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Optimization of the Construction System of Relief Tents Used in Emergency Accommodation

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Original Article

Abstract

INTRODUCTION: The frequency of natural disasters is high in Iran due to its special climatic and geophysical conditions. However, the provision of better services to trauma victims requires further research. Decisions on emergency accommodation and meeting the needs of the victims are often made in conditions of uncertainty, and the lack of appropriate studies leads to the provision of low-quality and intermittent services.

METHODS: This applied and descriptive-analytical study was conducted to determine the advantages and disadvantages of relief tents using documentary and library resources, observation, and interviews with officials and experts, and the effective standards for the construction system of emergency accommodation. The thermal comfort of the victims was then investigated using the guidelines of the American Society of Heating, Refrigerating, and Air-Conditioning Engineers (ASHRAE), interviews with the victims, and field tests. Moreover, solutions are introduced for the improvement and optimization of relief tents, and a new building system is introduced for the emergency accommodation of victims in incidents by removing the disadvantages of the systems previously used in emergency accommodation.

FINDINGS: According to the observations and investigations, the previously used emergency shelters do not meet the needs of the accident survivors properly and their design does not correspond to the users' culture and needs. The problems with the current accommodating methods include lack of privacy, lack of protection against disturbing cold and heat, and inappropriate and non-standard dimensions of the existing tents. Solutions have been presented to solve the existing problems and a new system for emergency accommodation has been introduced based on field observations and interviews with experts.

CONCLUSION: It is noteworthy that the votes of 22 percent of people are in the range of slightly warm to slightly cold; which shows that these people are satisfied with their accommodation regarding thermal comfort. 78 percent of the people's votes were outside the satisfaction range. Due to the chambered structure of the tent, direct sunlight in the summer, the lack of proper air exchange, the weakness of the structural components of the tent and the lack of heat retention in the winter, proper mechanical systems should be used to provide thermal comfort, which is not feasible in practice due to the extent of the incidents and large amounts of equipment and resources needed which bolds the importance of the proposed construction system.

Keywords: Building systems; Emergency accommodation; Natural disasters; Optimization; Relief tents.

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Introduction

Every year, many people around the world lose their homes due to natural disasters. In Iran, events such as earthquakes and floods have resulted in the largest number of homeless people in recent years. Usually, the residential areas become unusable after the occurrence of large-scale natural disasters, and the survivors are forced to live in places other than their homes.

People lose their morale and scatter after the loss of shelter. Therefore, having a suitable shelter and gathering the family is the first thing that

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brings security and peace to the affected people after disasters. It should be noted that there is very little time for decision-making after an earthquake and managers can make wrong decisions after the earthquake in the absence of a proper plan. In this situation, different organizations cannot act efficiently may cause disorder, chaos, and waste of resources. However, advance planning allows for the highest efficiency with the least cost.

The affected population in disasters has to settle down and return to everyday life in spite of the existing damages and problems. This means that the survivors must have access to basic living facilities, including shelter, food, water, and security despite the loss of family members, relatives, and homes, and get prepared for the reconstruction of their homes to resume their daily activities despite the mental and emotional trauma.

The period of emergency accommodation begins after the emergency response (rescue, relief, and basic medical measures) and the main activity in this period includes the provision of basic needs of the survivors, such as shelter, food, water, and security. The occurrence of destructive earthquakes in the country has highlighted the need for research on suitable plans for emergency accommodation means, according to the user's requirements.

In this regard, the following questions are raised:

1) What are the components that affect the design of accommodation building systems in emergency accommodation?

2) What was the performance of relief tents used in the past disasters?

3) How should the appropriate housing construction system corresponding to the country's culture and climate be designed?

Today, the increase in the relative prosperity of Iranian society necessitates the adoption of a building system that preserves the dignity of the victims and meets their minimum requirements.

Although natural disasters are inevitable and cannot be changed, they can be managed nonetheless. It is possible to accurately analyze the disasters that occur in the country using the scientific methods and invaluable experience available at the national and international levels. These methods play a vital role in reconstruction programs for society.

Table 1 presents various studies and features of temporary and emergency accommodations suggested in each study.

Table 1. Characteristics of temporary and emergency accommodation in previous studies

Omidvar (1)	Protection against heat, cold, wind, and rain; stabilization and maintenance of house boundaries (ownership); creation of basic conditions for the subsequent evacuation; reconstruction of the building and renewal of social organization; creation of psychological security and provision of the private environment; determination of a specific address for receiving services (e.g., medical services and food); accommodation of people where they can have access to work.
Nikravan Monfared(2)	Possession of a special identity in terms of general, technical, and functional specifications; provision of different areas regarding the users' needs; use of prefabricated and light constructs; resistant and stable constructs; use of existing and local materials; workable by those with simple technical skills; consideration of factors affecting comforts, such as climate and culture and meeting the requisites of lighting, heating, and cooling on the other hand.
Corsellis & Vitale(3)	Having proper privacy and security, durable and resistant housing, proper lighting and heating network and ventilation, suitable infrastructure (e.g., water supply), health and facilities for waste and waste management, and cultural identity.
Bemanian and Bakhtyarian (4)	High construction speed; lightweight; small volume before installation; easy storage in the warehouse; portability; few types and number of connections; simple implementation requiring little technical skill; the possibility of expansion in the future; the possibility of presentation and implementation on various areas; prefabrication of foundation and other parts, replicability of parts and particles; use of available materials.
Davis(5)	Protection against heat, cold, wind, and rain; safe storage of furniture and disaster leftovers; stabilization and maintenance of house boundaries; creation of psychological security; provision of private environment.
Lindell (6)	High construction speed; low weight and volume for storage; easy installation; minimum number of connections; expandability; exchangeability and replicability of parts; prefabricated building foundation, and simplicity of connecting and leveling.
Fallahi(7)	Adoption of indigenous technology; low transportation costs; suitability in terms of safety, culture, and climate; participation of the injured in construction/ installation; justice in equal distribution of temporary housing among victims; use of local and indigenous architectural and landscaping standards.
Sartipipour (8)	Easy to transport and deploy; applicability in different situations; use of appropriate structures; ease of production, ease of installation and simple implementation details; and compatibility with the environment, climate, and weather.
Behzadfar(9)	Protection against heat and cold, correspondence between the size of the tents and the household size; correspondence between the type of tents with the victims' culture and lifestyle (urban or rural); establishment of a temporary accommodation near the previous place of the victims' residence
Johnson Cassidy(10)	Provision of a proper level of quality of life in temporary accommodation based on the current standards of living; low price; possibility of making a series; construction of temporary housing according to the culture of the victims; reusability; easy and non-polluting removal of temporary dwellings.

[DOI: 10.32592/jorar.2022.14.3.3]

Methods

This field and descriptive-analytical study was conducted to determine the advantages and disadvantages of relief tents using documentary and library resources, observation, and interviews with officials and experts on the effective standards in designing the construction system of emergency accommodation.

The Cochran formula was used to calculate the study sample size:

$$n=\frac{\frac{Z^2pq}{d^2}}{1+\frac{1}{N}\left(\frac{Z^2pq}{d^2}-1\right)}$$

The data were collected through participatory observation of people affected by the 2016 Kermanshah earthquake, in-depth semi-structured interviews with key people involved in emergency accommodation, and conducting a questionnaire (300 Red Crescent rescuers) to investigate thermal comfort. Data logger tools were used for the field measurements and sampling to simultaneously measure temperature and humidity. The maximum and minimum thermometers were used to measure the highest and lowest temperature values.

The participants were classified into two groups. The first group of participants was selected from among 100,000 affected people who were accommodated by the Red Crescent Society (Red Crescent, 2016), including 20 experts, 30 officials, 14 local informants, and 386 people who were interviewed.

The second group was selected from among 2000 active aid workers of the Red Crescent Society, of whom 300 people were selected among those who were settled in tents for 10 days in the hot season and a period of ten days in the cold season. Studies have been conducted to check the comfort of tents.

The data analysis was performed using Maxqda-2020 software and SPSS-26 software. Reliability was determined using Cronbach's alpha (obtained at 0.836) and continuous comparison of data during the analysis.

In terms of validity, the study data were provided to some participants and experts to review and modify. According to the documentary studies, a list of criteria was prepared by the experts' opinion, including eight criteria for emergency accommodation (Figure 1).

Figure 1. Emergency accommodation criteria

Field studies were conducted to investigate the comfort of the tents from August 1 to 11, 2021, and from January 6 to 16, 2021 (starting at 6 a.m.), and temperature data were recorded every hour. To conduct field studies continuously, people were accommodated in tents.

This survey was conducted in an open field (without shelter) among the Red Crescent Society of Markazi Province, Iran. The thermal environment of the relief tents and the thermal comfort of the victims were investigated in two classes of relief tents (types 2 and 3) that were set up in the Red Crescent Society of Markazi Province, Iran (Figure 2).

Climate condition

A temperature and humidity recorder was used to record changes. The temperature and humidity outside and inside the tents were recorded during the test period (two periods of 10 days). Figure 3 shows the research process.

Investigation of the situation of Iran in natural disasters

Geographical, topographical, and climatic characteristics have exposed our country to various disasters caused by natural hazards. In general, 31out of 41 types of natural disasters known in the world have occurred in Iran, among which floods, earthquakes, and droughts are the most common natural phenomena that often cause the highest number of casualties (deaths and homelessness) compared to other natural disasters (11).

As indicated in Figure 4, Iran ranks fourth in the world in terms of deaths due to earthquakes (with 154,268 deaths). Figure 5 presented the frequency of natural disasters.

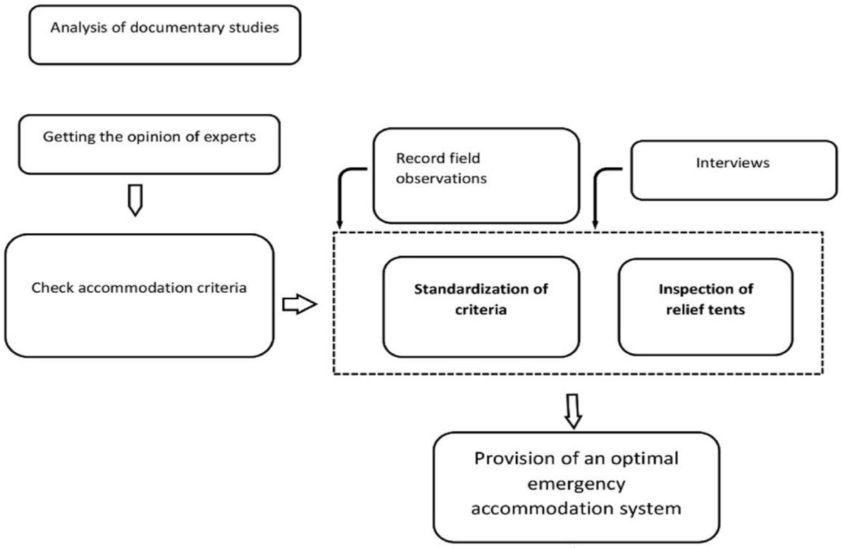

Figure 2. Site and the installed tents

Figure 3. Research process

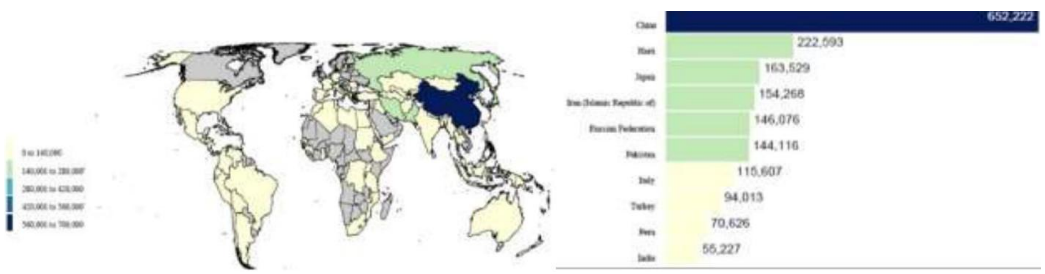

Figure 4. Number of deaths due to earthquakes in the world from 1900 to 2021(12)

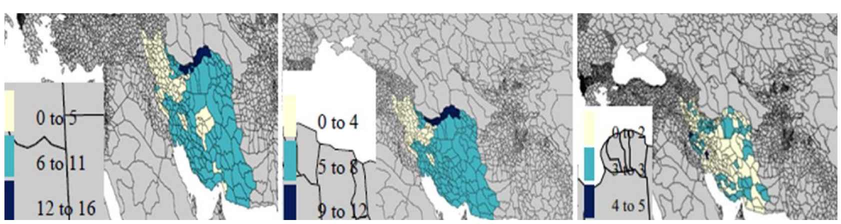

Figure 5. Frequency of natural disasters in Iran from 2000 to 2021 from left: natural disasters, floods, earthquakes (12)

History of emergency accommodation in Iran

During a natural disaster, emergency accommodation is provided for the immediate accommodation of the injured. Tents are the most popular type of emergency accommodation, due to their key features such as lightness, compactness, and easy erection.

Emergency accommodation has important and diverse functions. These are used to protect against cold, heat, wind, and rain; store furniture and maintain the property; create emotional security (through the provision of a private

[DOI: 10.32592/jorar.2022.14.3.3]

environment); determine a specific address for receiving services (medical services, food); and provide shelter for families who have evacuated their homes for the fear of accidents(13).

It has been observed that setting up a relief tent was an inseparable element in the emergency accommodation in the incidents that occurred in different regions of the country. Figure 6 presents different types of relief tents used.

Figure 6. Tents used in accidents (from the top right: Bayaz plain, Ghirokarzin, Tabas, Rudbar and Manjil, Bam (14)

Table 2. Technical specifications of relief tents Type 2 (15)

1	Body Material	Inner layer Outer layer (cover)	Polyester cotton (water repellent) which is 40% cotton and 60% polyester One side coated waterproof polyester with PVC material and 300*300 thread
2	Floor		One-sided waterproof polyester coated with PVC material and 600*600 thread Raising the floor cloth up to 15 cm 3*4 dimension
3	Ceiling		Waterproof polyester cotton
4	Color		White
5	Logo	Inner layer roof Roof coatings	Red Crescent logo Red Crescent logo
6	Weight		40 kg
7	Height	Walls Apex	1.75 m 2.10 m
8	Installation manner		It uses six bridges and a central base and two side bridge fasteners coiled around the bottom of the tent
9	Approximate volume		15 m^3
10	Installation time		10-15 min
11	Number		Requiring at least two people to install
12	Material of bridge and foundation		ST12 tube Diameter: 25 mm Thickness: 1 mm
13	Packing		A durable bag made of waterproof polyester that has the power and space needed to maintain the tent Bag dimensions: 95*40*30
14	Storage		The need for enclosed space The ability to stack five tents on top of each other
15	Door		Two doors in two widths of the tent can be folded to the side with four fasteners
16	Window		2
17	Standard		Obtaining the national standard Industrial, and health, and exploitation licenses -Sewing the nameplate of the mentioned specifications on the edge of the tent and stating the date of production and attaching the barcode of the product on its bag

Emergency accommodation in the city and rural area

Accommodation in rural and urban areas is different in many aspects. These differences are mainly related to the construction system, the relatively difficult living conditions used in rural areas, the major reliance on indigenous construction materials and technology, and the form of destruction caused by natural disasters in these areas.

1. In terms of life quality, people in rural areas mainly rely on local culture, while urban dwellers rely on domestic or sometimes foreign cultures.

2. Rural people are producers while urban people are often consumers.

3. In rural areas, victims play a more

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participatory role after incidents.

4. The rural population cannot be compared with the population density in the city.

5. Emergency work may not arise immediately post-incident (e.g., the occurrence of an earthquake) due to the spread over the land in vast rural areas.

6. The resources for emergency accommodation are much less needed in the rural areas (16).

7. In the rural areas, destruction of buildings occurs more frequently due to poor materials and non-compliance with construction standards (17).

Knowledge of the studied tents

A tent is an external cover that refers to any type of cover that protects people or their property from external hazards and can be erected and collected at any time and place. A tent is one of the simplest and most common types of emergency accommodation.

The most important part of aid and relief depends on the quick and principled provision of shelter that facilitates the distribution of other aid. The proper selection and installation of a suitable structure and provision of housing and basic services to injured people can increase their morale and helps them return to normal life. Tents, in any structure and form, are often composed of common components.

Despite its simplicity, the tent has many advantages, which have made it one of the most often used options for emergency accommodation throughout history. These include lightweight, small and portable volume, quick and easy installation, easy and small storage, and mass production capability. The tent is a temporary shelter that accelerates the initiation of reconstruction activities in the affected area.

The tent is conspicuous and indicates the presence of relief organizations which gives comfort to the victims. It is relatively easy to carry any number of tents to the site of incidence. This encourages the aid workers to proceed with reconstruction as soon as possible.

The Red Crescent society currently uses two types of tents (Type 2 and Type 3 tents) for emergency accommodation. We will explain these models in the following.

Tents type 2

Tents Type 2 have been widely used as an emergency shelter by the Red Crescent Society in the last two decades (Figure 7). The technical specifications of this tent model are presented in Table 2.

Figure 7. From the top right: exterior view, general requirements, interior view, tent frame, roof connections, and base connections in tents Type 2

Figure 8. From the top right: the outside view; the inside view, from the bottom right: connections, windows in tents Type 3

2-6 Tents type 3

Recently, the Red Crescent Society has produced and used tents Type 3. This model is more optimized and solves some of the problems associated with the previous type (Figure 8). However, it should be noted that this model of tents has not been widely used in incidents and has been only used in training courses.

Therefore, due to the limited conditions of use, it is not possible to examine its strengths and weaknesses thoroughly in practice.

However, the field observations and interviews with experts revealed that this tent still has some

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shortcomings of the previous model regarding the cultural incompatibility and the visibility of the entire interior space when the tent is open. Moreover, due to its wideness, the tent floor soon levels with the ground in the middle which increases the chance of soil and water penetration inside the tent as well as the collapse risk of heating equipment and fire hazards.

In general, tents Type 3 and Type 2 do not have many functional differences. Table 3 presents the technical specifications of this tent model.

Difference between relief tents type 3 and type 2

The cover installed on tents Type 3 has an extra shade (a space of about 30 cm) which protects the walls from rain. Moreover, two airflow dampers are installed on top of the doors in front and end of the tent to facilitate airflow circulation inside the tent. Tents Type 2 do not have this feature.

To prevent sand and pebbles from damaging the tent floor, a 12 m^2 coated polyolefin cloth is used on the tent floor, which is missing in tents Type 2. Double-coated polyolefin fabric is used as carpet soil in the lower wall of the tent to prevent the penetration of rainwater inside the tent.

Table 3. Technical specifications of Type 3 relief tents (15)

1	**Body material**	**Inner layer**	**Polyester cotton (water repellent) made up of cotton (40%) and polyester (60%)**
		Outer layer (cover)	**One side coated waterproof polyester, PVC material with 300*300 thread**
2	Floor		One-side coated waterproof polyester, PVC material with 600*600 thread Raising of floor cloth up to 15 cm Dimensions: 3 x 4 meters
3	Ceiling		Waterproof polyester cotton
4	Color		White
5	Logo	Inner layer roof	Red Crescent logo
		Roof coatings	Red Crescent logo
		walls	Red Crescent logo
6	Weight		54 kg
7	Height	wall	1.75 m
		Apex	2.15 m
8	Installation manner		Used six bridge fasteners and a central base and two side bridge fasteners coiled around the bottom of the tent
9	Approximate volume		23 m^3
10	Installation time		10-15 min
11	Number of people		Requiring at least two people to install
12	Bridge and foundation material		ST12 tube Diameter: 25 mm Thickness: 1 mm
13	Packing		A durable waterproof polyester bag with enough power and space to maintain the tent
14	Storage		Needing an enclosed space Ability to stack five tents on top of each other
15	Door		Two doors in two widths of the tent can be folded up with two retaining clips
16	Window		44
17	Standard		Obtaining national standard Industrial, health, and exploitation licenses Sewing the nameplate of the mentioned specifications on the edge of the tent and stating the date of production and attaching the barcode of the product on its bag

In total, four windows are implemented in this type of tent (Type 3) to increase the airflow inside the tent compared to Type 2.

To increase stability and durability, the metal skeleton structure of this tent (weighing 25.11 kg) is produced in a coiled form. In addition, plastic shields are used in the tent seams to prevent the fabric from attaching to the corners of the tent. In this new design, the wall angle is 90°, the entire metal skeleton is inside the tent, and the tent body is installed on this skeleton to increase the strength of the tent.

The inside space of the tent is 23 m^3, with a width and length of 3×4 meters. The height is 2.15 m along the crown and 1.75 m on the wall side. In the previous tents (Type 2), the useful space was 15 m^3 at maximum. To increase the strength of the tent sides, oval plastic buttons are used in addition to an adhesive zipper. All the tent doors have nets to prevent pests from entering the tent. The new

[DOI: 10.32592/jorar.2022.14.3.3]

tent door is U-shaped, while it was in the shape of an upside-down T in the previous tent type (15).

Emergency accommodation tents from the perspective of survivors

When an incident occurs, human morale is the first victim. On the other hand, the possession of a proper shelter and family members' reunion can heal the grief after the incident and gradually restores the affected person's confidence. Table 4 presents the results of the field observations and interviews with the victims.

Emergency accommodation tents from the perspective of managers and manufacturers

One of the major challenges facing project managers and producers is the problems related to maintenance and planning for exploitation in pre-disaster conditions.

In the field surveys and interviews with experts, managers believed that the tents are the main and even the only system for emergency accommodation due to factors such as suitable costs of maintenance and storage for proper emergency accommodation, the high production cost of other types of shelters, the desire to speed up the reconstruction process, and the possibility of mass production. On the other hand, the desire to reduce production costs may lead to the reduction of the quality and effectiveness of the relief tents.

Thermal comfort of the tent

The thermal comfort of the human body depends on three environmental factors: temperature, relative humidity, and airflow, with temperature, considered the most important factor. Much research has been conducted to determine the upper and lower limits of thermal comfort to determine the conditions in which the human body feels comfortable thermally.

Most people, with their clothes on and in the status of rest, need a temperature between 23 and 27 °C to feel thermal comfort, and this temperature range reaches 29-31°C without clothes (18).

Relative humidity can also influence thermal comfort as it presents the actual moisture content of the air. Therefore, it can affect the amount of heat a person can dissipate into the environment. High relative humidity reduces heat dissipation through evaporation. This usually happens at high temperatures. On the other hand, the rate of evaporation increases with the decrease in relative humidity. The level of relative humidity is desirable in the range of 30- 70%, and the relative humidity of 50% is considered ideal (19). Since most people do not feel hot or cold and there is no need for the body to use defense systems to regulate the temperature in this humidity level.

Strong airflow is another key factor in thermal comfort. Strong airflow is one of the most disturbing factors in the environment that can cause an unwanted feeling of coldness in some parts of the human body. Strong airflow disrupts thermal comfort for people wearing light clothing in the state of rest, while it is not so for people with heavy physical activity. Airflow speed in the winter and summer seasons should be kept to less than 9 m/min and 15 m/min, respectively, to minimize the feeling of thermal discomfort caused by strong airflow (19). However, the injured are in a state of constant discomfort due to the small and enclosed space inside the tent and the lack of proper ventilation. The thermal comfort of the injured has been evaluated using the ASHRAE-55 standard.

In this study, the comfort condition of 50 Red Crescent relief workers who were accommodated in tents was investigated as well as by surveying a number of injured people as field studies using the ASHRAE -55 standard. Researchers who use field methods to estimate the comfort zone believe that the comfort zone is the limit by which the three middle classes of the ASHRAE seven-point scale are chosen by people (Table 5). ASHRAE scale relies on thermal sensation. When asked what your thermal sensation is, a person should mark one of the seven cells in the table.

[DOI: 10.32592/jorar.2022.14.3.3]

Table 4. Results of field observations and interviews with victims

Criteria	Victims' viewpoints
Location of tent	Deployed the tents at the location selected by the Red Crescent Society. They moved the tents near their houses or places with water, electricity, and sanitary facilities. The tents were moved to build family camps.
Fear and insecurity(20)	Caused by wild animals Caused by property looting and robbery.
Lack of sanitary facilities	Insufficient number of bathrooms and their long distance from the tent. Lack of enough toilets and a long distance from the tent. Lack of sufficient facilities in the bathroom and toilet (e.g., soap, electricity, hot water, lockable door).
Unpleasant smell and the presence of insects	Due to the accumulation of garbage in the tent and the surrounding area.
Lack of washing facilities in the tent	The need to go to the washing place for washing even a single glass.
Lack of privacy	All sounds and conversations are transferred outside and heard by the people around the tent. Changing clothes was difficult for women in front of family members. Visibility of the inner space at night (as shadows) Visibility of the inner space of the tent while opening and closing of the tent door. No partitioning of the space inside the tent
Tent heating and cooling	Heating the tent was very difficult (difficulty in getting oil and a high possibility of catching fire). The tent's floor was very weak and it did not get warm with blankets. The heating device placed on the bottom of the tent could fall easily. To prevent children from getting burned, nothing should be placed on the bottom of the tent. The tent has many seams and the wind comes in from the seams and zippers. To prevent rain from entering the tent, a nylon cover is used, which makes a terrible sound, especially at night when the wind blows. When it rains, the water goes under the tent and causes high humidity due to the model of the tent cover. The entire heat would be lost after each opening and closing of the tent door Lack of cooling facilities. Insignificant temperature difference between the environment and inside the tent. Doors and windows should be opened to cool the space inside the tent, which reveals the interior part of the tent.
Lack of proper ventilation and inner pollution	Lack of light and air inside the tent due to the small number of windows. Lack of proper ventilation and air circulation due to the small number of windows.
Small living space in the tent	Lack of enough places to sleep. Disruption of daily tasks.
Cooking	Fear of catching fire Fear of overturning the food dish and burning the children. Fear of carbon monoxide gas spreading inside the tent. Cooking is time-consuming (one has to take the utensils to the washing place, get drinking water from another place, and go to the washing place again after eating to wash the dishes by standing in the queue for a long time.

Table 5. ASHRAE seven-point scale (21)

ASHRAE	Very hot	hot	A little hot	Neutral	A little cold	cold	Very cold
Respective value	+3	+2	+1	0	-1	-2	-3

[DOI: 10.32592/jorar.2022.14.3.3]

Table 6. Results of field observations and survey

Thermal sensation		First sample Hot season in Saveh	Second sample Cold season in Arak
Very hot	No	25	0
	%	50%	0
Hot	No	19	0
	%	38%	0
Little hot	No	6	0
	%	12%	0
Neutral	No	0	3
	%	0	6%
Little cold	No	0	13
	%	0	26%
Cold	No	0	22
	%	0	44%
Very cold	No	0	12
	%	0	24%

If all the individuals sharing the space mark the central cell (zero number) indicating the neutral state, it suggests that they are completely satisfied with their environment (21).
Based on ASHRAE seven-point scale, people were asked to record their thermal sensation by marking their respective cells. We noted that zero indicated the ideal condition. According to ASHRAE-55 regulations, thermal sensation between -1 and +1 is the acceptable condition and this is the thermal comfort range for at least 80% of people. Moreover, McIntyre stated that in case we refer to 90% of people, then the limit of thermal comfort should be between -0.5 and +0.5 (22). In the present study, the thermal sensation is considered between 1 and -1, according to ASHRAE regulations (Table 6)

To conduct a field test, a total of 50 rescuers who participated in the training course of emergency accommodation were accommodated in the relief tents for two periods (each period taking three days) and a survey was conducted for them. Table 6 presents these results.

In this phase, the tent temperature was checked once with cover and once without cover. As indicated in Figure 9, the temperature difference is up to 10° C. The frequency of expression of users' thermal sensation in the inner space of the tent is presented in Figure 10.

It is noteworthy that 22% of people selected the range of slightly warm to slightly cold, indicating that this proportion of population that used the space was satisfied with their thermal comfort. However, 78% of the people selected the options that were outside the range of satisfaction.

Due to the chambered structure of the tent, the lack of proper air exchange, direct sunlight in the summer, the weakness of the structural components of the tent, and the lack of heat retention in the winter, mechanical systems should be used to provide thermal comfort, which is not practical considering the extent of the incidents and the heavy need for lots of equipment.

Since low durability and short lifespan of the materials are two disadvantages of tent structures, the best ones should be chosen in terms of the quality of the materials so that the structure maintains its strength when exposed to different climatic conditions. Relatively poor ventilation inside the tent is another disadvantage that can be resolved by the addition of several windows to create optimal cooling and heating condition inside the tent.

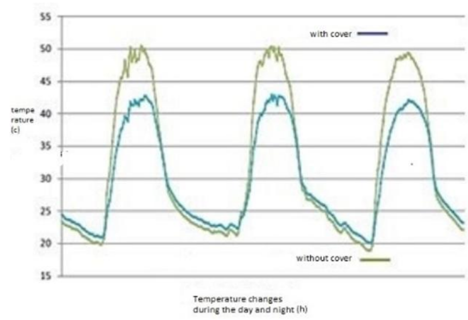

Figure 9. Results of field temperature tests inside the tent

The use of a wooden structure as a shade for tents can prevent extreme heat and deformation and decay caused by sunlight. The erection of a wall up to a height of half a meter around the tent using local materials can prevent water from penetrating under the tent which in turn prevents humidity and unpleasant odors.

[DOI: 10.32592/jorar.2022.14.3.3]

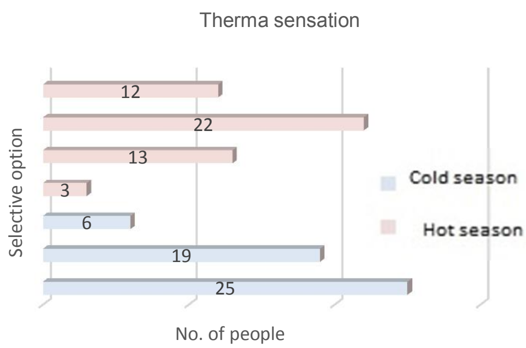

Figure 10. Statistics of the frequency of thermal sensation expression of users in the inner space of the tent (50 people sample)

Design concept

The process of design in emergency accommodation after incidents has fundamental differences from the usual designs. The placeless and timeless nature of the subject and the preferences for technical aspects, such as materials and construction methods are two of the obvious differences. Paying attention to the provision of a suitable living environment on a temporary basis, according to the pre-accident conditions for the victims suffering from the pains and injuries caused by the incident, is an issue that should be taken seriously.

Accordingly, the emergency living space should be designed and prepared in a way that guarantees the minimum conditions of comfort and convenience while protecting people from the changing conditions of the natural environment, such as heat, cold, wind, and atmospheric precipitation.

From this perspective, the realization of optimal living conditions is a special privilege for success. In such a situation, discovering the obvious and hidden properties of materials and their application for optimal use is considered an important issue. Moreover, searching for new and efficient approaches and methods of design and implementation for emergency accommodation in all countries that face the risk of disaster is a matter that requires initiative and creativity.

In such conditions, the application of technologies that facilitate resuming normal living conditions can be very helpful. Therefore, the use of technologies and materials that are cheap, simple, environment-friendly, and easy to install should be prioritized (23-25).

In many designs, due to the similarity of topics between different buildings and various experiences that have been obtained over time concerning these common topics, it is possible to identify patterns by summarizing and optimizing these experiences to speed up the design process, facilitate, and prevent the repetition of many mistakes in this regard. Based on the results obtained from the study of national experiences and field observations, the existing tent covers do not have suitable conditions for emergency accommodation.

When an accident occurs, there is usually a delay in receiving aid. To organize and create shelter until the arrival of an emergency accommodation system, two proposals are presented, one for the rural areas and one for the cities.

Based on field studies and observations in past incidents inside the country, the buildings of mosques in the village, unlike the mud houses of the villagers, are always structures with higher construction standards and sufficient resistance against incidents in many cases. These places can be used as temporary shelters for the local people until the implementation of emergency accommodation.

However, in cases where these structures are unavailable or non-responsiveness, given the number of the affected population, it is suggested to install a gabion system with the aid of local people and use waterproof fabric as a shelter (Figures 11& 12).

Due to the extent of the accident and the high number of the affected population in cities, it is suggested to use large hall structures that have been implemented in cities for several years by the Crisis Management Organization (Figure 13).

Our final proposal for the emergency accommodation system in this study is the combined system of Conex boxes and tents. The different parts of the structure have been examined separately, including the floor, the walls, the roof, the interior spaces, the doors, and the windows.

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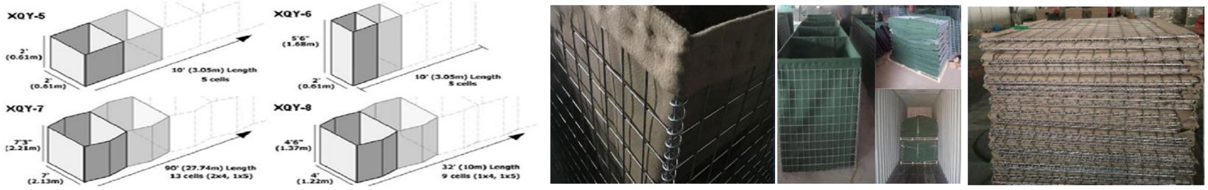

Figure 11. Gabion system and waterproof fabric (26)

Figure 12. From the right: Gabion wall, waterproof coating, and various roofs (27)

Figure 13. Application of large halls for emergency accommodation (28)

Proposed construction system

In many designs, due to the similarity of subjects in different buildings and the various experiences that have taken place over time concerning these subjects, it has been possible to identify patterns by summarizing and optimizing these experiences to speed up and facilitate the designing process and prevent the repetition of mistakes.

The final proposal for the integration of emergency and temporary accommodation is presented in this study, and different parts of the system (e.g., structure floor, walls, roof, interior space, doors, and windows) were examined separately.

The floor structure

The floor structure is designed in such a way that can be used as an external cover in the package and the product can be placed inside it (Figure 14). The extended floor can be observed in Figure 15. This design helps to minimize the burning possibility of the survivors, especially children, to a great extent. Figure 16 presents the dimensions of the floor structure. The floor has 10 cm bases that prevent freezing and water accumulation.

Walls

A double-wall design has been used for the structure of the walls to prevent heat exchange and can be used in different parts of the country with different weather conditions. The empty space between these double walls can be filled with the existing materials (e.g., soil and straw).

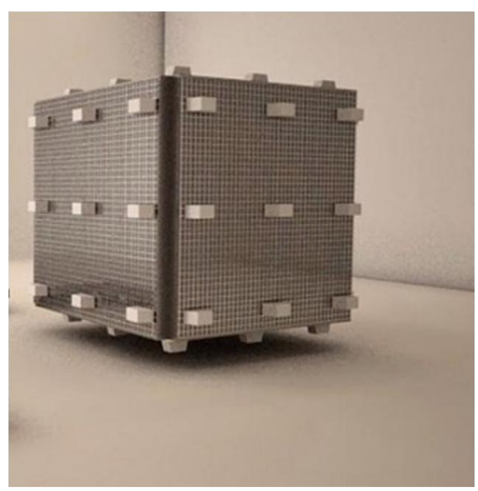

Figure 14. Packaging of the product

This design prevents the shadow inside the structure to be seen from outside at night after turning on the lights and also acts as a sound insulator and prevents the sound inside the

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structure from being heard and vice versa. The cost and materials used in the preparation of the walls vary according to the geographical and climatic conditions of the region.

Door and Window

The Islamic culture requires the blocking of the interior view of the structure and maintaining the psychological and physical safety of accommodated people. Therefore, the entrance structure has been designed as a tunnel corridor with two doors installed at the front and end of the structure and can be opened and closed independently (Figure 17).

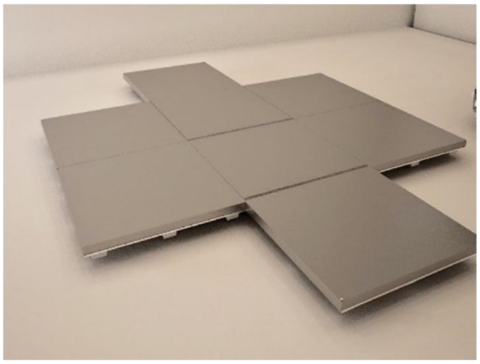

Figure 15. Expanded packaging

Connections

Considering the importance of using local labor for enhancing the morale of the affected individuals in the incidents, the structure is designed in such a way that requires no specific tools for installation and the execution method does not require technical knowledge and can be easily performed by the local labor (Figure 18).

According to Sphere standard, the covered space in the tent structure which should be available to the affected family is 3.5 m^2. In the

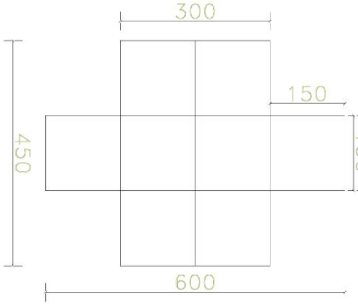

Figure 16. Dimensions of the floor structure (cm)

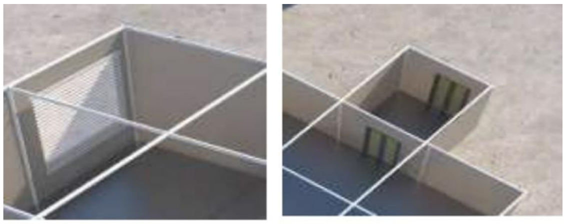

Figure 17. Tunnel corridor with two doors

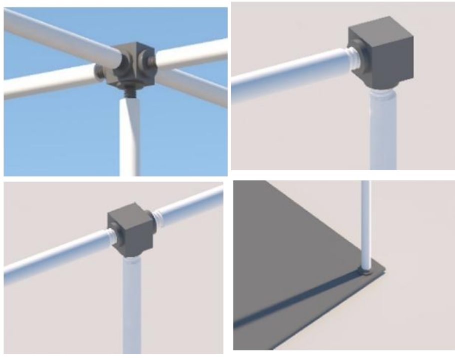

Figure 18. Connections of the proposed structure

standard followed by the Red Crescent Society, each family is considered to include five people and the Society plans its actions based on this assumed family size. However, according to the Population and Housing Census, 2016, each Iranian family is composed of 3.4 members on average.

Based on the field observations and interviews conducted by the authors, the affected people suffered from the lack of privacy in the relief tents, and given the Islamic culture, the women had a hard time regarding the lack of privacy. In the proposed structure, the interior space is partitioned and an attempt has been made to make the maximum use of available space (Figure 19).

The interior space of the structure is designed in such a way that it can be partitioned. This type of partitioning is easy to implement and assemble (Figure 20). Figure 21 presents the building system from the top and outside view. Eventually, the building system is modular and can be easily expanded and transformed into a larger space and a toilet can easily be installed in this system.

The windows are designed in a way that can be opened and closed from the inside and nothing can be seen from the outside when they are closed. Some important features of the system are presented in Table 7.

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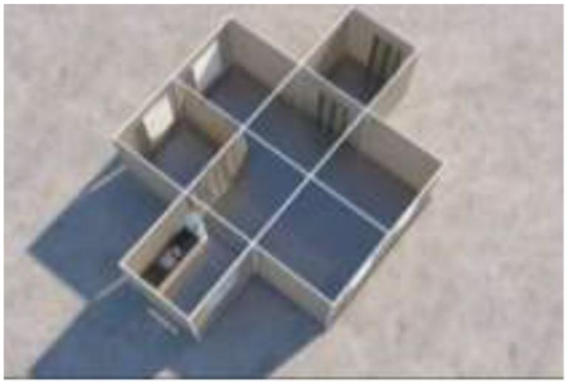

Figure 19. The space inside the proposed structure

Figure 20. Partitioning of the space inside the proposed structure

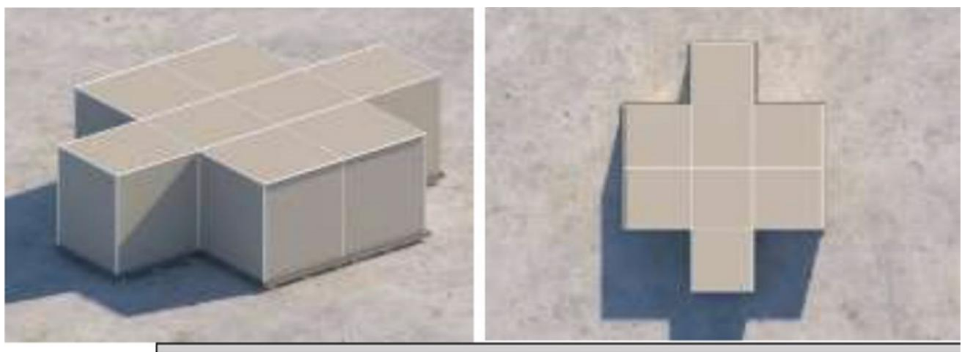

Figure 21. Top and side views of the proposed structure

Table 7. Important features of the proposed system

Approximate weight	Approximately 125 kg
Main materials and materials	Fiberglass parts are produced using frames of metal or PVC molds.
Installation method	It does not require any tools and the connections are threaded.
Necessary tools	Different parts are produced in the desired workshop and are quickly connected on the site.
Environmental conditions	It can be used in all environments.
Useful life	In the open environment for up to 30 years and in hot areas for up to 20 years.
Warehouse conditions	Chemicals do not require closed storage, but require safety and fire extinguishing conditions.
Shipping method	The structure produced by the container can be transported everywhere, and the production chambers are connected by the workforce at the given site and workshop.
Advantages	- No penetration of moisture into the structure -High compressive and mechanical resistance -Long lifespan -Very light compared to other materials -Fast and convenient modular production -Respect for privacy -Maintaining human dignity
Mass production	Can be easily mass-produced considering the type of materials available.

Discussion and Conclusion

In previous incidents, the Red Crescent Society of the Islamic Republic of Iran has provided tents to the affected people, which were made domestically and in some cases donated by foreign countries. In this study, it was found that these tents do not match the needs of the survivors and are not comfortable enough due to various problems in design.

In fact, these people had to endure living in these tents. In the current study, according to documentary resources, a list of criteria was prepared with the aid of experts (with items on climate and weather, production cost, mass production capability, observation of a minimum construction standard and human dignity, modularity, culture, and privacy, easy use, and lack of expertise) for designing emergency accommodation.

Considering the geographical and climatic range of our country, the existence of only one tent structure model cannot fully meet the diverse needs of survivors. Lack of privacy, annoying cold and heat, inappropriate and non-standard dimensions, lack of sufficient security, non-expandable size, and inflammability are the problems associated with the existing tents. A new system for emergency accommodation was introduced to solve the existing problems based on field observations, interviews with experts, and ideas taken from other accommodation systems.

Due to the relatively high costs and the time it takes to prepare the temporary accommodation structure, the affected people often have to live inside the tent for a long period of time. The proposed building system has provided the chance for better emergency and temporary accommodation by optimization of previous type of tents and adoption of new materials and designs. This new system is also modular in design and can easily be expanded and transformed into a bigger space that has the possibility of installing a toilet. Further studies should investigate the performance of pilot samples and conduct cost-benefit economic analyses.

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Conflict of Interests

The authors declare that there is no conflict of interest in this study.

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