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# Optimizing the Performance of the Final Coating in Terms of Thermal Exchange for Post-Disaster Temporary Shelter in Cold Climates; Case Study: Kermanshah City*

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## ABSTRACT

Natural disasters yearly cause millions of people to become homeless. After the occurrence of any accident destroying people's living environment, it is necessary to provide suitable shelter as soon as possible. The solutions for providing shelter in the first days reveal that shelters don't provide thermal comfort and have inappropriate thermal performance, causing victims to either make changes in the shelter or leave them. The present study attempts to provide suitable relative temperature conditions for accident victims by proposing suitable coatings for the shelter. The present study is applied research in which the Design Builder software is applied for simulating and testing internal temperature conditions to reach the research goal, i.e. to propose an optimal climate shelter for cold climates. The results indicate that the coating made of fiberglass and cardboard on the dome form provides higher thermal comfort. Also, it is inevitably necessary to apply non-vernacular materials to use vernacular materials and maintain the thermal comfort conditions inside the shelter.

**Keywords**: Natural Disasters, Earthquake, Climate Shelter, Coating, Cold Climate, DesignBuilder Software.



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## 1. INTRODUCTION

Natural disasters such as earthquakes always threaten people's lives and cause a lot of damage. Studies indicate the insufficient thermal comfort of conventional shelters. In this case, victims usually make changes in the shelters to use them or leave them with no change (El-Masri and Kellett 2001; Barenstein 2006; Sener and Altum 2009). The reason for this is the application of the same type of shelter in various regions with different climates. Therefore, the present study aims to achieve thermal conditions for a shelter through the final coating that can provide thermal comfort considering climate conditions.

## 2. RESEARCH BACKGROUND

Quarantelli proposed four distinct types of post-disaster sheltering instead of defining a shelter only for emergencies (Quarantelli 1995). According to Davis, a shelter should be a place that "makes people feel welcome, comfortable, and safe. It makes them feel that someone cares about them and that they deserve that care" (Davis 2004). Howard and Spice (1989), in their studies on shelter materials, used PVC for the structure and polyethylene sheets as shelter coating and proposed the use of fiberglass or mineral wood between two polyethylene layers as a solution to improve the thermal performance of plastic sheets (Howard 1989). Gerilla et al. (2007) examined two types of wood and steel-reinforced concrete buildings and stated that steel-reinforced concrete buildings cause higher destructive environmental impact (higher carbon emissions and the inability to recycle in the building life cycle) than wooden buildings (Gerrilla 2007). International Federation of Red Cross and Red Crescent Societies (2013), in the book "Post-Disaster Shelter: Ten Designs" provided a checklist for creating an optimal shelter using different materials (IFRC 2013). This book includes a technical review and functional analysis of 10 shelter designs between 2007 and 2011, in which materials including reinforced concrete, timber, brick, plywood, corrugated iron sheets, tile, plywood, clay and mortar, plastic, tent, bamboo were used.

Fe'lix (2014) preferred local plans over imported solutions (Fe´lix 2014). Regarding the need to prioritize the use of local materials or global materials, Escamilla et al., in their study in 2015, identified 20 shelters in 11 different places in the world. The results of their research indicated that both local and global materials can be used in the production of sustainable solutions. However, local materials have a high potential for low environmental impact and low cost while global materials have a high potential for providing better technical performance (Escamilla 2015). Yu et al., in their research entitled "Assessing the thermal performance of temporary shelters" in 2016, examined three samples of shelters constructed with bamboo in laboratory conditions and as a solution, they proposed the use of environmental materials which were easily installed and dismantled (Yu 2016). Wallbaum (2012) considered wood and bamboo to be suitable materials for creating low-cost housing.

## 3. THEORETICAL FRAMEWORK

The influence of climate on human comfort can't be denied. Contemporary houses are constructed with the same design and implementation in different climates, so they are not compatible with their environment (Nikqadam 2015). This is also seen in post-disaster shelters. Despite the provision of various solutions to enhance the quality of post-disaster shelters, there are still many problems in this area and the provided shelters do not meet the needs of the accident victims (Fallahi 2012). In addition to emphasizing the necessity of providing suitable shelters for victims, the present research aims to introduce a shelter that can meet its users' needs in a specific climate and sometimes can be used even as a permanent accommodation. Accordingly, the climate factor is assumed to be constant for all types of forms and materials, and considering this assumption, different forms and materials are examined to achieve an optimal form and coating (Fig. 1).

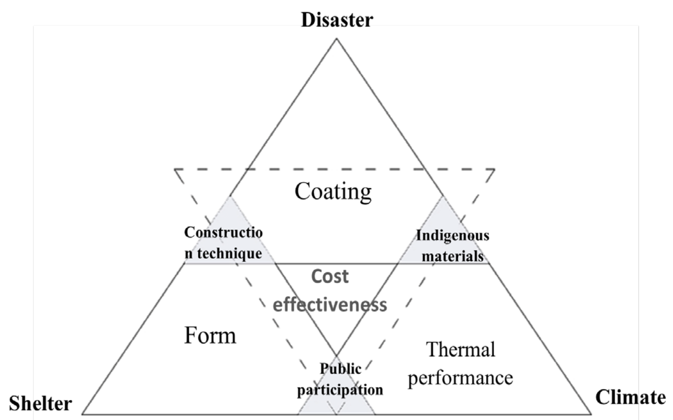



**Fig. 1. The Theoretical Framework Extracted from the Theoretical Foundations of the Post-Disaster Shelter Construction**

Numerous studies have widely investigated the need to use durable materials in conformity with local needs (Twigg 2006; Gulahane 2012). Some research has also assessed the thermal performance of different materials (Wang et al. 2010) and has provided suggestions for choosing the coating of appropriate materials for the shelter (Howard 1989). In the provision of shelters, one of the usual goals is to provide a suitable space with the lowest cost to support the low-income class (Kaminski 2013), and one of the effective solutions to this end is the use of available materials with optimal thermal performance as a shelter coating. Also, regarding the use of vernacular materials, due to the local people's familiarity with this type of materials, it is possible to hire local human forces with simpler technical skills (Nikravan 2007), all of these cases can be justified in the cost-effectiveness analysis of creating shelters.

## 4. METHOD

In the present study, Kermanshah was selected as the case study due to the occurrence of numerous earthquakes in it. The present study is applied developmental research that aims to optimize the existing shelter systems. To this end, the present study was carried out in two qualitative and quantitative sections, according to the findings of the previous research, the forms, and materials used in shelters were extracted (the qualitative section), and then, to choose the optimal option from the extracted ones, software analysis was applied (the quantitative section). To this end, first, the climate in Kermanshah was studied and examined using the Climate Consultant 6.1 software, and suitable months were selected to investigate the performance of shelters. Since the computer simulation of buildings has been considered a reliable strategy for evaluating the performance of buildings (Adekunle 2019) and there are relatively few studies on the energy modeling of shelters (Lee et al. 2021), it has been decided to perform the simulation in the DesignBuilder software V.6.1.4.006, conduct thermal modeling per ASHRAE 55 using the climate file of Kermanshah and applying various materials to different models, and investigate the thermal performance of the interior of the shelters in the cold months. It is noted that the materials used in previous studies, as mentioned in the "theoretical foundations" section, included fiberglass, timber, plastic, PVC, brick, plywood, reinforced concrete, corrugated iron sheet, tent, mortar, and bamboo, which will be considered the base materials at the beginning of modeling and evaluation. According to the climatic calendar graph (Fig. 2), in April, May, and October, the dry temperature would vary between 0 and 21 °C throughout the day and night with a probability of 67%. The same conditions would be observed in November from 6 am to 9 pm and in December from 7 am to 8 pm and at other times the temperature would be below zero with a probability of 21%.

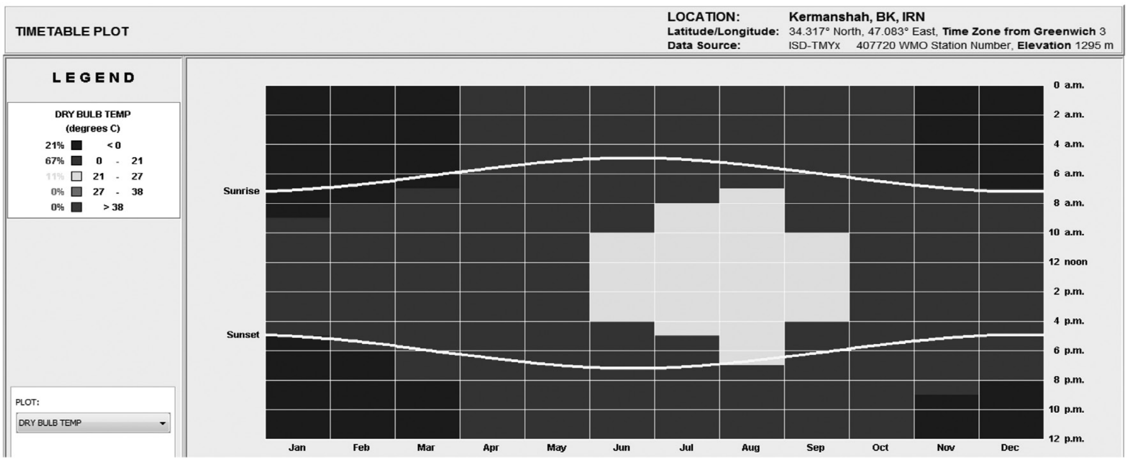
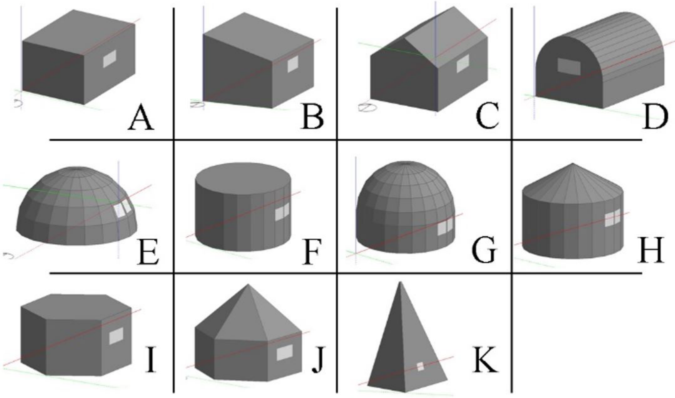



**Fig. 2. The Climatic Calendar Graph of Kermanshah, Obtained using the Climate Consultant 6.1 Software**

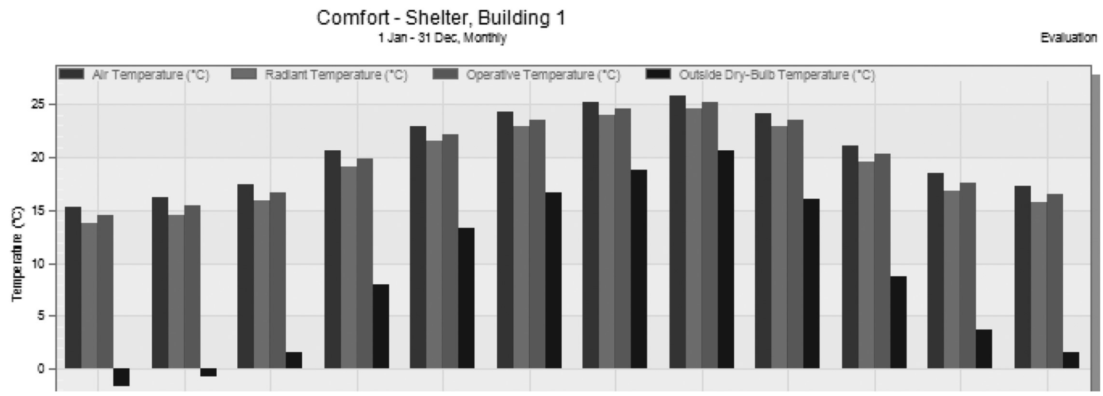
It should be noted that 11 possible forms were proposed for the shelter model by examining the types of forms implemented in past experiences of disasters (Fig. 3).




| Form | Dimension |
|---|---|
| A | a=3, b=4, h=2.2 |
| B | a=3, b=4, h=1.9, 2.7 |
| C | a=3, b=4, h=1.8, 2.8 |
| D | a=3, b=4, h=2.5 |
| E | r=2.35 |
| F | r=1.9, h=2.4 |
| G | r=1.9, h=1.1, 1.9 |
| H | r=1.87, h=1.07, 2.1 |
| I | a=2.15, h=2.25 |
| J | a=2.12, h=1.63, 1.84 |
| K | a=4.14, b=6.9, h=6.5 |

**Fig. 3. The Studied Shelter Forms for Temperature Assessment by Applying Various Coatings**

In all shelter forms, the minimum area per person was considered to be 3.5 m per the IFRC Shelter Kit Guidelines. An opening was placed on the south side to take advantage of the natural sunlight, and an entrance was placed on the east side to protect the shelter from the westerlies. In all forms, the ground was considered the shelter floor, and for all types of roofs, the roof coating was considered fixed with a heat transfer coefficient of 0.25 w/m2-k. It was also assumed that the shelter was used by a 4-person family, so, the total area of each shelter was assumed to be 12 m2 considering the abovementioned minimum area per person (3.5 m). The basic mode (model A) includes a cube with dimensions of 3 m in the north-south direction and 4 m in the east-west direction to receive more solar energy. Per the UNHCR (United Nations High Commissioner for Refugees) guidelines, the height of the shelter was considered about 2 m while in the basic model, the same height was considered to be 2.20 m as the minimum residential height. As a result, all shelter forms have the same volume of about 27 m3. Since the post-disaster conditions require victims to remain in these spaces continuously, they are usually considered round-the-clock accommodation. Since the spaces available to victims are the minimum possible space, no special physical activity can be envisaged for them inside the shelter. So, their activities are limited to eating and sleeping. Considering the presence of 4 persons in the shelter, occupancy density was estimated as 0.33, and winter clothing was considered 1, i.e. warm full cover. Moreover, the airtightness was considered to be 0.7 per ASHRAE 62.1 and 62.2. It is noted that in this case, the lighting system and mechanical equipment were inactive (Table 1). Since the shelter needs to be able to adjust the interior temperature in the cold months, only the months of December, January, and February were considered in the evaluations (Fig. 4).




| | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Air Temperature (°C) | 15.31 | 16.16 | 17.47 | 20.61 | 22.90 | 24.21 | 25.21 | 25.88 | 24.19 | 21.04 | 18.42 | 17.25 |
| Radiant Temperature (°C) | 13.72 | 14.57 | 15.93 | 19.11 | 21.50 | 22.84 | 23.96 | 24.63 | 22.90 | 19.61 | 16.86 | 15.68 |
| Operative Temperature (°C) | 14.51 | 15.37 | 16.70 | 19.86 | 22.20 | 23.53 | 24.59 | 25.25 | 23.54 | 20.32 | 17.64 | 16.46 |
| Outside Dry-Bulb Temperature (°C) | -1.70 | -0.69 | 1.56 | 8.01 | 13.24 | 16.70 | 18.83 | 20.70 | 16.08 | 8.69 | 3.75 | 1.56 |
| Relative Humidity (%) | 30.30 | 34.65 | 36.71 | 50.53 | 61.15 | 66.41 | 71.39 | 65.39 | 63.51 | 52.47 | 37.52 | 34.11 |

**Fig. 4. The Output of DesignBuilder Software, the Average monthly Indoor Temperature of the Shelter by Applying a Layer of Materials as a Coating**

**Table 1. Design Builder Software Input to Determine the Indoor Temperature of the Shelter**

| | | | |
|---|---|---|---|
| Occupancy Density (people/m2) | 0.33 | Opening | Glazing Template |
| Winter Clothing (clo) | 1 | Lighting | None |
| Summer Clothing (clo) | 0.5 | HVAC | None |
| Airtightness- Constant Rate (ac/h) | 0.7 | Natural Ventilation | On |

Also, for two shelter forms with plywood coating, the thermal performance was evaluated as hourly and average temperatures in January. Since, in these two models, the "hourly temperature" change pattern was the same as the "average temperature" change pattern, the average temperature was considered to compare the studied forms in the present research (Fig. 5).

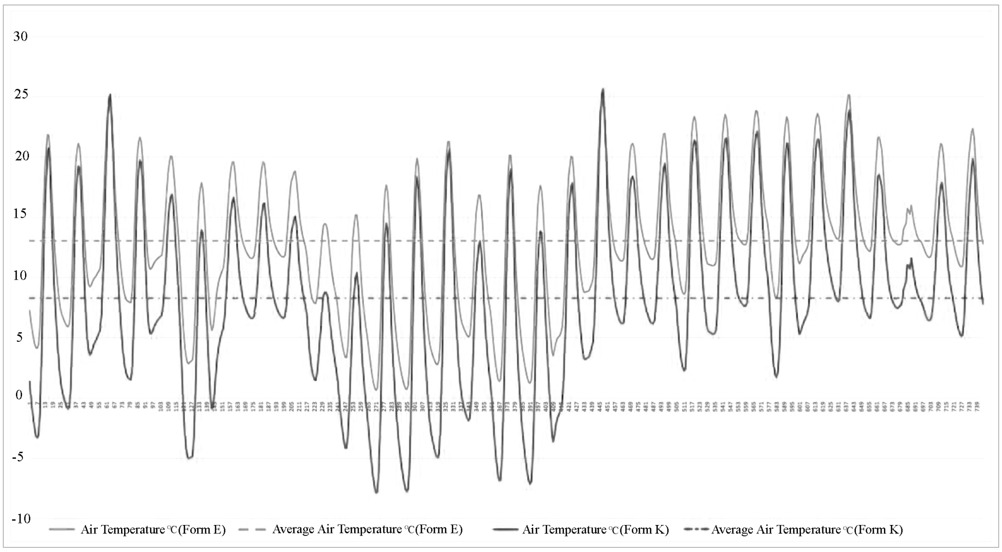



**Fig. 5. Comparison of two Shelter Forms with Plywood Coatings in Hourly Temperature and the Average Temperature in January**

## 4.1. Research Validation

To validate the research findings, two wooden cubes with dimensions of 30 × 45 cm, a height of 20 cm, and a thickness of 1.5 cm were made. According to the table containing two layers of materials, cork was placed in one of the boxes and styrofoam with a thickness of 1 cm in another box. The floor of both models was made of a timber layer of 1cm and a cardboard layer of 5 mm, and the roof was made of a timber board of 1.5 cm. The temperature was measured hourly and for one week from 10th to 16th January in Tehran by Hatol 2060 Temperature Humidity Data Logger (Fig. 6). According to climate studies, January is the coldest month of the year in the Kermanshah region, so it was selected for field study and research simulation. Similar conditions were also simulated in the DesignBuilder software and the temperature was measured for one week in the abovementioned period and the same climate. According to the results obtained from the simulation of the form containing cork, in general, the average temperature during a week was obtained 12.37 °C, while it was obtained 11.54 °C for the model containing Styrofoam, showing that the average temperature is about 0.8 °C higher in the model with cork than in the model with styrofoam. The results obtained for the field sample indicated that the model containing cork has an average temperature of 12.06 °C while the model containing styrofoam has an average temperature of 11.1 °C, showing a temperature difference of 0.96 °C between these two models. So, these results are consistent with the results of the simulation, implying that cork outperforms Styrofoam.

**Fig. 6. Construction of Field Samples to Test Temperature Results by the Data Logger**

Figure 7 shows the temperature graphs for the simulated models and the field samples, containing cork and Styrofoam. The graphs show that in both the simulated and real models, the use of cork improves the thermal performance in the studied volume. The temperature assessment results reveal that the simulated model containing cork has a higher average temperature of 0.31 °C than the field sample containing cork. Also, the temperature difference between the simulated and real models containing Styrofoam is 0.44 °C in favor of the simulated model. According to the study conducted in this field, the difference of ± 0.5 °C between the measured and simulated samples is acceptable (Taveres-Cachat 2020), so the present research can be considered authentic.

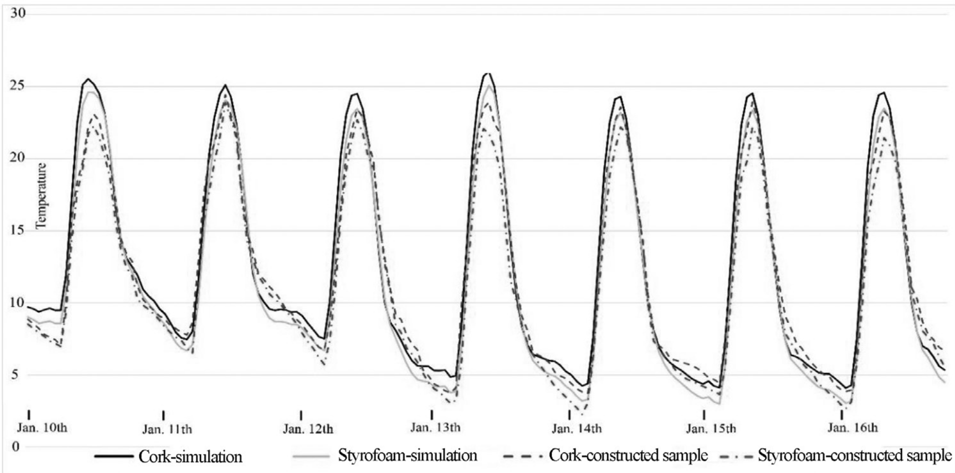



**Fig. 7. Comparison of Simulated and Field Samples in Hourly Temperature for one Week**

## 5. FINDINGS AND DISCUSSION

The provision of shelter can be improved with the selection of appropriate factors involved in the formation of a successful design. In this case, it is important to pay attention to items such as maintaining the statics of the final design, along with its proper thermal performance, which would result in the creation of relatively favorable conditions for the victims.

### 5.1. Thermal Analysis of the Basic Model by Applying Monolayer Coatings

To advance the research process, first, a simple cube-shaped shelter design (Form A), here mentioned as the basic model, was modeled in the DesignBuilder software by applying the conditions determined in the spatial application scenario, and 17 types of coatings supposed as wall coatings were applied on it and the temperature of the interior was evaluated after applying each coating.

Since the cold climate was considered the studied climate, the temperature was assessed in the cold months of December to February. As seen in Table 2, in model A, the fiberglass coating outperformed other coatings. For example, when the average monthly outdoor temperature in January is -1.7 °C, the indoor temperature of the shelter will be 15.30 °C. Next, the cardboard with a plastic cover on it was evaluated as suitable in the outdoor space, and the average indoor temperature of the shelter with this type of coating with a thickness of 5 cm will be between 13 and 16 °C in the cold months.

**Table 2. Average Monthly Temperatures in the Cold Months for the Basic Shelter Form in Various Monolayer Coatings**

|  Wall Coating in Model A 2.2×4×3 | Thickness (m) | Heat Transfer Coefficient (u-value) | Average Monthly Temperature in Dec °C | Average Monthly Temperature in Jan °C | Average Monthly Temperature in Feb °C | Average Monthly Outdoor Temperature in Jan | Priority |
|---|---|---|---|---|---|---|---|
| Lightweight Metal Cladding | 0.005 | 3.6 | 9.62 | 6.43 | 7.5 | -1.7 | 17 |
| Brick | 0.22 | 2.31 | 13.51 | 10.25 | 11.37 | -1.7 | 6 |
| Concrete Masonry Unit | 0.1 | 1.43 | 14.83 | 12.28 | 13.27 | -1.7 | 3 |
| Fiberglass | 0.04 | 0.76 | 17.24 | 15.3 | 16.16 | -1.7 | 1 |
| Air Cushion | 0.03 | 2.97 | 12.81 | 9.81 | 10.86 | -1.7 | 17 |
| Nylon | 0.004 | 5.37 | 11.47 | 8.05 | 9.13 | -1.7 | 14 |
| Aluminum | 0.004 | 5.88 | 11.8 | 8.19 | 9 | -1.7 | 12 |
| Stainless Metal | 0.004 | 5.87 | 10.93 | 7.46 | 8.27 | -1.7 | 15 |
| Water Cushion | 0.05 | 3.71 | 12.73 | 9.22 | 10.33 | -1.7 | 11 |
| Cardboard | 0.05 | 1.14 | 16.12 | 13.78 | 14.74 | -1.7 | 2 |
| Cane | 0.03 | 2.12 | 13.5 | 10.77 | 11.79 | -1.7 | 5 |
| Plywood | 0.04 | 2.29 | 14.15 | 11.21 | 12.26 | -1.7 | 4 |
| Carpet | 0.01 | 2.97 | 12.42 | 9.47 | 10.51 | -1.7 | 9 |
| Copper | 0.01 | 5.88 | 11.77 | 8.12 | 8.95 | -1.7 | 13 |
| PTFE | 0.03 | 3.44 | 12.59 | 9.36 | 10.45 | -1.7 | 10 |
| Rubber | 0.03 | 2.88 | 12.63 | 9.57 | 10.64 | -1.7 | 8 |
| Sand | 0.03 | 3.94 | 9.77 | 6.77 | 7.84 | -1.7 | 16 |

## 5.2. Thermal Analysis of the Basic Model by Applying Bilayer Coatings

The abovementioned process was repeated in this sub-section by putting together the materials listed in Table 1 and creating bilayer coatings. The results are listed in Table 3. The following results indicate that among these materials, the combination of cork (in the outer wall) and carpet (for the inner wall) with a total thickness of 16 mm with a heat transfer coefficient of 0.54 w/m2-k has the highest thermal performance and the average monthly temperature inside the shelter in form A is between 16.78 and 18.54 °C in cold seasons, which is acceptable. Considering the top 10 bilayer coatings for the shelter, one can find cork and fiberglass as the materials effective in regulating the indoor temperature of the shelter because they have a favorable performance in reducing the heat transfer coefficient and thereby reducing the heat exchange (Table 3).

**Table 3. Average Monthly Temperatures in the Cold Months for the Basic Shelter Form in Various Bilayer Coatings**

|  Wall Coating in Model A 2.2×4×3 | Thickness (m) | Heat Transfer Coefficient (u-value) | Average Monthly Temperature in Dec °C | Average Monthly Temperature in Jan °C | Average Monthly Temperature in Feb °C | Average Monthly Outdoor Temperature in Jan | Priority |
|---|---|---|---|---|---|---|---|
| Granite/PVC | 0.04 | 3.81 | 11.76 | 8.48 | 9.57 | -1.7 | 32 |
| Brick /Plaster | 0.23 | 1.79 | 13.79 | 10.75 | 11.87 | -1.7 | 26 |
| Plywood/Cork | 0.06 | 1.09 | 15.93 | 13.64 | 14.58 | -1.7 | 11 |
| Plywood/PVC | 0.06 | 1.49 | 14.81 | 12.25 | 13.25 | -1.7 | 13 |
| Brick/Cork | 0.11 | 1.57 | 14.69 | 11.91 | 12.92 | -1.7 | 16 |

|  Wall Coating in Model A 2.2×4×3 | Thickness (m) | Heat Transfer Coefficient (u-value) | Average Monthly Temperature in Dec °C | Average Monthly Temperature in Jan °C | Average Monthly Temperature in Feb °C | Average Monthly Outdoor Temperature in Jan | Priority |
|---|---|---|---|---|---|---|---|
| Nylon/PTFE | 0.008 | 2.04 | 14.35 | 11.32 | 12.39 | -1.7 | 21 |
| Mortar/Brick | 0.13 | 2.91 | 12.56 | 9.26 | 10.37 | -1.7 | 31 |
| Cork/Cardboard | 0.08 | 0.61 | 17.84 | 15.97 | 16.78 | -1.7 | 8 |
| Cement Mortar/Brick | 0.13 | 2.85 | 12.6 | 9.34 | 10.44 | -1.7 | 30 |
| Mortar/Sand | 0.08 | 2.91 | 12.63 | 9.42 | 10.51 | -1.7 | 29 |
| Nylon/Fiberglass | 0.07 | 0.52 | 18.51 | 16.78 | 17.54 | -1.7 | 2 |
| Aluminum/Plywood | 0.07 | 1.75 | 14.83 | 11.76 | 12.63 | -1.7 | 18 |
| Aluminum/Cork | 0.07 | 0.59 | 18.16 | 16.21 | 16.91 | -1.7 | 7 |
| Aluminum/Styrofoam | 0.07 | 1.83 | 14.67 | 11.57 | 12.43 | -1.7 | 20 |
| Aluminum/Fiberglass | 0.07 | 0.53 | 18.46 | 16.62 | 17.3 | -1.7 | 4 |
| Copper/Fiberglass | 0.065 | 0.53 | 18.48 | 16.65 | 17.32 | -1.7 | 3 |
| Copper/Plywood | 0.065 | 1.75 | 14.84 | 11.8 | 12.65 | -1.7 | 17 |
| Copper/Cork | 0.065 | 0.59 | 18.18 | 16.23 | 16.94 | -1.7 | 6 |
| Copper/Styrofoam | 0.065 | 1.83 | 14.69 | 11.6 | 12.46 | -1.7 | 19 |
| Fiberglass / Polycarbonate | 0.06 | 0.85 | 16.91 | 14.81 | 15.7 | -1.7 | 10 |
| Fiberglass/Cork | 0.06 | 0.56 | 18.15 | 16.4 | 17.18 | -1.7 | 5 |
| Plywood/Styrofoam | 0.06 | 1.79 | 15.01 | 12.18 | 13.22 | -1.7 | 14 |
| Plywood/Fiberglass | 0.06 | 0.81 | 17.47 | 15.37 | 16.25 | -1.7 | 9 |
| Cane/Nylon | 0.032 | 2.09 | 13.57 | 10.84 | 11.86 | -1.7 | 25 |
| Cane/Cardboard | 0.05 | 1.33 | 15.22 | 12.79 | 13.77 | -1.7 | 12 |
| Cane/Aluminum | 0.035 | 2.12 | 13.56 | 10.84 | 11.86 | -1.7 | 24 |
| Cane/Copper | 0.035 | 2.12 | 13.59 | 10.85 | 11.87 | -1.7 | 23 |
| Nylon/Carpet | 0.012 | 2.9 | 12.96 | 9.99 | 11.04 | -1.7 | 27 |
| Cork/Carpet | 0.016 | 0.54 | 18.54 | 16.78 | 17.56 | -1.7 | 1 |
| Aluminum/Carpet | 0.015 | 2.97 | 13.16 | 9.87 | 10.68 | -1.7 | 28 |
| Brick/Carpet | 0.21 | 1.62 | 14.23 | 11.3 | 12.38 | -1.7 | 22 |
| Plywood/Carpet | 0.04 | 1.86 | 14.75 | 12 | 13.03 | -1.7 | 15 |

### 5.3. Thermal Analysis of the Basic Model by Applying Trilayer Coatings

By combining the materials listed in Table 1, 41 trilayer coatings were obtained, all of which were applied one by one on the basic model (A), and the obtained results (average monthly temperatures) are listed in Table 4. The results indicate that the combinations including fiberglass, plywood, and polyurethane as an insulating layer between the walls outperform other materials and maintain the indoor temperature of the shelter within a suitable range in the cold months.

**Table 4. Average Monthly Temperatures in the Cold Months for the Basic Shelter Form in Various Trilayer Coatings**

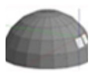
|  Wall Coating in Model A 2.2×4×3 | Thickness (m) | Heat Transfer Coefficient (u-value) | Average Monthly Temperature in Dec °C | Average Monthly Temperature in Jan °C | Average Monthly Temperature in Feb °C | Average Monthly Outdoor Temperature in Jan | Priority |
|---|---|---|---|---|---|---|---|
| Limestone/Mortar/Brick | 0.13 | 3.16 | 12.34 | 8.97 | 10.08 | -1.7 | 41 |
| Limestone/Air/Brick | 0.13 | 2.44 | 12.94 | 9.87 | 10.95 | -1.7 | 40 |
| Cement Mortar/Brick/Cork | 0.1 | 0.98 | 16.37 | 14.04 | 14.96 | -1.7 | |
| Cement Mortar/Brick/Plywood | 0.1 | 2.14 | 13.6 | 10.6 | 11.66 | -1.7 | 38 |
| Cement Mortar/Brick/PVC | 0.1 | 2.1 | 13.51 | 10.49 | 11.55 | -1.7 | 39 |
| Cement Mortar/Brick/Fiberglass | 0.1 | 0.88 | 16.71 | 14.47 | 15.36 | -1.7 | |
| Nylon/Cork/Cardboard | 0.083 | 0.54 | 18.41 | 16.62 | 17.4 | -1.7 | |
| Nylon/Styrofoam/Cardboard | 0.083 | 1.09 | 16.34 | 13.92 | 14.87 | -1.7 | |
| Nylon/Cork/Aluminum | 0.058 | 0.69 | 17.6 | 15.62 | 16.48 | -1.7 | |
| Nylon/Styrofoam/Aluminum | 0.058 | 2.02 | 14.28 | 11.42 | 12.46 | -1.7 | |
| Nylon/Cork/Fiberglass | 0.083 | 0.43 | 18.92 | 17.3 | 18.01 | -1.7 | 5 |
| Nylon/ Styrofoam/Fiberglass | 0.083 | 0.74 | 17.61 | 15.53 | 16.38 | -1.7 | |
| Plywood/Glass Wool/Plywood | 0.09 | 0.59 | 18.3 | 16.42 | 17.22 | -1.7 | |
| Plywood/Air/Plywood | 0.06 | 1.7 | 15.03 | 12.32 | 13.34 | -1.7 | |
| Plywood/Polyurethane/Plywood | 0.09 | 0.45 | 19.01 | 17.32 | 18.05 | -1.7 | 4 |
| Plywood/Mineral Wool/Plywood | 0.09 | 0.59 | 18.3 | 16.42 | 17.22 | -1.7 | |
| Plywood/Styrofoam/Plywood | 0.09 | 1.33 | 15.97 | 13.32 | 14.33 | -1.7 | |
| Plywood/Glass Wool/Aluminum | 0.075 | 0.64 | 17.94 | 15.99 | 16.83 | -1.7 | |
| Plywood/Polyurethane/Aluminum | 0.075 | 0.47 | 18.75 | 17.01 | 17.77 | -1.7 | 8 |
| Plywood/Mineral Wool/Aluminum | 0.075 | 0.64 | 17.94 | 16 | 16.83 | -1.7 | |
| Plywood/Styrofoam/Aluminum | 0.075 | 1.62 | 15.31 | 12.54 | 13.57 | -1.7 | |
| Fiberglass/Glass Wool/Plywood | 0.1 | 0.41 | 18.85 | 17.24 | 17.95 | -1.7 | |
| Fiberglass/Polyurethane/Plywood | 0.1 | 0.33 | 19.33 | 17.83 | 18.49 | -1.7 | 1 |
| Fiberglass/Mineral Wool/Plywood | 0.1 | 0.41 | 18.85 | 17.24 | 17.95 | -1.7 | 7 |
| Fiberglass/Styrofoam/Plywood | 0.1 | 0.67 | 17.5 | 15.52 | 16.39 | -1.7 | |
| Fiberglass/Cork/Plywood | 0.1 | 0.41 | 18.87 | 17.25 | 17.96 | -1.7 | 6 |
| Fiberglass/Nylon/Plywood | 0.053 | 0.85 | 16.91 | 14.82 | 15.71 | -1.7 | |
| Fiberglass/Glass Wool/Aluminum | 0.085 | 0.43 | 18.6 | 16.94 | 17.68 | -1.7 | 10 |
| Fiberglass/Polyurethane/ Aluminum | 0.085 | 0.35 | 19.14 | 17.6 | 18.28 | -1.7 | 2 |
| Fiberglass/Styrofoam/Aluminum | 0.085 | 0.74 | 17.11 | 15.04 | 5.93 | -1.7 | |
| Fiberglass/Cork/Aluminum | 0.085 | 0.43 | 18.63 | 16.96 | 17.69 | -1.7 | 9 |
| Fiberglass/Nylon/Aluminum | 0.038 | 0.96 | 16.34 | 14.19 | 15.11 | -1.7 | |
| Fiberglass/Plywood/Carpet | 0.06 | 0.75 | 17.29 | 15.3 | 16.16 | -1.7 | |

|  Wall Coating in Model A 2.2×4×3 | Thickness (m) | Heat Transfer Coefficient (u-value) | Average Monthly Temperature in Dec °C | Average Monthly Temperature in Jan °C | Average Monthly Temperature in Feb °C | Average Monthly Outdoor Temperature in Jan | Priority |
|---|---|---|---|---|---|---|---|
| Fiberglass/Cork/Carpet | 0.09 | 0.4 | 18.91 | 17.33 | 18.03 | -1.7 | 3 |
| Aluminum/Cork/Carpet | 0.065 | 0.63 | 18.02 | 16.05 | 16.76 | -1.7 | |
| Nylon/Cork/Carpet | 0.063 | 0.62 | 18.03 | 16.18 | 16.99 | -1.7 | |
| Nylon/Plywood/Carpet | 0.033 | 2.07 | 14.03 | 11.25 | 12.28 | -1.7 | 37 |
| Cane/Plywood/Carpet | 0.06 | 1.29 | 15.37 | 12.93 | 13.9 | -1.7 | |
| Cane/Nylon/Carpet | 0.043 | 1.54 | 14.68 | 12.16 | 13.15 | -1.7 | |
| Plywood/Carpet/Ptfe | 0.08 | 1.49 | 15.41 | 12.66 | 13.67 | -1.7 | |
| Cork / Carpet /Ptfe | 0.11 | 0.56 | 18.39 | 16.48 | 17.24 | -1.7 | |

### 5.4. Thermal Analysis of the Best Shelter Model by Applying Monolayer Coatings

The shelter form E can be inspired by the nomadic shelters, and investigating the thermal performance of the coatings in monolayer, bilayer and trilayer modes in cold climates can show their effects on this form in future conditions. The results indicate the fiberglass coating with the first rank and in this form, the average monthly indoor temperature in the cold months of December, January, and February is 19.69, 18.42, and 19.21 °C, respectively. If these results are compared with those obtained for the basic model (A), a temperature difference of 3 °C will be seen, indicating the improved performance of the dome-shaped form. In cases of forms B and C, one can see nearly the same temperature difference (Table 5).

**Table 5. Average Monthly Temperatures in the Cold Months for the Best Shelter Form in Various Monolayer Coatings**

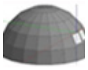
|  Wall Coating in Model E r = 2.35 | Thickness (m) | Heat Transfer Coefficient (u-value) | Average Monthly Temperature in Dec °C | Average Monthly Temperature in Jan °C | Average Monthly Temperature in Feb °C | Average Monthly Outdoor Temperature in Jan | Priority |
|---|---|---|---|---|---|---|---|
| Lightweight Metal Cladding | 0.005 | 3.6 | 9.67 | 6.94 | 8.32 | -1.7 | 17 |
| Brick | 0.22 | 2.31 | 15.2 | 12.42 | 13.87 | -1.7 | 6 |
| Concrete Masonry Unit | 0.1 | 1.43 | 16.71 | 14.77 | 15.9 | -1.7 | 3 |
| Fiberglass | 0.04 | 0.76 | 19.69 | 18.42 | 19.21 | -1.7 | 1 |
| Air cushion | 0.03 | 2.97 | 13.64 | 11.22 | 12.6 | -1.7 | 7 |
| Nylon | 0.004 | 5.37 | 11.6 | 8.7 | 10.24 | -1.7 | 14 |
| Aluminum | 0.004 | 5.88 | 12.61 | 9.28 | 10.26 | -1.7 | |
| Stainless Metal | 0.004 | 5.87 | 11.72 | 8.47 | 9.39 | -1.7 | 15 |
| Water Cushion | 0.05 | 3.71 | 13.53 | 10.48 | 12.02 | -1.7 | |
| Cardboard | 0.05 | 1.14 | 18.18 | 16.52 | 17.55 | -1.7 | 2 |
| Cane | 0.03 | 2.12 | 14.75 | 12.61 | 13.86 | -1.7 | 5 |
| Plywood | 0.04 | 2.29 | 15.41 | 13.05 | 14.41 | -1.7 | 4 |
| Carpet | 0.01 | 2.97 | 13.2 | 10.83 | 12.16 | -1.7 | 9 |
| Copper | 0.01 | 5.88 | 12.59 | 9.2 | 10.22 | -1.7 | 13 |
| PTFE | 0.03 | 3.44 | 13.32 | 10.62 | 12.07 | -1.7 | 10 |
| Rubber | 0.03 | 2.88 | 13.55 | 11.02 | 12.38 | -1.7 | 8 |
| Sand | 0.03 | 3.94 | 10.13 | 7.56 | 8.85 | -1.7 | 16 |

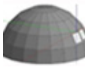
### 5.5. Thermal Analysis of the Best Shelter Model by Applying Bilayer Coatings

Evaluating the thermal performance of shelter form E by applying bilayer coatings on it shows that in almost the top 8 bilayer coatings, the average indoor temperature of the shelter in the cold months is at least 20 °C, which is very desirable because, in the post-disaster situation, where only the victims' primary accommodation is taken into consideration, there are no heating facilities. So, in such critical situations, shelter coatings can be hoped to provide shelters with a favorable interior in terms of temperature.

In this sample, the copper-fiberglass ranks first, followed by nylon-fiberglass, aluminum-fiberglass, cork-carpet, and fiberglass-cork, which have almost equal thermal performance, and in all cases, fiberglass and cork have a significant contribution to this trend (Table 6).

**Table 6. Average Monthly Temperatures in the Cold Months for the Best Shelter Form in Various Bilayer Coatings**

|  Wall Coating in Model E r = 2.35 | Thickness (m) | Heat Transfer Coefficient (u-value) | Average Monthly Temperature in Dec °C | Average Monthly Temperature in Jan °C | Average Monthly Temperature in Feb °C | Average Monthly Outdoor Temperature in Jan | Priority |
|---|---|---|---|---|---|---|---|
| Granite/PVC | 0.04 | 3.81 | 12.35 | 9.56 | 11.02 | -1.7 | 32 |
| Brick/Plaster | 0.23 | 1.79 | 15.81 | 13.28 | 14.62 | -1.7 | |
| Plywood/Cork | 0.06 | 1.09 | 18.06 | 16.43 | 17.42 | -1.7 | |
| Plywood/PVC | 0.06 | 1.49 | 16.58 | 14.65 | 15.79 | -1.7 | |
| Brick/Cork | 0.11 | 1.57 | 16.57 | 14.36 | 15.54 | -1.7 | |
| Nylon/PTFE | 0.008 | 2.04 | 15.9 | 13.43 | 14.76 | -1.7 | |
| Mortar/Brick | 0.13 | 2.91 | 13.67 | 10.82 | 12.27 | -1.7 | 31 |
| Cork/Cardboard | 0.08 | 0.61 | 20.82 | 19.66 | 20.41 | -1.7 | 8 |
| Cement Mortar/Brick | 0.13 | 2.85 | 13.72 | 10.92 | 12.36 | -1.7 | |
| Mortar/Sand | 0.08 | 2.91 | 13.64 | 10.92 | 12.33 | -1.7 | 30 |
| Nylon/Fiberglass | 0.07 | 0.52 | 21.27 | 20.22 | 20.86 | -1.7 | 2 |
| Aluminum/Plywood | 0.07 | 1.75 | 17.01 | 14.44 | 15.32 | -1.7 | |
| Aluminum/Cork | 0.07 | 0.59 | 21.06 | 19.76 | 20.29 | -1.7 | 7 |
| Aluminum/Styrofoam | 0.07 | 1.83 | 16.81 | 14.19 | 15.08 | -1.7 | |
| Aluminum/Fiberglass | 0.07 | 0.53 | 21.44 | 20.22 | 20.72 | -1.7 | 3 |
| Copper/Fiberglass | 0.065 | 0.53 | 21.45 | 20.24 | 20.73 | -1.7 | 1 |
| Copper/Plywood | 0.065 | 1.75 | 17.02 | 14.46 | 15.34 | -1.7 | |
| Copper/Cork | 0.065 | 0.59 | 21.07 | 19.77 | 20.3 | -1.7 | 6 |
| Copper/Styrofoam | 0.065 | 1.83 | 16.82 | 14.21 | 15.1 | -1.7 | |
| Fiberglass/Polycarbonate | 0.06 | 0.85 | 19.27 | 17.86 | 18.72 | -1.7 | 10 |
| Fiberglass/Cork | 0.06 | 0.56 | 20.84 | 19.76 | 20.43 | -1.7 | 5 |
| Plywood/Styrofoam | 0.06 | 1.79 | 16.62 | 14.41 | 15.69 | -1.7 | |
| Plywood/Fiberglass | 0.06 | 0.81 | 19.88 | 18.49 | 19.34 | -1.7 | 9 |
| Cane/nylon | 0.032 | 2.09 | 14.85 | 12.71 | 13.96 | -1.7 | |
| Cane/Cardboard | 0.05 | 1.33 | 17.1 | 15.31 | 16.39 | -1.7 | |
| Cane/Aluminum | 0.035 | 2.12 | 14.6 | 12.44 | 13.71 | -1.7 | |
| Cane/Copper | 0.035 | 2.12 | 14.64 | 12.46 | 13.73 | -1.7 | |
| Nylon/Carpet | 0.012 | 2.9 | 13.81 | 11.42 | 12.79 | -1.7 | 29 |

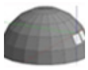


| Wall Coating in Model E r = 2.35 | Thickness (m) | Heat Transfer Coefficient (u-value) | Average Monthly Temperature in Dec °C | Average Monthly Temperature in Jan °C | Average Monthly Temperature in Feb °C | Average Monthly Outdoor Temperature in Jan | Priority |
|---|---|---|---|---|---|---|---|
| Cork/Carpet | 0.016 | 0.54 | 21.21 | 20.17 | 20.83 | -1.7 | 4 |
| Aluminum/Carpet | 0.015 | 2.97 | 14.77 | 11.84 | 12.74 | -1.7 | 28 |
| Brick/Carpet | 0.21 | 1.62 | 16.37 | 13.98 | 15.24 | -1.7 | |
| Plywood/Carpet | 0.04 | 1.86 | 16.27 | 14.12 | 15.4 | -1.7 | |

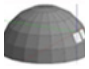
## 5.6. Thermal Analysis of the Best Shelter Model by Applying Coatings in Trilayer Mode

In the case of trilayer coatings, fiberglass-polyurethane, and fiberglass-cork combinations as well as the use of mineral wool and glass wool with one of the above combinations help to improve the indoor temperature conditions. For example, according to the following table, in the case of the fiberglass-polyurethane-plywood combination, which ranks first among the top 10 trilayer coatings, the average temperature difference between forms E and D in the investigated cold months is about 3 °C. The temperature difference between Form E and Forms A and C is between 3-4 °C, indicating the improvement of the thermal performance as a result of using the dome-shaped shelter form (E) (Table 7).

**Table 7. Average Monthly Temperatures in the Cold Months for the Best Shelter Form in Various Trilayer Coatings**



| Wall Coating in Model E r = 2.35 | Thickness (m) | Heat Transfer Coefficient (u-value) | Average Monthly Temperature in Dec °C | Average Monthly Temperature in Jan °C | Average Monthly Temperature in Feb °C | Average Monthly Outdoor Temperature in Jan | Priority |
|---|---|---|---|---|---|---|---|
| Limestone/Mortar/Brick | 0.13 | 3.16 | 13.35 | 10.42 | 11.9 | -1.7 | 41 |
| Limestone/Air/Brick | 0.13 | 2.44 | 14.19 | 11.65 | 13.01 | -1.7 | 40 |
| Cement Mortar/Brick/Cork | 0.1 | 0.98 | 18.73 | 17.06 | 17.98 | -1.7 | |
| Cement Mortar/Brick/Plywood | 0.1 | 2.14 | 15.06 | 12.58 | 13.89 | -1.7 | 38 |
| Cement Mortar/Brick/PVC | 0.1 | 2.1 | 14.92 | 12.43 | 13.74 | -1.7 | 39 |
| Cement Mortar/Brick/Fiberglass | 0.1 | 0.88 | 19.16 | 17.59 | 18.46 | -1.7 | |
| Nylon/Cork/Cardboard | 0.083 | 0.54 | 21.1 | 20.05 | 20.72 | -1.7 | 10 |
| Nylon/Styrofoam/Cardboard | 0.083 | 1.09 | 18.55 | 16.8 | 17.8 | -1.7 | |
| Nylon/Cork/Aluminum | 0.058 | 0.69 | 19.89 | 18.64 | 19.44 | -1.7 | |
| Nylon/Styrofoam/Aluminum | 0.058 | 2.02 | 15.52 | 13.2 | 14.52 | -1.7 | |
| Nylon/Cork/Fiberglass | 0.083 | 0.43 | 21.75 | 20.82 | 21.4 | -1.7 | 6 |
| Nylon/ Styrofoam/Fiberglass | 0.083 | 0.74 | 20.16 | 18.79 | 19.58 | -1.7 | |
| Plywood/Glass Wool/Plywood | 0.09 | 0.59 | 20.93 | 19.81 | 20.53 | -1.7 | |
| Plywood/Air/Plywood | 0.06 | 1.7 | 16.67 | 14.58 | 15.83 | -1.7 | |
| Plywood/Polyurethane/Plywood | 0.09 | 0.45 | 21.78 | 20.84 | 21.44 | -1.7 | |
| Plywood/Mineral Wool/Plywood | 0.09 | 0.59 | 20.94 | 19.81 | 20.53 | -1.7 | |
| Plywood/Styrofoam/Plywood | 0.09 | 1.33 | 18.02 | 16.02 | 17.16 | -1.7 | |
| Plywood/Glass Wool/Aluminum | 0.075 | 0.64 | 20.31 | 19.12 | 19.88 | -1.7 | |
| Plywood/Polyurethane/Aluminum | 0.075 | 0.47 | 21.32 | 20.34 | 20.98 | -1.7 | 9 |
| Plywood/Mineral Wool/Aluminum | 0.075 | 0.64 | 20.32 | 19.12 | 19.88 | -1.7 | |
| Plywood/Styrofoam/Aluminum | 0.075 | 1.62 | 16.88 | 14.68 | 15.94 | -1.7 | |
| Fiberglass/Glass Wool/Plywood | 0.1 | 0.41 | 21.73 | 20.83 | 21.4 | -1.7 | |

|  Wall Coating in Model E r = 2.35 | Thickness (m) | Heat Transfer Coefficient (u-value) | Average Monthly Temperature in Dec °C | Average Monthly Temperature in Jan °C | Average Monthly Temperature in Feb °C | Average Monthly Outdoor Temperature in Jan | Priority |
|---|---|---|---|---|---|---|---|
| Fiberglass/Polyurethane/Plywood | 0.1 | 0.33 | 22.27 | 21.48 | 21.99 | -1.7 | 1 |
| Fiberglass/Mineral Wool/Plywood | 0.1 | 0.41 | 21.74 | 20.83 | 21.4 | -1.7 | 5 |
| Fiberglass/Styrofoam/Plywood | 0.1 | 0.67 | 20.14 | 18.84 | 19.63 | -1.7 | |
| Fiberglass/Cork/Plywood | 0.1 | 0.41 | 21.75 | 20.84 | 21.42 | -1.7 | 4 |
| Fiberglass/Nylon/Plywood | 0.053 | 0.85 | 19.24 | 17.86 | 18.71 | -1.7 | |
| Fiberglass/Glass Wool/Aluminum | 0.085 | 0.43 | 21.33 | 20.37 | 20.96 | -1.7 | 8 |
| Fiberglass/Polyurethane/Aluminum | 0.085 | 0.35 | 21.97 | 21.12 | 21.66 | -1.7 | 2 |
| Fiberglass/Styrofoam/Aluminum | 0.085 | 0.74 | 19.44 | 18.04 | 18.88 | -1.7 | |
| Fiberglass/Cork/Aluminum | 0.085 | 0.43 | 21.32 | 20.37 | 21 | -1.7 | 7 |
| Fiberglass/Nylon/Aluminum | 0.038 | 0.96 | 18.35 | 16.82 | 17.77 | -1.7 | |
| Fiberglass/Plywood/Carpet | 0.06 | 0.75 | 19.75 | 18.46 | 19.25 | -1.7 | |
| Fiberglass/Cork/Carpet | 0.09 | 0.4 | 21.78 | 20.9 | 21.45 | -1.7 | 3 |
| Aluminum/Cork/Carpet | 0.065 | 0.63 | 20.89 | 19.56 | 20.1 | -1.7 | |
| Nylon/Cork/Carpet | 0.063 | 0.62 | 20.62 | 19.48 | 20.2 | -1.7 | |
| Nylon/Plywood/Carpet | 0.033 | 2.07 | 15.38 | 13.18 | 14.47 | -1.7 | 37 |
| Cane/Plywood/Carpet | 0.06 | 1.29 | 17.32 | 15.51 | 16.58 | -1.7 | |
| Cane/Nylon/Carpet | 0.043 | 1.54 | 16.38 | 14.48 | 15.63 | -1.7 | |
| Plywood/Carpet/PTFE | 0.08 | 1.49 | 17.34 | 15.2 | 16.36 | -1.7 | |
| Cork/Carpet/PTFE | 0.11 | 0.56 | 21.22 | 19.99 | 20.66 | -1.7 | |

### 5.7. Comparison of eleven Shelter Forms in Temperature by Applying the Best Bilayer Coatings in Cold Months

According to the obtained average temperatures for the different materials in the above tables, which were presented for all 11 forms with equal volume, the best coatings were selected, and the temperature conditions were assessed for them in January, which is the coldest month of the year. In the case of bilayer coatings, one of the best coatings in terms of temperature performance is cork-carpet coating. The comparison of different shelter models with this coating in temperature shows that Model E has the highest temperature performance with an average temperature of 20.17 °C in January, followed by Model J with an average temperature of 18.34 °C, and Model D with a cubic body, a vaulted roof, and an average temperature of 17.52 °C (Table 8).

**Table 8. Comparison of 11 Shelter Forms with the Best Bilayer Coatings in Temperature**

| Material | Cork/Carpet | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|
| Shelter Model | A | B | C | D | E | F | G | H | I | J | K |
| December | 18.54 | 18.62 | 18.82 | 19.09 | 21.21 | 18.85 | 18.30 | 18.95 | 18.80 | 19.81 | 16.47 |
| January | 16.78 | 16.86 | 17.14 | 17.52 | 20.17 | 17.20 | 16.61 | 17.30 | 17.08 | 18.34 | 14.34 |
| February | 17.56 | 17.64 | 17.92 | 18.33 | 20.83 | 17.96 | 17.48 | 18.05 | 17.84 | 19.02 | 15.31 |
| Material | Nylon/Fiberglass | | | | | | | | | | |
| December | 18.51 | 18.60 | 18.79 | 19.07 | 21.27 | 18.83 | 18.26 | 18.94 | 18.78 | 19.81 | 16.34 |
| January | 16.78 | 16.87 | 17.15 | 17.53 | 20.22 | 17.21 | 16.61 | 17.32 | 17.08 | 18.36 | 14.28 |
| February | 17.54 | 17.64 | 17.90 | 18.33 | 20.86 | 17.95 | 17.44 | 18.05 | 17.83 | 19.02 | 15.22 |
| Material | Aluminum/Fiberglass | | | | | | | | | | |
| December | 18.46 | 18.58 | 18.74 | 19.04 | 21.44 | 18.80 | 18.37 | 18.91 | 18.74 | 19.79 | 16.33 |
| January | 16.62 | 16.73 | 17.00 | 17.40 | 20.22 | 17.06 | 16.54 | 17.19 | 16.94 | 18.25 | 14.04 |
| February | 17.30 | 17.40 | 17.67 | 18.13 | 20.72 | 17.71 | 17.20 | 17.84 | 17.61 | 18.85 | 14.82 |

| Material | Fiberglass/Cork | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|
| December | 18.15 | 18.22 | 18.45 | 18.78 | 20.84 | 18.44 | 17.75 | 18.62 | 18.44 | 19.54 | 15.73 |
| January | 16.40 | 16.47 | 16.78 | 17.21 | 19.76 | 16.79 | 16.08 | 16.97 | 16.72 | 18.07 | 13.65 |
| February | 17.18 | 17.25 | 17.56 | 18.03 | 20.43 | 17.55 | 16.93 | 17.72 | 17.49 | 18.75 | 14.61 |
| Material | Cork/Cardboard | | | | | | | | | | |
| December | 17.84 | 18.26 | 18.49 | 18.79 | 20.82 | 18.49 | 17.88 | 18.63 | 18.48 | 19.53 | 16.05 |
| January | 15.97 | 16.37 | 16.69 | 17.10 | 19.66 | 16.69 | 16.05 | 16.86 | 16.63 | 17.95 | 13.73 |
| February | 16.78 | 17.19 | 17.50 | 17.95 | 20.41 | 17.50 | 16.98 | 17.65 | 17.44 | 18.66 | 14.75 |
| Material | Copper/Cork | | | | | | | | | | |
| December | 18.18 | 18.27 | 18.47 | 18.80 | 21.07 | 18.47 | 17.99 | 18.65 | 18.47 | 19.56 | 15.93 |
| January | 16.23 | 16.32 | 16.63 | 17.07 | 19.77 | 16.63 | 16.04 | 16.83 | 16.57 | 17.95 | 13.49 |
| February | 16.94 | 17.01 | 17.33 | 17.82 | 20.30 | 17.31 | 16.74 | 17.51 | 17.26 | 18.57 | 14.30 |

In the case of fiberglass-cork coating, comparing different forms in temperature indicates that shelter model E, which has a dome-shaped form, outperforms other shelter forms, followed by shelter model J, and the temperature difference between these two models is more than 1.5 °C. It is noted that in the case of Form E, the temperature difference between the top 5 bilayer coatings will be about 0.5 °C (Fig. 8).

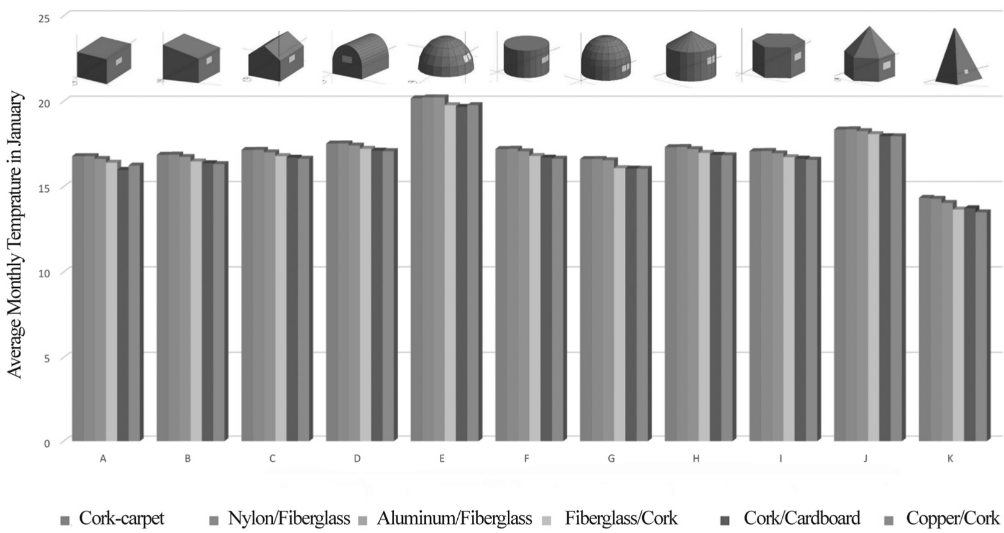



**Fig. 8. Evaluation of the Studied Shelter Forms in the Case of Using Bilayer Coatings**

In the case of trilayer coatings, comparing shelter forms shows that in the case of using one of the best coatings, i.e. fiberglass-polyurethane-plywood combination, in all forms except Form K, the average temperatures of the shelters in cold months are within an acceptable range. So, the important point here is that in any shelter form, increasing the layers of coatings improves temperature conditions. According to the above table, for all the coatings, Form E has the most suitable temperature condition, followed by Form J. In the case of the fiberglass-polyurethane-aluminum coating, Form E with an average indoor temperature of 21.12 °C still ranks first (Table 9).
According to the table comparing the forms with this coating, Form E ranks first, followed by Form J. Form J has a better thermal performance than similar forms H and I with a temperature difference of about 1°C. in the case of the fiberglass-polyurethane-aluminum coating, examining the forms of F, G, and H with different roofs shows that the two forms F and H have similar temperature conditions, indicating that there is no certain temperature difference in the forms with the same circular plan but different roofs (conical or flat). In the case of the fiberglass-cork-carpet coatings, comparing the forms with a circular plan, such as F, G, and H shows that the temperature conditions of the two forms F and H were the same. So, in the case of the trilayer coating and the forms with a circular plan, the implementation of a roof with a conical form will not affect the thermal performance of the interior (Fig. 9).

**Table 9. Comparison of 11 Shelter Forms with the Best Trilayer Coatings in Temperature**

| Material | Fiberglass/Polyurethane/Plywood | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|
| Shelter Model | A | B | C | D | E | F | G | H | I | J | K |
| December | 19.33 | 19.53 | 19.57 | 19.73 | 22.27 | 19.80 | 19.49 | 19.70 | 19.60 | 20.43 | 17.76 |
| January | 17.83 | 18.04 | 18.14 | 18.37 | 21.48 | 18.42 | 18.10 | 18.27 | 18.11 | 19.13 | 15.99 |
| February | 18.49 | 18.69 | 18.81 | 19.10 | 21.99 | 19.07 | 18.76 | 18.92 | 18.77 | 19.73 | 16.78 |
| Material | Fiberglass/Polyurethane/Aluminum | | | | | | | | | | |
| December | 19.14 | 19.32 | 19.40 | 19.59 | 21.97 | 19.57 | 19.15 | 19.53 | 19.40 | 20.29 | 17.43 |
| January | 17.60 | 17.80 | 17.94 | 18.21 | 21.12 | 18.16 | 17.72 | 18.08 | 17.89 | 18.98 | 15.61 |
| February | 18.28 | 18.47 | 18.62 | 18.95 | 21.66 | 18.81 | 18.40 | 18.74 | 18.55 | 19.59 | 16.44 |
| Material | Fiberglass/Cork/Carpet | | | | | | | | | | |
| December | 18.91 | 19.07 | 19.17 | 19.39 | 21.78 | 19.32 | 18.88 | 19.31 | 19.19 | 20.11 | 17.03 |
| January | 17.33 | 17.49 | 17.67 | 17.96 | 20.90 | 17.86 | 17.40 | 17.82 | 17.63 | 18.76 | 15.14 |
| February | 18.03 | 18.18 | 18.37 | 18.72 | 21.45 | 18.53 | 18.12 | 18.50 | 18.32 | 19.39 | 16.00 |
| Material | Plywood/ Polyurethane/Plywood | | | | | | | | | | |
| December | 19.01 | 19.15 | 19.26 | 19.47 | 21.78 | 19.39 | 19.00 | 19.38 | 19.27 | 20.17 | 17.29 |
| January | 17.32 | 17.45 | 17.65 | 17.95 | 20.84 | 17.82 | 17.39 | 17.79 | 17.61 | 18.73 | 15.21 |
| February | 18.05 | 18.18 | 18.38 | 18.73 | 21.44 | 18.53 | 18.17 | 18.50 | 18.32 | 19.38 | 16.12 |
| Material | Nylon/Cork/Fiberglass | | | | | | | | | | |
| December | 18.92 | 19.05 | 19.18 | 19.40 | 21.75 | 19.30 | 18.86 | 19.32 | 19.18 | 20.11 | 17.04 |
| January | 17.30 | 17.44 | 17.64 | 17.95 | 20.82 | 17.80 | 17.34 | 17.79 | 17.59 | 18.74 | 15.10 |
| February | 18.01 | 18.15 | 18.35 | 18.71 | 21.40 | 18.49 | 18.09 | 18.48 | 18.29 | 19.38 | 15.98 |
| Material | Fiberglass/Cork/Plywood | | | | | | | | | | |
| December | 18.87 | 19.02 | 19.12 | 19.34 | 21.75 | 19.27 | 18.84 | 19.27 | 19.15 | 20.07 | 16.99 |
| January | 17.25 | 17.41 | 17.58 | 17.88 | 20.84 | 17.78 | 17.32 | 17.74 | 17.56 | 18.68 | 15.03 |
| February | 17.96 | 18.11 | 18.30 | 18.65 | 21.42 | 18.47 | 18.06 | 18.43 | 18.26 | 19.32 | 15.93 |
| Material | Plywood/Polyurethane/Aluminum | | | | | | | | | | |
| December | 18.75 | 18.86 | 19.02 | 19.26 | 21.32 | 19.09 | 18.56 | 19.14 | 19.00 | 19.95 | 16.85 |
| January | 17.01 | 17.13 | 17.37 | 17.71 | 20.34 | 17.46 | 16.90 | 17.51 | 17.29 | 18.51 | 14.73 |
| February | 17.77 | 17.88 | 18.12 | 18.51 | 20.98 | 18.20 | 17.73 | 18.24 | 18.04 | 19.18 | 15.68 |

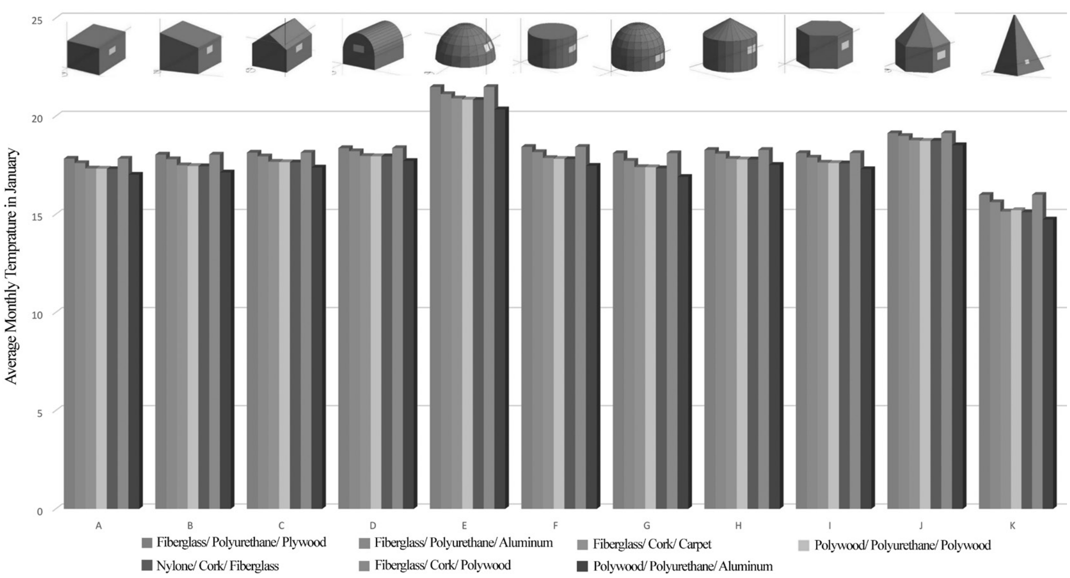



**Fig. 9. Evaluation of the Studied Shelter Forms in the Case of Using Trilayer Coatings**

### 5.8. Comparison of the Research Results with the Results of Previous Research

Various factors play a role in determining the best option for post-disaster shelters, among which, one can refer to the selection of a suitable coating for the shelter that is both suitable for performance and acceptable to users while helping to improve the indoor temperature conditions. Among the materials frequently mentioned as suitable materials are wooden products, which are suitable since they are light, have no harmful environmental effects, and can be reused in permanent buildings. In addition, sandwich panel material was identified as one of the recommended materials for the shelter coatings. These results are consistent with the studies by Escamilla (2015) and Wallbaum (2012), who knew timber and bamboo as the most promising technology in the field of construction of cheap houses. Previous studies on the type of materials used in the construction of shelters reveal that some of the provided shelters were prefabricated, and made of concrete. Apart from the users' reluctance to live in them, these samples are also environmentally inappropriate (Johnson 2007a). Many other shelters established by the Red Crescent and Red Cross societies in different places show that in the construction of these shelters, monolayer materials such as bricks, concrete masonry units, timber, and vernacular materials were also used (IFRC 2013). These materials have been evaluated in the table comparing shelter coatings in this research. Although these materials obtained higher ranks than other materials in improving the thermal performance of the shelter, a low average monthly temperature was obtained in the case of using them in a monolayer mode, and it is preferred to use them in combination with other materials in a multi-layer form. Since it is attempted to close the indoor temperature of the shelter to an acceptable level, the obtained results on the vernacular materials show that in Kermanshah, the use of vernacular materials alone cannot provide acceptable temperature conditions for the shelter and it is required to use them in combination with other materials to enhance the thermal performance of the shelter. These findings negate the applied opinions indicating the preference for local resources over imported solutions (Fe´lix 2014). One of the goals stated earlier is to try to build a light and modular shelter that can be easily moved and provided to users. Therefore, to obtain a light shelter, its coating materials are expected to be light and flexible, and easily assembled and dismantled. In this case, they will likely have poorer thermal performance than hard surfaces (Thrall 2014). While the findings of the present study showed that the thermal performance of materials such as cardboard is much higher than hard aluminum or metal coatings. According to Figure 10 and the comparison of the experts' opinions on different materials with the results of the present research, one can find that according to the findings of the present research, many of the opinions presented in the field of the post-disaster shelter construction can be modified with changes in the type of coating, resulting in the improved results.

Numerous studies have investigated vernacular materials and construction skills. For example, in some cases, the use of local construction skills and vernacular materials has been mentioned as a positive point (Aslani 2017; Nikravan 2007) and in some studies, inattention to vernacular materials and lack of use of local construction skills have been criticized (Bashawri 2014). In the importance of using vernacular materials, the role of timber in providing suitable shelter has been also mentioned (Rezaei 2014). However, these materials alone cannot provide suitable temperature conditions and it is required to use other materials, even non-vernacular materials, to regulate the temperature conditions inside the shelter.

## 6. CONCLUSION

- In the case of monolayer coatings, fiberglass, and cardboard outperformed other materials and were able to create acceptable temperature conditions.
- In the case of bilayer coatings, the combinations of cork and carpet, nylon and fiberglass, cork and cardboard, and copper and cork outperformed other combinations, indicating that the two materials of fiberglass and cork will play a significant role in adjusting the temperature conditions.
- In the case of trilayer coatings, one can mention the combinations of fiberglass and polyurethane with plywood or aluminum, fiberglass and cork with carpet or plywood, and finally, plywood and polyurethane with plywood or aluminum.
- If we want to reach favorable temperature conditions inside the shelter, in addition to reducing the costs of providing shelters, and also be determined to use vernacular materials, we have to use non-vernacular materials, along with vernacular ones, which is feasible by proper planning and considering it in advance. This also facilitates the provision of optimal coatings.

Finally, Figure 11 shows the general results on the effects of materials on shelter forms according to the research findings.

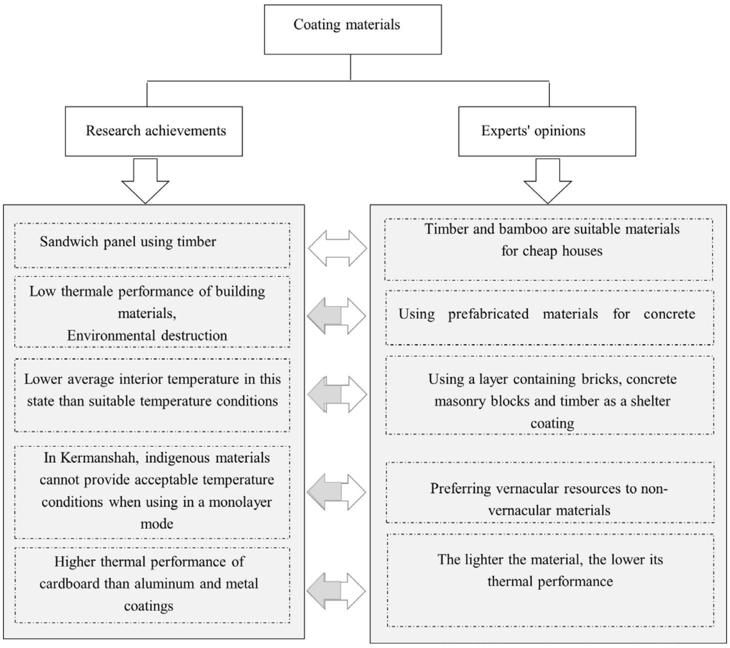



**Fig. 10. Comparing Research Findings with the Experts' Opinions on the Coating Materials of Post-Disaster Shelters**

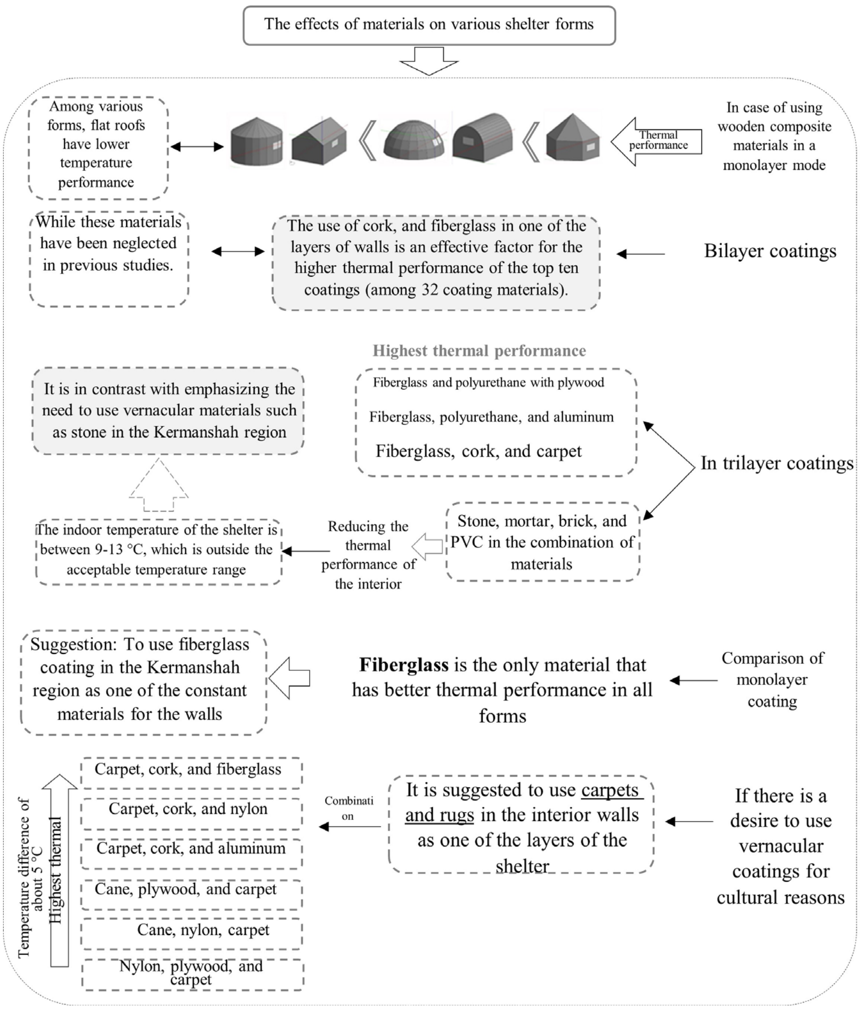



**Fig. 11. The Results on the Effects of Materials on Various Shelter Forms**

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