The Study of Fire Safety for Multi-Storey Container Hotel: A Case Study in Muar PPT Hotel

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Abstract. Recent trends show diversified usage of container that usually intended as mobile transportation case for trading industry and now applied as building materials especially for commercial building such as hotel. However, as new material, it should comply with basic fire safety requirement which spelled out in the Uniform Building By-Laws (UBBL) 1984. In the construction laws of a building in Malaysia, the characteristics of building must comply with the requirement and regulations before it is being approved in the Certificate of Completion and Compliance (CCC). Thus, this study is focusing on the container materials and its compliance of fire safety requirements and strategies for multi-storey container hotel building. Literature review and case study are used in order to get the information and to compare the ability of the materials and construction to comply with UBBL 1984 in terms of passive design. The results of the evaluation show the possibilities of Multi-Storey Container Hotel to be built and used complied with passive fire safety requirement.

1. Introduction
The usage of container has becoming renowned building materials for the construction industry nowadays [1]. Prior to building approval from the local authority, this type of building materials are likely to be ascertained in the fire safety requirements just like the conventional building materials. Fire safety can be define as the precautions and factors to be considered in preventing and reducing fire and Malaysia has imposed legislations regarding requirements and methods of construction based on the standards that must be complied from UBBL and Fire Department of Malaysia (JBDP). There have been few discussions and disputes about the building constructions using shipping containers [2]. Steel that is a good conductor of heat may result specification of the steel shipping container as a major source of heat transfer and spread in the case of fire occurrence. A clear usage of the containers buildings have not been stated clearly in the UBBL and hence the existing requirements shall have to be scrutinized and adapted for the practicality of the modern containers as one of the building materials [3]. Thus, this study will aim to determine the application of fire safety for a case study of container building in relation to passive and active design approaches that will help to minimise the travel distance period during fire evacuation for purpose group of hotel building [3].

2. Literature Review
Container is a steel storage unit commercially used in transportation system especially in for long distance international trade. It is also reported that lower production cost of new containers has contributed to major increase in the number of used containers worldwide [2]. Known for its nature form
of flexibility in stacking arrangement, withstanding various conditions and temperature difference, container has now becoming a new trend of adaptive reuse in building construction \cite{4}. This method which has been widely used in applying for temporary building structures such as office, shoplots and house, has not only significantly reduced the construction waste and but also contributed to the cost-saving plan of a particular project \cite{4}. Due to the characteristic of good heat conductor, few exceptions and considerations however should made be clear on the benefits and disadvantages of using the steel containers.

2.1. Background of PPT Hotel, Muar
Located in the city of Muar, PPT Hotel Muar consists of the old and new building blocks (Figure 1).

2.2. Concrete and steel comparison
Concrete and steel have their own segregated properties and characters in the building materials. This comparison differentiate their strength in relations to fire resistance:

a) Concrete Properties. The strength of concrete will be slightly decreased when exposed to fire at 60-80\(^\circ\)C \cite{9}. The strength then increased about 10\% when exposed to fire at 150\(^\circ\)C (Figure 2). The strength of the concrete will however decreased back about from the last state when continue to be exposed to 400-500\(^\circ\)C of fire and becoming weaker from time to time until the strength is 40\% from the origin.
The crack of concrete can be examined by observation when exposed to the fire at 600-1000°C. It will then continuously develop with the increase in temperature. The strength of concrete is 20% from origin when tested with fire at 1000°C [6]. In the presence of fire, the gel between particles from the reaction of cement and water will continue to break and weaken the particle bonds which ultimately will turn the concrete brittle and fail to withstand the load.

b) Steel Properties. In July 1976, a large-scale test has been done by U.S Coast Guard Fire and Safety Detachment on steel container indicated that the maximum heat for internal fire can exceed 498°C in 8 minutes based on the oxygen and material contain in the container (Figure 3).

For external fire test, aluminium container loss its structural integrity when exposed to the fire at 232°C and start to melt at that temperature. Steel container shows no reaction when
exposed to the fire and maintain a sturdy condition [7]. However, it takes 4 minutes for fire to spread to adjacent container at the temperature 232°C for both types of container. This findings shows that steel container was designed with ability to withstand the above load for about 6-9 adjacent containers stacked on it.

2.3. Thermal environment during fire
During the fire in building, maximum temperature will cause the building structure to fail and collapse [8]. Thermal environmental during fire is depending on certain factors such as fire resources, condition, fuel composition and ventilation system. International Association of Firefighter (IAFF) have classified thermal condition to four classes that is routine, hazardous, extreme and critical (Table 1). In the event of critical class, it is recorded that the fire temperature are exceeding 1100°C and involved a flashover.

| Group, Year | Designation | Description | Ranges |
|-------------|-------------|-------------|--------|
| USFA FEMA, 1992 | Emergency | Severe and unusual, 15 to 30 s for escape | Temperature 300 °C (572 °F) to 1000 °C (1832 °F), Flux 25 kW/m² to 125 kW/m² |
| Apeles Project Fires, 1980 | Class 4 | Flashover or backdraft, up to 10 s | Temperature 250 °C (482 °F) to 815 °C (1500 °F), Flux 1.75 kW/m² to 42 kW/m² |
| IAFF (Based on Apeles), 1983 | Class 4 | Flashover or backdraft, up to 10 s | Temperature 260 °C (500 °F) to 815 °C (1500 °F), Flux 1.75 kW/m² to 42 kW/m² |
| Foster and Roberts, FRDG, 1995 | Critical | Could be encountered briefly | Temperature 235 °C (455 °F) to 1000 °C (1832 °F), Flux 10 kW/m² to 100 kW/m² |
| Coletta, 1976 | Emergency | Not normally encountered, may be during flashover | Temperature 300 °C (572 °F) to 1000 °C (1832 °F), Flux 8.3 kW/m² to 105 kW/m² |
| Abbott, 1976 | Emergency | Not normally encountered, may be during flashover | Temperature 300 °C (572 °F) to 1100 °C (2012 °F), Flux 12.5 kW/m² to 208 kW/m² |

2.4. Characteristics of Fire Safety in Building
It was established by the local governments in Malaysia that every development shall comply with the legislations imposed and obtain the required approval in writings before occupied by the user [9]. In this study, the scope of compliance is based on the fire safety requirement for building according to the requirements stated in UBBL and standards stipulated by JBDP. The requirements for fire safety in building was categorized by two systems that are passive system and active system [10]. Active systems serves as a protective and fire extinguishing system with additional equipment or systems installed in buildings such as automatic sprinkles, water spray system, high expansion foam system, wet and dry riser, fire alarm, command and control centre, communication system and emergency route plan[3].

The passive systems are measures in where inculcated during the preliminary design or conceptual stage for sufficient travel distance strategies for the building [10]. Below are few examples on the list of passive fire system according to UBBL:

a) Isolation of risk area. The area that classified as highly risk and contain fire-aid material such as fuel storage, laundry, workshop and harmful storage will be isolated from the user’s area to avoid the critical of fire.

b) Fire fighter access. Every building must be provided with enough fire fighter access which is 12 metre width opposite to the building according to UBBL.

c) Wall. The wall for the building must be built based on the function of the spaces. Internal divider wall must be more than 100mm thick and party wall with thickness 200mm with at least half hour of fire resistance.
**d) Insulated area.** Insulated area serves as a save area to the users and must be built for staircase, escalator to protect users to escape from the building from fire.

e) **Door.** According to Section 162 of UBBL, every area must be protected by fire resistance door for one hour. The door must be closed automatically by mechanical system and have openings that obey the requirements.

f) **Exit way.** The maximum exit-way with water sprinkler must be less than 45 meter and less than 30 meter for the exit-way without sprinkler system.

g) **Staircase.** Minimum width of the staircase was 700mm and the size of the staircase is based on 7th Schedule UBBL.

h) **Assembly area.** Assembly area is an evacuation point for users during the fire and it must have specific travel distance route accordingly.

### 3. Methodology

To complete this study, methods that have been used includes observation at site and interview with the local authorities involved in approving the PPT Hotel. Based on the observation, all information and graphical evident were collected to be analysed. The authorities involved in this study were MPM and JBDP Muar. The collected data is primary data type and this study is a qualitative research.

### 4. Results and Discussions

**4.1. Compliance to fire safety requirements for multi-storey buildings**

The floor plan in Figure 4 shown part of active fire protection appliances provision of the new wing extension to indicate and notify the occupants on position of emergency lights aligned with the exit route in the event of emergency. The plan also disclosing the nearest location of dry powders and hose reel systems to the users in which they are positioned in the designated pocket areas along the corridors. Prior to this approval of building plan from the local authority, submission of BOMBA plan addressing both of the passive and active fire protection system shall be concurrently submitted. It was highlighted under the submission procedure that those approximately 41 nos. ‘Kehendak-kehendak BOMBA’ or fire requirements which include passive and active system shall be verified by the submitting person prior to JBDP approval [9]. The following items are the fire safety requirements in terms of passive system complied in the earlier process:

1. An access road with a width of at least 6 meters which can carry a load of 25 tons indicated in the plan.
2. All electrical wiring for the emergency system installed in the conduit metal or from cables with fire-resistant mineral insulation. Installation was throughout the area with the least risk of fire and complied with fire section 253 of UBBL.
3. Usage of building ceilings fibre insulation board finished with one coat of flat oil-paint which complied to 8th Schedule of UBBL.
4. One hour fire door indicated in the plan and installation were self-closing, close-in and the opening lead to the stairwell.
5. Air conditioner ducting’s fitted with a fire damper where possible operated by 'fisible link/motorised' according to standard set by JBDP.
6. Dedicated electrical isolation switch not affected the emergency light. As per section 253 of UBBL, emergency light shall be provided to supply essential power automatically to save life and property in the event of normal supply failure.
7. The openings in the exterior walls located vertically above each other shall be protected by a fire extinguisher whether extended 750mm beyond the outer wall or on the floor level not less than 900mm.
8. Usage of glass on the exterior walls of the building was authorized by JBDP.
Below are list of JBDP compliance to the active fire protection system for the hotel new extension:

1. Emergency "Exit" sign using two power lines authorized by JBDP indicated in the plan.
2. Emergency light that uses two different power sources permitted by JBDP marked in the plan.
3. Hose reel system was applied in accordance to permitted provisions by JBDP.
4. Heat/Smoke detector was applied in accordance to permitted provisions by JBDP.
5. Fire glass alarm system was installed in accordance JBDP standards as per 10th Schedule of UBBL.
6. Fire extinguisher shall indicated in the plan according to Malaysian Standard (MS) 1539: Part 1: 2002
7. All fire safety appliances used complied with MS 982, 1985
8. 'Graphic Design of Floor Plan' signage with white based colour showing fire staircase, fire exit route, fire exit door and fire safety equipment installed were visible to occupants.
9. A break point installed on the exterior walls of the building for convenience purpose of firefighters to carry out operations.

Figure 4. Ground Floor Plan of the New PPT Hotel Wing

4.2. Exemptions requirements by authorities
The initial phase during the preliminary design checklist, submitting person will have to identify and establish the Usage Group stipulated in the 5th schedule of UBBL [3]. It was recorded through the discussion with JBDP in which this initial development fall under the 3rd purposed group and few exemptions which related to passive and active design system were later being identified and concurred by both authorities, i.e MPM and JBDP [9]. Below are agreed waivers of the passive fire protection system:

1. **Partition Wall.** Under Section 141 UBBL, this method was ignored since the containers used as the hotel rooms are the compartmentation wall and separating wall by itself in where authorities had given their permission in approving for the half an hour fire resistance for compartment wall.
2. **Exit-way limit/Maximum travel distance/Dead End Limit.** Under Section 165 UBBL, this hotel extension which uses un-sprinklered extinguishing system do complied with the maximum standard of travel distance of 30m stipulated in the UBBL to the nearest fire door escape. However, 12m dead end distance on the first floor level was not complied to the minimum standard of 10m was been given exception by JBDP.
3. **Compartment wall thickness of 112mm / 225mm brick to be built until roof or floor level as per floor plans.** Under Section 134, 136, 138 of UBBL, compartment wall should be built to the minimum standard imposed especially for those for the Purpose Group II (i.e. institutional, hospitals for living accommodation for persons suffering with disabilities, where such persons sleep in the premises) and but it was recorded on a discussion with authority that with the usage of containers for building wall and structure,

4. **Separation of fire risk area.** Boiler rooms, laundries, flammable liquids stores, transformer rooms and substations, linen rooms, liquefied petroleum gas, hazardous storage areas, repair shops involving hazardous processes and materials are among the fire risk area according to UBBL. These areas shall be separated from the other areas of the occupancy in which they are located by fire resisting construction of elements that to be determined by the local authority based on the degree of fire hazard. In the case of this hotel extension, the designated pipeline did not fall under the separation risk areas since none flammable gases were involved.

5. **Fire hydrant.** Located adjacent to the Main Block Hotel, the fire hydrant was also one of the requirements on the waiver lists since the existing nearby fire hydrant is within the 90m radius which is the minimum standard of compliance.

6. **Rising systems.** This specification is imposed for every building in which the topmost floor exceeding 18.3 meters as per section 232 of UBBL and installation shall be done immediately after the building exceeds the height to allow fire prevention system during the construction stage as per section 232 of UBBL.

7. **Automatic sprinkler system.** Automatic sprinkler system in accordance with Landmarks Provision Commission (LPC) regulations or JBDP standards was waived and according to 10th Schedule of UBBL the minimum requirement for the types of fixed extinguishing system for this particular purpose group is hose reel.

8. **Pump rooms.** It is required for fire pump rooms and generators to be constructed from two-hour fire-resistant brick walls and one-hour fire rated doors. However, in the case of this new PPT Hotel wings, the existing pump room in the old block will be utilised to accommodate fire appliances.

9. **Fixed carbon dioxide system.** It is required by JBDP where all 'Kitchen Hood' to be protected with fixed CO² system in accordance with NFPA requirements or JBDP standard. However, in this particular development, kitchen was not designated to serve in new hotel wing.

10. **Liquid petroleum gas room compliance.** Liquid petroleum gas (LPG) in bulk storage must be compliant as stipulated in MS 830 and MS 930 and to be built as a separate compartment wall. Due to none existence of kitchen spaces in this building, this requirement was being waived for compliance.

11. **Fire control centre.** Fire control centre is only required for building exceeding 30.5m high and shall situated on the designated floor and equipped with a panel monitor the public address, fire brigade communication, sprinkler, water flow detectors, fire detection and alarm systems and with a direct telephone communication to the appropriate fire station by-passing switchboard.

12. **Ventilation system for fire staircase either on a regular basis or mechanical.** In accordance to section 196 of UBBL, a single staircase may be permitted in any building the top most floor of which does not exceed 12m in height provided that each element of structure shall have fire resistance protection not less than one hour. Apart from that, it is also required that the travel distance shall be 12m measured from the door of the room or area to the exit provided path of travel from any point.

13. **Fire staircase to be enclosed with 115mm thick brick wall as indicated in the plans.** The top most floor for this new wing is approximately 8.3m and as per stipulated in the section 229 of UBBL only buildings exceeding 18.3 m above fire appliances access level shall be provided with means of gaining access and fighting fire from within the building consisting of firefighting access lobbies, firefighting staircases, fire lifts and dry or wet rising system.

14. **Fire lift.** Fire lifts has to be indicated in the plan accordingly to the requirements of the British Standard 2655: Part 1: Appendix E. As opposed to this particular development which is the top most floor is less than 18.3m, fire lift provision is not required.
15. **Firefighting access lobbies.** Requirement of the lift lobby does not apply for this particular extension project due not exceeding the minimum height but however should the firefighting access lobbies be constructed, two-hour fire rated materials and smoke detectors must be provided in accordance with UBBL, 1984.

16. **Emergency phone.** Due to none means of access for firefighting in building below 18.3m, emergency phone are not required for this new hotel wing. This phone will normally be allocated in fire staircase, protected lobby, elevator motor room, fire pump room and power room if it is required.

17. **Fire staircase to be designated for fire escape route.** JBDP do imposed a strict guideline for all stairs of any buildings exceeding 30 m to be designed for fire escape route till roof level which this requirement did not applied for this hotel extension.

18. **Central core staircase.** As per section 197 of UBBL, due to none existence of protected lobbies which must be provided to serve staircase in the building exceeding 18m above ground level, this requirement is being waived for this new wing extension and shall central core staircase be required to be built for any building exceeding 18m, it should comply to standard system of Australia 1668: Part 1: 1974 or any determination permitted by JBDP and for building exceeding 45m such protected lobbies shall also be pressurized as per JBDP standard.

The following are list of waivers of the active fire protection system agreed by JBDP:

1. **Computerised Monitoring System.** This requirement only applied for each premises or building larger than 30.5 meters high shall equip with a Computerised Monitoring System to JBDP as per article 228 and article 238, UBBL, 1984.

2. **Wet/Dry riser.** This particular requirement did not imposed to the hotel extension due the top most floor was not exceeding the minimum requirement for rising system which 18.3m height and shall the wet or dry or both required in building, its installation shall complied in accordance to the section 230 and 231 of UBBL.

3. **Smoke extractor system.** Smoke extractor system was not imposed to this building due to none existence of the basement level and this system are required for a building which has basement and lower ground floor and to be installed accordingly to Australian Standards 1668: Part 1: 1974 or any provision authorized by JBDP.

4. **'Smoke spill water' system.** As per 10th Schedule of UBBL which discussed on the fire extinguishing system, alarm system and emergency lighting system, this hotel extension do only required fire hydrant system for fixed extinguishing system as opposed to the smoke spill water system.

Automatic sprinkler system in accordance with Landmarks Provision Commission (LPC) regulations or JBDP standards was waived and according to 10th Schedule of UBBL the minimum requirement for the types of fixed extinguishing system for this particular purpose group is hose reel.

5. **Installations of CO² gas installation.** Installations of CO² gas in accordance with National Fire Protection Association (NFPA) requirements or JBDP standard as indicated in the plan shall be imposed for the transformer room, high voltage switch room (which applicable), power room and TNB electrical room with two-hour fire rated door in the room.

5. **Conclusions**

This research paper which discussed on fire safety study of multi-storey containers hotel demonstrate the feasibility of steel container and its compliance to the fire safety regulation in terms of passive and active system.

It is proven that the general current standards spelled out in the acts can still be implemented. However, specific requirements and specifications dedicated for container building is required to be addressed to allow clear understanding on the safety and method of constructions in future [11].
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