Designing post-disaster temporary housing inspired by the housing of indigenous nomads of Iran

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Abstract

The significance of post-disaster temporary housing for the victims has led to the problem of designing a good model of temporary housing. According to research hypothesis, using the design of Iranian nomads’ housing instead of common forms of temporary housing contributes to energy saving. Investigating the architecture of nomads’ housing indicates that there is a type of indigenous knowledge for designing and constructing this type of housing. After the study, data collection and a review of the types of Iranian nomads’ housing using library and causal method, thermal simulation was conducted to investigate the effect of changing the temporary housing form inspired by the nomads’ housing on energy consumption. Findings showed that using shapes like Kapars of Baluchistan nomads, wigwams of Shahsavan tribe in Ardabil and mudhifs of Khuzestan will save energy for 36%, 24% and 25%, respectively.

Keywords: post-disaster temporary housing; nomads housing; energy saving

1. INTRODUCTION

Usually, after a wide and large-scale natural disaster, residential areas become useless. Therefore, the first thing that creates security and comfort for the victims is to have a good housing for the family gathering together [1]. Housing is not limited to a ceiling. People need housing to maintain their health, security and, above all, to preserve their honor and self-esteem [2].

1.1. Housing

Housing is literally defined as to relax and to be in peace [3, 4]. Housing should bring security and comfort to the family with a sense of belonging [5]. Tackling the homelessness problem and housing of the victims is a major issue that is of special importance in the phase of post-disaster confrontation [6]. One of the phases of relief is the temporary housing of the survivors in the post-crisis harsh conditions [7].

1.2. The priorities of post-disaster housing design

The problems of current housings are as follows: lack of privacy, irritating cold and heat and inappropriate, non-standard tents and CONEX boxes [8].

In the crisis, provision of housing and meeting the victims’ needs are of special importance. Indoor thermal comfort in the housing is a priority when designing and building temporary housing. Relief seekers need good housing in terms of safety, culture and climate, with simple maintenance [9]. Although, temporary shelter is a short period of living for survivors and injured people, usually about few months till completion of permanent housing (this period usually lasts several months and sometimes up to two years until the permanent housing is ready). Also, emergency shelter is for a shorter period of stay as we should be concerned about the quality of the victim’s life in this period [10].

Climate is a fixed environmental factor affecting architecture and its built environment [11].
The proposed plan (temporary housing) should be according to the climatic conditions of the region while observing technical and architectural principles [12].

1.3. Reduce the buildings’ dependence on fossil fuels
Various studies conducted on temporary housing [13–16] highlight its importance. Using renewable energies should be anticipated for new buildings, which has been considered in the passive buildings [17, 18]. Passive architecture is a climate-responsive building that provides environmentally friendly architecture (which does not pollute the environment) [19, 20].

According to theoretical studies, given that the Iranian vernacular and nomadic homes are climate-responsive buildings and using natural energies is a priority to supply indoor thermal comfort, these native constructions are classified as passive buildings. To this purpose, the present study was conducted to model the Iranian nomadic homes to design temporary housing. Post-disaster temporary housing should be in line with the climatic conditions of the affected area and minimize the need for fossil fuels.

3. THEORETICAL STUDIES
Disaster is defined as a ‘catastrophic situation that suddenly occurs naturally or by humans, imposes hardships on the human community, and requires emergency and extraordinary measures to be overcome’ [21]. The age of post-disaster temporary housing in the world is less than five decades. Here, studies conducted on social, economic, cultural and environmental features of housing are more recent and date back to late 1970s [9]. In the studies conducted on disasters, provision of suitable housing for victims includes a continuous process of temporary housing to permanent housing that usually deals with emergency housing, temporary housing and, finally, permanent housing [22]. This study deals with temporary housing that is usually the housing of victims for a long time until they enter their permanent housing. Table 1 shows types of post-disaster temporary housing used in different countries.

Design and focus on post-disaster temporary housing are of significant importance and it should be started before the crisis (through studies and research) for post-disaster temporary housing [23]. The problem in this study was to provide indoor thermal comfort for users of temporary housing. It attempts to obtain a good shape for temporary housing via investigating the Iranian nomadic homes focusing on saving energy.
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Table 2. Features of nomads housing in different geographies of settlement in Iran [34].

| Row | Nomads ethnicity       | Type of housing | The used climate          | Compatibility features                              | Materials used                     | Shape and geometry |
|-----|------------------------|-----------------|---------------------------|-----------------------------------------------------|-----------------------------------|--------------------|
| 1   | Shahsavan nomads       | Wigwam          | Cold and mountainous      | Full compliance with environmental conditions       | Wood, reed, goat hair             | Plan: circular     |
|     |                        |                 |                           |                                                     | Exterior view: hemisphere          |        |
| 2   | Qashqai nomads         | Black tent      | Hot and dry               | Easy to carry, ability to change form in different seasons | Wood, reed, goat hair, stone      | Plan and exterior |        |
|     |                        |                 |                           |                                                     | view: rectangular                 |        |
| 3   | Turkmen nomads         | Kapar           | Temperate and humid; hot and dry | Easy take down, transportation and loading, reverse | Wood, reed, goat hair, camel hide | Plan: circular     |
|     |                        |                 |                           |                                                     | Exterior view: hemisphere          |        |

4. NOMADS HOUSING

Organized settlement of nomads in Iran began in the Pahlavi Era in 1933 [24, 25, 26]. The Iranian nomads mainly dwell in the western and southern regions of Iran around Zagros mountain range, and the tribes are more settled in the middle Zagros [27]. A moving lifestyle is the oldest lifestyle for humans, which is formed by employing natural resources and compliance with climatic-geographical conditions [28]. The housing of indigenous nomads of Iran, including wigwam, black tent and Kapar, are appropriate and environmentally friendly in their particular climate. Table 2 represents the classification of nomads housing in different geographies of Iran.

4.1. Tent
Black tents are used in hot and dry climates with a rectangular plan and exterior view. The hot air inside the tent pumps in the cold air [35].

4.2. Kapar
Kapars are installed in temperate and humid areas (in north of Iran), hot desert (in eastern and southeastern Iran) climate with a circular plan and a hemisphere exterior view [34].

4.3. Mudhif
Mudhif, which is a resistant structure with a complicated architecture, is regarded as a sacred housing for the guests in Arab tribes of Khuzestan [36].

4.4. Wigwam
Wigwam is a light-weighted and transportable structure, which is common among moving and herding nomads [34]. The housing of Iranian nomads is introduced in Tables 3 and 4.

5. RESEARCH METHODOLOGY

This was an applied study with a quantitative approach. The research method used in the first phase of the present study to collect data related to the nomads housing was library method. In the second phase, to test the hypothesis, the causal method and computer simulation were used. Simulation is among suitable methods in architecture studies, and it provides the opportunity to construct and investigate numerous construction models [37]. DesignBuilder was the research instrument in this study. This software employs EnergyPlus base solver to analyze the processes of thermal transfer governing the building [38]. When categorized, results from energy Demand of simulated models were analyzed using analogy and induction.

5.1. Validation of research instrument: DesignBuilder software
To examine the accuracy of the results of DesignBuilder, an experimental sample of ASHRAE Standard 140 Case 600 (2001) was tested, and the obtained results were compared to the results in the manual. The software version was validated and approved by ASHRAE Standard [44]. DesignBuilder with EnergyPlus simulation engine was used in the simulation stage. EnergyPlus is a common simulation tool in energy and construction sector, which was used in the studies in this area [45–53].

5.2. Phases of research
In eight steps, the research was done. The research structure is introduced in Figure 1.

5.3. Simulation in DesignBuilder
After the initial studies, for instance types of temporary housing (Table 1) and collecting data related to the Iranian nomads housing (Tables 3 and 4), modeling of temporary housing was conducted inspired by the indigenous nomad housing in Iran...
Table 3. Nomads housing with closed shape in different geographies of Iran.

| Name                      | Mudhif    | Houses of Baluchistan nomads (Kapar) | Wigwam (Shahsavan tribe in Ardabil) | Turkmen Wigwam |
|---------------------------|-----------|-------------------------------------|-------------------------------------|-----------------|
| Exterior view             | ![Mudhif](image1) | ![Houses of Baluchistan nomads](image2) | ![Wigwam](image3) | ![Turkmen Wigwam](image4) |
| Texture of the structure  | ![Mudhif](image5) | ![Houses of Baluchistan nomads](image6) | ![Wigwam](image7) | ![Turkmen Wigwam](image8) |

Table 4. Nomads housing with enclosed shape in different geographies of Iran.

| Tribe                      | Qashqai tribe | Chaharmahal and Bakhtiari nomads | Torkashvand tribe, nomads of central regions |
|----------------------------|---------------|---------------------------------|--------------------------------------------|
|                            |               | ![Qashqai tribe](image9)        | ![Torkashvand tribe](image10)              |

and simulation was conducted in four shapes of building shell. The independent variable of the study was the shape of temporary housing and the dependent variable was the amount of energy demand (of temporary housing) to provide indoor thermal comfort. In the software, the range of indoor thermal comfort was defined in the climate file based on globally approved standards. The climate file was loaded in the software based on the representative city of four climates. The intervening variables were controlled during simulation phases. Variables including the number of people living in the housing, equipment used by them and the location and area of the windows in all modeling were considered as equal.

5.3.1. Area of the sample temporary housing

One of the reasons of users’ dissatisfaction is the temporary housing dimensions and the lack of living space requirements. Each temporary housing must have a room, a small kitchen and a bathroom (Table 5).

According to the rankings in the brainstorming meetings and the Delphi method applications, the authors scrutinized the case, and ultimately standards for the minimum area required for temporary housing were extracted according to the results that supply the least survivors’ demands, which is 30 m² (Authors, 2018). The inventory used in Delphi method contained six items, which was filled by 24 experts in architecture and building.
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5.3.2. Height of temporary housing
The height of the sample is 3 m. According to Nikravan Mofrad, floor-to-ceiling height between 2700 and 2800 mm is the most desirable height for common residential urban units [54]. The interior height of samples was 2.70 m.

5.3.3. Shapes & materials used in simulated models.
The features of shapes under study, which are simulated to obtain the optimal shape for temporary housing, are shown in Table 6.

Based on the main theme of the study, the shapes modeled by nomads housing are shapes A, B and C (as shown in Table 6).

Afterwards, simulation of the shapes in the building materials software for temporary housing was considered as Table 7. Cement was used for simulation due to its being shapeable; however, other materials that match the location of disaster could also be used. Given that to compare energy demand of the models, the effect of the form of temporary housing was considered and construction materials and the thickness of the external shell of the building were considered as equal in all models. In any case, construction materials are among the controlled variables.

6. DISCUSSION AND ANALYSIS OF FINDINGS
According to the research hypothesis, using the design of Iranian nomads’ housing instead of common forms of temporary housing contributes to energy saving. To test the hypothesis, causal method and thermal simulation were used.

The effect of the shape of temporary housing on energy demand was investigated. Considering the hypothesis, energy demand of the building could be reduced by changing the shape of the building without changing the area of the plan. To obtain an optimal shape for temporary housing, a building with lowest annual energy demand is considered. Four cities were selected...
Figure 2. Education level and gender of the respondents.

Table 6. Introducing modeled shapes (according to the nomads housing).

| Type                                      | Image | Type                                      | Image |
|-------------------------------------------|-------|-------------------------------------------|-------|
| **Prism**                                 |       | **Cube (housing cube)**                   |       |
| common shapes of temporary                |       | **Cylinder**                              |       |
|                                           | E-S-A | E-S-A                                     | 93.3  |
|                                           |       |                                           | 81.1  |
| **Hemisphere**                            |       | **Without base (shape A)**                |       |
| Hemisphere like a wigwam used by Shahsavan tribe |       | **With base 1 m (shape B)**               |       |
|                                           | E-S-A |                                           | 53.9  |
|                                           |       |                                           | 61.7  |
| **Angles of the wall**                    |       | **Square**                                |       |
| (15° to the vertical axis)                |       | **8-sided**                               |       |
|                                           | E-S-A |                                           | 69.5  |
|                                           |       |                                           | 66    |
|                                           |       |                                           | 66.7  |
| **Cone**                                  |       | **10°**                                   |       |
|                                           | E-S-A |                                           | 68.4  |
|                                           |       |                                           | 63    |
| **Building with a barrel vault**          |       | **Without base (shape C)**                |       |
| Barrel vaulted cuboid like a mudhif       |       | **Base 1 m (shape Cb)**                   |       |
|                                           | E-S-A |                                           | 71.8  |
|                                           |       |                                           | 77.1  |

Exterior surface area (m²): E-S-A

as representatives of four climates in Iran to be simulated in DesignBuilder according to Table 8. They are as follows: Yazd was selected for a climate with hot and dry summers and cold winters; Bandar Abbas was selected for a climate with hot and humid summers and moderate winters; Shahrood was selected for a climate with moderate summer and cold winters; and Tabriz was selected for a climate with moderate summers and very cold winters.

In the first phase, the energy demand of three shapes of regular geometrical shapes and shapes modeled by Iranian nomads
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Table 7. Materials used in simulated models.

| Details from outside to inside, centimeters | Floor | Concrete (5 cm) | Details of the ceiling | Concrete (10 cm) | Air (10 cm) | Concrete (10 cm) | External walls | Concrete (10 cm) | Air (10 cm) | Concrete (10 cm) |
|------------------------------------------|-------|-----------------|------------------------|------------------|------------|-----------------|---------------|-----------------|------------|------------------|
| Windows                                  | Double-glazed windows | Usual double glass, 0.3 cm | the air between of glasses, 0.13 cm | 4 cm UPVC |

Table 8. Introducing the sample cities from four different climates [57].

| City          | Climate                                    |
|---------------|--------------------------------------------|
| Tabriz        | Very cold winter and moderate summer       |
| Yazd          | Cold winter and hot and dry summer         |
| Shahrood      | Cold winter and moderate summer            |
| Bandar Abbas  | Moderate winter and hot and humid summer   |

Table 9. Energy demand of the shapes modeled by nomads housing.

|               | Kwh/m²/Per year | Common shape | Shape A | Shape B | Shape C |
|---------------|-----------------|--------------|---------|---------|---------|
| Yazd          | Sum of energy   | 218          | 130     | 157     | 153     | 170     |
|               | Heating         | 159          | 105     | 122     | 124     | 134     |
|               | Cooling         | 59           | 25      | 35      | 29      | 36      |
| Tabriz        | Sum of energy   | 384          | 251     | 291     | 296     | 320     |
|               | Heating         | 380          | 249     | 288     | 294     | 317     |
|               | Cooling         | 4            | 2       | 3       | 2       | 3       |
| Shahrood      | Sum of energy   | 238          | 159     | 184     | 185     | 199     |
|               | Heating         | 231          | 157     | 181     | 183     | 196     |
|               | Cooling         | 7            | 2       | 3       | 2       | 3       |
| Bandar Abbas  | Sum of energy   | 132          | 82      | 104     | 99      | 110     |
|               | Heating         | 12           | 9       | 10      | 11      | 11      |
|               | Cooling         | 120          | 73      | 94      | 88      | 99      |

(Table 9) housing were modeled, simulated and calculated in Yazd (Figure 3). After comparing the energy demand of the mentioned shapes, the selected samples of the second phase (from the results of the first phase assessments) were examined in the rest three cities for energy demand (Figure 4).

The area of the plan for selected shapes was 30 m².

Among different envelope elements (i.e. walls, roofs and windows), exterior walls are the most influential building element in the energy analysis [55]. Since the dimensions of opening and materials used in all models are the same, reduced heat exchange between inside and outside of the building is affected by the external shell of the building. As the shape of the temporary housing changes, the area of walls and the ceiling also changes such that the area of external shell also reduced. The reduced area of the external shell in the shapes modeled (from the nomads’ housing) relative to the cube (Table 6) reduced energy loss and energy demand of the building (Table 9).

6.1. Investigating energy demand of the shapes modeled by nomads housing

Table 9 shows (heating-cooling) energy demand. In the heating phase, it determines the building’s demand for thermal heating in cold weather (heating period). In the cooling phase, it determines the building’s demand for indoor thermal comfort in warm weather (cooling period, when the building is equipped with external canopy and natural conditioning). The sum of cooling and heating energy shows energy demand of the building to provide indoor thermal comfort all around a year. Findings showed that in four cities from different climates investigated, as the shape of the housing changes, the trend in the energy demand graph is similar. Changing the shape of the temporary housing from cuboid into shape A showed the best results (Figure 4; Table 9).

Annual energy demand of the common shape of temporary housing (cuboid) was 384 Kwh/m² in Tabriz. Annual energy
demand of shape A (hemisphere like a wigwam used by Shahan nomads in Ardabil) was 251 kwh/m² in Tabriz. In the other cities, changing the shapes from a cube into the shapes modeled by nomads housing reduces energy demand. In Yazd, with cold winters and hot and dry summers, changing the shape of temporary housing from a cube into shape B (hemisphere with a post like a Kapar used by houses of Baluchistan nomads) reduced energy demand, by 61 Kwh/m². According to the research, on the dome-shaped roof, thermal changes outside have little effect on the indoor temperature [56].

Using Microsoft Excel and AutoCAD, and according to Figure 5, the proposed area (minimum space) for temporary housing is shown in Table 5.

In Bandar Abbas with moderate winters and hot and humid summers, changing the shape of temporary housing from a cube into shape C (a barrel vaulted cuboid like a mudhif used in Khozestan) reduced energy demand by 33 Kwh/m². Findings showed that in Shahrood, changing the shape of temporary housing from the common shape into shapes A, B and C reduced energy demand.
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In order to compare vernacular materials in terms of energy consumption, cube and hemisphere were simulated with brick and investigated. Given the similar movement trend of energy consumption diagram for two shapes, while changing materials, the use of proposed shapes was still valid (Figure 6).

6.2. Investigating CO$_2$ emissions by changing the typical form of temporary housing
One of the important variables to protect the environment and to create a sustainable architecture was to reduce CO$_2$ emissions. Conservation of fossil fuels leads to a reduction in carbon dioxide emissions. Given that the shapes modeled from indigenous nomads housing in Iran save energy by $\sim$24–36% in each climate on average, the amount of reduction in CO$_2$ emissions in these shapes was calculated (Figure 7).

As shown in Figure 7, changing the shape of temporary housing from cube into hemisphere in Tabriz, Shahrood and Yazd reduced CO$_2$ emissions by 27, 24 and 30% respectively. To provide indoor thermal comfort for the residents of temporary housing in Tabriz, cube housing emitted 125.61 tons and hemisphere emitted 91.29 tons of CO$_2$ in a year. A 34% reduction in CO$_2$ emissions was observed by changing the shape of housing from a cube into a hemisphere (Figure 7).

7. CONCLUSION

The present study was conducted to improve the quality of indoor thermal comfort and to optimize energy consumption in post-disaster temporary housing using the vernacular knowledge of the Iranian nomadic housing on the shape of the housing. The research question was to create a passive post-disaster housing and to save energy consumption by changing the common shape of the temporary housing. According to research hypothesis, using the shape of Iranian nomads’ homes instead of common forms of temporary housing contributes to energy saving. To test the hypothesis, the causal method and computer simulation were used through DesignBuilder.

Based on the investigations, three vernacular nomadic and local housing with enclosed spaces are presented like a house, are as
Kapars are set up in temperate and humid areas with a circular plan and a hemisphere exterior view.

- Wigwam used in cold mountainous climate with a circular plan and a hemisphere shape, or a hemisphere with a cylindrical plan.
- Mudhif is a Kapar with a rectangular plan and a barrel vaulted architecture.

Findings suggested that using shapes like Kapar used by houses of Baluchistan nomads, wigwams of Shahsavan tribe in Ardabil and mudhifs of Khuzestan will save energy on average, by 36, 24 and 25%, respectively.

Percentage of energy saving in temporary housing as the shape changes from cube into other shapes A, B and C (Figure 8).

CO₂ emissions using fossil fuels (to provide indoor thermal comfort) experienced a 25% reduction by changing the typical shape of temporary housing into the modeled shapes (from Iranian nomads’ housing). The percentage of reducing CO₂ emissions in temporary housing determined by changing the shape from cube to hemisphere is shown in Table 10. In Tabriz, a 30% reduction in the CO₂ emissions during heating period is a result of changing the shape, and, by changing the shape of temporary housing in Yazd, a 45% reduction in CO₂ emissions was observed in the cooling period.

By changing the shape of temporary housing from a cube into a hemisphere, a 26%, 25%, 29% and 24% reduction in CO₂ emissions was observed in the cold winter and temperate summer climate, cold winter and warm summer climate, cold winters and hot and dry summer climate and temperate winter and hot and humid summer climate, respectively.

It is suggested to provide hemisphere and barrel vaulted ceiling for post-disaster temporary housing. These shapes could be constructed using assorted materials including brick, sand bags (Nader Khalili), cement and even light materials like construction foams, etc., to provide thermal comfort and to save fossil fuels and energy consumption in order to result in sustainability and protecting the environment.

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**Table 10. The percentage of reducing carbon dioxide emitted by temporary housing determined by changing the shape from cube to hemisphere.**

|        | Tabriz | Shahrud | Yazd | Bandar Abbas |
|--------|--------|---------|------|--------------|
| Jan    | 30%    | 27%     | 27%  | 7%           |
| Feb    | 30%    | 26%     | 25%  | 4%           |
| Mar    | 28%    | 22%     | 21%  | 4%           |
| Oct    | 17%    | 8%      | 4%   | 38%          |
| Nov    | 26%    | 22%     | 20%  | 6%           |
| Dec    | 29%    | 26%     | 25%  | 8%           |
| April  |        |         |      |              |
| May    | 25%    | 18%     | 16%  | 41%          |
| June   | 24%    | 33%     | 45%  | 37%          |
| July   | 32%    | 38%     | 46%  | 33%          |
| Aug    | 33%    | 34%     | 46%  | 30%          |
| Sept   | 18%    | 22%     | 37%  | 38%          |

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