A New Technique for Preserving Thermal Conditions of Disasters Rapid Succor Shelters

(Comparative Analysis Study Using Thermal Imaging Devices)

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ABSTRACT.

Nowadays, the need of temporary shelters rise rapidly for several purposes such as rapid host shelters against natural disasters, refugee camps, remote camps, construction sites …etc.

Tents, caravans and kiosks are types of temporary shelters, while canvas, wood, PVC or other materials are the traditional construction materials of these sorts of shelters.

The effects of the weather conditions on these sorts of shelters are vital, especially in cold weather. Temperature preservation is an important factor that affects the living conditions inside the shelters as the need of offering appropriate environmental conditions inside the shelter will assist in enhancing the living situation of the shelter users.

The main goal of this research is to innovate sort of protective material covers for temporary shelters. These covers will be in the form of an outer envelope that needs short execution time. The covers will be capable of preserving the temperature degrees inside the temporary shelters for longer period with minimum cost. To achieve this goal, the research examines experimentally the insulation effectiveness of some materials that can be used as an envelope to deduce a new technique for enhancing the internal environmental conditions of these sorts of shelters.

Key words

Temporary Shelters - refugee camps - Thermal preservation- Thermal imaging

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1-The research outline:

To achieve the goal of the research, a 1:10 scale test model representing a building will be prepared, in which its internal temperature could be regulated and controlled using an electrical coil and an electrical thermostat. A group of innovative materials representing thermal insulation materials will be selected to be used on the outer envelope of that model. A thermal camera will be used as a measuring device to test the temperature values at the outer surface of the building envelope and the temperature difference will be calculated to examine the effectiveness of such materials.

2- Setting the test model:

A heating coil (heater) shaped in a box form with dimensions (50*35*30) cm will be used (Fig 1), to form the outer skeleton of the building internal space (scale modelling 1:10). An electrical thermostat will be used to control the coil temperature. A gypsum board cover, larger than the coil by 10 cm in all directions, will be used to represent the building's outer surfaces (Fig 2). The gypsum board material has been chosen as it mostly has nearly the same physical characteristics of bricks (thermal conductivity)[1].

A wooden base will be used to fix and hold the electric heater and the electric wires (Fig 3). Wood has been chosen to make the whole experimental model electrically isolated and to facilitate the process of carrying the model from place to another in different conditions where the experiment will be carried out.

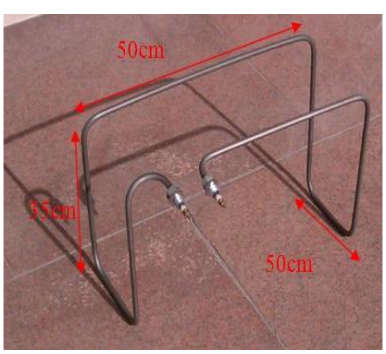

Fig (1): The heating coil shaped in box form.

Fig (2): The Gypsum boards cover.

Fig (3): The carrying wooden base.

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2.1 Temperature control:

To control the internal temperature inside the test model, an electrical thermostat will be attached to the electric circuit of the heating coil (Fig 4), to regulate the electric current passing through it and controls its temperature. This will assist in adjusting the internal space temperature of the test model. From the other side, a thermometer will be fixed (Fig 5) to measure the model's internal space temperature.

Fig (4): The electric thermostat attached to the electric circuit of the heating coil.

Fig (5): A thermometer for measuring the model's internal space temperature.

2.2 The innovative materials:

To examine an object and assign it as a temperature preservative model through its surroundings, it had to be covered by a low emissivity appropriate thermal insulation material on its outer surfaces.

In this research, two types of treatment materials will be used to examine their effect on temperature preservation. These materials will be in the form of either covering materials or paintings.

Aluminum foil, glass wool and glass wool covered by aluminum foil are chosen as covering materials, while aluminum oxide paint and aluminum powder paint (in the Nano-scale) are chosen as paintings.

These materials were chosen due to:

- Their flexibility as they can easily cover any architecture form of buildings also they can be easily fixed or applied.
- These materials are considered of very low emissivity materials which are between 0.04 to 0.09 for the Aluminum foil sheets [2], as an example, depending on its purity, shines and roughness.
- They can be used either as temporary cover or as permanent cladding surface for buildings, depending on the building construction circumstances.
- These materials can be easily fixed or applied by labors in different places by a little effort of training.
- These materials are available on public markets with convenient prices.

2.3 The measurement device:

For the process of measurements, a thermal camera Fluke Ti20 Imager (Fig 6) will be used to detect the apparent temperature from the sources in its scene and represent them as colored images with a color scale depending on the different temperature of the objects in the scene.

Fig (6): The thermal imaging camera Fluke Ti20 Imager.

The camera will be located at a distance of 170 cm; from the test model as this distance is among the optimum distance of the Field OF View (FOV) of the Fluke Ti20 Imager (20° Horizontal x 15°Vertical) [3] (Fig7) the matter that shows obviously the changes on the apparent surface temperature of the test model.

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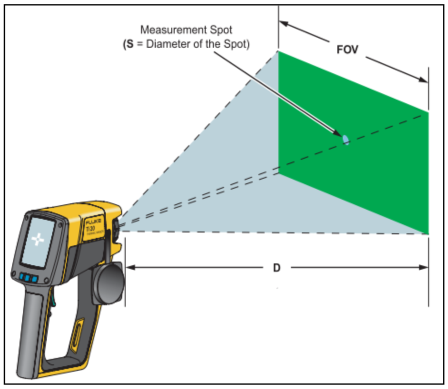


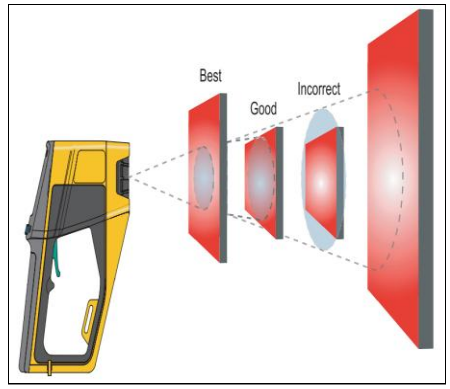


Fig (7): Relationship between FOV and measurement spots[3].

3-The experimental work:

To study and examine the effectiveness of using new innovative materials on the outer envelope surfaces of the building planned to be thermally protected; a group of comparative experiments based on some criteria will be carried out.

These experiments will compare the results coming out from a reference model temperature (see 3.1) with the results of using innovative materials as covers (envelope) on the test model.

3.1 The reference model &the reference temperature:

The reference model is the model enclosed by the gypsum board cover while the reference temperature is the apparent surface temperature of that reference model without covering it with any protective material.

3.2 The apparent temperature:

Apparent temperature is the temperature seen on the output of a detector (thermal imager) corresponding to the target temperature attenuated by atmospheric path parameters as wind speed, humidity and air temperature [4].

3.3 Internal temperature adjustments of the test model:

To adjust the internal temperature of the test model to a specific degree, a group of indoor tests were carried out. The purpose of these tests is to assign the steady internal temperature degree of the test model (which represents the real temperature inside the building) associated with the thermostat adjustments, also the time needed to reach this steady temperature.

As a conclusion of these tests, two internal temperature degrees were assigned, as shown in table (1), to carry out the experiments. These steady temperatures will be reached after one hour of operation.

Thermostat degree (ºC)	Thermometer degree (ºC) (Internal temperature)
50	40
130	60

Table (1): The assigned internal temperature degree of the test model.

4-Comparative experiments:

To run up the experiments, the outer surface of the gypsum board model (test model) will be divided into equal portions. Each portion will be covered by a different material as declared in table (2), while a portion of the gypsum board model will be left untreated(see 3.1 the reference model), to compare its values with the other materials in the same conditions (Fig 8).

Portion No.	Material used
Portion 1	Untreated gypsum board (original surface)
Portion 2	Aluminum oxide paint
Portion 3	Aluminum powder paint
Portion 4	Glass wool covered with aluminum foil
Portion 5	Glass wool only
Portion 6	Aluminum foilStuck on surface
Portion 7	Aluminum foil fixed using a skeleton frame

Table (2): The different materials used on the test model surface.

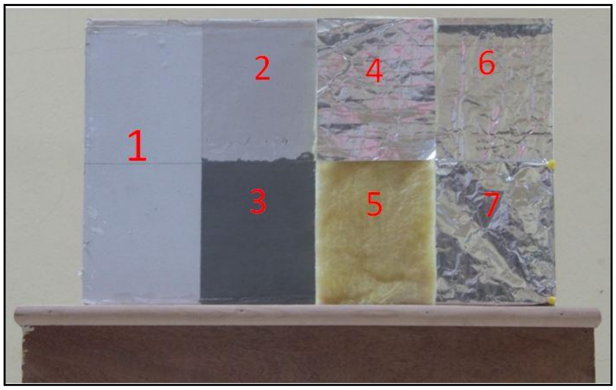


Fig (8): The gypsum board model divided equally intoequal portions ofcovered materials.

The comparative experiments will be carried out twice. The first experiment (experiment 1) is when the internal temperature of the test model reaches 40ºC, while the second experiment (experiment 2) is when the internal temperature reaches 60ºC (See 3.3: Internal temperature adjustments).

The surrounding indoor air temperature of the indoor experiments is controlled using an A/C unit to be 28ºC which is average temperature[5].

5- Indoor experiments implementation:

The experiments will be carried out by adjusting the heater thermostat to the previously specified temperatures inside the model (see 3.3 internal temperature adjustments). Thermal shoots will be taken every 15 minutes and for three consecutive hours, to detect the temperature changes for every material, (three hours were found enough to reach steady results).

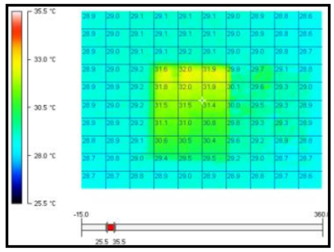
The thermal images will be analyzed using the 'Inside IR', a companion software application[3]that deduces the temperature degrees from the thermal image.

5.1 Experiment 1 (Internal temperature = 40ºC):

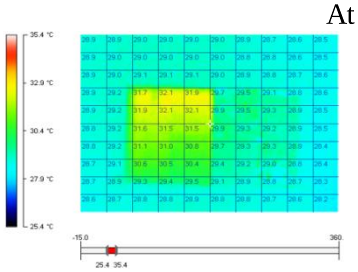
Experiment 1 will be executed using the test model with its face divided into 7 portions; each portion represents a specific material (Fig 8).

The experiment will start by adjusting the heater thermostat to 50°C, and when the internal temperature of the test model reaches 40ºC, consecutive thermal shoots using the thermal camera will started to be taken and every 15 minutes and for three consecutive hours (Fig 9 shows the three hours thermal shots).

The experiment outcome readings were recorded as shown in table 3 and a graph declaring the comparative results is deduced (graph 1).



At the beginning of the experiment (Time = 0).



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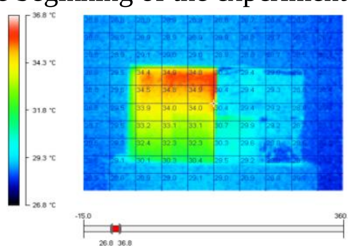

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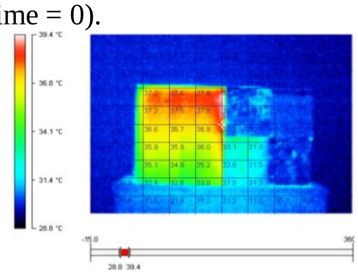

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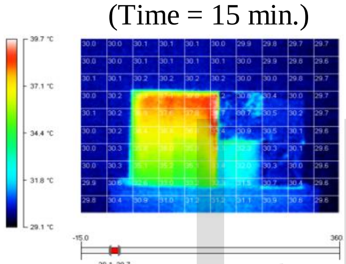

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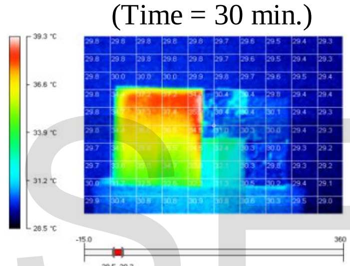

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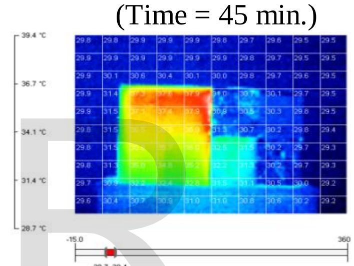

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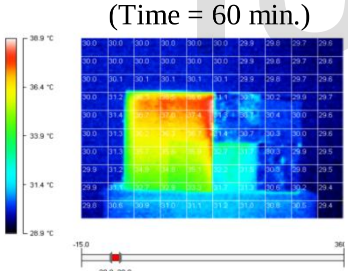

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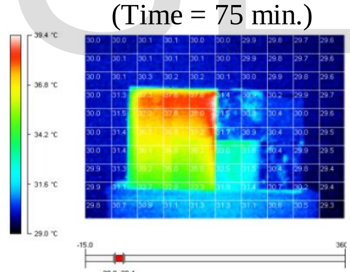

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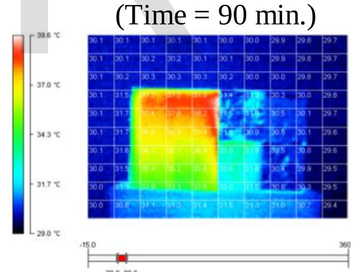

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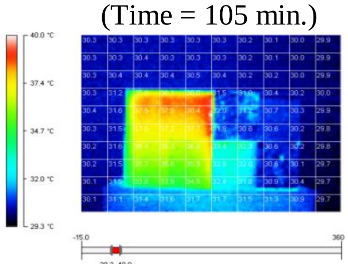

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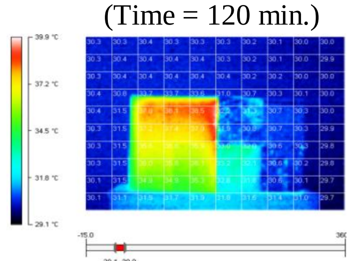

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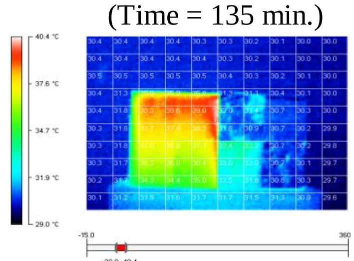
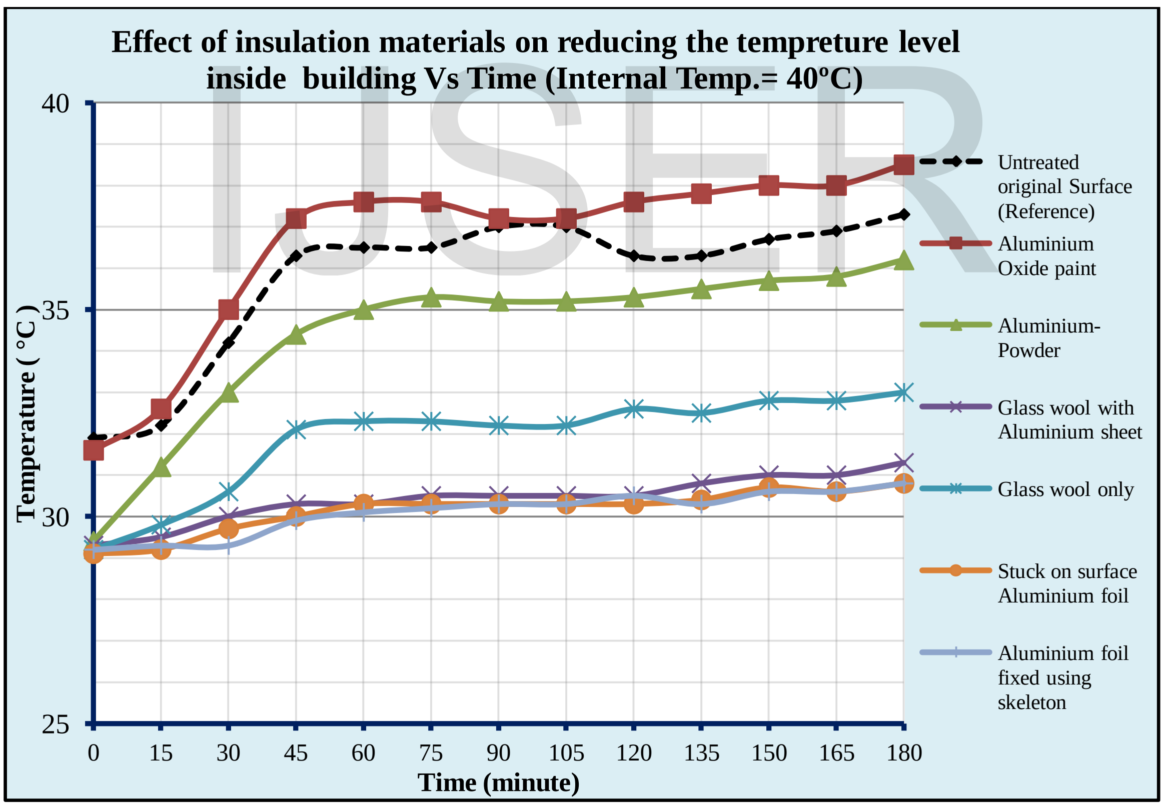


(Time = 180 min.)

Fig (9): The three hours thermal images taken every 15 minutes
for internal temperature = 40ºC.

Mat-erial / Time	Untreated original Surface	Aluminum Oxide Paint	Aluminum Powder Paint	Glass wool covered by aluminum foil	Glass wool only	Stuck on surface aluminum foil	Aluminum foil fixed using skeleton
0	31.9	31.6	29.4	29.3	29.2	29.1	29.2
15	32.2	32.6	31.2	29.5	29.8	29.2	29.3
30	34.2	35	33	30	30.6	29.7	29.3
45	36.3	37.2	34.4	30.3	32.1	30	29.9
60	36.5	37.6	35	30.3	32.3	30.3	30.1
75	36.5	37.6	35.3	30.5	32.3	30.3	30.2
90	37	37.2	35.2	30.5	32.2	30.3	30.3
105	37	37.2	35.2	30.5	32.2	30.3	30.3
120	36.3	37.6	35.3	30.5	32.6	30.3	30.5
135	36.3	37.8	35.5	30.8	32.5	30.4	30.3
150	36.7	38	35.7	31	32.8	30.7	30.6
165	36.9	38	35.8	31	32.8	30.6	30.6
180	37.3	38.5	36.2	31.3	33	30.8	30.8

Table (3): Apparent temperature readings for different types of materials for three consecutive hours (Internal temperature = 40ºC).



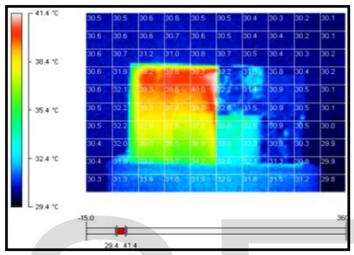
Graph (1): A graph for the apparent temperature readings for different types of insulation materials through time (Internal temperature = 40ºC).

5.2 Experiment 2 (Internal temperature = 60ºC):

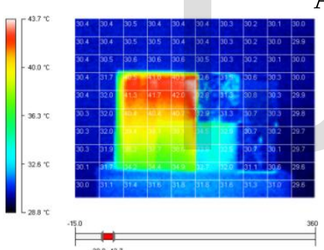
Experiment 2 will be executed using the same test model that was used in experiment 1 (Fig 8).

The experiment will start by adjusting the heater thermostat to 130ºC, and when the internal temperature of the test model reaches 60ºC, consecutive thermal shoots using the thermal camera will started to be taken every 15 minutes and for three consecutive hours (Fig 10 shows the three hours thermal shots).

The experiment outcome readings were recorded as shown in table 4 and a graph declaring the comparative results is deduced (graph 2).



At the beginning of the experiment (Time = 0).



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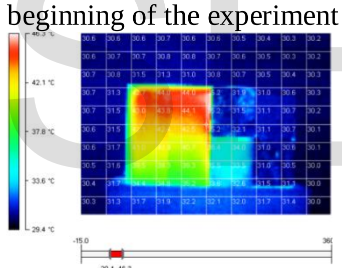

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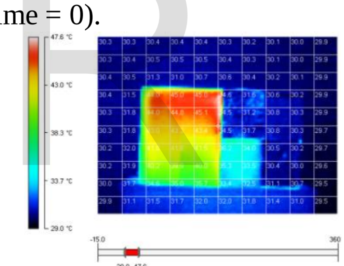

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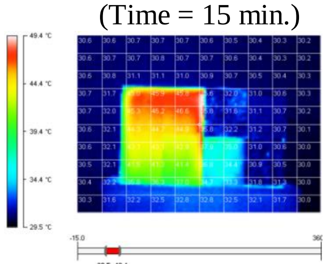

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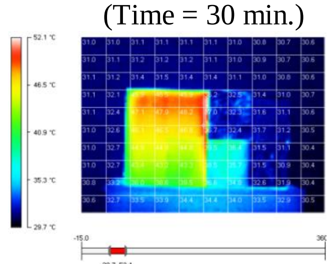

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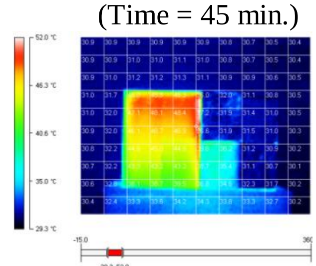

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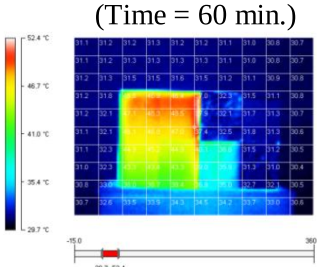

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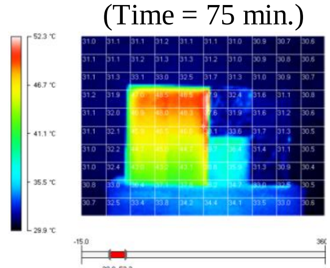

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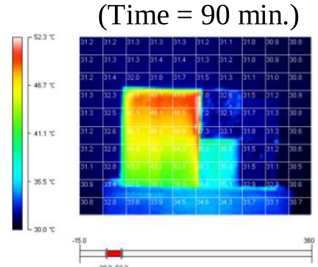

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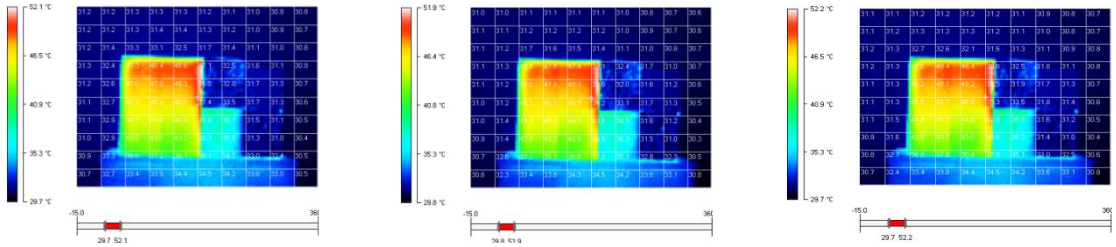
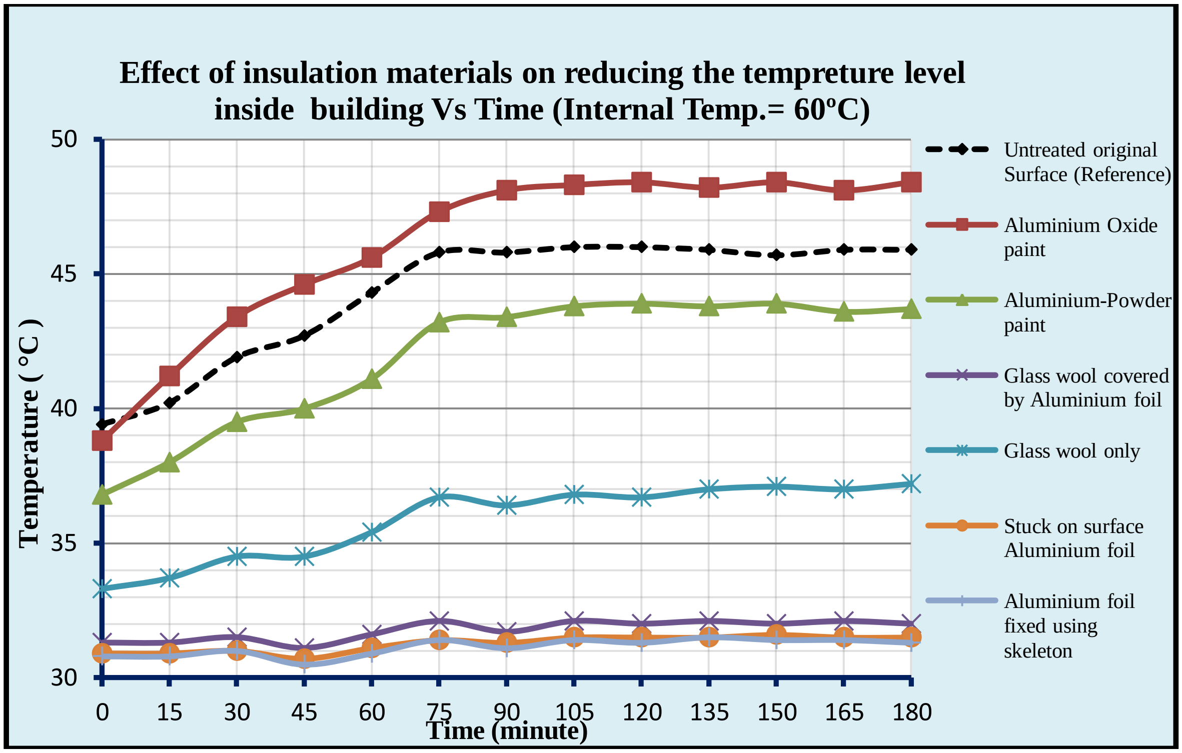


(Time = 150 min.) (Time = 165 min.) (Time = 180 min.)

Fig (10): The three hours thermal images taken every 15 minutes for internal temperature = 60ºC.

Mat-erial / Time	Untreated original Surface	Aluminum Oxide Paint	Aluminum Powder Paint	Glass wool covered by aluminum foil	Glass wool only	Stuck on surface aluminum foil	Aluminum foil fixed using skeleton
0	39.4	38..8	36.8	31.3	33.3	30.9	30.8
15	40.2	41.2	38	31.3	33.7	30.9	30.8
30	41.9	43.4	39.5	31.5	34.5	31	31
45	42.7	44.6	40	31.3	34.5	30.7	30.5
60	44.3	45.6	41.1	31.6	35.4	31.1	30.9
75	45.8	47.3	432	32.1	36.7	31.4	31.4
90	45.8	48.1	43.4	31.7	36.4	31.3	31.1
105	46	48.3	43.8	32.1	36.8	31.5	31.4
120	46	48.4	43.9	32	36.7	31.5	31.3
135	45.9	48.2	43.8	32.1	37	31.5	31.5
150	45.7	48.4	43.9	32	37.1	31.6	31.4
165	45.9	48.1	43.6	32.1	37	31.5	31.4
180	45.9	48.4	43.7	32	37.2	31.5	31.3

Table (4): Apparent temperature readings for different types of materials for three consecutive hours (Internal temperature = 60ºC).



Graph (2): A graph for the apparent temperature readings for different types of insulation materials through time (Internal temperature = 60ºC).

6-The Architecture scope for using the new technique:

The new techniques of using the insulating materials will be in the form of a cover or envelop that protect the original shelter as shown in fig.(13).

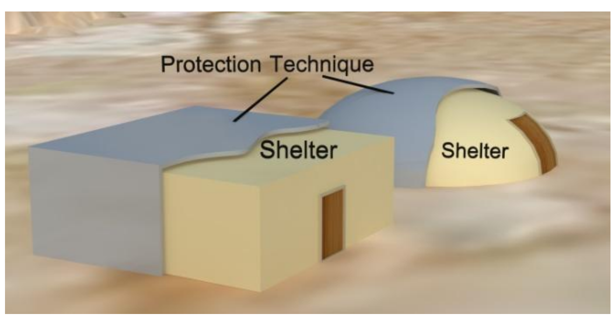


Fig (13): Illustrating the use of protection technique on shelters

7-Conclusions:

From the previous indoor experimental work that focused on evaluating the effectiveness of thermal insulating materials on the performance of thermal preservation, the following findings could be deduced:

1. All proposed materials have a significant effect on reducing the heat temperature on the gypsum board model through time, except for the Aluminum oxide paint which increases the temperature values with time.
2. Covering materials have shown better insulation effectiveness than when using the paintings.
3. The aluminum foil (either stuck on the surface or fixed using skeleton) and the covered glass wool with aluminum foil both have an excellent ability in decreasing the surface temperature of the test model.
4. Aluminum powder paint, as a new painting cover, expressed sufficient ability in decreasing the surface temperature of the test model; however it still needs more development in its mixture formation and its ingredients to achieve an acceptable thermal insulation.
5. Aluminum oxide paint has proved to be insufficient material in reducing the surface temperature of the test model.
6. The thermal image camera, Fluke Ti20 Imager (Fig 6), was found to be a convenient method for detecting & measuring the apparent temperature and evaluating the effectiveness of various insulating materials.
7. Table (5) declares the average percentage of temperature reduction at the model external surface for each material related to the model internal temperature (in case of 40°C& ambient temperature 28°C).

   N.B:

The ambient temperature 28°C is the minimum (optimum) temperature that could be achieved while the maximum temperature (worst) is 40°C. i.e.: the average percentage of temperature reduction is calculated considering the temperature difference = 12°C.

No.	Enveloping material	Material surface temperature (°C)	Amount of heat reduction Vs. internal temperature(°C)	Average Percentage of temperature reduction
1	Untreated original Surface	35.7	4.3	35.8 %
2	Aluminum oxide paint	36.6	3.4	28.3 %
3	Aluminum powder paint	34.4	5.6	46.6 %
4	Glass wool covered with aluminum foil	30.4	9.6	80.0%
5	Glass wool only	31.8	8.2	68.3 %
6	Stuck Aluminum foil	30.1	9.9	82.5%
7	Aluminum foil fixed using skeleton	30.1	9.9	82.5%

Table (5): The average percentage of temperature reduction (Internal temperature = 40ºC).

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8. Table (6) declares the average percentage of temperature reduction at the model external surface for each material related to the model internal temperature (in case of 60°C & ambient temperature 28°C).

N.B:

The ambient temperature 28°C is the minimum (optimum) temperature that could be achieved while the maximum temperature (worst) is 60°C. i.e.: the average percentage of temperature reduction is calculated considering the temperature difference = 32°C.

No.	Enveloping material	Material surface temperature (°C)	Amount of heat reduction Vs. internal temperature(°C)	Average Percentage of temperature reduction
1	Untreated original Surface	44.2	15.8	49.3 %
2	Aluminum oxide paint	46	14	43.7 %
3	Aluminum powder paint	41.9	18.1	56.5%
4	Glass wool covered with aluminum foil	31.7	28.3	88.4%
5	Glass wool only	35.8	24.2	75.6 %
6	Stuck Aluminum foil	31.2	28.8	90.0%
7	Aluminum foil fixed using skeleton	31.1	28.9	90.3%

Table (6): The average percentage of temperature reduction (Internal temperature = 60ºC).

8-Refrences:

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