PAKIS-STEM BLOCKS AS THERMAL RESISTANCEON FLAT CONCRETE ROOF IN WARM-HUMID TROPIC OF SURABAYA IN INDONESIA

DANNY SANTOSO MINTOROGO

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Faculty of Built Environment
UniversitiTeknologi Malaysia

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ABSTRACT

For decade many shop-stores and shop-houses have been built on the central business district areas of Surabaya to meet the rapid growth of business activities. The shop-stores and shop-houses even with some dwellings are built with flat bare concrete roofing systems. The concrete roof constructed is simple where most of the flat concrete roofs are built with concrete of 12.5 to 20 cm thick and plastered with Portland cement of 2 to 5 cm thickness. None of these flat roofs built are habitually equipped with external and internal insulations to prevent the impact of high solar irradiation on horizontal or tilted roof surfaces. The solar radiation intensity on horizontal surface in Surabaya with latitude 7^{o} 17'-21' South has an average of around 300 to 400 watt/m^2 per hour; total intensity radiation from 6 am to 6 pm is somewhat 3,000 to 5,000 watt-hour/m^2 (Mintorogo 2007).

The room thermal performance will be higher for cooling loads due to bare concrete roofing systems; meanwhile most of shop-stores and shop-houses used air conditioning throughout days and nights. This phenomenon will lead to an un-sustainable domain.This research attempts to provide alternative by incorporating eco-friendly and sustainable material with Pakis-stem blocks on flat concrete roof for passive cooling strategy.

The Pakis-stem blocks system as outer roof barrierwill be a good thermal resistance to absorb the heat from solar radiation and provides natural cooling through its interlacing porous trunks by convective-wind and evaporative-cooling effects without adding substantial loads to the roof structures.Furthermore, "Pakis-stem blocks" are easier, cheaper and more valuable than other sub-structure roofing materials available as thermal resistant layer on a flat concrete rooftop deck for example if compare togreen roofing systems and roofpond systems.

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CHAPTER 1

INTRODUCTION

1.1 Research aims

The research will look for eco-friendly outer thermal resistant to flat concrete roof systems in the built environment; participate to the world energy crisis and sustainable architecture. Light-weight Pakis's blocksbas natural material to insulate rooftop thermal heat on flat bare concrete roof will not add substantial loads to either new or existing roof structures.

1.2 Research objective

To accomplish the sustainable architecture, energy-savings, and eco-friendly realms of the world, thermal loads or cooling loads should be diminished maximally from roof systems. Flat bare concrete roofs are the most installed to commercial buildings and have been caused thermal problems.

1.3 Research scopes

The research project will become an eco-friendly and sustainable outer thermal barrier to diminish thermal loads for flat bare concrete roof systems; Pakis-stem blocks are the means of it, and will search deeply in terms of:

1. The ability of Pakis-stem-block to absorb thermal heat solar radiation maximally and to perform direct cooling to flat concrete.
2. The ability of Pakis-stem blocks for dealing with evaporative cooling effect: tested the dry Pakis-stem blocks and wet Pakis-stem blocks for 12-hour period.
3. The durabolity of the light-weight Pakis-stem blocks in nature: tested the long-lasting Pakis-stem blocks putting on a flat bare concrete roof for a year.
4. The thickness of Pakis-stem blocks layer over flat bare concrete roof: examined layers of Pakis-stem blocks for reaching as thermal barrier maximally.
5. Looking for the substitute of Pakis-stem blocks for achieving its durability, strength, and ease of use: compared to thermal performance between the original Pakis-stem blocks and concrete-Pakis-stem blocks (pouring concrete over a nature Pakis-stem blocks).
6. The reflecting levels of solar heat radiation to surrounding atmosphere: dry-Pakis-stem blocks versus wet-Pakis-stem blocks as well as concrete-Pakis-stem blocks.

1.4 Significance of research

The research project rooftop Pakis-stem blocks will have outstanding values, it has image of:

1. The green building;the rooftop usesnatural material.
2. The sustainable architecture; the rooftop saves energy.
3. Sustainable built environment; the rooftop is an eco-friendlymaterial
4. Sustainable economic; the rooftop structure insulation is economical accessible (cheapest) and light-weight material (add no substantial loads to new or existing roof-structures).

5. Reduced effect Urban Heat Island in town (natural material).

CHAPTER 2

PAKIS-STEMBLOCKS

2.1 Natural material

2.1.1 Tropical forest

"Pakis" trees grow healthly in the tropical rain forest likes Indonesia and subtropical rain forest such as Australia and New Zealand. Pakis has hundreds of species and some species have strong trunk likes Dicksoniaceaeand Cyatheaceae in Cyatheales family. Figure 8 (a and b) illustrates Pakis trees "Antarctica" in CombeMartin'sfaunaand Dinosaur Park, Devon , English; thosePakis trees could grow till around 2.5 to 4 meter height and have plenty of big leaves. Its stem has diameter roughly 200 to 400 mm, and very porosity. The stems then are sliced to pieces of stem-blocks with dimension of 260 mm length, 130 mm width, and 30 mm thick. Figure 8 (c)gives a closer look to the Pakis trees after slicing into blocks.Figure 8 (d) Pakis-stemblocks are widely soled in flourish stores and exclusively use for orchid flourish avenue attaching to trees.

(a)

(b)

(c)

(d)

Figure 8 Pakistrees in the forest (a) and (b), sliced Pakis-stem-block (c), used by orchid flourish as media (d).

2.1.2 Eco-friendly and Sustainable Materials

"Pakis" trees grow healthly in the tropical rain forest likes Indonesia and subtropical rain forest such as

CHAPTER 3

RESEARCH METHODOLOGY

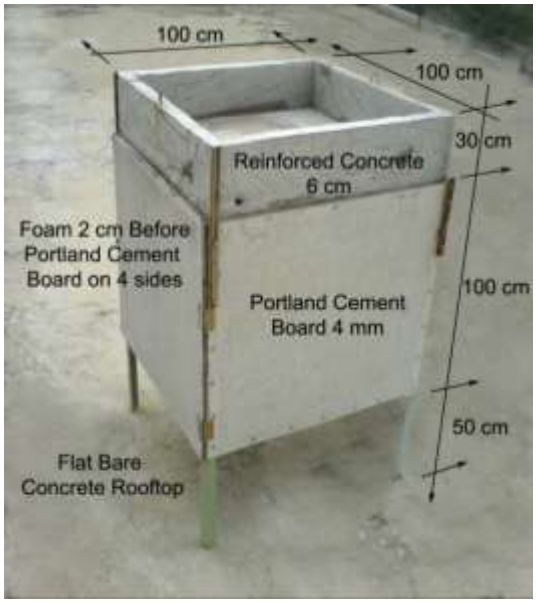
3.1. General

Research on gathering the sustainable rooftop flat concrete thermal performance for savings energy on cooling loads will deal with two models; one is for reference model, and the other two will be covered with organic Pakis-stemblocks. Each model will be measured its thermal performance for one month continuously and simultaneously. There will be two-mode measurements; one measurement is dry Pakis-stemblocks, and the rest is wet Pakis-stemblocks. In wet mode, the Pakis-stemblocks will be sprayed two times per day; that is at 6 am and 12 noonrespectively for 15 minutes each. All test models are in closed mode system—no ventilation opening; just having infiltration through windows and walls.

3.1.1 Models

The models have dimension of 1000 wide x 1000 length x 1000 mm height. The model floor is lifted 500 mm with distance to ground. The dimension of rooftop flat concrete flat deck of 800 mm thick is 1000 wide x 1000 length x 400 mm height. The walls are of portland cement (kalsi) boards of 40 mm thick. The walls and floor

are covered with 200 mm foam boards as interior surfaces. Figure 9descrebes the model reference (a) and one layer Pakis-stemblocks covered model (b); one layer of Pakis-stem block of 1 square meter has 27 blocks. The total weight of dry Pakis-stemblocks of 1 m^2 is 6 kilogram, meanwhile the wet Pakis-stemblocks on 1 m^2weigh up 9 kg. Figure 9 (c) shows two model of flat concrete rooftop will be tested simultaneously all the time; one model will be as reference model (base values) and others will be covered interchangeable with dry or wet Pakis-stem blocks.



(a)

(b)

(c)

Figure 9 The Researched Models with flat concrete rooftop(a) and Pakis-Stem Blocks covered on Model (b),Two Models; one as Reference Model (c)

A horizontal shading device length 1 meter is providing on 4 sides of all models; even that a 2 cm foam on 4-side walls of external models is attached for extra protection from solar heat radiation impacted.

(a) **(b)**

Figure 10. 1 meter length of horizontal shading device around the models (a), 4 sides of external walls covered with 2 cm foam (b)

3.1.2 Equipment

The measuring equipmentsaretwo piece of HOBO U15 with four external data logger water/soil temperature sensors. The first sensor is connected to Pakis-stem block; and the second sensor is positionedto concrete surface. The third sensor is sticked to the internal surface of concrete model; then the fourth is for measured the interior temperature. Figure 10 shows the HOBO U family has a mesurement range of temperature from -20^{o}C to 70^{o}C; Rh is 5% to 95%. The external input channels have a 0 to 2.5 DC volts; and the mesurement range is -40^{o}C to 50^{o}C in water, while it ranges -40^{o}C to 100^{o}C in air.

Figure 11 HOBO U Family Data Logger and External Water or Soil Sensor

Figure 11 shows the equipment used to measure the solar heat radiation is 5 series of silicon pyranometer smart sensors from “HOBO” and Weather Station Data Logger with the specification of the measurement ranging from 0 to 1280 W/m^2.The BoxCar Pro4 software is needed to set-up and read the data from the lodger units.

Figure 12 HOBO Data Logger and Pyranometers

3.1.3 Processing diagram

The measuring process will be involved with 2 models made of reinforce flat concrete rooftop and combined walls (foam and cement board), same instruments.Two models are measured simultaneously for 15 days each for dry and wet style for a year.

Meanwhile, 3 pyranometers will be used to measure intensity of direct and global solar radiation (1 sensor up); two sensors will be set up down to measure

direct bounce back solar irradiation from flat concrete rooftop and flat concrete covered with Pakis-stem blocks rooftop.

The depth of Pakis-stemblock layers covered over the concrete rooftop will be done prior to do regular measurement on two models for a year (looking the minimal of outer flat concrete surface temperature).

Instruments:

HOBO sensor 1: measured Pakis-stem blocks temperature

sensor 2: measured outer flat concrete surface temperature

sensor 3: measured inner concrete surface temperature

sensor 4: measured indoor space of temperature and humidity

sensor 5: measured outdoor temperature and humidity

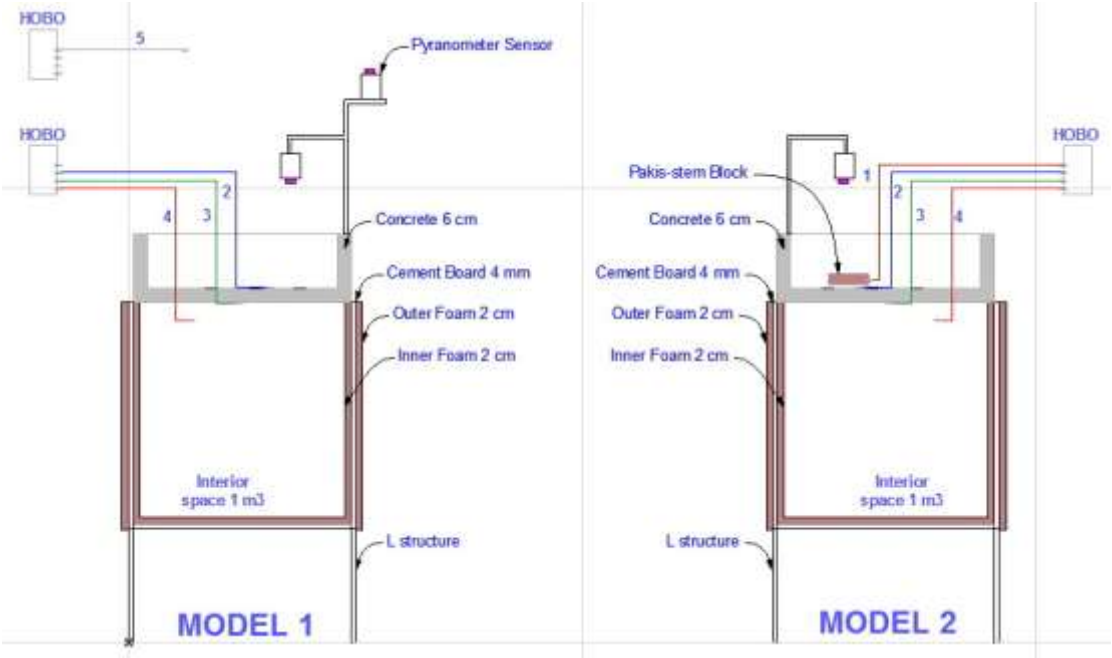


Figure 13 Diagram Processing on Models, Equipment and Procedures

CHAPTER 4

TESTED RESULTS

4.1. Progressive results

The monitoring on models has been done to give a closer look to Pakis-stem blocks to overcome the heat sun solar radiation on flat bare concrete rooftop. The measurement is taken with Pakis-stem blocks for 5 layers during the hottest season (September, October, and mid November) for gathering thermal performances on dry pakis blocks and wet pakis blocks; each type of dry and wet pakis test is running for 15 days.

4.2. Room Thermal Performances on the hottest months

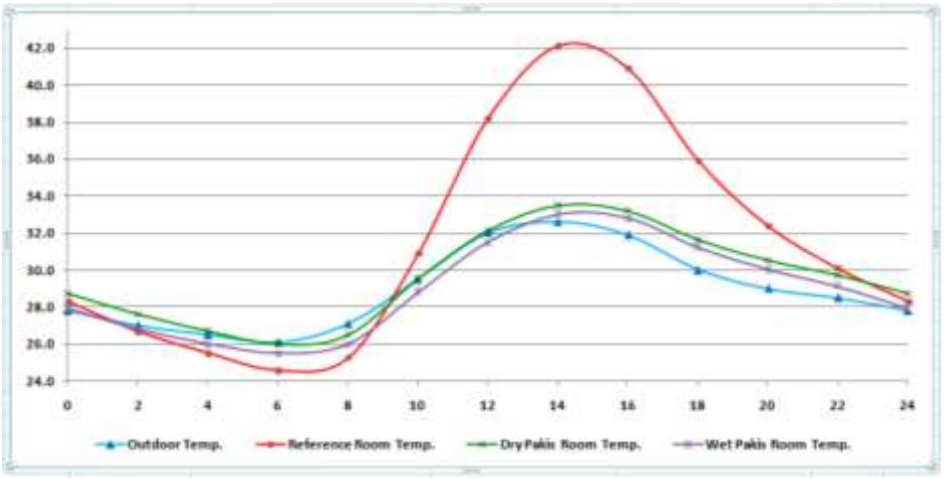


Figure 14 Room Temperatures on 3 models for September 2011

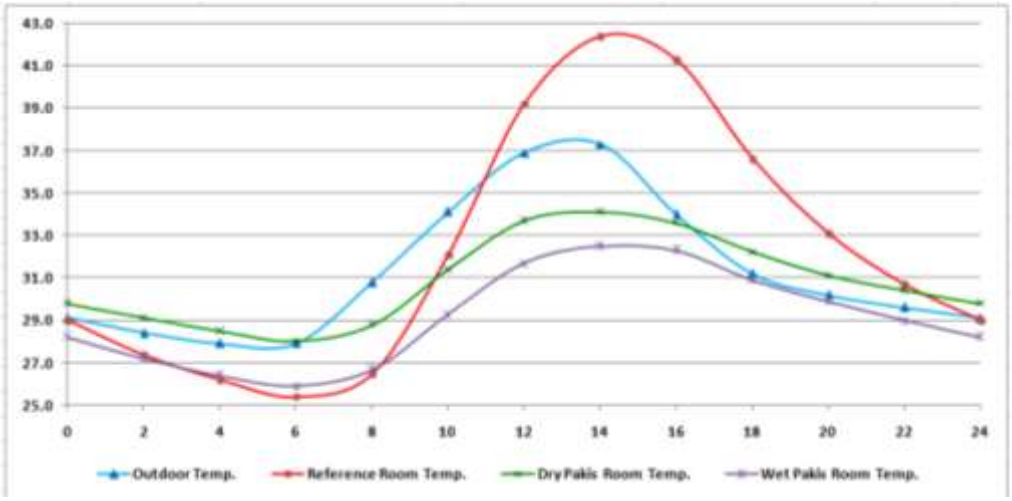


Figure 15 Room Temperatures on 3 models for October 2011

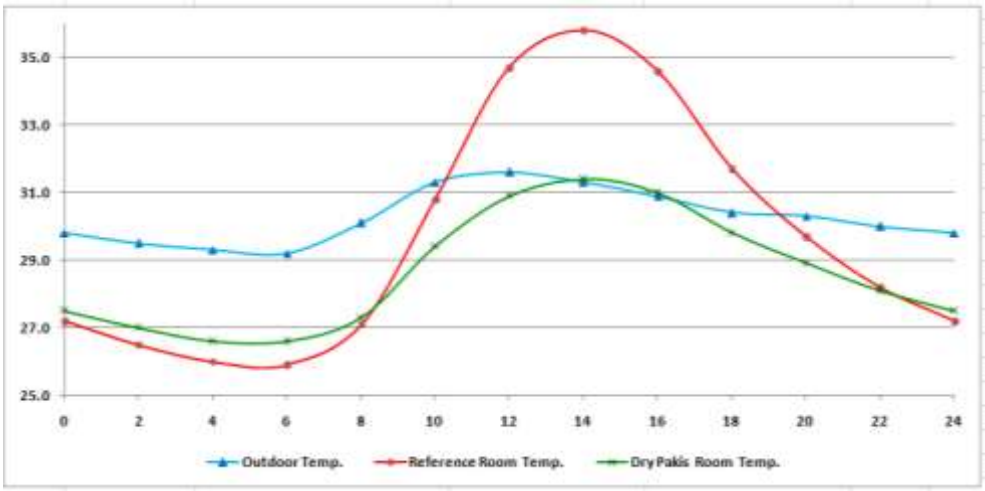


Figure 16 Room Temperatures on 3 models for November 2011

4.3. Thermal Performances for Pakis Thickness (Layers of Pakis Blocks)

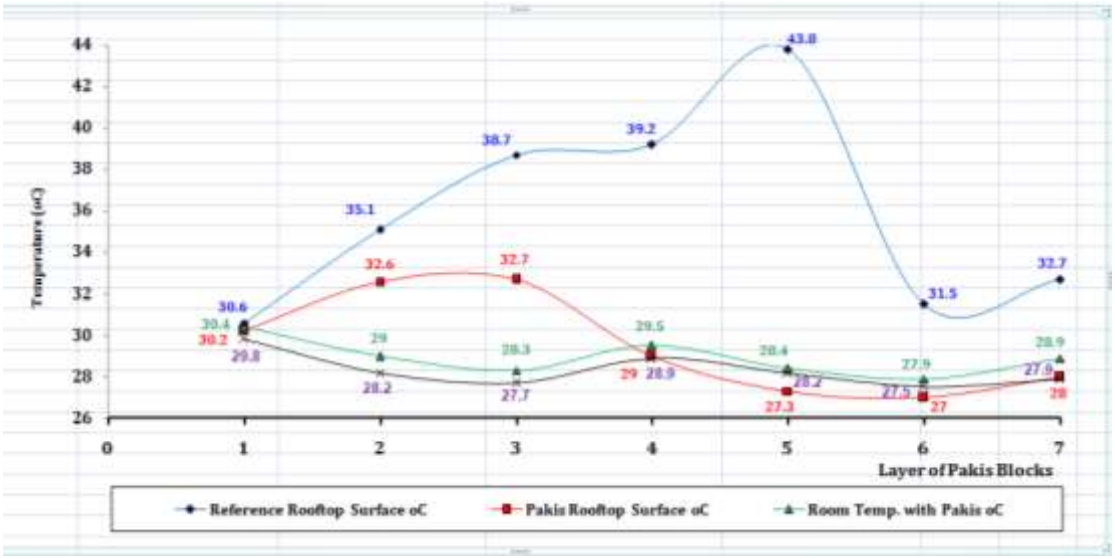


Figure 17 Thermal Performances of Pakis Thickness

4.4 Thermal Performances for Pakis 3-layer versus Pakis 4-layer

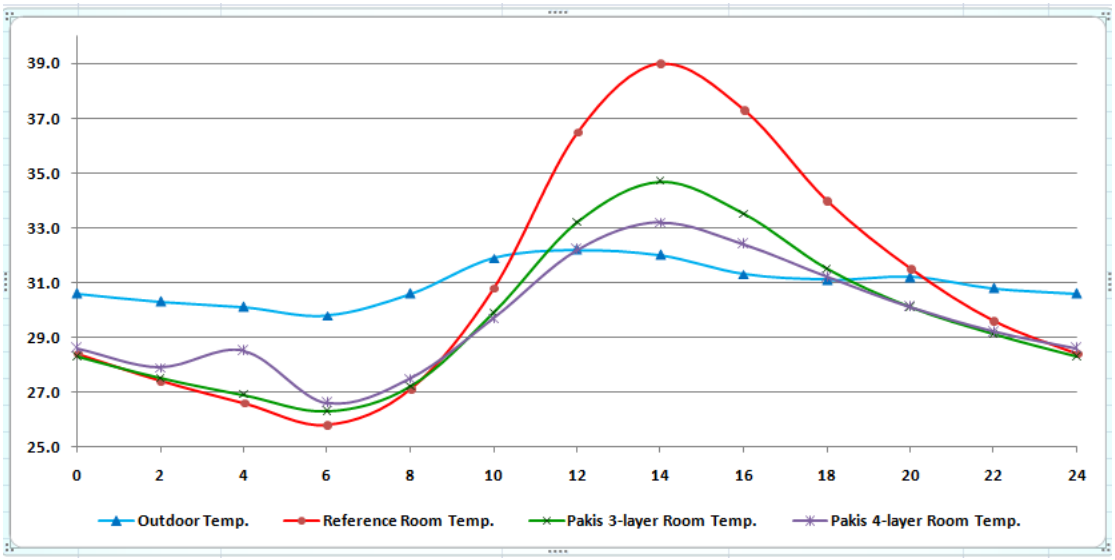


Figure 18 Room Temperatures on November 2011

4.5 Thermal Performances for Pakis 5-layer versus Foam 1-layer

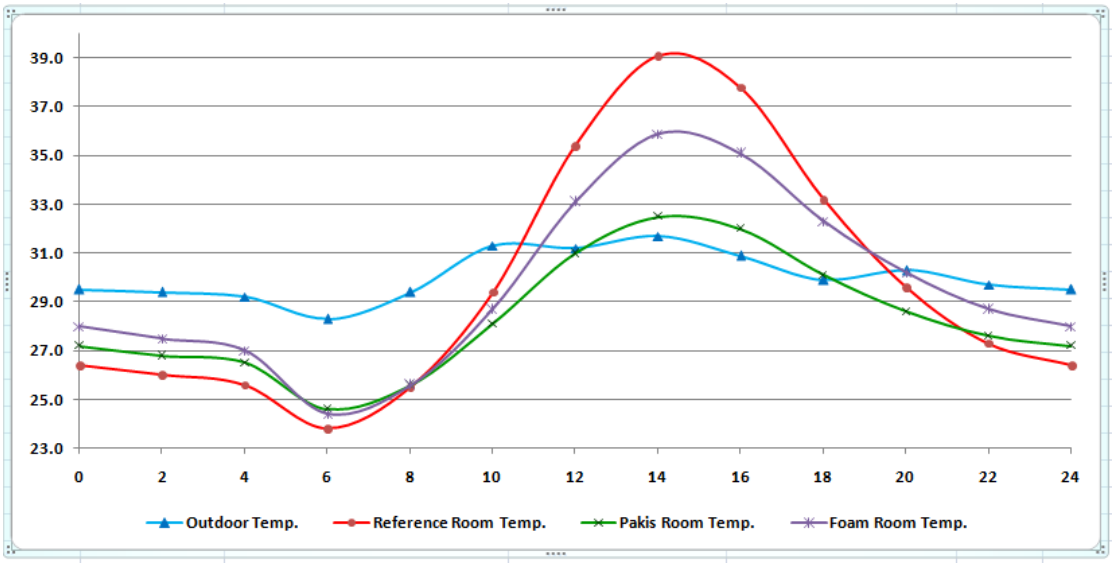


Figure 19 Room Temperatures Pakis 5-layer >< Foam 1-layer on November 2011

4.6 Thermal Performances for Pakis 5-layer versus Foam 2-layer

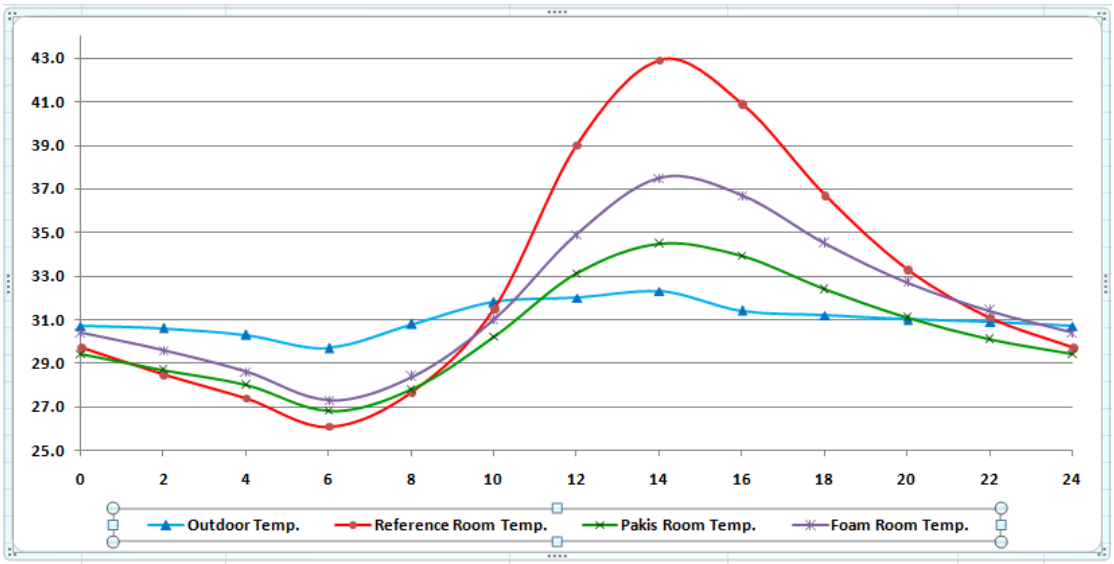


Figure 20 Room Temperatures Pakis 5-layer >< Foam 2-layer on November 2011

4.7 Thermal Performances for Pakis 5-layer versus Foam 3-layer

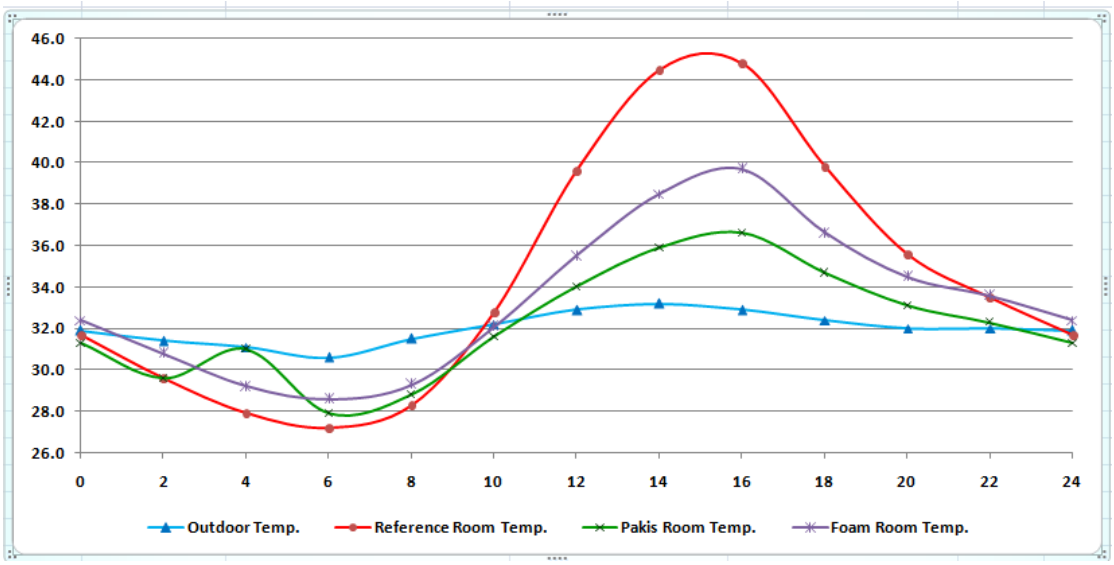


Figure 20 Room Temperatures Pakis 5-layer >< Foam 3-layer on November 2011

4.8 Thermal Performances for Pakis 5-layer versus Foam 4-layer

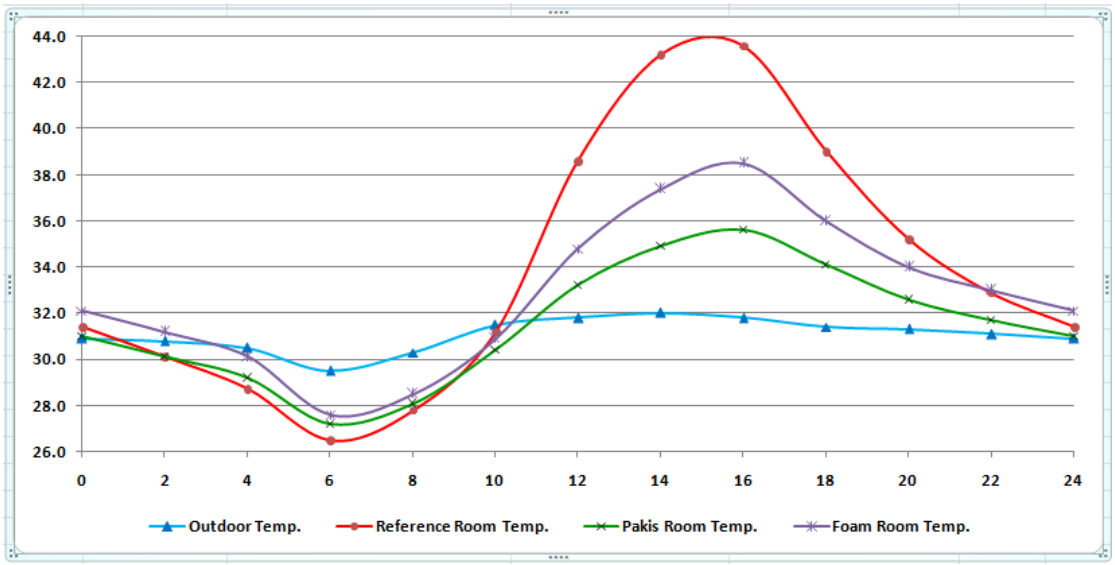


Figure 21 Room Temperatures Pakis 5-layer >< Foam 4-layer on November 2011

4.9 Thermal Performances for Pakis 5-layer versus Foam 5-layer

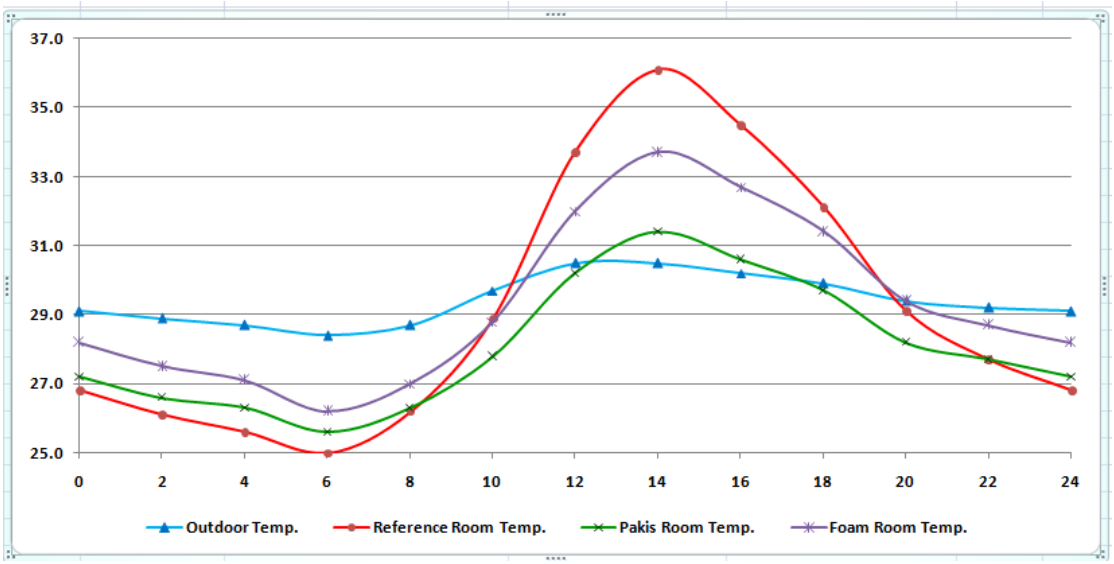


Figure 22 Room Temperatures Pakis 5-layer >< Foam 5-layer on November 2011

5.0 Thermal Performances for Pakis 5-layer versus Foam 6-layer

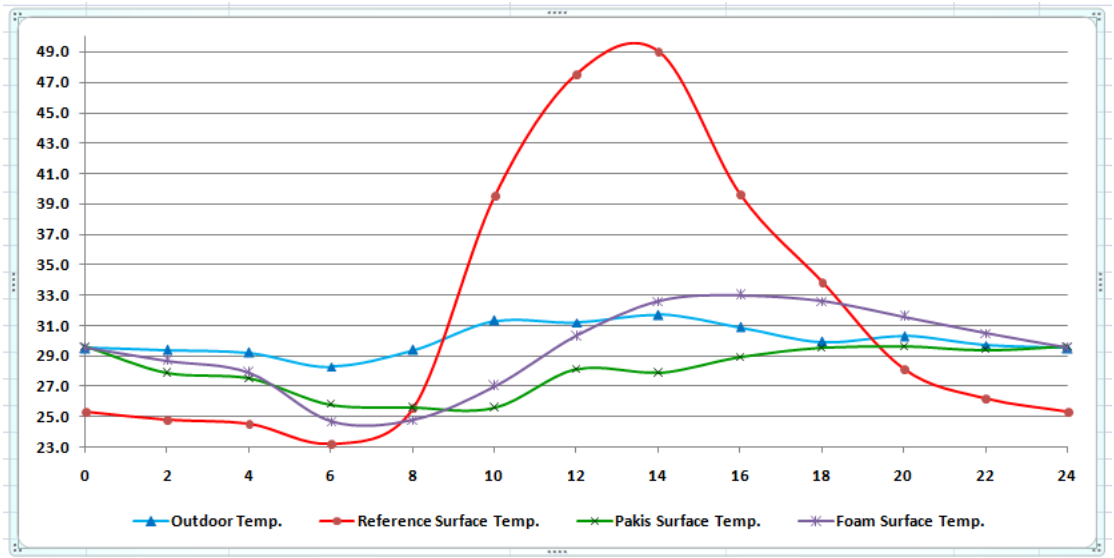
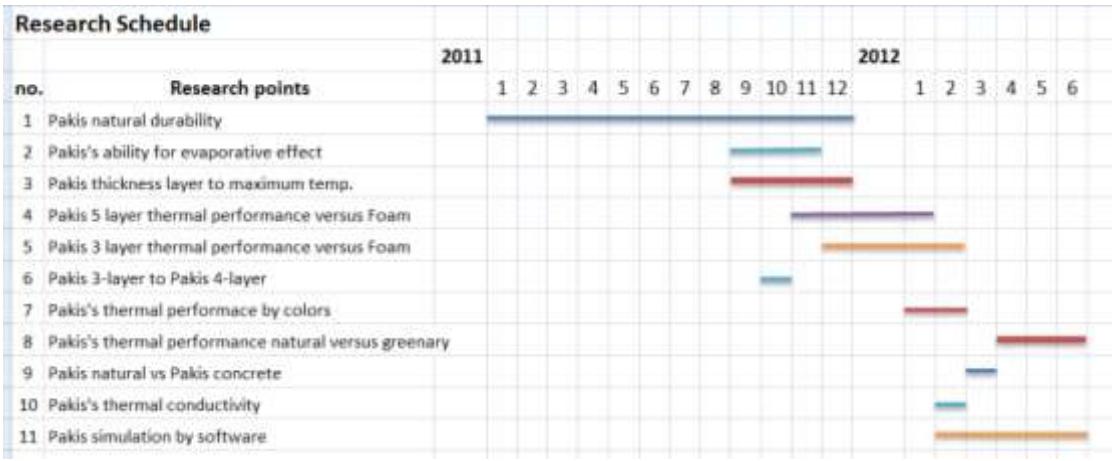


Figure 23 Room Temperatures Pakis 5-layer >< Foam 6-layer on November 2011

Research schedule



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