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AN EXPERIMENTAL INVESTIGATION ON REDUCING HEAT FLOW OF PROFILED STEEL SHEET USING HEAT INSULATING MATERIALS IN ROOF

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ABSTRACT

Climate change is an important issue now- a-days. Climate around us is changing day by day. The causes of climate change are numerous. Increase of heat generation of the roof surface has become a discomfortable aspect for indoors habitants. Due to this, rising of temperature causes thermal discomfort and increase energy consumption. An experimental investigation was conducted to determine the temperature effects of the profiled steel sheet with various composite materials such as fiber wood, cork sheet, gypsum board, felt with and without providing vacuum. The objective of this study was to find out the effects of temperature difference for different conditions and using different insulating materials. The main focuses of this study is to reduce the heat flow in profiled steel sheet and improves thermal comfort in roof-top floor. A series of test were conducted to know the heat reducing in roof top floor by profiled steel sheet with heat insulation materials. In this paper, the properties of heat insulating materials that are conjugated with profiled steel sheet are investigated. It was found that heat was reduced by the profiled steel sheet was lower heat energy but heat insulating materials i.e. gypsum board, glass wool, ply wood etc. with the profiled steel sheet can restrict the heat flow significantly passing from the exposed to unexposed side and keeps the temperature lower at indoor side of the room. For instance, near about 29% of temperature was reduced by profiled steel sheet after investigated for 20 minutes. Whereas above 90% of temperature was reduced for the same duration by conjugating gypsum board with profiled steel sheet. The results indicated that the use of heat insulation materials is very efficient for heat flow reducing. The profiles steel sheet with insulating material in roofing system has a great potential to be exploited for the construction of housing.

Keywords: *Reducing heat flow, Profiled steel sheet, Heat Insulating Materials, Roof system*

1. INTRODUCTION

Shelter, the second basic need of man, has been a preoccupation for many governments all over the world trying to house their growing population. The roof protects the building and its occupants from the effects of weather, but it also is an architectural feature that gives the building a desired appearance. Roof accounts to a substantial part (about 25%) of the total cost of a building whether it is residential or industrial by Jagannath and Sekar (1989).Therefore, it demands high technical and design specifications for both of the individual products, elements and for the roof as a whole in order to achieve a satisfactory design life. Profiled steel sheet are increasingly used in structural applications in recent years due to their lightness, corrosion resistance, high strength-to-weight ratio, ease of production, recyclable and availability.Tests on structural strength and behavior of self-supporting cylindrical profiled steel sheet proof roofing elements have been recently performed by Zahurul-Islam et al (2006). Test results showed that the parabolic corrugated roofing element provided significant improvements to the roof's structural performance.

Climate change is an important issue now- a-days. The causes of climate change are numerous. Recently however, concern has grown that mankind's pollution of the atmosphere may be causing global-scale changes in climate, with accompanying shifts in regional climate regimes all over the world. Global readings are running warmer. As a result, many countries, not only in Asia but also in some parts of Southern Europe, South America as well as US has experienced problems with power outages during pick hours due to rising demand for electricity. Bangladesh has a subtropical monsoon climate characterized by wide seasonal variations in rainfall, high temperatures and humidity. In Bangladesh the highest temperature in 1995 was recorded as 43 degrees in Rajshahi by Asian Tribune. Qin et. al. (IPCC, 2013) discussed about the global surface temperature. There has been further strengthening of the evidence for human influence on temperature extremes. It is now very likely that human influence has contributed to observe global scale changes in the frequency and intensity of daily temperature extremes since the mid 20th century. Akbari (2005) studied about roof temperature in hot season. Study shows that the roof and present temperature may increase 50-90°F (27-50°C) hotter than the air temperature-often in rural surrounding remain close to air temperature in hot season. Bush et. al. (2008) studied about the properties of metal roofing and cool metal roofing for reducing heat flow. Metal roofing is available in a wide variety of substrates, colors, textures and profiles. Domingueza et. al. (2011) considered indirect benefits of rooftop photovoltaic (PV) systems for building insulation are quantified through measurements and modeling. Wang and Tan (2006) proposed an analytical approach, as a reduced form of the more general multi-flux and discrete ordinate method for radiative transfer.

Common roofing system in Bangladesh is flat concrete roof. When sunlight incidents on top of roof, some portion of heat energy are reflected, some portion is absorbed. The last process is the conduction of heat which is transferred through solid object. In hot weather, tends to deteriorate the quality of concrete. Concrete is an evaluative material in time, which depends strongly on its surrounding environment. The room temperature of concrete roof top level becomes high than the other level of building and day by day it becomes difficult for housing. The reduction of effect of thermal conduction is much important. Profile steel sheet can be considered as an alternately solution for such problem. Profile steel sheet having ultra-weather resin can be considered as the best and most durable roofing elements for affordable quality housing in the world. Little research is being reported on study structural strength & reducing heat flow of profiled steel sheet using heat insulating materials. There is need to investigate the structural strength and behaviour of profile. Profile sheet is stronger because of its rib and section modulus. Therefore, it is novel to study structural strength & reducing heat flow of profiled steel sheet using heat insulating materials.

An experimental program was conducted to investigate the thermal behavior of profiled steel sheet by changing different materials. A series of test were conducted to know the heat reducing in roof top floor by profiled steel sheet with heat insulation materials. The objective of this study was to find out the effects of temperature difference for different conditions and using different insulating materials. The main focuses of this study is to reduce the heat flow in profiled steel sheet and improves thermal comfort in roof-top floor. This investigation was divided into five groups. It was found that 90% of temperature was reduced by conjugating gypsum board with profiled steel sheet. The results indicated that the use of heat insulation materials is very efficient for heat flow reducing. The profiles steel sheet with insulating material in roofing system has a great potential to be exploited for the construction of housing.

2. MATERIAL PROPERTIES

2.1 Profile Steel Sheet

Profile steel sheets are being used on an increasing scale for roofing. Profile steel sheet element is suitable for roofing because of its efficiency as load carrying member with a high degree of reserved strength and structural integrity, high strength to weight ratio, very small thickness ratio to other dimension, very high stiffness and containment of space. The main advantages of using of profile steel sheet as a roofing material are speedy installation, no shuttering required, less installation errors, lower dead load on the walls, light weight and easy handling, high strength to weight ratio, corrosion-resistant, economical considering mean service life. Profiled steel sheet is extremely durable against corrosion because of the usage of seven layers of coating as shown in Fig. 1(b). Profile steel sheet and composition layer of profiled steel sheet is shown in Fig. 1. Moreover, profiled steel sheet can be used in relief center after disaster for short-term construction.

The material properties of the profiled steel sheet were determined by tensile coupon tests. The tensile coupons were prepared and tested according to the American Society for Testing and Materials Standard, ASTM (1997) and the Australian Standard AS 1391 (1991) for the tensile testing of metals using 12.5 mm wide coupons. The coupons were tested in a Universal Testing Machine and the load is applied gradually. Deformation is measured by using deformation gauge. The test set-up and tested specimen after tensile test is shown in Fig. 2(a) and 2(b) respectively. Measured material properties obtained from tensile coupon tests are given in Table 1.

(a) Profiled steel sheet (b) Composition layer of profiled steel sheet

Figure1: Profile steel sheet and its composition

(a) Coupon test (b) Failure mode

Figure 2: Tensile coupon test and failure mode of profiled steel sheet

Table 1. Measured material properties obtained from tensile coupon tests

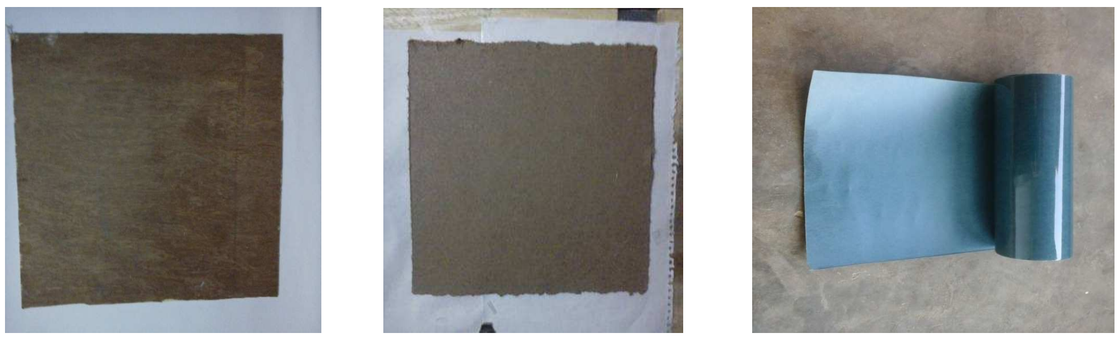
Specimen No.	**Width bc (mm)**	**Thickness tc (mm)**	**Yield Stress σy (N/mm2)**	**Ultimate Stress σu (N/mm2)**
1.	12.7	0.66	232.7	251.6
2.	12.6	0.65	238.6	261.5
3	12.7	0.66	244.8	268.2

2.2 Plywood

Plywood consists of numbers of thin sheets of wood (veneers) which are pressed and bonded together with some binding or cementing material like glue or synthetic adhesives. Plywood is also light in weight in comparison to those of cement-bonded boards, which is also very convenient for transporting and handling as shown in Fig 3(a). Heat insulating material hard board is shown in Fig 3(b). Plywood has a cross-laminated structure and is durable through drastic temperature and moisture changes, making it ideal for flooring and framework in locations where exposure to moisture is likely. Because of plywood's laminated structure, it distributes weight over a large area on its opposite side. This means that plywood can accommodate up to twice its designated load for short periods of time, making It ideal for use in locations where seismic activity or strong winds occur. There are four types of plywood, and each one is designed for a different application. Structural plywood is used in permanent structures like form work, flooring, bracing and manufactured beams. Internal plywood is used in interior structures that are aesthetically appealing and do not need to bear weight, such as wall paneling, furniture, ceiling linings and interior door skins. External plywood is used in external applications that are not subject to loads, such as exterior door skins, signs and cladding. Marine plywood is meant for use in marine applications, such as the hulls of boats and yachts. It minimizes potential water damage.

2.3 Heat Insulating Fibres

Felt is foremost a pliable material. It is relatively elastic, so to some degree small dimensional errors can be compensated for. Highly reliable woolen felt conforming to the JIS L3201 standard is also available. It has a remarkable ability to maintain its shape, and if deformed it can be easily returned to its original shape. It breathes well, holds water, dyes readily, and has good fluid permeability. Second, it is flexible. Felt can be thick, thin, pliable, or rigid. It has excellent dyeing properties, and can be dyed any color. In addition, because felt has heat insulating properties, heat retaining properties, is shock absorbent, and can shut out sound , it has uses in many fields as shown in Fig 3(c).



(a) Plywood (b) Hard Board (c) Heat insulating fiber

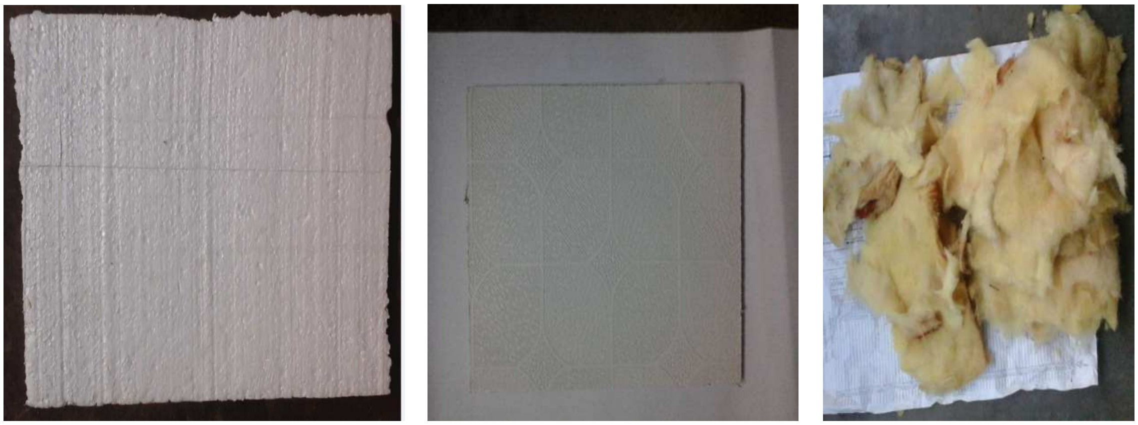
Figure 3: Plywood, Hard Board and Heat Insulation Fiber

2.4 Cork Sheet

Cork sheets are one of the most widely used agglomerated cork product. Cork is an impermeable and buoyant material as shown in Fig. 4 (a). Cork's bubble-form structure and natural fire retardant make it suitable for acoustic and thermal insulation in house walls, floors, ceilings and facades. The by-product of more lucrative stopper production, corkboard is gaining popularity as a non-allergenic, easy-to-handle and safe alternative to petrochemical-based insulation products which are flammable and emit highly toxic fumes when burned. Granules of cork can also be mixed into concrete. The composites made by mixing cork granules and cement have lower thermal conductivity, lower density and good energy absorption. Some of the property ranges of the composites are density (400–1500 kg/m^3), compressive strength (1–26 MPa) and flexural strength (0.5–4.0 MPa). Fig 4(b) shows the photograph of gypsum board.

2.5 Glass Wool

Glass wool is an insulating material made from fibers of glass arranged using a binder into a texture similar to wool as shown in Fig 4(c). The process traps many small pockets of air between the glass, and these small air pockets result in the thermal insulation properties. Glass wool is produced in rolls or in slabs, with different thermal and mechanical properties. It may also be produced as a material that can be sprayed or applied in place, on the surface to be insulated. Glass wool is a thermal insulation that consists of intertwined and flexible glass fibers, which causes it to "package" air, resulting in a low density that can be varied through compression and binder content (as noted above, these air cells are the actual insulator). Glass wool can be a loose fill material, blown into attics, or, together with an active binder sprayed on the underside of structures, sheets and panels that can be used to insulate flat surfaces such as cavity wall insulation, ceiling tiles, curtain walls as well as ducting. It is also used to insulate piping and for soundproofing.



(a) Cork Sheet (b) Gypsum board (c) Glass Wool

Figure 4: Cork sheet, gypsum board and glass wool

3. TEST PROGRAM

3.1 Test Specimen

For the investigation the heat flow of profiled steel sheet, this experimental program was set up. In this program, corrugated profiled steel sheet was selected as prime specimen. Then various heat insulating materials were conjugated individually and thus specimens were obtained. For obtaining the desired result, ten samples were prepared. The samples were divided according to the materials used. The samples were divided into five groups. The five groups were named as A, B, C, D and E respectively. In group B and C, three samples were used, whereas two samples were used in group E. Group A and D have one sample each. For avoiding the inconvenience of the placement of specimens in the experimental box, the length and height of the samples were restricted to 10.5"X7.5". The following table shows the specimens used in the experimental program. Table 3.1 shows the sample number and type which is used in this experimental program.

Table 2: Different specimens for experimental program

Sample group	No. of sample	Sample Type
A	01	Corrugated profiled steel sheet
B	02	Profiled steel sheet conjugated with gypsum board
	03	Profiled steel sheet conjugated with gypsum board(providing 1" vacuum)
	04	Profiled steel sheet conjugated with gypsum board and cork sheet
C	05	Profiled steel sheet conjugated with plywood
	06	Profiled steel sheet conjugated with plywood (providing 1" vacuum)
	07	Profiled steel sheet conjugated with plywood and cork sheet
D	08	Profiled steel sheet conjugated with heat insulator paper and glass wool (.5" thickness)
	09	Profiled steel sheet conjugated with aluminum foil paper and glass wool (1" thickness)
E	10	Profiled steel sheet conjugated with hard board
	11	Profiled steel sheet conjugated with hard board and cork sheet

3.2 Preparation for Heat Resisting Experimental Box

For the preparation of sample the welding shop of the Rajshahi University of Engineering & Technology was used. A snipping tool was used to cut the profiled steel sheet to get required dimension. And the bolts were used to join the profiled steel sheet with different heat insulating materials which is act as a heat reducer. The following figures show the various types of heat insulating materials used for samles: In order to determine the effect of temperature on concrete specimens some devices were needed first. The list included Stopwatch, Electric bulb, Microcontroller device and , Heat resistant experimental box.A wooden box was prepared for this experiment. Its outer dimension was 16.5in.X 12in.X 10in. with a thickness of 0.6 in. Two electric bulbs were setup by holder in a way that could remain horizontal in front of the specimen. Two holes were done at one side of the box at approximate 4in. distance for easy entrance of the temperature sensor. The inner sides of the box were covered by aluminum foil paper to resist the inner temperature to pass outside of the box. This investigation was divided into five groups. First group was only corrugated steel sheet. 2nd and third Group were observed conjugated with Gypsum board and Plywood with tree samples respectively. In fourth group only glass wool was conjugated. Finaly fifth group was conjugated with hard board in two different samples. The entire samples have two points to measure the temperature such as exposed side and unexposed side. The heat energy was supplied in one direction. The experimental box was made of wood and rapping with aluminum foil paper and temperature was observed with the help of microcontroller device. Bulbs were used as the energy source. The entire specimens were tested and data was recorded.

Figure 5: Inside of heat resisting experimental box

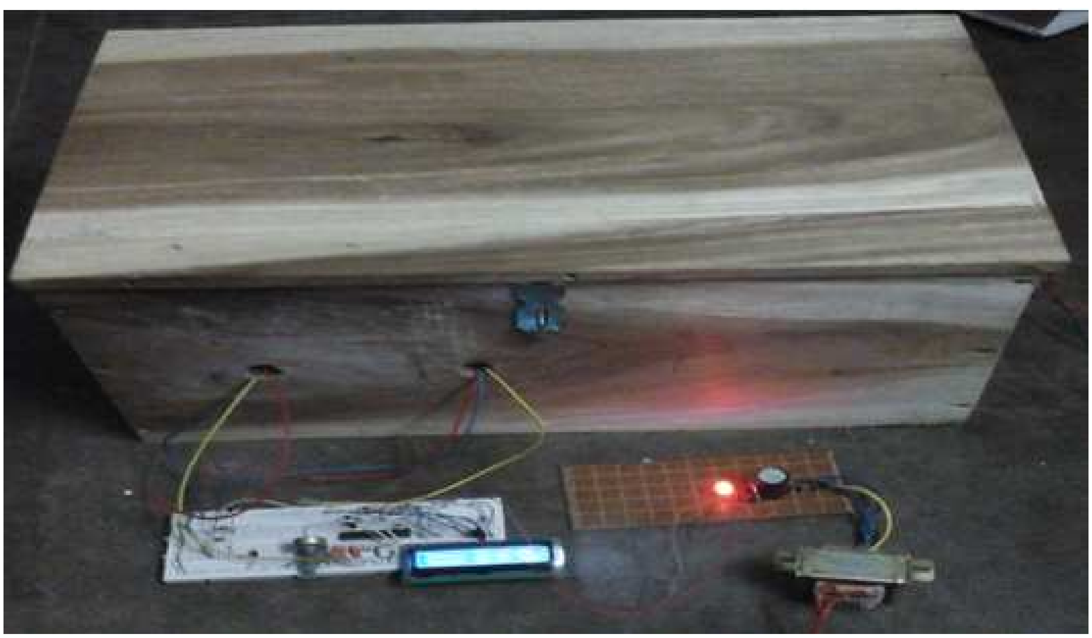


Figure 6: Outside of heat resisting experimental box

3.3 Setting of the Specimen and Data Collections

The specimen was placed in the box carefully as shown in Figure 7. Then the two sensors were adjusted at the exposed and unexposed side of the specimen. The specimens were fitted in the box in such a way no air can pass from the exposed to unexposed side. After placing the specimen the cover of the box was closed and any possible way of air leakage was checked before start of the experiment procedure. Two temperature sensor (LM35) was placed near the exposed and unexposed sides of the specimen respectively through the side holes made at the side of the box. Then the stopwatch was set ready to count the time and after that two bulbs were power powered on. The temperature was taken up to 20 minutes from the LCD output. After taking the reading the box was cooled and rested for the time to be in room temperature again. The specimens were fitted in the box in such a way no air can pass from the exposed to unexposed side. After placing the specimen the cover of the box was closed and any possible way of air leakage was checked before start of the experiment procedure. Two temperature sensor (LM35) was placed near the exposed and unexposed sides of the specimen respectively through the side holes made at the side of the box. Then the stopwatch was set ready to count the time and after that two bulbs were power powered on. The temperature was taken up to 20 minutes from the LCD output. After taking the reading the box was cooled and rested for the time to be in room temperature again.

Figure 7: Setup of the specimen in the heat resisting experimental box

4. TEST RESULTS AND DISCUSSIONS

This investigation was divided into five groups. First group was only corrugated steel sheet. 2nd and third Group were observed conjugated with Gypsum board and Plywood with tree samples respectively. In fourth group only glass wool was conjugated. Finaly fifth group was conjugated with hard board in two different samples. The entire samples have two points to measure the temperature such as exposed side and unexposed side.

4.1 Test results for Group A

The results are presented in terms of temperature-time relationship and net temperature difference. The temperature-time of profile steel sheet is ahown in Figuer 8. A change of temperature was found at the exposed side of the specimen after 20 minutes comparing with the unexposed side of the corresponding specimen. Two bulbs of total 160W generate 115.34ºC. After 20 minutes the rise of temperatures of exposed and unexposed sides of profiled steel sheet were 94.14ºC and 66.77ºC respectively; which shows that about 70.93% temperature passes through the exposed to unexposed side of the profiled steel sheet.

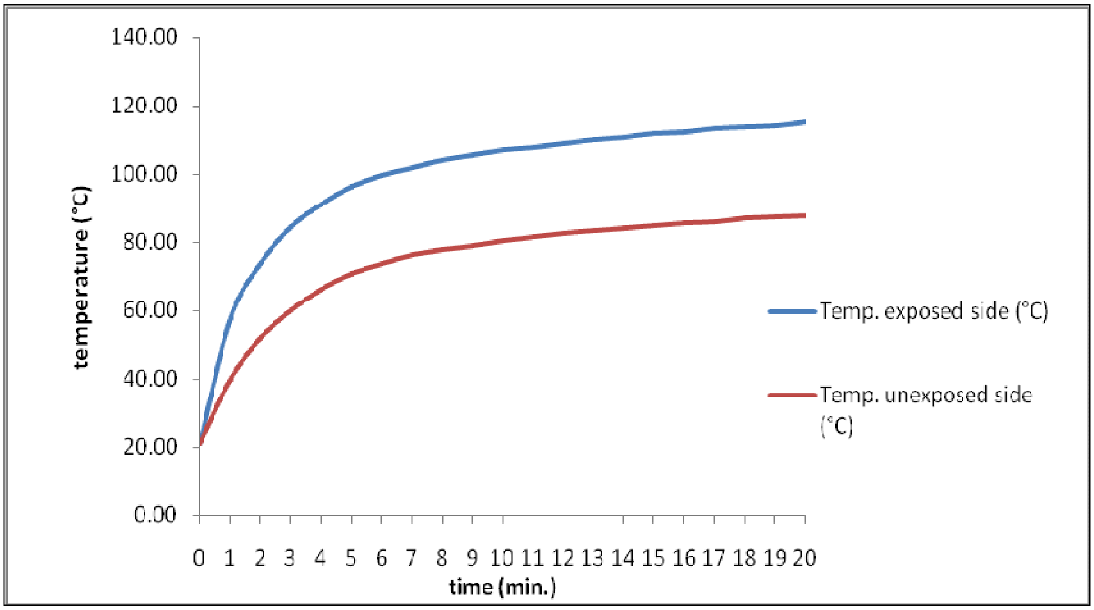


Figure 8: Temperature-time relationship on corrugated profiled steel sheet (sample 01)

4.2 Test Results for Group B

Temperature-time relationships were plotted for profiled steel sheet conjugated with gypsum board in three different formations. The corresponding three graphs were prepared from the tested data.as shown in Figure 9. A change of temperature was noticed at the exposed side of the specimen after 20 minutes comparing with the unexposed side of the corresponding specimen. Two bulbs of total 160W generate 122.18ºC for sample 2, 125.07ºC for sample 3 and 126.06ºC for sample 4. After 20 minutes the rise of temperatures of exposed and unexposed sides of sample 2 were 99.85ºC and 24.10ºC, 102.66ºC and 10.84ºC for sample 3 and 102.75ºC and 8.45ºC respectively. Where, P = Profiled Steel Sheet, V= Vacuum, C= Cork Sheet, Gb= Gypsum Board, Pw = Plywood, Gw = Glass Wool, Hb = Hard Board.

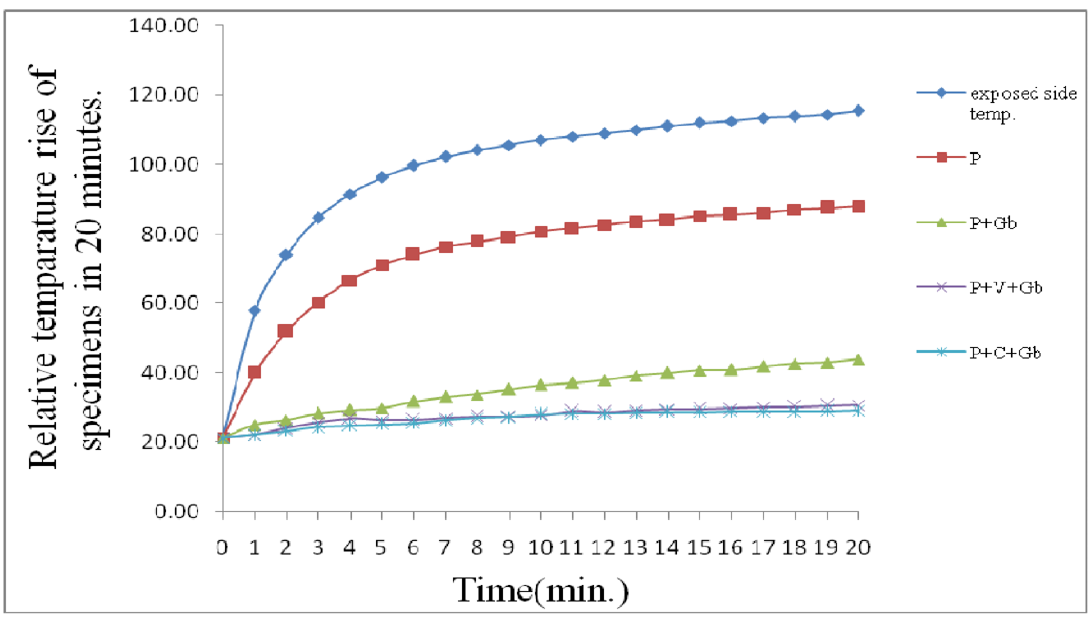


Figure 9: Relative rise of temperature in 20 minutes for specimens of gypsum board (Group B)

4.3 Test Results For Group C

Based on expertational results, temperature-time relationships were plotted for profiled steel sheet conjugated with plywood in three different formations. The corresponding three graphs were prepared from the tested data as shown in Figure 10. A change of temperature was noticed at the exposed side of the specimen after 20 minutes comparing with the unexposed side of the corresponding specimen which was shown in Bar Chart. Two bulbs of total 160W generate 124.14ºC for sample 5, 127.95ºC for sample 6 and 127.33ºC for sample 7. After 20 minutes the rise of temperatures of exposed and unexposed sides of sample 5 were 101.04ºC and 31.15ºC, 104.85ºC and 23.82ºC for sample 6 and 103.44ºC and 10.32ºC for sample 7 respectively

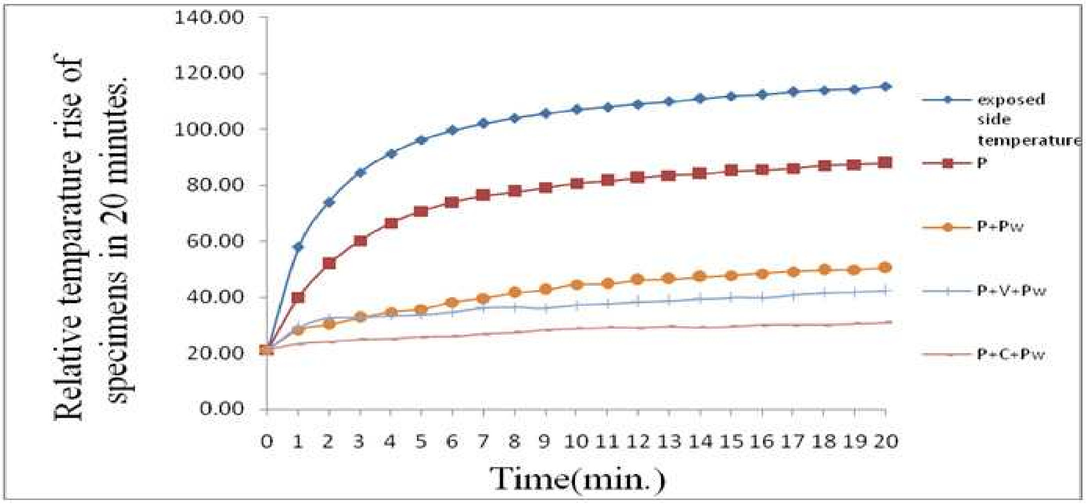


Figure 10: Relative rise of temperature in 20 minutes for specimens of plywood (Group C)

4.4 Test Results For Group D And E

Temperature-time relationships were plotted for profiled steel sheet conjugated with 0.5” glass wool formations. The corresponding graphs were prepared from the tested data as shown in Figure 11. A change of temperature was noticed at the exposed side of the specimen after 20 minutes comparing with the unexposed side of the corresponding specimen. Two bulbs of total 160W generate 132.45ºC for sample 8. After 20 minutes the rise of temperatures of exposed and unexposed sides of sample 8 were 80.65ºC and 16.12ºC respectively. Two bulbs of total 160W generate 116.32ºC and 137.82ºC for sample 9 and sample 10 respectively. After 20 minutes the rise of temperatures of exposed and unexposed sides of sample 9 were 93.35ºC and 34.21ºC and for sample 10 were 111.92ºC and 17.50ºC respectively.

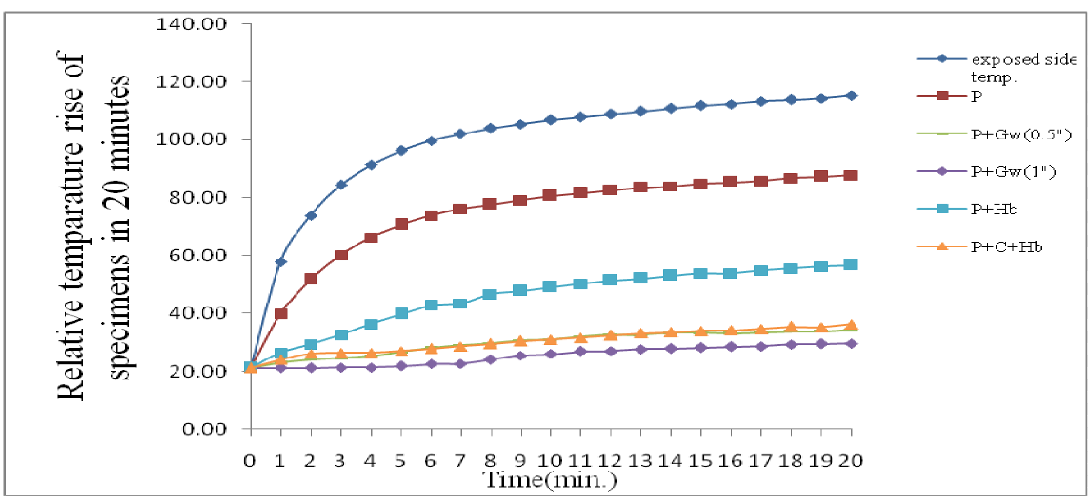


Figure 11: Relative rise of temperature in 20 minutes for specimens of glass wool and hard board (Group D & Group E)

Relative rise of temperature in 20 minutes for all specimens is shown in Figure 12. Table 2 shows the percentage of reducing heat flow into different sample. Baased on reading after 20 minutes, it is observed that the maximum temperature can be reduced by sample 04 (Profiled steel sheet conjugated with gypsum board and cork sheet). Percentage of temperature reduction is shown in Bar chart Figure 13. From the graph, the maximum temperature is reduced by gypsum board. It is observed that above 90% temperature is reduced in 20 minutes by gypsum board and cork sheet (sample 4). It is noticed that only glass wool of around 1 inch. thickness reduced 86.63% temperature in 20 minutes.

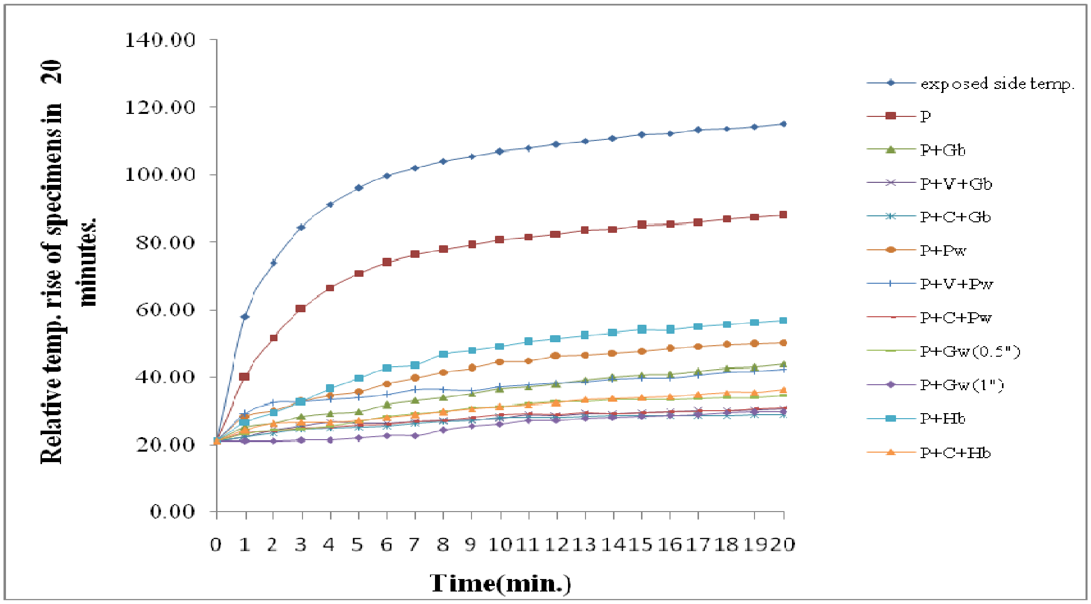


Figure 12: Relative rise of temperature in 20 minutes for all specimens

Table 2: Percentage of reduction of heat flow.

Sample no.	Sample type	Temp. reduction (%)
1	Corrugated profiled steel sheet	29.07
2	Profiled steel sheet conjugated with gypsum board .	75.8
3	Profiled steel sheet conjugated with gypsum board(providing 1” vacuum)	89.44
4	Profiled steel sheet conjugated with gypsum board and cork sheet	91.78
5	Profiled steel sheet conjugated with plywood	69.17
6	Profiled steel sheet conjugated with plywood (providing 1” vacuum)	77.28
7	Profiled steel sheet conjugated with plywood and cork sheet	90.02
8	Profiled steel sheet conjugated with heat insulator paper and glass wool (.5” thickness)	84.08
9	Profiled steel sheet conjugated with heat insulator paper and glass wool (1” thickness)	86.63
10	Profiled steel sheet conjugated with hard board	63.35
11	Profiled steel sheet conjugated with hard board and cork sheet	84.3

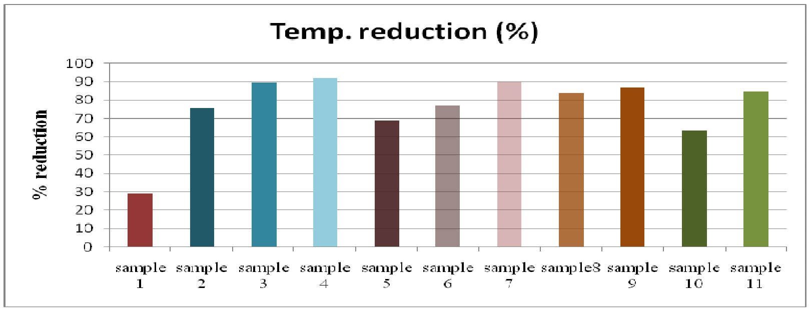


Figure 13: Bar chart showing the percentage of reduction of different samples

5. CONCLUSIONS

An experimental program was conducted to investigate the effects of temperature difference for different conditions and using different insulating materials. A series of test were conducted to know the heat reducing in roof top floor by profiled steel sheet with heat insulation materials. This investigation was divided into five groups. Based on the experimental invetgation, It was found that heat was reduced by the profiled steel sheet was lower heat energy but heat insulating materials i.e. gypsum board, glass wool, ply wood etc. with the profiled steel sheet can restrict the heat flow significantly passing from the exposed to unexposed side and keeps the temperature lower at indoor side of the room. For instance, near about 29% of temperature was reduced by profiled steel sheet after investigated for 20 minutes. Whereas above 90% of temperature was reduced for the same duration by conjugating gypsum board with profiled steel sheet. It was found that gypsum board and cork sheet; plywood and cork sheet; heat insulator paper and glass wool can reduced heat flow 91.78%, 90.02%,and 86.63% respectively. The results indicated that the use of heat insulation materials is very efficient for heat flow reducing. The profiles steel sheet with insulating material in roofing system has a great potential to be exploited for the construction of housing.

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