EFFECTS OF ROOF INSULATION ON INDOOR THERMAL ENVIRONMENT

FINAL REPORT

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1. Introduction

This final report enumerates the research design and presents the results and analysis of the research project carried out under a Senate Research Committee Grant No. 98/01/12.

One of the main contributors to thermal discomfort in tropical buildings is the high incidence of radiant temperature. The primary reason for the increased radiant temperature is the heat gain through the roof composite. If the heat gain through the roof composite could be minimized radiant temperatures inside buildings can be maintained at or around the comfort levels. Together with adequate air movement, such a radiation reduction strategy will enhance the comfort levels of tropical buildings.

Insulation plays an important role in controlling heat gain through the roof composite. Since the intensity of solar radiation and solar altitudes are high in the tropics, buildings in this region must concentrate more on ***minimizing heat gain from roof*** than any other component of the building envelope.

2. Objectives

The present study aimed at ascertaining the degree of thermal insulation of conventional and new roofing materials with / without popular roof insulation systems. The purpose of the exercise was to quantify the reduction in radiant temperature resulting from the use of roof insulation and to rank them according to empirical data. This data will be useful for the estimation of thermal comfort effects of various roof insulation materials which will be studied subsequently.

3. Theory

The solar intensity is defined as the rate at which the Sun's energy is received per unit area of a surface in the absence of the atmosphere by a perfectly absorbing surface at the mean distance of the earth from the sun and so placed that the radiation falls normally on it.

If dQ is the quantity of heat received in time dt by a surface having an area of A, then the solar intensity I, is given by:

$$I = \frac{\frac{dq}{dt}}{A} \quad \dots\dots\dots\dots\dots\dots\dots\dots\dots\dots (1)$$

The heat that falls on a block of material will cause its temperature to rise. Ignoring the heat loss to the surrounding, if m is the mass of the block and C its specific heat, the rise in temperature $^{d\theta}/_{dt}$ and the intensity of heat are related thus:

$$\frac{dq}{dt} = mC \times \frac{d\theta}{dt} \quad \dots\dots\dots\dots\dots\dots\dots\dots\dots\dots (2)$$

Combining (1) and (2), the following can be derived:

$$I = \frac{mC}{A} \times \frac{d\theta}{dt} \quad \dots\dots\dots\dots\dots\dots\dots\dots\dots\dots (3)$$

Thus, radiation intensity received by two identical surfaces are proportional to the rate of increase in their respective temperatures.

3. Method

Two slotted angle iron structures were constructed to support the heat sink/data logger assembly. *Figure 1* shows a cross section of the support assembly. The heat sink comprised an aluminum block (*150x150x25mm thick*) painted matt black and insulated on all but one side with *20mm* thick white polystyrene insulation. The only exposed side sported the matt black painted surface. A hole was drilled on the side to hold the thermometer. *Figure 2* shows an isometric view of the heat sink assembly.

One slotted angle iron structure supported the heat sink together with a roofing material placed on the exposed side of the heat sink. The other assembly was covered with the same roof cladding plus an insulation material placed between the heat sink and the roof cladding. *Table 1* gives details of the roof cladding and insulation materials tested.

Table 1 - Characteristics of the roof cladding and insulation materials tested

Material	*Trade Name*	*Size*	*Nominal Thickness*	*Thermal Conductivity*
Roof cladding				
Clay tile	Calicut	250 x 375	20	
Corrugated asbestos cement sheet	Rhino	300 x 600	06	
Colored zinc-aluminum sheet	Metroof	450 x 450	16 gauge	
Insulation materials				
Reinforced double-sided aluminum foil	Sisilation	225 x 225	24 gauge	
Polyehelene sheet insulation	Thermasheet FR	200 x 225	06	0.038
- - do - - with aluminum foil	Thermasheet Alu Stucco	200 x 225	06	
Glasswool fiber batt w/ aluminum foil	Ductwrap 16	200 x 300	50	0.037

Note: Size and Thickness, unless otherwise indicated, are in millimeters; Thermal conductivity is in W/mK.

Surface temperature readings from the pair of heat sinks were taken at 5 minute interval for an hour. The percentage of radiation transmitted through the insulator was calculated as following:

$$\frac{Temperature\ change\ in\ heat\ sink\ with\ insulator}{Temperature\ change\ in\ heat\ sink\ without\ insulator} \times 100 \quad \ldots\ldots (4)$$

Since solar radiation intensity varies with time of day, cloud cover, atmospheric purity and humidity levels and is influenced by changes in wind pattern, it was decided to use an artificial heat source instead of exposing the heat sink/roof system assembly to the sun. An electric-powered 500 W Tungsten lamp with a parabolic aluminum reflector was used as a heat source. A voltage stabilizer ensured the stability of the electricity supply.

Surface temperature measurements were taken by a digital thermometer. The thermometer was statically and dynamically calibrated. Static calibration used crushed ice to test whether the readings were significantly different from 0°C. The results show that the probe measured freezing temperature well (there was no difference between 0°C and the digital thermometer readings - see *Table 2*).

Table 2 - Static calibration of digital thermometer with crushed ice

Time	*Temperature Readings (°C)*	
	Mercury	*Digital*
12:00	0.0	0.0
12:02	0.0	0.0
12:04	0.1	0.0
12:06	0.0	0.0
12:08	0.0	0.1
12:10	0.1	0.1
12:12	0.1	0.2

Dynamic calibration was performed against a previously calibrated mercury thermometer. Both the mercury and the digital thermometers were immersed in hot water and the water was allowed to cool. Temperature readings were taken at 2 minute intervals while the water was heated. Readings were also taken when the water was cooling down. The results were then subjected to statistical tests to verify whether the differences, if any, were statistically significant. The results of the dynamic calibration are shown in *Table 3* and the statistical results are given in *Table 4*.

Table 3 - Dynamic calibration of digital thermometer with Mercury thermometer

Mercury Thermometer	*Digital Thermometer*		*Mercury Thermometer*	*Digital Thermometer*	
	Heating	*Cooling*		*Heating*	*Cooling*
29.0	28.8	28.6	45.0	45.1	44.4
30.0	29.8	30.0	46.0	45.9	45.9
31.0	31.2	31.0	47.0	46.9	46.3
32.0	32.4	32.0	48.0	47.2	47.9
33.0	33.2	33.0	49.0	48.9	49.1
34.0	34.6	34.0	50.0	50.0	50.2
35.0	34.7	35.0	51.0	51.1	51.4
37.0	37.0	37.2	52.0	51.8	51.9
38.0	38.6	38.2	53.0	52.9	53.0
39.0	39.2	39.5	54.0	54.0	54.2
40.0	40.0	40.1	55.0	55.0	55.3
41.0	40.8	41.0	56.0	56.0	56.2
42.0	42.0	42.0	57.0	57.0	57.3
43.0	42.8	42.8	58.0	58.0	58.3
44.0	44.0	43.6	59.0	59.0	59.4
45.0	45.1	44.4	60.0	60.0	60.2

Table 4 - Simple Linear Regression (SLR) of calibration results

Digital Thermometer Reading	*SLR Results*			*Characteristics of Residuals*		
	slope	*intercept*	R^2	*Skewness*	*Kurtosis*	*Lilliefor's**
Heating	0.994	0.279	0.999	-0.057	-1.140	0.156
Cooling	1.010	-0.395	0.999	-0.044	-1.146	0.201

* - *The hypothesis that residuals are normally distributed can be rejected only if $L_{max} > L_{1-\alpha}$ In both of the above cases $L_{1-\alpha}$ is 0.258. Therefore the residuals can be assumed to be normally distributed*

4. Work Program

The study involved ten tasks and Table 5 shows the duration of each task carried out under the SRC Grant No. 98/01/12.

Table 5 - Research Tasks

Task	*Duration*
Procurement of measuring instruments	Nov 01 - Dec 01, '98
Supply and fabrication of the slotted iron support assembly	Dec 02 - Dec 24, '98
Calibration of measuring instruments	Jan 05 - Jan 24, '99
Development of data recording format	Jan 25 - Jan 31, '99
Pilot study	Feb 01 - Feb 07 '99
Data collection	Feb 08 - Mar 15, '99
Interim report	Feb 12 - Feb 15, '99
Data analysis	Mar 16 - Apr 15, '99
Final report	May 01, '99

5. Results

Three roof cladding materials and four insulation materials (see *Table 1*) were used for the study. Manufacturers / dealers of roof insulation materials supplied the cladding materials free of charge. These materials produced 12 combinations (3 by 4). The results can be used not only to calculate the insulation potential of the four insulators but also the relative performance of the three roof cladding systems in reducing the heat gain. This was made possible due to the constancy of the heat output from the artificial heat source. Tables 6 - 17 show the raw data collected.

Table 6
Clay Tile with
Aluminum Foil Insulation

Time	Surface Temperature of the Heat Sink (deg. C)	
	Roof Cladding Only	Roof Cladding + insulation
9:05	28.0	28.0
9:10	28.0	28.0
9:15	28.5	28.5
9:20	29.0	29.0
9:25	29.5	29.0
9:30	30.0	29.5
9:35	30.0	30.0
9:40	30.5	30.0
9:45	31.0	30.5
9:50	31.5	30.5
9:55	32.0	31.0
10:00	32.5	31.5
10:05	33.0	32.0
10:10	33.5	32.0
10:15	34.0	32.5
10:20	34.0	33.0
10:25	34.5	33.5

Table 7
Clay Tile with
Polyethylene Insulation

Time	Surface Temperature of the Heat Sink (deg. C)	
	Roof Cladding Only	Roof Cladding + insulation
9:10	29.5	29.5
9:15	29.5	29.5
9:20	29.5	29.5
9:25	30.0	29.5
9:30	30.5	30.0
9:35	31.0	30.5
9:40	31.5	30.5
9:45	32.0	31.0
9:50	32.5	31.0
9:55	33.0	31.5
10:00	33.5	32.0
10:05	34.0	32.0
10:10	34.5	32.5
10:15	35.0	33.0

Table 8
Clay Tile with
Polyethylene w/ Aluminum Foil

Time	Surface Temperature of the Heat Sink (deg. C)	
	Roof Cladding Only	Roof Cladding + insulation
10:00	27.0	27.0
10:05	27.5	27.0
10:10	27.5	27.0
10:15	28.0	27.0
10:20	28.5	27.5
10:25	29.0	27.5
10:30	29.5	28.0
10:35	30.5	28.0
10:40	31.0	28.5
10:45	31.5	28.5
10:50	32.0	29.0
10:55	32.5	29.0
11:00	33.0	29.5
11:05	33.5	29.5
11:10	34.5	30.0
11:15	35.0	30.0

Table 9
Clay Tile with
Glass Fiber Batt Insulation

Time	Surface Temperature of the Heat Sink (deg. C)	
	Roof Cladding Only	Roof Cladding + insulation
9:45	28.0	28.0
9:50	28.5	28.0
9:55	29.0	28.5
10:00	29.0	28.5
10:05	29.5	28.5
10:10	30.0	29.0
10:15	30.5	29.0
10:20	31.0	29.0
10:25	31.5	29.5
10:30	32.0	29.5
10:35	32.5	30.0
10:40	33.0	30.0
10:45	33.5	30.0
10:50	34.0	30.5

Table 10
Corrugated Asbestos with Aluminum Foil Insulation

Time	Surface Temperature of the Heat Sink (deg. C)	
	Roof Cladding Only	Roof Cladding + insulation
9:25	28.0	28.0
9:30	28.0	28.0
9:35	28.5	28.5
9:40	29.0	29.0
9:45	29.5	29.5
9:50	30.0	30.0
9:55	30.5	30.5
10:00	31.0	31.0
10:05	31.5	31.0
10:10	32.0	31.5
10:15	32.5	32.0
10:20	33.0	32.5
10:25	33.5	33.0
10:30	34.0	33.5

Table 11
Corrugated Asbestos with Polyethylene Insulation

Time	Surface Temperature of the Heat Sink (deg. C)	
	Roof Cladding Only	Roof Cladding + insulation
9:30	27.5	27.5
9:35	28.0	27.5
9:40	28.0	27.5
9:45	28.5	28.0
9:50	29.0	28.0
9:55	30.0	28.5
10:00	30.5	29.0
10:05	31.0	29.0
10:10	31.5	29.5
10:15	32.5	30.0
10:20	33.0	30.0
10:25	33.5	30.5
10:30	34.0	31.0
10:35	34.5	31.0
10:40	35.0	31.5
10:45	35.5	31.5
10:50	36.0	32.0

Table 12
Corrugated Asbestos with
Polyethylene w/ Aluminum Foil

Time	Surface Temperature of the Heat Sink (deg. C)	
	Roof Cladding Only	Roof Cladding + insulation
9:25	28.0	28.0
9:30	28.0	28.0
9:35	28.5	28.5
9:40	29.0	28.5
9:45	29.5	29.0
9:50	30.0	29.0
9:55	30.5	29.5
10:00	31.0	29.5
10:05	31.5	30.0
10:10	32.0	30.5
10:15	32.5	31.0
10:20	33.0	31.0
10:25	33.5	31.5
10:30	34.0	31.5
10:35	34.5	32.0
10:40	35.0	32.0

Table 13
Corrugated Asbestos with
Glass Fiber Batt Insulation

Time	Surface Temperature of the Heat Sink (deg. C)	
	Roof Cladding Only	Roof Cladding + insulation
8:45	27.5	27.5
8:50	27.5	27.5
8:55	28.0	27.5
9:00	28.5	27.5
9:05	29.0	28.0
9:10	30.0	28.5
9:15	30.5	28.5
9:20	31.0	28.5
9:25	31.5	29.0
9:30	32.0	29.0
9:35	32.5	29.0
9:40	33.0	29.0
9:45	33.5	29.5
9:50	34.0	29.5
9:55	34.5	29.5
10:00	35.0	30.0

Table 14
Color-coated Zinc-Aluminum + Aluminum Foil Insulation

Time	Surface Temperature of the Heat Sink (deg. C)	
	Roof Cladding Only	Roof Cladding + insulation
9:00	27.0	27.0
9:05	27.5	27.0
9:10	28.0	27.5
9:15	29.0	28.5
9:20	29.5	29.0
9:25	30.3	29.5
9:30	31.0	30.0
9:35	31.5	30.8
9:40	32.0	31.0
9:45	32.5	31.5
9:50	33.0	32.0
9:55	33.5	32.5
10:00	34.0	33.0
10:05	34.5	33.5
10:10	35.0	34.0
10:15	35.5	34.5

Table 15
Color-coated Zinc-Aluminum + Polyethylene Insulation

Time	Surface Temperature of the Heat Sink (deg. C)	
	Roof Cladding Only	Roof Cladding + insulation
8:55	27.5	27.5
9:00	28.0	27.5
9:05	28.5	28.0
9:10	29.5	28.5
9:15	30.0	28.5
9:20	31.0	29.0
9:25	31.5	29.0
9:30	32.0	29.5
9:35	33.0	30.0
9:40	33.5	30.0
9:45	34.0	30.5
9:50	34.5	30.5
9:55	35.0	31.0
10:00	35.5	31.5
10:05	36.0	32.0
10:10	37.0	32.5
10:15	37.5	32.5

Table 16
Color-coated Zinc-Aluminum
Polyethylene w/ Aluminum Foil

Time	Surface Temperature of the Heat Sink (deg. C)	
	Roof Cladding Only	Roof Cladding + insulation
9:10	29.5	29.5
9:15	30.0	29.5
9:20	31.0	30.0
9:25	32.0	30.5
9:30	33.0	31.0
9:35	33.5	31.0
9:40	34.5	31.5
9:45	35.0	32.0
9:50	35.5	32.5
9:55	36.0	32.5
10:00	36.5	33.0
10:05	37.0	33.5
10:10	37.5	34.0
10:15	38.0	34.0
10:20	38.5	34.5
10:25	39.0	35.0

Table 17
Color-coated Zinc-Aluminum
Glass Fiber Batt Insulation

Time	Surface Temperature of the Heat Sink (deg. C)	
	Roof Cladding Only	Roof Cladding + insulation
9:20	28.0	28.0
9:25	28.5	28.0
9:30	29.0	28.5
9:35	30.5	28.5
9:40	31.0	29.0
9:45	31.5	29.0
9:50	32.5	29.0
9:55	33.0	29.5
10:00	34.0	29.5
10:10	34.5	30.0
10:15	35.0	30.0
10:20	35.5	30.5
10:25	36.0	30.5
10:30	36.5	30.5

6. Analysis

6.1 Thermal performance of roof claddings

Figure 3 shows the rate of heat change in the three roof cladding materials without insulation. The mean surface temperatures of the three roof claddings are:

Tile	=	30.2°C
Asbestos	=	30.6°C
Zinc-Alum	=	31.3°C

The mean difference between Tile and Asbestos roof claddings though statistically significant (p-value = 0.009), is too small to offer any thermal comfort enhancement (Temperature reduction was less than 0.4°C. Thus, Calicut tile roof appears to transmit the least amount of heat, but the heat transmission through corrugated asbestos roof is not very different from that of the tile. Zinc-Alum sheet without insulation, provided the least amount of thermal insulation.

6.2 Thermal performance of insulation materials on tile roof

Figure 4 shows the thermal performance of four roof insulation materials on heat transmission through calicut roof tiles. The mean surface temperatures of tile roof and tile roof with the insulation materials is given below. A matrix of pair-wise differences are given in Table 18. Differences that are not statistically significant are underlined. Differences may not tally due to rounding off errors.

Tile only	=	30.2°C
Tile + Sisilation	=	29.6°C
Tile + Polyethylene	=	29.2°C
Tile + Alu Stucco	=	28.1°C
Tile + Batt	=	28.4°C

Table 18 - Matrix of pair-wise differences with tile roof

	Tile	*+ Sisi-lation*	*+ PE*	*+ Alu-stucco*	*+ Batt*
Tile	0.0				
+ Sisilation	-0.5	0.0			
+ PE	-1.0	-0.4	0.0		
+ Alu-Stuccot	-2.0	-1.5	-1.1	0.0	
+ Batt	-1.7	-1.2	-0.8	0.3	0.0

It appears that Aluminum foil insulation ("Sisilation") does not offer any significant insulation over that of the tile (average temperature reduction was 0.5°C only). Polyethylene sheet with Aluminum Foil ("Alu-Stucco") offers the best insulation and the insulation potential of Fiberglass Batt insulation is as good as "Alu Stucco" (average temperature reduction by Batt insulation was 1.7°C as opposed to 2.0°C by "Alu-Stucco").

6.3 Thermal performance of insulation materials on asbestos roof

Figure 5 shows the thermal performance of four roof insulation materials on heat transmission through corrugated asbestos cement roof sheets. The mean surface temperatures of the asbestos roof and asbestos roof with the insulation materials are given below. A matrix of pair-wise differences is given in Table 19. Differences that are not statistically significant are underlined. Differences may not tally due to rounding off errors.

Asbestos only	=	30.6°C
Asbestos + Sisilation	=	30.4°C
Asbestos + Polyethylene	=	28.9°C
Asbestos + Alu Stucco	=	29.5°C
Asbestos + Batt	=	28.5°C

Table 19 - Matrix of pair-wise differences with asbestos roof

	Asbest.	*+ Sisilation*	*+ PE*	*+ Alu-stucco*	*+ Batt*
Asbestos	0.0				
+ Sisilation	<u>-0.2</u>	0.0			
+ PE	-1.7	-1.5	0.0		
+ Alu-Stuccot	-1.1	-0.9	<u>0.6</u>	0.0	
+ Batt	-2.1	-1.9	<u>-0.4</u>	-1.0	0.0

Here too, it appears that Aluminum foil insulation ("Sisilation") does not offer any significant insulation over that of the asbestos sheet by itself (average temperature reduction was 0.2°C only). Fiberglass Batt insulation offers the best protection (Average reduction was 2.1°C) while polyethylene sheet is equally good (reduction = 1.7°C).

6.4 Thermal performance of insulation materials on Zinc-Alum roof

Figure 6 shows the thermal performance of four roof insulation materials on heat transmission through color-bonded Zinc-Alum profile roof sheets. The mean surface temperatures of the zinc-alum roof and zinc-alum roof with the insulation materials are given below. A matrix of pair-wise differences is given in Table 20. Differences that are not statistically significant are underlined. Differences may not tally due to rounding off errors.

Zinc-Alum only	=	31.3°C
Zinc-Alum + Sisilation	=	30.5°C
Zinc-Alum + Polyethylene	=	29.0°C
Zinc-Alum + Alu Stucco	=	29.0°C
Zinc-Alum + Batt	=	28.2°C

Table 20 - Matrix of pair-wise differences with Zinc-alum roof

	Zinc-Alum	*+ Sisilation*	*+ PE*	*+ Alu-stucco*	*+ Batt*
Zinc-Alum	0.0				
+ Sisilation	<u>-0.8</u>	0.0			
+ PE	-2.3	-1.6	0.0		
+ Alu-Stuccot	-2.3	-1.5	<u>0.0</u>	0.0	
+ Batt	-3.1	-2.4	<u>-0.8</u>	<u>-0.8</u>	0.0

Here too, it appears that Aluminum foil insulation ("Sisilation") does not offer any significant insulation over that of the Zinc-Alum sheet by itself. However, the reduction in surface temperature is larger here than with tiles or asbestos (0.7°C as opposed to 0.2°C and 0.5°C respectively). Fiberglass Batt insulation offers the best protection (average reduction = 3.1°C) while polyethylene sheet and "Alu-Stucco" offer identical insulation (average reduction = 2.3°C). In addition to offering the best insulation, Batt insulation on Zinc-Alum sheet provides the greatest heat reduction as opposed to its use with tile and asbestos roof (3.1°C against 1.7°C and 2.1°C respectively).

6.5 Relative performance of insulation materials on all three roof cladding systems

Further analysis of the relative efficacy of a given roof insulation material on the three roof cladding systems was also carried out. Table 21 shows the average surface temperatures that resulted when the four insulation materials were used with the three roof claddings.

Table 21 - Average temperature differences on the three roofing system

	+ Sisilation	*+ PE*	*+ AluStucco*	*+ Batt*
Tile	29.6	29.2	28.1	28.4
Asbestos	30.4	28.9	29.5	28.5
Zinc-Alum	30.5	29.0	29.0	28.2

The performance of "Alu-Stucco" showed the greatest variation among the three roof cladding systems tested (up to 1.4°C). Insulation performance was the least differentiated when Polyethylene or Batt insulation were used (less than 0.3°C). the lowest surface temperatures resulted when Batt insulation was used. The reduction is particularly striking in the case of Zinc-Alum roof cladding (up to 2.3°C). the performance of Batt insulation is even better when compared with the case of Zinc-Alum roof sheet without any roof insulation (over 3.0°C).

7. Recommendations

The summary of findings of the present study are:

i. Calicut tile roof appears to transmit the least amount of heat, but the heat transmission through corrugated asbestos roof is not very different from that of the tile.
ii. Zinc-Alum sheet provided the least amount of thermal insulation.
iii. It appears that Aluminum foil insulation ("Sisilation") does not offer significant insulation over any of the roofing systems tested.
iv. Polyethylene sheet with Aluminum Foil ("Alu-Stucco") offers the best insulation for the Tile roofing system.

v. Fiberglass Batt insulation offers the best protection for corrugated Asbestos and Zinc-Alum roof cover.
vi. The performance of "Alu-Stucco" is the most consistent among all three roof covers tested.

In view of the above findings, the study recommends the following roof cover / insulation strategies for Sri Lankan buildings.

i. Among the roof systems tested, Calicut Clay Tile roof cover is the most preferable for hot, humid environments.
ii. The thermal performance of Calicut roof will be greatly enhanced by the use of Polyethylene insulation covered with Aluminum foil ("Alu-Stucco"). This combination offers the best insulation potential among the materials tested.
iii. Buildings that necessitate Asbestos or Zinc-Alum roofing systems must seriously consider the use of an insulation layer. Fiberglass Batt insulation showed the best potential.
iv. As a lower cost alternative, "Alu-Stucco" could be used with Asbestos or Zinc-Alum roof covers.
v. The use of Aluminum foil insulation ("Sisilation") need to be re-evaluated, particularly in conjunction with Asbestos and Zinc-Alum roofing. Although, the insulation potential is improved in these cases, they are still warmer than Clay tile roofing without any insulation layer.

8. Limitations

The present study considered only three roof covers. These covers are by no means the most widely used in Sri Lanka. The rural buildings are still dominated by thatched roof cover. Furthermore, a relatively new practice of using half-round tiles on top of corrugated Asbestos sheets was also not tested.

Another drawback is that the study evaluated only the heat flow rates through roof cover/insulation combinations. What is of greater value to Architects and building designers is the effect roof cover / insulation combinations on thermal comfort.

However, this study *attempted to analyze the most widely prevalent contemporary roof cover / insulation combinations with a view to empirically establish their suitability for Sri Lankan conditions*. Although the combinations are not exhaustive, the study points out the existence of more economical and freely available roof cover/insulation combinations for the use of the local building industry. It also questions the efficacy of some expensive insulation solutions available in the market. In as much as an awareness of the issues are raised, a good start is being made.

The author proposes to study the *thermal comfort effects* of roof cover/insulation combinations using a full scale model in the near future.

Figure 4 - Effect of Insulation on Clay Tile Roof

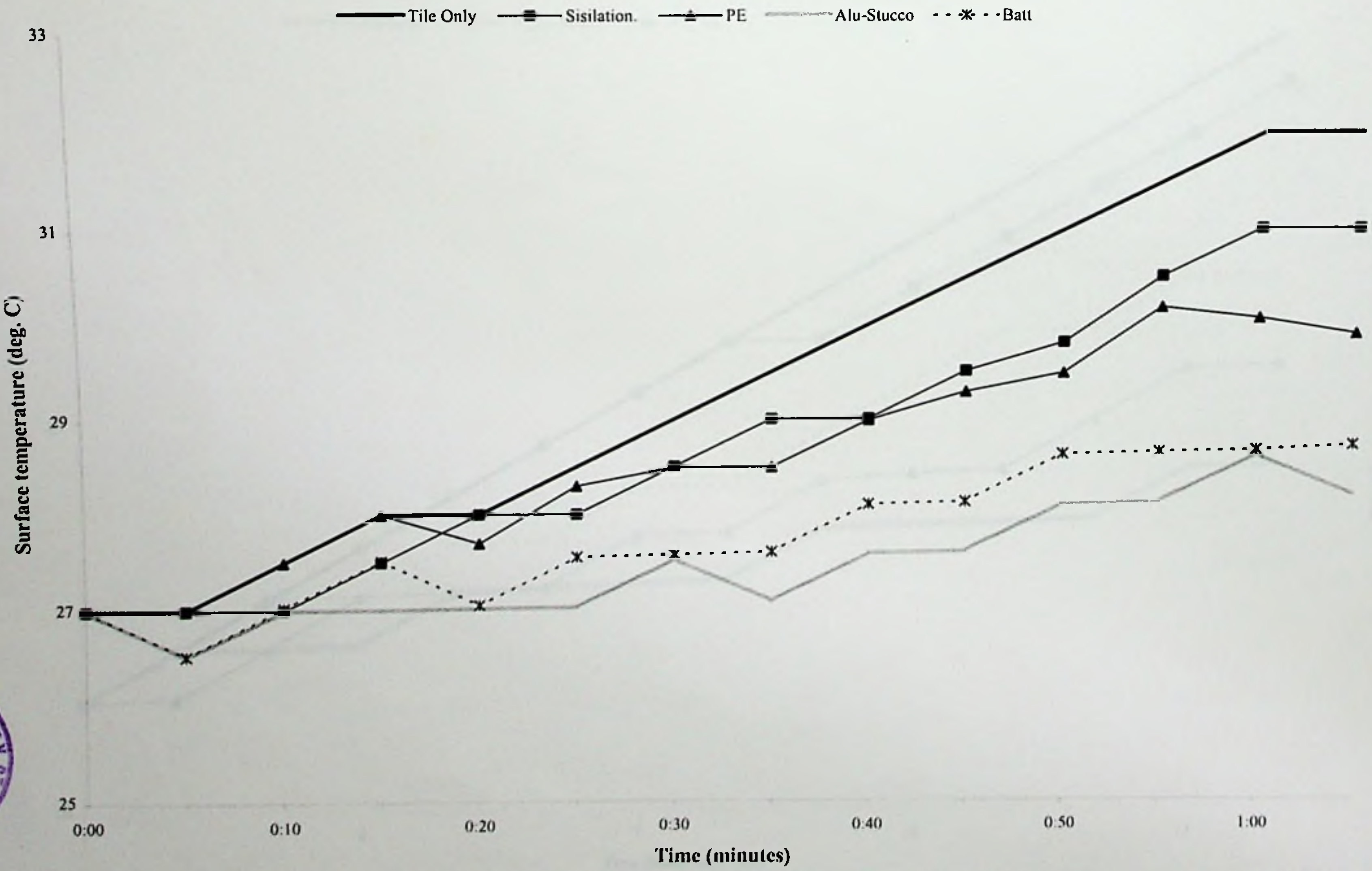

Fig. 5 - Performance of different Roof Insulation Materials with Corrugated Asbestos Sheet

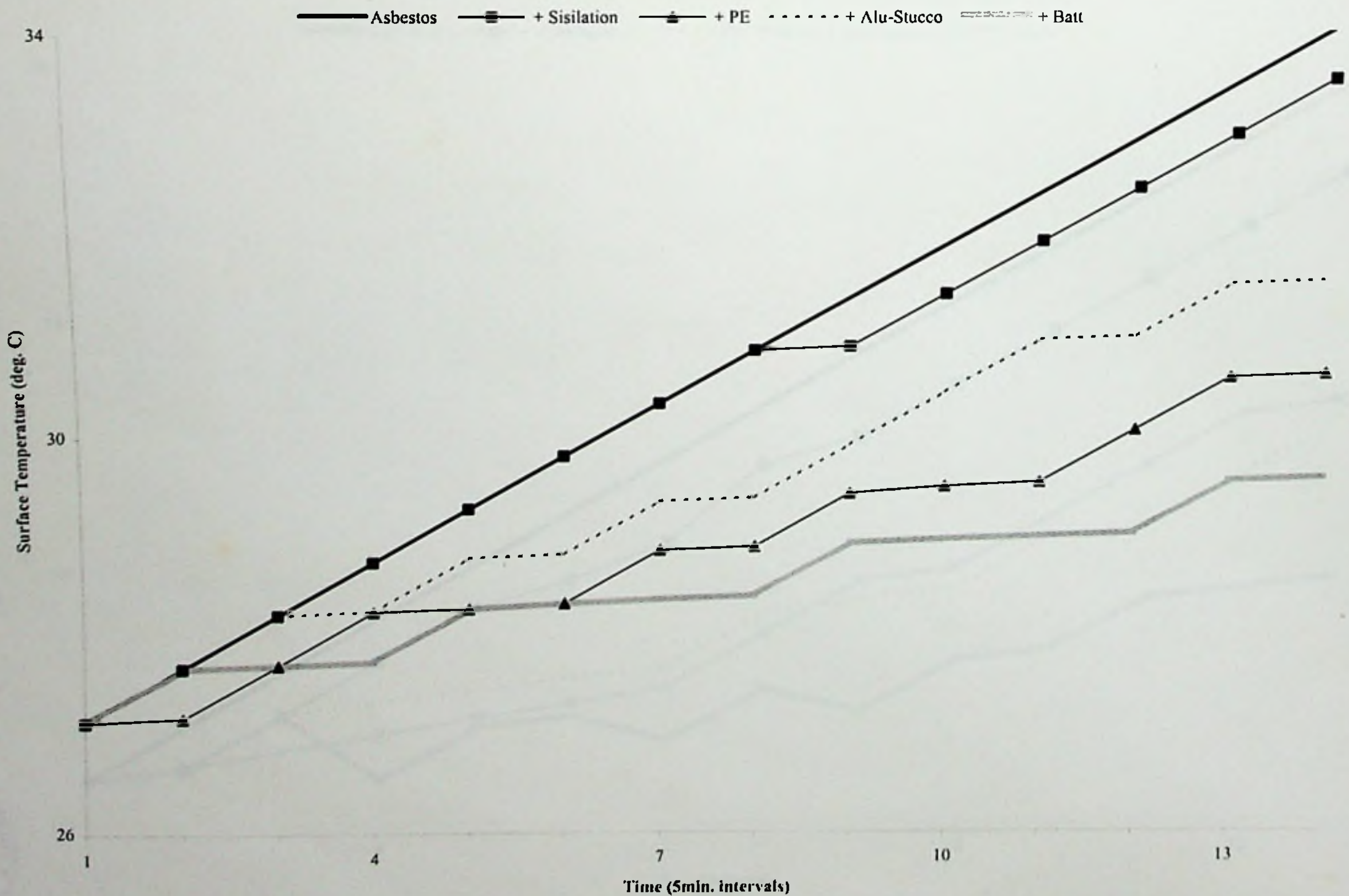

Fig. 6 - Performance of Different Roof Insulation Materials with "Color-Bond Zinc-Alum" Roof