UNIVERSITI PUTRA MALAYSIA

FIRE PERFORMANCE ASSESSMENT OF SIX MALAYSIAN WOOD SPECIES FOR FURNITURE APPLICATIONS

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By

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Chair : Datin Ir. Siti Aslina Binti Hussain, PhD
Faculty : Engineering

The main objective of this research is to determine the HRR of fire in compartments containing Malaysian wooden furniture. Thus, this work decided on an appropriate fire model to simulate the designated fire scenario as well as necessary bench-scale tests to evaluate the fire properties of selected wood species for use as input data in the fire model. Since this work is the first of its kind, six species of untreated Malaysian wood have been selected for this research; *Shorea-laevis*, *Vatica-rassak*, *Koompassia-malaccensis*, *Heritiera-albiflora*, *Shorea-parvifolia*, and *Cratoxylum-arborescens*. The cone calorimeter testing, the bomb calorimeter testing, and the thermogravimetric analysis were bench-scale tests used to quantify the fire properties of the wood. In addition, the Coats and Redfern method was used to determine the pyrolysis kinetics of the wood. While the B-RISK fire simulation software was used to simulate the designated fire scenario.

The result of the cone calorimeter test shows that the *Vatica-rassak* is recognised to be the most resistant in the fire resistance assessment of ignition time, critical heat flux, and ignition temperature from the perspective of relative performance. In relation to the amount of energy released during the combustion of one mole of a substance in the bomb calorimeter test, the range of energy released for the six untreated wood is between 31.10 and 35.96 kJ/g. From the thermogravimetric analysis, the wood encountered moisture dehydration up to ~ 170°C. Followed by the second stage of decomposition, between 170 - 510°C, and the third stage of decomposition occurred between 380 - 740°C. The maximum decomposition for each wood was observed to occur at the peak temperature, and as the heating rate increased, the maximum decomposition for all wood shifted to a higher temperature. The wood's pyrolysis kinetics analysis showed that the second stage of decomposition requires more activation energy (E_a) than the third stage. The E_a is the minimum amount of energy that molecules need to cause a reaction or begin to break bonds. In the heavy hardwood category, *Vatica-rassak* was found to have a higher E_a than *Shorea-laevis*, while in the medium hardwood category, *Heritiera-*

albiflora was found to have a higher E_a than *Koompassia-malaccensis*. In the light hardwood category, *Cratoxylum-arborescens* requires more E_a than *Shorea-parvifolia*. These bench-scale test results are then used as input data in B-RISK version 2019.03, an open-source fire model software. Six fire scenarios were designed and developed in the B-RISK fire model software, each with 1000 iterations, featuring an office with 14 common office furniture and electrical appliances including a wooden table, two wooden cabinets, and a wooden drawer. According to the fire simulation, the *Vatica-rassak* is the best choice for making high-end office furniture since it contributes to the lowest total heat release.

The performance-based method applied in this study has successfully provided the best option for fire assessment in a compartment equipped with wooden furniture in a limited time and at a low cost.

Abstrak tesis yang dikemukakan kepada Senat Universiti Putra Malaysia sebagai memenuhi keperluan untuk ijazah Doktor Falsafah

PENILAIAN PRESTASI KEBAKARAN BAGI ENAM SPESIS KAYU MALAYSIA UNTUK APLIKASI PERABOT

Oleh

SULAIHA BINTI ALI

November 2021

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Tujuan utama kajian ini adalah untuk menilai kadar pembebasan haba kebakaran di dalam ruang yang dilengkapi perabot diperbuat daripada kayu tempatan Malaysia. Enam spesis kayu tempatan yang tidak dirawat telah dipilih bagi tujuan kajian ini, termasuk Balau, Resak, Kempas, Mengkulang, Meranti sarang punai dan Geronggang. Pengujian kalorimeter kon, pengujian kalorimeter bom dan analisis termogravimetrik adalah ujian berskala makmal yang dilaksanakan untuk mengukur sifat kebakaran bagi kayu-kayu di atas. Bagi memperolehi keupayaan kinetik yang disebabkan oleh pirolisis yang berlaku semasa analisis termogravimetrik ke atas setiap spesis kayu, Kaedah *Coats and Redfern* telah digunakan. Kesemua data yang diperolehi dari perujian di atas digunakan sebagai input ke dalam perisian untuk membolehkan simulasi kebakaran dapat dilakukan. Perisian model kebakaran yang dikenali sebagai B-RISK telah digunakan untuk mensimulasikan senario kebakaran di dalam kajian ini.

Hasil ujian kalorimeter kon menunjukkan bahawa spesis kayu Resak mempunyai sifat rintangan api terbaik berbanding kayu lain kerana ia memerlukan masa yang lebih lama, suhu dan fluks haba kritikal yang lebih tinggi untuk mula terbakar. Di samping itu, ujian kalorimeter bom memperlihatkan bahawa julat tenaga yang dibebaskan oleh enam spesis kayu yang telah diuji adalah di antara 31.10 dan 35.96 kJ/g. Manakala, daripada perujian termogravimetrik yang dilaksanakan, kayu-kayu yang diuji mengalami proses dehidrasi sehingga suhu mencapai ~170°C. Ini diikuti dengan penguraian peringkat kedua, di antara suhu 170-510°C dan penguraian peringkat ketiga di antara suhu 380 - 740°C. Berdasarkan analisis tenaga kinetik dari proses pirolisis yang berlaku semasa perujian termogravimetrik, peringkat kedua penguraian memerlukan lebih banyak tenaga pengaktifan (E_a) daripada peringkat ketiga. E_a ialah jumlah minimum tenaga yang diperlukan oleh molekul untuk berlakunya tindak balas atau pemecahan ikatan. Bagi kategori kayu keras, Resak didapati memiliki E_a yang lebih tinggi berbanding Balau, sementara dalam kategori kayu keras sederhana, Mengkulang mempunyai E_a yang lebih

tinggi daripada Kempas. Didapati juga bahawa spesis kayu Geronggang memerlukan lebih banyak E_a daripada spesis kayu Meranti sarang punai bagi kayu keras di bawah kategori ringan. Kesemua hasil ujian berskala makmal yang diperolehi kemudiannya digunakan sebagai data input perisian B-RISK versi 2019.03 untuk mensimulasikan enam set kebakaran di dalam ruang pejabat yang dilengkapi 14 peralatan pejabat merangkumi perabot dan peralatan elektrik. Perabot yang dimaksudkan termasuk sebuah meja kayu, dua buah kabinet kayu dan sebuah laci kayu. Hasil simulasi menunjukkan bahawa kadar pelepasan haba adalah paling rendah dalam ruang pejabat yang dilengkapi perabot diperbuat daripada kayu Resak. Berdasarkan kepada dapatan ini, spesis kayu Resak adalah pilihan terbaik bagi penghasilan perabot pejabat berkualiti tinggi.

Kaedah berasaskan prestasi yang diaplikasikan menerusi kajian ini telah berjaya memberikan pilihan terbaik untuk penilaian kebakaran dalam ruang pejabat dilengkapi perabot kayu dengan mengambilkira masa dan kos yang terhad.

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This thesis was submitted to the Senate of Universiti Putra Malaysia and has been accepted as fulfilment of the requirement for the degree of Doctor of Philosophy. The members of the Supervisory Committee were as follows:

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Declaration by Members of Supervisory Committee

This is to confirm that:

- the research and the writing of this thesis were done under our supervision;
- supervisory responsibilities as stated in the Universiti Putra Malaysia (Graduate Studies) Rules 2003 (Revision 2015-2016) are adhered to.

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LIST OF ABBREVIATIONS

PU	Polyurethane
IMPs	Industry Master Plans
NATIP	National Timber Industry Plan
MTIB	Malaysian Timber Industry Board
SEM	Scanning Electron Microscope
HRR	Heat release rate
MLR	Mass loss rate
EHoC	Effective heat of combustion
ASTM	American Society of Testing Materials
ISO	International Standard Organization
THR	Total heat release
PF	Phenol-formaldehyde
MF	Melamine-formaldehyde
FRT	Fire retardant treated
FDS	Fire Dynamic Software
TGA	Thermogravimetric analysis
DTA	Differential thermal analysis
DSC	Differential scanning calorimeter
FRDM	Fire and Rescue Department of Malaysia
AHJ	Authorities of Jurisdiction
UBBL	Uniform Building By Law
CFD	Computational fluid dynamics
ABS	Agent-based Simulation
SFS	Social-force Simulation
NFPA	National Fire Protection Association

SFPE	Society of Fire Protection Engineer
FED	Fractional effective dose
FVM	Finite volume method
FDM	Finite differences method
FEM	Finite element method
CLT	Cross-laminated timber
OD	Optical density
FTP	Flux time products
DFG	Design fire generator
FLED	Fire load energy density
OSB	Oriented strand board
LOI	Limiting oxygen index
SBI	Single burning item
NBS	National Bureau of Standards
FTIR	Fourier transform infrared spectrometer
HRRPUA	Heat release rate per unit area
THRR	Total heat release rate
SEA	Specific extinction area
CHF	Critical heat flux
HoC	Heat of combustion
BTU	British thermal unit
LSM	Least squares method
AAS	Atomic absorption spectroscopy
GC-MS	Gas chromatography-Mass spectroscopy
CR	Coats and Redfern

SRF	Short rotation forestry
KAS	Kissinger–Akahira–Sunose
FWO	Flynn–Wall–Ozawa
WT	Wooden table
LWC	Large wooden cabinet
SMC	Small wooden cabinet
WD	Wooden drawer
ICC	Intraclass correlation coefficient
FO	Flashover
PDF	Portable document
AEGL	Acute exposure guideline level

CHAPTER 1

INTRODUCTION

In the archaeological record, wooden furniture first appeared in ancient Mesopotamia and Egypt. The vicinity to European forests gave easier access to timber in ancient Greece and later in ancient Rome. The expertise of finely crafted wooden furniture was kind of lost after the fall of Rome. The beginning of furniture making in the peninsula of Malaya can be dated as recently as the last quarter of the 19th century, while the production was almost exclusively limited to the immediate royal court circles of the seven Sultanates in which the peninsula is segregated (Maudlin, 1999). Historically, native Malays did not use furniture; instead, they sat cross-legged on the floor, while the royals sat on the padded dais. With the relatively recent entrance of the British people into the royal courts, the inclusion of furniture was unavoidable. This integration of western culture is clearly shown in a trilogy of official court photographs on display in the Royal Perak Museum (Maudlin, 1999). In the early picture of the 1890s, the Malay court members sat on the floor, the Sultan sat on a padded dais in the centre of the court flanked by the British resident, and his staff sat on chairs. By 1900 the court was still cross-legged on the floor, but the Sultan used a chair, and by the 1920s the whole court had chairs. It was no doubt convenient for artisans used to working on the scale of palaces to turn their joinery and carving skills into furniture making. The palace was then furnished with furniture made by the same men who built the palace. The furniture created for the royal courts was a combination of European design and features enriched with classical Malay carving patterns. They were made from Malaysian wood species known as Chengal in the local community (*Neobalanocarpus-heimii*).

There are numerous reasons why wood is the greatest material for furniture, but here are a few of the most important ways that any furniture concept can benefit from incorporating a wooden element; strength, durability, sustainability, variety, versatility, appearance, and feel. Moreover, wood is the only massive source that contributes to the reduction of greenhouse gas emissions that is both naturally renewable and abundant. When a tree is harvested ethically, the carbon, known as biogenic carbon, is locked in the wood and stays there for the lifespan of the items manufactured. Historically, wood has long been used for the production of home and office furniture in the country, therefore it is familiar that Malaysian prefer to use wood-based furniture over other materials (Malaysian Investment Development Authority, 2020; T. M. Wong, 1982). In 2020, Malaysia is recognised as the fourth greatest Asian exporting country for wooden furniture after China, Vietnam, and Indonesia (Pijar Sukma, 2020). The country holds a significant position in the global furniture business, with large markets in the United States, Japan, and Australia. This demonstrates the reputation of Malaysia in supplying high-quality local wooden-based furniture, which is well recognised by the majority of nations around the world. With an enormous increase in exports to the United Kingdom, the United Arab Emirates, Saudi Arabia, the Philippines, and Russia, Malaysia is now eyeing countries such as Algeria, Greece, Puerto Rico, and Libya.

Malaysia offers a diverse spectrum of wooden furniture production segments, including general utility furniture, heavy-duty furniture, and decorative furniture. The wood species chosen for each component varies according to the intended usage of the furniture. Since the establishment of the National Committee on Sustainable Forest Management, the reduction in authorised cutting rate has had an influence on raw material availability as a result of the government's commitment to sustainable forest management. Back in 1978, rubberwood rose as an alternative supply for the wood industry and value-added products as a result of the work of the Forest Research Institute Malaysia (FRIM). The rubberwood was used to manufacture general utility furniture that was well accepted internationally, where Malaysia is now a leading producer and exporter of wood furniture to more than 160 countries worldwide. However, this study focuses on the wood species used to build office furniture, including tables, desks, cabinets, and drawers built entirely of wood. Since different people will use the office furniture throughout time, it must be long lasting products. Purchasing new office furniture regularly is impractical due to the high expense. Hardwood is preferred for office furniture in Western countries due to its durability, superior finishing, and workability; species used include Oak, Walnut, Cherry, African hardwood, and Maple.

1.1 Malaysian wood certification

Malaysia produces a wide range of furniture that is sold in both the domestic and foreign markets, including heavy-duty furniture, general utility furniture, and decorative furniture, with a wide range of species available for each. Malaysia, as a prominent producer and exporter of tropical wood products, has taken significant steps to ensure that it can provide wood products sourced from sustainably managed forests. The Malaysian Timber Certification Council (MTCC) was established in October 1998 as an autonomous organisation to create and run the Malaysian Timber Certification Scheme (MTCS) (MTC, 2014). The MTCS is a voluntary program that provides independent assessment for forest management and chain of custody certification to assure the sustainable management of Malaysia's Permanent Reserved Forests (PRF). In 2009, the MTCS became the region's first tropical timber certification scheme to be accredited by the Programme for Endorsement of Forest Certification (PEFC), an accreditation organisation of the world's largest forest area. The Malaysian Criteria and Indicators for Forest Management Certification (Natural Forest) [MC&I (Natural Forest)] is the standard utilised under the MTCS for natural forest management certification. The MC&I (Forest Plantations), on the other hand, is used to evaluate forest plantations. The Certificate for Forest Management is given to the Forest Management Unit (FMU) which has fulfilled the criteria of the forest management standard. The Certificate for Chain of Custody is issued to a wood product manufacturer or exporter who has met the requirements of the PEFC international standard for the chain of custody. The MTCS assures buyers that PEFC-certified wood products come from sustainably managed FMUs.

The MTCS, as a PEFC-endorsed scheme, has been accepted under the national wood procurement policies of Belgium, Denmark, Finland, France, Germany, New Zealand, Switzerland, and the United Kingdom, and has been recognised by green building systems in Abu Dhabi, Australia, Canada, Italy, Japan, Singapore, the Netherlands, the United Kingdom, the United States, and the United Arab Emirates, as well as the Green Building Index (GBI) in Malaysia. According to the above information, there is no doubt why Malaysian wood are highly ranked in term of quality and reliability, and wooden-based products are being chosen by foreign countries. Even while wood has been widely regarded as the superior material for making furniture, whether entire or upholstered, there are still concerns about its capacity to spread fire in the event of a building fire.

1.2 Wood fire hazard

For many reasons, the choice of wood for furniture making will be linked to the ability to burn, whether as the first item to be ignited by the fuel source or the role of propagating the spread of fire (DeHaan, 2021; Ellis, 1981). According to UK fire statistics, 77% of fire fatalities occurred in dwellings between 2009 and 2014 (George, 2017). Although only 12.6% of fires take place in bedrooms, living rooms, and dining rooms, they account for 71.2% of fire fatalities during that period. Since most of the household furniture is in those rooms, this emphasizes its connotation in fire fatalities. In Malaysia, fire in residences is responsible for 67% of fire fatalities according to fire statistics from 2016 to 2018 (Fire and Rescue Department of Malaysia, 2018). However, there is no record of the precise location of the original ignition.

Generally, wood is considered to be a combustible material, since it is believed that the surfaces may, in particular, add to the fire loading of the compartment, promote the spread of flames, accelerate the outbreak of flashovers, and produce smoke, toxic gases, and heat that can harm the living. Scientifically, as a porous material, wood gets burned when exposed to high heat fluxes and goes through pyrolysis. When wood is heated to 300 °F (150 °C), the cellulose, hemicellulose, and lignin are decomposed to unstable gases, tar (levoglucosan), and carbonaceous char (Lowden & Hull, 2013). The smoke released from wood contains harmful gases, and the compositions are influenced by combustion conditions, the pattern of decomposition, ventilation, temperature, heat exposures, oxygen, moisture, species of wood, treatments or finishes that may have been applied, and fuel chemical nature (Ali et al., 2019; Neviaser & Gann, 2004; Quintiere, 1982; Rasbash & Drysdale, 1982; Tewarson, 1980). Figure 1.1 shows a standard fire growth curve in a compartment and describes the phases and characteristics thereof.

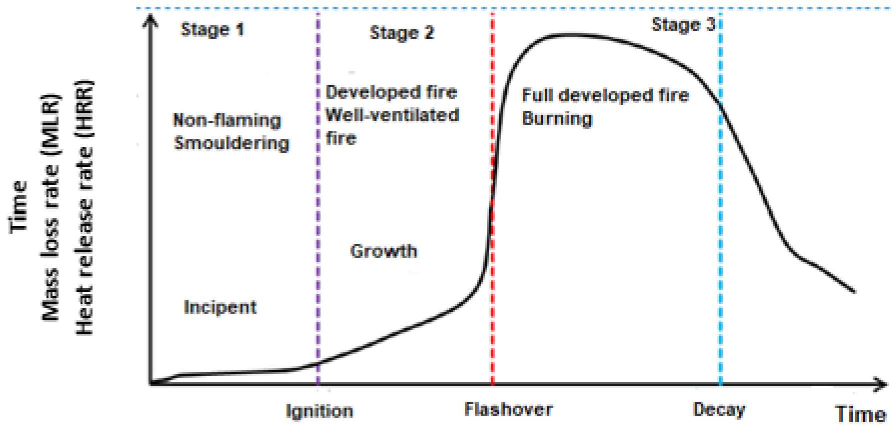

Figure 1.1 : Standard compartment fire development curve
(Studhalter, 2012)

Compartment fires begin mainly by ignition and a small fire (Drysdale, 1986; Quintiere, 1986), which further begin to progress by generating more smoke and heat. In the incipient and growth stages, a burning item in the compartment can ignite wooden furniture if it discharges enough energy and both are close enough to one another. In many cases, the fire will not be affected by the enclosure factor in the process at this early stage, since it is fuel-driven. Depending on the type of fuel and the ventilation conditions, the fire then grows at a slow or quick pace. A smouldering fire may have a lengthy period of development and may be extinguished without a fully developed condition. The average temperature and heat released during smouldering are lower than those generated during flaming combustion, roughly 600°C versus up to 1500°C. If a smouldering fire is given enough fuel, heat, and oxygen, it will erupt into flame combustion. In the event of a residential or office fire, the furniture is the major fuel source, resulting in the development of additional heat, smoke, and toxic fumes, producing untenable conditions for occupants and the commencement of flashover. Flashover is the shift between the point of growth and the fully developed fire which involves a transition from fuel-controlled to ventilation-controlled fire.

Flashover, which occurs at approximately 593 °C, can develop well under five minutes (Poh, 2011). The upper layer temperature can achieve up to 500 - 600 °C, while the compartment ground-level radiation can reach up to 15 - 20 kW/m^2. According to the International Standards Organization, the British Standards Institute, and the European Standardization Committee (BS EN ISO13943, 2010), flashover is the transition to a state of complete surface involvement in an enclosure fire by combustible materials. This is a critical stage in the development of fire because once it is achieved, conditions in the fire section are incompatible with life (Lattimer et al., 1998; Martinka et al., 2016a; Xu et al., 2008). Another explanation for this phase's decisive influence is that fire extinguishing may save a fire section until a flashover occurs, but once that occurs, the operation is primarily focused on saving adjacent fire sections. If a space isn't safe for firemen to enter, trapped victims aren't likely to make it out alive. The state of the flashover signifies major changes in the development of the fire, including; (1) the growth process of the fire has ended and now includes a fully formed fire; (2) search and relief operation has come to an end; (3) start of the possibility of structural failure; and (4) death of anyone trapped in the burning room, including a civilian or firefighter. According to Drysdale (1986), those who did not leave the fire compartment before the flashover are unlikely to survive because post-flashover fires pose a greater risk of fire spreading to other parts of the building or other buildings, as well as to people in or evacuating from rooms within the same building, than pre-flashover fires. Thus, flashover is a critical fire safety criterion that describes the implications of the heat release rate (HRR) on fire hazards in a comprehensive perspective in order to achieve the goals of life safety and property protection. On the other hand, upon experiencing a flashover, a blazing fire will normally progress to a fully developed fire. Several studies have been conducted to better understand the phenomenon, including one by Shields et al. (1999), who studied the flashover by measuring the ignition of the reference item at the floor level, and another by Lai et al. (2010), who designed the flashover scenario as the fire burst out through a window or other opening. The flashover phenomenon caused by a specific material can be predicted using Equation 1.1 as follows (Östman & Tsantaridis, 1994):

$$t_{fo=}\ a\frac{t_{ig}^{0.25}\rho^{1.72}}{THR_{300}^{1.3}}+b \qquad (1.1)$$

Where t_{fo} is time to flashover in-room fire test (s); t_{ig} is the time to ignition in cone calorimeter test at 50 kW/m^2 (s); THR_{300} is the total heat released at 300 s after ignition in cone calorimeter test at 50 kW/m^2 (J/m^2); ρ is the mean density (kg/m^3); a and b are constant values of 0.0716 (J/m^2)$^{1.30}$ (kg/m^3)$^{-1.72}$ s$^{0.75}$ and 57.4 s respectively. The t_{fo} is commonly used to categorise material under two essential groups: (1) flashover (FO) category (Hansen & Hovde, 2002); and (2) European Reaction to Fire Classification System (Euroclasses) (Hansen & Hovde, 2002; Martinka et al., 2013; Xu et al., 2013). In ISO 9705-1:2016, the FO category is used to categorise materials based on the time required to flashover. The application of the following set of rules in Tables 1.1 and 1.2 determines membership in one of these categories.

Table 1.1 : The category of flashover for grouping material

Group of material	Time to flashover
FO category 1	Products did not reach flashover during 1,200 seconds of testing time.
FO category 2	600 seconds ≤ t_{fo} ≤ 1,200 seconds
FO category 3	120 seconds ≤ t_{fo} ≤600 seconds
FO category 4	t_{fo} ≤ 120 seconds

Table 1.2 : Euroclasses fire rating according to the time to flashover

Euroclasses	Definition	Flashover in Room Corner Test (Reference test – 20 minutes)	Examples of products
A1	Non-combustible	No	Product of natural stone, concrete, bricks, ceramic, glass, steel, and most metallic products
A2	Limited-combustibility	No	Product similar to A1 including small amounts of organics compound
B	Combustible	No	Gypsum board with different (thin) surface lining Fire retardant timber products
C	Combustible	Flashover after 10 minutes	Phenolic foams, gypsum board with different surface lining (thicker than in Class B)
D	Combustible	Flashover between 2 to 10 minutes	Timber products with a thickness of ≥ about 10 mm and density ≥ 400kg/m^3
E	Combustible	Flashover before 2 minutes	Low-density fiberboard, plastic-based insulation products
F	Combustible	No performance requirement	Products not tested

A fully developed fire (post-flashover) is the stage in which the HRR in a fire enclosure peaks and the fire size is controlled by the amount of oxygen which is known as a ventilation-controlled fire. During this stage, unburnt gases are generated and accumulated at the ceiling level at which the temperature reaches 700 to 1200 °C. As these unburnt gases escape through the openings, they burn and create flames outside the openings of the enclosure. The yields of toxic products are typically much greater at this stage than under fuel-controlled fire conditions and most of the fire load in the compartment is used. The HRR subsequently decreases as the fuel is consumed, cooling down the upper layer temperature and entering the fire decay stage. In this stage, the fire normally turns from a ventilation-controlled into a fuel-controlled fire.

1.3 Problem statement

There is a global trend toward introducing more fire-safe furniture, with the emphasis on fire-safe furniture serving as a fire countermeasure while meeting the requirements of performance-based building codes. In the European region, the furniture industry has moved to educate customers about decision-making in the purchasing of furniture by promoting the quality of their products for consumers including the general information, leather information, flammability information, design safety information, and environmental stability information. Malaysia needs to set the standard for industry best practises and establish its own identity when it comes to furniture quality. The traditional method of promoting furniture based on its strength, durability, or other physical characteristics is no longer applicable in this period. The hidden value in the visible information, such as fire properties, fire resistance, fire sensitivity, or even demonstrating fire simulation, must be exposed. This is critical since clients are increasingly interested in value-added information when deciding whether or not to purchase wood-based furniture. The most common concerns that will be examined by one in making a decision are safety in terms of design and safety in the event of a fire. Environmental concerns, such as the long-term sustainability of the product base, will also play a role in the decision-making process. As a result, gathering additional information about the wood used to build furniture, particularly high-end office furniture, is critical. For the time being, the physical properties of the local wood are available, while the fire properties and reaction to fire in terms of the probability of heat emitted in the event of a fire breaking out are lacking. Since there is still a lot of opportunity for improvement in terms of giving better information about local wooden furniture, this study will focus on the fire properties of the wood species used to produce high-end office furniture. Knowing that the wood used to manufacture furniture is fire safe is a huge relief for furniture buyers. Except for certification of conformance in furniture design safety by the Forest Research Institute Malaysia (FRIM), Malaysia currently lacks specific regulations and standards on wooden furniture to be fire resistant to any degree.

The best method to quantify the fire is by managing a real full-scale fire experiment which can typically examine the fire spread and the HRR by fuel item in fire scenarios such as the ISO 9705 room-corner test. Since there is more than one probability of fire behaviour in any fire scenario, a real full-scale fire experiment is a time-consuming attempt that refuses fast results when quick decisions are needed. The best approach to overcome the aforementioned issue is by implementing a performance-based fire design. Since the 1990s, along with developments in computer and information technology, the fire-safety professionals in most developed countries have adopted the performance-based approach to accurately measure the fire risks in achieving an acceptable level of safety to reduce the consequences of unintended fire by not only fulfilling the criteria of prescriptive codes but also achieving fire design objective (Meacham, 1996). Currently, there is very little knowledge on the success stories of implementing a performance-based approach among those working in the fire safety field in Malaysia except in certain mega construction projects involving international firms.

The core of performance-based fire design is the combustion and fire development models that describe the origin, spread, and growth of a fire in a compartment or building through the application of the material's fire properties. In addition to providing data on the heat release rate of fire in space, the numerical method provides various outputs that are crucial as inputs for other sub-models such as the barrier failure model, the economic model, the smoke spread model, and the evacuation model for further analysis of building damage and life risk. When modelling a fire, some significant aspects to consider include the space where the fire is predicted to start, the geometry of the space, the content of the space, the ventilation of the space, and the tenancy. Typically, upholstered and wooden furniture are used extensively in modern homes, hotel rooms, hospitals, and offices, and they serve as a fuel load in the event of a fire. The output of the fire models, however, is heavily dependent on the input information of the fuel items such as physical properties, fire properties, and chemical properties. Particularly for the determination of a material's fire properties, bench-scale tests have historically been used, but there is no single bench-scale test method available to quantify each fire property. As a result, various techniques and instrumentation are required, such as cone calorimeter and bomb-calorimeter to measure the combustion parameters, thermogravimetric to measure the thermal degradations and pyrolysis kinetics parameters, different scanning calorimetry to define the specific heat capacity and effective heat of reaction, and hot disk thermal constant analyser to measure thermal conductivity and many others to name. If Malaysian fire safety engineers adopt a performance-based approach in the management of residential or building fire safety, they may find information on the physical and chemical properties of commonly used materials in utilising fire models, but there will be some difficulties in finding the fire properties when it involves local wood-based products due to a lack of available data. On the other hand, there are also barriers to the implementation of performance-based design in fire safety in the country, such as a lack of knowledge and expertise in using fire model software and a lack of fire safety awareness among building caretakers.

Even though there are many works executed on the reaction-to-fire of wood, the archival material related to the fire properties of Malaysian wood is found to be very limited in scope and incomplete (Wong, 1995). For instance, there is a compilation of data on the strength and physical properties of local wood (MTIB, 1986; Tahir et al., 1996) but none available on fire properties. To date, some studies conducted to rectify issues and challenges of using local wood in Malaysia (Marsono & Balasbaneh, 2015; Mohamed & Abdullah, 2014; Ratnasingam et al., 2016), but none conducted on the fire properties. Although some tropical species such as Merbau, Red-Meranti, Mempening, Malas, Garo-garo, Dillenia, Albizia, and Gmelina (Seo et al., 2016; Xu et al., 2015; Chuang et al., 2008; and Subyakto, 2003), have readily available fire properties data, this is insufficient because many other species are used to make furniture. Therefore, there is an urge for knowledge of the combustion properties of Malaysian wood species and the HRR of fire in compartments containing Malaysian wooden furniture.

1.4 Significance of the research

There has always been a need to learn more about fires to make improvements to fire safety protocols, regulations, and education. Because of the unpredictable and devastating nature of fires, the threats they pose to societies are continually evolving as populations, cities, and communities expand and develop. As a consequence, the fire research community strives to keep up with the changes, necessitating the need to broaden knowledge of fires, especially in modern residential settings. One of the most critical parameters in fire safety is the HRR. It is a critical metric of fire energy derived from the overall process of fire growth, spread, and development and used in fire safety design for material, space, or building (Babraukas & Peacock, 1992; Quintiere et al., 1998). The HRR is fed into many analytical and numerical models that are used to execute fire hazard and fire risk assessments, which influence fire safety judgments including evacuation. Due to the significance of the HRR, it must be ensured that the magnitude of the heat released is measured with confidence and that specific characteristics of the fuel source and environmental conditions are taken into account. For instance, there are no written records on local wood fire properties in Malaysia and it should be noted that many countries have already compiled the HRR records of commonly used materials in their countries including the wood (Hasegawa, 2013). The characterization of wood fire properties is a useful reference for the furniture industry, as it aids in the selection of wood for furniture production based on its fire resistance. Thus, the fire properties obtained in this study can serve as the initial input for the local wood fire properties database, which might become available in the near future.

1.5 Objectives of the research

The main objective of this research is to determine the HRR of fire in a compartment furnished with Malaysian wooden furniture. Therefore, the specific objectives of the research are as follows:

1. To evaluate the combustion parameters of selected Malaysian wood species using the cone calorimeter test and the bomb-calorimeter test.

2. To determine the thermal degradations and to determine pyrolysis kinetics parameters of selected Malaysian wood species using the thermogravimetric test.

3. To assess the fire performance of selected Malaysian wood species using the B-RISK fire simulation software with heat release rate and heat of combustion data as input.

1.6 Scope and limitation of the research

For the study, six Malaysian wood species were chosen from three categories: heavy hardwood, medium hardwood, and light hardwood. The wood that has been selected was kiln-dried and untreated. Three different experiments were carried out to determine the fire properties of the selected wood species: cone calorimeter test, bomb-calorimeter test, and thermogravimetric test. The data obtained are analysed to provide input into a selected fire model. The B-RISK zone fire model is used to run fire simulations for six separate design fires in a small confined compartment with a closed door and window which contain office furniture and electrical appliances. To determine the probability of HRR in the design fire, the configuration of objects in the academic office is auto-populated, and the first item to be ignited is selected at random by the fire model software.

Malaysian furniture is made from a diverse range of wood species. However, based on the availability of solid wood, only six species were considered for this research. There are a variety of single bench-scale test methods available to quantify the fire properties of materials; however, only cone calorimeter tests, bomb-calorimeter tests, and thermogravimetric analyses are performed in this study because these experiments could provide the fire properties required to achieve the objectives of this research. The B-RISK zone fire model was chosen for fire simulation since its governing equations and assumptions are appropriate for the task at hand. Since complex geometry is typically incapable of being accurately simulated in a fire model, the fire simulation was designed in a confined space.

1.7 Thesis Outline

The works in this thesis were organized as follows:
Chapter 1 presents the introduction, the problem statements, the significance of the research, the research objectives, the scopes, the limitations, and the organization of the thesis.

Chapter 2 provides an overview of current research, including the fundamentals of wood burning, the performance-based design approach to fire safety, the foundations of fire modelling with an emphasis on the B-RISK fire design tool, and the tools used to conduct experiments in this work, which include the cone calorimeter, bomb calorimeter, and thermogravimetric analyser. The previous work on the characterization of wood fire properties is also discussed in-depth in this chapter.

In Chapter 3, the experimental techniques used to characterise the fire properties of wood are described in detail, including the cone calorimeter test, bomb calorimeter test, and thermogravimetric analysis. This chapter also includes the design of the B-RISK fire simulation for simulating fire in a compartment.

In Chapter 4, the results of the cone calorimeter test were verified and analysed to determine the wood fire properties, and the calorific value of each species was calculated and discussed based on the bomb calorimeter test results. The thermal degradation and pyrolysis kinetics derived from the thermogravimetric analysis have been studied, and the findings are explained in this chapter. The results of the B-RISK fire simulation are also detailed here.

In Chapter 5, the conclusions of this study and the recommendations for future studies are presented.

REFERENCES

Abu-Bakar, A. S., & Moinuddin, K. A. M. (2012). Effects of Variation in Heating Rate, Sample Mass and Nitrogen Flow on Chemical Kinetics for Pyrolysis. *18th Australasian Fluid Mechanics Conference*, (December), 18–21.

Ahrens, M. (2017). *Home Fires That Began With Upholstered Furniture*. *National Fire Protection Association*. Quincy, Massachusetts. Retrieved from https://www.nfpa.org/News-and-Research/Data-research-and-tools/US-Fire-Problem/Upholstered-furniture

Ahrens, M. (2019). *Home Structure Fires*. The United States. Retrieved from https://www.nfpa.org/News and Research/Data research and tools/Building and Life Safety/Home Structure Fires

Akhyani, A. H., & Tohir, M. Z. M. (2019). Tenability analysis of office rooms using probabilistic fire load energy density data. *Journal of Advanced Research in Fluid Mechanics and Thermal Sciences*, *56*(2), 257–266.

Alén, R., Kuoppala, E., & Oesch, P. (1996). Formation of the main degradation compound groups from wood and its components during pyrolysis. *Journal of Analytical and Applied Pyrolysis*, *36*(2), 137–148. https://doi.org/10.1016/0165-2370(96)00932-1

Ali, S., Hussain, S. A., Mohd Tohir, M. Z., & Nuruddin, A. A. (2020a). Statistical Analysis of Malaysian Timber's Combustion Data from Cone Calorimeter Test. *Pertanika Journal of Science and Technology*, *28*(September), 185–198. Retrieved from http://www.pertanika.upm.edu.my/Pertanika PAPERS/JST Vol. 28 (S1). 2020/13 JST(S)-0553-2020.pdf

Ali, S., Hussain, S. A., Mohd Tohir, M. Z., & Nuruddin, A. A. (2020b). Thermogravimetric Analysis and Pyrolysis Kinetics of Malaysian Wood Species. *IOP Conference Series: Materials Science and Engineering*, *811*(1). https://doi.org/10.1088/1757-899X/811/1/012003

Ali, S., Hussain, S. A., & Tohir, M. Z. M. (2019). Fire test and effects of fire retardant on the natural ability of timber: A review. *Pertanika Journal of Science and Technology*, *27*(2), 867–895.

Alvarez, A., Meacham, B. J., Dembsey, N. A., & Thomas, J. R. (2013). Twenty years of performance-based fire protection design: Challenges faced and a look ahead. *Journal of Fire Protection Engineering*, *23*(4), 249–276. https://doi.org/10.1177/1042391513484911

Anca-Couce, A., Zobel, N., Berger, A., & Behrendt, F. (2012). Smouldering of pine wood: Kinetics and reaction heats. *Combustion and Flame*, *159*(4), 1708–1719. https://doi.org/10.1016/j.combustflame.2011.11.015

Aseeva, R., Serkov, B., & Sivenkov, A. (2014). Fire Protection of Timber Building Structures and Constructions. In *Fire Behavior and Fire Protection in*

Timber Buildings (pp. 199–226). Springer Science + Business Media Dordrecht 2104. https://doi.org/10.1007/978-94-007-7460-5

Atreya, A., Carpentier, C., & Harkleroad, M. (1986). Effect of Sample Orientation on Piloted Ignition and Flame Spread. In *FIRE SAFETY SCIENCE-PROCEEDINGS OF THE FIRST INTERNATIONAL SYMPOSIUM* (pp. 97–109). Berkeley, California: International Association for Fire Safety Science.

Atreya, Arvind. (1983). *Pyrolysis, ignition and fire spread on horizontal surfaces of wood*. Harvard University.

Atwater, W. O., & Snell, J. F. (1903). Description of A bomb-calorimeter and method of its use. *Journal of the American Chemical Society*, *25*(7), 659–699. https://doi.org/10.1021/ja02009a001

Babraukas, V., & D. Peacock, R. (1992). Heat Release Rates: The Single Most Important Variable in Fire Hazard. *Fire Safety Journal*, (18), 255–272. https://doi.org/10.1016/0379-7112(92)90019-9

Babrauskas, V. (1982). *Development of the Cone Calorimeter --A Bench-Scale Heat Release Rate Apparatus Based on Oxygen Consumption*. Washington, DC.

Babrauskas, V. (2002). Ignition of Wood: A Review of the State of the Art. *Fire Protection Engineering*, *12*(August), 164–189. https://doi.org/10.1106/104239102028711

Babrauskas, V. (2016). The cone calorimeter. In *SFPE Handbook of Fire Protection Engineering, Fifth Edition*. https://doi.org/10.1007/978-1-4939-2565-0_28

Babrauskas, V., & Peacock, R. D. (1992). Heat Release Rate : The Single Most Important Variable in Fire Hazard *. *Fire Safety Journal*, *18*, 255–272.

Babrauskas, V., Peacock, R. D., & Reneke, P. A. (2003). Defining flashover for fire hazard calculations: Part II. *Fire Safety Journal*, *38*(7), 613–622. https://doi.org/10.1016/S0379-7112(03)00027-4

Baker, G., Fleury, R., Spearpoint, M., Fleischmann, C., & Wade, C. (2011). Ignition of secondary objects in a design fire simulation tool. In *FIRE SAFETY SCIENCE-PROCEEDINGS OF THE TENTH INTERNATIONAL SYMPOSIUM* (pp. 1359–1372). https://doi.org/10.3801/IAFSS.FSS.10-1359

Baker, G., Spearpoint, M., Fleischmann, C., & Wade, C. (2012). Development of a Design Fire Generator for a risk-informed fire safety engineering tool. In *9th International Conference on Performance-Based Codes and Fire Safety Design Methods*. Hong Kong.

Bal, N., & Rein, G. (2015). On the effect of inverse modelling and compensation effects in computational pyrolysis for fire scenarios. *Fire Safety Journal*, *72*, 68–76. https://doi.org/10.1016/j.firesaf.2015.02.012

Bartlett, A. I., Hadden, R. M., Hidalgo, J. P., Santamaria, S., Wiesner, F., Bisby, L. A., … Lane, B. (2017). Auto-Extinction of Engineered Timber: Application to Compartment Fires with Exposed Timber Surfaces. *12th International Symposium on Fire Safety Science*, (February), 1–7. https://doi.org/10.1016/j.firesaf.2017.03.050

Barzegar, R., Yozgatligil, A., Olgun, H., & Atimtay, A. T. (2020). TGA and kinetic study of different torrefaction conditions of wood biomass under air and oxy-fuel combustion atmospheres. *Journal of the Energy Institute*, *93*(3), 889–898. https://doi.org/10.1016/j.joei.2019.08.001

Batiot, B., Rogaume, T., & Fateh, T. (2013). Experimental and numerical investigation of thermal degradation for two kinds of wood. In *13th International Conference and Exhibition Fire and Materials 2013* (pp. 192–201). San Francisco.

Beikircher, W., Hartmann, P., & Kögl, J. (2014). Charring Rate of Intumescent Fire Protective Coated Norway Spruce (Picea Abies L .). *World Conference on Timber Engineering 2014*.

Bhargava, A., Dlugogorski, B. Z., & Kennedy, E. M. (2002). Emission of polyaromatic hydrocarbons, polychlorinated biphenyls and polychlorinated dibenzo-p-dioxins and furans from fires of wood chips. *Fire Safety Journal*, *37*(7), 659–672. https://doi.org/10.1016/S0379-7112(02)00025-5

Bin Marsono, A. K., & Balasbaneh, A. T. (2015). Combinations of building construction material for residential building for the global warming mitigation for Malaysia. *Construction and Building Materials*, *85*(July), 100–108. https://doi.org/10.1016/j.conbuildmat.2015.03.083

Bisby, L., Gales, J., & Maluk, C. (2013). A contemporary review of large-scale non-standard structural fire testing. *Fire Science Reviews*, *2*(1), 1–27. https://doi.org/10.1186/2193-0414-2-1

Book Review: An introduction to fire dynamics by Dougal Drysdale. (1986). *Fire Safety Journal*, *10*(2), 161–162. https://doi.org/10.1016/0379-7112(86)90046-9

Browne, F. L. (1958). *Theories of the combustion of wood and its control*. *Forest Products Laboratory*. Madison, Wisconsin, USA. Retrieved from http://scholarsarchive.library.oregonstate.edu/xmlui/handle/1957/2668

Bukowski, R. W. (1985). Hazard-assessment Computer Model, *9*(4), 159–166. https://doi.org/https://doi.org/10.1002/fam.810090403

Bukowski, R. W., & Babrauskas, Y. (1994). Developing Rational, Performance-based Fire Safety Requirements in Model Building Codes. *Fire and*

Materials, *18*, 173–191. https://doi.org/10.1002/fam.810180305

Burhenne, L., Messmer, J., Aicher, T., & Laborie, M. P. (2013). The effect of the biomass components lignin, cellulose and hemicellulose on TGA and fixed bed pyrolysis. *Journal of Analytical and Applied Pyrolysis*, *101*, 177–184. https://doi.org/10.1016/j.jaap.2013.01.012

Burra, K. R. G., & Gupta, A. K. (2019). Modeling of biomass pyrolysis kinetics using sequential multi-step reaction model. *Fuel*, *237*(September 2018), 1057–1067. https://doi.org/10.1016/j.fuel.2018.09.097

Carosio, F., Cuttica, F., Medina, L., & Berglund, L. A. (2016). Clay Nano paper as multifunctional brick and mortar fire protection coating-Wood case study. *Materials and Design*, *93*, 357–363. https://doi.org/10.1016/j.matdes.2015.12.140

Carpenter, K., & Janssens, M. (2005). Using Heat Release Rate to Assess Combustibility of Building Products in the Cone Calorimeter. *Fire Technology*, *41*(2), 79–92. https://doi.org/10.1007/s10694-005-6390-z

Chai, Y. B., Liu, J. L., & Xing, Z. (2012). Analysis on the Combustion Performance of the MMFU-Boric Acid/Borax Treated Poplar Wood. *Applied Mechanics and Materials*, *174–177*, 375–379. https://doi.org/10.4028/www.scientific.net/AMM.174-177.375

Chen, R., Lu, S., Li, C., Ding, Y., Zhang, B., & Lo, S. (2016). Correlation analysis of heat flux and cone calorimeter test data of commercial flame-retardant ethylene-propylene-diene monomer (EPDM) rubber. *Journal of Thermal Analysis and Calorimetry*, *123*(1), 545–556. https://doi.org/10.1007/s10973-015-4900-x

Cheng, K., Winter, W. T., & Stipanovic, A. J. (2012). A modulated-TGA approach to the kinetics of lignocellulosic biomass pyrolysis/combustion. *Polymer Degradation and Stability*, *97*(9), 1606–1615. https://doi.org/10.1016/j.polymdegradstab.2012.06.027

Chuang, C.S., Tsai, K.C., Wang, M.K., Ou, C.C., Ko, C.-H., & Shiau, I.L. (2008). Effects of intumescent formulation for acrylic-based coating on flame-retardancy of painted red lauan (Parashorea spp.) thin plywood. *Wood Science and Technology*, *42*(7), 593–607. https://doi.org/10.1007/s00226-008-0197-2

Chung, Y. J. (2010). Comparison of combustion properties of native wood species used for fire pots in Korea. *Journal of Industrial and Engineering Chemistry*, *16*(1), 15–19. https://doi.org/10.1016/j.jiec.2010.01.031

Cicione, A., & Walls, R. S. (2020). Towards a simplified fire dynamic simulator model to analyse fire spread between multiple informal settlement dwellings based on full-scale experiments. *Fire and Materials*. https://doi.org/10.1002/fam.2814

Coats, A. W., & Redfern, J. P. (1963). Thermogravimetric Analysis : A Review. *Analyst*, *88*, 906–924. https://doi.org/10.1002/0471266965.com029.pub2

Coats, A. W., & Redfern, J. P. (1965). Kinetic parameters from thermogravimetric data. II. *Polymer Letters*, *3*, 917–920. https://doi.org/10.1038/201068a0

Collins, S., & Fink, G. (2020). Mechanical behaviour of sawn timber of silver birch under compression loading. *Wood Material Science and Engineering*, *0*(0), 1–8. https://doi.org/10.1080/17480272.2020.1801836

Cox, G. (1994). The Challenge of Fire Modelling. *Fire Safety Journal*, *23*, 123–132. https://doi.org/10.1016/0379-7112(94)90021-3

Cuevas, J. C., & García-Vidal, F. J. (2018). Radiative Heat Transfer. *ACS Photonics*, *5*(10), 3896–3915. https://doi.org/10.1021/acsphotonics.8b01031

Curran-Everett, D. (2009). Explorations in statistics: confidence intervals. *Advances in Physiology Education*, *33*(2), 87–90. https://doi.org/10.1152/advan.00006.2009

DeHaan, J. (2021). Our Changing World: Fires, Fuels, Investigations and Investigators. Part 1: Furnishings. Retrieved April 1, 2020, from https://www.interfire.org/features/ourchangingworld.asp

Delichatsios, M. A. (2000). Ignition times for thermally thick and intermediate conditions in flat and cylindrical geometries. *Fire Safety Science*, 233–244. https://doi.org/10.3801/IAFSS.FSS.6-233

Delichatsios, M., Paroz, B., & Bhargava, A. (2003). Flammability properties for charring materials. *Fire Safety Journal*. Methodology. https://doi.org/10.1016/S0379-7112(02)00080-2

Didomizio, M. J., Mulherin, P., & Weckman, E. J. (2016). Ignition of wood under time-varying radiant exposures. *Fire Safety Journal*, *82*, 131–144. https://doi.org/10.1016/j.firesaf.2016.02.002

Dietenberger, M. A., & Hasburgh, L. E. (2016). *Wood Products: Thermal Degradation and Fire*. *Reference Module in Materials Science and Materials Engineering*. Elsevier Incorporated. https://doi.org/10.1016/b978-0-12-803581-8.03338-5

Dillon, S. E. (1998). *Analysis of the ISO 9705 Room/Corner Test: Simulations, correlations, and Heat flux Measurements*. *Nist-Gcr-98-756*. The United States.

Drean, V., Schillinger, R., Leborgne, H., Auguin, G., & Guillaume, E. (2018). Numerical Simulation of Fire Exposed Façades Using LEPIR II Testing Facility. *Fire Technology*, *54*(4), 943–966. https://doi.org/10.1007/s10694-018-0718-y

Duffy, C. (2014). *Committee Input No . 77-NFPA 130-2014 [Chapter B] National Fire Protection Association Report*. *National Fire Protection Association*.

Echiegu, E. A., Nwoke, O. A., Ugwuishiwu, B. O., & Opara, I. N. (2013). Calorific Value of Manure from some Nigerian Livestock and Poultry as Affected by Age. *International Journal of Scientific & Engineering Research*, *4*(11), 999–1004.

Ellis, R. C. (1981). Building contents, the Real Fire Problem in The Room. In *Building Content - The Real Fire Problem, Fall Conference*. Philadelphia.

Elsagan, N., & Ko, Y. (2020). A Parametric Study of Numerical Modelling of Water Mist Systems in Protection of Wood Frame Buildings. In Linda Makovicka Osvaldova, S. L. Zelinka, & F. Markert (Eds.), *Wood & Fire Safety* (pp. 166–172). Strbske Pleso, Slovakia: Springer. https://doi.org/https://doi.org/10.1007/978-3-030-41235-7_25

Eseyin, A. E., Steele, P. H., Pittman, C. U., Ekpenyong, K. I., & Soni, B. (2016). TGA Torrefaction Kinetics of Cedar Wood. *Journal of Biofuels*, *7*(1), 20. https://doi.org/10.5958/0976-4763.2016.00004.0

Fateh, T., Richard, F., Batiot, B., Rogaume, T., Luche, J., & Zaida, J. (2016). Characterization of the burning behavior and gaseous emissions of pine needles in a cone calorimeter – FTIR apparatus. *Fire Safety Journal*, *82*, 91–100. https://doi.org/10.1016/j.firesaf.2016.03.008

Fire and Rescue Department Malaysia, J., Pertubuhan Akitek Malaysia, P., Institute of Engineers Malaysia, I., & Association of Consulting Engineers Malaysia, A. (2006). *Guide to Fire Protection in Malaysia*. (H. Abu Bakar, Ed.). Kuala Lumpur: The Institution of Fire Engineers (UK) Malaysia Branch (IFEM).

Fire And Rescue Department Of Malaysia. (2018). *Statistic of Investigated Structural Fire by Source of Ignition for the Year of 2018*. Kuala Lumpur.

Flynn, J. H., & Wall, L. A. (1966). A Quick, Direct Method For The Determination Of Activation Energy From Thermogravimetric Data. *Journal of Polymer Science Polymer Letters*, *4*, 323–328. https://doi.org/10.1098/rstb.1988.0133

Fonseca, E. M., Silva, L., & Leite, P. A. (2020). Numerical model to predict the effect of wood density in wood–steel–wood connections with and without passive protection under fire. *Journal of Fire Sciences*, *38*(2), 122–135. https://doi.org/10.1177/0734904119884706

Food and Agriculture Organization of the United Nations. (2020a). *Global Forest Resources Assessment 2020: Terms and Definition*. *Food and Agriculture Organization of the United Nations*. Retrieved from http://www.fao.org/forestry/58864/en/

Food and Agriculture Organization of the United Nations. (2020b). *Global Forest Resources Assessment 2020*. Rome.

Food and Agriculture Organization of the United Nations. (2020c). *The State of the World's Forests (In Brief)*.

Fotini, K., Konstantinos, A., Georgia, S., Polychronis, A., & Grigorios, A. (2017). Using least squares method for minimizing the total energy value measurements error for olive oil and alcoholic beverages with bomb calorimeter. In *3rd IMEKOFOODS Conference: Metrology Promoting Harmonization and Standardization in Food and Nutrition* (Vol. 0, pp. 118–121).

Frangi, A., & Fontana, M. (2005). Fire performance of timber structures under natural fire conditions. *Fire Safety Science*, 279–290. https://doi.org/10.3801/IAFSS.FSS.8-279

Friedman, R., Friedman, J., & Linvelle, L. (2003). Principles of fire protection chemistry and physics: Part II - fire protection chemistry and physics. In *Fire Characteristic: Solid Combustible* (3rd edition). Jones & Bartlett Publishers, London.

Friquin, K. L. (2010). Material properties and external factors influencing the charring rate of solid wood and glue-laminated timber. *Fire and Materials*, *35*, 303–327. https://doi.org/10.1002/fam

Fu, Q., Medina, L., Li, Y., Carosio, F., Hajian, A., & Berglund, L. A. (2017). Nanostructured Wood Hybrids for Fire-Retardancy Prepared by Clay Impregnation into the Cell Wall. *ACS Applied Materials and Interfaces*, *9*(41), 36154–36163. https://doi.org/10.1021/acsami.7b10008

Fufa, S. M., Hansen, A. S., Jelle, B. P., & Hovde, P. J. (2014). Reaction to fire and water vapour resistance performance of treated wood specimens containing TiO2 and clay nanoparticles. *Fire and Materials*, *38*, 717–724. https://doi.org/10.1002/fam.2211

Fufa, S. M., Jelle, B. P., & Hovde, P. J. (2013). Durability, reaction to fire properties, and environmental impact of treated and untreated wooden claddings. *Wood Material Science and Engineering*, *8*(3), 175–187. https://doi.org/10.1080/17480272.2013.803500

Gelder, K. van. (2020). Leading exporting countries of furniture worldwide in 2018. Retrieved February 20, 2021, from https://www.statista.com/statistics/1053231/furniture-leading-exporters-worldwide/

George Walker, R. (2017). *Practical Assessment of the Dependence of Fire Service Intervention Times on Life Safety*. University of Central Lancashire. Retrieved from https://pdfs.semanticscholar.org/b584/8c62cdb84abedbf39edf724ead0a8d200171.pdf

Grewolls, K. (2010). Computer simulation of fire hazards and evacuation. In *Fire Toxicity* (pp. 607–618). Woodhead Publishing Limited. https://doi.org/10.1533/9781845698072.6.607

Grexa, O., & Lubke, H. (2001). Flammability parameters of wood tested on a cone calorimeter. *Polymer Degradation and Stability*, *74*, 427–432. https://doi.org/10.1016/s0141-3910(01)00181-1

Grønli, M. G., Várhegyi, G., & Di Blasi, C. (2002). Thermogravimetric analysis and devolatilization kinetics of wood. *Industrial and Engineering Chemistry Research*, *41*(17), 4201–4208. https://doi.org/10.1021/ie0201157

Grześkowiak, W. (2017). Effectiveness of new wood fire retardants using a cone calorimeter. *Journal of Fire Sciences*, *35*(6), 565–576. https://doi.org/10.1177/0734904117737464

Guo, F., Liu, Y., Wang, Y., Li, X., Li, T., & Guo, C. (2016). Pyrolysis kinetics and behavior of potassium-impregnated pine wood in TGA and a fixed-bed reactor. *Energy Conversion and Management*, *130*, 184–191. https://doi.org/10.1016/j.enconman.2016.10.055

Hadjisophocleous, G., & Benichou, N. (2000). Development of performance-based codes, performance criteria and fire safety engineering methods. *International Journal on Engineering Performance-Based Fire Codes*, *2*(4), 127–142.

Hagen, M., Hereid, J., Delichatsios, M. A. A., Zhang, J., & Bakirtzis, D. (2009). Flammability assessment of fire-retarded Nordic Spruce wood using thermogravimetric analyses and cone calorimetry. *Fire Safety Journal*, *44*(8), 1053–1066. https://doi.org/10.1016/j.firesaf.2009.07.004

Hansen, A. S., & Hovde, P. J. (2002). Prediction of time to flashover in the ISO 9705 room corner test based on cone calorimeter test results. *Fire and Materials*, *26*(2), 77–86. https://doi.org/10.1002/fam.788

Harada, T. (2001). Time to ignition, heat release rate and fire endurance time of wood in cone calorimeter test. *Fire and Materials*, *25*(4), 161–167. https://doi.org/10.1002/fam.766

Harada, T., Matsunaga, H., Kataoka, Y., Kiguchi, M., & Matsumura, J. (2009). Weatherability and combustibility of fire-retardant-impregnated wood after accelerated weathering tests. *Journal of Wood Science*, *55*(5), 359–366. https://doi.org/10.1007/s10086-009-1039-z

Harada, T., Nakashima, Y., & Anazawa, Y. (2007). The effect of ceramic coating of fire-retardant wood on combustibility and weatherability. *Journal of Wood Science*, *53*(3), 249–254. https://doi.org/10.1007/s10086-006-0846-8

Harada, T., Uesugi, S., & Masuda, H. (2006). Fire resistance of thick wood-based boards. *Journal of Wood Science*, *52*(6), 544–551. https://doi.org/10.1007/s10086-006-0805-4

Hasalová, L., Ira, J., & Jahoda, M. (2012). Measurement and evaluation of experimental data for modelling thermal decomposition of solid materials. *Chemical Engineering Transactions*, *29*, 1405–1410. https://doi.org/10.3303/CET1229235

Hasburgh, L. E., White, R. H., Dietenberger, M. A., Boardman, C. R., Forest, U. S., Forest, S., & Pinchot, O. G. (2015). Comparison of the Heat Release Rate from the Mass Loss Calorimeter to the Cone Calorimeter for Wood-Based Materials. *Proceedings of Fire and Materials*, 116–127.

Hasegawa, T. (2013). *Introduction to the Building Standard Law - Building Regulation in Japan*. Tokyo, Japan: Building Center of Japan.

Heskestad, A. W., & Hovde, P. J. (1999). Empirical prediction of smoke production in the ISO room corner fire test by use of ISO cone calorimeter fire test data. *Fire and Materials*, *23*(4), 193–199. https://doi.org/10.1002/(SICI)1099-1018(199907/08)23:4<193::AID-FAM684>3.0.CO;2-T

Hirata, T., Kawamoto, S., & Nishimoto, T. (1991). Thermogravimetry of Wood Treated with Water-insoluble Retardants and a Proposal for Development of Fire-retardant Wood Materials. *Fire and Materials*, *15*, 27–36.

Hoffmann, P., & Jones, M. A. (1989). Structure and Degradation Process for Waterlogged Archaeological Wood. In S. E. M. Joan Comstock (Ed.), *Archaeological Wood* (pp. 35–65). American Chemical Society. https://doi.org/10.1021/ba-1990-0225.ch002

Hopkin, D., Anastasov, S., & Brandon, D. (2018). Reviewing the veracity of a zone-model-based-approach for the assessment of enclosures formed of exposed CLT. In *Applications of Fire Engineering - Proceedings of the International Conference of Applications of Structural Fire Engineering, ASFE 2017*. https://doi.org/10.1201/9781315107202-18

Hopkins, D., & Quintiere, J. G. (1996). Material fire properties and predictions for thermoplastics. *Fire Safety Journal*, *26*(3), 241–268. https://doi.org/10.1016/S0379-7112(96)00033-1

Hostikka, S., & Matala, A. (2017). Pyrolysis model for predicting the heat release rate of birch wood. *Combustion Science and Technology*, *189*(8), 1373–1393. https://doi.org/10.1080/00102202.2017.1295959

Hugget, C. (1980). Estimation of rate of heat release by means of oxygen consumption measurements. *Fire and Materials*, *4*(2), 61–65. https://doi.org/10.1002/fam.810040202

Hugi, E., & Weber, R. (2012). Fire Behaviour of Tropical and European Wood and Fire Resistance of Fire Doors Made of this Wood. *Fire Technology*, *48*(3), 679–698. https://doi.org/10.1007/s10694-010-0207-4

Hull, T. R., & Paul, K. T. (2007). Bench-scale assessment of combustion toxicity-A critical analysis of current protocols. *Fire Safety Journal*, *42*(5), 340–365. https://doi.org/10.1016/j.firesaf.2006.12.006

International Organization for Standardization. (2019). *International Organization for Standardization (ISO/DIS 13571-1)-Life-threatening components of fire — Part 1: Guidelines for the estimation of time to compromised tenability in fires*. Retrieved from https://www.iso.org/obp/ui#iso:std:iso:13571:-1:dis:ed-1:v1:en:sec:B

Jalil, A. (2020). Malaysian furniture exporters to benefit from US-China trade war. Retrieved February 20, 2021, from https://themalaysianreserve.com/2020/09/04/malaysian-furniture-exporters-to-benefit-from-us-china-trade-war/

Jancik, J., Magdolenova, P., & Markert, F. (2020). Comparison of Cone Calorimetry and FDS Model of Low-Density Fiberboard Pyrolysis. In L. Makovicka, O. Frank, & M. Samuel (Eds.), *Wood & Fire Safety* (pp. 144–151). Strbske Pleso, Slovakia: Springer. https://doi.org/10.1007/978-3-030-41235-7

Janssens, M. (1991). Rate of heat release of wood products. *Fire Safety Journal*, *17*(3), 217–238. https://doi.org/10.1016/0379-7112(91)90003-H

Jiang, J., Li, J., & Gao, Q. (2015). Effect of flame retardant treatment on dimensional stability and thermal degradation of wood. *Construction and Building Materials*, *75*, 74–81. https://doi.org/10.1016/j.conbuildmat.2014.10.037

Jiang, T., Feng, X., Wang, Q., Xiao, Z., Wang, F., & Xie, Y. (2014). Fire performance of oak wood modified with N-methylol resin and methylolated guanylurea phosphate/boric acid-based fire retardant. *Construction and Building Materials*, *72*, 1–6. https://doi.org/10.1016/j.conbuildmat.2014.09.004

Jiang, Y. (2006). *Decomposition, Ignition and Flame Spread on Furnishings Materials*. Victoria University, Australia. Retrieved from https://vuir.vu.edu.au/481/1/02whole.pdf

Jin, T. (1978). Visibility through fire smoke. *Journal of Fire and Flammability*, *9*(2), 135–155.

Johnson, P. (2002). Performance Based Fire Safety Regulation & Building Design – The Challenges in the 21st Century. In *Proceedings of the 4th International Conference on Performance-Based Codes and Fire Safety Design Methods* (pp. 3–13). Society of Fire Protection Engineers.

Ju, Y. M., Ann, B. J., & Lee, J. (2016). Comparative analysis of gross calorific value by determination method of lignocellulosic biomass using a bomb calorimeter. *Journal of the Korean Wood Science and Technology*, *44*(6), 864–871. https://doi.org/10.5658/WOOD.2016.44.6.864

Kallada Janardhan, R., & Hostikka, S. (2019). Predictive Computational Fluid Dynamics Simulation of Fire Spread on Wood Cribs. *Fire Technology*, *55*(6), 2245–2268. https://doi.org/10.1007/s10694-019-00855-3

Kamikawa, D., Kuroda, K., Inoue, M., Kubo, S., & Yoshida, T. (2009). Evaluation of combustion properties of wood pellets using a cone calorimeter. *Journal of Wood Science*, *55*(6), 453–457. https://doi.org/10.1007/s10086-009-1061-1

Kang, H., Ma, L., Zhang, S., & Li, J. (2015). Synthesis and characterization of nitrogen-phosphorus-based fire retardants modified by boride/propanetriol flyeidyl ether complex. *IOP Conference Series: Materials Science and Engineering*, *87*(1). https://doi.org/10.1088/1757-899X/87/1/012028

Khalid, K., Khalid, K., Othman, M., Hamid, K. H. K., & Chowdhury, Z. Z. (2011). Determination of Some Properties of used cooking oil using AAS, bomb calorimeter and GC-MS techniques. *Oriental Journal of Chemistry*, *27*(3), 1045–1048.

Kim, H.Y. (2014). Analysis of variance (ANOVA) comparing means of more than two groups. *Restorative Dentistry & Endodontics*, *39*(1), 74. https://doi.org/10.5395/rde.2014.39.1.74

Kim, H. S., Kim, S., Kim, H. J., & Yang, H. S. (2006). Thermal properties of bio-flour-filled polyolefin composites with different compatibilizing agent type and content. *Thermochimica Acta*, *451*(1–2), 181–188. https://doi.org/10.1016/j.tca.2006.09.013

Kim, J., Lee, J. H., & Kim, S. (2012). Estimating the fire behavior of wood flooring using a cone calorimeter. *Journal of Thermal Analysis and Calorimetry*, *110*(2), 677–683. https://doi.org/10.1007/s10973-011-1902-1

Kim, S., & Park, J. K. (1995). Characterization of thermal reaction by peak temperature and height of DTG curves. *Thermochimica Acta*, *264*, 137–156.

Kögl, J., Beikircher, W., Flach, M., & Lackner, R. (2014). The effects of non-fire-retardant coatings applied on Norway spruce in case of fire. *Proceedings of the WCTE 2014 World Conference on Timber Engineering, Quebec City / Canada, August 10-14, 2014*, 1–6.

Koo, T. K., & Li, M. Y. (2015). A Guideline of Selecting and Reporting Intraclass Correlation Coefficients for Reliability Research. *Journal of Chiropractic Medicine*. https://doi.org/10.1016/j.jcm.2016.02.012

Kowaluk, G., & Wronka, A. (2019). Influence of density on selected properties of furniture particleboards made of raspberry Rubus idaeus L. lignocellulosic particles. *Forestry and Wood Technology*, *105*, 62–70. https://doi.org/10.5604/01.3001.0013.7719

Kumar, B. S., & Rao, C. V. S. K. (1997). Fire loads in office buildings. *Journal of Structural Engineering*, *123*, 365–368.

Kumar, S. P., Takamori, S., Araki, H., & Kuroda, S. (2015). Flame retardancy of clay-sodium silicate composite coatings on wood for construction purposes. *RSC Advances*, *5*(43),109–116. https://doi.org/10.1039/c5ra04682c

Kurniati, D. R., & Rohman, I. (2018). The concept and science process skills analysis in bomb calorimeter experiment as a foundation for the development of virtual laboratory of bomb calorimeter. *Journal of Physics: Conference Series*, *1013*(1). https://doi.org/10.1088/1742-6596/1013/1/012088

Lahtela, V., & Karki, T. (2015). The influence of melamine impregnation and heat treatment on the fire performance of Scots pine (Pinus sylvetris) wood. *Fire and Materials*. https://doi.org/10.1002/fam.2338

Lai, C. M., Ho, M. C., & Lin, T. H. (2010). Experimental investigations of fire spread and flashover time in office fires. *Journal of Fire Sciences*, *28*(3), 279–302. https://doi.org/10.1177/0734904109347165

Lardet, P., Georges, V., Terrei, L., & Nichane, M. (2018). An engineering model for ignition and extinction of wood flames using bench-scale data. *Journal of Physics: Conference Series*, *1107*(3). https://doi.org/10.1088/1742-6596/1107/3/032005

Lattimer, B. Y., Vandsburger, U., & Roby, R. J. (1998). Carbon monoxide levels in structure fires: Effects of wood in the upper layer of a post-flashover compartment fire. *Fire Technology*, *34*(4), 325–355. https://doi.org/10.1023/A:1015366527753

Lee, B.-H., Kim, H.-S., Kim, S., Kim, H.-J., Lee, B., Deng, Y., … Luo, J. (2011). Evaluating the flammability of wood-based panels and gypsum particleboard using a cone calorimeter. *Construction and Building Materials*, *25*, 3044–3050. https://doi.org/10.1016/j.conbuildmat.2011.01.004

Lee, B. H., Kim, H. S., Kim, S., Kim, H. J., Lee, B., Deng, Y., … Luo, J. (2011). Evaluating the flammability of wood-based panels and gypsum particleboard using a cone calorimeter. *Construction and Building Materials*, *25*(7), 3044–3050. https://doi.org/10.1016/j.conbuildmat.2011.01.004

Legal Research Board. (2013). *Uniform Building By-Laws (UBBL) 1984* (G.N. 5178/). Kuala Lumpur: International Law Book Services.

Li, P., & Oda, J. (2007). Flame retardancy of paulownia wood and its mechanism. *Journal of Materials Science*, *42*(20), 8544–8550. https://doi.org/10.1007/s10853-007-1781-9

Lindholm, J., Brink, A., & Hupa, M. (2009). Cone calorimeter – a tool for measuring heat release rate. https://doi.org/10.1002/fam

Lizhong, Y., Zaifu, G., Jingyan, Z., Xiaojun, C., & Zhihua, D. (2002). Experimental study on scale effect on mass loss rate of some woods. *Journal of Fire Sciences*, *20*(1), 23–35. https://doi.org/10.1177/0734904102020001608

Lowden, L., & Hull, T. (2013). Flammability behaviour of wood and a review of the methods for its reduction. *Fire Science Reviews*, *2*(1), 4. https://doi.org/10.1186/2193-0414-2-4

Lu, K. M., Lee, W. J., Chen, W. H., & Lin, T. C. (2013). Thermogravimetric analysis and kinetics of co-pyrolysis of raw/torrefied wood and coal blends. *Applied Energy*, *105*, 57–65. https://doi.org/10.1016/j.apenergy.2012.12.050

Magnusson, S., & Thelandersson, S. (1970). Temperature - Time Curves of Complete Process of Fire Development. *Bulletin of Division of Structural …* Retrieved from http://lup.lub.lu.se/record/1245423/file/1245424.pdf

Makaringe, N. P., van der Walt, I. J., Puts, G. J., & Crouse, P. L. (2016). Tga-Ftir Characterisation Of Bamboo Wood, Napier Grass, Pine Wood And Peach Pips For Gasification Applications. *Brazilian Journal Of Thermal Analysis*, *6*(1), 1–19. https://doi.org/10.18362/bjta.v6.i1

Maksimuk, Y., Antonava, Z., Ponomarev, D., & Sushkova, A. (2018). Standard molar enthalpies of formation for crystalline vanillic acid, methyl vanillate and acetovanillone by bomb calorimetry method. *Journal of Thermal Analysis and Calorimetry*, *134*(3), 2127–2136. https://doi.org/10.1007/s10973-018-7247-2

Malaysia Timber Council. (2016). *Commercials Malaysian Timbers*. Kuala Lumpur.

Malaysian Investment Development Authority. (2020). Wood & Wood Products and Furniture & Fixtures. Retrieved from https://www.mida.gov.my/home/wood-&-wood-products-and-furniture-&-fixtures/posts/#:~:text=The%20Government%20has%20set%20an,fibreboard%20(MDF)%20and%20plywood.

Malaysian Timber Industry Board. (2020). *Publication & Timber Statistic*. Kuala Lumpur. Retrieved from https://mytis.mtib.gov.my/csp/sys/bi/%25cspapp.bi.index.cls?scnH=609&scnW=1350

Maraveas, C., Miamis, K., & Matthaiou, C. E. (2015). Performance of Timber Connections Exposed to Fire: A Review. *Fire Technology*, *51*(6), 1401–1432. https://doi.org/10.1007/s10694-013-0369-y

Martinka, J., Chrebet, T., Hrušovský, I., Balog, K., & Hirle, S. (2014). Fire Risk Assessment of Spruce Pellets. *Applied Mechanics and Materials*, *501–504*, 2451–2454. https://doi.org/10.4028/www.scientific.net/AMM.501-504.2451

Martinka, J., Hroncová, E., Chrebet, T., & Balog, K. (2013). A Comparison of the Behaviour of Spruce Wood and Polyolefins during the Test on the Cone Calorimeter. *Advanced Materials Research*, *726–731*, 4280–4287. https://doi.org/10.4028/www.scientific.net/AMR.726-731.4280

Martinka, J., Hrušovský, I., Chrebet, T., & Rantuch, P. (2014). Study of Selected Natural Materials Ignitability. *Advanced Materials Research*, *1001*, 201–261. https://doi.org/10.4028/www.scientific.net/AMR.1001.201

Martinka, J., Kačíková, D., Rantuch, P., & Balog, K. (2016a). Investigation of the influence of spruce and oak wood heat treatment upon heat release rate and propensity for fire propagation in the flashover phase. *Acta Facultatis Xylologiae*, *58*(1), 5–14. https://doi.org/10.17423/afx.2016.58.1.01

Martinka, J., Kačíková, D., Rantuch, P., & Balog, K. (2016b). Investigation of the Influence of Spruce and Oak Wood Heat Treatment Upon Heat Release Rate and Propensity for Fire Propagation in the Flashover Phase. *Acta Facultatis Xylologiae Zvolen*, *58*(1), 5–14. https://doi.org/10.17423/afx.2016.58.1.01

Martinka, J., Rantuch, P., & Liner, M. (2018). Calculation of charring rate and char depth of spruce and pine wood from mass loss. *Journal of Thermal Analysis and Calorimetry*, *132*(2), 1105–1113. https://doi.org/10.1007/s10973-018-7039-8

Matala, A., Hostikka, S., & Mangs, J. (2008). Estimation of pyrolysis model parameters for solid materials using thermogravimetric data. *Fire Safety Science*, 1213–1223. https://doi.org/10.3801/IAFSS.FSS.9-1213

Maudlin, D. (1999). Malaysian Furniture. *Regional Furniture*, *13*, 113–116. Retrieved from https://regionalfurnituresociety.files.wordpress.com/2013/03/malaysian-furniture-daniel-maudlin.pdf

Meacham, B. J. (1996). *The evolution of performance-based codes & Fire safety design methods*. Boston, Massachusetts: Society of Fire Protection Engineers.

Meacham, B. J. (1997). Concepts of a Performance-based Building Regulatory System for the United States. In *The Fifth International Symposium on Fire Safety Science* (pp. 701–712). Melbourne, Australia: National Institute of Standards and Technology. Retrieved from https://www.nist.gov/publications/concepts-performance-based-building-regulatory-system-united-states

Mehrabian, R., Scharler, R., & Obernberger, I. (2012). Effects of pyrolysis conditions on the heating rate in biomass particles and applicability of TGA kinetic parameters in particle thermal conversion modelling. *Fuel*, *93*(2012), 567–575. https://doi.org/10.1016/j.fuel.2011.09.054

Menon, P. K. B., Burgess, H. J., & Sim, H. C. (1990). *Malaysian timbers for furniture*. (L. P. K. Malaysia., Ed.), *Timber trade leaflet*. Kuala Lumpur: Malaysian Timber Industry Board.

Merci, B., & Vandevelde, P. (2007). Comparison of calculation methods for smoke and heat evacuation for enclosure fires in large compartments. *Thermal Science*, *11*(2), 181–196. https://doi.org/10.2298/TSCI0702181M

Merk, V., Chanana, M., Gaan, S., & Burgert, I. (2016). Mineralization of wood by calcium carbonate insertion for improved flame retardancy. *Holzforschung*, *70*(9), 867–876. https://doi.org/10.1515/hf-2015-0228

Mettler-Toledo. (n.d.). *TGA evaluation*. Schwerzenbach.

Mierlo, R., & Sette, B. (2005). The Single Burning Item(SBI) test method- a decade of development and plans for the near future. *Heron*, *50*(4), 191–207. Retrieved from http://heron.tudelft.nl/50-4/1.pdf

Mikkola, E., & Wichman, I. S. (1989). On the thermal ignition of combustible materials. *Fire and Materials*, *14*(3), 87–96. https://doi.org/10.1002/fam.810140303

Ministry of Plantation Industry and Commodities Malaysia. (2009). *National Timber Industry Policy 2009-2020*. Kuala Lumpur: Malaysian Timber Industry Board (MTIB).

Mishra, R. K., & Mohanty, K. (2018). Pyrolysis kinetics and thermal behavior of waste sawdust biomass using thermogravimetric analysis. *Bioresource Technology*, *251*, 63–74. https://doi.org/10.1016/j.biortech.2017.12.029

Mitchual, S. J., Frimpong-Mensah, K., & Darkwa, N. A. (2014). Evaluation of Fuel Properties of Six Tropical Hardwood Timber Species for Briquettes. *Journal of Sustainable Bioenergy Systems*, *04*(01), 1–9. https://doi.org/10.4236/jsbs.2014.41001

Moghtaderi, B., Novozhilov, V., Fletcher, D. F., & Kent, J. H. (1997). A New Correlation for Bench-scale Piloted Ignition Data of Wood. *Fire Safety Journal*, *29*(1), 41–59. https://doi.org/10.1016/S0379-7112(97)00004-0

Mohamed, S., & Abdullah, R. (2014). Timber use practices in Malaysia's construction industry: Single-family residential building sector. *Pertanika Journal of Tropical Agricultural Science*, *37*(4), 475–482.

Moinuddin, K. A. M. (2018). Fire safety engineering and sustainable development. In *Proceedings of the 4th International Conference on Civil Engineering for Sustainable Development (ICCESD 2018)* (pp. 1–23).

MTC, (2014). Timber Malaysia. *Malaysian Timber Council*, *20*(5), 16–19.

MTIB, (1986). *100 Malaysian Timbers*. Kuala Lumpur: Malaysian Timber Industry Board (MTIB).

Mulholland, G. W. (1983). Smoke Production and Properties. *SFPE Handbook of Fire Protection Engineering, 2nd Edition, Chapter 15, Section 2*, 2/217-2/227.

Mulholland, G. W., & Choi, M. Y. (1998). Measurement of the mass specific extinction coefficient for acetylene and ethene smoke using the large agglomerate optics facility. *Symposium (International) on Combustion*, *27*(1), 1515–1522. https://doi.org/10.1016/S0082-0784(98)80559-6

Nakamura, M., Yoshioka, H., Kanematsu, M., Noguchi, T., Hagihara, S., Yamaguchi, A., Hayakawa, T. (2016). Reaction-to-fire performance of fire-retardant treated wooden facades in Japan with respect to accelerated weathering. *MATEC Web of Conferences*, *46*, 1–12. https://doi.org/10.1051/matecconf/20164605011

National Research Council Canada; International Code Council (USA); New Zealand. Dept. of Building and Housing; Australian Building Codes Board. (2005). *International Fire Engineering Guidelines*. Australian Building Codes Board.

Neviaser, J. L., & Gann, R. G. (2004). Evaluation of toxic potency values for smoke from products and materials. *Fire Technology*, *40*(2), 177–199. https://doi.org/10.1023/B:FIRE.0000016842.67144.12

Nishino, T., & Kagiya, K. (2019). A multi-layer zone model including flame spread over linings for simulation of room-corner fire behavior in timber-lined rooms. *Fire Safety Journal*. https://doi.org/10.1016/j.firesaf.2019.102906

Njankouo, J. M., Dotreppe, J. C., & Franssen, J. M. (2005). Fire resistance of timbers from tropical countries and comparison of experimental charring rates with various models. *Construction and Building Materials*, *19*(5), 376–386. https://doi.org/10.1016/j.conbuildmat.2004.07.009

Núñez Regueira, L., Rodríguez Añón, J. A., Proupín Castiñeiras, J., Vilanova Diz, A., & Romero García, A. (2002). Using bomb calorimetry for determination of risk indices of wildfires originating from pine residues. *Thermochimica Acta*, *394*(1–2), 291–304. https://doi.org/10.1016/S0040-6031(02)00261-7

Olenick, S. M., & Carpenter, D. J. (2003). An Updated International Survey of Computer Models for Fire and Smoke. *Journal of Fire Protection Engineering*, *13*, 87–110. https://doi.org/10.1177/104239103033367

Onsree, T., & Tippayawong, N. (2017). Application of Gaussian Smoothing Technique in Evaluation of Biomass Pyrolysis Kinetics in Macro-TGA. *Energy Procedia*, *138*, 778–783. https://doi.org/10.1016/j.egypro.2017.10.059

Östman, B. A.-L. (2017). Fire performance of wood products and timber structures. *International Wood Products Journal*, *8*(2), 74–79. https://doi.org/10.1080/20426445.2017.1320851

Östman, B. A. -., & Tsantaridis, L. D. (1994). Correlation between cone calorimeter data and time to flashover in the room fire test. *Fire and Materials*, *18*(4), 205–209. https://doi.org/10.1002/fam.810180403

Ostman, B. A. L., & Tsantaridis, L. D. (1995). Heat release and classification of fire retardant wood products. *Fire and Materials*, *19*(6), 253–258. https://doi.org/10.1002/fam.810190603

Pan, J., Mu, J., Wu, Z., & Zhang, X. (2014). Effect of nitrogen–phosphorus fire retardant blended with Mg(OH)2/ Al(OH)3 and nano-SiO2 on fire-retardant behavior and hygroscopicity of poplar. *Fire and Materials*, (38), 817–826. https://doi.org/10.1002/fam.2224

Park, H. J., Wen, M. Y., Cheon, S. H., Kang, C. W., & Matsumura, J. (2015). Fire retardant performance and thermal degradation of Korean pine treated with fire retardant chemical. *Journal of the Faculty of Agriculture, Kyushu University*, *60*(1), 188–189.

Parr Instrument Company. (2007). Introduction to Bomb Calorimetry. *Parr Instrument Company*, (483), 1–11. Retrieved from http://www.scimed.co.uk/wp-content/uploads/2013/03/Introduction-to-bomb-calorimetry.pdf

Parr Instrument Company. (2013). Introduction to Bomb Calorimetry. *Parr Instrument Company*. Moline, Illinois, USA: Parr Instrument. Retrieved from http://www.scimed.co.uk/wp-content/uploads/2013/03/Introduction-to-bomb-calorimetry.pdf

Parr Instrument Company. (2014). *Parr Instrument Company: Plain Jacket Calorimeter 1341Operating Instruction Manual*. Retrieved from https://www.parrinst.com/products/oxygen-bomb-calorimeters/1341-plain-jacket-bomb-calorimeter/documents/

Pearce, E. M., Khanna, Y. P., & Raucher, D. (1981). Thermal Analysis in Polymer Flammability. In *Thermal Characterization of Polymeric Materials* (pp. 793–843). New York, USA: Academic Press, New York, USA.

Pijar Sukma. (2020). 4 Greatest Asian Exporting Countries for (Wooden) Furniture Manufacture. Retrieved February 17, 2021, from https://pijarsukma-furniture.com/furniture-manufacturers-asia/

Poh, W. (2011). Tenability criteria for design of smoke hazard management systems. *Ecolibrium*, 32–37. Retrieved from https://www.airah.org.au/Content_Files/EcoLibrium/2011/August2011/2011_08_01.pdf

Poletto, M. (2016). Thermogravimetric Analysis and Kinetic Study of Pine Wood Pyrolysis. *Revista Ciência Da Madeira - RCM*, *7*(2), 111–118. https://doi.org/10.12953/2177-6830/rcm.v7n2p111-118

Poletto, Matheus, Dettenborn, J., Pistor, V., Zeni, M., & Zattera, A. J. (2010). Materials produced from plant biomass. Part I: Evaluation of thermal stability and pyrolysis of wood. *Materials Research*, *13*(3), 375–379. https://doi.org/10.1590/S1516-14392010000300016

Przybylak, M. W. (2013). Combustion characteristics of wood protected by intumescent coatings and the influence of different additives on fire retardant effectiveness of the coatings. *Molecular Crystals and Liquid Crystals Science and Technology. Section A. Molecular Crystals and Liquid Crystals*, *354:1*, 449–456. https://doi.org/10.1080/10587250008023638

Purser, D. (1989). Modelling Toxic And Physical Hazard In Fire. *Fire Safety Science*, *2*, 391–400. https://doi.org/10.3801/iafss.fss.2-391

Purser, D. A., & McAllister, J. L. (2016). Assessment of Hazards to Occupants from Smoke, Toxic Gases, and Heat. In M. J. Hurley, D. Gottuk, J. R. Hall, K. Harada, E. Kuligowski, M. Puchovsky, C. Wieczorek (Eds.), *SFPE Handbook of Fire Protection Engineering, Fifth Edition* (Fifth Edit, pp. 1–3493). New York: Springer, New York, NY. https://doi.org/10.1007/978-1-4939-2565-0

Quintiere, J., Torero, J., & Long, R. (1998). Material fire properties. In *Advanced Materials Proceedings* (pp. 1–14). New Jersey: Federal Aviation Administration. Retrieved from http://www.fire.tc.faa.gov/1998Conference/presentations/JimQuintiere.pdf

Quintiere, J.G. (1986). Book Review: An Introduction to Fire Dynamics by Dougal Drysdale. *Fire Safety Journal*, *10*, 161–162.

Quintiere, James G. (1982). Smoke Measurements: An Assessment of Correlations between Laboratory and Full-scale Experiments. *Fire and Materials*, *6*(1), 145–160. https://doi.org/10.1002/fam.810060308

Rasbash, D. J., & Drysdale, D. D. (1982). Fundamentals of smoke production. *Fire Safety Journal*, *5*(1), 77–86. https://doi.org/10.1016/0379-7112(82)90008-X

Ratnasingam, J., Liat, L. C., Ramasamy, G., Mohamed, S., & Senin, A. L. (2016). Attributes of sawn timber important for the manufacturers of value-added wood products in Malaysia. *BioResources*, *11*(4), 8297–8306. https://doi.org/10.15376/biores.11.4.8297-8306

Renda, A., Pelkmans, J., Schrefler, L., Luchetta, G., Simonelli, F., Mustilli, F., … Busse, M. (2014). *The Eu Furniture Market Situation and A Possible Furniture Products Initiative*. Brussels. Retrieved from https://www.ceps.eu/ceps-publications/eu-furniture-market-situation-and-possible-furniture-products-initiative/

Reszka, P., & Torero, J. L. (2008). In-depth temperature measurements in wood exposed to intense radiant energy. *Experimental Thermal and Fluid Science*, *32*(7), 1405–1411. https://doi.org/10.1016/j.expthermflusci.2007.11.014

Richardson, J. K. (1994). Moving Towards Performance-Based Fire Codes. *NFPA Journal*, *88*(3), 70–78.

Richardson, J. K., Yung, D., Lougheed, G. D., & Hadjisophocleous, G. V. (1996). The Technologies Required for Performance-Based Fire Safety Design. In *International Conference on Performance- Based Codes and Fire Safety Design Methods* (pp. 191–201). Ottawa, Ontario, Canada: Society of Fire Protection Engineers.

Richter, F., & Rein, G. (2020). A multiscale model of wood pyrolysis in fire to study the roles of chemistry and heat transfer at the mesoscale. *Combustion and Flame*, *216*, 316–325. https://doi.org/10.1016/j.combustflame.2020.02.029

Saele, S. O. (2020). Feasibility Study of Correlating Mass Quantity Output and Fuel Parameter Input of Different Simulations Using Fire Dynamics Simulator. In L.M. Osvaldova, S. L. Zelinka, & F. Markert (Eds.), *Wood & Fire Safety* (pp. 197–202). Strbske Pleso, Slovakia: Springer. Retrieved from https://doi.org/10.1007/978-3-030-41235-7_30

Särdqvist, S. (1993). *Initial Fires*. *Lund University, Sweden*. Lund.

Schartel, B., & Hull, T. R. (2007). Development of fire-retarded materials—Interpretation of cone calorimeter data. *Fire and Materials*, *31*, 327–354. https://doi.org/10.1002/fam

Sedghkerdar, M. H., Mahinpey, N., & Ellis, N. (2013). The effect of sawdust on the calcination and the intrinsic rate of the carbonation reaction using a thermogravimetric analyzer (TGA). *Fuel Processing Technology*, *106*, 533–538. https://doi.org/10.1016/j.fuproc.2012.09.024

Seo, H. J., Jeong, S.-G., & Kim, S. (2015). Development of Thermally Enhanced Wood-Based Materials with High VOCs Adsorption using Exfoliated Graphite Nanoplatelets for Use as Building Materials. *BioResources*, *10*(4), 7081–7091. https://doi.org/10.15376/biores.10.4.7081-7091

Seo, H. J., Kang, M. R., Park, J. E., & Son, D. W. (2016). Combustion characteristics of useful imported woods. *Journal of the Korean Wood Science and Technology*, *44*(1), 19–29. https://doi.org/10.5658/WOOD.2016.44.1.19

Shafizadeh, F. (1984). The Chemistry of Pyrolysis and Combustion, 489–529. https://doi.org/10.1021/ba-1984-0207.ch013

Shangguan, W., Chen, Z., Zhao, J., & Song, X. (2018). Thermogravimetric analysis of cork and cork components from Quercus variabilis. *Wood Science and Technology*, *52*(1), 181–192. https://doi.org/10.1007/s00226-017-0959-9

Sharma, P., & Diwan, P. K. (2017). Study of thermal decomposition process and the reaction mechanism of the eucalyptus wood. *Wood Science and Technology*, *51*(5), 1081–1094. https://doi.org/10.1007/s00226-017-0924-7

Shen, J., Zhu, S., Liu, X., Zhang, H., & Tan, J. (2012). Measurement of Heating Value of Rice Husk by Using Oxygen Bomb Calorimeter with Benzoic Acid as Combustion Adjuvant. *Energy Procedia*, *17*, 208–213. https://doi.org/10.1016/j.egypro.2012.02.085

Shi, L., & Chew, M. Y. L. (2013). Experimental study of woods under external heat flux by autoignition: Ignition time and mass loss rate. *Journal of Thermal Analysis and Calorimetry*, *111*(2), 1399–1407. https://doi.org/10.1007/s10973-012-2489-x

Shi, L., Chew, M. Y. L., Liu, X., Cheng, X., Wang, B., & Zhang, G. (2017). An experimental and numerical study on fire behaviors of charring materials frequently used in buildings. *Energy and Buildings*, *138*, 140–153. https://doi.org/10.1016/j.enbuild.2016.12.035

Shi, L., & Lin Chew, M. Y. (2012). Experimental study of carbon monoxide for woods under spontaneous ignition condition. *Fuel*, *102*, 709–715. https://doi.org/10.1016/j.fuel.2012.06.053

Slopiecka, K., Bartocci, P., & Fantozzi, F. (2012). Thermogravimetric analysis and kinetic study of poplar wood pyrolysis. *Applied Energy*, *97*, 491–497. https://doi.org/10.1016/j.apenergy.2011.12.056

Snell, J. E. (1993). Elements of a Framework for Fire Safety Engineering. In C. A. Franks (Ed.), *International Fire Conference* (pp. 447–456). Oxford, England: Interscience Communication Ltd.

Soria-Verdugo, A., Goos, E., & García-Hernando, N. (2015). Effect of the number of TGA curves employed on the biomass pyrolysis kinetics results obtained using the Distributed Activation Energy Model. *Fuel Processing Technology*, *134*, 360–371. https://doi.org/10.1016/j.fuproc.2015.02.018

Spearpoint, M. J., & Quintiere, J. G. (2001). Predicting the piloted ignition of wood in the cone calorimeter using an integral model - effect of species, grain orientation and heat flux. *Fire Safety Journal*, *36*, 391–415. Retrieved fromhttp://ezproxy.upm.edu.my:2110/S0379711200000552/1-s2.0 S0379711200000552-main.pdf?_tid=fe33cc3a-6b8b-11e7-a1ba-00000aab0f6b&acdnat=1500363646_b8bc7ff737863898f9e644eece7336

Spinardi, G., Bisby, L., & Torero, J. (2017). A Review of Sociological Issues in Fire Safety Regulation. *Fire Technology*. Springer US. https://doi.org/10.1007/s10694-016-0615-1

Staggs, J., & Whiteley, R. (1999). Modeling the combustion of solid-phase fuel in cone calorimeter experiments. *Fire and Materials*, *23*, 63–69. https://doi.org/10.1002/2F(SICI)10991018(199903/2F04)23/3A23.0.CO/3 B2-3

Steckler, K. D., Baum, H. R., & Quintiere, J. G. (1985). Fire induced flows through room openings-flow coefficients. *Symposium (International) on Combustion*, *20*(1), 1591–1600. https://doi.org/10.1016/S0082-0784(85)80654-8

Steckler, K. D., Quintiere, J. G., & Rinkinen, W. J. (1982). Flow induced by fire in a c o m p a r t m e n t. In *Nineteenth Symposium (International) on Combustion* (pp. 913–920). Gaithersburg, USA: National Bureau of Standards.

Studhalter, J. (2012). *A probabilistic comparison of times to flashover in a compartment with wooden and non-combustible linings considering variable fuel loads*. University of Canterbury Christchurch.

Su, Y., Luo, Y., Wu, W., Zhang, Y., & Zhao, S. (2012). Characteristics of pine wood oxidative pyrolysis: Degradation behavior, carbon oxide production and heat properties. *Journal of Analytical and Applied Pyrolysis*, *98*, 137–143. https://doi.org/10.1016/j.jaap.2012.07.005

Subramaniam, C., Ali, H., & Shamsudin, F. M. (2012). Initial emergency response performance of fire fighters in Malaysia. *International Journal of Public Sector Management*, *25*(1), 64–73. https://doi.org/10.1108/09513551211200294

Subyakto, Subiyanto, B., Hata, T., & Kawai, S. (2003). Evaluation of fire-retardant properties of edge-jointed lumber from tropical fast-growing woods using cone calorimetry and a standard fire test. *Journal of Wood Science*, *49*(3), 241–247. https://doi.org/10.1007/s10086-002-0473-y

Sun, Q. F., Lu, Y., Xia, Y. . Z., Yang, D. J., Li, J., & Liu, Y. X. (2012). Flame retardancy of wood treated by TiO 2 /ZnO coating. *Surface Engineering*, *28*(8), 555–559. https://doi.org/10.1179/1743294412Y.0000000027

Swann, J., Hartman, J., & Beyler, C. (2008). Study of radiant smoldering ignition of plywood subjected to prolonged heating using the cone calorimeter, TGA, and DSC. *Fire Safety Science*, 155–166. https://doi.org/10.3801/IAFSS.FSS.9-155

Szubel, M., Filipowicz, M., Goryl, W., & Basista, G. (2016). Characterization of the wood combustion process based on the TG analysis, numerical modelling and measurements performed on the experimental stand. In *Synthetic Biology: Engineering, Evolution & Design (SEED) 2016* (pp. 1–8). https://doi.org/10.1051/e3sconf/20161000133

Taha, Z., Abdul Rashid, S. H., Alli, H., & Mohamad Sabudin, S. (2015). Final Report Furniture Industry. Retrieved from www.akademisains.gov.my

Tahir, H. M., Midon, M. S., Pun, C. Y., Kasby, N. A. M., & Mohd, R. (1996). *Handbook Of Structural Timber Design: Simple Solid Members*. Kuala Lumpur: Forest Research Institute Malaysia (FRIM).

Tamat, A., Pawanchik, S., Kamil, A. A., Halmi, M. F., Lateh, H. H., Hasan, M. Z., … Hossain, M. K. (2014). Analysis of Variation in ToT and Response in Penang. *Journal of Environmental Science and Technology*. https://doi.org/https://dx.doi.org/10.3923/jest.2014.200.208

Tan, Y. R., Akashah, F. W., & Mahyuddin, N. (2016). The analysis of fire losses and characteristics of residential fires based on investigation data in Selangor, 2012-2014. In *The 4th International Building Control Conference 2016 (IBCC 2016)* (Vol. 66, p. 6). Retrieved from https://www.matec-conferences.org/articles/matecconf/pdf/2016/29/matecconf_ibcc2016_00109.pdf

Terrei, L., Acem, Z., Georges, V., Lardet, P., Boulet, P., & Parent, G. (2019). Experimental tools applied to ignition study of spruce wood under cone calorimeter. *Fire Safety Journal*, *108*(January), 102845. https://doi.org/10.1016/j.firesaf.2019.102845

Terzi, E., Kartal, S. N., White, R. H., Shinoda, K., & Imamura, Y. (2011). Fire performance and decay resistance of solid wood and plywood treated with quaternary ammonia compounds and common fire retardants. *European Journal of Wood and Wood Products*, *69*, 41–51. https://doi.org/10.1016/j.ibiod.2010.10.014

Terzi, E., Taşçioĝlu, C., Kartal, S. N., & Yoshimura, T. (2011). Termite resistance of solid wood and plywood treated with quaternary ammonia compounds and common fire retardants. *International Biodeterioration and Biodegradation*, *65*(3), 565–568. https://doi.org/10.1016/j.ibiod.2010.10.014

Tewarson, A. (1980). Heat Release Rate in Fires. *Fire and Materials*, *4*(4), 185–191. https://doi.org/10.1002/fam.810040405

Tewarson, A. (2002a). Generation of heat and chemical compounds in fires. In *SFPE handbook of fire protection engineering* (3rd edition, pp. 83–161).

Tewarson, A. (2002b). Generation of Heat and Chemical Compounds in Fires. In M. J. Hurley, D. Gottuk, J. R. Hall Jr., K. Harada, E. Kuligowski, M. Puchovsky, … C. Wieczorek (Eds.), *SFPE Handbook of Fire Protection Engineering* (Third, pp. 82–170). Quincy, Massachusetts: National Fire Protection Association.

The Institution of Fire Engineers (UK) - Malaysia Branch. (2013). Latest Malaysian Standard - Fire Safety and Prevention. Retrieved February 22, 2021, from https://www.ife.org.my/malaysian_standards.asp

Thomas, G. C. (1996). *Fire resistance of light timber framed walls and floors. University of Canterbury*. University of Canterbury. Retrieved from http://ir.canterbury.ac.nz/handle/10092/5877

Thornton, W. M. (1917). XV. The relation of oxygen to the heat of combustion of organic compounds. *Philosophical Magazine and Journal of Science*, *33*(194), 196–203. https://doi.org/10.1080/14786440208635627

Towonsing, A. (2017). Malaysian forest distribution [Online image]. Malaysian Ghost Research. https://www.malaysian-ghost-research.org/masa-depan-hutan-dan-hidupan-liar-di-malaysia/

Tran, H. C., & White, R. H. (1992). Burning Rate of Solid Wood Measured in a Heat Release Rate Calorimeter. *Fire and Materials*, *16*(4), 197–206.

Tsantaridis, L. D., & Östman, B. A.-L. (2002). Charring of protected wood studs. *Fire and Materials*, *22*(2), 55–60. https://doi.org/10.1002/(sici)1099-1018(199803/04)22:2<55::aid-fam635>3.3.co;2-k

Tsatsoulas, D., Phylaktou, H. N., & Andrews, G. (2009). Thermal behaviour and toxic emissions of various timbers in cone calorimeter tests. *WIT Transactions on The Built Environment*, *110*, 181–194. https://doi.org/10.2495/DMAN090181

Tsoumis, G. Thomas (2020, December 22). Wood. Encyclopedia Britannica. https://www.britannica.com/science/wood-plant-tissue

Tsuyumoto, I., & Oshio, T. (2009). Development of fire resistant laminated wood using concentrated sodium polyborate aqueous solution. *Journal of Wood Chemistry and Technology*, *29*(4), 277–285. https://doi.org/10.1080/02773810903033721

Uner, I. H., Deveci, I., Baysal, E., Turkoglu, T., Toker, H., & Peker, H. (2016). Thermal analysis of Oriental beech wood treated with some borates as fire retardants. *Maderas. Ciencia Tecnología*, *18*(2), 293–304. https://doi.org/10.4067/S0718-221X2016005000027

Van Krevelen, D., Van Herdeen, C., & Huntjens, F. (1951). Physicochemical aspects of the pyrolysis of coal and related organic compounds. *Fuel*, *30*, 253–259.

Vermesi, I., DiDomizio, M. J., Richter, F., Weckman, E. J., & Rein, G. (2017). Pyrolysis and spontaneous ignition of wood under transient irradiation: Experiments and a-priori predictions. *Fire Safety Journal*, *91*(March), 218–225. https://doi.org/10.1016/j.firesaf.2017.03.081

Vhathvarothai, N., Ness, J., & Yu, J. (2014). An investigation of thermal behaviour of biomass and coal during co-combustion using thermogravimetric analysis (TGA). *International Journal of Energy Research*, *38*, 804–812. https://doi.org/10.1002/er

Vyazovkin, S., & Wight, C. A. (2010). Isothermal and non- isothermal kinetics of thermally stimulated reactions of solids. *International Reviews in Physical Chemistry*, *17*(3), 407–433. Retrieved from http://dx.doi.org/10.1080/014423598230108

Wade, C. A. (2013). *B-RISK 2013 Software Benchmarking Examples*. Judgeford, New Zealand. Retrieved from https://d39d3mj7qio96p.cloudfront.net/media/documents/SR292_B-RISK_2013_software_benchmarking_examples.pdf

Wade, C, Baker, G., Frank, K., Robbins, A., Harrison, R., Spearpoint, M., & Fleischmann, C. (2016). *B-Risk 2016 User Guide and Technical Manual*. *Branz Study Report 282*. Porirua, New Zealand.

Wade, Colleen, & Barnett, J. (1996). A room-corner model including fire growth on linings and enclosure smoke-filling. *Journal of Fire Protection Engineering*, *8*(4), 27–36. https://doi.org/10.1177/2F104239159600800403

Wade, Colleen, Spearpoint, M., Fleischmann, C., Baker, G., & Abu, A. (2018). Predicting the Fire Dynamics of Exposed Timber Surfaces in Compartments Using a Two-Zone Model. *Fire Technology*, *54*(4). https://doi.org/10.1007/s10694-018-0714-2

Wang, F., Liu, J., & Lv, W. (2017). Thermal degradation and fire performance of wood treated with PMUF resin and boron compounds. *Fire and Materials*, *41*(8), 1051–1057. https://doi.org/10.1002/fam.2445

Wang, W., Zammarano, M., Shields, J. R., Knowlton, E. D., Kim, I., Gales, J. A., … Li, J. (2018). A novel application of silicone-based flame-retardant adhesive in plywood. *Construction and Building Materials*. https://doi.org/10.1016/j.conbuildmat.2018.08.214

Wen, L., Han, L., & Zhou, H. (2015). Factors Influencing the Charring Rate of Chinese Wood by using the Cone Calorimeter. *BioResources*, *10*, 7263–7272. https://doi.org/10.15376/biores.10.4.7263-7272

Wen, L., Han, L., Zhou, H., & Zhuge, C. (2017). Developing charring rate models for Chinese species based on the thermodynamic theory. *Wood Science and Technology*. https://doi.org/10.1007/s00226-017-0920-y

Werkelin, J., Lindberg, D., Boström, D., Skrifvars, B. J., & Hupa, M. (2011). Ash-forming elements in four Scandinavian wood species part 3: Combustion of five spruce samples. *Biomass and Bioenergy*. https://doi.org/10.1016/j.biombioe.2010.10.010

White, R.H., & Dietenberger, M. A. (2001). Wood Products : Thermal Degradation and Fire. In *Encyclopedia of materials : science and technology.* (pp. 9712–9716). Elsevier Science Ltd.

White, Robert H, & Dietenberger, M. a. (2010). Fire Safety of Wood Construction. In *Wood Handbook : Wood as an Engineering Material* (pp. 1–22). Madison, Wisconsin, USA.

Wilkins, E., & Murray, F. (1980). Toxicity of Emissions from Combustion and Pyrolysis of Wood. *Wood Science and Technology*, *100*, 89–100.

Wong, T. M. (1982). *A dictionary of Malaysian timbers. Forest Department, Peninsular Malaysia*. Kuala Lumpur: Forest Department, Peninsular Malaysia. Retrieved from https://www.cabdirect.org/cabdirect/abstract/19830685859

Wong, W.S. (1995). *Timber Structures in Malaysian Architecture and Buildings*. University of Tasmania at Launceston. Retrieved from https://eprints.utas.edu.au/21980/1/whole_WongWai-Sung1997_thesis.pdf

Xiao, Z., Liu, S., Zhang, Z., Mai, C., Xie, Y., & Wang, Q. (2018). Fire retardancy of an aqueous, intumescent, and translucent wood varnish based on guanylurea phosphate and melamine-urea-formaldehyde resin. *Progress in Organic Coatings*, *121*(January), 64–72. https://doi.org/10.1016/j.porgcoat.2018.04.015

Xiao, Z., Xu, J., Mai, C., Militz, H., Wang, Q., & Xie, Y. (2016). Combustion behavior of Scots pine (Pinus sylvestris L.) sapwood treated with a dispersion of aluminum oxychloride-modified silica. *Holzforschung*, *70*(12), 1165–1173. https://doi.org/10.1515/hf-2016-0062

Xie, Y., Liu, N., Wang, Q., Xiao, Z., Wang, F., Zhang, Y., & Militz, H. (2014). Combustion behavior of oak wood (Quercus mongolica L.) modified by 1,3-dimethylol-4,5-dihydroxyethyleneurea (DMDHEU). *Holzforschung*, *68*(8), 881–887. https://doi.org/10.1515/hf-2013-0224

Xie, Y., Xu, J., Militz, H., Wang, F., Wang, Q., Mai, C., & Xiao, Z. (2016). Thermo-oxidative decomposition and combustion behavior of Scots pine (Pinus sylvestris L.) sapwood modified with phenol- and melamine-formaldehyde resins. *Wood Science and Technology*, *50*(6), 1125–1143. https://doi.org/10.1007/s00226-016-0857-6

Xu, Q., Griffin, G. J., Burch, I., Jiang, Y., Preston, C., Bicknell, A. D., … White, N. (2008). Predicting the time to flashover for GRP panels based on cone calorimeter test results. *Journal of Thermal Analysis and Calorimetry*, *91*(3), 759–762. https://doi.org/10.1007/s10973-007-8244-z

Xu, Qiang, Majlingová, A., & Jiang, Y. (2013). Evaluation of plywood fire behaviour by ISO tests. *European Journal of Environmental and Safety Sciences*, *1*(1), 1–7.

Xu, Qingfeng, Chen, L., Harries, K. A., & Li, X. (2016). Combustion performance of engineered bamboo from cone calorimeter tests. *European Journal of Wood and Wood Products*, *75*(2), 161–173. https://doi.org/10.1007/s00107-016-1074-6

Xu, Qingfeng, Chen, L., Harries, K. A., Zhang, F., Liu, Q., & Feng, J. (2015). Combustion and charring properties of five common constructional wood species from cone calorimeter tests. *Construction and Building Materials*, *96*, 416–427. https://doi.org/10.1016/j.conbuildmat.2015.08.062

Yorulmaz, S. Y., & Atimtay, A. T. (2009). Investigation of combustion kinetics of treated and untreated waste wood samples with thermogravimetric analysis. *Fuel Processing Technology*, *90*(7–8), 939–946. https://doi.org/10.1016/j.fuproc.2009.02.010

Zakaria, N. A., Merous, N. H., & Ahmad, I. (2014). Assessment of rubberwood value-added in Malaysia's wooden furniture industry. *International Journal of Economics and Management*, *8*(1), 1–9.

Zhang, H., Zhang, W., Jin, C., & Li, S. (2016). Inorganic Antiflaming Wood Caused by a-Decorated ZnO Nanorod Arrays Coating Prepared by a Facile Hydrothermal Method. *Journal of Nanomaterials*, *2016*, 1–9. https://doi.org/http://dx.doi.org/10.1155/2016/2358276

Zhang, S., Ni, X., Zhao, M., Feng, J., & Zhang, R. (2015). Numerical simulation of wood crib fire behavior in a confined space using cone calorimeter data. *Journal of Thermal Analysis and Calorimetry*, *119*(3), 2291–2303. https://doi.org/10.1007/s10973-014-4291-4