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A historical experience of local seismic proof shelters in Quchan-northeast of Iran

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Abstract

Despite the utilization of several earthquake resistant traditional techniques in Iranian architecture throughout the centuries, the high seismic vulnerability of Iranian vernacular constructions is obvious. One of the latest innovations in building earthquake-proof emergency dwellings, prior to introducing the modern seismic design codes, took place during the successive destructive earthquakes of 1871, 1893 and 1895 in Quchan, located in northeast of Iran. These new shelters withstood shocks successfully during the 1893 and 1895 quakes and were in use for at least the next 30 years. Therefore, this local effort of building earthquake-proof constructions will be introduced in this paper not only as an intangible heritage of the regional knowledge, but also as a successful experience in building earthquake resistant installations. In this article, the process of innovation of these new shelters, their specific earthquake resistant features which did not have any peers in shape in the history of the construction in the region, their evolution and finally extinction is described. Furthermore, the paper comprehensively focuses on describing the capability of these shelters in comparison with similar geometrical forms of construction to indicate how local people chose the best shape alternative based on the following three factors: seismic resistance, ease of built and the amount of spatial similarity with previous local buildings.

Keywords: *Vernacular seismic resistant technique, Earthquake resistant configuration, Geometry, 19th century Quchan earthquakes.*

1. Introduction

So far, relatively weak seismic performances of the Iranian local houses have been reported during several earthquakes. Nicolas Ambraseys (1982) carried out comprehensive researches on the Middle East and Mediterranean earthquakes by comparing Anatolian and Iranian methods of construction. He concluded that while vernacular buildings in Anatoly are relatively modified to withstand earthquake shocks, Iranian traditional constructions do not, in general, have such adaptability. Implementation of any notable modification in reconstruction process was somewhat rare in Iranian traditional buildings. This, however, is mostly true about the local settlements and traditional methods of construction in vernacular housings rather than architectural monuments of the region. Ray, Nishabour and Tabriz are three of the most important historical cities in Iran which have been reconstructed several times after successive earthquakes with no seismic resistance changes [1].

The aftermath reconstructions, mostly, began soon after the events. There are several reports on cities which were rebuilt directly on the wreckages of collapsed buildings just a few days after the disaster. This quick reconstruction relatively represents the lowest amount of modification in traditional method of construction employed aftermath [2].

Beside this high vulnerability of the above mentioned local settlements, there are several examples of earthquake resistant methods of construction which are used in the region's local houses or monumental structures. As the dominant material of structures in northern part of Iran is wood, these structures have relatively had more acceptable seismic performances than structures of the other parts of the country. In the central part of Iran with masonry dominant constructions, use of wooden ties inside the joints and between the arches, vaults and domes is the most common traditional method for improving seismic responses of the buildings [3]. Strengthening vaulted and domed structures with ribs and use of buttresses against walls are some other solutions that improve seismic performance of the structures [3]. There are also some rare reports on the usage of wood inside the

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foundations in this region [1]. In mountainous areas of the country where wood could be found easier than the arid areas, use of wood inside the walls as framed structures had been applied sporadically as an earthquake proof method of construction. Among all these experiences, the earthquake proof dwelling of Quchan which is mostly known as innovation rather than modification was one of the most successful methods of earthquake resistant construction. It should be mentioned that these dwellings should be categorized as emergency shelters rather than permanent housings.

Successive earthquakes in Quchan from 1871 up to 1895 caused a unique situation which led to the innovation of local earthquake proof shelters. A high frequency of shocks and the unsafe condition of the local houses, and the intended relocation of the town forced people to design temporary earthquake proof structures. The proper performance of these new shelters after the two destructive earthquakes of 1893 and 1895, increased people's trust in them and led to the planning of their house extension as their permanent huts.

The following sections will explain the history of this innovation as seismic resistant local structure and the extensions of the primary ones. The paper specifically focuses on the seismic responses based on their configuration and tries to estimate the rate of success of these shelters in comparison to the other geometrical shapes built with the same materials.

2. The process of earthquake proof dwellings' innovation in Quchan

On the 23rd of December 1871, Quchan was stricken by an intensive earthquake (7.1 M) [4]. Nearly all the local houses built with masonry walls and flat timber composite roofs (Fig. 1) were completely . Reconstruction of the buildings started soon after the disaster based on the traditional methods. However, the frequency of aftershocks for the following two years, particularly the strong 7.0 M shock of 6th January 1872 [4], forced people to live inside the tents as they were safer shelters. Use of Turkmen and Kurdish tents was reported after the successive earthquakes of these years [5].

In 1875, McGregor described a new kind of structure innovated by the local people for being used as a shelter against severe climatic condition of the region [6]. The shape of these shelters looked like a tent (Fig. 2) and Yate (1894) resembles them to wigwams [7]. These new constructions had no walls and seemed as if gable roofs placed on the ground. People were erecting old timbers pulled out of ruins against the ridge pole and then plastered them with bushes and mud [5]. More detailed features of these shelters in addition to the process of their extension through the years following the quakes will be described in section 3.

It is unclear whether these huts were initially designed as an earthquake-proof buildings or their acceptable seismic responses made them be known as such. McGregor mentions the faith of the people living in these structures during the earthquakes in 1875, before they had a chance of being tested during the destructive earthquakes of 1893 and 95 [5]. The seismic behavior of these huts will be discussed in section 3.

The destructive shock on November 17th 1893 totally destroyed the town which was rebuilt after the 1871 earthquake. The traditional method of construction of the local houses failed again [1]. The public structures which mostly had arch-shaped roofs also collapsed [8].

Wooden huts were some of the few structures which remained intact aftershocks [1]. This proper performance resulted in the wide use of these structures as safe shelters after the earthquake. Rapid construction, high capability of sheltering against the severe climate, and the earthquake-proof feature made these shelters the common emergency housings. Use of these cottages as a post-earthquake shelter became a costume for, at least, the next 40 years. Yate, during his visit to Quchan in December of 1894, mentions that about 10000 people who had survived the earthquake inhabited these shelters [7]. During this time, the planning of relocating the town was in progress [9].

After the 3rd strong shock of 17th of January 1895, a small number of the people who refused to leave their town started to extend these shelters to suit them for long term living (Fig. 3). Pumpelly, in 1904, described this extension which enabled the shelters to encompass 3 separated rooms [11].

Fig. 1 Traditional houses of Quchan with masonry walls and wooden composite roofs [10]

Fig. 2 Earthquake-proof "A shaped" shelters of Quchan [1]

The last strong earthquake of the region in the first half of the 20th century occurred on 1st of May 1929 near Shirvan, approximately 60 kilometers from Quchan [4]. There are several reports and photographs representing these shelters which were used as an emergency shelters after the quakes (Fig. 4).

3. Features of construction and seismic behavior of the “A shaped” shelters

The “A shaped” shelters had wooden frame taken from the debris of the collapsed structures. Reusing the material from the ruins for reconstruction purposes has been a kind of tradition in almost all parts of the country in Iran. While use of the old material sometimes causes more vulnerability in structural behavior of the buildings, it helps people to decrease the cost of rebuilding and increase the construction speed.

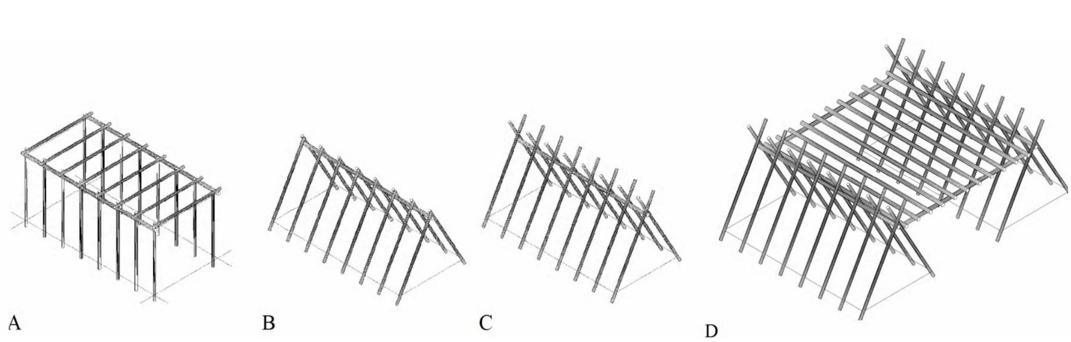
To build the “A shaped” shelters, the timbers which had remained intact were pulled out of the ruins. These timbers were erected in diagonally against the ridge pole and then tied together and to the ridge’s beam [5]. Due to the varying sizes of the old timbers, the upper part of the timbers crossed the ridge beam. The final configuration of the structure section resembled the letter x in which the crossing point shifted toward the upper part. Other ends of the timbers were buried in the ground [5]. The rectangular shaped frame was also added to the frame as the entrance of the shelters. After setting up the construction, the spaces between the wooden rafters were filled with a light material such as bushes. In the last stage, all the surfaces were plastered with mud. Two main points that people tried to consider on "A shaped" shelters construction, were achieving the lightest structure and the firmest ties in joints [7]. Shelters were erected in various sizes; however, these structures were commonly about 4.5 m in width, 9 m in length, and 4 m in height. Wooden timbers were also set in the perimeters of the structures in 12 cm intervals.

The “A shaped” structures have better seismic responses than the rectangular cube shaped traditional houses. (Graphic 1-A,C) This is mostly true when the seismic shocks are parallel to the diagonal timbers of the shelters. Lack of any bracing between the vertical elements of the rectangular cube shaped model causes the structural deflection toward the parallelogram shape. This is mostly because of the rigidity of the structural elements and the semi-pin joints of connections of the structure. In this case the structures become unstable and the vertical load of the roof increases this instability. Therefore, the structure will collapse easily under moderate lateral loads. Deformations in the elements of “A shaped” structures is lower than the rectangular ones.

When the quake loads are parallel to the diagonal timbers, the structural elements bend under the shock loads. In this case, the elements on the other side resist against this deflection, thus represent a proper seismic performance (Graphic 2).

Fig. 3 Extended model of “A shaped” shelters consist of 2 tent-models bridged with a flat roof [11]

Fig. 4 Timbers of “A shaped” shelters and a Kurdish tent can be seen backward of the Red Crescent group aftermath of 1929 Shirvan earthquake [12]



Graphic 1 Diagrams of rectangular and triangular frames deflections under lateral forces

However, the shelters cannot have this earthquake-proof response against the shocks perpendicular to the diagonal elements; despite the fact that their seismic behavior still is better than the rectangular cube shapes. This is mostly because of their lighter structure. The half of the dead load of the diagonal roofs (walls) is transferred to the ground. Therefore, the loads which a structure should carry decreases. As all the successive shocks of Quchan had the same direction, maybe the shelters which their diagonal elements had been erected parallel to this direction represented more suitable seismic responses.

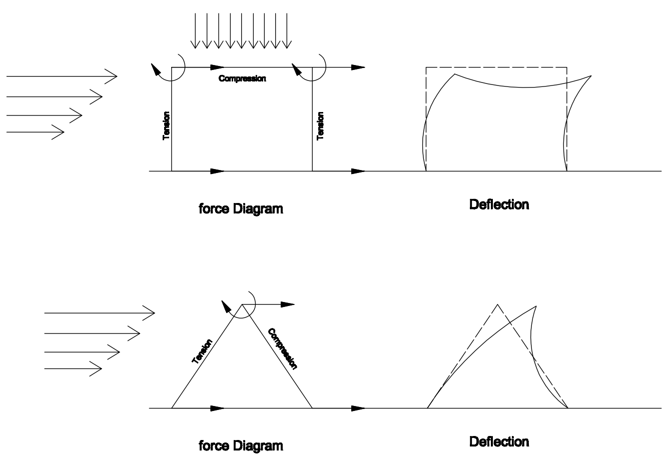
The disjointing of the connections or breakage of the structural elements are the two main reasons of the probable collapse of "A shaped" buildings. The X shaped joints and the extra length of the timbers in this part help to reduce the dangers of disjointing and therefore destruction of the structure. This means that these "A shaped" shelters have better seismic response than the ordinary gable shaped ones (Graphic 1- B,C).

The earthquake proof feature of these shelters which is described above, led to their further extension after the 1895 earthquake. For the extension, at first, two primary structures of "A shaped" shelters were set up. Most of the time one of them is erected and settled before. Then, a flat-roof room connects the two shelters to one another [11]. The structure of this flat roof was made of timber beams parallel to the ridge beam of "A shaped" frames. Each of the three parts of these dwellings had a separate entrance (Graphic 1-D).

These extensions; however, reduce the seismic resistance of the shelters. The bridged flat roof, when is not exactly located on the same level of the ridge beam, causes breakage of the diagonal load-bearing timbers. When the roofs are erected on the same level as the ridge beam, the vulnerability will be reduced. However, the seismic resistance still will be lower than the single "A shaped" shelters.

The A shaped shelters were in use for approximately 60 years. People not only set them up as an emergency shelters after the earthquakes but also counted on their proper seismic performances.

As it was mentioned before, the main purpose of the paper is to analyze the success of this structural innovation which represents the progress of the local knowledge in the region. The "A shaped" shelters have had two main innovative characteristic in comparison with Quchan traditional buildings. Firstly, they had wooden structure and, secondly, their shapes were not cubic.



Graphic 2 Diagrams of rectangular and triangular frames deflections under lateral forces

In next sections of the essay, first, the history of using wood in earthquake proof buildings of Mediterranean and Middle East will be presented. Then, the shape of the shelters in comparison to the other common geometries which have been used to build small dwellings will be thoroughly analyzed.

4. A review of the wooden earthquake resistant structures of Mediterranean and Middle East

Timber-framed buildings are the most well known earthquake-proof structures among various construction methods of the Mediterranean and the Middle East. Wooden framed buildings have been widely used in central, eastern and northern part of Anatolia. Some experts believe that this type of construction originates from Mycenaean era and were developed to resist the earthquake shocks. The first written evidence on the use of timber-frame construction to withstand earthquake acceleration dates back to the early 16th century. Two main form of Turkish earthquake-proof structures which remained up to the 20th century were "Himis" (of timber framed group) and "Bag˘dadi" (of timber lath group) [13]. Earthquake-proof timber framed constructions also could be found in Greece [14]. In Kashmir there are two main types of seismic resistant local structures named "dhajjidewari" and taq [15]. There is a method of construction similar o "taq" in Pakistan named "bhatar" [15]. A type of dual structure which consists of load bearing walls with horizontal wooden bands and separated row of columns capable of carrying the roof when the walls collapse and is common in north-east of Pakistan (pattan) [16].

Use of wood in Iranian methods of construction also has been known as a proper method of constructing structures capable of withstanding earthquakes. In mountainous parts of the country, where wood is moderately available, the roofs of the houses were built from timber beams. However, use of wood inside the walls was not common. Reinforcement of the walls with wooden elements has been found just in the mountainous part of north of Iran [3], Ardabil [17], Tabriz. It is called "Takhteh Poush" (had been common after the 1780 earthquake of Tabriz) [1]. "Taleh Bast" is another timber framed structures which used to be a common method of construction. Taleh Bast consists of timbers set vertically and horizontally in about 1 meter or more and then is braced with lateral timbers [3].

Wood also was the dominant structural material of vernacular housings of north of Iran. The plentiful resource of wood in this region made use of this material the most economical one. Based on several reports, timber structures of the region have displayed proper seismic performances. Two of the most recent earthquake reports before introducing modern methods of construction were the 5th of March 1935 earthquake of Tallar Roud and 11th of April 1935 earthquake of Kasout in Mazandaran province both of which reported proper seismic response of local wooden structures [1].

The structure of the "A shaped" shelters also consisted of wooden timbers. The main purpose of using wood as structure and bushes as filler between the timbers was their light weight. This is mentioned in the reports. Use of wood also increases the speed of construction more than the masonry ones. Furthermore, wooden structures did not have the vulnerability of masonry brittleness against the seismic shocks.

In the next step, the essay mostly will concentrate on the shape of these dwellings. An analysis examines the viability of the "gable shaped" models as an earthquake proof emergency shelter and compares it with various geometrical models of shelters. The shape perspective comparison does not mean inattention to the other factors of constructions such as the material effects or the influence of the joints on the seismic behavior of the models. This mostly means that during the analysis of different models, geometry will be varied but the other factors such as material or type of joints will be same in all models and during the analysis all these factors will be considered.

5. Geometrical analysis of the A shaped shelters

As it was mentioned before, the main innovative aspect of "A shaped" shelters was their geometrical configuration which had not had any peers among the settlements of the region. To understand how much this configuration was able to cover the needs of "Quchan situation" (the condition of the town after three successive earthquakes of the late 19th century), it is important to indicate what criteria should the vernacular post disaster shelters fulfill.

The post disaster sheltering and housings are mostly divided in definition. Emergency shelters are the first sheds which are constructed after the disaster. They could be even tents or kinds of prefabricated mobile homes. Post disaster housings; however, need more time to plan for the analysis of reconstruction and the fact that they need to be suitable for the long term life style of the local people. Between these two stages there is an intermediate stage named temporary housing. Temporary housings can be core of the main and could be extended in future. This can solve the paradoxical items of urgent needs of sheltering and the necessity of considerable amount of time takes to reconstruct suitable housing [18]

The "A shaped" shelters were constructed soon aftermath and were used for more than two years. This indicates that among the three stages of post disaster sheltering, "A shaped" shelters are more similar to temporary housings. "The urgency and rapid construction" are two of the most fundamental features of the intermediate stage of reconstruction as is in case of emergency sheltering. However, these temporary housings should contain "spatial values adapting to the local life style" as the permanent reconstructed housings do; even though, it is clear that the most critical characteristic of the post earthquake temporary shelters should be the seismic resistance.

It is believed that these three main features should be achieved via cooperation between the government (and any assistance from outside) and the local people. Outside assistance helps in: 1. Financing the project, 2. Provision or acceleration of the provision of constructional resources such as proper material and labor, 3. Introduction of more suitable methods of construction (for example, techniques to achieve more seismic resistance) [18]

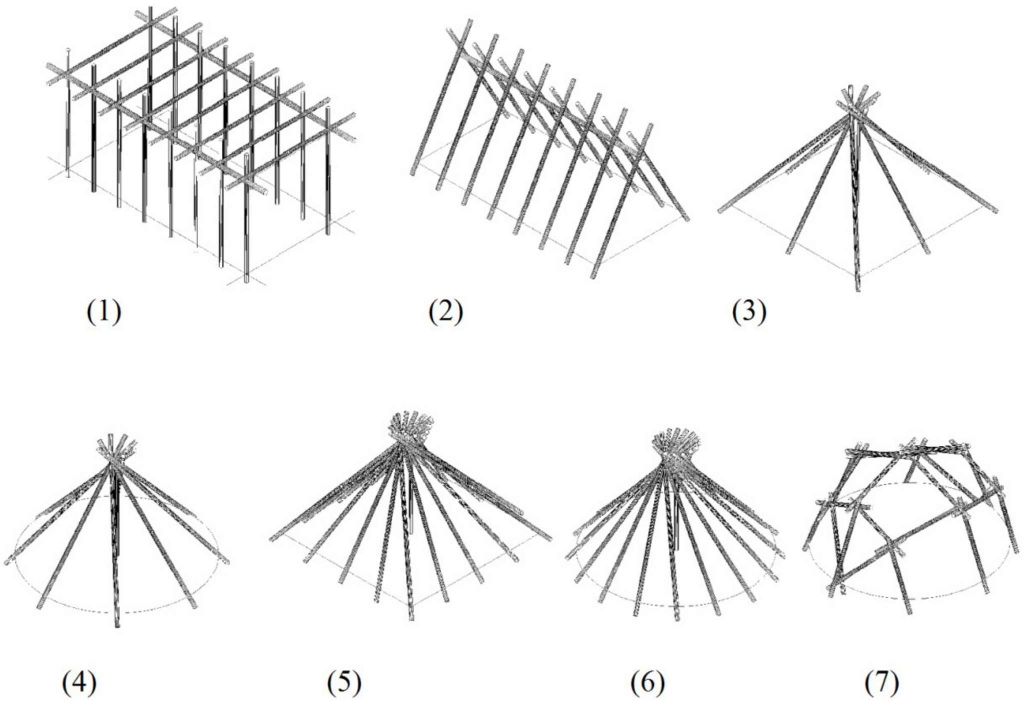
As in "Quchan case" there was not any outside assistance, at least during the construction of the temporary shelters, all the process of post disaster urgent housing were done by the local people. While use of local simple and available method of construction always helps to increase the participation of people in reconstruction programs, lack of any assistance intensifies the importance of these items. Therefore, in addition to the rapid construction, simplicity is also critical. Both of them are categorized as the first criterion of the analysis named "ease of construction". Two other features, "earthquake resistance" and "spatial similarities", which were described as the main characteristics of the post earthquake temporary shelters, are the other criteria.

In this paper, it is tried to investigate how much different shelters with different shapes and similar materials could be suitable for the Quchan situation (the condition of the town after three successive earthquakes of the late 19th century) with regards to the three main aspects of ease of construction, earthquake resistance and spatial similarities. How they rank and where the place of "A shaped" shelters among other geometrical alternatives is. All three main aspects include several criteria. In the following sections, these three main aspects will be named as the three main "categories". Each of these "categories" consists of "criteria" as their subsets.

The main purpose of the paper is to investigate the degree of success of the local people's innovation of new kind of earthquake-proof shelters. This will be achievable by comparing "A shaped" geometry with other simple shapes which could be used for setting up the huts. The results will indicate to what extent the locals made a proper decision. The introduction and study of this regional knowledge helps to save it as a successful local experience in the history of construction in Iran.

The mechanism of the following analysis is based on the Multi Criteria Decision Making methods. To organize the analysis, seven geometrical models will serve as alternatives and three main categories will provide the raw data for the analysis. The final results try to rate the suitability of the alternatives in comparison with the "Quchan situation". The criteria have numerical scale or are converted to this type of scaling. In some criteria the least number indicates the most value which will be rated by the minimum ranking and the opposite situation will be rated by the maximum ranking.

The geometrical alternatives of the analysis are rectangular cubic, gable shaped, pyramidal, conic and dome-shaped models (Graphic 3). The dimensions of these shelters have been defined with regard to equal areas and height of the plan. The diameter of timbers has been chosen to be 15cm, the joints of all models are considered flexible. Timbers are set up in 12cm intervals next to one another in two models with rectangular cubic and gable shapes. For the pyramidal and conic models, two patterns of construction are considered. In the first pattern, the number of timbers is chosen similar to the vertical elements of the gabled and rectangular cubic models (eight timbers). In this case, while models can be built with lower number of timbers, filling the spaces between them with bushes becomes difficult because of the notable gap between the timbers (3.25 m on the base of the pyramidal and 2.83 m on the base of the conic model). In the second type, the number of timbers can be increased to simplify the process of filling;



Graphic 3 7 geometrical models (1. rectangular cubic, 2. gable shaped, 3. pyramidal type 1, 4. conic type 1, 5. pyramidal type 2, 6. conic type 2, 7. domed shaped models)

however, an extra load without any necessity is imposed on the structure. The full information of the alternative models' dimensions is presented in table 1.

5.1. Category no.1: Ease of construction

The ease of construction as one of the main categories based on "Quchan situation" consists of six subset criteria. Due to the description of the most important features of temporary shelters in section 5, it was mentioned that because of the lack of outside assistance, urgency should be followed by simplicity and availability of resources for the "Quchan case". In general, the main reasons for the use of outside assistance in construction programs are provision of: 1. the materials, 2. construction equipments 3. Building tools and. 4. Skilled labor or training the unskilled labor force [18]. Therefore; in the case of lack of outside assistance, choosing the way of construction using the available materials, the least number of needed of skilled labor force and sophisticated building tools are critical. Consequently, all the criteria of the first category are chosen due to the availability of the raw materials, speed of construction and the least amount of extra gadgets, scaffoldings or skilled labor. The first criterion of this category is availability of useable timber. Due to the shortage of intact timbers pulled out of the ruins aftermath, the models which need less timber will be known as the most suitable alternatives. The similarity of the length of timbers is considered as the second criterion in the first category (where the type of joints in the models could use timbers with different length, this difference should not be notable.). As the reusable timbers from the ruins used to span the roofs of the traditional buildings, are 5 to 6.5 meter in length, the models which need timbers longer or shorter than these sizes are considered in the third criterion. This represents the number of aforementioned timbers. The next item in the first category is the number of joints which indicates the ease and speed of construction. In both of the pyramidal and conic models, each one of the two timbers next to one another has separated joints. In the end, a final joint ties all the timbers together. An "Ease of erection" criterion is scored from number 1 for the easiest to number 3 for the hardest models to be erected. Ease of plastering is rated in two scores of 1 and 4. This is measured due to the spaces between the timber structures. These two score indicates the interval in their value. All criteria of the first category have minimum ranking. As the importance of these items is not equal, there are specific weighting for each of them. The values are presented in the table 2.

Table 1 dimensions of alternative models

shape	Width (m)	Length (m)	Height (m)
Rectangular cubic	4.5	9.1	4
Gable shape	4.5	9.1	4
Pyramidal type 1	6.5	6.5	4
Conic type 1	Radius: 3.6		4
Pyramidal type 2	6.5	6.5	4
Conic type 2	Radius: 3.6		4
Domed shape	Radius: 3.6		3.6

5.2. Category no.2: earthquake resistance

The overall shape of the buildings consisting of their geometry, size, and proportion has a significant impact on the seismic behavior of the structures [19]. Any kind of asymmetry in plans causes torsion during the quake. Shapes like + or U in plans in addition to irregularity in the volume of the buildings lead to variable seismic performances and; therefore, the failure

Table 2 Criteria of the 1st category: ease of construction

shape	No. of timbers	No. of types of timbers	No. of timbers longer than 6.5 m or shorter than 5 m	No. of joints	Ease of erection	Ease of plastering
Rectangular cubic	26	3	2	16	2	1
Gable shape	17	2	1	8	1	1
Pyramidal type 1	9	3	5	9	1	3
Conic type 1	9	2	9	9	1	3
Pyramidal type 2	17	4	13	17	2	1
Conic type 2	17	2	17	17	2	1
Domed shape	24	4	24	11	3	1
Weight of criteria in %	30	15	25	10	10	10

of structural resistance against earthquake shocks [20]. In addition, some forms like domes [18] and pyramids have better seismic behavior in comparison to the others [20].

Different geometries in addition to their intrinsic different seismic responses, cause variable seismic behaviors according to the kind of structures that various shapes dictate to their construction. All these items will be considered in the seismic assessments of the second category.

In the analysis of seismic behavior of the alternatives, models are scored from 10 being the best value of the assumptive ideal model. As the direction of the shocks may vary the seismic performance of models, two kinds of ranking will be considered for either of the shocks in X or Y direction. These two separated rankings are of maximum type.

To analyze these structures comparatively, the simple analysis mostly based on engineering judgment is used. This is because use of classic structural analysis based on seismic codes results in a considerable amount of uncertainty originating from the following items:

1. Uncertainty in the mechanical features of all the timbers mostly after the earthquakes as they were pulled out of debris.
2. Type of the joints of the “A shaped” shelters’ elements are too unreliable as these joints (ties with ropes) do not obey any specific rules or guidelines.
3. Uncertainty and variety on the parts of the timbers buried inside the earth and the dimension of timbers in the ground.
4. Lack of enough information on the ground and mechanical characteristics of the soil under the structure.
5. Construction by local people, without enough care and accuracy.

Therefore, the gable shaped models have the proper response in x direction due to the structural behavior which was explained in section 3 of the paper, grades 9 of 10 in X axis direction and 5 of 10 in Y axis direction. The domed shape model which behaves as the industrial frame also is scored 9 out of 10 in two directions.

The scores of Pyramidal and conic models relatively are similar. The circular plan of conical shelter improves its seismic performance more than the pyramidal model. However, timbers of the conic models are longer than the pyramidal ones and therefore face more bending and the risk of breaking. According to this explanation, the score of these two models are estimated to be equal. Seismic behavior of Pyramidal and conic models in the direction of both axes is quite similar to the gable shaped model response in X axis direction. The most difference between these models and the gable one is in their joints. As each timber lies on the next timber, any kind of leaning of timbers from the vertical plane increases the seismic vulnerability of the joints. As all timbers are joined together, any kind of disjointing leads to a thorough collapse. Type 1 of these two models with fewer timber have better seismic behavior than the second types with more structural elements which increase the dead load without any structural advantages. The scores of all the alternatives in both X and Y direction is presented in table 3.

5.3. Category no.3: spatial similarities

The similarity between living spaces of the shelters and the traditional local houses can improve the spatial quality of the shelters due to its capability with the local lifestyle. There are several reports on the rejection of the aftermath shelters by the local people because of their incapability to adapt to the new spaces. For example, lack of corner was introduced as one of the main reasons of abandonment of the “igloo” shaped emergency shelters after the 1971 earthquake of Caraz, Peru, by the locals [21]. In the “Quchan case”, two items of similarity in shape of the plan and verticality of the walls are considered as the main criteria in the third category. These two criteria can show the spatial vertical and horizontal resemblance. In the first criterion, the models with rectangular or square plan scored number 1 and models with circular plan scored 0. Such scoring shows the importance which presence of corner have, and as described above, lack of it had caused problems for the local people in Caraz. In the second criterion, the number of vertical walls which, for example, are more suitable to build the openings and doors will be presented as an advantage of the shelters. These two criteria have the maximum ranking. The third criterion, which mostly focuses on the least interruption in the interior space, counts the number of columns which should be erected inside the space. Therefore, the ranking of the third criterion is a minimum type. The last criterion of the third category is the

Table 3. Criteria of the 2nd category: earthquake resistance

shape	Seismic responses in X direction of 10 score	Seismic responses in Y direction of 10 score
Rectangular cubic	4	3
Gable shape	9	5
Pyramidal type 1	7	7
Conic type 1	7	7
Pyramidal type 2	6	6
Conic type 2	6	6
Domed shape	9	9
Weight of criteria in %	50	50

volume of the spaces which obviously has the maximum ranking. Similar to the first category for each of these criteria a specific weight is allocated which is presented in the table 4.

6. Multi criteria decision making

The main analysis is processed in the D-sight decision making software. The 3 main categories of criteria, ease of construction, earthquake resistance and spatial similarities are weighed 30%, 50% and 20% respectively. This weighting is determined as the earthquake proof feature was the most important aspect of the emergency shelters' construction in "Quchan case". After this, the ease of construction is slightly more decisive than the spatial similarity, because the first one fulfils the primary need of sheltering. The final results of the ranking the models, with their final scores, is shown in table 5. Rankings indicate that the rectangular and the pyramid type 1 place in the first and second positions with relatively similar scores. This shows, by a little change in weighting or score, that the place of these two models may vary. Therefore, both of them will be known as the most successful alternatives for the "Quchan situation".

7. Conclusion

The main purpose of this paper was to estimate the degree of successes of the "A shaped" shelters which were innovated after the successive earthquakes of Quchan in the late 19th century. To achieve the rate of success of this type of shelter, it was compared with 6 other geometrical alternative models. This comparison was based on three main criteria of the ease of construction, earthquake resistance and spatial similarities. They were determined as the three main features of the aftermath emergency shelters. The results of the Multi Criteria Decision Making analysis indicated that gable shaped shelter and the pyramidal model with less structural timber are the most proper choice for the "Quchan situation". Therefore, the A shaped shelters as a regional experience can be considered to be among the successful local efforts of traditional seismic designs.

Table 4. Criteria of the 3rd category: special similarities

shape	Rectangular geometry of plan	No. of vertical walls	No. of Columns inside the space	Space volume m³
Rectangular cubic	1	4	0	164
Gable shape	1	2	0	82
Pyramidal type 1	1	0	1	56
Conic type 1	0	0	1	54
Pyramidal type 2	1	0	1	56
Conic type 2	0	0	1	54
Domed shape	0	0	0	98
Weight of criteria in %	30	20	10	40

Table 5. Criteria of the 2nd category

action	Rank	Score
Gable shape	1	0.288
Pyramidal type 1	2	0.288
Domed shape	3	0.198
Conic type 1	4	0.177
Pyramidal type 2	5	-0.236
Conic type 2	6	-0.317

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