Journal of Engineering and Applied Sciences 14 (5): 1430-1437, 2019
ISSN: 1816-949X

A Study on a Plan for an Assembly-Type Temporary Housing Facility Usable in Times of Disaster

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Abstract: Natural disasters have been on the rise due to the effects of environmental pollution. In addition, man-made disasters have also, been on the rise due to the effects of urbanization. As the types of such disasters have become increasingly varied and their associated damages have also, increased in scale, interest in ensuring appropriate responses and providing supplies to disaster victims has also, increased. In light of this, there is a need to quickly provide facilities that can ensure the safety of disaster victims who have lost their homes or are in need of evacuating. This study compared domestic and overseas cases to extract factors necessary for temporary housing facilities. The ultimate goal of this study is the development of a plan that includes assembly-type temporary housing facilities with high provisional capacities that are usable prior to the establishment of permanent housing facilities.

Key words: Disaster, assembly-type, temporary, housing facility, changeability, expandability

INTRODUCTION

Background and purpose of the study: Due to the effects of climate change, the frequency of natural disasters has increased while man-made disasters have also been on the rise due to the rising population densities associated with urbanization. As the types of disasters have become increasingly varied and their scale and damages have also, become larger the number of victims of such disasters has also been on the rise. For the purpose of safeguarding minimal rights to housing and ensuring the safety of disaster victims it is essential to provide victims who have lost their homes and been evacuated a space in which they can safely reside for a certain period of time.

Because of this, temporary housing facilities capable of accommodating various types and scales of disasters, regional conditions and environmental conditions are needed and such facilities must satisfy the required standards associated with applicability and minimum area. Despite a global increase in research and development regarding spaces and forms of temporary housing facilities, there has been a lack of related studies in South Korea and due to the limited applicability of the findings of overseas research to South Korea, a plan that is appropriate for South Korea is needed. This study aims to develop a plan for temporary housing facilities that can be used until permanent housing can be provided to disaster victims who have lost their homes.

Scope and method of research: After calculating the minimum required area of temporary housing facilities, this study established the direction in which the plan for temporary housing facilities should develop in consideration of provisional capacity, safety, sustainability, changeability, potential for storage and environmental friendliness and based on analyses of domestic and overseas temporary housing facilities. As a result of these efforts, forms of temporary housing facilities and cluster layouts were proposed and further studies regarding their suitability were undertaken. Before engaging in research, the previous research was analyzed to identify problems and analyze the means of improving and developing existing temporary housing facilities. Using factors extracted from the analysis of cases, methods of improvement were proposed. The temporary housing facilities discussed in this study are limited to the residential sector, core sector facilities are excluded from this study.

Analysis of existing research: Kyeong-Nam *et al*. (2007) undertook research to develop temporary housing facilities that address the disadvantages of some temporary housing facilities. These research efforts, however do not include considerations for provisional capacity and are focused on improving residential environments regarding the supply of space that provide physical safety for disaster victims who have lost their homes.

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Yeong-Hak *et al*. (2011) undertook comparative research related to minimum residential spaces in South Korea and Japan based on Post Occupancy Evaluations (POE) associated with assembly-type housing deployed during the shelling of Yeonpyeong Island. The study proposed plans based on different combinations of modular units that account for differences in the size and composition of the families of disaster victims. However, like the first study mentioned, this study, also, focused on improving the residential environment of disaster victims and excluded further studies associated with provisional capacities.

The study that most closely resembles the current one was the study by Dong-Un and Tae-Hyeon (2011) on panel assembly-type temporary housing facilities capable of quick deployment due to the use of panel modules and lightweight materials. However, the solution proposed by this study had shortcomings in the area of simplicity and panel production in that a total of 9 modules were needed for assembly.

Using the findings of 3 domestic and overseas research papers, data from 6 WHO, UN and IFRC reports and cases of uses of outdoor temporary housing facilities between 2001 and 2013 in Southeast Asia, Sara and Kyeong-Sook (2015) published a study regarding the 'features and details required of temporary housing during times of disaster' and this was considered as appropriate to use as reference material for this study.

Review and analysis of domestic and overseas temporary housing facilities: Comparative analyses and case studies regarding domestic and overseas temporary housing facilities were undertaken. By referring to the features of existing research, criteria appropriate for South Korea were extracted. The criteria consist of 6 technological aspects and 2 environmental aspects. The comparative analysis table is as presented in Table 1.

Table 1: Comparative analysis table

Characteristics/Criterion	Details
Technological	
Transport ability	A criterion used to compare different loads appropriate for transportation for the purpose of deployment
Storage ability	A criterion used to compare the ability to preserve the durability of a facility during storage for the purpose of preventing one-time use
Structurality	A criterion used to compare structural autonomy in response to outdoor environments
Assemblability	A criterion used to compare the number of tools needed for assembly or the simplicity of assembly during installation of facilities
Changeability	A criterion used to compare additional expandability, time needed to install or the simplicity of the installation and transportation process
Environmental friendliness	A criterion used to compare the composition of environmental friendly materials in a facility
Environmental	
Sustainability	A criterion used to compare minimal amounts of energy generation
Layout plan	A criterion used to compare layout plans and the existence of layout planning accounting for greater psychological stability of disaster victims

A total of 8 cases of temporary housing facilities including 2 domestic and 6 overseas cases were studied. The study contents are as shown in Table 2.

Table 2: Comparative analysis table of south korean temporary housing facilities characteristics

Criterion	A	B	C	D	E	F	G	H
Technological								
Transportability	Δ	○	○	○	○	○	○	Δ
Storage ability	Δ	Δ	Δ	Δ	○	○	○	Δ
Structurality	○	Δ	Δ	Δ	Δ	Δ	Δ	○
Assemblability	×	Δ	○	Δ	×	○	Δ	×
Changeability	×	×	×	Δ	○	Δ	Δ	○
Environmental Friendliness	×	×	Δ	×	Δ	Δ	○	○
Environmental								
Sustainability	Δ	○	Δ	Δ	×	Δ	Δ	○
Layout plan	×	Δ	×	○	×	○	×	×

○: Excellent application of the criterion; Δ: Partial application of the criterion; ×: No application of the criterion

Container type-(A) is a facility initially used as a temporary housing facility in South Korea that is a simple improved version of a container. Such facilities did not consider any aspects associated with assembly and changeability and were inconvenient to transport and store. This type of facility had no structural problems but lacked facilities fit for residential environments and did not account for any layout planning. To address this issue, assembly type housing-(B) was manufactured. However, this type of facility proved difficult to assemble on-site and was developed without consideration of the need for facility expansions. In the case of overseas facilities with the exception of EDV-01 (Emergency Disaster Vehicle-01)-(H) most of the facilities took transportability into consideration. The facilities, also, needed only small spaces for storage but there were concerns over reduced durability. However, in the case of MyHab-(C) its envelope which is based on recyclable plastics, makes it possible for it to be easily replaced in the event of damage. In addition, most of the facilities were designed to have a changeable structure or assembly-type structure for the purpose of convenient transportation and Recovery Huts-(F) were found to have excellent cluster layout plans. Upon opening the EDV-01 (Emergency Disaster Vehicle-01)-(H) the facility expands to include 2 floors. The facility presented the most excellent residential environment with residential spaces in the 2nd floor and spaces for other facilities in the 1st floor, yet was lacking in terms of provisional capacity (Table 3) (Hannah and Kil-Yong, 2004; Hyun-Sun, 2016; Won *et al*., 2015; Woo-Chul *et al*., 2012, 2013).

Table 3: Cases of temporary housing facilities

Items	Photo	Features	Parameters
Container type (A)		Size	20 ft, 6,000×2,450×2,650 m^3
		Spatial composition	No separate composition of spaces; Flooring has been renovated for winter season insulation and heating purposes
		Materials	Same materials as existing containers
Assembly type housing (B)		Size	6,000×3,000 mm^2
		Spatial composition	Living Room 1, Kitchen 1, Bathroom 1, Storage room 1, Boiler room 1
		Materials	Sandwich panels including fire resistant materials
Myhab (C)		Spatial composition	Single space, 2 person housing
		Materials; Frame	Recyclable plastic
		Walls	Waterproof boards
		Environmental friendliness	Use of recyclable plastic
Sphere emergency shelter (D)		Spatial composition	Composed of 19 lower area tents and roofing
		Materials; Frame	Fibreglass plastic
		Interior	Lightweight nylon material
		Exterior	Waterproof canvas
		Environmental friendliness	Long lifespan, recyclable
		Expandability	Expansion and contraction of spaces using partitions
Recovery shelter (E)		Spatial composition	Single space with no partitions
		Materials	Non-toxic polypropylene
		Environmental friendliness	Collection of water achieved through roofing structure; 100% recyclable
		Convenience	Blocking of outdoor air reinforced using on-site materials 1 man installation under 1 minute possible Transportation in a horse-shoe shape or board shape possible
		Changeability	Shapes change according to unfolding methods
		Size	Width 3~3.6 m, Height 2.4 m (7.89)
Recovery huts (F)		Spatial composition	Single space; Bent shaped area 0.6 m in height on top of the 1.8 m structure used as storage space
		Materials; Frame	Biax material
		Walls	Biax material, semi-transparent material allowing natural light
		Provisional capacity	1 man assembly under 30 min. possible. Composed of 4 overlapping pieces in which each piece does not weigh more than 27.21 kg
		Convenience	Possible to connect all shelters
Better shelter of IKEA foundation (G)		Module size	3320×5680×2830 mm^2 (17.5 m^2)
		Spatial composition	Single residential space
		Materials; Frame; Panel	Galvanized steel, Polyolefin with UV blocking features
		Environmental friendliness	PV system solar panels; Roof ventilation Possible to individually replace parts; Recyclable
		Convenience	Two board-type package boxes weighing 80 kg 4 man assembly within 4-8 hours without tools possible
EDV-01 (Emergency 6058×Disaster vehicle-01) (H)		Module size	1 Floor: 6058×2591×2438 mm^2 (WHD) 2 Floors: 4511×2438 mm^2 (WHD)
		Module area	15.7 m^2
		Spatial composition	
		2 Floors	1 Bedroom; 2 foldable beds, 2 seats, 4 shelves
		1 Floors	1 Bathroom; 1 Bathroom
		1 Kitchen	1 Sink and stove
		1 Shower room	1 Shower room
		1 Capacitor room	1 Li-ion capacitor, 1 Fuel cell
		Materials	Aluminum

Table 3: Continue

Items	Photo	Features	Parameters
		Environmental friendliness	Solar photovoltaic panel (2 kW), non-supplied water remover (collects water vapors); Decomposition of fecal matter using microorganisms; Hydrogen generation
		Convenience	Container modules that are convenient to transport; Automatic leveling adjustment device; Electrical instantaneous water heating; Power storage and collection of water
		Changeability	Envelope elevates to form 2nd floor

Such facilities were easy to supply and install. Yet, due to their typical application in warm climates, their applicability in countries having four distinct seasons such as South Korea is limited. This highlights a need for further improvements regarding the selection of materials and structural performances. The comparative analysis table of the 8 facilities is presented in Table 3.

MATERIALS AND METHODS

Proposed direction of temporary housing facility developments: An analysis of the case studies above indicated, first, the existence of a key problem associated with domestic container type facilities involving its lack of consideration for storage and transportation. To resolve this issue, assembly type and modular type facilities were applied in the cases, in consideration of the future need for facility expansions and layout planning, the assembly type was deemed appropriate. Second, considerations for structural stability associated with problems typically found in temporary housing facilities suitable for warm climates were lacking. Facilities appropriate for South Korea, a country having four distinct seasons, must have durable envelopes and structural frames capable of withstanding the weight of the facility. Third, the nature of temporary housing facilities means that energy supply is difficult. In facilities used overseas, additional facilities such as solar photovoltaic panels and water collectors were installed to solve this problem. Fourth, facility expansion and layout plans must consider differences in the composition of disaster victim families and the scale of disasters. Fifth, the temporary housing facilities must allow for repairs and storage for reuse after recovery from a disaster. A means of reducing the volumes of the facilities must be considered and the facilities must be manufactured to enable easy partial repairs should they be needed.

Calculation of floor areas of temporary housing facilities: A floor area of 3,000×2,400 mm which is the size of a 10 ft container was calculated as an area appropriate for rapid deployment. This is a size that allows for loading on a 2.5 ton truck. Considering that as per the (Disaster Relief Planning Guidelines) an area of 3.3 m^2 per person is

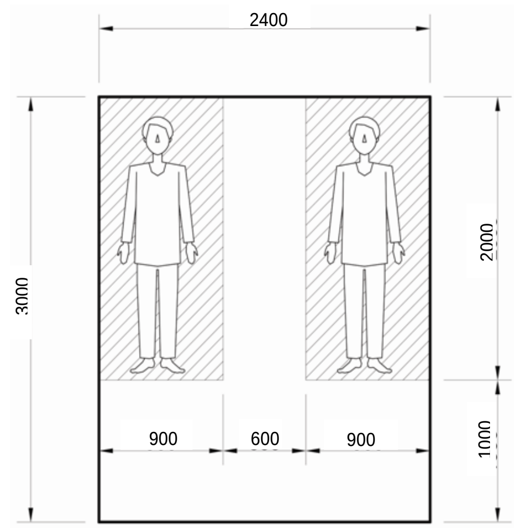

Fig. 1: Calculation of floor area

to be provided, an area of 3.000×2.400 mm (7.200 mm^2) can be used by two people. In consideration of the narrow spaces, sleeping areas were planned to be 2.000×900 mm which is smaller than a single sized bed (Fig. 1).

A proposal for an outdoor temporary housing facility: The proposed method involved the assembly of wall panels categorized as A and B-type panels. The thickness of the panels was the same at 50 mm. The A-type panel was 2,400×2,400 mm and included an entrance with a width and length of 900×1,800 mm. The B-type panel was 3,000×2,400 mm and included a window with a width and length of 1,200×600 mm. Materials capable of withstanding loads, external impacts and environmental considerations while being lightweight were planned for use.

A frame was provided to fix the corner areas of the panels during assembly. The 3 frames were designed to be foldable for storage by having the frames connected through hinges between the frames. During assembly, the frames and panels come together which is expected to make the hinges structurally irrelevant. The frames were based on 50×50 mm sized rods and the wall panels and frames were each distinguished as male and female parts joined together.

The ceiling panel was planned to be 200 mm thick. In consideration of load factors, only solar photovoltaic panels for electrical supply were installed. This resulted in the supply of power being somewhat lacking and only lightweight flexible solar photovoltaic panels were used.

The floor panel was planned to be at a height of 300 mm to block cold temperatures from the ground's surface. A foldable table and mattress were included indoors. Due to the application of a hard mattress cover, the cover can be closed during normal times. As the foldable table can potentially be stored underneath the floor, the area can be used as a flat floor as is the case for general living room areas. A unit section was planned to be included between the two mattresses in which capacitors storing electricity generated from the ceiling solar photovoltaic panels or other facilities can be installed.

The total thickness of overlapping the 300 mm floor panel, 200 mm ceiling panel and four 50 mm walls is 700 mm having a width and length of 3,000×2,400 mm. These dimensions make it possible to store 8 facilities in an area equal to that occupied by a 20 ft 6,000×2,400×2,500 mm sized container (Fig. 2-4).

Cluster layout plan: Assembly-type temporary housing facilities include methods of simple layout types and mixed clustering types. Simple layout types of joining regard a layout involving the separate joining of residential sectors and core type modules which has the advantage of having a hallway and a place where people can gather. However, this is not different from existing facilities and does not entail joining with a core sector, resulting in structural instability.

Mixed types of joining involve a method of joining the residential sector with the core type module. The method involves joining with the core type module by removing the wall of the area to be joined. Joining types have a disadvantage in that hallways and living room areas cannot be freely created. However, due to the separate joining of the core type module and the temporary housing facility the resulting structure is structurally safer (Fig. 5 and 6).

Analysis of the temporary housing facility plan: Assembly-type outdoor temporary housing facilities have the same dimensions as 10 ft sized containers and are more easily loadable and transportable compared to

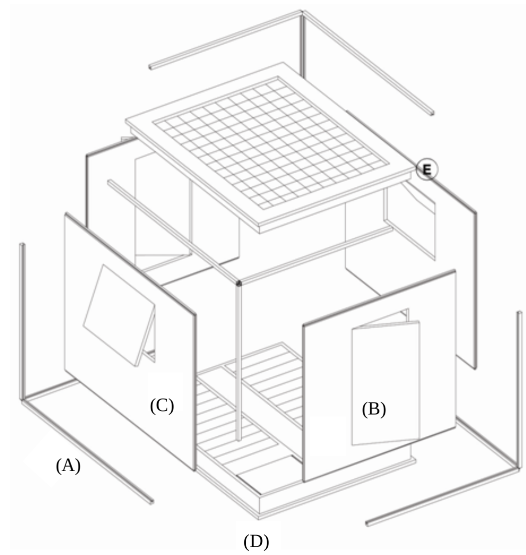

Fig. 2: Disassembly map

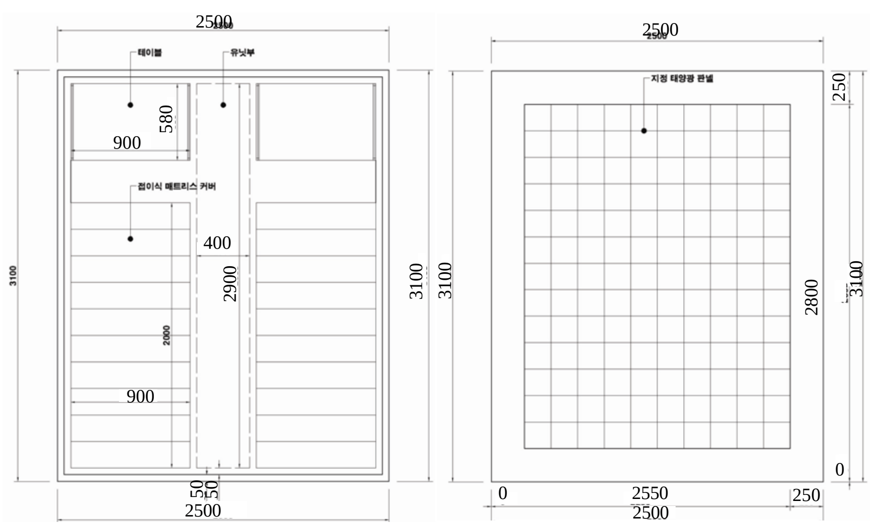

Fig. 3: Floor plan

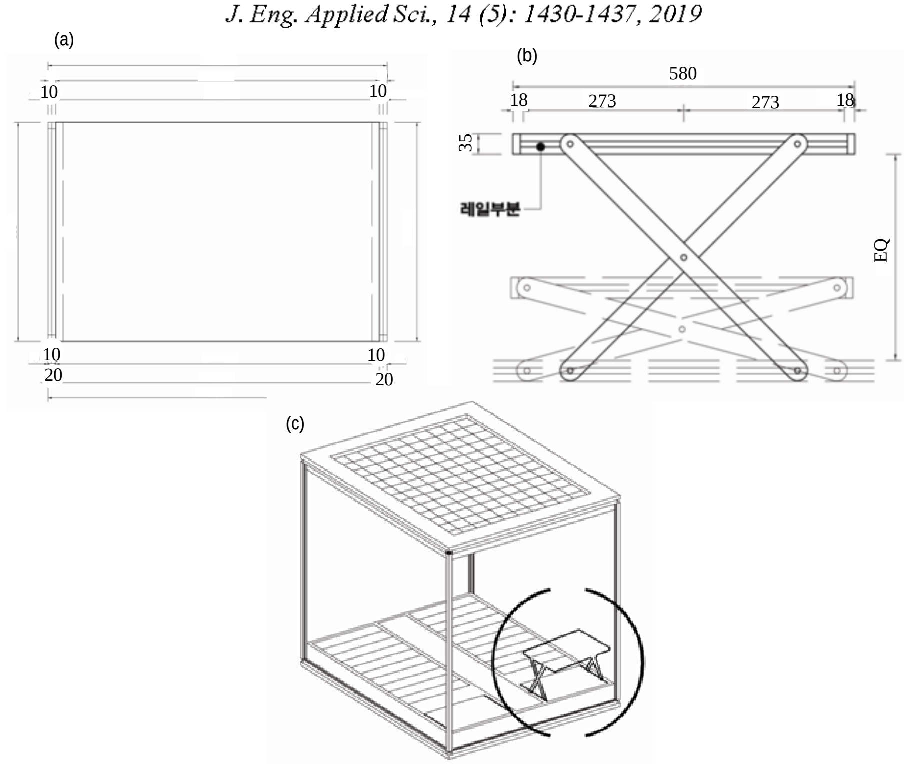

Fig. 4: a-c) Foldable table detailed drawings

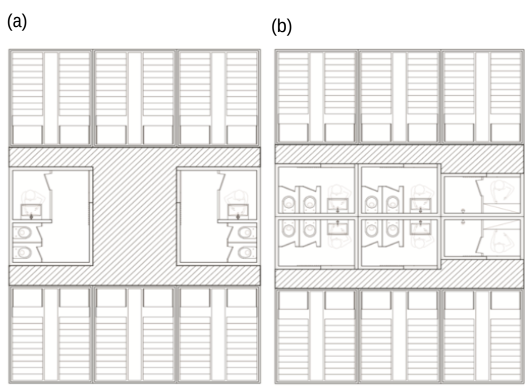

Fig. 5: a, b) Simple layout type

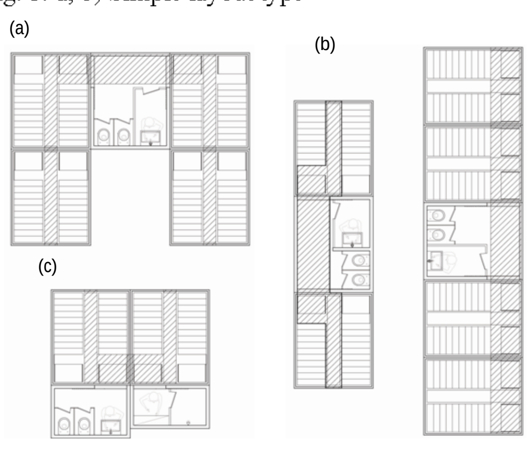

Fig. 6: a-c) Joining type

Table 4: Comparative analysis table of south korean temporary housing facilities

Characteristics/Criterion	Assembly-type outdoor temporary housing facility
Technological	
Transportability	○
Storage ability	○
Structurality	○
Assemblability	○
Changeability	×
Environmental Friendliness	Δ
Environmental	
Sustainability	Δ
Layout plan	○

existing temporary housing facilities. The facility is also lightweight and is made from highly durable materials which lessen concerns that its durability could be compromised during storage. Due to the frames and wall panels interlocking together, the facility is structurally stable and is easy to install thanks to its slide method of assembly. Its walls are also, removable due to it being an assembly-type facility which makes it excellent for layout planning, via., means of joining facilities. Also as it is an assembly-type facility, changeability was not considered. The facility had the disadvantage of only having solar photovoltaic panels for use as self-energy producing facilities for its residential sector module excluding the core module. Because of this its use solely as an assembly-type temporary housing facility was considered to result in reduced levels of sustainability (Table 4).

RESULTS AND DISCUSSION

There are three discussion topics in this study: First, the development of a core type temporary housing facility. The temporary housing facility proposed in this study corresponds to the residence of the victims. For this reason, facility such as toilets, showers and kitchens are required for living. Therefore, it is essential to develop core type temporary housing facilities. However, in the case of core type temporary housing facilities, a lot of facilities such as water supply system, electrical system, ventilation system are facility system. Installing the facility system in a temporary housing facility will increase the cost of production. In addition, special care is required for transportation, loading and storage and repair costs are expected to increase in the event of damage to the facility system. There is also, a disadvantage that it is not easy to use because the facility system has been added in large quantities. We need to discuss how to address these issues and requirements.

Secondly, it is about the post-occupancy evaluation through the actual production. Since, it is still in the planning stage in development it is doubtful about the performance of the facilities after production. It is made lightweight for storage and transportation and in order to cope with the external environment, the exterior of the facility was also, considered. Also, partial repair due to breakage was considered but discussion is needed to see if you will be able to achieve the desired performance when using temporary housing in an extreme environment.

Third, it discusses economic aspects of temporary housing facilities. Because it is a planning stage in development it is somewhat difficult to grasp the economic part. It was made to be able to repair parts in case of breakage and it is modular, so, it is expected to be economical. However, it is difficult to know how much it will cost in actual production. Since, the economical aspects of using temporary housing facilities can not be overlooked it is necessary to discuss how to reduce the cost of production (Jung-In and Sang-Ho, 2006; Kang and Hakkyong, 2016; Lee and Yoe, 2016; Park and Kim, 2017).

CONCLUSION

Disaster victims require residential spaces where they can reside for a certain period. This study undertook research into the design of temporary housing facilities that can be effectively and quickly supplied in the event of a disaster.

Typical temporary housing facilities in South Korea were found to lack considerations for transport and loading issues and also, were found to lack facilities to supply energy. In addition, the adding of more facilities was the only solution in the event of a lack of space. The absence of cluster layout plans meant that a community capable of providing psychological stability to disaster victims was not possible (Yun, 2016).

In overseas cases, several examples of facilities that considered provisional capacities over residential environments were found to exist and were considered appropriate for use until permanent housing could be provided. In consideration of the simplification and load bearing capacities of the facilities, there were rarely any instances of facilities installed with high capacity energy generation equipment. However, several of the facilities were installed with minimal energy generation equipment. Such facilities, also, took expandability and spatial conservation into consideration by employing assembly-type and open-type models.

Based on the case analyses, a temporary housing facility plan was proposed. First, the plan involved the use of an assembly-type facility that was easily loadable and transportable for quick supply. Second, a facility having an envelope capable of withstanding outdoor environments during all 4 seasons and made from highly durable materials was considered necessary. Third, solar photovoltaic panels were installed for the purpose of supplying minimal amounts of energy. Fourth, the plan involved a means of connecting the facilities together for further application in layout planning. Fifth, the facility considered the need for further dismantling and storage after the disaster situation ended. A facility capable of maintaining durability through non-application of loads during dismantling and a facility capable of conveniently being repaired in separate parts was considered (Yeun-Sook *et al*., 2013).

The temporary housing facility proposed in this study can be used to ensure the safety of disaster victims through its rapid supply and is expected to provide appropriate periods of relief before permanent housing facilities can be installed. In addition, through cluster layouts, the facilities had the advantage of being able to form communities in which disaster victims can establish a sense of psychological stability.

RECOMMENDATIONS

As this study focused only on the planning of the residential sector, future research regarding core type modules is needed. Solar photovoltaic panels were installed in the residential sector for the purpose of conserving space and establishing structural stability. Additional research regarding the facilities needed to improve the residential environments of disaster victims in the core type modules is also, needed. Further advancement of the layout plan should be achieved through further study of the joining area of the core-type module. As this is a study regarding plans, POE regarding the facility was not possible. POE through mock-ups is considered to be needed and further supplementary research to account for problems discovered during this process is also, required.

ACKNOWLEDGEMENT

This research was supported by a grant (17CTAP-C115046-02) from Technology Advancement Research Program (TARP) funded by Ministry of Land, Infrastructure and Transport of Korean government.

REFERENCES

Dong-Un L. and P. Tae-Hyum, 2011. A basic research for development of emergency housing model in Islands. J. Korean Hous. Assoc., 22: 35-45.

Hannah, L. and P. Kil-Yong, 2004. A study on the methods of temporary housing for the refugee disastered. J. Archit. Inst. Korea Acad. Conf. Plann. Des., 24: 143-146.

Hyun-Sun, K., 2016. [A study on considerations and methods to establish an effective disaster recovery system (In Korean)]. Secur. Eng. Res., 13: 487-500.

Jung-In, M. and L. Sang-Ho, 2006. Lin construction and overseas large scale construction application: London Heathrow airport. J. Archit. Inst. Korea, 22: 141-148.

Kang, W. and K. Hakkyong, 2016. [A comparative study into the USA's disaster management system: Focused on all-hazard approach and CERT program (In Korean)]. J. Secur. Eng., 13: 41-54.

Kyeong-Nam, L., M. Jung-In, K. Hong-Yong, L. Kang-Hee and Y. Sang-Ho, 2007. A Study on Manufacture of Mock-up in Terms of Improved Temporary Residences. Architectural Institute of Korea, Korea, East Asia,.

Lee, M.H. and H. Yoe, 2016. [Design of ICT based protected horticulture for recovering natural disaster (In Korean)]. Asia Pac. J. Multimedia Serv. Convergent Art Humanities Sociology, 6: 373-382.

Park, J.K. and M.G. Kim, 2017. PPK GNSS system based UAV photogrammetry for construction of urban disaster prevention information. Asia Pac. J. Multimedia Serv. Convergent Art Humanities Sociology, 7: 355-362.

Sara, K. and N. Kyung-Sook, 2015. A study on spatial characteristics of post-disaster interim housing focusing on Asian precedents of natural disasters. Korean Inst. Interior Des. J., 24: 108-116.

Won, M.S., K.K. Hee and N. Ken, 2015. [A study on necessary elements for refugees' stability in temporary housing (In Korean)]. Digital Des. Stud., 15: 501-510.

Woo-Chul, W., L. Chang-Jae and L. Suk-Ho, 2013. A study on the planning characteristic of temporary housing considering the needs of temporary residence. J. Archit. Inst. Korea Plann. Des., 33: 39-40.

Woo-Chul, W., S. Young-Hak and L. Suk-Ho, 2012. A research study on comparative analysis of architectural planning improvement on temporary housing of Korea and Japan. J. Archit. Inst. Korea Plann. Des., 28: 29-37.

Yeun-Sook, L., C. Jae-Woo and L. Ji-Hye, 2013. Case study on temporary houses for poor class residents. Asia Digital Art Des Assoc., 1: 444-445.

Young-Hak, S., L. Seok-Ho and W. Woo-Chul, 2011. A study of temporary housing design with unit modular method. J. Archit. Instit. Korea, 29: 155-162.

Yun, H.J., 2016. [A model for urban regeneration by constructing contemporary publicness (In Korean)]. Asia Pac. J. Multimedia Serv. Convergent Art Humanities Sociology, 6: 657-666.