**Combinations of Building Construction Material for Residential Building**

**for The Global Warming Mitigation for Malaysia**

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**Abstract**

Global warming mitigation is used as a key to devise built environment strategies and sustainable policies in developed countries that aim to reduce the rate of carbon emissions. The goal of this research is to mitigate global warming from building construction by suggesting an alternative building scheme for Malaysia. A problem related to the building industry is releasing carbon dioxide emission. Use of timber for construction has less impact on the environment due to less carbon dioxide emissions, thus making wood the best material for wall construction. However, as the Malaysian climate is hot and humid, wood encounters many defects and deteriorates. Presently, most buildings in Malaysia are built from other materials such as concrete or brick. In the last 40 years, wood materials in building schemes in Malaysia have dropped from 60% to almost 5%. This research proposed a new approach to minimize the effect of CO2 emission for buildings as well as to improve their structural stability for a longer lifespan because these would encourage the Malaysian construction industry to use wood components in their building schemes. In this study, SIMAPRO Software was used to assess CO2 emissions caused by seven different types of building schemes in wall constructions. The results from a simulation of three time frames of twenty, one hundred and five hundred years showed that timber scheme is the best choice for construction. To promote the use of timber, a new building scheme that would solve the problem of timber wood structure in Malaysia were proposed. The alternative building scheme has combined precast concrete and timber (H8) to improve the timber scheme deficiency while releasing less CO2 emissions compared to other systems. Therefore (H8) could replace current building schemes. This research can facilitate decision-maker to choose the most flexible scheme for Malaysian housing. Thus, this system could be positively and widely used in the Malaysian construction industry.

Keyword: building materials defect; environmental impact; climate change; Sustainability; Life cycle assessment

1. **Introduction**

Building construction has a vast impact on the environment and more importantly buildings are responsible for producing a large portion of carbon dioxide emissions (Keysar and Pierce 2007). Climate change mitigation of building construction or improvement in the building construction process will lead to extensive benefits of social, financial, economic, and environmental (Wang et al 2005). To obtain such benefits it is not merely necessary to choose wisely the appropriate strategies or technologies, but the right materials for the local (Moeck and Yoon 2004). Most barriers to building material selection have been addressed with the support of analytical tools such as multi-objective optimization (Sirisalee et al 2004).

Since 1958 the Keeling Curve has been used to measure carbon dioxide gas in the atmosphere generated by human activity and the result shows that CO2 has been increasing steadily in recent years. Recent research about climate change has estimated that CO2 level will increase by as much as 415 PPM during the Pliocene. If CO2 levels reach 415 ppm in atmosphere, average global temperatures will rise by 3 or 4 C° and by about 10 C° warmer at the poles. Consequently sea level ranged to 10 to 40 beats higher than where they are today (Keeling\_Curve 2013).

Malaysia is one of the highest CO2 emission producers in the world (Jan Burck et al, 2014). Malaysia is ranked in the category of “in trouble” in terms of the ability to control carbon dioxide in the climate change performance index (CCPI). Malaysia has been rated as in “very poor” condition ranking 51st of 61 countries. Hence, Malaysia is one of the poorest countries in controlling CO2 emission. On the other hand construction and manufacturing is one of the fundamental keys to control and decrease CO2 emissions. Therefore, this study can account for a reduction of these emissions by a focus on controlling building emissions. The goal of this research is proposing a new strategy for Malaysian construction to improve their ranking on CCPI by eliminating CO2 emitted from the building sector.

There are plenty of studies that have compared alternative building materials and their effect on the environment. Monteiro et al (2012) assessed seven different wall schemes and result reveal that timber wall is most preferable scheme due to less release of CO2 emission. The problem associated with Malaysian construction is that almost new projects and buildings have been built with brick and concrete (Housing and Population Census Malaysia, 2010). The rete of natural resource consumption in Malaysia is amongst the highest in the region and the world and one sector that appear to corporate this challenge is the building sector. Building construction and material consumption in this sector contribute significantly to carbon dioxide emissions. Therefore, need for better designs that reduce the overall contribution of the sector to climate change.

In 2009, Prime Minister of Malaysia, Datuk Seri Najib Razak announced that Malaysia would cut 40 per cent of the carbon emission intensity by 2020, based on 2005 carbon emissions levels. However, the CCPI ranking (Jan Burck et al, 2014) has shown there has been no improvement since 2005 and in fact Malaysia’s ranking dropped slightly from 52nd in 2009 to 55th in 2013. While all the previous research has shown that wood is the best component for house scheme as it has less effect on climate change, why does new construction building trend in Malaysia not use timber material and the wood scheme in their own construction?

Malaysia Carbon Dioxide Emissions are at a current level of 218.76M (2012), up from 215.52M (2011) one year ago, a change of 1.50% (Malaysia Carbon Dioxide Emissions Historical Data). Results show an increasing trend every year in Malaysia despite attempts to decrease CO2 emission (Levine et al, 2007).

Choice of appropriate material for building scheme is constantly a critical decision. This research assesses the current building schemes in Malaysia; meanwhile shows what is the problem of current construction that stops built the timber frame in Malaysia. The solution can help decision makers with the selection of an appropriate combination of materials aimed to decrease climate change.

1. **Literature review**

Many studies have focused on building material and their effect on the environment. For example, a study has been conducted by Cole and Kernan (1999) on office building in Canada that constructed by different frames namely: wood, steel, or concrete structural frame. The result indicated that the manufacturing and production of concrete frame used more energy than production of steel and wood frames about 6% and 14%.therefore, wood has nominated as less energy needs for production. Meanwhile wood has a less carbon emission compare to other building material choice. Koch (1992) study about carbon emission of structural wood, steel, aluminum, concrete and brick. The result reveals that the net CO2 emission in wood structure has less effect and emission to environment.

Ku¨nniger and Richter (1995) assessed three different materials namely: concrete, wood and steel. The result shows that wood have lower environmental impact consequently lower GHG emission, than the other materials. Another study about net GHG has accomplished by Scharai-Rad and Welling (2002). Scharai-Rad assessed the single-family house that made with wood or brick. Result reveals that net GHG emission decreased as the volume of recovered wood increased. Petersen and Solberg (2002, 2003 and 2004) assessed the applying of wood components instead of non-wood components in Norway and the result shows wood has release much lower GHG emission than non-wood components in buildings. Gustavsson and Sathre (2006) studied the CO2 emission of buildings with wood and concrete frames. The study found that wood-framed buildings had lower energy and CO2 balances than concrete-framed buildings.

Some study has assessed the environmental impact of a single building material on the environment. Keoleian et al (2001) assessed the LC energy, greenhouse gas (GHG) emissions, and costs of a single-family house in Michigan to discover opportunities for conserving energy throughout the whole phase of the life cycle of residential building.

Other studies have compared alternative building materials and their effect on the environment. Monteiro et al. (2012) characterized the main LC processes assessing seven alternative exterior walls to identify environmentally preferable solutions. Monteiro et al (2012) studied a Portuguese single-family house and compared three different life cycle impact assessment methods. Thus, the result of this study indicated that wood-wall is the preferable solution. Peuportier et al (2011) accomplished a life cycle assessment study for three different houses namely: concrete blocks, house with a solar heating system and high-insulated wood house. The result shows that wood high-insulated house mainly had the lowest impacts, holding about half of the concrete house. Ortiz, O et al (2010) assessed the exterior and interior wall scenarios of typical block to evaluate environmental impacts during the construction phase. The CML LCIA method had been chosen to assess the GWP (global warming potential, acidification, and ionizing radiation). The result revealed that with regard to the environmental impact of global warming potential (GWP), 85% of energy is consumed during the fabrication of material while the rest was due to the energy consumed (8%), transport (6%) and waste management (1%).

Although in previous studies wood structures have been nominated as most environmentally friendly products for buildings because of zero carbon, thermal efficiency, speed of construction and design flexibility, timber houses in Malaysia are considered a forgettable house scheme. There are so many building companies and house-makers that prefer to use an alternative material for housing than timber as timber performs poorly in the humid weather in Malaysia. The report from Housing and Population Census 1970 in Peninsular Malaysia shows that timber had been used more extensively in building construction in Malaysia. However, since the 1970s, it has been replaced by concrete, brick and block. Other research had reported on the defects of timber housing or the negative impact on the environment such as humidity on timber components. Many studies have assessed construction material and their related environmental impact of nature, but few studies have been able to suggest a new approach that can improve the effect of construction to the environment.

1. **Life Cycle Inventory for a Single Family House**

This research represents a life cycle assessment study for a Malaysian single-family unit and compares seven different building scheme material (H1 to H7) solutions aimed at identifying less CO2 emission scheme. In addition to being focused on GHG this study will represent an alternative scheme to improve global warming mitigation to Malaysian building industry. In this study, the main life cycle processes affected by the building scheme (interior and exterior walls) such as material production in manufacturing, transport and maintenance have been characterized in terms of energy and greenhouse gas effect. Meanwhile, other activities for the energy requirement of other operation-phase activities such as lighting, cooking, electric appliances, and domestic hot water have not included since it is not affected by the exterior wall and building scheme (Helena Monteiro et al 2012).

The different scheme was assessed using the Simapro 7.3.3 Software based on a architecture model as shown in figure 1 that representing different schemes and materials (precast, block work, etc.) of single family house located in Johor, in the south of Malaysia, with an expected life span of 50 years and 75 m2 of living area. The house construction phase includes extracting raw materials, manufacturing, transportation and erection. The building materials have been accounted for in terms of mass of the various building components which are described in Table 1.



Fig. 1. Schematic model of the single family house. A) With roof, B) interior and exterior walls

In this research, IPCC (The Intergovernmental Panel on Climate Change) GWP (global warming potential) has been chosen for life cycle impact assessment. LCA results are presented in the form of aggregation of environmental loads or impacts related to the functional unit without considering their distribution in time and space (Jonsson A., 2000). The Intergovernmental Panel on Climate Change (IPCC) provides the generally accepted values for GWP (global warming potential), which changed slightly between 1996 and 2001. The time frame has been chosen for long periods (up to 500 years) because the effect on the atmosphere will not be disappearing in a short time.

To evaluate and present the environmental impact of building scheme, a functional unit has to be chosen. According to ISO 14040, functional unit is a reference unit used to quantify the system performance in LCA techniques (Ardente et al., 2008). It is provided to relate the inputs and outputs of a system. There are several functional units to choose in LCA of a building. In the present study, the functional unit “m2 of wall area” was chosen. The usable wall area is defined as the wall area in the bedroom, kitchen and dining room. Selecting the related functional unit basically depended on the goal of LCA study. For instance, when attempting to compare the material of exterior and interior wall product use of traditional and local material versus prefabricated concrete, the following functional unit is 1 m2. The functional unit for the LCI was limited to material building components.

**Table 1 Description of base-case building components.**

|  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- |
| Buildings components | **H** | **Area**  **(m2)** | **Material layers** | **Thickness (m)** | **Weight** | **Total weight (kg)** |
| Timber house | H7 | 168 | Wood | 0.12 | 146(kg/m2) | 24528 |
| screw |  | 10(kg/m2) | 40 |
| Brick | H3 | 168 | Brick | 0.100 | 1,920 (kg/m3) | 46500 |
| mortar |  |  | 1674 |
| Timber & brick | H6 | 168 | Timber | 0.12 |  | 15468 |
| brick | 0.100 |  | 15048 |
| screw |  |  | 26.4 |
| mortar |  |  | 552.4 |
| Brick & concrete | H2 | 168 | Brick | 0.100 |  | 23250 |
| concrete |  |  | 5487 |
| mortar |  |  | 837 |
| Precast concrete | H4 | 168 | Concrete | 0.100 | 343(kg/m2) | 57624 |
| Steel stud | H5 | 168 | Steel stud |  |  | 4650 |
| wool |  |  | 2715 |
| screw |  |  | 15 |
| gypsum |  |  | 2380 |
| block work | H1 | 168 | Block | 0.100 | 1,281(kg/m3) | 19044 |
| mortar |  |  | 670 |

A life-cycle model has been developed for a one story house in Malaysia by computing the most significant building LC phases and processes for seven different building schemes with the same structure. This study accomplished for solutions assessed on global warming. The scope of this research included the construction phase (material production and transport processes) and use phase (maintenance, processes).

The Malaysian Government is continuously encouraging the industry to use prefabrication material, partly if not wholly, from the Industrialized Building System (IBS), which is considered to be an essential part of sustainable construction initiative (Nawi, M. N. M 2011). The IBS assessed in this study are precast concrete, block work, steel frame and timber house and the rest of the house are conventional building. The walls are considered to have different materials in their composition (Timber house, brick, Timber & brick, Brick & concrete, precast concrete, steel stud and block work).

Data have also been collected from different sources such as books, journals and a visit to the manufacturing facility. The remainder of this research has been organized as follows: Section I of the paper is related to the introduction and explanation of the problem of project. Section II expanded and described the Literature review. Section III explained the Impact assessment methods and goal of this study. Finally, in Section VII representation and interpretation of result with specific concentration on CO2 emission (Bowyer, J. L 2007). Building construction possesses life cycle stages, and construction, operation & maintenance, transportation and use phase of the building have been assessed in this study. The use phase includes maintenance and operational requirements.

Climate change is related to emissions of greenhouse gases to the air. IPCC list (IPCC 2001) represents factors for global warming (kgeq-CO2 into air/kg emi) and the current modeling up to the damage of the impact of climate change. Therefore, the interpretation takes place directly at midpoint level, which can be interpreted as damage on life support systems. There has been some study on residential building (Jeroen B 1993) that used an endpoint method such as Recipe, CML 2001 (Institute of Environmental Sciences of Leiden University), Ecosystem Damage Potential (EDP) and Eco-indicator 99. The different issue in this research is that environment assessment has been accomplished by the midpoint method (IPCC 2001). Furthermore, midpoint results have a lower level of uncertainty compared to endpoint result and are more reliable.

In this study, the environmental assessment tools are restricted to the production process called “gate to gate”. A gate-to-gate study was carried out whereby the system boundary was set to only include the process of the wall material production, transportation and setup of the walls.

Life cycle inventory measures all the raw materials and energy related to the particular product or process, inputs and outputs to manufacture on a per unit basis within carefully defined system boundaries of this research. Table 1 described the quantity of materials in all schemes.

The total resource input for building mass is the sum of all attributes expressed in kilogram. The weight of the functional unit for (timber post & beam -H7) hardwood of 1 m2 is 146 kg/m2 and the total weight of screws to attach the panels and beams is 40 kg for the whole scheme. The transportation to carry the wood frame and beam structure to site by truck for 40 kilometers from manufacturing site as well as screws and other components has been used by passenger car with a distance of 4 kilometers have also been included.

The User Input for the precast concrete (H4) category has various elements such as columns, beams, elevated slabs, spread footings, pile caps, retaining walls, grade walls, and slab on grade. All the components have been manufactured off-site and there is no concrete production activity on the site. The weight of the functional unit of precast concrete of 1 m2 is 343 kg/m2. The majority of sites surveyed in this study accomplished the manufacturing somewhere close to the site, therefore the transportation for carrying the components to site was considered 10 kilometers by lorry.

In Brick (H3) input, the user enters the quantity information on the total area of the brick wall (interior and double wall exterior) as 92 kg/m2 and average distance of brick delivery is 60 kilometers by lorry (exterior walls are made of double brick). Cement mortar applied 10 kg/m2 for brick wall and was operated off-site by mortar mixer and transported to site within 5 kilometer distance.

Block (H1) input is similar to brick input, except the size of block is different. The weight of the functional unit for a lightweight block of 1 m2 is 117 kg/m2 and it is transported by lorry for 30 kilometers on the way. The mortar for block used was 4 kg/m2.

The steel (H5) scheme is constructed in a different manner compared with other categories such as concrete or lightweight block. The total quantity of steel is input in kilometers, and the average distance for transportation is input in kilometers. The user selects from three types of equipment options for steel installation and erection: crane, air compressor, and gas welding machine. The weight of the functional unit for 1 m2 of steel wall has been divided into subcomponents as steel stud, wool, screw and other iron components for attachment and finally gypsum board to cover the external side of the wall. The quantity of weight for steel stud is 10 kg/m2, the weight of wool is 17 kg/m2, 15 kg/m2 for gypsum board and 2 kg/m2 for screws. The distance from manufacturing to site has been assumed to be 40 kilometers by lorry.

Another scheme is brick and concrete (H2) which contains about 1/3 brick and 2/3 timber wall panel. This scheme consists of bricks, hardwood, screw for hardwood attachment and finally brick mortar for the brick wall. The last scheme in this research is ½ brick wall with ½ precast concrete walls. The concrete wall was manufactured off-site and transferred to the building site by lorry within 5 kilometers. The column and beam of the structure, and the interior walls were built using concrete frame and the outside frame was made from bricks. And finally Timber & Brick (H6) were comprised of Timber, brick, screw and mortar.

In the literature review, we discussed climate change in different regions of the world and other countries, but this study creates the assessment based on Malaysian manufacture, energy mix and transport.

1. **Results and discussion**

This study is about trying out to substantially reduce the global warming emission of current methods of built approaches in Malaysia by choosing the right strategy for building scheme. Therefore, it will be necessary to assess existing ways of constructing buildings and finding a building scheme that has less impact during its life-cycle. Life cycle assessment has been taken to assess the global warming potential for residential building in Malaysia. The International Organization for Standardization (ISO-14040, Principles and Framework, 2006) defines life cycle assessment as Compilation and evaluation of the inputs, outputs and the potential environmental impacts of a product system throughout its life cycle. IPCC 2007 (Jan Burck et al, 2014) is a new version of the previous method IPCC 2001 and it was developed by the International Panel on Climate Change for climate change factors with a time frame of 20, 100 and 500 years.

Global Warming Potential provides a tool that can be used to implement comprehensive and cost-effective policies (UNFCCC). The metric will differ depending on whether a long-term climate change constraint has been set (Manne and Richels, 2001) or no specific long-term constraint has been agreed upon (as in the Kyoto Protocol). However, earthquake issue is not concerned of this study because Malaysia has very low seismicity and not known to include any seismic provision in the structural design. Therefore no assessment has been made in this area (A. B. NABILAH 2012).

In this section, environmental results are presented. First, section one showed the result of seven materials, walls and determined which one imposed less burden and carbon emission on the environment. Second, it surveyed why Malaysia encountered a lack of interest in using wood material in buildings for the past 40 years. Finally a new scheme for Malaysian construction was presented which can be suited to single family house while releasing less emission and removing the negative points of present component wall material.

* 1. **Walls Schemes Comparison**

In this section, seven different conventional and IBS houses have been assessed. Based on the result timber is more environmentally friendly material compared to other building schemes. Table 2 shows the result of seven buildings with three different timeframes (IPCC GWP 20a, IPCC GWP 100a and IPCC GWP 500a). Different time frames are chosen due to the long effect of CO2 in the atmosphere. (H) Samples of this research include Block work (H1), Brick & concrete (H2), Brick (H3), precast (H4), Steel (H5), Timber & Brick (H6) and timber (H7). Table 2 shows the result of global warming emission on seven different scenarios by three different time frames (20,100 and 500 years).

**Table 2 comparisons of seven different wall material schemes**

|  |  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- | --- |
| Method | **H1** | **H2** | **H3** | **H4** | **H5** | **H6** | **H7** |
| IPCC GWP 20a | 2.07E+04 | 6.71E+03 | 1.21E+04 | 7.19E+03 | 1.68E+04 | 4.10E+03 | 4.19E+02 |
| IPCC GWP 100a | 1.93E+04 | 6.37E+03 | 1.15E+04 | 6.91E+03 | 1.68E+04 | 3.88E+03 | 3.85E+02 |
| IPCC GWP 500a | 1.88E+04 | 6.23E+03 | 1.12E+04 | 6.79E+03 | 1.67E+04 | 3.80E+03 | 3.68E+02 |

IPCC GWP 20a represent global warming emission for 20 years, IPCC GWP 100a represent global warming potential for 100 years and IPCC GWP 500a IPCC GWP 500a for 500 years. All figures are based on KG CO2.

The result reveals that the block work system (H1) has released more carbon dioxide than other building schemes. The material which represents the second heaviest environmental load due to release of CO2 in their life span is a steel wall scheme (H5). The GWP by a steel structure in 20 years is 1.68E+04 Kg CO2 and 1.68E+04 Kg CO2 and 1.67E+04 Kg CO2 for 100 and 500 years respectively. Brick (H3) is another type of conventional building in Malaysia that has been used widely as access to the raw material to build bricks is easy. The global warming for a brick wall are 1.21E+04 Kg CO2, 1.15E+04 Kg CO2 and 1.12E+04 Kg CO2 for 20, 100 and 500 years respectively. The result shows that brick has a high global warming emission but is still a better choice compared to the block work system and steel structure.

**Fig.2. LCIA IPCC GWP scenario analysis results.** Block work (H1), Brick & concrete (H2), Brick (H3), precast (H4), Steel (H5), Timber & Brick (H6) and timber (H7)

Brick & concrete (H2) is another scheme that has been used widely in Malaysia combining concrete and brick within the same structure. This scheme has an effect on climate change by releasing 6.71E+03 Kg CO2, 6.37E+03 Kg CO2 and 6.23E+03 Kg CO2 in time frames of 20, 100 and 500 years. Timber & Brick (H6) is a scheme that has been used in construction and the frame in this structure has been applied by timber. The effect of H6 to atmosphere by releasing CO2 are 4.10E+03 Kg CO2, 3.88E+03 Kg CO2 and 3.80E+03 Kg CO2 for timeframe of 20, 100 and 500 year lifespan of scheme wall. H6 is the second most preferable scheme after H7 that has less effect on global warming. Precast concrete (H4) effect on climate change are 7.19E+03 Kg CO2, 6.91E+03 Kg CO2 and 6.79E+03 Kg CO2 for timeframe of 20, 100 and 500 years. Use of precast concrete has increased in the last decade in Malaysian construction.

Finally, timber (H7) shows the most environmentally building scheme compared with other materials. Timber house determined the GWP 4.19E+02 Kg CO2, 3.85E+02 Kg CO2 and 3.68E+02 Kg CO2 respectively, for 20, 100 and 500 years. So far based on the result of life cycle assessment of the IPCC GWP timber house is most preferable building to the environment from the emission of less CO2. H6 and H7 are considered abandoned scheme structures in the Malaysian construction industry. These two schemes are comprised of wooden post and beam in their structure.

* 1. **Designing Building Structure to Meet Global Warming Challenges in Malaysia**
     1. **Rate of Built Timber House in Malaysia**

Natural forest and plantations has covered about two-third of whole Malaysia (Robert Bangau Tiku, 1991). And with 56% proportion of natural forest Malaysia has one of the highest forest lands in the word. Therefore, Malaysia industry has the largest producers and exporters of timber product in the word with raw materials such as logs, sawn timber and veneer, as well as processed products such as plywood. Timber can be obtained easily in a tropical country such as Malaysia which will provide better opportunities for key players in the construction industry to apply and use wood components (Mohd, R. et al. 2013).

The earlier census of Housing and Population Census (1970) found that almost 2/3 of the living quarters in Peninsular Malaysia used timber in the construction of walls, while another 7.8% had walls made of bricks and planks. Bricks and concrete walls were found in 9.9% and 6.8% respectively (Housing and Population Census 1970). These figures show the importance of the use of timber as a building material for Malaysian houses, but the trend is moving towards the increasing use of brick and concrete as building materials.

Likewise many nations, the census in Malaysia has been carried out every 10 years, since 1960. The next census should be carried out in 2020. The most recent census was from July 6 to August 22, 2010.

Modern houses of basically western design and concrete construction which have been introduced within the past fifty years which has gradually replaced timber houses in the urban centers. Despite Malaysia being blessed with abundant timber resources, a solid track record in timber-based manufacturing and a highly skilled and diverse woodworking industry, timber in building construction is underappreciated by this industry and also designers and house-makers. Consequently the trend of using wood in building components has decreased tremendously by the last four decades in Malaysia. According to the Housing and Population Census (2010) in Malaysia timber accounts for only 5 % of components in building construction and the rest have used brick and concrete in building walls (Housing and Population Census 2010).

Wood is a renewable resource product which also cleans the air and water. Wood product in timber frame building has provided for habitat, beauty and recreation and utilizes almost 100% of its resource or products (Weaver, M.E. 1997). Meanwhile, wood requires the least energy for its manufacture. There is a growing interest in designs which have a minimal impact on global warming and which can minimize the amount of embodied carbon in the world.

Although there are a many reasons why timber frame is an ideal method of construction such as environmental issues and zero carbon, thermal efficiency, speed of construction and design flexibility, a timber house in Malaysia is considered an abandoned scheme structure. There are so many building companies and house-maker that prefer to use alternative material such as concrete or brick for housing instead of timber scheme.

* + 1. **Lack of Interest of Wood Components in Building in Malaysian**

This research has been looking into the lack of interest in wood components of a building in Malaysian construction over the last forty years. The low resistance of wood structure against load bearing (high humidity) in the Malaysian climate means that wood is not the first choice of house builders. According to Burden (2004), defects refer to an improper condition that affects the structure, leading to failure or low performance and utilization of a heritage building. Consequently, it not only results in an aesthetically unsatisfactory appearance, intervention for users’ safety may be required. High humidity in Malaysia poses a number of threats to the life expectancy of timber structures including shrinking, warp, cup, crown, twist, and swell (caused by moisture/humidity).

Based on the report of “International construction cost survey 2012” the cost of material in 2011 showed that timber frame cost less (11 USD) compared to concrete (75 USD) or brick (131 USD) and other building materials on the same quantity in Malaysia. However, timber has not been one of the famous building materials in the last 40 years in Malaysia and in contrast has been forgotten.

Che-Ani et al., (2011) reported that the defects in timber beams effected by humidity can lead to structural problems and this is the main reason why timber houses are not being constructed in Malaysia at the present time. Defects of timber frames include insect, fungal, weathering, mechanical failure. In the survey, the beam element is found to have serious defects caused by fungal infestation, with the type of defect being dry rot.

Another defect that has been effected timber structures is wood split which can be the result of high humidity in Malaysia. Depending to some characterization such as size of the beam or type of the wood that has been used on the beam, split may significantly weaken beams and thus affect the integrity of the whole structure. When the split starts to increase in width or lengthen, then it is a definite sign that the beam is giving way and remedial measures must be adopted immediately. This is the beginning of the problem because it is not easy to replace and exchange the beam on every building and structure at great cost to the house owner. Loss of bearing in beams and joists over foundation walls, docks, or columns are due to movements made by long-term deflection of the wood beams or joists, differential movements of the foundation elements, localized crushing, or wood decay. The monetary value of changing the beams is high and in multi-story could be construed as a dilemma.

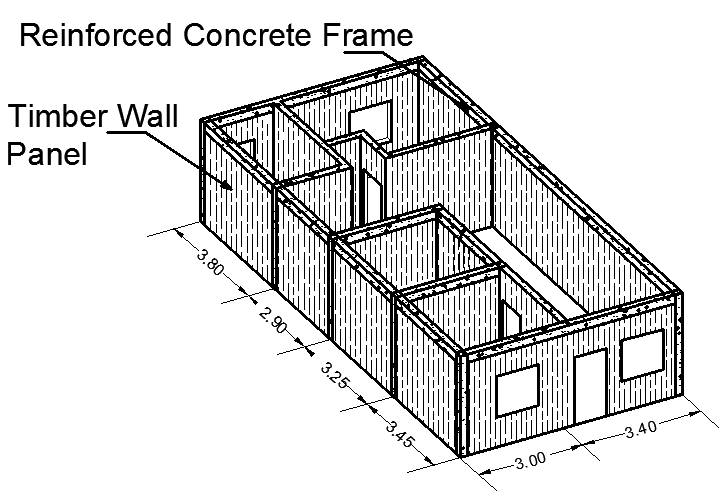
Fungi are a group of organisms in the plant category that can cause decay and discoloration of cellulose material, such as wood (Ridout, 2000). The white rot decay attacks lining, leaving a white cellulose residue that frequently has black lines through it and feels spongy. According to Weaver (1997), the fungi prefer hardwood, but are sometimes found in softwood. Brown rot fungi have been divided into two cases known as dry rot and wet rot. Fungi of this group attack wood and leave dark brown effects. The consequence of decay on wood beam can split the shaft and make it weaken in terms of load bearing, resulting in structural collapse.

Structure defect in timber requires that the structure be demolished. To avoid reaching this level, this study has proposed a new combination of material which can lead to longer life expectancy of building structure. Nor Haniza Ishak (2007) performed a study about timber defects of selected traditional houses in Malaysia. The study focused on maintenance and defect of timber house and their related problems.

* 1. **Developing a New Building Scheme for Global Warming Mitigation**

The study thus far has described the problems with wood scheme and the main reasons why house builders are reluctant to use wood frame in Malaysia. Thus, this study intends to cover the timber frame negligence problem by introducing a new frame. The new frame must eliminate the short lifespan problem of timber frame while still offering the advantage of using timber frame in terms of releasing less CO2 emission.

In light of the above negative points which may result from use of timber material, home builders have lost interest in timber and combined with the high humidity in Malaysia or usual deterioration related to timber structure most construction has used alternative material. Homebuilders and Construction Companies prefer using alternative material for homes such as concrete and brick. The best reason to suggest the use of wood in building components in Malaysia is that this land is plentiful in several types of biomass renewable energy resource such as forest and thus there is no limitation and shortage of this product (http://www.mida.gov.my/env3/index. ).



**Figure 3** schematic model of Timber & Precast Concrete house

This research offers a novel scheme for Malaysian construction and has three marks to encourage both government sector and individual sector use of timber elements in buildings. First, the new structure has removed the negative details of timber structure by applying alternative material to trim down the monetary value of extensive repair. Second, removing structural deterioration can decrease the amount of retrofit and consequently postpone the structure defection and finally and third, achieve the major aim which is to encourage Malaysian construction to move toward climate change mitigation. Figure 3 has shown the proposed scheme of entire reinforced concrete frame with timber wall panels in all walls. All the elements of this new scheme have been strongly recommended as prefabricated materials for two reasons. The first is due to cost saving as compared to the conventional system in Malaysia (Mohd, R. et al. 2013) and second GHG emission due to the on-site construction is slightly higher for wood compared to prefabricated material (R.J. Cole. 1999).

Therefore, to encourage the Malaysian construction industry to use more wood components in building this study has introduced a new combination of material conducted by the forest. Use of wood has led to the release of less CO2 emission from Malaysian industry into air, placing Malaysia in a “very poor” condition at this point (CCPI, 2013).

In the new suggestion for building the wood beams and columns have been replaced by concrete precast beams and pillars. The solution is presented in Table 3 as (H8) for three different time frames. Quantities of materials are 18749 kg for wood, 2939 for reinforcement concrete and 32 kg for bolt or screw and other iron joint in the new proposed system. Applying fire resistance coating of wood wall (H8) can provide a protective layer to the surface against fire. This insulates the surface from heat and oxygen and therefore helps control the spread of fires. This implies that offering fire resistance to protect the material below will assist in preserving the structural stability of the construction. Coatings that can be applied to walls will help forestall the spread of fire (if one was to take place). Table 3 represents the result of assessing new scheme comprised of timber wall panel and precast concrete frame.

**Table 3. Result of assessing the proposed scheme for Malaysian construction**

|  |  |  |
| --- | --- | --- |
| **Method** | **Unit** | **H8** |
| IPCC GWP 20a | KG CO2 | 6.11E+02 |
| IPCC GWP 100a | KG CO2 | 5.81E+02 |
| IPCC GWP 500a | KG CO2 | 5.69E+02 |

Figure 4 has presented the comparison of new proposed scheme with the other schemes which are currently under construction in Malaysia. In Figure 4 (H7) has been replaced by H8 to show the more explicit comparison of the new scheme. H8 has the compromise of concrete precast beam and column with a wood exterior and interior wall panels. H8 has shown a less effect on global warming by its life span and also the negatives of timber structure have been removed by applying the concrete frames. Therefore it can be the best replacement for timber house.

The GWP for H8 (precast concrete & timber) is 6.11E+02 Kg CO2, 5.81E+02 Kg CO2 and 5.69E+02 Kg CO2 for 20, 100 and 500 years respectively. H8 (precast & timber wall system) has released nearly 6 times less CO2 emission than the H6 and much less compared to other construction systems in Malaysia. This subject area can support decision makers in the Malaysian construction industry in all single-family houses to establish the best structure by releasing less CO2 emission.

**Fig.4. LCIA IPCC GWP scenario analysis results.**

Block work (H1), Brick & concrete (H2), Brick (H3), precast (H4), Steel (H5), Timber & Brick (H6) and (H8) is a building combine of timber walls with precast beam and column

The new scheme (H8) has removed the timber structure problem, and has reduced the climate change compared to current building schemes such as brick or concrete building in Malaysia today. For example, precast structure has been applied widely in Malaysia at the present time and applications are growing every day. Thus, post and beam concrete with timber wall panel (H8) released almost 12 times less CO2 emission compared to concrete precast (H4) scheme. Therefore H8 can be replaced by current precast construction as this is a great amount of saving of CO2 emission in merely one unit of the house. Brick is another well-known material in Malaysian construction, ranked second only to precast concrete. Comparing the novel scheme of this research (H8) and brick total loading scheme (H3) it can be seen that brick scheme produces almost 20 times more CO2 emission than H8. Hence the new scheme (H8) can be suggested to cut CO2 emissions from the building industry in Malaysia. The timber wall panel is not for load bearing in the new system and therefore physical damage will not affect the walls.

The new timber scheme structure (H7) offers many advantages such as flame resistance, strong structure against wood disease and most importantly, it produces substantially less CO2 compared to any other building scheme in Malaysia. Hence, it can be replaced with Malaysian construction buildings. Consequently, H8 has not left any excuse in the sector of social organization and material defect at all.

1. **Conclusion**

Buildings should be constructed to reduce and minimize their effect on climate modification by human action. This research proposed a novel combination of building material for minimizing the issue of climate alteration. The new suggested building should be better the previous social system problem. Malaysia has problems controlling CO2 emissions (CCPI, 2014) and building construction has contributed 1/3 of the global warming potential.

In conclusion, in this study compared seven different combinations of real construction scenarios for external and interior walls while taking into account the environmental aspects. The results indicate that timber house release significantly less CO2 and thereby it has a minimum effect on global heating. Based on Housing and Population Census Malaysia use of wood in building elements has decreased from 65% (2/3 of buildings used timber before 1970) to 5% in the last forty years. Thus to encourage Malaysian building industry to use wood in their building this study first reviewed the grounds for this lack of interest in wood in construction and then presented a new scheme for residential construction.

The survey shows that the impact of construction products on climate modification by human activity can be significantly reduced by encouraging the role of alternative techniques of expression, increasing the life span of the building and eliminating substantial maintenance requirements. Therefore, this study represents the new building scheme which improves the structure while representing a more environmentally aware house that released less emission. The problem of moisture protection and structural integrity has been resolved by changing the station and beam timber to concrete beam and tower. The novel scheme has released 6.579E+03 Kg CO2 less emission than precast concrete frame, 11.489E+03 Kg CO2 less than brick and also 16.189 E+03 Kg CO2 less than the steel frame system. Hence, the result has indicated that new combination of beams and columns precast with wood walls (H8) is also more adjustable and environmentally preferable for making walls.

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