		Kuala Lumpur.		
17	23/9/93	**Stadium Shah Alam**	Stadium	Photographs & slides
		Shah Alam,		
		Selangor.		
	October 1993			
18	10/4/93	**Sentul Train Station**	Store	Photographs & slides
		Jalan Sentul,		
		Kuala Lumpur.		
19	10/5/93	**Air Keroh Mini Malaysia**	Traditional Malay Houses	Photographs & slides
		Air Keroh,		
		Melaka.		
20	10/6/93	**Ponderosa Golf and Country Resort**	Club House	Photographs
		Taman Molek, Johor Bahru,		
		Johore.		
21	10/7/93	**Johor Train Station**	Train Station	Photographs & slides
		Jalan Jim Quvee, Johor Bahru,		
		Johore.		
22	10/8/93	**Istana Leban Tunggal**	Palace	Photographs & slides
		Pekan,		
		Pahang.		
23	15/10/93	**Istana Mangga Tunggal**	Palace	Photographs
		Pekan,		
		Pahang.		
24	15/10/93	**Rumah Kelahiran Tun Abdul Razak**	Residence	Photographs & slides
		Kampung Pulau Keladi,		
		Pahang.		
25	15/10/93	**ASPA Mosque**	Mosque	Photographs & slides
		Pekan,		
		Pahang.		
26	16/10/93	**Hyatt Kuantan**	Resort	Photographs & slides
		Telok Chempedak, Kuantan,		
		Pahang.		
27	18/10/93	**Mediterranean Club**	Resort	Photographs & slides
		29 Miles North, Jalan Kemaman, Kuantan,		
		Pahang.		
28	19/10/93	**Istana Tele**	Palace	Photographs & slides
		Losong, Kuala Terengganu,		
		Terengganu.		
29	19/10/93	**Muzium Negeri Terengganu**	Museum	Photographs & slides
		Losong, Kuala Terengganu,		
		Terengganu.		
30	19/10/93	**Istana Tengku Long**	Palace	Photographs & slides
		Losong, Kuala Terengganu,		
		Terengganu.		
31	19/10/93	**Rumah Bujang**	Residence	Photographs & slides
		Losong, Kuala Terengganu,		
		Terengganu.		

32	19/10/93	**Rumah Tenun Sutera**	Museum	Photographs
		Losong, Kuala Terengganu,		
		Terengganu.		
33	20/10/93	**Tanjung Jara Beach Hotel**	Resort	Photographs & slides
		8th Miles of Dungun, Dungun,		
		Trengganu.		
34	19/10/93	**Rantau Abang**	Resort	Photographs & slides
		Dungun,		
		Trengganu..		
35	20/10/93	**Terengganu Market**	Market	Photographs
		Trengganu.		
36	21/10/93	**Muzium Sultan Abu Bakar**	Museum	Photographs & slides
		Jalan Sultan Ahmad, Pekan,		
		Pahang.		
37	21/10/93	**Rumah Kerabat Diraja**	Residence	Photographs
		Jalan Sultan Ahmad, Pekan,		
		Pahang.		
38	21/10/93	**Rumah Rakit**	Residence	Photographs & slides
		Jerantut,		
		Pahang.		
39	21/10/93	**Mat Kilau Mosque**	Mosque	Photographs & slides
		Kampung Tawau, Jerantut,		
		Pahang.		
40	22/10/93	**Chief Rest House**	Rest House	Photographs & slides
		Pekan,		
		Pahang.		
41	23/10/93	**Pahang Club House**	Club House	Photographs & slides
		Kuala Lipis,		
		Pahang.		
42	23/10/93	**Kuala Lipis Bus stop**	Shed	Photographs & slides
		Kuala Lipis,		
		Pahang.		
43	23/10/93	**Traditional Kelantan house**	Residence	Slides
		Pekan,		
		Pahang.		
44	24/10/93	**Stadium MCA, Raub**	Basketball	Measured drawings
		Raub,	Court	Photographs & slides
		Pahang.		
45	27/10/93	**Awana Golf Course & Country Club**	Club House	Photographs & slides
		Genting Highland,		
		Pahang.		
	November 1993			
46	11/3/93	**Istana Jahar**	Museum	Photographs & slides
		Muzium Negeri Kelantan, Kota Bahru,		
		Kelantan.		
47	11/4/93	**Ship Yard**	Ship	Photographs & slides
		Tumpat, Kota Bahru,		
		Kelantan.		

48	11/3/93	**Sekolah Tadika**	School	Photographs & slides
		Jalan Pos Office Lama, Kota Bahru,		
		Kelantan.		
49	11/5/93	**Masjid Tua Kampong Laut**	Museum	Photographs & slides
		Nilam Puri, Kota Bahru,		
		Kelantan.		
50	11/8/93	**Istana Balai Besar**	Palace	Photographs & slides
		Kota Bahru,		
		Kelantan.		
51	11/10/93	**Impiana Resort**	Resort	Photographs & slides
		32km, Jalan Kuantan-Kemaman, Kuantan,		
		Pahang.		
52	11/10/93	**Road Sign Board**	Sign Board	Photographs
		Terengganu.		
53	17/11/93	**Bengkel Kejuruteraan Hospital Besar Ipoh**	Workshop	Photographs & slides
		Ipoh,	Office	
		Perak.		
54	17/11/93	**Timber shed**	Shed	Photographs
		Pengkalan Pegoh, Ipoh,	Office	
		Perak.		
55	17/11/93	**Muzium Darul Ridzuan**	Museum	Photographs & slides
		Jalan Panglima Bukit Gantang, Ipoh,		
		Perak.		
56	17/11/93	**Pejabat Daerah Negeri Perak**	Office	Photographs & slides
		Jalan Panglima Bukit Gantang, Ipoh,		
		Perak.		
57	18/11/93	**Istana Kenanga**	Palace	Photographs & slides
		Bukit Chandan, Kuala Kangsar,		
		Perak.		
58	18/11/93	**Rumah Baitul Rahmah**	House	Photographs & slides
		Bukit Chandan, Kuala Kangsar,		
		Perak.		
59	19/11/93	**Bangunan Stesyen Keretapi Taiping**	Shed	Photographs & slides
		Jalan Stesyen, Taiping,		
		Perak.		
60	19/11/93	**Bangunan Majlis Perbandaran Taiping**	Office	Photographs & slides
		Jalan Stesyen, Taiping,		
		Perak.		
61	19/11/93	**Bangunan Pejabat Pos**	Office	Photographs & slides
		Jalan Kota, Taiping,		
		Perak.		
62	19/11/93	**Bangunan Masjid Lama Bandar Taiping**	Mosque	Photographs & slides
		Jalan Kota, Taiping,		
		Perak.		
63	19/11/93	**Bangunan Rumah Rehat Bandar**	Rest House	Photographs & slides
		Jalan Stesyen, Taiping,		
		Perak.		

64	19/11/93	**Bangunan Kompleks Sejarah Perak**	Museum	Photographs & slides
		(Rumah Ngah Ibrahim) Matang,		
		Perak.		
65	19/11/93	**Bangunan Masjid Tengku Menteri**	Mosque	Photographs & slides
		Matang,		
		Perak.		
66	19/11/93	**Bangunan Balai Penghulu**	Office /	Photographs & slides
		Matang,	Residence	
		Perak.		
67	19/11/93	**Bangunan Tokong China**	Temple	Photographs & slides
		Matang,		
		Perak.		
68	19/11/93	**Muzium Negeri Perak**	Museum	Photographs & slides
		Jalan Taming Sari, Taiping,		
		Perak.		
69	19/11/93	**Peking Hotel**	Hotel	Photographs & slides
		Taiping,		
		Perak.		
70	20/11/93	**Food Stall**	Shed	Photographs & slides
		Jalan Leboh Light,		
		Pulau Pinang.		
71	20/11/93	**Snake Temple**	Temple	Photographs & slides
		Jalan Gelugor,		
		Pulau Pinang.		
72	21/11/93	**Kek Lok See Temple**	Temple	Photographs & slides
		Air Itam,		
		Pulau Pinang.		
73	21/11/93	**Shophouses**	Shophouses	Slides
		Jalan Barakabh,		
		Pulau Pinang.		
74	21/11/93	**Shophouses**	Shophouses	Slides
		Jalan Maxwell,		
		Pulau Pinang.		
75	21/11/93	**Shophouses**	Shophouses	Slides
		Lebuh Melayu,		
		Pulau Pinang.		
76	21/11/93	**Shophouses**	Shophouses	Slides
		Kampung Java Melayu,		
		Pulau Pinang.		
77	21/11/93	**Shophouses**	Shophouses	Slides
		Lorong Macalister,		
		Pulau Pinang.		
78	21/11/93	**Shophouses**	Shophouses	Slides
		Jalan Irving,		
		Pulau Pinang.		
79	21/11/93	**Shophouses**	Shophouses	Slides
		Jalan Seang Teak,		
		Pulau Pinang.		

80	22/11/93	**Shophouses**	Godown	Slides
		Lebuh Pantai,		
		Pulau Pinang.		
81	22/11/93	**Khoo Kongsi**	Temple	Photographs & slides
		Jalan Acheh,		
		Pulau Pinang.		
82	22/11/93	**V.T.M. Chettiers Temple**	Temple	Photographs & slides
		Balik Pulau,		
		Pulau Pinang.		
83	22/11/93	**Tomb**	Shed	Photographs
		Jalan Acheh,		
		Pulau Pinang.		
84	22/11/93	**Shophouses**	Shophouses	Slides
		Jalan Melaka,		
		Pulau Pinang.		
85	23/11/93	**Ban Guan Thye Sawmill Sdn. Bhd.**	Sawmill	Photographs & slides
		Sungai Puyu, Seberang Perai,		
		Pulau Pinang.		
86	25/11/93	**Banding Island Resort**	Resort	Photographs & slides
		Lake Temengor, Grik,		
		Perak.		
87	26/11/93	**Masjid Kampung Paloh**	Mosque	Photographs & slides
		Jalan Datoh, Ipoh,		
		Perak.		
88	26/11/93	**Muzium Kampong Pasir Salak**	Museum	Photographs & slides
		Pasir Salak		
		Perak.		
89	27/11/93	**Majistret Court**	Office	Photographs & slides
		Jalan Mahkamah, Teluk Intan,		
		Perak.		
90	28/11/93	**Teluk Intan Clock Tower**	Clock Tower	Photographs & slides
		Teluk Intan,		
		Perak.		
	December 1993			
91	13/12/93	**Lembaga Muzium Negeri Sembilan**	Museum	Photographs & slides
		Jalan Sungai Ujung, Seremban,		
		Negeri Sembilan.		
92	13/12/93	**Minangkabau House**	Museum	Photographs & slides
		Jalan Sungai Ujung, Seremban,		
		Negeri Sembilan.		
93	13/12/93	**Istana Ampang Tinggi**	Museum	Photographs & slides
		Jalan Sungai Ujung, Seremban,		
		Negeri Sembilan.		
94	13/12/93	**Istana Sri Menanti**	Royal	Photographs & slides
		Sri Menanti,	Museum	
		Negeri Sembilan.		
95	14/12/93	**Gelanggang Gasing**	Indoor Court	Photographs & slides
		Jalan Sungai Ujung, Seremban,		
		Negeri Sembilan.		

96	14/12/93	**Air Keroh Information Centre**	Office	Photographs & slides
		Air Keroh,		
		Melaka.		
97	14/12/93	**Air Keroh Country Resort**	Resort	Photographs & slides
		Air Keroh,		
		Melaka.		
98	15/12/93	**Memorial Pengistiharan Kemerdekaan**	Museum	Photographs & slides
		Kompleks Istana, Jalan Kota,		
		Melaka.		
99	15/12/93	**Rumah TYT Yang Dipertua Negeri Melaka**	Residence	Photographs & slides
		Kompleks Istana, Jalan Kota,		
		Melaka.		
100	15/12/93	**Christ Church**	Church	Photographs & slides
		Jalan Gereja,		
		Melaka.		
101	15/12/93	**Chinese Temple**	Temple	Photographs & slides
		Jalan Laksamana Cheng Ho,		
		Melaka.		
102	16/12/93	**Bangunan Stadthuys**	Museum	Photographs & slides
		Kompleks Istana, Jalan Kota,		
		Melaka.		
103	16/12/93	**Muzium Sastera**	Museum	Photographs & slides
		Kompleks Istana, Jalan Kota,		
		Melaka.		
104	16/12/93	**Muzium Budaya**	Museum	Photographs & slides
		Jalan Istana,		
		Melaka.		
105	16/12/93	**Jabatan Bekalan Air**	Museum	Photographs
		Kompleks Istana, Jalan Kota,		
		Melaka.		
106	16/12/93	**A Formosa**	Gateway	Photographs & slides
		Jalan Istana,		
		Melaka.		
107	16/12/93	**St. Paul's Hill**	Church	Photographs & slides
		Jalan Istana,		
		Melaka.		
108	16/12/93	**Muzium Belia Malaysia**	Museum	Photographs
		Jalan Istana,		
		Melaka.		
109	16/12/93	**Timber Ship**	Shipyard	Photographs & slides
		Melaka.		
110	17/12/93	**Majlis Daerah Alor Gajah**	Office	Photographs & slides
		Alor Gajah,		
		Melaka.		
111	17/12/93	**Muzium Jasin**	Museum	Photographs & slides
		Jasin,		
		Melaka.		

112	17/12/93	**Rumah Penghulu Mohd. Natar**	Residence	Photographs & slides
		Batu 14 1/2, Merlimau,		
		Melaka.		
113	18/12/93	**Masjid Kampung Hulu**	Mosque	Photographs & slides
		Jalan Kampong Hulu,		
		Melaka.		
114	18/12/93	**Masjid Kampung Kling**	Mosque	Photographs & slides
		Jalan Hang Lekiu,		
		Melaka.		
115	18/12/93	**Masjid Tengkera**	Mosque	Photographs & slides
		Jalan Tengkera,		
		Melaka.		
116	18/12/93	**Cheng Hoon Teng Temple**	Temple	Photographs & slides
		Jalan Tokong,		
		Melaka.		
117	19/12/93	**Masjid Peringgit**	Mosque	Photographs & slides
		Jalan Peringgit,		
		Melaka.		
118	18/12/93	**Masjid Jamik Duyung Melaka**	Mosque	Photographs & slides
		Duyung,		
		Melaka.		
119	18/12/93	**Mahkamah Majistret Melaka**	Court	Photographs & slides
		Jalan Kota,	House	
		Melaka.		
120	19/12/93	**Majlis Agama Jasin**	Office	Photographs
		Jasin,	House	
		Melaka.		
121	24/12/93	**Masjid Jamik Lama Air Baloi**	Mosque	Photographs & slides
		Air Baloi, Pontian,		
		Melaka.		
122	24/12/93	**Masjid Jamik Baru Air Baloi**	Mosque	Photographs & slides
		Air Baloi, Pontian,		
		Melaka.		
123	25/12/93	**Masjid Parit Bakar**	Mosque	Photographs & slides
		Jalan Abdul Rahman, Muar,		
		Melaka.		
124	25/12/93	**Rumah Daeng Mat Diew**	Residence	Photographs & slides
		Kampung Parit Pecah, Muar,		
		Melaka.		
125	26/12/93	**Shophouses**	Shophouses	Photographs & slides
		Jalan Tun Tan Cheng Lok,		
		Melaka.		
126	26/12/93	**Multi-purpose Hall**	Shed	Photographs & slides
		Muar,		
		Melaka		
127	26/12/93	**Muzium Daerah Alor Gajah**	Museum	Photographs & slides
		Alor Gajah,		
		Melaka.		
		Negeri Sembilan.		

128	26/12/93	**Hulu Bendul Stall** Hulu Bendul, Negeri Sembilan.	Restaurant	Photographs & slides
	January 1994			
129	1/11/94	**Hospital Daerah Kuala Nerang** Kuala Nerang, Kedah.	Hospital	Photographs & slides
130	1/11/94	**Makam Di Raja Kedah** Alor Setar, Kedah.	Pavilion	Photographs & slides
131	1/12/94	**Kee Leong Sawmill (Sdn.) Berhad** Sungai Ketapan, Gurun, Kedah.	Sawmill	Photographs & slides
132	1/12/94	**Istana Balai Besar** Lebuhraya Darulaman, Bakar Bata, Alor Setar, Kedah.	Museum	Photographs & slides
133	13/1/94	**Delima Resort Langkawi** Kuala Muda, Pulau Langkawi, Kedah.	Resort	Photographs & slides
134	14/1/94	**Sheraton Langkawi Resort** Teluk Nibong, Pulau Langkawi, Kedah.	Resort	Photographs & slides
135	14/1/94	**Pelangi Beach Resort** Pantai Cenang, Pulau Langkawi, Kedah.	Resort	Photographs & slides
136	15/1/94	**The Datai Langkawi** Jalan Teluk Datai, Pulau Langkawi, Kedah.	Resort	Photographs & slides
137	15/1/94	**Langkawi Island Resort** Pulau Langkawi, Kedah.	Resort	Photographs & slides
138	15/1/94	**Berjaya Langkawi Beach Resort** Teluk Burau, Pulau Langkawi, Kedah.	Resort	Photographs & slides
139	17/1/94	**Traditional Melaka House** Forest Research Institute Malaysia, Selangor.	Museum	Photographs & slides
140	17/1/94	**Traditional Terengganu House** Forest Research Institute Malaysia, Selangor.	Museum	Photographs & slides
141	17/1/94	**Glued Lamination Shed** Forest Research Institute Malaysia, Selangor.	Shed	Photographs & slides
142	17/1/94	**Sawmill Shed** Forest Research Institute Malaysia, Selangor.	Shed	Photographs & slides

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List of Collection of Measured Drawings

- "Air Keroh Information Centre", Air Keroh, Malacca.
- Fire Resistant Shed, Forest Research Institute Malaysia, Selangor.
- Forest Research Institute's Mosque, Kepong, Selangor.
- "Gedong Raja Abdullah", Kelang, Selangor.
- General Lumber (Holdings) Bhd., Kelang, Selangor.
- General Lumber Fabricators & Builders, Kelang, Selangor.
- "Istana Ampang Tinggi", Seremban, Negeri Sembilan.
- "Istana Balai Besar", Kota Bahru, Kelantan.
- "Istana Besar Tengku Long", Losong, Kuala Terengganu, Terengganu.
- "Istana Jahar", Kota Bahru, Kelantan.
- "Istana Leban Tunggal", Pekan, Pahang.
- "Istana Seri Menanti", Seri Menanti, Negeri Sembilan.
- Kayu Sedia Sdn. Bhd., Off Jalan Sungai Besi, Kuala Lumpur.
- Kim Chin Hoe Sawmill Sdn. Bhd., Jalan Kapar, Kelang, Selangor.
- "Kuil Cina Cheah Kongsi", Penang.
- "Madrasah dan Rumah Tok Janggut", Langgar, Alor Setar.
- "Masjid Kampung Keling", Malacca.
- "Masjid Tengkera", Malacca.
- "Masjid Tua Kampung Laut", Kota Bahru, Kelantan.
- Mediterranean Club, Kuantan, Pahang.
- "Memorial Pengistiharan Kemerdekaan", Kompleks Istana. Jalan Kota, Malacca.
- "Pejabat Agama Islam dan Mahkamah Kadi", Malacca.
- "Pelangi Beach Resort", Pantai Cenang, Pulau Langkawi, Kedah.
- "Rumah Daeng Mat Diew", Parit Pecah, Johore.
- "Rumah Haji Su", Kampong Losong Haji Su, Kuala Terengganu
- "Rumah Pak Ali", Sabak Bernam, Selangor.
- "Rumah Penghulu Mohamed Natar", Merlimau, Malacca.
- "Rumah Tele", Loosing, Kuala Terengganu.
- Space Frame Structure, Forest Research Institute Malaysia, Kepong, Selangor.
- Stadium M.C.A, Raub Pahang.
- "Teluk Intan Clock Tower", Teluk Intan, Perak.
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Glossary

Attap : palm leaf thatch, using fronds from the nipah in particular, although other local palm leaf is also used in Malaysia; also, a building covered with such thatch.
Baji : wedges used to tighten the mortise and tenon joints of the Malay house.
Balai : the eastern portion of the "ibu rumah"..
Bamboo (buluh) : a quick growing reed whose strong stems reach lengths of over 12.0 metres; useful in construction, although it cannot be nailed or pegged. Commonly used for the walls of traditional Malay houses.
Batak : indigenous people of North Sumatra, particularly of the Lake Toba region.
Bendul : the beam at the threshold of a Malay house.
Bolt : a fastener consisting of a cylindrical metal body with a head at one end and a helical thread at the other, intended to be inserted through holes in adjoining pieces of material and closed with a threaded nut.
Bowstring or Belfast truss : the truss consists of a system of lattices fixed between lower horizontal members and curved top members in the form of a bow.
Brace, bracing : a secondary structural element or set of elements, usually placed diagonally between primary elements, serving to maintain the total configuration of the primary elements in the face of secondary lateral loads or disturbances and thereby stiffening and strengthening the structure as a whole.
Capitan China : the leader of the Chinese community in each settlement in Malaysia, particularly in Malacca.
Chengal : known as "Neobalanocarpus hemii"; a fine quality timber for common rafters, joists, flooring, shipbuilding and barrel construction. Also known locally in Malaysia as "Luis", "Selangan" or "Gagil".
Cross-beam : the main beam which runs the length of a Chinese roof as a structural support, held by corbel brackets (tou kung).
Depa : the measurement between the tips of the fingers of the outstretched arms.
Dou gong (tou kung) : a cantilevered support which rests upon the head of a column, and supports cross-beams through a system of corbelled brackets. The dou (tou) is the base, often with notches into which the lowest gong (kung) are fitted.
Dovetailed joint : a joint in which two pieces meet at an angle and are joined by pins and sockets in the shape of a dove's tail.
Eaves corner : the junction of eaves from two adjacent sides of a Chinese building forming a ridge which is often accentuated and moulded into carving projection; a dominant motif in Southern Chinese architectural practice.
Frame : the most general term for an open assembly of interconnected linear or planar structural elements designed to serve a primary load-bearing function. In a building, it is usually clothed or in-filled to some extent by secondary elements that play little or no part in the primary structural action but may give useful added stiffness.
Gelegar : the main floor girders of a Malay house.
Giruf : a roof pitched or inclined at more than 45 degrees on a Malay house.
Glued laminated timber : a timber made up of a large number of small strips of wood glued together.
Half-timbering : a method of construction where walls are built of timber framework, with the intervening spaces being filled in by plaster, brickwork, or wattle and daub; also known as "timber framing".
Hanging beam : a beam placed on edge over ceiling joists to prevent them sagging over long spans
Hasta : the measurement between the tip of the second finger and the outside joint of the elbow.
Iban : the Iban trace their origins to the Kapus Lake Region of Kalimantan. Iban settlements are still predominantly in the forms of long house.
Ibu rumah : the central portion of a Malay house, often being divided into sections
Jack roof : an elevated gabled or pyramidal roof segment, sheltering a clerestory opening which separates it from the main roof.

Jengkal : the measurement between the tip of the thumb and the tip of the second finger.

Joist : one of a series of parallel beams used to support floor or ceiling loads, supported in turn by bigger beams, girders or bearing walls.

Kampung : a village of Malay settlement.

Kasau betina : the subsidiary roof rafters at the eave end of the thatched roof of a Malay house.

Kasau jantan : the main roof rafters supporting purlins in a Malay house roof.

King post : the central vertical member of a roof truss, that which extends from the centre of the tie beam to the apex of the roof to support the ridge.

Lantern beam : a horizontal tie-beam connecting two pillars near their tops, forming a bay as part of the facade of a Chinese temple.

Meranti : a dipterocarpacaea wood of the genus Pentacme, commercially called "White Lauan", and also known locally known as "Seraya". An excellent wood for cabinetry, construction, and flooring. Also another genus, Shore, commercially known as Red Meranti, is used for beams, joists, flooring, and square lumber.

Merbau : a non-dipterocarpacaea wood of the genus Intsia, also locally known as "Ipil" and "Kwila", which is suitable for heavy construction, panelling, and cabinetry.

Meru : sacred structure in Hindu-Javanese temple, characterised by its multi-layered roof.

Minangkabau : indigenous people of central West Sumatra, a dominant cultural influence among the Malays of Malacca.

Module : a measure of proportion adopted for an individual building on which all other dimension are based; also more generally a standard basic unit of measurement.

Mortise and tenon joint : a traditional joint formed by a rectangular slot (mortise) into which a tongue (tenon) from another piece fits.

Nipah : a variety of creeping palm (Nipa fruiticans) whose fronds are used as thatch; also, the thatch made from such palms.

Notching : the joint formed where two pieces cross, by cutting a piece out of timber to fit over another piece.

Pagoda : a circular or octagonal structure built to preserve relics, commemorate unusual acts of devotion, act as an omen of good geomantic conditions, or as an observation tower. Usually built of an odd number of storeys.

Penang Kongsi : a type of Chinese clan temple unique to Penang Island, distinguished by a projecting elevated front porch and construction on pillars so that the main worship area is a storey above the ground level. Additionally, these clan temples exclusively employ the Minnan style of roof tops with large coping ends.

Purlin : a horizontal beam spanning the principal rafters in a roof to carry the roof covering, usually via secondary rafters.

Queen post : one of a pair of upright supporting posts set vertically between the rafters and the tie-beam, or between one tie-beam and a longer one which supports it.

Rafter : one of the inclined beams of a pitched roof that meet along the ridge and directly or indirectly carry the roof covering. Principal rafters receive no intermediate support. Secondary rafters receive intermediate support from purlins carried by the principal rafters.

Rasuk : a transverse cross-beam attached to the upright pillars of a Malay house, supporting the elevated floor.

Serambi : a verandah or shaded porch of a Malay house, usually on the northern side of the building.

Shear connector : a mechanical dowel-like interconnection, usually between a flange of a steel beam and a reinforced-concrete slab, to hold two structural elements or parts of an element together and in particular, to prevent or limit relative slip at their interface.

Stiffener : a rib-like projection from a thin structural member loaded in compression (either simple compression or that arising from bending or shear) and particularly from a steel plate forming part of a large beam or column, to increase the stiffness in bending and thereby prevent a buckling failure.

Structural component : a full unit of construction, which may be as small as a brick or bolt, or as large as a prefabricated section of a large steel beam or a precast concrete wall or slab. Thus it may be a sufficient structural element, or it may serve only as part of such an element. It is identified essentially in terms of the construction or fabrication process rather than the structural role.

Structural element : a basic unit of construction capable of carrying its self-weight and other loads to its support. Frames, grids, and trusses designed to act in analogous ways to some of these simpler elements may themselves also be regarded as elements. Alternatively their constituent beams, columns, struts, or ties should be so regarded.

Structural form : a term used here to denote both the external geometric configuration of a structure or structural element, its ability to carry loads and withstand deformation, and its intended role in so doing.

Structure : a system of structural elements. Commonly, in the case of a building or bridge, the complete system that plays the primary load-bearing system role as distinct from in filling, finishes, etc., that can be removed without significant loss of overall stiffness, strength, or stability.

Tanjak langit : the king post or central ridge support in a Malay house.

Tiang seri : the main column which is located in the main part of a Malay house. It is the first column to be raised in the erection of the house and it is erected with a religious ritual.

Tie beam : a horizontal beam that connects the rafters in a roof, usually rests upon the queen post or cross beams in a Chinese beam-frame roof system.

Wall plate : the principal beam of a timber frame wall, which supports the roof truss or the joists for an upper storey.

Wedge : a fixing piece. A small tapered piece of timber used for exerting pressure.