PVC Temporary Shelters

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Abstract
Providing temporary shelter after major disasters is one of the major challenges for survivors and relief and reconstruction officials. In Iran, besides the distribution of tents, a common solution is to construct and deliver containers to the damaged areas. Following the 2017 earthquake in Kermanshah province, extensive damage was inflicted on urban and rural settlements, especially in the Dasht-e Zahab and Qasr-e-shirin districts. The high extent of the destruction, the proximity to the cold season, the rain, and the problems of living in emergency accommodation tents necessitated the acceleration of the provision of temporary housing and permanent shelter. The present article is a report of an action research project to find a different solution to this problem. Experience shows that accident survivors, especially in rural areas, provide shelter for their families by the locally available materials and technology, or the materials remained from the destroyed buildings. Aware of such a capacity, we tried to take a step towards providing temporary shelter by making maximum use of local materials and some non-local but inexpensive and affordable materials.
For the first time, PVC pipes were used as the main structure of a temporary shelter. In the first phase, in December 2017, researchers visited the city of Sarpol-e Zahab and several villages in the region for six days in order to identify and evaluate the conditions of the region. Then, the design and execution of the first experimental sample of this structure called Kashaneh with dimensions of 2 × 3 meters was done in the Faculty of Architecture and Urban Planning of Shahid Beheshti University. During the execution, many points were identified and corrected, the strength of the structure was tested under gravity loading, and the structural calculations were performed using SAP2000 software. In the next step, the original sample with dimensions of 3 × 4 was built in the village of Kuik Aziz in the city of Sarpol-e Zahab. The willingness to participate among the residents and the positive feedback of the people towards the original sample indicated the success of this type of temporary shelter. Monitoring the samples, lower costs, speed of execution, participation of local labor force, ability to develop and attention to the psychological needs of the survivors in terms of similarity of the created space to a normal building, are among the advantages of this project.
Keywords: Temporary housing, Permanent housing, PVC pipe, Earthquake, Action research, Sarpol-e Zahab.

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Introduction

Providing safe shelter is one of the main measures needed after natural disasters to save the lives and property of the injured and return them to normal life. Emergency accommodation is often provided by officials, aid workers or public institutions in the form of tents. In practice, however, survivors do not wait idly for the official help to arrive and work on their own, using the available local materials and technologies to provide immediate shelter for themselves and their families.

Temporary shelter is easier in rural areas because villagers often have experience building their own homes and using ecofriendly materials. In addition, higher physical strength, which is less common in urban areas, is also effective. Lower expectations and the ability to adapt to difficult conditions are also among the cultural characteristics that facilitate working in the field of temporary shelter. The village of Jalizi near the city of Hamidiyeh is a notable example of rapid construction using local materials and creativity. While the reconstruction of the village was slowly going on during 1982-1983, in order to protect themselves from the harsh weather, the war-torn people built another village next to the new site with mudbricks. They used the doors and windows of their ruined houses to build these temporary shelters and housed their families and livestock in them for two to three years (Miri and Shakeri, 1390: 54-64).

As a matter of course, climatic conditions, the time of the accident and the amount of damage are all effective in the performance of man-made shelters and distributed tents.

In cases where the extent of destruction is high, the process of reconstruction is sometimes longer than two years. In such circumstances, the provision of temporary shelter becomes even more important. The earthquakes of 1990 in Gilan and Zanjan and the earthquakes of 2003 in Bam and 2017 in Sarpolzahab are examples of this.

Following the 1990 Manjil earthquake, based on previous experiences, the Iranian government changed its reconstruction policy in order to reduce the survivors' dissatisfaction with the reconstructed housing units. The familiarity of survivors and local carpenters with Zogali[1] structure, local materials and basic patterns of local architecture in temporary housing, encouraged officials to use this type of structure as much as possible to benefit from public participation in the process of reconstruction and to lower the costs of providing post-disaster temporary shelters. Therefore, using this native structure, temporary accommodation rooms were set up in the vicinity of the destroyed houses to help the villagers overcome the harsh weather of the region during autumn and winter. Most of the temporary accommodation units were ready for operation by the end of summer and were used by the survivors for six months until the the establishment of a permanent shelter at the beginning of spring (Fallahi, 1994) and (Akhundi and Bahraini, 2000). The results of Baqaeifar's (2009) studies show that having a shelter with walls and roof instead of tents creates a sense of satisfaction among people because this way they can participate in the process of building their own houses.

The occurrence of devastating earthquakes in the country has made it more serious to have a variety of temporary housing plans that can meet the needs of their residents. This is further a great opportunity for specialized groups to design and implement shelters. In this regard, the following questions are raised:

- What are the effective indicators of designing a temporary shelter?
- What are the needs of rural residents in Sarpol-e Zahab?
- Is it possible to use PVC pipes as the main structure of temporary housing to achieve the above goals?

The present article is a report of an action research to provide temporary post-disaster shelter with maximum use of eco-friendly, common and cheap materials, and the capacity of survivors. Among the available materials, this paper investigated the use of PVC pipes to provide temporary shelter with the desired quality.

For this purpose, while reviewing the past experiences of using different types of temporary shelter to address the positive and negative points of each, we started field studies to identify the needs of survivors in the damaged areas. Due to the importance of providing temporary shelter in earthquake-prone areas, the initial sample was designed based on theoretical and field studies. In order to investigate the problems of the original design and its modification, a prototype was built on the campus of Shahid Beheshti University of Tehran. In the next stage, the main sample was made in Kuik Aziz village, located in Sarpol-e Zahab city, which is described in detail in the fourth section of this article. Finally, by examining the feedback of villagers and responding to their needs, we evaluated the achievement of the objectives of the action research.

An overview of the Theoretical Framework

The general meaning of shelter and temporary accommodation extends beyond the living space and includes concepts such as peace of mind, convenience and mental comfort. It should be noted that people who survive a disaster do not only lose the building of their residence but also their homes. Therefore, besides providing a temporary place to stay, a post-disaster shelter should also be able to provide peace, security, reassurance and psychological rehabilitation for the injured person (Saedi Khameneh and Hosseini, 1389, 13).

Providing a suitable living space in accordance with pre-accident conditions is an important matter that should be seriously considered in the reconstruction architecture for victims who suffer from pain and injuries. From this perspective, emergency and temporary living spaces should be designed and prepared in such a way that while protecting people from the changing conditions of the natural environment such as heat, cold, wind, precipitation and the like, ensure the basic needs of comfort and convenience (Sartipipour, 2011: 19). In such a situation, it is very helpful to use technologies that have the ability to quickly set up and recover living conditions. This reason the reason of prioritizing the use of technologies and materials that are cheap, easy-to-use, eco-friendly, recyclable and quickly implemented"(Sartipour, 1390: 19-34).

Table 1 lists some of the criteria that are mentioned in different sources for planning temporary accommodation after an accident.

Source	Main criteria of post-disaster accommodation
Fallahi (2007)	Use of indigenous technologies, low transportation costs, adaptation to the needs of the victims in terms of safety, culture and climate, participation of victims in the process of establishment, justice in the equal distribution of temporary accommodation among the victims, giving importance to the criteria of local and indigenous architecture and landscaping
Sartipipour (2011)	Quick transportation and deployment, adaptable to different conditions, use of suitable structures, ease of production, ease of installation and operation, eco-friendly, suitable for different climates
Omidvar et al. 2007	Protection against heat, cold, wind and rain, stabilizing and maintaining the boundaries of the house (ownership and occupation), providing psychological security of the private environment, determining a specific place for receiving services (medical services, food, etc.), locating the site in a place that is easy for people to access their work. Provide a good level of quality of life in temporary housing in accordance with the prevailing standards of living, low price, fast construction housing, fit the culture of the victims, reusable, easy and non-polluting removal of temporary housing
Bahreini and Akhoundi (2000)	Protection against heat, cold, wind and rain, providing storage for the remaining equipment that survived the disaster, demarcation and protection of houses, providing psychological security and private environment
Corsellis and Vitale (2005)	Having proper privacy and security, providing sustainable and resilient housing, having sufficient lighting, heating network and proper ventilation, using proper infrast ructure including water supply, paying attention to the health conditions and facilities used for waste management and meeting cultural identity manifestations

T1. Temporary Housing Planning and Design Criteria.

When a disaster hits, those who survive need a shelter that can provide basic needs of survival for them. The use of modular structures such as containers is a common solution to provide temporary housing in many countries. The use of these structures is widely used in many countries due to the ease of connection and separation of parts, easy transportation, high speed of execution, usability for wide applications, recyclability etc. (Yan Hong, 2017). However, the results show that there are many problems in the use of these units, including: lighting, ventilation, water supply, sewage, sound and heat insulation. In addition, users are dissatisfied with the important issues of safety against fire hazards and electrical problems (Yoo et al., 2012).

Research Methods

The need for immediate provision of temporary and permanent housing is a great challenge for the responsible bodies due to the unfavorable weather of many areas damaged by accidents.

As a result, researchers began their studies to find a solution that can retain the dignity of the injured. Due to the concurrence of the research with the extensive damage caused after the earthquake in Sarpol-e Zahab and the process of providing temporary housing in that area, we used action research method for this study.

In many sources, this method is considered as an applied method that improves the status of the target community and leads to the acquisition of reliable local information through participation and engagement with the community (McNiff, Lomax and Whitehead, 2003: 28, quoted by Kamiz and Mac Tegart, 1982). This method, which is done as an experiment during the operation, is also considered as a tool that improves the level of knowledge. Action research is the process of producing knowledge that leads to insight in researchers and all participants (Greenwood & Levin, 1998: 50).

Therefore, the present study was conducted in two stages. first stage; In December 2017, a test sample of a temporary housing structure with dimensions of 2 × 3 meters was built in the Faculty of Architecture and Urban Planning of Shahid Beheshti University. Then, the main sample was constructed in January 2017, with dimensions of 3 × 4 meters, in one of the damaged areas, located in Kuik Aziz village, Sarpol-e Zahab area. Each of the steps of making these two examples includes a process that includes identifying issues and facilities in the area, planning, implementing, and observing and receiving feedback. In this section, a summary of the implementation process of these activities is described is described in detail.

Following initial investigations during the trip to the affected area, the necessary information was collected and the needs and capacities of the area were assessed. During this trip, providing temporary accommodation was evaluated as the main need of the residents of the area during that period. After the initial evaluations, using information obtained from desk and field studies, a shelter was planned and designed for temporary accommodation. Finally, the main criteria were extracted and applied in design and planning.

In order to test the design and ensure the efficiency of the structure, we executed a prototype on a one-to-one scale. During the implementation, we reviewed the problems and issues and made the required modifications in the plan. After that, the information and findings obtained from this stage were regularly summarized and recorded and then evaluated. Finally, the load-bearing structure was gravitated and analyzed. Following this stage, the preparations for planning and implementation of the main sample in Sarpol-e Zahab were provided.

Due to the special conditions of the damaged area and the restrictions on the supply of materials, as well as the existence of capacities such as debris left over from the demolition of buildings, changes were made in the materials used. After preparing the desired resources in January 2017, the construction of a prototype structure was carried out in Sarpol-e Zahab area, a village of Kuik Aziz. Due to the local conditions, the participation of the natives, the confrontation with the problems and issues in the region, the climatic conditions, the possibility of more detailed studies was provided. In fact, this stage increased the credibility of the research due to the use of action research method in order to provide more reliable information and in accordance with the real conditions of the region and improved the quality of the research.

Monitoring and evaluating the stages of work is one of the highlights of this research method. Examining the feedback of local residents to the implemented sample, has shown the involvement of the residents and provided construction training to them.

The last stage of an action research is dedicated to publishing a report for the community of experts for project accreditation. Therefore, the documents of the research and its findings were presented in the Road, Housing and Urban Development Research Center and were reviewed and followed up (Source: Construction Industry Information Database 2018). Each of these steps are described in detail below.

The Process of Design Formation

Need Assessment and Problem Recognition

In the evening of November 13, 2017, an earthquake measuring 7.3 on the Richter scale shook the Azgeleh region of Kermanshah province. The villages of Dasht-e Zahab and Salas Babajani areas and the cities of Qasr Shirin and Sarpol-e Zahab suffered serious damages. According to official figures, about 620 people died, 9,388 were injured and, 70,000 were left homeless. According to the deputy director of the Housing Foundation of Iran, 12,000 urban and rural housing units were affected by the earthquake and entirely destroyed leaving 15,000 housing units needed to be repaired (ISNA, November 13, 2017).

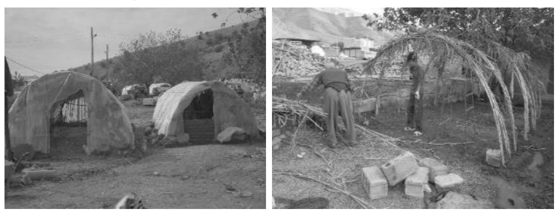
As a result, due to the onset of the cold season and the mountainous nature of a large part of the affected areas, it was necessary to speed up the provision of temporary shelter. For this purpose, 72,000 Red Crescent tents for emergency accommodation distributed, transferred and built in one week.

Due to the long time needed for transportation and preparation, construction workshops were set up by the IRGC in the affected area and about 18,800 shelters were distributed by government organizations and other groups in the area (Mizan News Agency, November 14, 2016). However, field studies by researchers on subsequent trips show that these temporary structures have not been able to obtain sufficient satisfaction from residents. Among the reasons for people's dissatisfaction are inadequate location, inadequate insulation and infiltration of rainwater and their high heat exchange, poor ground connection and problems with their cooling and heating. The risk of fire is also another issue of these structures.

Moreover, the collection of distributed containers from the damaged areas after the completion of reconstruction has been associated with many problems. In general, the difficulty and high cost of collecting and repairing the containers and the lack of sufficient space for their storage after the reconstruction period, leads to the loss of the country's resources and expensive processes. It also deprived the public from participation because needed specialized personnel and construction and repair workshops. As a result, it seems that these structures do not fully meet the needs of the affected areas and in some cases, add to the problems (Researchers' Field Visits, Fall 2017).

According to the needs of the people and the existing capacities in the region, the design of light, cheap and fast-executing structures with the participation of the people was examined. In order to identify the problems and facilities of the region, to study the culture and patterns of shelter construction among the indigenous people, a group of 5 people collected their information, observations and interviews during a six-day trip to the affected areas.

Accordingly, in the aftermath of the earthquake, people settled in Red Crescent tents, drawing on their past capacities and skills, and using reeds to build shelters for their families and livestock. It should be noted that in this area, especially in Qasr Shirin, there are many trees that in their place is a good opportunity to build a temporary shelter (Figure 1).



F1. Some of the shelters which are being constructed by the villagers of Sarpol-e Zahab (November 2017).

By examining the problems and shortcomings of various shelters, the current project has tried to address these shortcomings and create opportunities for the future by positing the below goals:

- Reduce construction costs

- Reduce structure weight
- Minimize the time to set up a shelter
- Availability of raw materials throughout the country
- Ability to adapt to different climates
- Resistance to wind and possible earthquake
- Use of familiar and common forms
- Ability to use public participation
- Continuing to use the shelter as part of permanent accommodation

Examining the situation of the affected area, we selected the materials that were available in all parts of the country and have a normal price. PVC pipes were among these materials. The use of these materials, while achieving the above goals, provides the possibility of training, construction, repair and maintenance of the structure by residents.

It should be noted that according to research, the use of PVC pipe as a load-bearing member of a structure has been conceived for the first time. This pipe with low diameters has been used in the world as light structures with plastic coverings and fabrics, most of which have been used in greenhouses, warehouses, and car park covers. In Iran, except for piping in buildings, it is only used for the purpose of building a greenhouse that does not need a high load-bearing capacity. Therefore, no structure has been found that has used this pipe as a load-bearing member. Examples of different applications of these pipes are shown in Figures 2 and 3.


F2. (right) Structure using 50 mm PVC pipe in a warehouse (Source: Mascus UK. 2017).
F3. (left) Structure using PVC pipe in a greenhouse (Source: Payesh, 2017).

In fact, a lightweight structure can be designed by using pipes and fittings and reinforcing them with wire that has the desired bearing capacity and also can be implemented in various areas. The primary components, including pipes and pivot fittings, are easily transportable, and for wall and ceiling fillers, the materials available in the climate of each region can be used. This project is designed as a habitable space in two consecutive phases of emergency accommodation and temporary accommodation after accidents, and later can be converted into permanent accommodation.

Execution of a Test Sample

With the completion of the primary plans and consideration of the points of implementing them, the initial studies began on the sixth day after the earthquake. After completing the design and studies, it was decided to build a single-scale experimental sample unit with dimensions of 2 to 3 meters on the campus of Shahid Beheshti University in Tehran. At this stage, the implementation of a 2-to-3 meter unit was planned and in order to be more adaptable to the environment, the use of available materials was selected as filler elements. Therefore, in this sample, the pruned branches of the trees on the campus were used. Also, in the process of simultaneous study and design, the possibility of using straw as the dominant vegetation in Sarpol-e Zahab was considered. Figure 4 shows the process of formation and design of this idea.

F4. Design process formation diagram.

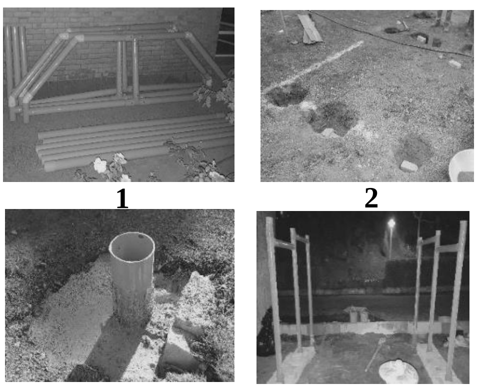
Construction Process

In the implementation of this sample, PVC pipes were used as the main structure. In this way, high pressure PVC pipes with a diameter of 110 mm are intended for foundations and semi-strong pressure PVC pipes with a diameter of 90 mm are intended for columns and roof frames (Figure number, step 1).

First, six points with a depth of 50 cm were dug in the ground and after leveling the bottom of the holes, six pieces of PVC pipes with a diameter of 110 mm and a height of 70 cm were placed in the holes as expected and completely filled and fixed with lime mortar (Figure 5, steps 2 and 3). Then, six columns of PVC pipes with a diameter of 90 mm were placed inside the foundation pipes, so that they had a complete overlap until the end, and were connected by installing horizontal pipes with a length of 1 meter at the top between the columns. After ensuring the vertical installation of the columns, the inside was completely filled with gypsum mortar in a ratio of one to three from above (Figure 5, step 4).

At this stage, the truss frames, which were made separately for the roof (Figure 5, Step 1), were placed on the columns (Figure 6, Step 5) and fixed together with existing joints (three-way and elbow) made of PVC and were fully secured with automatic screws (Figure 6, Step 6). Although truss members could be attached with PVC glue, the use of automatic screws made it possible to separate the truss parts and reassemble them. Since there is a possibility of errors during execution by local workers, the use of this method can make the execution more flexible and reduce the problems of prefabricated structures during work by local forces. After ensuring the correct position of the parts, it is appropriate to use glue.

To stabilize the structure and increase its resistance to lateral forces (wind and earthquake forces), galvanized iron wire (two or three layers of 1.5 mm twisted wire with a final thickness of 4-6 mm) is used (Figure 6, step 7) and crosswise and reciprocating in all openings in a completely retracted way through the holes created at the lowest point of the column and closed to the bottom of the roof frames (Figure 6, steps 8, 9 and 10).



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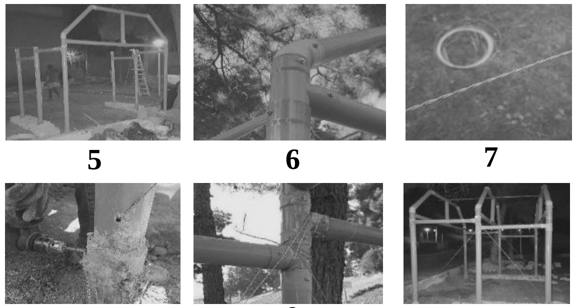
F5. The first four steps of executing the sample made in Tehran.



5 6 7 8 9 10

F6. Steps 5 to 10 of executing the sample made in Tehran.

Then the elements of the main structures, with the help of PVC pipes with a diameter of 25 mm (Figure 7, step 11), were formed into interconnected networks. The wire and the automatic screw were completely tightened. This increases the contact area between the two pipes and provides a better connection. It is worth mentioning that these narrow pipes were used for the ceiling and the wall with a distance of 30 to 50 cm from each other. At the same time, in order to integrate and strengthen the foundations of the columns, a brick chair with a brick height of half a meter was made around the structure (Figure 7, step 12). The floor of the interior space was removed and after reaching a suitable bed, first the floor was filled with lime mortar, then blockage was done with sifted stones and existing rubbish. Thus, the interior and exterior space are about 30 cm different from each other in height. It should be noted that due to the high cost of waterproofing, the use of nylon layers under the blockage and on the porcelain chair can also improve the moisture insulation of the floor and walls.

Moreover, the compressive loads due to the weight of the roof of the shelter are transferred to the roof beams and are transferred to the ground through columns filled with gypsum mortar.

Then, using the chicken net, all the inner and outer walls were covered (Figure 7, step 13) and then the empty space between the walls and the chicken net was filled with tree branches (Figure 7, steps 14 and 15). Using 1.5 mm wire, the two sides of the chicken net were connected (sewn) together with the filler branches of the wall (Figure 7, step 16).

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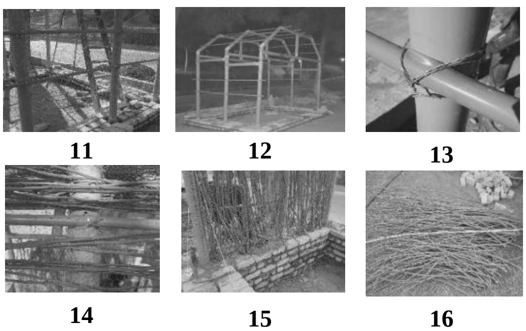
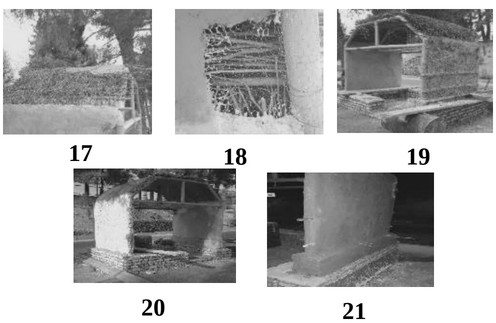
Then, using plaster mortar in a ratio of one to three, as a final coating on all surfaces, the walls and ceiling was covered (Figure 8, steps 17, 18 and 19). In the last layer of gypsum mortar in a ratio of one to two, it was applied softly on the walls to find a smooth surface. Finally, the wall thickness was between 10 and 13 cm (Figure 8, step 20).

At the end, the entire outer wall of the structure was soaked with lime slurry and then its roof was covered with 5 cm thick straw as a waterproof. In order to prevent the accumulation of precipitation on the structure by using thatch, a suitable slope has been given from the middle of the roof to around the structure (Figure 8, step 21) (Figure 9).



F7. Steps 11 to 16 of the sample made in Tehran.



F8. Steps 17 to 21 of the sample made in Tehran.

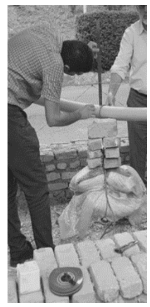
F9. Structural Designer and the Executive Team with the final sample of Kashaneh, Tehran, December, 2017.

Loading PVC pipes

After completing the construction of the prototype, to better evaluate the behavior of the structure, the team checked the load bearing capacity of the structure. In this test, a number of pipes with different diameters were tested for spot loading by 20-kg plaster pockets and 2-kg bricks in four different weights.

The deflection of the pipes was measured before, during and after loading and thus the best type and thickness of the pipe was selected according to its rise, the availability of connections for the construction of roof frames and considering the economic efficiency.

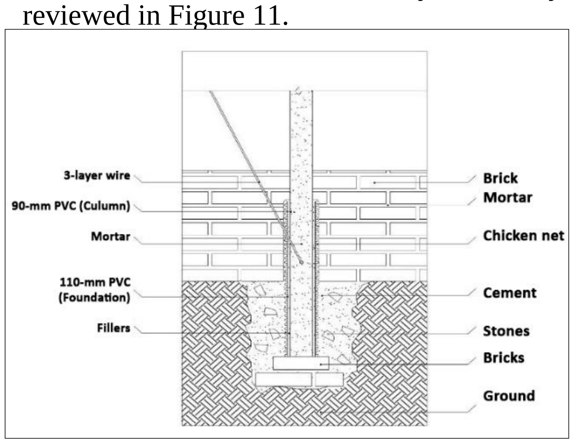
Finally, a high-pressure pipe with a diameter of 90 mm was considered as the best option according to the obtained results and cost estimation. In Figure 10, the load and measure of the deflection can be seen.



F10. 56-kg loading.

Executive Details

It should be noted that to better understand some of the executive details, they are briefly reviewed in Figure 11.



F11. Executive details of foundation.

Execution of the Original Sample

The second prototype was built on a one-to-one scale, located in the village of Kuik Aziz, 15 km north of the city of Sarpol-e Zahab, a city which was severely damaged.

Initially, the selection of the site for the construction of the sample was considered. The method and steps of construction in this sample were very similar to the Tehran sample and only a few changes were made to complete the design as follows:

The dimensions of the construction of the structure in Kuik Aziz were changed to 4 to 3 meters. For this purpose, 10 columns and 5 truss frames were used (Figure 12).

Among the differences, we can mention the construction bed. According to the type of soil (hand soil), to achieve a suitable bed, a little excavation and leveling was done. It is worth mentioning that the rubbish of this soil was used to block the floor. After that, the excavation operation started (Figure 13, steps 1 and 2).

In this structure, instead of lime mortar, cement-sand mortar was used for the foundations, which, of course, was easier to find than lime.

At all stages of the construction of the structural skeleton, in order to create a better bond between the PVC pipes and the gypsum coating, all the components were completely covered with chicken net before installation (Figure 13, step 3).

F12. Framework of Kashaneh (Kuik Aziz Village, January 2018).

1 2 3

F13. Steps 1 to 3 of the sample made in Sarpol-e Zahab – Kuik Aziz village (January 2018).

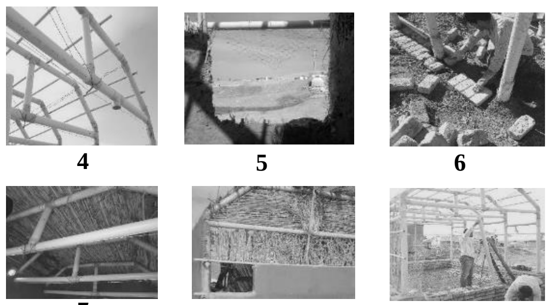
During the construction of the brickwork around the columns, pressure bricks that were left from the rubble of the neighboring villages were used (Figure 14, step 4).

Another part of the process of completing the structure was the installation and execution of doors and windows for the house, which used the doors and windows of the destroyed structures of the village.

Another difference between the two structures was the filler materials used in the walls. In Tehran, branches were used, but in Kuik, due to the abundance of reeds, 2 to 3 meter nails were used to fill the walls and cover the roof (Figure 14, steps 8 and 9).

In order to prevent the infiltration of moisture from the floor of the structure, at a height of 30 cm from the inside, blockage was done by rubble stones in the screened soils for wall mortar, and it was completely leveled and uniformed with cement mortar (Figure 15, step 10).

Finally, after the completion of the structure, due to heavy rainfall in this area, the flat part of the roof, with a thickness of 10-15 cm, was covered with thatch. In the middle of the roof, thatch was 5 cm thicker creating a gentle slope. This way, water conduction occurs faster. The exterior walls were also covered with lime slurry in two stages (Figure 15, stages 11 and 12).



F14. Steps 4 to 9 of the sample made in Sarpol-e Zahab – Kuik Aziz village (January 2018).

One of the important goals of the designers was to spend the least amount of money to select the materials and implement this shelter. In this regard, without considering the cost of human labor, in the winter of 2018, the construction cost was estimated to be equal to eighteen million rials.

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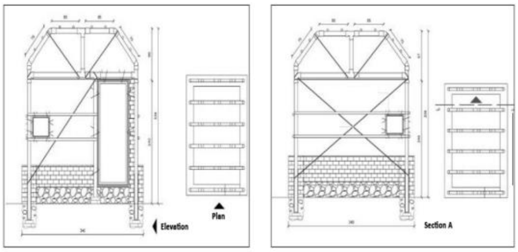
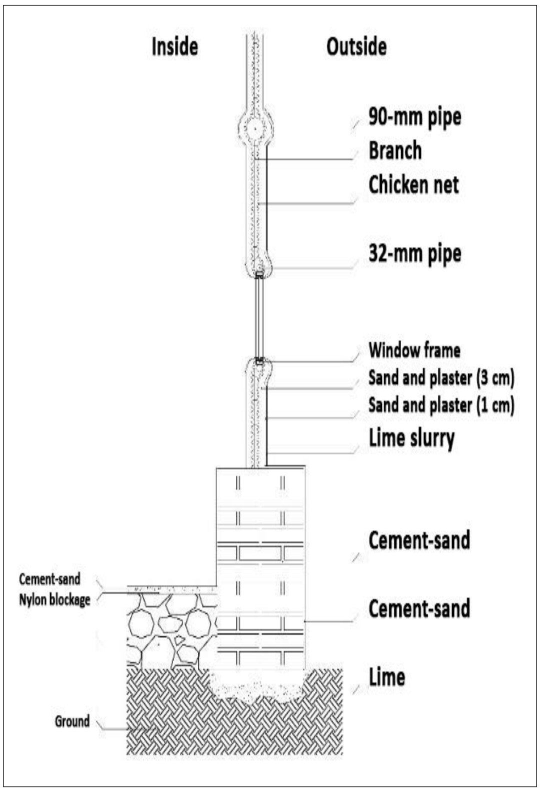
F15. Steps 10 to 12 of the sample made in Sarpol-e Zahab – Kuik Aziz village (January 2018).

Detailed Executive Plans

In Figure 16, a number of plans executed in the sample of the village of Kuik Aziz can be seen.



West elevation **East section**

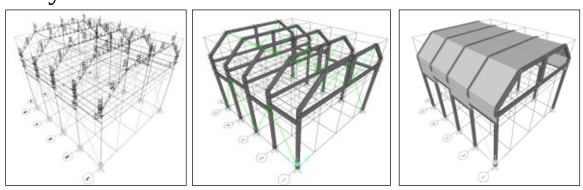


F16. Detailed plans of the sample executed in Kuik Aziz.

Calculations and Loading

In order to study the behavior of the structures under the applied loads and to select the appropriate sections in terms of strength, the structure was modeled by the SAP2000 software (Figure 17). Modeling was done statically under the effect of equivalent loads and assuming linear behavior of materials.

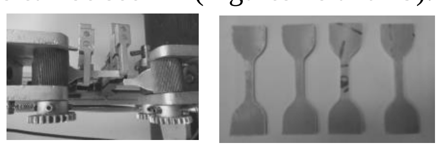
It should be noted that in this modeling, the structural strength of the thatch and fillers inside the walls, as well as the horizontal pipes (25 mm) used for the integrity of the structure, are completely ignored and only the loads on the structure and load-bearing elements were considered. Also, although all the columns of the structure are completely filled with gypsum mortar under the connection to the roof beams and increase the strength of the structure, but in the modeling, they are considered as hollow.



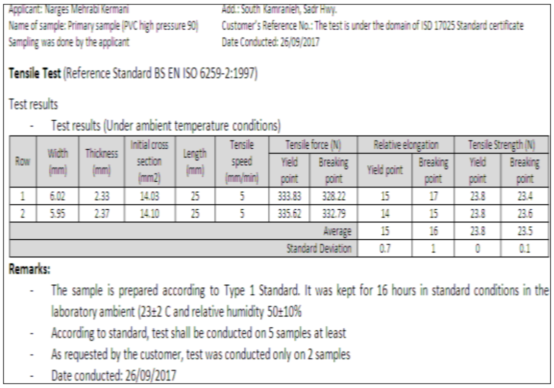
F17. Structural modeling in SAP2000 software (in this case the gray members are PVC pipes and the thin green members are metal wires). The last image shows how the load is distributed to the load-bearing members.

Materials

PVC pipes that were used in the structure bears Iranian standard 9119, but since the specifications in this standard are not sufficient for structural design, to verify the technical calculations of the structure and determine the mechanical characteristics of the materials used, samples of PVC pipes were sent to the laboratory of Razi Metallurgy Research Center to be tested once again. The results of yield stress and rupture stress can be seen in (Figures 18 and 19).



F18. Samples before and after testing (Razi Metallurgy Research Center).


Applicant: Narges Mehrabi Kermani
Add.: South Kamranieh, Sadr Hwy.
Name of sample: Primary sample (PVC high pressure 90)
Customer's Reference No.: The test is under the domain of ISO 17025 Standard certificate
Sampling was done by the applicant
Date Conducted: 26/09/2017

Tensile Test (Reference Standard BS EN ISO 6259-2:1997)

Test results

- Test results (Under ambient temperature conditions)

Row	Width (mm)	Thickness (mm)	Initial cross section (mm2)	Length (mm)	Tensile speed (mm/min)	Tensile force (N)		Relative elongation		Tensile Strength (N)	
						Yield point	Breaking point	Yield point	Breaking point	Yield point	Breaking point
1	6.02	2.33	14.03	25	5	333.83	328.22	15	17	23.8	23.4
2	5.95	2.37	14.10	25	5	335.62	332.79	14	15	23.8	23.6
							Average	15	16	23.8	23.5
							Standard Deviation	0.7	1	0	0.1

Remarks:

- The sample is prepared according to Type 1 Standard. It was kept for 16 hours in standard conditions in the laboratory ambient (23±2 C and relative humidity 50±10%
- According to standard, test shall be conducted on 5 samples at least
- As requested by the customer, test was conducted only on 2 samples
- Date conducted: 26/09/2017

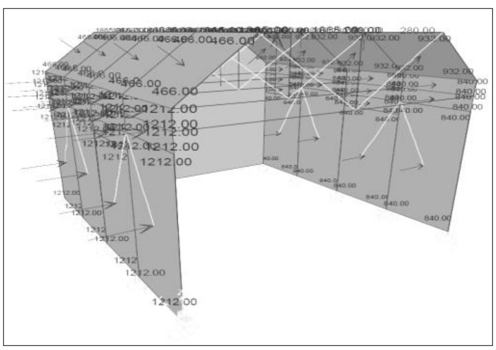
F19. Tensile test results.

Applied Loads and Loading Compounds

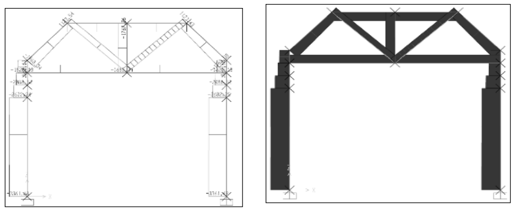
In the structural analysis of this building, the combinations of dead load, dead load with earthquake load in two main directions, and dead load with wind load in two main directions have been studied. Loads were applied as a static load equivalent to the structure and the analyzes of the performed structures are also linear static.

Earthquake load with calculation of earthquake coefficient equal to 0.32 is calculated according to code 2800 and is considered in structural analysis.

The calculation of wind load, based on the maximum wind speed mentioned in Para. 6 of the National Building Regulations, is equal to 130 kilometers per hour. This is equal to 1,036 kN /m2. Relevant coefficients, and pressure and wind coefficients for forward, backward and parallel winds have been adjusted in accordance with the vertical and parallel wind standards of the building (Figure 20).



F20. Distribution of wind load perpendicular to the load-bearing members of the structure

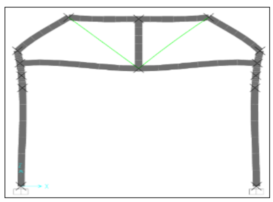


F21. Demonstration of stress in structures under tensile and compressive forces.

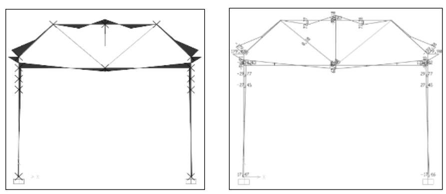
From the results of structural analysis, it can be seen that the force in the pipe is much less than the final strength of the section (taking into account the geometric characteristics of the section). Similarly, the tensile force calculated in a metal wire with an acceptable reliability is less than the final strength of the wire. In (Figure 23) the bending of the elements is observed under these loads.

Displacement Diagrams

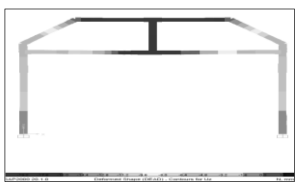
As an example in (Figures 24 and 25), two diagrams of displacement of the frame of the structure, under the effect of dead load, and dead load + earthquake load parallel to the direction of the building, are shown, and the frame is affected by the maximum displacement values.



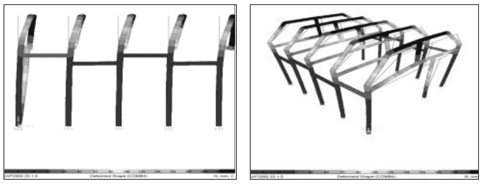
F22. Structural deformation affected by gravity load.



F23. Bending moment of the structure.



F24. Structure displacement diagram under dead load.

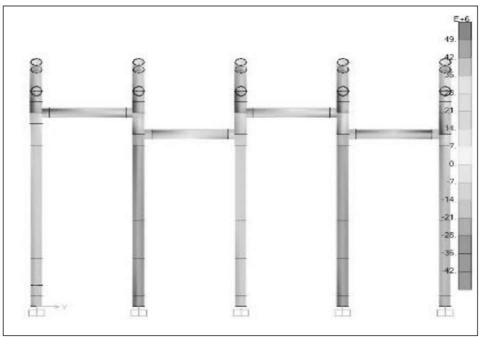


F25. Diagram of displacement of the structure under the influence of dead load + earthquake load parallel to the direction of the building.

Stress diagrams

The values of maximum compressive-tensile stress in the plane perpendicular to the longitudinal direction of the members can be seen in the following figures. Negative values indicate compressive stress and positive values indicate tensile stress.

The minimum and maximum values of stress resulting from the loading of members in the whole structure are equal to 49 and -42 MPa, respectively (Figure 26).



F26. Structural tension diagram.

Results and Findings

The results of the analysis show that the structure is desirable under constant and random loads and constant gravitational loads, and even without considering the increase in the strength of the structure due to the overlying shell, and it guarantees a reliability coefficient of 1.3 for permanent loads. Regarding random and lateral loads entering the structure, it was found that without taking into account the effect of additional strength caused by the shell covering, weaknesses are evident in parts of the structure, which in most cases these weaknesses were related to the low junction of longitudinal elements.

However, according to the specifications presented in the first part of this report, the middle space of all parts of the structure is connected by horizontal pipes and fillers as well as gypsum mortar.

It should also be noted that the lateral loads applied to the building were based on the solutions mentioned in the National Building Regulations and based on the maximum possible values. However, these values are recommended for designing a building with a normal long-term life, taking into account return periods of more than 50 years and a probability of occurrence of less than 2% (National Building Regulations). It is clear that for structures with a temporary settlement approach, the amount of force used for random loads is beyond the required limits. However, in the absence of specific instructions for loading temporary buildings, these overvalues were used and it was found that due to these loads, exceeding the limits of resistance occurred locally and did not overshadow the overall stability of the system. If the strength of the overlapping parts is taken into account in the lateral load of the structure (which is remarkable in its kind), the lateral stability of the building under the effect of the applied loads is guaranteed.

Conclusion

The recurrence of natural disasters such as earthquakes and floods in Iran is clear to everyone and causes the homelessness of many of our compatriots every year. This highlights the need for emergency and temporary shelter. At present, the common methods of providing temporary shelter in Iran are the distribution of tents and containers. Also seen in practice, in the emergency accommodation phase, survivors and victims use shelter materials and the least facilities left over from the accident to build shelter for themselves.

In addition to the common and stated solutions, this study has tried to bring the maximum use of eco-friendly materials and provide a suitable temporary shelter by using some conventional, cheap and available materials. Naturally, the design and implementation of the proposed shelter is not possible based on a single and similar version, and will vary depending on the climatic conditions of the affected area, as well as the facilities and materials available on site.

To test this claim, the shelter plan was designed and built by several students in the field of post-accident reconstruction under the supervision of the relevant professor. The first sample was performed experimentally on the campus and the second sample with real size in the affected area (Kuik Aziz village).

In this project, for the first time, the use of ordinary PVC pipes and fittings, which are available and cheap, was considered as the main structure of the building in the construction of temporary shelters.

Simultaneously with the construction of the second sample, with the help of SAP2000 software, all the incoming forces were calculated, and the result of the calculations was especially favorable for a light building that has a temporary accommodation use. The benefits of this plan include the use of non-specialist indigenous forces, speeding up implementation time, reducing construction costs, providing some construction materials for free, as well as the ability to adapt to the climate. In addition, it seems that the different appearance of this unit, which is quite similar to local residential houses, is one of the attractions of this project. It is also expected that after the completion of the reconstruction phase, this structure will be used as a side space of the damaged houses.

The sample made in Tehran has been controlled and monitored for several consecutive years in different climatic conditions. The plan was also considered in a call issued by the Road, Housing and Urban Development Research Center in the spring of 2018. During this call, Kashaneh, along with two other projects, were introduced as the top three projects.

The results of continuous monitoring of this sample of shelter and estimation of all the mentioned points show that the use of PVC pipes can be used as a suitable solution in providing shelter for victims of accidents. The authors of this article believe that this experience makes it possible to consider the use of ecological materials and the use of cheap and conventional materials in any region of the country, after the occurrence of possible accidents to provide temporary shelter.

Endnotes

1. A type of structure local to the north of Iran

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