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DESIGN CONSIDERATION OF CONTAINER SHELTER IN MALAYSIA

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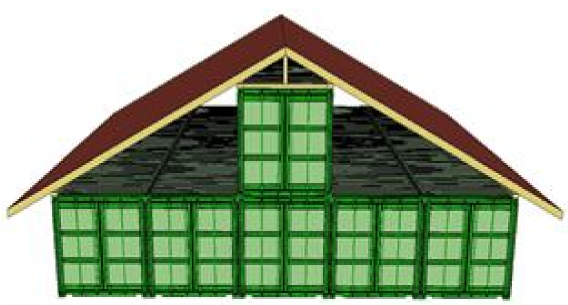
Graphical abstract



Abstract

Freight container can become a potential candidate for shelter provision to resolve the housing crisis from increasing refugee population. Currently the freight container is made in accordance with ISO standard, but for living purpose other consideration must be included, especially the requirement from local government. This paper aims to investigate the design consideration of container shelter from legislative perspective in Malaysia. Uniform Building By-Law 1984 was referred, and ventilation, structural and fire requirement of by-law were compared with ISO standard for freight container. Suggestions were made to ensure the structural and legal integrity of container shelter in Malaysia. Potential container building concept was proposed based on design suggestion.

Keywords: UBBL, ISO, shipping container, shelter, design recommendation

Abstrak

Kontena kargo merupakan calon potensi sebagai tempat perlindungan untuk meneyelesaikan krisis perumahan disebabkan dari penambahan populasi pelarian. Walaupun kontena kargo dibuat mengikut piawai ISO, pertimbangan kediaman lain terutamanya keperluan kerajaan tempatan mesti dirangkumi. Tujuan artikel ini adalah untuk menyiasat pertimbangan reka bentuk tempat perlindungan kontena dari perspektif perundangan Malaysia. Merujuk Uniform Building By-Law 1984, keperluan undang bagi pengudaraan, struktur dan api telah dibandingkan dengan piawai ISO kontena kargo. Cadangan struktur dan integriti undang-undang bagi tempat perlindungan kontena dalam Malaysia juga dicadangkan. Konsep bangunan kontena berpotensi juga dicadangkan.

Kata kunci: UBBL, ISO, kontena kargo, tempat perlindungan, cadangan reka bentuk

1.0 INTRODUCTION

Shelter provision had become more challenging as the refugee population had increased during recent years. With more than 68.5 million people been forced to displaced due to persecution, conflict and natural or man-made disasters [1]. In Malaysia alone, there were more than 100,000 refugees been registered to United Nations High Commissioner for Refugees [2]. Lots of these refugees still do not have their personal accommodation, more precisely 39% of 16.9 million global refugees whose accommodation was known [1].

Traditional shelter provision such as camp and tarpaulin can only be temporary solution as these shelters were not designed for long-term residential purpose. Besides, they also impact the surrounding environment by using natural resources and emit solid or liquid wastes [3]. Some alternatives had been proposed and one of the more appealing solution is transitional shelter. In short, transitional shelter is the shelter that can be upgraded, reused, relocated, resold and recycled [4]. This incremental approach to provide shelter had been implemented in several countries, such as Sri Lanka, Jogjakarta, Aceh, Peru and Haiti [5]. Recently the uses of freight container as transitional shelter had gained attention among researchers. Due to its faster erection time and ability to be pre-fabricated in factory, container shelter can be purposed as transitional shelter [6]. Research had also been carried out on the feasibility of container transitional shelter [7, 8] and the acceptance of local developer on container house [9].

Most of the commercial freight container are manufactured according to ISO specification. However, they are designed for cargo transportation purpose in mind. The residential building should be constructed in accordance with Code of Practice and local government law. In Malaysia, Uniform Building By-Laws 1984 [G.N. 5178/85] (UBBL) as at 1st November 2015 was often referred as the legislative requirement on building [10]. UBBL is categorized into nine parts with ten schedules as supporting documents.

This paper aims to investigate the structural design consideration of a container shelter based on legislative requirement in Malaysia. Uniform Building By-Laws was referred and all related clause on residential building was extracted and compared with container shelter specification. The mandatory requirements were listed out and compared to specification of freight container which in compliance to ISO standard. Suggestions were made on container shelter construction in order to fulfil the UBBL requirement.

2.0 METHODOLOGY

Uniform Building By-Laws 1984 [G.N. 5178/85] was referred in this paper for investigation of the legislative requirement of building in Malaysia. For the shelter construction purpose, the discussion focused on Part 3- Space, light and ventilation, Part 5- Structural requirements, and Part 7- Fire requirements. The legislative clauses were then compared with ISO requirement for standard cargo container to check for fulfilment of clauses. Some design recommendations of container shelter were proposed in accordance to the discussion.

3.0 RESULTS AND DISCUSSION

3.1 Space, Light and Ventilation.

UBBL had specified minimum opening size of each room for natural lighting and air ventilation, which were summarized in Table 1. According to Clause 39, every room, except bathroom, shall have one or more windows with total opening area not less than 10% of clear floor area of the room with not less than 5% of total opening area is capable of allowing uninterrupted air passage. For bathroom or water-closet, the minimum opening area of 0.2 m^2 should be provided for uninterrupted passage of air.

According to Clause 40, if air-well is used for natural lighting, each air-well should have minimum width of 2.5 m and minimum size of 7 m^2. For air-well in bathroom the minimum width and size can be reduced to 2 m and 3.5 m^2 respectively.

Both clauses 39 and 40 may be waived if permanent mechanical ventilation or air-conditioning is provided with provision that Third Schedule to By-law is applied at the discretion of the local authority.

UBBL had also established the minimum room dimension of residential building for ventilation requirement in clauses 42, 43 and 44. For any habitable room, minimum width of 2 m shall be applied and minimum area of 11 m^2, 9.3 m^2 and 6.5 m^2 should be provided for first habitable room, second habitable room and subsequent other rooms. These rooms shall also have height of no less than 2.5 m. For kitchen, the minimum width, height and floor area specified by UBBL were 1.5 m, 2.25 m and 4.5 m^2 respectively. As for bathroom with closet fitting, the minimum width, height and floor area of 0.75 m, 2 m and 2 m^2 shall be complied.

Table 1 Light and ventilation requirement by UBBL [10]

Usage of room	Minimum opening area	Minimum air-well width / area	Minimum room width (m)	Minimum room height (m)	Minimum room area (m^2)
Bedroom	>10% of floor area	2.5 m / 7 m^2	2	2.5	11 (1st room) 9.3 (2nd room) 6.5 (subsequent room)
Kitchen			1.5	2.25	4.5
Dining room and public room			2	2.5	Not applicable
Toilet	0.2 m^2	2 m / 3.5 m^2	0.75	2	2

Table 2 Imposed floor load by UBBL Fourth Schedule [10]

Usage of room	Intensity of distributed load (kN/m^2)	Concentrated load over any square with 300mm side (kN)
Bedroom	1.5	1.8
Kitchen	3.0	4.5
Dining room and public room	2.0	2.7
Laundry	3.0	4.5
Toilet	2.0	2.0
Staircase	1.5	1.8

3.2 Structural Requirement

According to clause 54 in UBBL, all dead load and imposed load shall be calculated with reference to latest British Standard Code of Practice. Since British standard had been superseded by Eurocode, it is recommended that MS EN 1991-1-1:2010 to be referred in current state [11]. However, the designer shall alert on difference between Eurocode and UBBL requirement and consult to local authority if necessary.

The unit weight of materials shall refer to Fourth Schedule of By-law in accordance with Clause 56. In MS EN 1991, Annex A is referred, and term density is used instead of unit weight. Eurocode provides more extensive range of material selection and more detailed material classification compared to UBBL.

For imposed load on the floor, table "Uses and Loads" in Fourth Schedule shall be referred in accordance with Clause 59. Table 2 summarized the requirement on imposed floor load for residential purpose building. UBBL had specified that all floor slabs shall be able to sustain distributed load or concentrated load whichever will produce maximum stresses. The concentrated load should be applied at position where maximum stress occurs, or position where maximum deflection if deflection is considered in design criteria.

The imposed roof load of building was given in Clause 63. For flat roof as barebone container shelter, 1.5 kN/m^2 of distributed load and 1.8 kN of concentrated load over square with 125 mm side shall be included if roof is accessible for repair and cleaning. If the roof is not accessible except for maintenance, the imposed load can be reduced to 0.25 kN/m^2 of distributed load and 0.9 kN of concentrated load

3.3 Fire Requirement

Clause 165 of UBBL had stated that the maximum travel distance of any room inside building to exists should comply to requirement specified in Seventh Schedule. For small residential building such as detached container shelter, there is no mandatory requirement for maximum travel distance, which makes the room layout to be more flexible.

According to Part 2 of Ninth Schedule, minimum fire resistance period (FRP) of building elements in single storey residential building is half-hour. In addition to that, all external wall shall have FRP of half-hour and any separating wall adjoining two buildings shall have FRP of one hour. Steel wall such as container shelter shall also comply the FRP requirement in accordance with Table B and C of Part 1 "Notional Periods of Fire Resistance" in Ninth Schedule. The minimum FRP depends on the type of cladding used in wall construction. Part 5 of Ninth Schedule also stated the minimum thickness of different protection required to cover structural steel for different FRP. In general, UBBL allowed both solid protection and hollow protection with some protection only limited for shorter FRP.

3.4 ISO Specification of Freight Container and Design Consideration of Container Shelter

ISO had standardized both the external and internal dimensions of freight container as shown in Table 3 [12]. With internal width of 2.3 m for every container class, the minimum width of 2 m required by Clause 42 can be fulfilled. For minimum height requirement, all standard container will only have 2.35 m of clear height whereas the high cube container has 2.655 m of internal height. Since the UBBL requires minimum height of 2.5 m for habitable room, only high cube container such as 1EEE, 1AAA and 1BBB type container are allowed without any modification. However, any ceiling works such as false ceiling more than 15 cm depth shall be avoided.

Table 3 ISO Specification on Dimension and Rating of Freight Container [12]

ISO Designation	Common Name	External dimension (mm)			Internal dimension (mm)			Rating (kg)
		Length	Width	Height	Length	Width	Height	
1EEE	45' high cube	13716	2438	2896	13542	2330	2655	30480
1EE	45' standard			2591			2350	
1AAA	40' high cube	12192		2896	11998		2655	
1AA	40' standard			2591			2350	
1BBB	30' high cube	9125		2896	8931		2655	
1BB	30' standard			2591			2350	
1CC	20' standard	6058		2591	5867		2350	

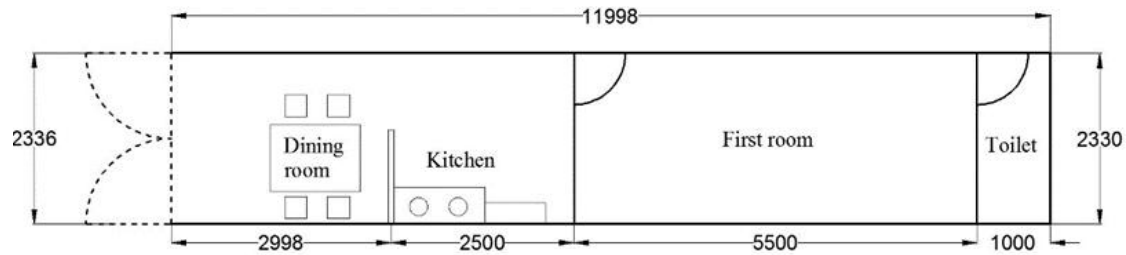


Figure 1 Layout suggestion for 40-feet container

For standard type container, major modification on roof is necessary for minimum clear height at habitable room whereas for kitchen area and bathroom the existing internal height is enough.

For size of opening at container wall, although currently there is no limitation of maximum opening size suggested in Eurocode, some recommendations had been proposed by European Convention for Constructional Steelwork (ECCS) [13]. In general, ECCS suggested that maximum area of opening to be controlled to 12.5% of total area in each container wall or 15% with detailed calculation on wall stiffness control. With the consideration of minimum opening for natural light and ventilation, 10% to 15% of container wall can be modified as windows with minimum 5% of opening for uninterrupted air passage. All openings should also be supported by steel trimmers as reinforcement of structure suggested by ECCS. These opening sizes can be further reduced by introducing air-conditioning as alternative ventilation.

By considering minimum room dimension, 20-feet container can only have one bedroom, one kitchen and one bathroom with closet fitting. If minimum floor area of 11 m^2 for first habitable room is applied, a single 20-feet container can only have one room and one bathroom. Hence, the available space limitation of freight container can be solved by either extension of building, using open kitchen, external bathroom etc. For 40-feet container, suggested room layout was proposed as shown in Figure 1.

By taking average distributed load of 2.0 kN/m^2, total imposed load on container shelter can be estimated to be 105 kN. With every container had to achieve 300 kN of loading including selfweight of container (2300 kg for 20 feet container and 3750 kg for 40 feet container), the container steel is considered capable to sustain residential loading according to ISO 1496 requirement [14, 15]. However, the strength of timber floor in container had to be investigated and replaced if deflection requirement is not fulfilled. In Eurocode 3, the vertical deflection limit of the floor should be less than 16 mm for 20-feet container and 33.3mm for 40-feet container [16].

For fire resistance requirement, since container steel is exposed to air for both structural members and wall, suitable insulation shall be done to fulfil the FRP rating. Both BS EN 1363 and ISO 834 had provided standard fire resistance test for building [17, 18]. For steel structure design, BS EN 1993-1-2 provides structural fire design guideline under ultimate and serviceability limits [19]. For ease of installation, 12.5 mm plasterboard on steel wall is recommended for one-hour FRP. For structural members, either solid protection or hollow protection is suggested with consideration of wall thickness, availability and ease of installation.

To summarize all clauses for the design requirement across each standard, the designer can refer to Table 4.

3.5 Potential Construction Recommendation for Container Shelter

One of the advantages of using container in housing construction is their modular design and stacking ability. From Clause 124, it is compulsory to have lift provided for all non-residential building with more than four storeys. Hence for residential container shelter it is recommended to build up to four storeys for ease of future repurpose into commercial building such as shop or office.

Table 4 Summary of design requirement for each standard

Design requirement	UBBL	Eurocode	ISO
A) Space, light and ventilation 1. Minimum opening size 2. Minimum room dimension	Clause 39, 40, 41 Clause 42, 43, 44	ECCS 1995 No.88	ISO 668
B) Structural requirement 1. Dead load and Imposed load 2. Unit weight of materials	Clause 59, 63, BSCP 3 / 4th Schedule BS 648 / 4th Schedule	MS EN 1993-1-1	ISO 1496
C) Fire requirement 1. Minimum travel distance 2. Minimum fire resistance period	7th Schedule 9th Schedule	BS EN 1993-1-2	ISO 834

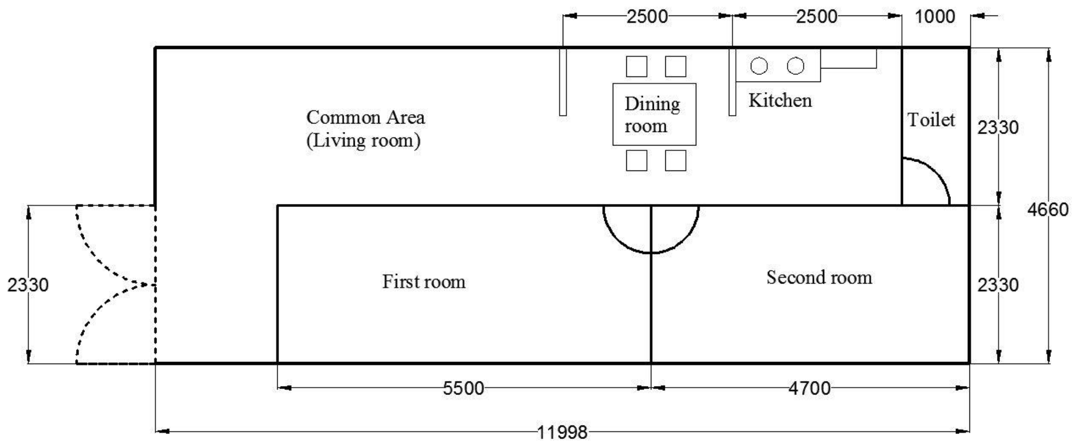


Figure 2 Layout suggestion for two 40-feet container

Container can also be located side-by-side to increase the usable floor area, thus accommodate more vacant areas for bigger family or more comfortable living space, for example with Figure 2.

Although UBBL does not limit how the container can configure during stacking, in most practice the rule of thumb for cantilever length of container should be less than 25% of total container length [20]. Some ideas of container shelter cluster were illustrated as Figure 3 to Figure 7.

Figure 3 demonstrated residential house with five 40-ft containers stack side by side to provide more usable space. A container can be located at second storey to provide more vertical space and support for inclined roof design. The additional spacing beneath the roof can also be modified as storage room.

Figure 3 Concept of residential container house

Figure 4 showed the concept of container warehouse. By utilizing the stackable container to provide height, a simple warehouse with clearance on ceiling can be constructed. Additional space among two container stacks can also be adjusted provide that the roof load, pitch and span is controlled.

Figure 4 Concept of container warehouse

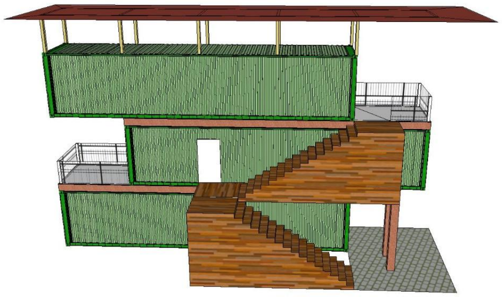


Figure 5 A three-storey container house with cantilever balcony

Figure 5 showed the container stacks with cantilever design. The space provided by cantilever design can be used as balcony and provides shading for lower storey. Cantilever container design can be a more efficient use of limited land area and provide more usable space.

Figure 6 showed the usage of container in school building with conventional layout. The provision of balcony can increase usable space and prevent the main office building from direct expose to sunlight.

Figure 6 A three-storey container school building with balcony

In Figure 7, both 20-feet and 40-feet containers are used and stacked together to construct a container building with balcony and carpark with shading. 20-feet containers together with additional column can provide support for 40-feet container at upper level, with more uninterrupted land area can be utilized as carpark or other purpose such as recreational zone.

Figure 7 Container building with both 20ft and 40ft containers

4.0 CONCLUSION

Container shelter can become a feasible solution for housing supply shortage. With some modification on container structure the container shelter can fulfil the UBBL requirement and able to deliver satisfactory living experience in Malaysia. For recommendation of further research, other considerations that are not covered in UBBL such as lighting protection and corrosion of steel materials are encouraged to be investigated for more comprehensive study.

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References

[1] United Nations High Commissioner for Refugees. 2018. Global Trends: Forced Displacement In 2017.
[2] United Nations High Commissioner for Refugees. Accessed in 2nd June 2019. UNHCR Statistics: The World in Numbers. http://popstats.unhcr.org/en/overview#_ga=2.27996412.1175683717.1559477569-470370476.1559477569.
[3] Suwattana Thadaniti and Supang Chantavanich. 2014. The Impact of Displaced People's Temporary Shelters on their Surrounding Environment.
[4] International Federation of Red Cross and Red Crescent Societies. 2011. Transitional Shelters-Eight Designs (G. Saunders Ed.).
[5] UN-HABITAT. 2009. Shelter Projects 2008: International Federation of Red Cross and Red Crescent Societies (IFRC).
[6] J. D. Smith. 2006. Shipping Containers as Building Components. Thesis. University of Brighton.
[7] Tan C. S. and Ling P. C. H. 2018. Shipping Container as Shelter Provision Solution for Post-Disaster Reconstruction.

E3S Web of Conferences 65. 08007. https://doi.org/10.1051/e3sconf/20186508007.

[8] Tan, C. S. and Nussbaumer A. 2018. Structural Feasibility of ISO Shipping Containers for Core-dwelling Housing. *IABSE Conference – Engineering the Developing World.* April 25-27th 2018, Kuala Lumpur, Malaysia.

[9] Wong E. K. H., Tan C. S. and Ling P. C. H. 2018. Feasibility of Using Iso Shipping Container to Build Low Cost House in Malaysia. *International Journal of Engineering & Technology*. 7(2.29): 33-939.

[10] Uniform Building By-laws 1984 [G.N. 5178/85]. 2015. *Laws of Malaysia.*

[11] Department of Standards Malaysia. 2010. MS EN 1991-1-1:2010. Eurocode 1: Actions on Structures- Part 1-1: General Actions- Densities, Self-Weight, Imposed Loads for Buildings.

[12] British Standard Institution. 2016. BS ISO 668:2013+A2:2016. Series 1 freight containers—Classification, Dimensions and Ratings.

[13] European Convention for Constructional Steelwork (ECCS). 1995. European Recommendations for the Application of Metal Sheeting Acting as a Diaphragm—Stressed Skin Design.

[14] DSV - Global Transport and Logistics. Accessed in 2nd June 2019. http://www.dsv.com/sea-freight/sea-container-description/dry-container.

[15] British Standard Institution. 2016. BS ISO 1496-1:2013+A1:2006. Series 1 freight containers—Specification and testing Part 1: General Cargo Containers for General Purposes.

[16] Department of Standards Malaysia. 2010. MS EN 1993-1-1:2010 (NA): Malaysia National Annex to Eurocode 3: Design of Steel Structures - Part 1-1: General Rules and Rules for Buildings.

[17] British Standard Institution. 2012. BS EN 1363-1:2012. Fire Resistance Tests. General Requirements.

[18] International Organization for Standardization. 1999. ISO 834:1999. Fire-resistance Tests — Elements of Building Construction.

[19] British Standard Institution. 2006. BS EN 1993-1-2:2005. Eurocode 3: Design of steel structures—Part 1-2: General Rules — Structural Fire Design.

[20] Socrates A.I. and Ruddy, P. E. 2000. Rules of Thumb for Steel Design. *North American Steel Construction Conference 2000.*