Exploring the **Agro Bio-Waste Cellulosic Fibers** as a **Potential Drywall Insulation Board** Material for Sustainable Building Use

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PRESENT CONDITION Analysis

1

Present State of <u>BANANA INDUSTRY</u>

1. Food and Agriculture
2. Papyrus Australia Ltd. developed a world-first technology that *converts banana stem wastes* into alternative wood products to be used in the paper, packaging, furniture, **building construction**, and other industries.

2

Present State of **<u>RICE INDUSTRY</u>**

1. Food and Agriculture
2. *Enviro* Board Corporation introduces their **Enviro Board Panels** which are solid "concrete-like" fiber panel comprised of *highly compressed straw fibers*.

3

Present State of **<u>PAPER INDUSTRY</u>**

1. Versatile material for writing, packaging, advertising, and others
2. Trending application of waste paper in developing new building material is its *integration with concrete*. This is also known as ***papercrete***.

PRESENT CONDITION Analysis

4

Present State of **DRYWALL INDUSTRY**

1. Faster Construction
2. Lightweight
3. Flexibility
4. High Performance (Acoustic and Thermal)
5. Sustainable

5

Building **THERMAL PERFORMANCE**

1. Design Variables
2. **Material Data/ Property >> BIO-WASTE DRYWALL PARTITION**
3. Weather Data
4. Building Data Usage

GENERAL objective

The goal of this study was to **explore the thermal performance of bio-wastes cellulosic fibers** that can become potential thermal insulating material based on their thermal properties.

STATEMENT of the problem

General Problem:

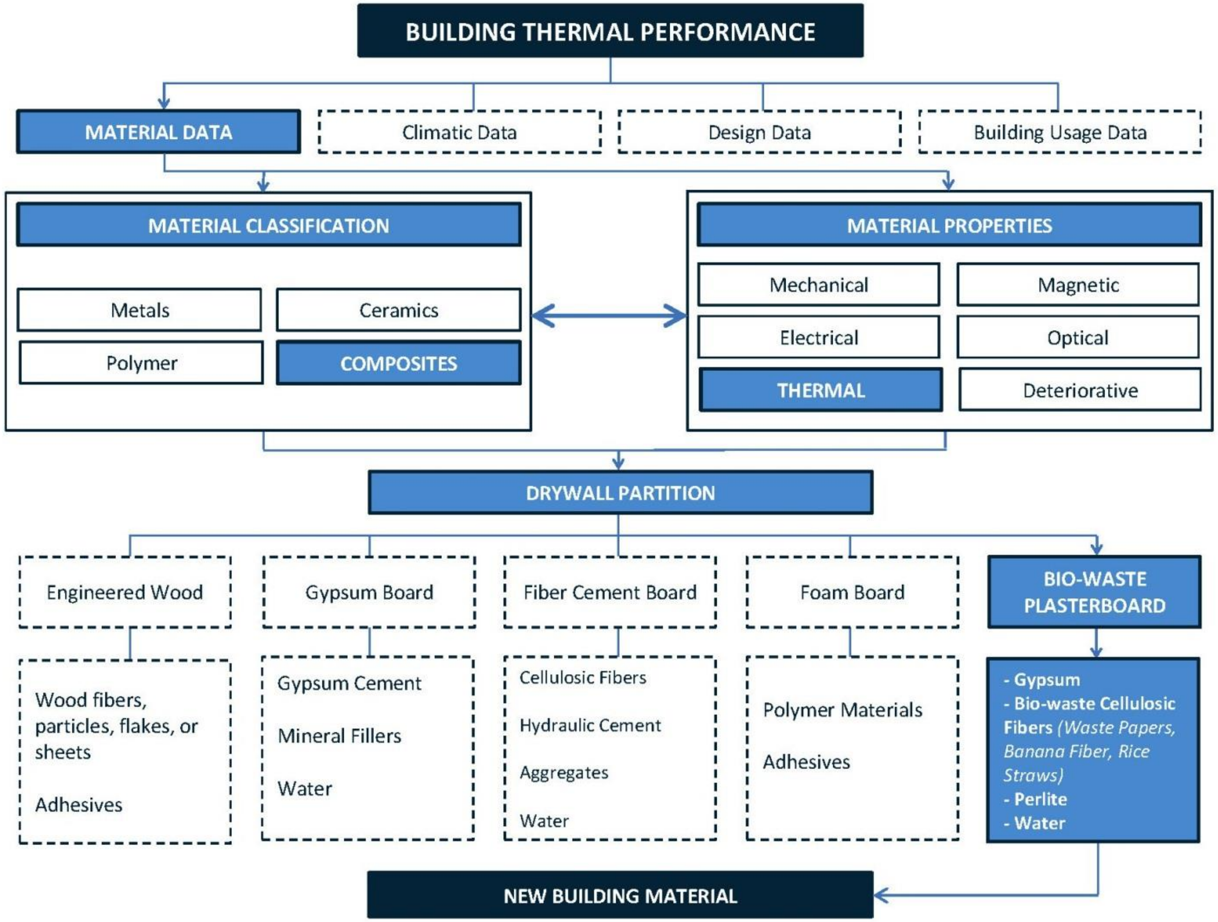
Which among the various mixture formulation of bio-waste cellulosic fibers (*Banana Fiber, Rice Straw, and Waste Paper*) exhibits low thermal conductivity and the best thermal insulating value?

STATEMENT of the problem

Specific Problem:

- What thermal conductivity and resistivity values were obtained among the various fiber-formulation ratios and which the *fiber – plaster formulation exhibited a high thermal conductivity and the best thermal insulating value*?
- What were their respective moisture and water absorptivity?
- What were the difference in values of its *thermal conductivity and resistivity,* and the *heating capacity* of the material compared with the current commercial drywall partition (*e.g. Plasterboards, Gypsum Wallboard, and etc*.)?

CONCEPTUAL Framework



Phase | ONE

Sample COLLECTION and PREPARATION

formulation

RAW materials


1 Plaster of Paris


3 Banana Fiber


5 Rice Straw


2 Perlite


4 Waste Paper Fiber


6 Water

material sample	Water	Plaster of Paris	Perlite	Banana Fiber	Rice Straw	Waste Paper
P-1	600 g	600 g				
P-2	720 g	420 g	180 g			
WR	1140 g	420g	90 g		45 g	45g
WB	600 g	420 g	90 g	45g		45 g
RB	600 g	420 g	90 g	45 g	45 g	
WRB	600 g	420 g	45g	30 g	30 g	30 g

MIXTURE formulation

1 Sun-dried Rice Straws

2 Cutting/ Chopping

3 Disintegration *(for finer particles)*

4 Sieved Rice Straw Sample

5 Weighing

RICE STRAW extraction process

BANANA FIBER extraction process

1. **Sun-dried Banana Fiber**

2. **Cutting/ Chopping**

3. **Disintegration** *(for finer particles)*

4. **Sieved Banana Fiber Sample**

5. **Weighing**

WASTE PAPER extraction process

1. Sorting

2. Shredding

3. Weighing

4. Soaking for 24 hours

5. Paper Sludge

1 • • • • • • • • • • 2 • • • • • • • • • • 3 • • • • • • • • • • 4

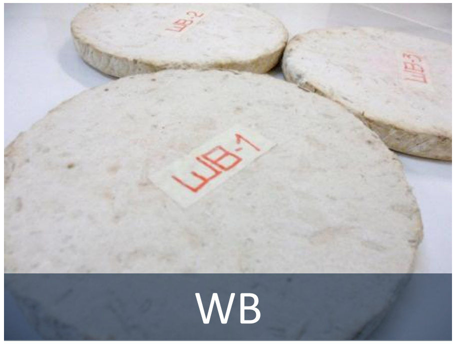
Pouring Slurry into Steel Molds	Screeding	Air-curing *(2 to 3 days)*	Kiln-drying

FORMING and DRYING process

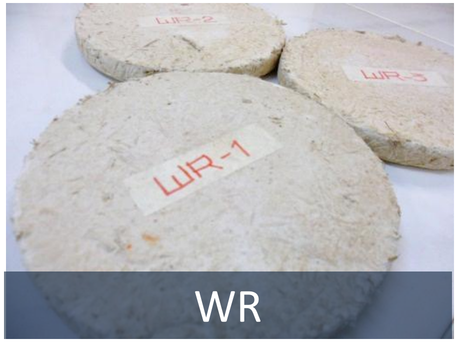
material samples

P-1

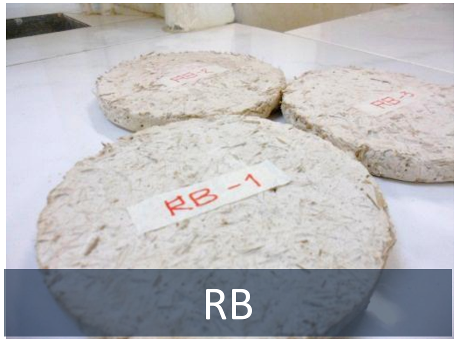
P-2



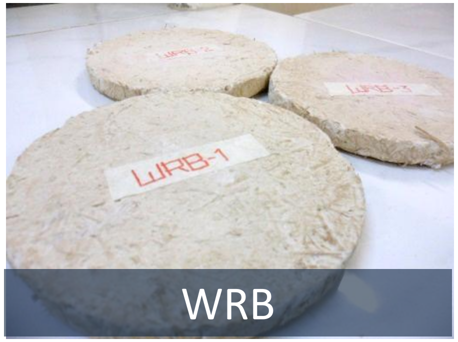
WB



WR



RB



WRB

material sample	TOP face	TEXTURE	Color	Texture	Chipped Corners
P-1			White	Fine Texture	None
P-2			Snowy White	Finer Texture	None
WR			Dirty White	Finer Fibrous Texture, More Powdery	Yes
WB			Dirty White	Fine Fibrous Texture, More Powdery	Yes
RB			Light Brown	Fibrous Texture, Rougher Texture Powdery	Yes
WRB			Lighter Brown	Fibrous Texture, Rough Texture Powdery	Yes

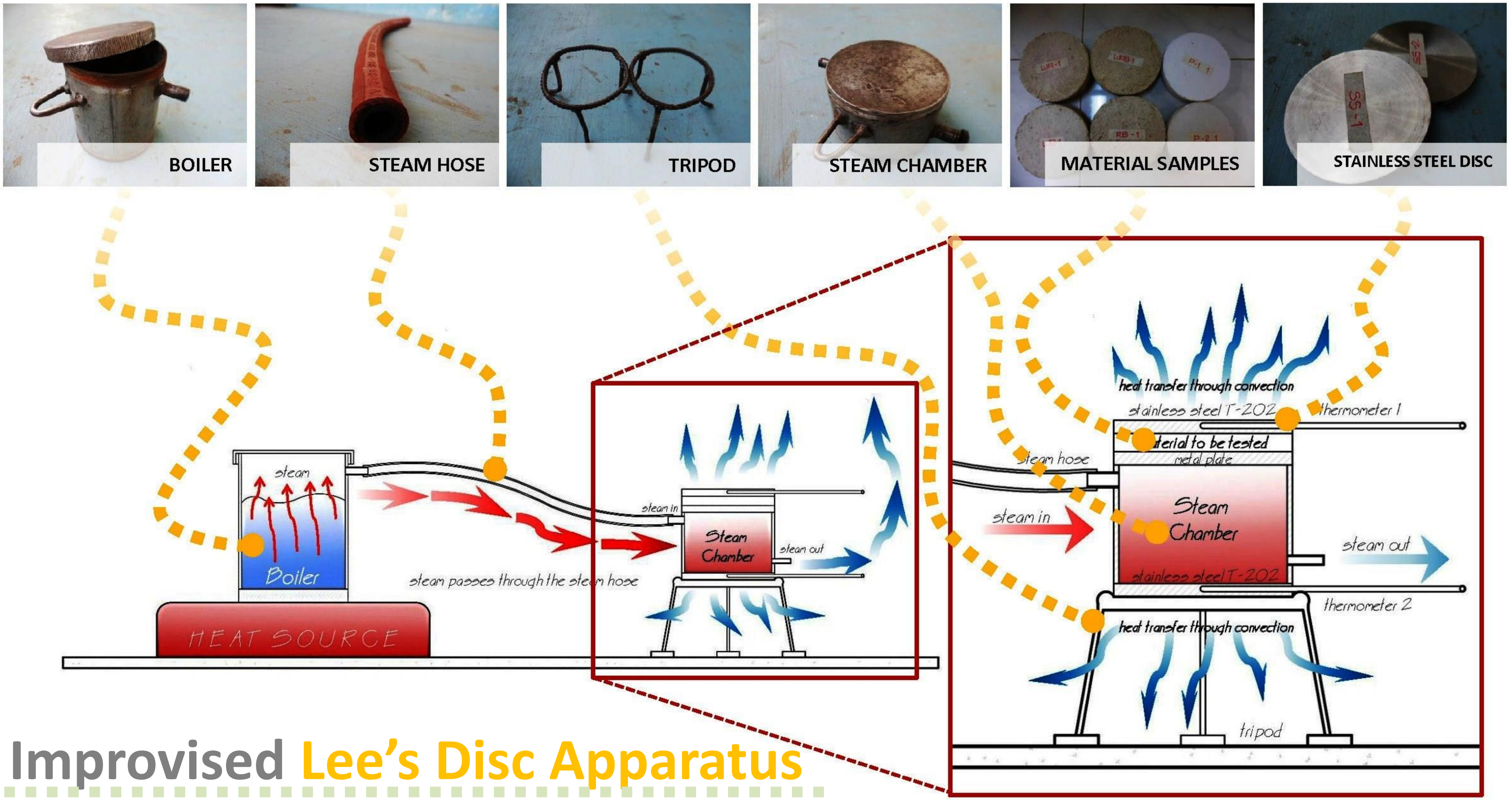
PHYSICAL Characteristics

Phase | TWO

MATERIAL TESTING:

Determining Thermal Conductivity, Thermal Resistivity, and Moisture and Water Absorptivity

experimental set-up



Improvised Lee's Disc Apparatus

Determination of Thermal Conductivity and Thermal Resistivity

ACTUAL experimental set-up

ACTUAL experimental set-up

THERMAL Conductivity and Resistivity

FORMULA:

1. Thermal Conductivity (k):

$$k = \frac{m_{SS} c_{SS} d_{SS} \left(\frac{dT}{dt}\right)}{A_{MS}\,(T_1 - T_2)}$$

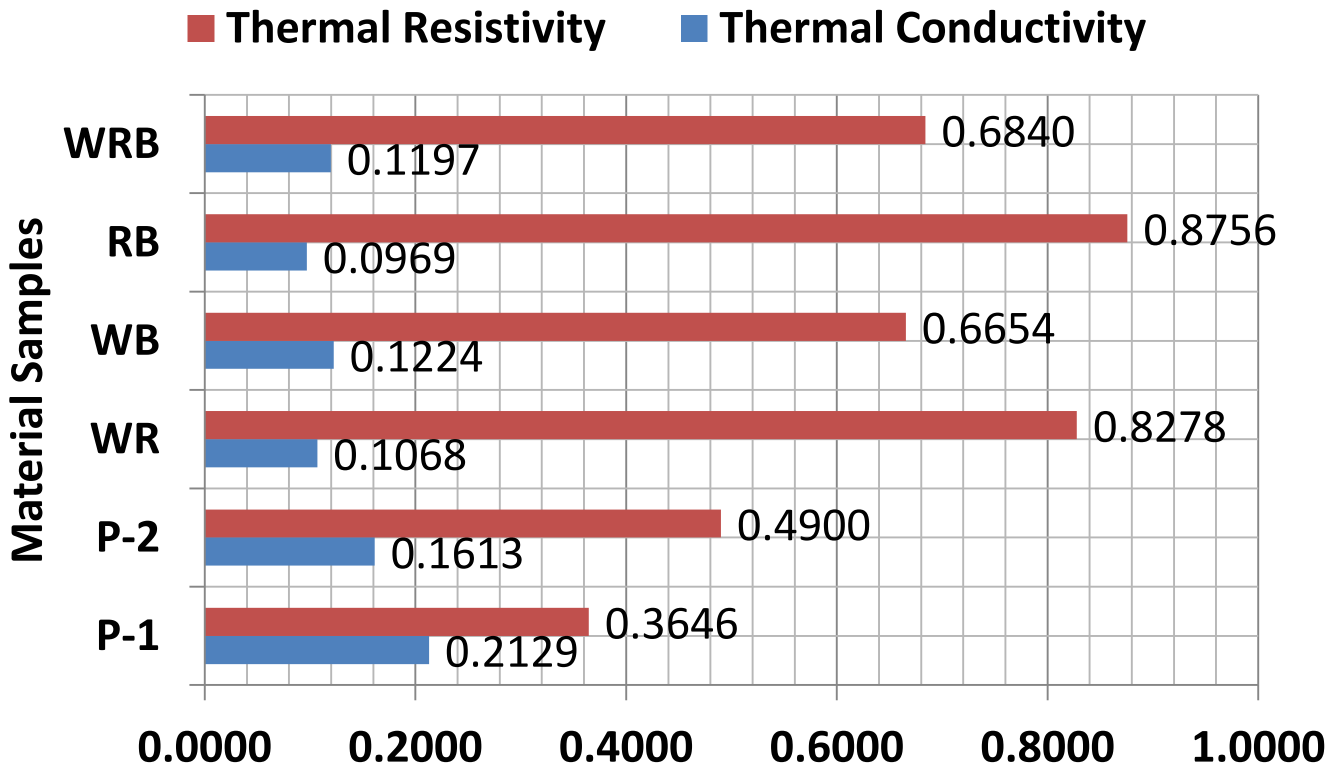
m_{SS} - mass of stainless steel
c_{SS} - specific heat of stainless steel
d_{SS} - thickness of stainless steel
$\left(\frac{dT}{dt}\right)$ - rate of cooling
A_{MS} - area of Material Sample
$(T_1 - T_2)$ – Temperature Difference

2. Thermal Resistivity (R-Value)

$$R = \frac{x}{k}$$

x - thickness of material sample
k – thermal conductivity

THERMAL Conductivity and Resistivity



Moisture Absorptivity Testing

1 2 3 4

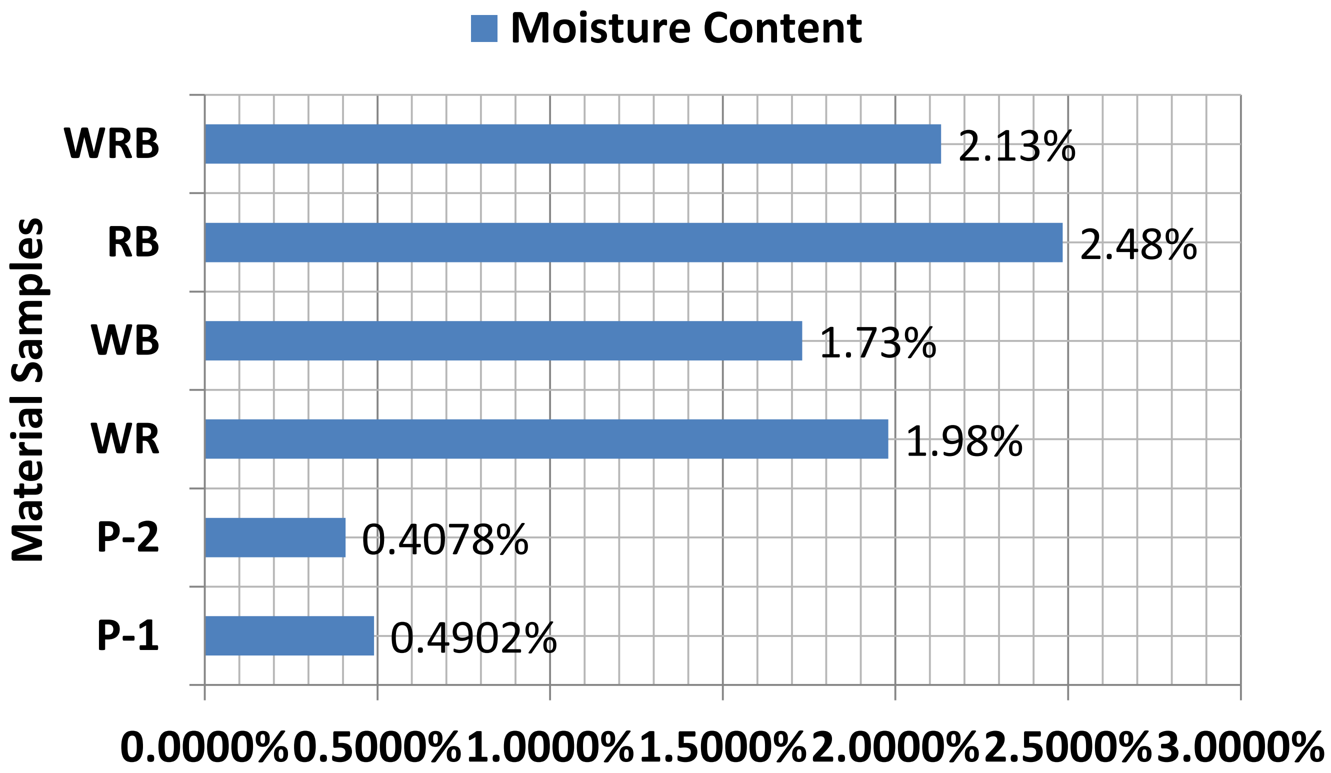
1. Weighing of Materials
2. Placing Materials inside a Circulating oven at 90±2°C for 1 hour
3. Cooling down of Material samples inside a Desiccator at Room Temperature for 30 minutes
4. Weighing of Materials

MOISTURE Absorptivity Testing

FORMULA:

$$\boldsymbol{M\% = \frac{|Initial\,Weight - Final\,Weight|}{|Final\,Weight|} X\,100}$$

MOISTURE Content



WATER Absorptivity Testing

1 ··············· 2

Soaking of Material Samples in Water for 24 hours

Weighing of Material Samples

WATER Absorptivity Testing

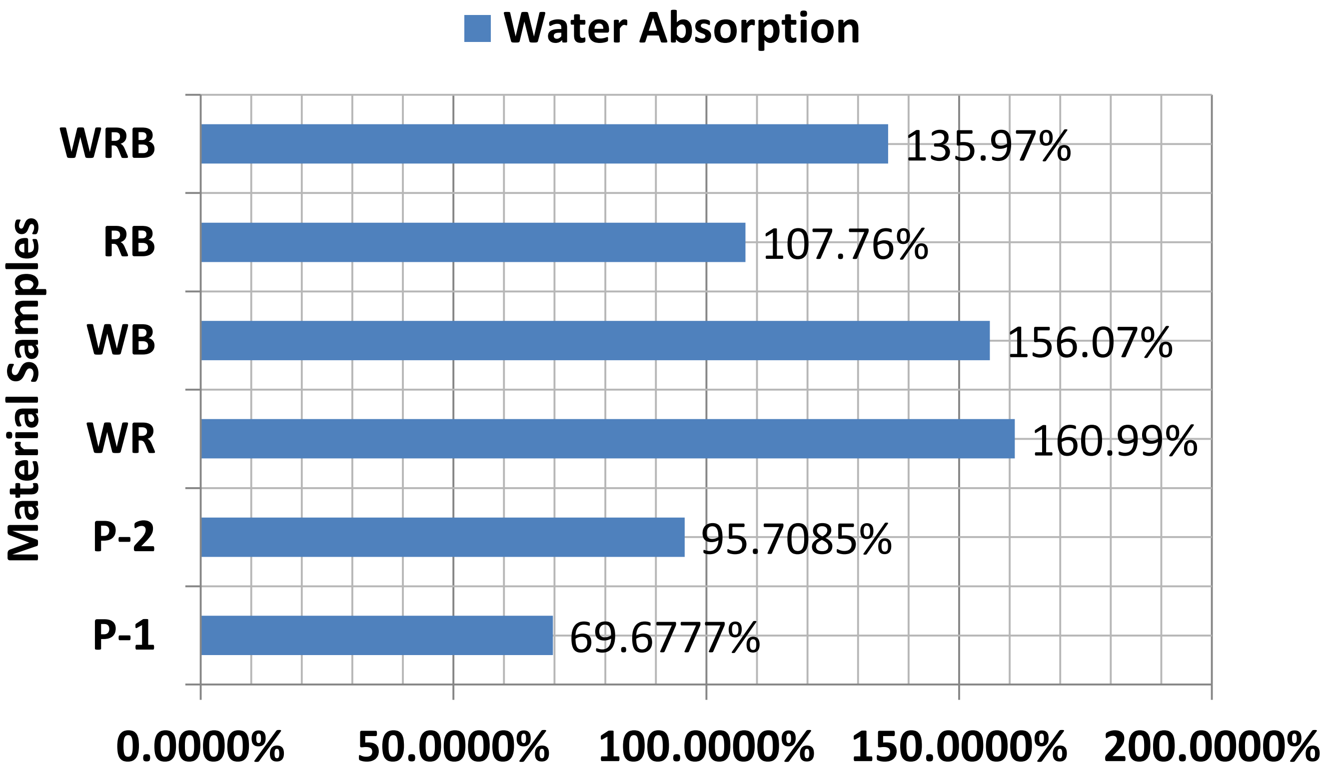
FORMULA:

$$M\% = \frac{|W_s - W_d|}{|W_d|} X\ 100$$

where,

W_s *is the weight of saturated samples in grams and;*
W_d *is the weight of dry samples in grams*

WATER Absorptivity



Phase | three

1. **Statistical** Analyses
2. **Comparative** Analyses
3. **Building Heat Gain** Analyses

STATISTICAL Analyses

ONE-WAY Anova

ANOVA

		Sum of Squares	df	Mean Square	F	Sig.
THERMAL_CONDUCTIVITY	Between Groups	.028	5	.006	25.219	.000
	Within Groups	.003	12	.000		
	Total	.031	17			
THERMAL_RESISTIVITY	Between Groups	.573	5	.115	56.881	.000
	Within Groups	.024	12	.002		
	Total	.597	17			
MOISTURE_CONTENT	Between Groups	.001	5	.000	66.832	.000
	Within Groups	.000	12	.000		
	Total	.001	17			
WATER_ABSORPTIVITY	Between Groups	1.950	5	.390	308.927	.000
	Within Groups	.015	12	.001		
	Total	1.966	17			

p value *< 0.005*

COMPARATIVE Analyses

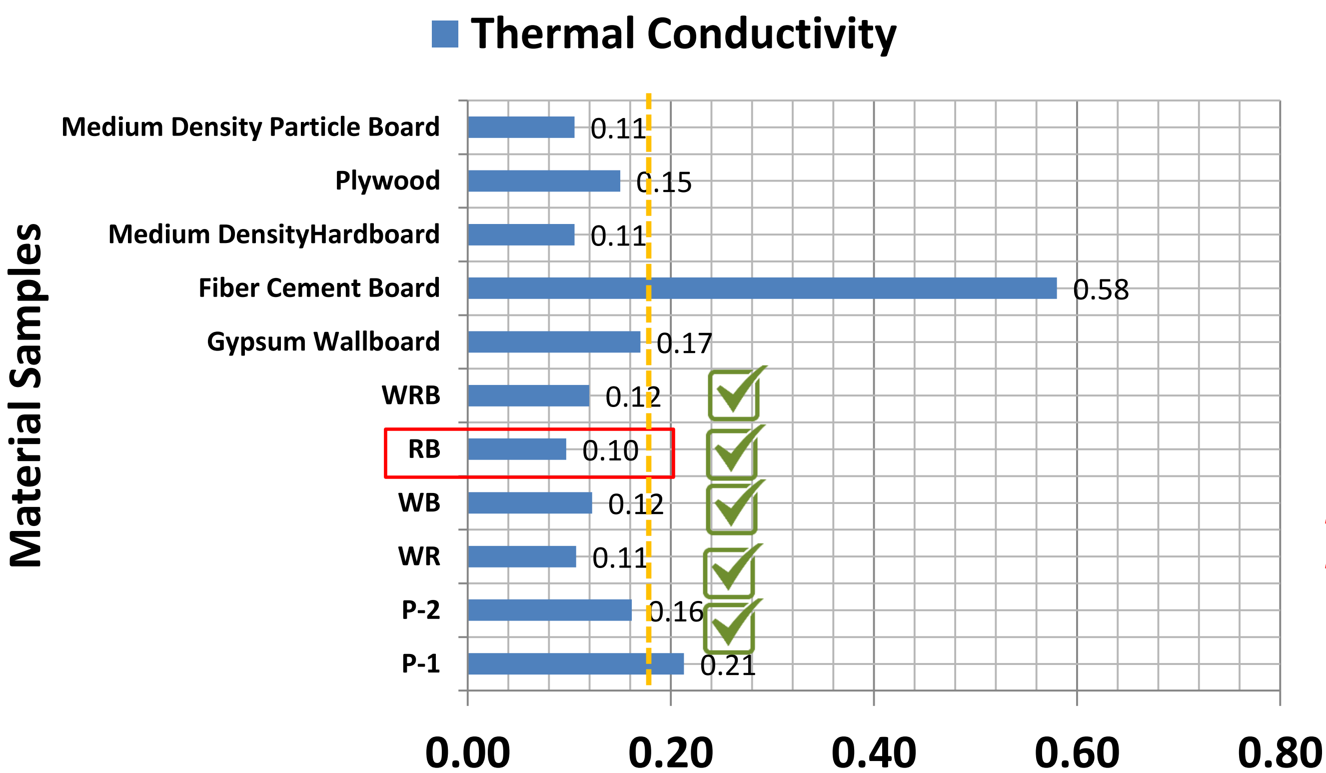
TESTED MATERIAL

vs.

Commercially Available

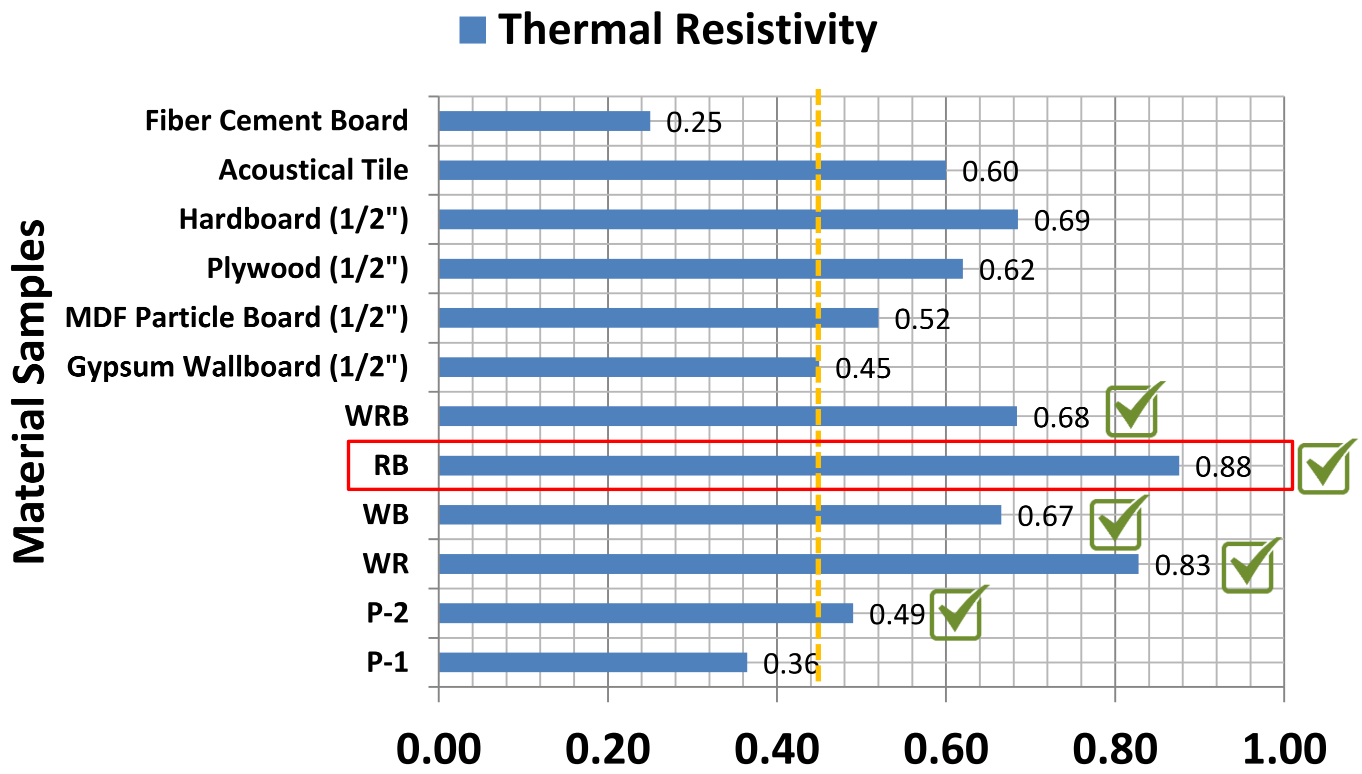
Drywall Partition Boards

THERMAL Conductivity and Resistivity



Remarks:
The lower the value means the slower heat transfer

THERMAL Conductivity and Resistivity



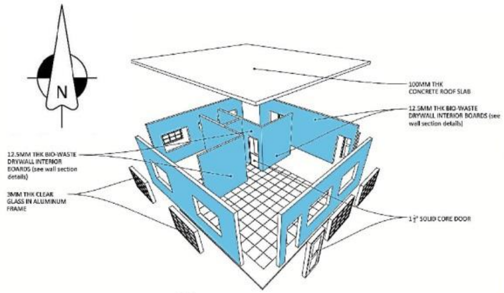
Remarks:
The Higher the value means the more Thermal Insulating

BUILDING HEAT GAIN Analyses

HEAT GAIN - calculated for the purpose of cooling system design.

1. *Identification of Heat Gain Factors, U-Factor (Walls, Roof, Door, Glass)*
2. *Determining heat loads caused by opaque building construction*
3. *Calculation of solar heat gains through all opening, using shading coefficients – glass, shading screens, etc.*
4. *Identification and computation of internal heat gain (occupants, appliances, lighting)*
5. *SUMMATION.*

Thermal Transmittance (U-Value)

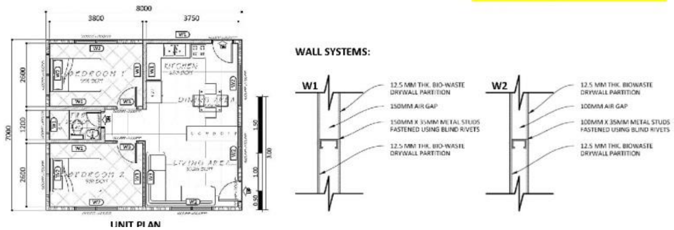


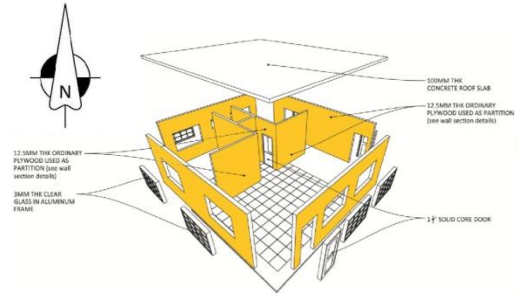
R Values: W1

Airfilm Outside	0.20
Airfilm Inside Building	0.70
Air Gap (6")	1 (6)
Bio-Waste Drywall Partition (1/2")	0.88 (2)
Total	8.66
U-Factor ($1/R_{Total}$), *BTU/ft²-hr-°F*	0.12
U-Factor(in metric), W/m²-K	**0.66**

R Values: W2

Airfilm Inside Building	0.70 (2)
Air Gap (4")	1 (4)
Bio-Waste Drywall Partition (1/2")	0.88 (2)
Total	7.16
U-Factor ($1/R_{Total}$), *BTU/ft²-hr-°F*	0.14
U-Factor(in metric), W/m²-K	**0.79**



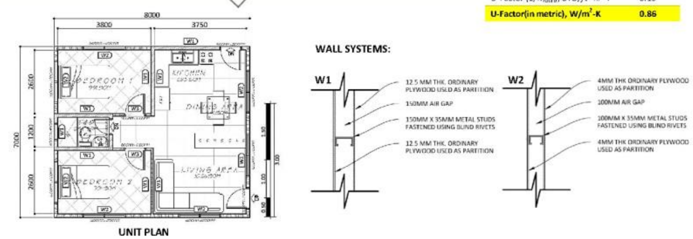


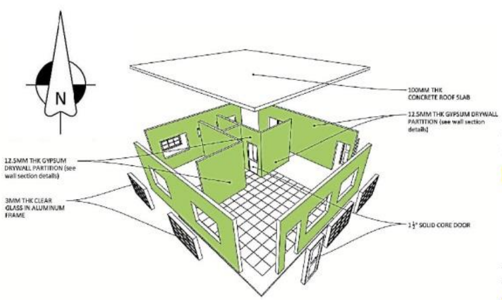
R Values: W1

Airfilm Outside	0.20
Airfilm Inside Building	0.70
Air Gap (6")	1 (6)
Ordinary Plywood (12.5mm)	0.62 (2)
Total	8.14
U-Factor ($1/R_{Total}$), *BTU/ft²-hr-°F*	0.12
U-Factor(in metric), W/m²-K	**0.70**

R Values: W2

Airfilm Inside Building	0.70 (2)
Air Gap (4")	1 (4)
Ordinary Plywood (12.5mm)	0.62 (2)
Total	6.64
U-Factor ($1/R_{Total}$), *BTU/ft²-hr-°F*	0.15
U-Factor(in metric), W/m²-K	**0.86**



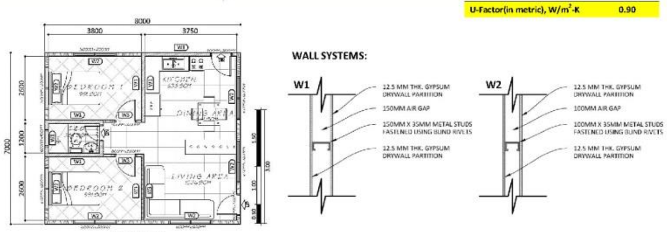


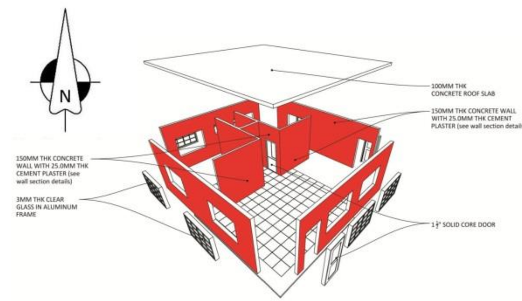
R Values: W1

Airfilm Outside	0.20
Airfilm Inside Building	0.70
Air Gap (6")	1 (6)
Gypsum Drywall Partition (1/2")	0.45 (2)
Total	7.80
U-Factor ($1/R_{Total}$), *BTU/ft²-hr-°F*	0.13
U-Factor(in metric), W/m²-K	**0.73**

R Values: W2

Airfilm Inside Building	0.70 (2)
Air Gap (4")	1 (4)
Gypsum Drywall Partition (1/2")	0.45 (2)
Total	6.30
U-Factor ($1/R_{Total}$), *BTU/ft²-hr-°F*	0.16
U-Factor(in metric), W/m²-K	**0.90**



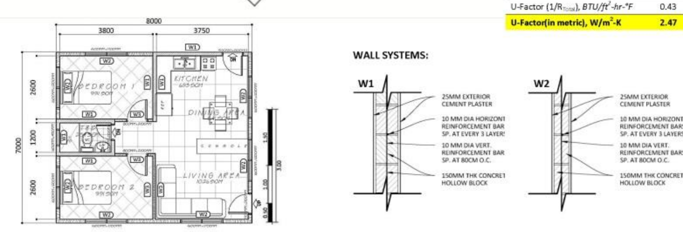


R Values: W1

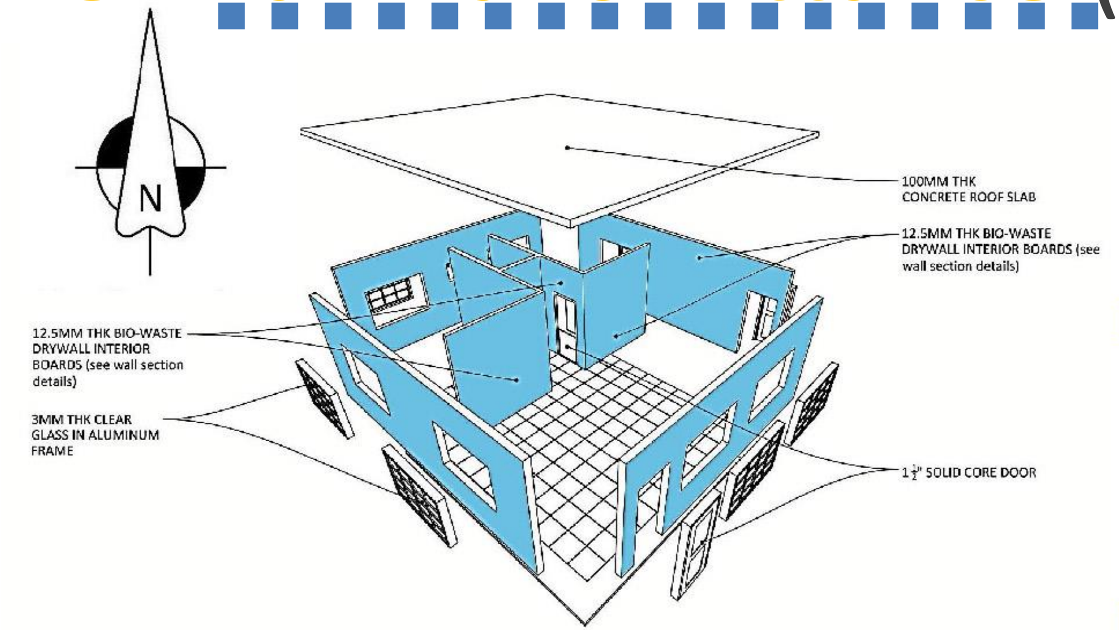
Airfilm Outside	0.20
Airfilm Inside Building	0.70
Cement Plaster (1")	2 (0.10)
Concrete Hollow Block (5")	0.875
Total	1.98
U-Factor ($1/R_{Total}$), *BTU/ft²-hr-°F*	0.51
U-Factor(in metric), W/m²-K	**2.87**

R Values: W2

Airfilm Inside Building	0.70 (2)
Cement Plaster (1")	2 (0.10)
Concrete Hollow Block (4")	0.70
Total	2.30
U-Factor ($1/R_{Total}$), *BTU/ft²-hr-°F*	0.43
U-Factor(in metric), W/m²-K	**2.47**



Thermal Transmittance (U-Value)



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Air Gap (6")	1 (6)
Bio-Waste Drywall Partition (1/2")	0.88 (2)
Total	8.66
U-Factor ($1/R_{Total}$), *BTU/ft²-hr-°F*	0.12
U-Factor(in metric), W/m²-K	**0.66**

R Values: W2

Airfilm Inside Building	0.70 (2)
Air Gap (4")	1 (4)
Bio-Waste Drywall Partition (1/2")	0.88 (2)
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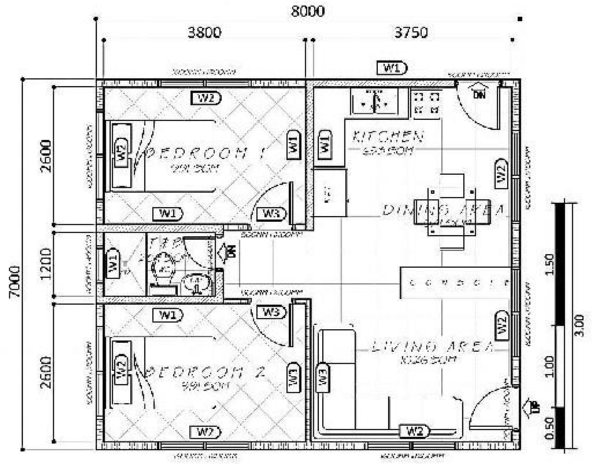
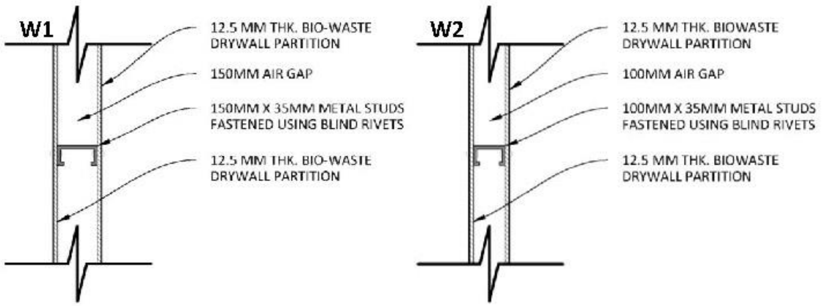


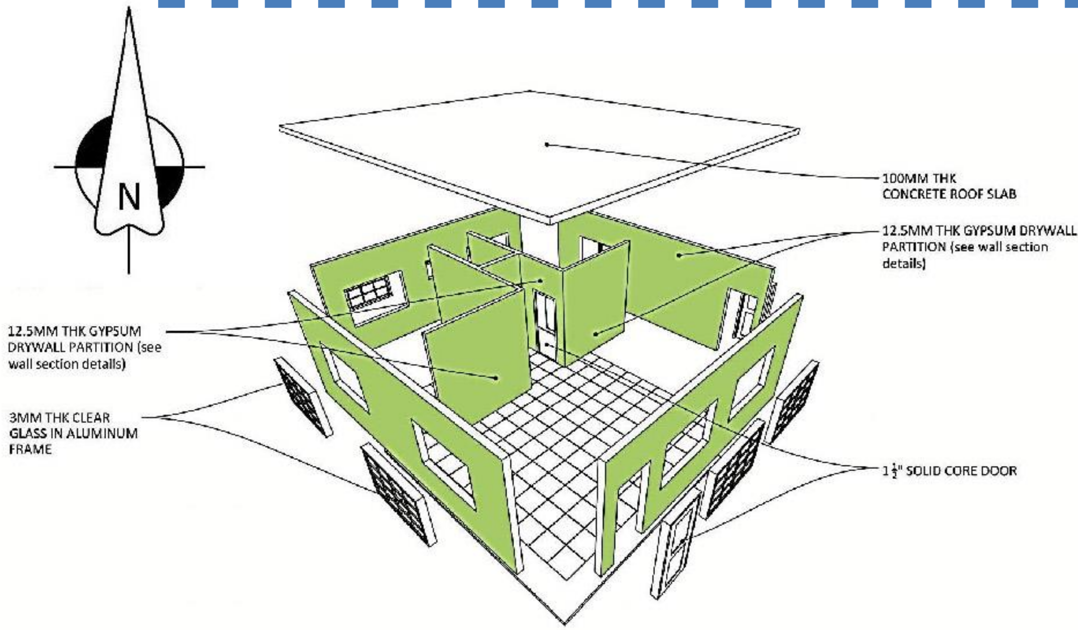
UNIT PLAN

WALL SYSTEMS:



BIO-WASTE Drywall Partition

Thermal Transmittance (U-Value)



R Values: W1

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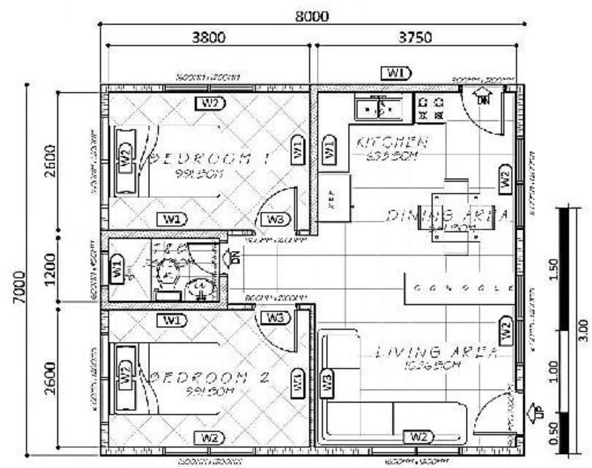
Airfilm Inside Building	0.70
Air Gap (6")	1 (6)
Gypsum Drywall Partition (1/2")	0.45 (2)
Total	7.80
U-Factor ($1/R_{Total}$), BTU/ft^2-hr-°F	0.13
U-Factor(in metric), W/m^2-K	**0.73**

R Values: W2

Airfilm Inside Building	0.70 (2)
Air Gap (4")	1 (4)
Gypsum Drywall Partition (1/2")	0.45 (2)
Total	6.30
U-Factor ($1/R_{Total}$), BTU/ft^2-hr-°F	0.16
U-Factor(in metric), W/m^2-K	**0.90**



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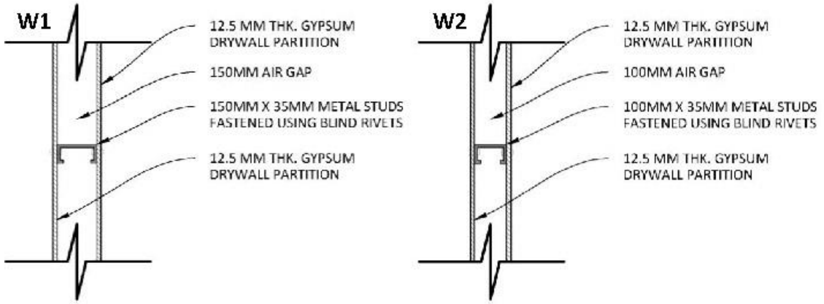
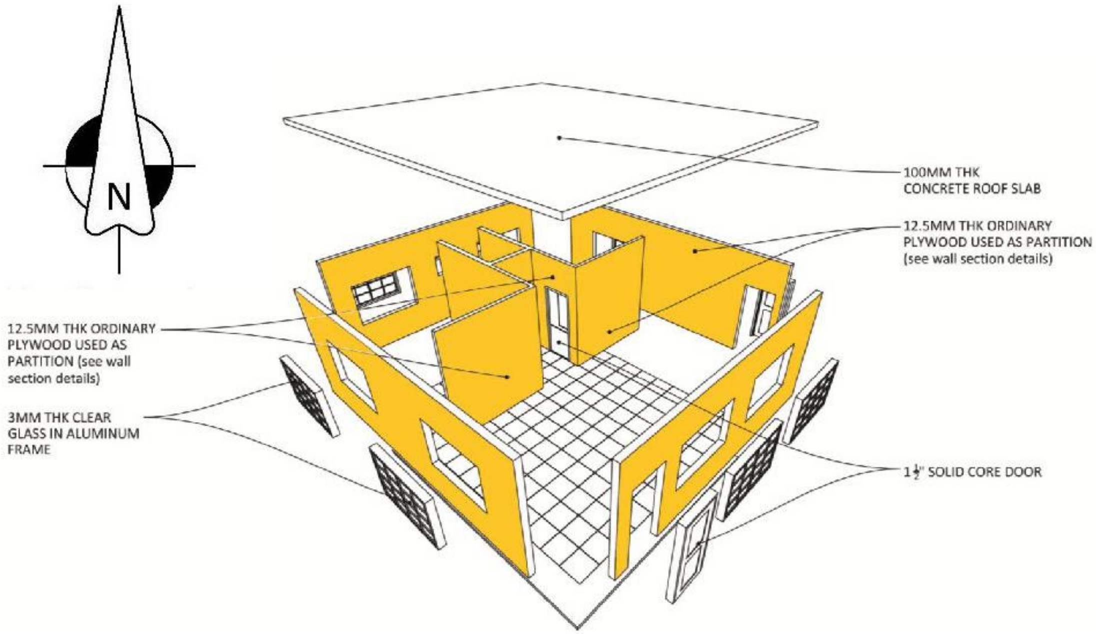
WALL SYSTEMS:



GYPSUM Drywall Partition

Thermal Transmittance (U-Value)

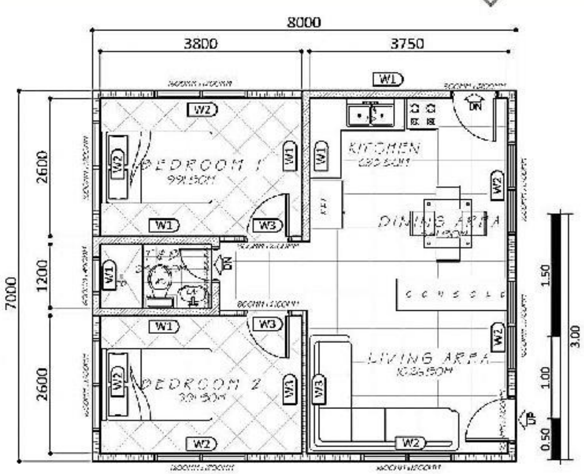


R Values: W1

Airfilm Outside	0.20
Airfilm Inside Building	0.70
Air Gap (6")	1 (6)
Ordinary Plywood (12.5mm)	0.62 (2)
Total	8.14
U-Factor (1/R_{Total}), BTU/ft^2-hr-°F	0.12
U-Factor(in metric), W/m²-K	**0.70**

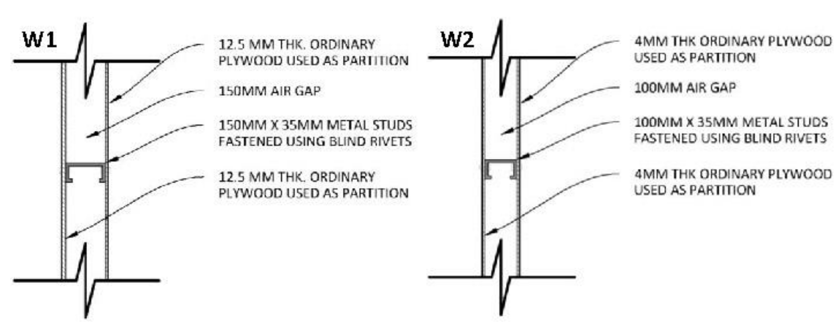
R Values: W2

Airfilm Inside Building	0.70 (2)
Air Gap (4")	1 (4)
Ordinary Plywood (12.5mm)	0.62 (2)
Total	6.64
U-Factor (1/R_{Total}), BTU/ft^2-hr-°F	0.15
U-Factor(in metric), W/m²-K	**0.86**



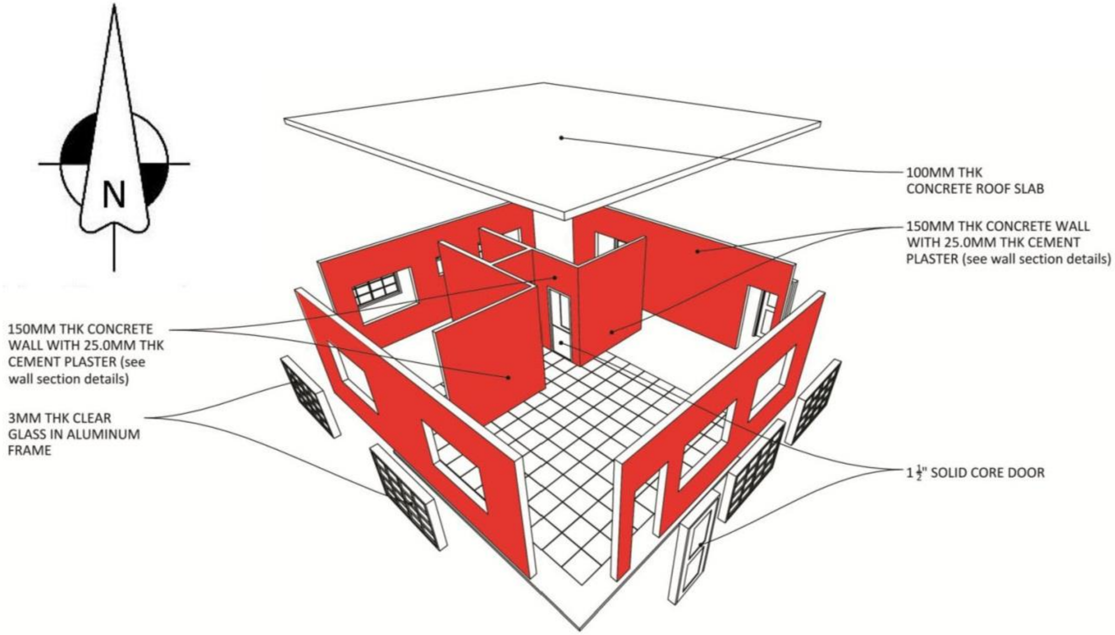
UNIT PLAN

WALL SYSTEMS:



PLYWOOD Wall System

Thermal Transmittance (U-Value)

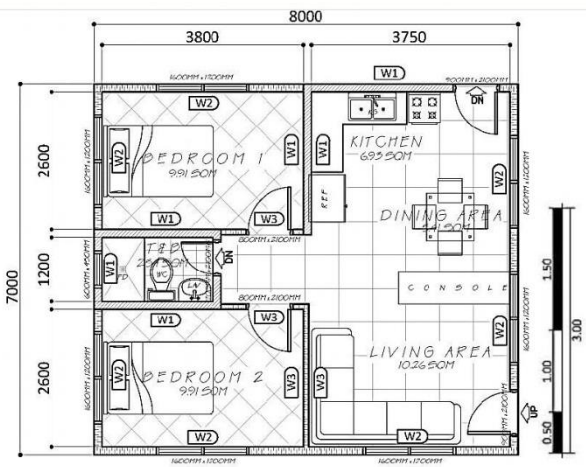


R Values: W1

Airfilm Outside	0.20
Airfilm Inside Building	0.70
Cement Plaster (1”)	2 (0.10)
Concrete Hollow Block (5”)	0.875
Total	1.98
U-Factor (1/R_{Total}), *BTU/ft²-hr-°F*	0.51
U-Factor(in metric), W/m²-K	**2.87**

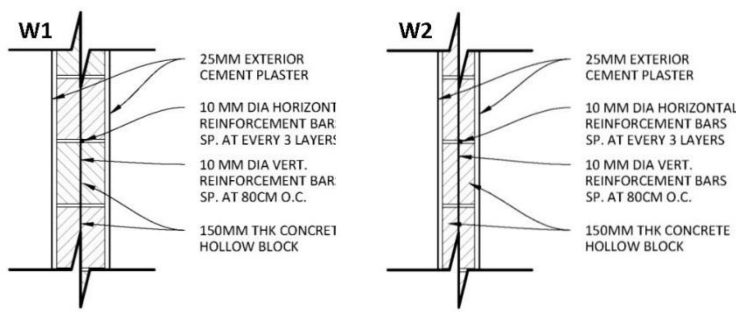
R Values: W2

Airfilm Inside Building	0.70 (2)
Cement Plaster (1”)	2 (0.10)
Concrete Hollow Block (4”)	0.70
Total	2.30
U-Factor (1/R_{Total}), *BTU/ft²-hr-°F*	0.43
U-Factor(in metric), W/m²-K	**2.47**



UNIT PLAN

WALL SYSTEMS:



CONCRETE Wall System

SUMMARY of Analyses (*Heat Gain*)

WALL SYSTEM	THERMAL TRANSMITTANCE of Walls (U-Value)	TOTAL HEAT GAIN (kW)
Bio-Waste Drywall Board	1.45	22.46
Gypsum Drywall Board	1.63	22.57
Ordinary Plywood	1.56	22.52
Concrete Wall System	5.34	24.88

The lower the values, the ***HIGHER THERMAL INSULATING PROPERTY***

- **THANK YOU FOR YOUR PATIENCE…**