FIRE SAFETY CONCERN FOR TIMBER PARTITION IN THE FAR EAST

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ABSTRACT

Past records indicated that using timber products without adequate safety provisions might lead to big building fires in case of accidents. As surveyed in the Far East including Hong Kong, timber partition walls are commonly installed in offices, hotels, karaokes and even residential apartments. There is not much fire data of local partition timber materials. With the number of fires appears to be increasing all over the world, fire behaviour of those local timber products should be studied carefully. Results are useful for fire engineering approach (or performance-based fire codes) in designing passive building construction for fire safety such as the partitioning of offices and karaoke music boxes.

The first stage is to study the ignition of those products. With the smooth reunification of the Hong Kong Special Administrative Region to China, stronger collaborations of universities between the two areas are encouraged. Some joint works with the SAR in this area was worked out in a national 973 project on fire dynamics. Reporting the preliminary study becomes the objective of this paper.

1. INTRODUCTION

Timber partition and lining materials commonly used in the Far East would give fire problems [1,2] if there is no suitable protection. Partition might be taken as a separating material such as wall and board inside an open plan area in places like Hong Kong under British Administration before. Wall lining is the surface material of a partition. Partition assemblies include the main supporting elements such as the walling substrates, the surface wall finishes or lining materials. There might be materials for sound and thermal insulations. These partitions of fire safety concern are commonly used in buildings including those residential apartments, might be made of either combustible or non-combustible materials.

In Hong Kong, partitions constructed for compartmentation are required [3] to be non-combustible and should have adequate fire-resistance period (FRP) under British Standard BS 476: Part 22 [4] or equivalent in following the fire-resistance test for building elements as specified in the local code [3]. There is an ignition test under small flame for assessing materials tested with fire retardants. For non-loadbearing partitions, no regulation is applied and so might be constructed by combustible materials. However, there is an upper limit on the fire load density for a compartment to avoid storing too much combustibles. Note that surface linings like wallpaper and paints can be ignited with flame spreading over the surface. All lining materials within the protected means of escape are required [5] to be assessed by the BS 476: Part 7 on surface spread of flame [6]. Note that the two tests [4,6] on assessing fire performances of partitions are following the British Standards. Fire tests with a cone calorimeter [7,8] or the room calorimeter [9] are not yet considered. Contribution of partitioning materials including the wall substrates, surface linings as well as the insulating materials to a fire is proposed to be assessed by those tests [10,11].

Fire safety problems in using timber materials should be studied carefully. In applying the ‘engineering approach’ for fire safety design (or the implementation of engineering performance-based codes), the heat release rates of the materials have to be known. Since there is no fire database on the timber materials used in the Far East, experimental data for local materials for estimating the heat release rate of burning those partition assemblies should be developed. Before doing so, the ignition of timber product has to be studied first. The results can be applied for fire hazard assessment.

2. TIMBER STUD OR PLYWOOD PARTITION

Major partitioning design before 1996 in Hong Kong was the timber stud or plywood partition [1,2]. There had been proposals in using fire protected gypsum instead of wood. The cost of gypsum board is more expensive and the design might not be so flexible. The timber stud or plywood partition is still commonly used. The installation procedures of timber stud partitions include cutting the wooden studs and plywood boards into specific sizes, fixing the studs and tracks, as well as applying lime and other top finishes.

Plywood partitions are found in many offices and residential apartments. In shops, wood panels were used for covering of walls and partitioning of fitting rooms because of the low cost of wood, easy alignment and setup. People usually install some wood studs on the wall in the form of grids and attached plywood. Rendering and finishing of rough wall surfaces is much cheaper and easier.

Common construction of a plywood partition consists of hard board trips with sectional area 50 mm by 25 mm, arranged in grids, say of 300 mm by 300 mm. Two pieces of plywood, say 6 mm thick, are nailed on each side of the partition. The cavity is filled up by thermal and sound insulating materials such as wool or fiberglass. Different designs of partition walls were reported with a schematic diagram on the construction details as shown in Fig. 1.

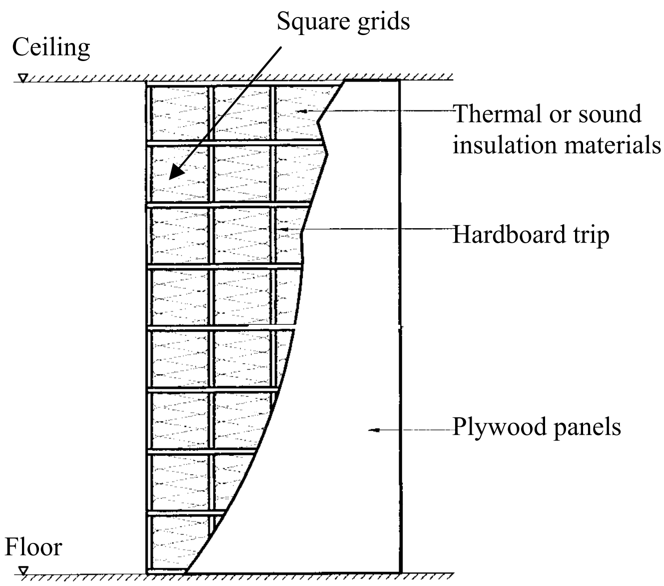

Fig. 1: Construction of plywood partition

3. IGNITION OF TIMBER

Ignition of the timber product is the first point to investigate. There are two kinds of ignition, piloted ignition and spontaneous ignition. Many accidental fires started from piloted ignition due to electric faults or small match flames. Experiments on the piloted ignition at low heat fluxes were carried out by Janssens [12], Fangrat et al. [13] and Yang et al. [14]. Results show that ignition temperature is affected by radiant heat flux, combustible species, geometry of the burning environment, size of the building and use.

On the other hand, there are many pyrolysis models of woods reported in the literature [14-17]. An improved model of pyrolysis of woods was proposed by Yang et al. [14] with surface shrinkage. However, the thermal conductivity varying with the temperature and effect of moisture content were not included. A model on the kinetics of pyrolysis was prepared by Bilbao [15]. There, effect of moisture content and heat lost were ignored. Pyrolysis of woods was studied by Bryden et al. [17] using a more complicated mathematical model by including variation of moisture content, shrinkage and mass transfer of the volatiles. Temperature can be predicted precisely. The timber structure is complicated and not isotropic. Taking the timber as a homogeneous structure in modelling pyrolysis is not good enough. Modelling pyrolysis and ignition of timber should be a multi-phase problem with non-isotropic structure for giving a better simulation under a fire.

A pyrolysis model of timber was proposed by Yuan [18] with the effect of moisture content and heat lost due to volatilesconvection and radiation. Temperature variation can be predicted during pyrolysis. Effects of radiant heat flux and moisture content on the pyrolysis were studied.

Many experiments had been carried out recently [19-21] on studying pyrolysis and ignition of woods under different radiant heat fluxes. Results [21] suggested that the pyrolysis and ignition of the tested timber products such as birch, basswood, fir and plywood depend on the timber species, radiant heat fluxes and moisture content.

4. TESTS ON SELECTED SAMPLES

A modified cone calorimeter with adjustable heat flux emitted and environmental atmosphere was developed. Ignition of five different timber products were studied:

- White pine
- Birch

- Basswood
- High density chipboard
- Plywood with three layers
- Plywood with five layers

Analysis on the volatiles, ash, carbon, and moisture of the above timber products were carried out. Composition of elements and results of preliminary analysis including carbon content C_{ad}, hydrogen content H_{ad}, oxygen content O_{ad}, nitrogen content N_{ad}, sulphur content S_{ad}, ash A_{ad}, moisture content M_{ad}, volatile content V_{ad} and the calorific value Q_{bad} of those samples are shown in Table 1. These information are useful for combustion calculation.

On ignition tests, samples were cut into 10 cm by 10 cm and tested with heat fluxes varying from 30 kWm^{-2} to 80 kWm^{-2}. The effects of heat flux on ignition time, ignition temperatures and mass lost of the five samples are shown in Figs. 2 to 5. It is observed that the rate of the surface temperature and the mass loss rate of material increased quickly when the radiant heat flux increased. Ignition times of the material were shortened, while the ignition temperature decreased. When the radiant heat flux was lower than a certain value, no spontaneous ignition occurred. This critical heat flux of ignition was recorded for setting up a fire database.

Note that moisture content will affect the ignition properties. Taking birch as an example, the surface temperature and mass loss of the sample tested at 40 kWm^{-2} under different moisture contents are shown in Figs. 6 and 7. Increase in moisture content would slow down the increasing rate of the surface temperature and the mass loss rate of material.

Table 1: Plywood properties of the samples

Samples	Moisture Content M_{ad}/%	Ash A_{ad} / %	Volatile V_{ad} / %	Carbon C_{ad} / %	Hydrogen H_{ad} / %	Nitrogen N_{ad} / %	Sulphur S_{ad} / %	Oxygen O_{ad} / %	Calorific Value Q_{bad} / J/g
White pine	8.94	0.50	74.02	16.54	6.00	0.15	0.07	37.88	18719
Birch	12.63	0.36	73.60	13.41	4.94	0.35		37.79	16863
Basswood	10.53	0.39	76.97	12.11	3.82	0.12	0.02	39.14	18129
High density chipboard	7.93	0.87	72.27	18.93	5.44	3.33		36.37	18317
Plywood with three layers	8.28	4.12	73.00	14.60	3.94	3.86	0.39	35.61	17046
Plywood with five layers	7.14	0.64	77.57	14.65	4.30	2.59	0.04	39.58	17733

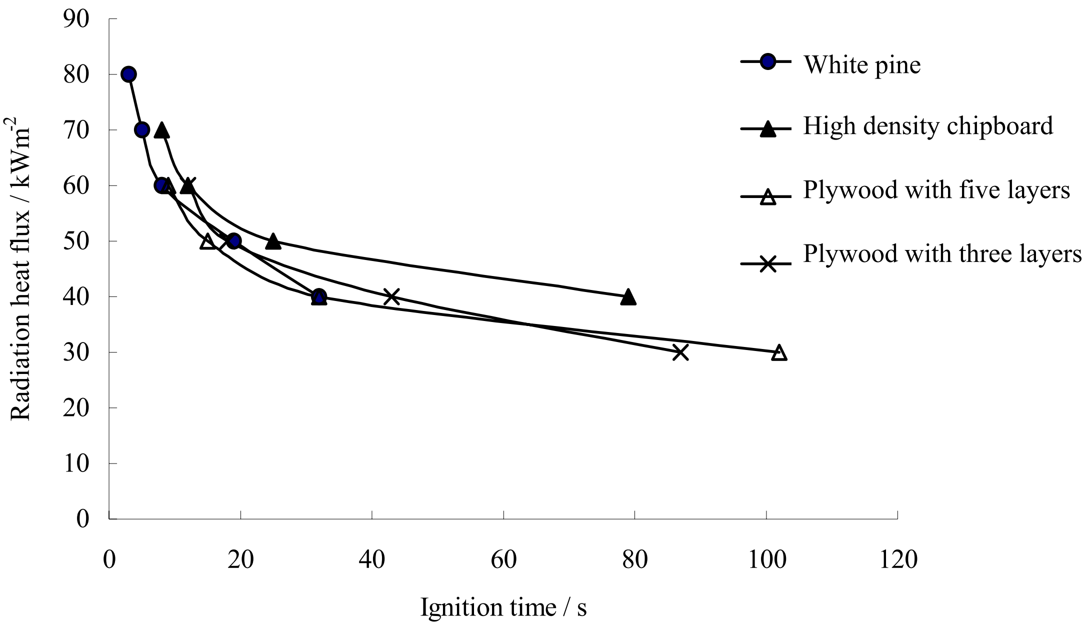

Fig. 2: Ignition times under different external heat fluxes

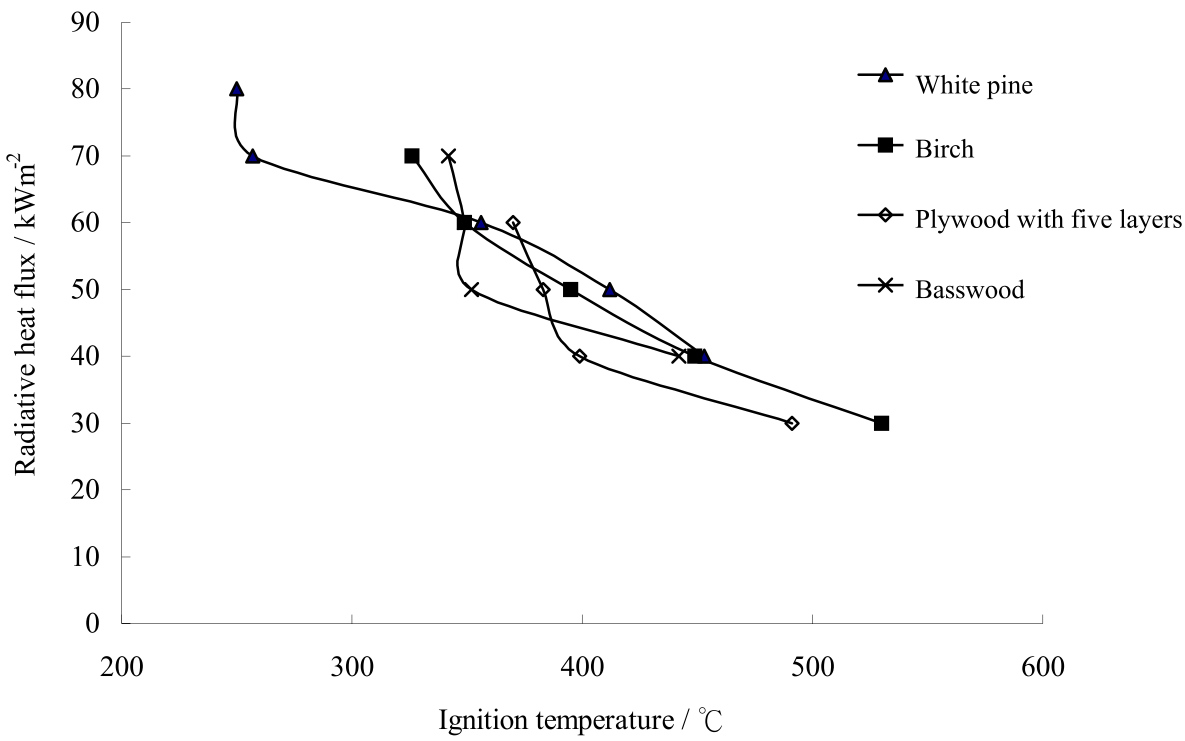

Fig. 3: Ignition temperatures at different external heat fluxes

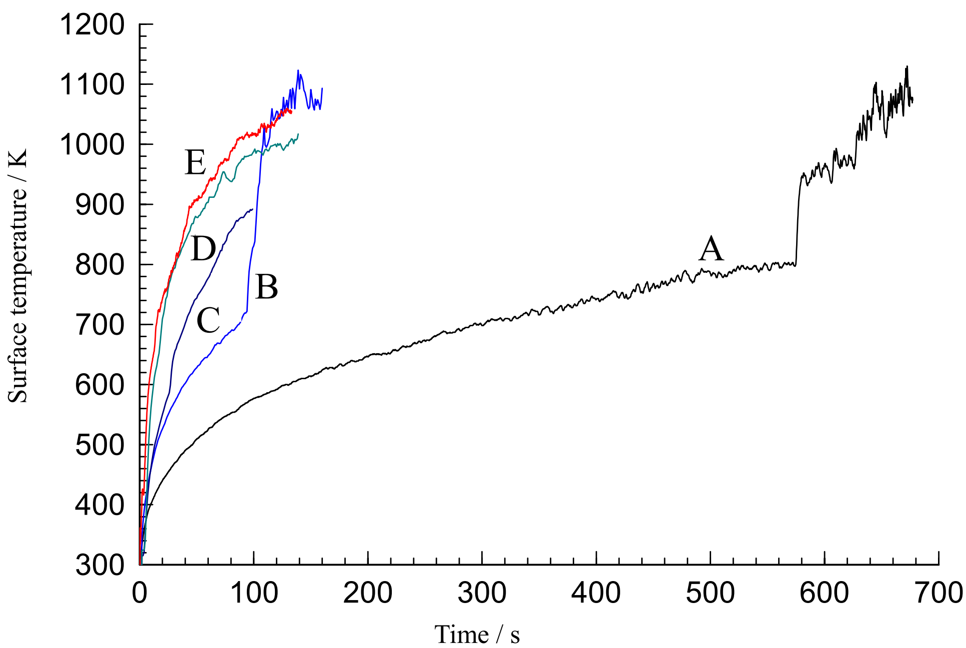

Fig. 4: Effect of heat flux on surface temperature

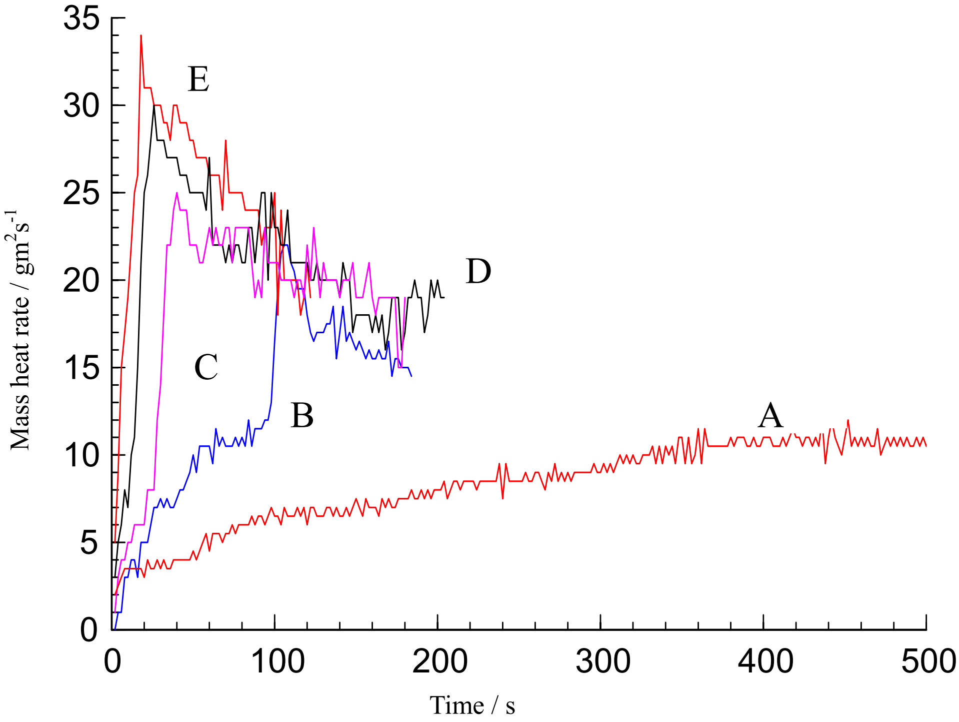

Fig. 5: Mass loss rate of birch under different heat flux

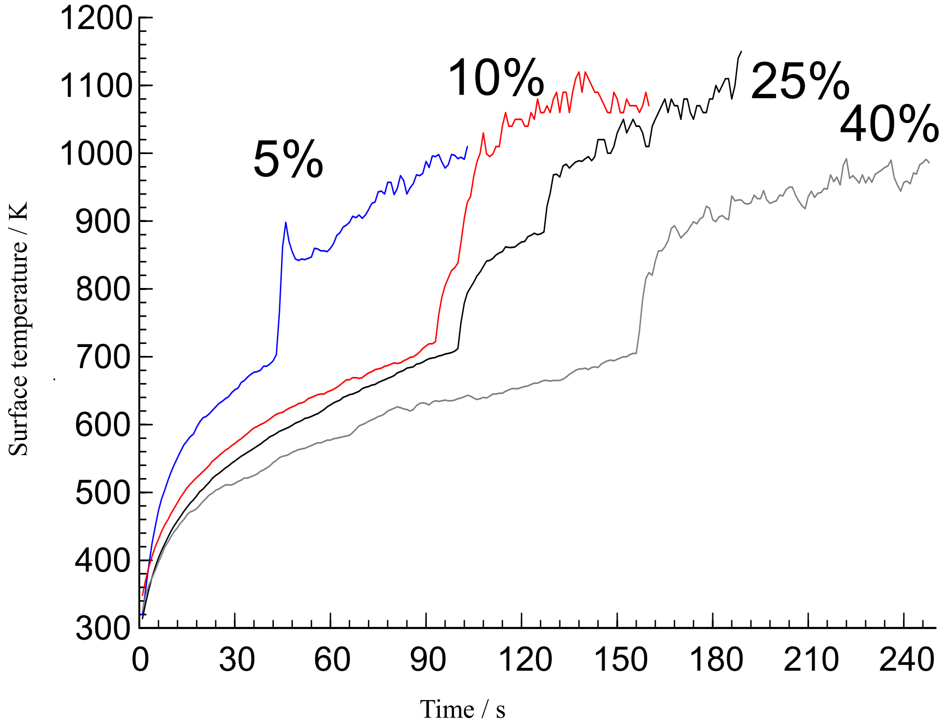

Fig. 6: Effect of moisture content on surface temperature of birch at 40 kWm^{-2}

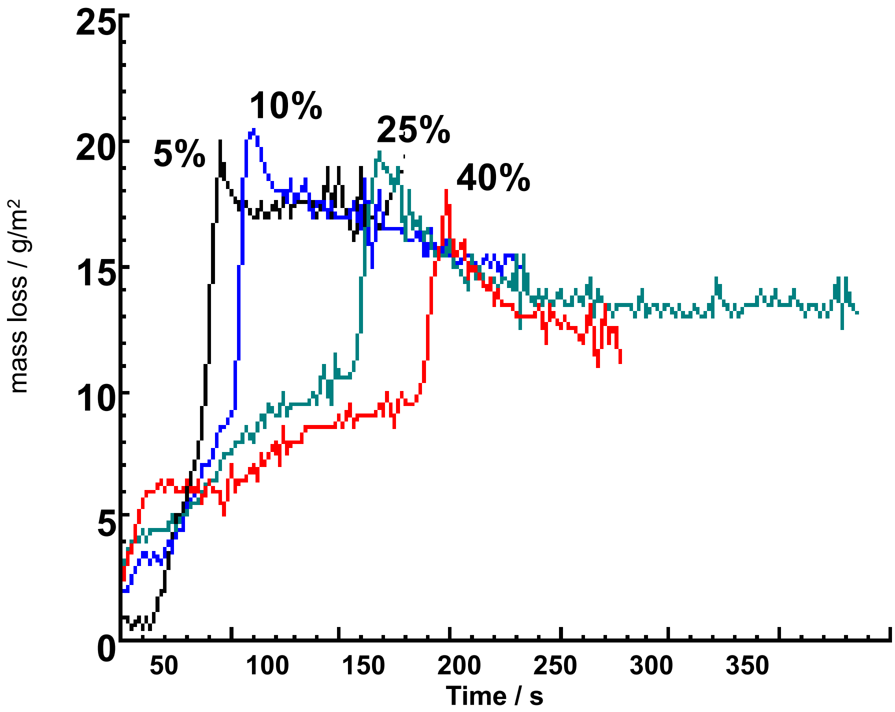

Fig. 7: Mass loss of birch at different moisture content tested under 40 kWm^{-2}

5. CONCLUSION

Fire safety of timber partition used in the Far East such as in Hong Kong is a concern. Timber might be ignited easily without any protection by fire retardant. The materials might be burnt completely under high radiative heat flux. A foam furniture burning adjacent to it would emit strong enough thermal radiation heat flux to ignite the timber partition.

In the fire safety codes of Hong Kong [e.g. 3], fire tests specified are the BS 476 on testing fire resistance [4] and surface spread of flame [6], or might include combustibility [22]. There are ignition tests on samples treated with fire retardant. However, full-scale burning tests such as the ISO 9705 room-corner fire test [9] on assessing the fire behaviour of partition walls are not yet specified. An immediate action is therefore to study the ease of ignition of local partition walls, then investigate how the results can be put into the building codes.

Pyrolysis and ignition of timber were affected by species, radiant heat flux and moisture content. The ignition temperature, ignition time and critical heat flux for ignition were measured to give a fire database for woods. There are still different pyrolysis models of woods. Effects of moisture content, shrinkage and mass measurement of volatiles should be considered. As the structure of the wood is complicated and not isotropic, a more realistic model should be developed for practical engineering use.

Appropriate fire tests on assessing the performance of partition wall are specified. All these will lead to answering the following question by means of measuring at least the rate of heat release [23]:

How big is the fire?

Full-scale burning tests on local partition materials should be carried out to have a good database.

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