HUYS ADVIES

21 Examples of Floor Insulation

Technical Working Paper ~ Number 4

Existing and Added Thermal Insulation Values for Floors in the Himalayas

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Glossary

AAC	Autoclaved Aerated Concrete	GBM	General Building Materials (ε = 0.9)
EPS	Expanded Polyester	HRF	Highly Reflective Foil (ε = 0.04)
GI	Galvanised Iron	RFPE	Reflective Foil with 3 mm Polyethylene foam backing (ε = 0.1)
MDF	Medium Density Fibre Board		
PE	Polyethylene	Alum	Aluminium reflective foil (ε = 0.04)
PET	Polyethylene Terephthalate	ε = emissivity of material (= < 1)	
PP	Polypropylene (agricultural fibre bags)		

Calculations made in: PKR = Pakistan Rupees   April 2011: Euro 1 = Rupee 120

***Photo Front Page*:**
Elevated timber floor in the dining area of a restaurant.
When sitting on a floor, body heat is lost due to contact with the cold floor. Improving the floor insulation greatly improves the comfort level of the occupants of the house. Keeping the foundation and ground under the house dry avoids a decrease in the insulation value due to moisture.

INTRODUCTION

This document provides examples of insulation methods for floors in existing or new constructions. The designs are feasible in mountain areas where other types of more sophisticated thermal insulation materials are unavailable.

The minimum recommended insulation value is based on the latitude of the Himalayan range (26°-40°North) and the altitude of the house location (1500–4000 m). This value needs to be increased when there is lack of sunshine in the winter. The insulation value is measured between the heated winter room and the ground under the house; this can include a hollow space under the floor.

This recommendation is far below the currently obliged insulation values of Europe where similar climate conditions exist. However, based on the currently available insulation materials, the local resources in the mountain villages and the low-income level of the local inhabitants, these recommended insulation values and the design options have been chosen.

The 21 floor insulation examples compare various insulation methods and materials:

- Straw - Wood Shavings
- EPS - Glass Wool
- Polyethylene (PE) Foam
- Elevated Floor with Air Cavity
- Gas or Aerated Concrete
- Wood-Fibre, Hemp and Straw-Cement
- Reflective Metalized Plastic Foils

Floor Insulation Examples

The number of designs provided is only a sample and can be extended. All the cost options need to be recalculated based on the location and taking self-help or the supply of materials by the house owner into consideration. By comparing different designs with similar insulation values, the Cost/R_C value will indicate which design is more cost-effective.

For the "old situation", basic floors have been used. This will naturally differ per individual situation and the insulation value will need to be adjusted accordingly. The Cost/R_C value of the examples is calculated based on the total insulation (old and new together) as should be undertaken in each individual case.

Calculation Sheets

It would be beneficial to make a booklet with the 100 most common thermal insulation methods for the various altitudes (walls, roofs, floors, windows and doors). The client can then easily choose the insulation method and finishing that best suits his/her situation.

Condensation Point

The calculation sheets have a temperature column. This column can be filled out according to the expected temperatures in the housing area of the client. Based on these temperatures, a temperature line can be drawn in the construction drawing. With the aid of the Mollier diagram, the condensation point can then be determined. Details of the calculation method are presented in HA Technical Working Paper #2 ~ Calculation TI (February 2012).[1]

Cost Reduction

When applying thermal insulation, good quality tools (such as staple machines and nail guns) can substantially reduce the installation cost. Efficient working with adequate scaffolding is important.

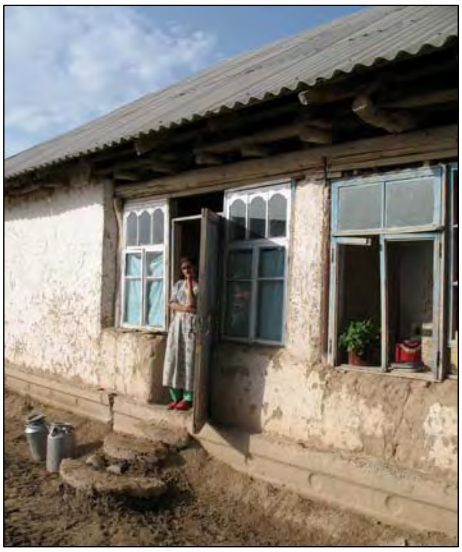
Calculation Methods

For basics on thermal insulation, calculation methods of thermal insulation values and detailed tables of various values of materials, see: www.nienhuys.info (page thermal insulation).

[1] See: www.nienhuys.info

1. MOISTURE IN FOUNDATIONS

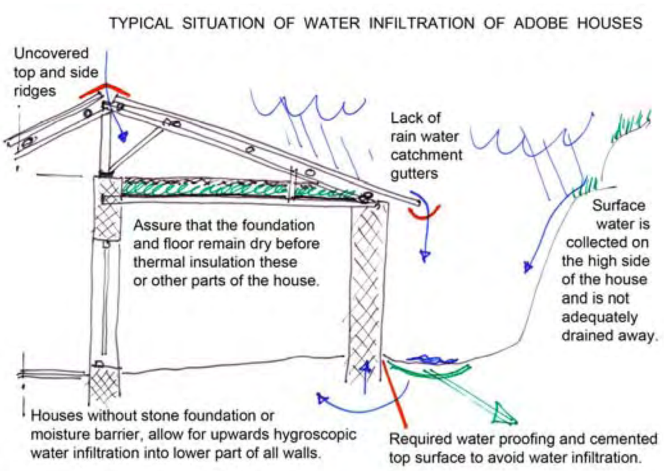
The calculations in the tables are based on the situation during the winter. Snow will cause wet soils and this moisture can get under the building or rise into the walls by hygroscopic action. Keeping the walls and underground dry is necessary to have optimum insulation and to avoid rotting of timber elements. A damp-proofing layer in the foundation walls is necessary to keep the upper wall dry. Damp proofing can be done with thick plastic foils (0.2 mm), asphalt paper, butyl foils (rubber) or a very high-density reinforced concrete layer.



The waterproofing course (photo above) is visible between the natural stone foundation and the adobe upper structure. The natural stone will not be affected by moisture. The waterproofing course eliminates moisture rising from the underground through the mortar.

The foundation of the adobe house (above right-hand photo) is made of reinforced concrete posts. Due to their high density, the posts will stop any hygroscopic action.

It is important that water from the roof is drained away from the foundation or that the foundation is well protected by an outside cemented splash plinth at least 90 cm high. Especially with houses built on slopes, care must be taken to avoid water from the upper slope infiltrating behind and under the house.



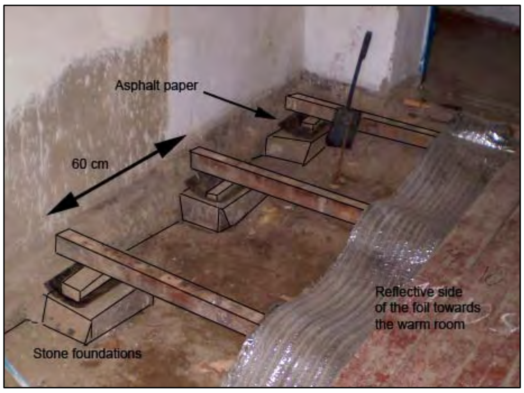
Houses with moist or wet underground are uncomfortable during the winter. When adobe walls remain moist for a long period, their foundations can weaken and the construction can deform.

1.1 ***Drainage of Rainwater***

The red arrows indicate the gutter drainpipes for evacuating rainwater from the large roof surfaces. Most of these drainpipes end at the cemented plinth, whereby the rainwater floods the ground around the foundations. To avoid humidity damage and infiltration into the foundation of the (adobe) wall structure, it is important that the drainpipes be extended horizontally to evacuate the rainwater well away from the building. This will require long drainpipes at ground level in between the buildings and soak away pits at least 10 m away from the foundations.

1.2 ***Elevated Floor***

An elevated floor provides additional thermal insulation because of the air space below. With a closed area, the insulation value is $R_C = 0.2\ m^2.K/W$, but when it is slightly ventilated, the insulation value is only $R_C = 0.1\ m^2.K/W$.



Construction of an elevated, ventilated floor on cemented supports. The timbers are placed on asphalt paper to avoid humidity from the masoned supports.

Ventilation is necessary for timber floors placed over a humid underground to remove the moist air and reduce the possibility of fungus and timber rot.

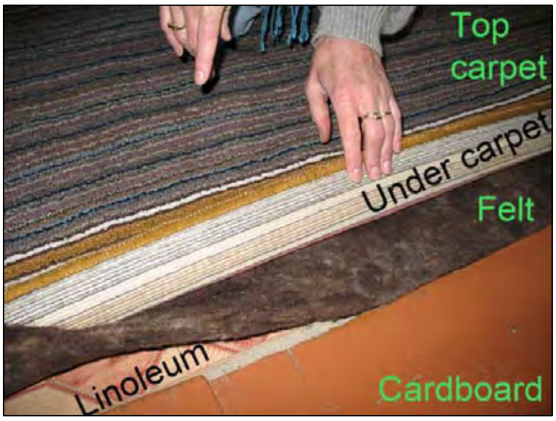
The use of reflective foils under the floor to stop downward heat emission is very effective insulation. However, if reflective foil is used under a non-sealed floor, its function will reduce over time due to dust falling through the plank floor and settling on the shiny surface. For this reason, the reflective foil should be protected by another plastic right under the plank floor.

When several layers of reflective foils are placed above each other, the lower foils, being protected from dust by the highest foil, can be counted for their full insulation value.

Timber beams need moisture protection at the location where these come in contact with the cemented supports because the supports allow moisture to rise from the soil.

2. INSULATION MATERIALS

Usually several layers of plastic, linoleum (damp proofing), cardboard, felt and carpets are used to increase the insulation. Mattresses and quilts are placed over these basic layers.



In the calculations on the following pages, the insulation values of the mattresses and quilts are not taken into consideration.

2.1 Straw or Wood Shavings

Because of similar insulation values, straw can be substituted with wood shavings. In the most rural areas, straw is the lowest cost option if the villagers supply the material. This needs to be dusted with lime powder to reduce insects. When applied horizontally in non-compacted layers, the low-cost straw is one of the most economical insulation materials.

2.2 EPS or Glass Wool

Expanded Polystyrene (EPS) is one of the most cost-efficient imported materials. Medium or high-density EPS is advised with a hard cover such as plywood, when the floor needs to be walked upon. Low-quality glass wool can absorb moisture and become less effective as a thermal insulator. Glass wool cannot be walked upon but can be used under a supporting timber floor.

2.3 Polyethylene (PE) Foam

PE foam on the floor under a carpet is rather efficient in reducing the firewood needs for space heating. Such PE foam is usually only 7 mm thick and sold as carpet underlay. Because the thickness of the material is not very large, its floor insulation value is not very large. The closed-cell PE foam has a good resistance against tearing. Rolls can be easily transported to villages.

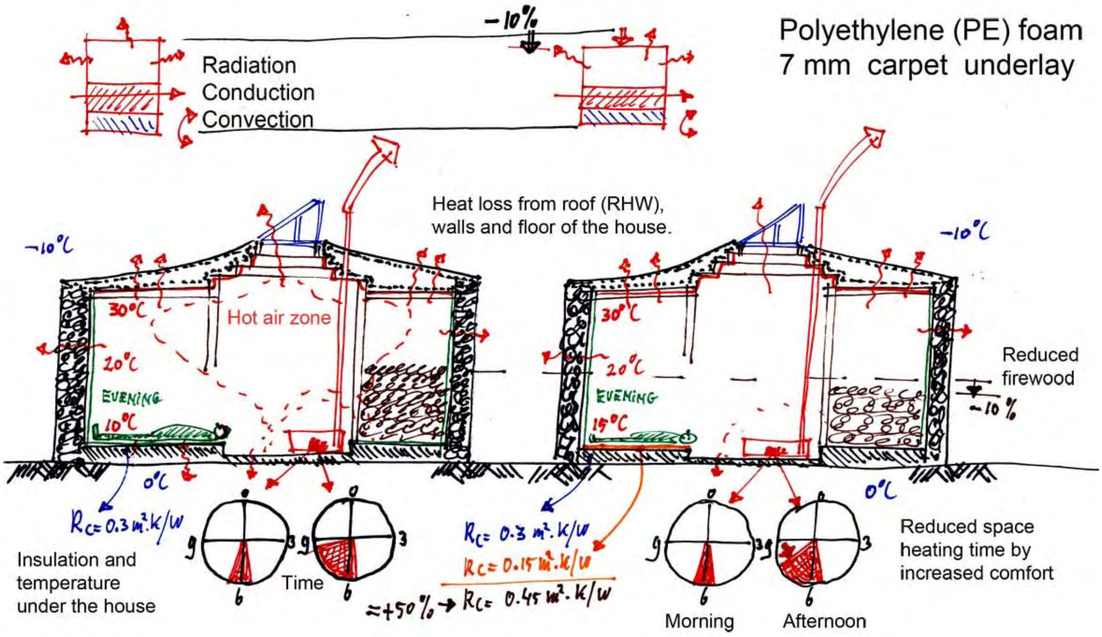
The positive effect of the 7 mm PE foam insulation is related to creating personal comfort and to a lesser extent its (limited) thermal insulation aspect. Because people living in traditional houses sit and sleep on the floor, they have intense contact with the floor for over 16 hours (minimum 4 hours sitting and 12 hours sleeping) causing their bodies to lose a lot of heat by conduction.

The photo (left) shows a stack of bedding material in the corner of the house and a mattress on the floor. These mattresses often have cotton or wool filling, but they are compressed because of the body weight.

The amount of heat loss from a building is related the ΔT between the inside and outside temperature and the thermal insulation value of each construction element. For the floor of a traditional house with an outside air temperature of -10°C, the ΔT is 15°K because the soil temperature under the house is about 0°C. For the roof, the ΔT in the same house will be more than double since the inside ceiling temperature will be about 30°C, thus in total the ΔT = 40°K.

The average floor insulation value is at best R_C = 0.3 m^2.K/W. The insulation of a 3 cm thick cotton mattress is also about R_C = 0.3 m^2.K/W. When sleeping on the floor, the contact with the floor is both intense and long, resulting in a high discomfort level due to the cold being felt.

The 7 mm thick PE foam[2], having an R_C = 0.15 m^2.K/W, increases the floor insulation value by 50% and with that reduces possible condensation of body humidity into the mattress, both increasing a person's sleeping temperature and comfort. Condensation in the mattress reduces its insulation value. Because of the increased comfort level, the fire is extinguished earlier and thus firewood is saved. Roughly estimated, at least 10% of the firewood is saved with PE foam on the whole floor.



Although the actual thermal insulation value of the PE foam is not very high, the 50% increment of the floor insulation has a large impact because people sit and sleep on the floor; the contact with the cold floor being long and intense.

Elevated beds allow body moisture to evaporate better and reduce the risk of condensation of body moisture in the bedding material. Airing out and ventilating the bedding material or placing it on a bedding rack will reduce moisture in the bedding.

2.4 Elevated Floor

Thermal insulation of the floor is strongly enhanced by creating an elevated timber floor. The air chamber provides an insulation of about R_C = 0.2 m^2.K/W and a 2.5 cm plank floor R_C = 0.15 m^2.K/W, together R_C = 0.35 m^2.K/W. The elevated area is used both as a sitting and sleeping area. Applying reflective foil as well will substantially increase the total insulation value.

[2] The R_M of PE foam = 22 m^2.K/W for 7 mm. This translates to R_C = 0.154 m^2.K/W.

2.5 ***Aerated Cement Floor***

Lightweight aerated cement mortar is an excellent floor insulator and can be cast directly on the soil. The particular advantages are that it blocks moisture, provides good insulation, cannot be affected by fungus or rot and is firm to walk on (but needs a protective cover; otherwise it will easily erode). The disadvantage is that it requires a large amount of cement.

To make an insulating aerated cement base floor, five ingredients are necessary:

(1) Clean sand having a large amount of quartz. The amount of sand is about 75% by volume. Soil content should be no more than 25%. The quartz in the sand is necessary as it reacts with the hydrogen and creates strong walls of bubbles.
(2) Lime powder, contains calcium hydrogen and reacts with the aluminium powder.[3]
(3) Cement, reacts with the water and the aluminium powder.
(4) Aluminium powder, creates hydrogen bubbles within 15 minutes when mixed with cement and lime water. Powder (D50) has a purity of over 99% aluminium and a grain of 0.05 mm maximum (50 μ= 50 micrometer).[4]
(5) Water. When the mixture is very dry, the amount of air bubbles will be less than when the mixture is a little fluid. When casting the fluid mass, the volume will rise about 500% depending on the amount of aluminium powder.

After some time, the hydrogen escapes and is replaced by air. It takes several months before the floor is fully dried out. It is not recommended to work with the material below 15°C.

With each 500 kg of dry material (sand, soil and cement), about 1 m^3 floor volume is produced. Increasing the soil content in the sand will reduce the expansion.
A well aerated and expanded floor will have a density of 400 kg/m^3 (R_M = 10 m^2.K/W) to 600 kg/m^3 (R_M = 8 m^2.K/W) and a pressure resistance of 20 kg/cm^2 to 40 kg/cm^2 respectively. These are more than adequate for floors in housing.

Aerated Concrete: Commercial name, but incorrect because there are no course stone aggregates in the material.
Foam Concrete: Another aerated cement product. This is not made by adding aluminium powder or through a chemical process. The air bubbles are brought into the concrete from an outside pump or EPS pearls (or another type of pellets); mixed with the cement mortar during the casting process. This requires an all mechanized production process.
Aircrete: A commercial name for AAC (Autoclave Aerated Concrete); being a mechanized factory process using steam-curing tanks.

Village Housing
Before casting the new insulating floor, the excavated area is covered with paper or plastic foil.
The floors in several village houses in Tajikistan have aerated cement floors consisting of:
(a) Dry mix of 500 kg pure river sand + 300 kg soil[5], together 800 kg = **0.5 m^3**.
(b) Dry 100 kg cement = 2 bags of 50 kg. This is equivalent to 30 litres or **0.03 m^3** volume, representing 12.5% by weight or 6% by volume.
(c) 1 kg aluminium powder, representing <0.09% of dry materials or **1% by weight of cement**.
(d) The above dry materials are well mixed before adding the lime water.
(e) Dry lime: 10 litres = 15 kg (1 bucket = 0.15% by weight of total or **15% by weight of cement** or 15 x the weight of the aluminium powder). Mix this first with 10 buckets of water.
(f) The lime water is now mixed with the dry mix until a rather fluid paste is obtained.
(g) In 15 minutes, a layer of 3 cm (for 18 m^2) expands to about 15 cm and hardens (500%).[6]
(h) After hardening, the top side can be equalized with a thin layer of light cement mortar.

For 1016 kg	Dry Sand	Cement	Dry Lime	Aluminium Powder	Water
By volume	0.5 m^3	0.03 m^3	0.01 m^3	-	-
By weight	800 kg	100 kg	15 kg	1 kg	100 kg

[3] For aerated building blocks: sand 65%, cement 20%, lime 15%, aluminium powder 0.05%. These are made in steam pressure tanks (autoclave) and need to rest one month after manufacturing because of shrinkage.
[4] The aluminum powder is commercially available from factories making aerated concrete and from export or trading companies in both China and India. Standard YS/T602-2007 applies.
[5] The specific mass of loose, dry river sand or dry soil is 1600 kg/m^3.
[6] Because the "air" bubbles develop quickly, working fast or in small floor sections is required.

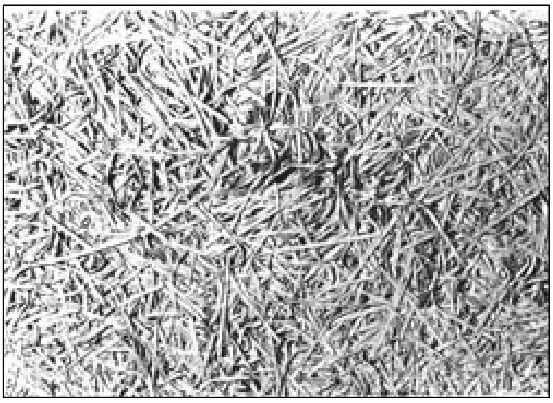
2.6 ***Wood-Fibre, Hemp and Straw-Cement***

Mixing wood shavings, hemp or straw with cement creates durable insulation material, which can be used under and above floors, against walls and in ceilings. Hemp-cement panels and hemp-lime-cement wall constructions are being used in northern Europe and have an excellent performance as building insulators. They have been used for more than 100 years in building construction.

All three materials are durable, do not rot and have good moisture regulating properties. They absorb and release the moisture, stabilizing indoor climate. They are fire and insect resistant. The porous fibre panels can be easily plastered or tiled.

Wood-Fibre Cement Panels

The manufacturing process of self-supporting wood-fibre cement panels requires long, thin dry wood shavings, preferably not the short shavings from the electric shaving machines. The long fibres give strength to the panels against bending. The panels are cast in a form and slightly compressed during the hardening in the mould.



The dry weight of the wood shavings is approximately 300 kg/m^3 with an R_C = 10 $m^2.K/W$. The weight of the factory-made, lightly compressed wood-fibre cement panels is 800 kg/m^3 with an R_C = 3.3 $m^2.K/W$.

(a) The shavings are weighed and 25% of the weight of the dry material is added as water. This is thoroughly mixed. The water amount should not be more or less.
(b) Two times the weight of the dry wood shavings is added as cement (wood:cement is 1:2).
(c) The cement powder is thoroughly mixed with the wet wood shavings and cast immediately in the formwork or layered into position and slightly compacted.

The same proportions can be used for horizontal floor insulation. In this situation, shorter shaving chips can be used as resistance against bending of the panels is not required. The short shavings can be mixed with cement as the base floor. The freshly cast layer is compacted by a person having half meter long planks attached under his feet and systematically walking over the surface.

Straw-Cement Mixture[7]

Since straw (waste product from maize or wheat production) is widely available, it can be used for the manufacturing of insulation material or cast in-situ with cement powder as floor insulation.

The straw should be stripped of the thin leaves (the leaves can be used for animal fodder). The thicker stems are chopped into 1-2 inch long pieces and treated like the wood shavings above. Half the amount of cement can be replaced with lime if this is locally available and economically interesting. Straw-cement/lime panels have an R_M = 3-5 m.K/W.

The layer of slightly compacted and hardened straw-cement can be covered with a thin layer of plaster to equalize and smoothen the surface. Covering the floor with PE foam before placing the carpets will provide a suitable surface for houses.

In buildings having large floor loads, the compacting should be stronger and the cement plaster covering thicker. In buildings where impact on the floor is expected, thin chicken wire mesh, thick expanded metal mesh or a strong 6 mm bar reinforcement web can be applied, depending on the situation.

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[7] Strawcrete and Hempcrete are cement and lime bonded materials used in house building, mainly in wall constructions. For the supporting structure of the building, however, a timber frame construction is used.

2.7 Reflective Metalized Plastic Foils

The use of metalized plastic or Highly Reflective Foils (HRF) in combination with horizontal cavities under the floor will greatly increase the insulation value of the floor construction.

It is important that the upward facing reflective foil surface stays clean and free from dust; this can be done by placing a separate plastic foil above the reflective foil.

During the winter, the soil temperature under the house is much higher than the outside air temperature. Therefore, the minimum recommended insulation value for floors directly on the ground or over a non-ventilated air space is half the value recommended for outside walls and roofs. However, when the area under the floor is ventilated, such as is needed for timber floors over a moist underground, the minimum insulation value should be higher.

Recommended Minimum Average R_C Value for Floors

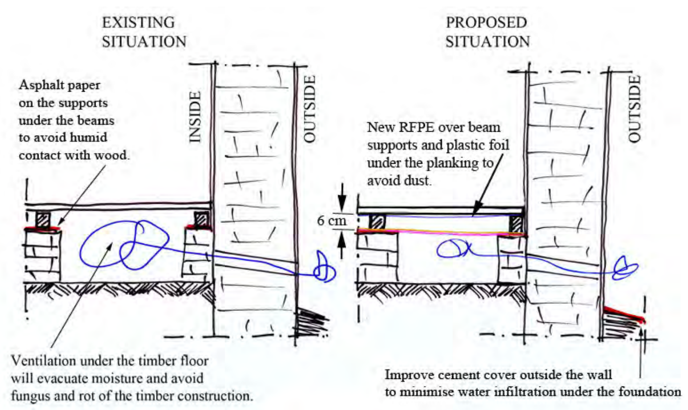
- Directly on the ground or ground cavity = 1/2 {0.5 + (altitude m/1000 m)} $m^2.K/W$
- Slightly ventilated areas under floors = 3/4 {0.5 + (altitude m/1000 m)} $m^2.K/W$
- Strongly ventilated areas under floors = 1 {0.5 + (altitude m/1000 m)} $m^2.K/W$

The calculations on the following page are based on reflectivity (r) and emissivity (ε) of materials:
$r + R_C + \varepsilon = 1$ in which the R_C is the insulation value of the foil itself (very little).[8]

GBM	All General Building Materials (ε = 0.9; r = 10%)
HRF or HRF2	Highly Reflective Foil and 2 sided HRF (ε = 0.04, r = 95%)
RFPE	Reflective Foil with 3 mm Polyethylene foam backing (ε = 0.1, r = 90%)
Alum	Aluminium Foil, both sides (ε = 0.04, r = 95%)

When the reflectivity of the foil is less than 90%, an intermediate line can be drawn.

Print the page 9 in colour for easy reference.



Example of an elevated floor lightly ventilated to remove the moist air away from under the timber floor. This will minimise the development of fungus and rot.

Reflective foil placed under a timber floor over the ground. This solution substantially increases the overall insulation quality of the classroom.

[8] See also: http://en.wikipedia.org/wiki/Emissivity and http://en.wikipedia.org/wiki/Radiant_barrier

Insulation values for horizontal cavities with <u>heat-flow from above.</u>

This applies for floors and roofs over heated by the sun.

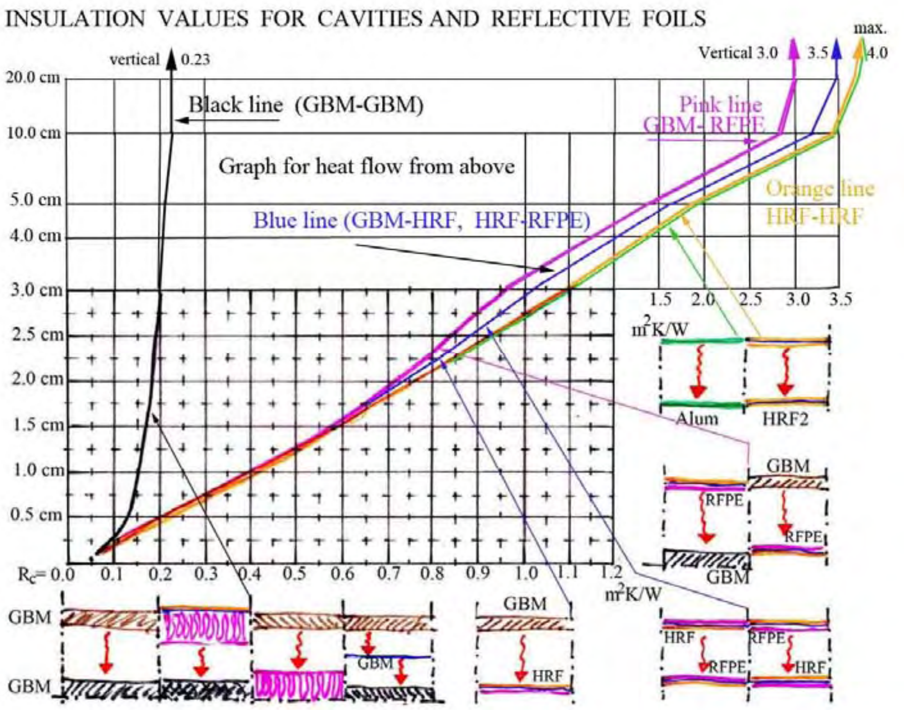
The **Black** line represents GBM-GBM cavities, the thermal insulation value between General Building Materials. For a 3 cm cavity, this is R_C = 0.19 m^2.K/W (see also graph).

The **Pink** line represents RFPE-GBM cavities, the thermal insulation value between Reflective Foils with PE backing and GBM. For 3 cm cavity, this is R_C = 0.96 m^2.K/W (see also graph).

The **Blue** line represents HRF-GBM and HRF-RFPE cavities, the thermal insulation value between Highly Reflective Foils and GBM / Reflective Foils with PE backing. For 3 cm cavity, this is R_C = 1.02 m^2.K/W (see also graph).

The **Orange** and **Green** lines represent HRF-HRF or Alum-Alum cavities and combinations thereof, the thermal insulation between Highly Reflective Foils and Aluminium. For pure aluminium, there is little difference between the shiny and non-shiny side. Pure aluminium will corrode in a moist atmosphere and reflect less than RFPE. Plasticized HRF or Alum rates the same as RFPE.

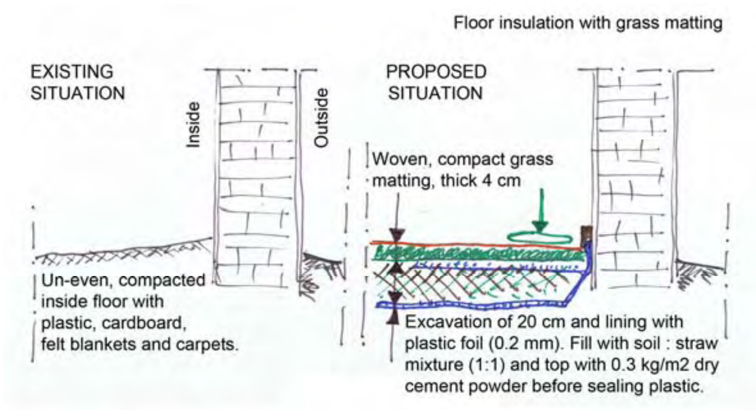
Height in cm	GBM-GBM Black Line: $R_C = m^2$.K/W	GBM-RFPE RFPE-GBM Pink Line: $R_C = m^2$.K/W	GBM-HRF, HRF-RFPE HRF-GBM Blue Line: $R_C = m^2$.K/W	HRF-HRF HRF-Alum Alum-Alum, Alum-HRF Orange and Green Lines: $R_C = m^2$.K/W
0.1	0.035	0.04	0.04	0.04
0.5	0.11	0.2	0.2	0.2
0.7	0.13	0.28	0.28	0.28
1.0	0.15	0.39	0.39	0.4
1.5	0.17	0.55	0.56	0.58
2.0	0.18	0.72	0.74	0.76
2.5	0.185	0.86	0.88	0.92
3.0	0.19	0.96	1.02	1.1
4.0	0.20	1.15	1.2	1.45
5.0	0.21	1.5	1.6	1.7
10.0	0.21	2.8	3.2	3.5
>20.0	0.23	3.0	3.5	4.0



The red arrows indicate the direction of the heat flow.

Thermal Insulation Example Floor #1 Old and New Construction

Recommended Minimum <u>Average</u> R_C Value for Floors = 1/2 {0.5 + (altitude m/1000 m)} m^2.K/W



When people sleep on the floor, higher insulation values are recommended.

For each hour less than 5 hrs sun, the insulation value needs to be increased with R_C = 0.1 m^2.K/W.

Floor #1: Excavation (20 cm), plastic foil (0.2 mm), refill with straw clay-soil (20 cm), stabilized, straw-grass mat (4 cm), PE foam (5 mm). Thickness x R_M = R_C					New Value	Surface Unit of Estimation = **10 m^2**		
#	Description of the Existing Construction Layers	Thick Meter	R_M	R_C	Temp ºC	Material in PKR	Skilled Labour Cost	Non-skilled Labour
1	Soil transmission factor	-	-	0.00				
2	Carton sheets, flattened	0.005	5.00	0.025		replace		
3	Carpets, thin, existing	0.005	10.0	0.05		replace		
4	Inside transmission factor	-	-	0.17				
Subtotal Existing Construction R_C				**0.245**				
#	Description of Each New Layer or New Activity to Install Insulation	Thick Meter	R_M	R_C	Temp ºC	Material in PKR	Skilled Labour Cost	Non-skilled Labour
10	Excavation existing floor	0.20	-	-		*free*	-	-
11	Plastic foil 0.2 mm	-	-	-		*100*	*50*	*20*
12	Straw clay-soil layer, dry	0.20	1.67	0.334		*free*	*100*	*50*
13	Cement powder bonding	-	-	-		*100*	*100*	*50*
14	Straw-grass matting	0.04	5.0	0.2		*free*	*100*	*50*
15	PE foam	0.007	22	0.154		*100*	*100*	*50*
Subtotal Newly Added Value R_C				**0.688**		*300*	*450*	*220*
Total Existing and New R_C Values				**0.933**		***Total Cost 10 m^2***		***970***
Altitude Above Sea Level ___________m		Recommended R_C Value		2.0--2.5 3.0--3.5 4.0--4.5	$\triangle$**T**	Ratio = Total Cost / R_C Total		***1040***

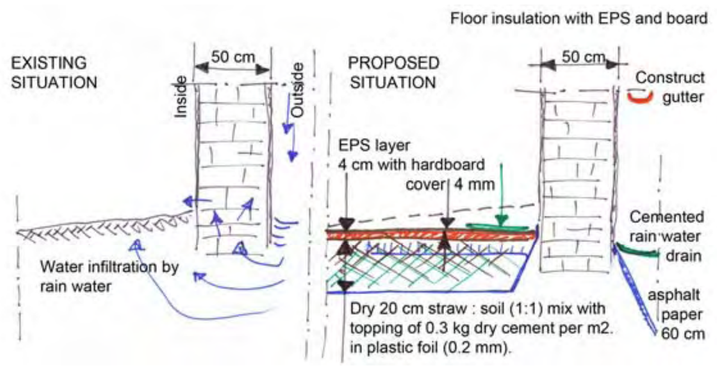
The above design is all locally available materials and labour and therefore very low cost. The soil-straw layer, covered with the grass mat is sufficiently strong for people to walk on, but no more. When furniture needs to stand on the floor, a supporting plank will be required or another design.

<u>Remarks</u>:

- Excavation and straw supplied by the house owner. Lime-cement by craftsman.
- Plastic moisture barrier under the excavation is necessary to ensure a dry base.
- Plinth finishing not included.
- Additional mattresses, PE foam, quilts or pillows not included in calculation.

Thermal Insulation Example Floor #2 Old and New Construction

Recommended Minimum <u>Average</u> R_C Value for Floors = 1/2 {0.5 + (altitude m/1000 m)} m^2.K/W



When people sleep on the floor, higher insulation values are recommended.

For each hour less than 5 hrs sun, the insulation value needs to be increased with R_C = 0.1 m^2.K/W.

Floor #2: Excavation (20 cm), plastic foil (0.2 mm), refill with straw clay-soil (20 cm), stabilized, EPS (4 cm), hardboard. Thickness x R_M = R_C					New Value	Surface Unit of Estimation = **10 m²**		
#	Description of the Existing Construction Layers	Thick Meter	R_M	R_C	Temp ºC	Material in PKR	Skilled Labour Cost	Non-skilled Labour
1	Soil transmission factor	-	-	0.00				
2	Carton sheets, flattened	0.005	5.00	0.025		remove		
3	Carpets, thin, existing	0.005	10.0	0.05		replace		
4	Inside transmission factor	-	-	0.17				
	Subtotal Existing Construction R_C			**0.245**				
#	Description of Each New Layer or New Activity to Install Insulation	Thick Meter	R_M	R_C	Temp ºC	Material in PKR	Skilled Labour Cost	Non-skilled Labour
-2	Remove carton layer	0.005	5.00	-0.025		-	-	-
10	Excavation existing floor	0.20	-	-		*free*	-	-
11	Plastic foil 0.2 mm	-	-	-		*100*	*50*	*20*
12	Straw clay-soil layer, dry	0.20	1.67	0.334		*free*	*100*	*50*
13	Cement powder bonding	-	-	-		*100*	*100*	*50*
14	EPS layer	0.04	25.0	1.0		*400*	*100*	*50*
15	Hardboard cover	0.004	5.6	0.022		*150*	*100*	*50*
	Subtotal Newly Added Value R_C			**1.331**		*750*	*450*	*220*
	Total Existing and New R_C Values			**1.576**			***Total Cost 10 m²***	***1420***
	Altitude Above Sea Level ____________m	Recommended R_C Value		2.0--2.5 3.0--3.5 4.0--4.5	**△T**	Ratio = Total Cost / R_C Total		***901***

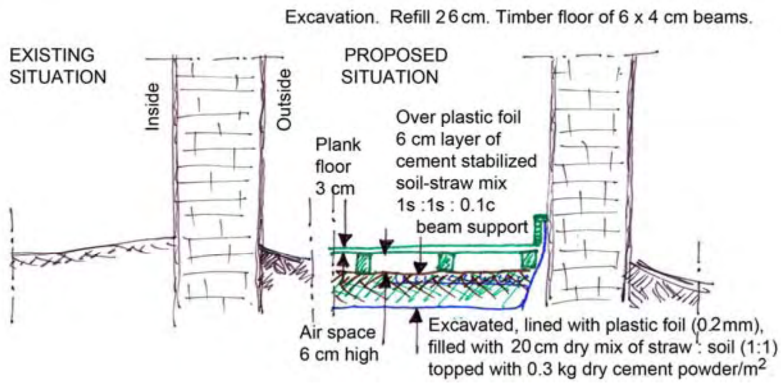
Similar construction as design #1. Because the EPS has a good insulation value, the ratio is lower.

<u>Remarks</u>:

- Outside excavation and waterproofing foundation not included. Roof drainage not included.
- Excavation and straw supplied by the house owner. Lime-cement by craftsman.
- Plastic moisture barrier under the excavation is necessary to ensure dry base.
- Plinth finishing not included.
- Additional mattresses, PE foam, quilts or pillows not included in calculation.

Thermal Insulation Example Floor #3 Old and New Construction

Recommended Minimum <u>Average</u> R_C Value for Floors = 1/2 {0.5 + (altitude m/1000 m)} m^2.K/W



When people sleep on the floor, higher insulation values are recommended.

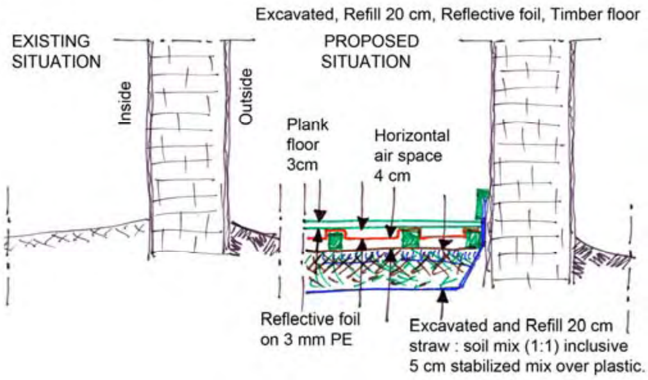
For each hour less than 5 hrs sun, the insulation value needs to be increased with R_C = 0.1 m^2.K/W.

Floor #3: Excavation (20 cm), plastic foil (0.2 mm), refill with straw clay-soil (20 cm), stabilized, timber floor. Thickness x R_M = R_C					New Value	Surface Unit of Estimation = **10 m^2**		
#	Description of the Existing Construction Layers	Thick Meter	R_M	R_C	Temp ºC	Material in PKR	Skilled Labour Cost	Non-skilled Labour
1	Soil transmission factor	-	-	0.00				
2	Carton sheets, flattened	0.005	5.00	0.025		remove		
3	Carpets, thin, existing	0.005	10.0	0.05		replace		
4	Inside transmission factor	-	-	0.17				
Subtotal Existing Construction R_C				**0.245**				
#	Description of Each New Layer or New Activity to Install Insulation	Thick Meter	R_M	R_C	Temp ºC	Material in PKR	Skilled Labour Cost	Non-skilled Labour
-2	Remove carton layer	0.005	5.00	-0.025		*free*	-	-
10	Excavation existing floor	0.20	-	-		*free*	-	-
11	Plastic foil 0.2 mm	-	-	-		*100*	*50*	*20*
12	Straw clay-soil layer, dry	0.20	1.67	0.334		*free*	*100*	*50*
13	Cement powder bonding	-	-	-		*100*	*100*	*50*
14	Timber floor	0.025	6	0.15		*300*	*100*	*50*
15	Cavity, horizontal, closed	0.06	**Black**	0.4		*400*	*100*	*50*
Subtotal Newly Added Value R_C				**0.859**		*900*	*450*	*220*
Total Existing and New R_C Values				**1.104**		***Total Cost 10 m^2***		***1570***
Altitude Above Sea Level ___________m		Recommended R_C Value		2.0--2.5 3.0--3.5 4.0--4.5	**ΔT**	Ratio = Total Cost / R_C Total		***1422***

<u>Remarks</u>:
- Outside waterproofing of foundation or roof gutter and drain not included.
- Floor painting/varnish and plinth finishing not included.
- When raising the floor, the doors need to be adjusted.
- PE foam and carpets can be added on top of the timber floor for extra comfort.

Thermal Insulation Example Floor #4 Old and New Construction

Recommended Minimum Average R_C Value for Floors = 1/2 {0.5 + (altitude m/1000 m)} m^2.K/W



When people sleep on the floor, higher insulation values are recommended.

For each hour less than 5 hrs sun, the insulation value needs to be increased with R_C = 0.1 m^2.K/W.

There is NO plastic foil under the plank floor, above the upper cavity (required to avoid dust falling on the reflective foil); therefore it has only half the value.

Floor #4: Excavation (20 cm), plastic foil (0.2 mm), refill with straw clay-soil (20 cm), stabilized, 1 x RFPE, timber floor. Thickness x R_M = R_C					New Value	Surface Unit of Estimation = **10 m^2**		
#	Description of the Existing Construction Layers	Thick Meter	R_M	R_C	Temp ºC	Material in PKR	Skilled Labour Cost	Non-skilled Labour
1	Soil transmission factor	-	-	x				
2	Carton sheets, flattened	0.005	5.00	0.025		remove		
3	Carpets, thin, existing	0.005	10.0	0.05		replace		
4	Inside transmission factor	-	-	0.17				
	Subtotal Existing Construction R_C			**0.245**				
#	Description of Each New Layer or New Activity to Install Insulation	Thick Meter	R_M	R_C	Temp ºC	Material in PKR	Skilled Labour Cost	Non-skilled Labour
-2	Remove carton layer	0.005	5.00	-0.025		*free*	-	-
10	Excavation existing floor	0.20	-	-		*free*	-	-
11	Plastic foil 0.2 mm	-	-	-		*100*	*50*	*20*
12	Straw clay-soil layer, dry	0.20	1.67	0.334		*free*	*100*	*50*
13	Cement powder bonding	-	-	-		*100*	*100*	*50*
14	Plastic foil cover	-	-	-		*100*	-	*20*
15	Cavity hor. GBM-RFPE (½)	0.02	**Pink**	0.35		-	-	-
16	Reflective foil, RFPE	0.003	22	0.066		*100*	*100*	*50*
17	Cavity horizon. GBM-HRF	0.04	**Blue**	1.20		*400*	*100*	*50*
18	Timber floor	0.025	6	0.15		*300*	*100*	*50*
	Subtotal Newly Added Value R_C			**2.075**		*1100*	*550*	*290*
	Total Existing and New R_C Values			**2.32**			***Total Cost 10 m^2***	***1940***
	Altitude Above Sea Level ____________m	Recommended R_C Value		2.0--2.5 3.0--3.5 4.0--4.5	$\triangle$**T**	Ratio = Total Cost / R_C Total		***836***

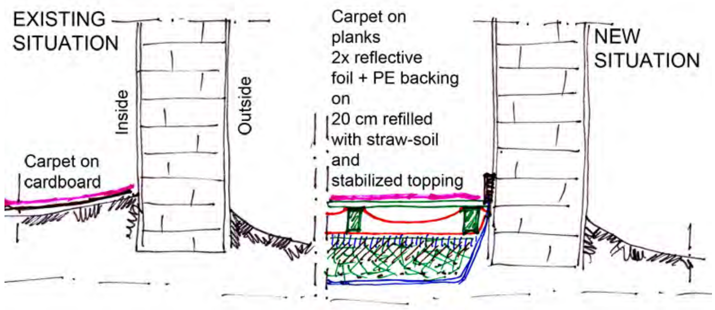
The insulation value would be R_C = 0.35 m^2.K/W greater with a plastic foil under the timber floor.

Remarks:

- Outside waterproofing of foundation or roof gutter and drain not included.
- Floor painting/varnish and plinth finishing not included.
- When raising the floor, the doors need to be adjusted.

Thermal Insulation Example Floor #5 Old and New Construction

Recommended Minimum <u>Average</u> R_C Value for Floors = 1/2 {0.5 + (altitude m/1000 m)} m^2.K/W



When people sleep on the floor, higher insulation values are recommended.

For each hour less than 5 hrs sun, the insulation value needs to be increased with R_C = 0.1 m^2.K/W

Floor #5: Excavation (20 cm), plastic foil (0.2 mm), refill with straw clay-soil (20 cm), stabilized, 2 x RFPE, timber floor. Thickness x R_M = R_C					New Value	Surface Unit of Estimation = **10 m^2**		
#	Description of the Existing Construction Layers	Thick Meter	R_M	R_C	Temp ºC	Material in PKR	Skilled Labour Cost	Non-skilled Labour
1	Soil transmission factor	-	-	0.00				
2	Carton sheets, flattened	0.005	5.00	0.025		remove		
3	Carpets, thin, existing	0.005	10.0	0.05		replace		
4	Inside transmission factor	-	-	0.17				
	Subtotal Existing Construction R_C			**0.245**				
#	Description of Each New Layer or New Activity to Install Insulation	Thick Meter	R_M	R_C	Temp ºC	Material in PKR	Skilled Labour Cost	Non-skilled Labour
-2	Remove carton layer	0.005	5.00	-0.025		*free*	-	-
10	Excavation existing floor	0.20	-	-		*free*	-	-
11	Plastic foil 0.2 mm	-	-	-		*100*	*50*	*20*
12	Straw clay-soil layer, dry	0.20	1.67	0.334		*free*	*100*	*50*
13	Cement powder bonding	-	-	-		*100*	*100*	*50*
14	1^{st} reflective foil RFPE	0.003	22	0.066		*100*	*100*	*50*
15	Cavity horizon, RFPE-HRF	0.03	**Blue**	1.0		-	-	-
16	2^{nd} reflective foil RFPE	0.003	22	0.066		*100*	*100*	*50*
17	Half value HRF-GBM	0.03	**Pink**	0.45		-	-	-
18	Timber floor + beams	0.025	6	0.15		*600*	*200*	*100*
	Subtotal Newly Added Value R_C			**2.041**		*1000*	*650*	*320*
	Total Existing and New R_C Values			**2.286**		***Total Cost 10 m^2***		***1970***
	Altitude Above Sea Level ___________m	Recommended R_C value		2.0--2.5 3.0--3.5 4.0--4.5	**ΔT**	Ratio = Total Cost / Rc Total		***862***

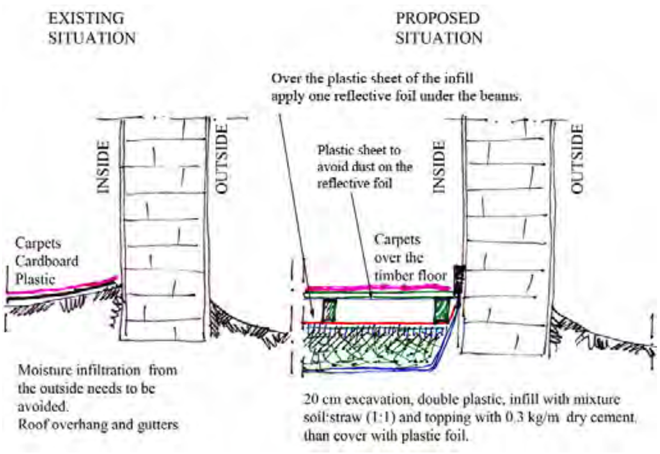
The above solution is a triple insulation design with the straw-soil fill, elevated timber floor and double reflective foil. From the figures, the insulation value is very high and comparable to R_C = 4.5 m^2.K/W for outside wall or roof constructions. The cost is also high.

<u>Remarks</u>:

- Outside waterproofing of foundation or roof gutter and drain not included.
- The upper reflective foil only counts half if not dust protected.

Thermal Insulation Example Floor #6 Old and New Construction

Recommended Minimum <u>Average</u> R_C Value for Floors = 1/2 {0.5 + (altitude m/1000 m)} m^2.K/W



When people sleep on the floor, higher insulation values are recommended.

For each hour less than 5 hrs sun, the insulation value needs to be increased with R_C = 0.1 m^2.K/W

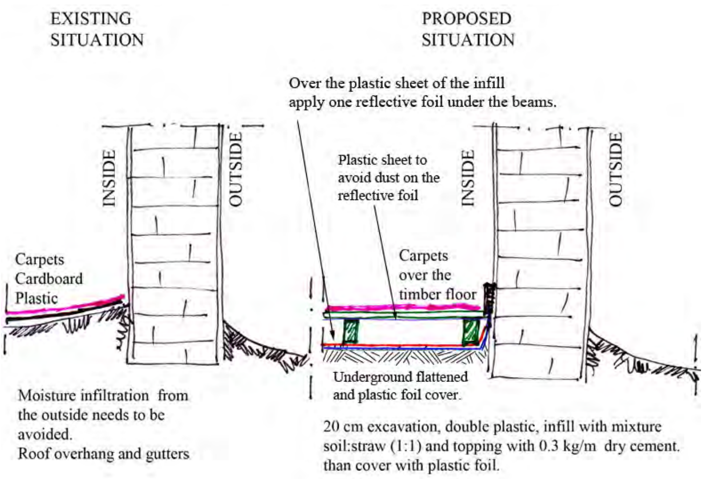
Variation on Floor 5 without the hanging reflective foil, but with a plastic foil to prevent dust falling on the reflective foil.

Floor #6: Excavation (20 cm), plastic foil (0.2 mm), refill with straw clay-soil (20 cm), stabilized, 1 x RFPE, plastic, timber floor. Thickness x R_M = R_C					New Value	Surface Unit of Estimation = **10 m^2**		
#	Description of the Existing Construction Layers	Thick Meter	R_M	R_C	Temp ºC	Material in PKR	Skilled Labour Cost	Non-skilled Labour
1	Soil transmission factor	-	-	0.00				
2	Carton sheets, flattened	0.005	5.00	0.025		remove		
3	Carpets, thin, existing	0.005	10.0	0.05		replace		
4	Inside transmission factor	-	-	0.17				
Subtotal Existing Construction R_C				**0.245**				
#	Description of Each New Layer or New Activity to Install Insulation	Thick Meter	R_M	R_C	Temp ºC	Material in PKR	Skilled Labour Cost	Non-skilled Labour
-2	Remove carton layer	0.005	5.00	-0.025		*free*	-	-
10	Excavation existing floor	0.20	-	-		*free*	-	-
11	Plastic foil 0.2 mm	-	-	-		*100*	*50*	*20*
12	Straw clay-soil layer, dry	0.20	1.67	0.334		*free*	*100*	*50*
13	Cement powder bonding	-	-	-		*100*	*100*	*50*
14	Reflective foil RFPE	0.003	22	0.066		*100*	*100*	*50*
15	Cavity horizon. RFPE-HRF	0.06	**Blue**	1.6		-	-	-
16	Plastic sheet under planks	0.002	-	-		*20*	*10*	-
17	Timber floor + beams	0.025	6	0.15		*600*	*200*	*150*
Subtotal Newly Added Value R_C				**2.125**		*920*	*560*	*320*
Total Existing and New R_C Values				**2.37**		***Total Cost 10 m^2***		***1800***
Altitude Above Sea Level ___________m		Recommended R_C value		2.0--2.5 3.0--3.5 4.0--4.5	**△T**	Ratio = Total Cost / R_C Total		***759***

From the figures, the insulation value is higher than Floor 5, but the cost is lower; thus the ratio improves. Floor 5 is therefore not the most cost-efficient design compared with Floor 6.

Thermal Insulation Example Floor #7 Old and New Construction

Recommended Minimum <u>Average</u> R_C Value for floors = 1/2 {0.5 + (altitude m/1000 m)} m^2.K/W



When people sleep on the floor, higher insulation values are recommended.

For each hour less than 5 hrs sun, the insulation value needs to be increased with R_C = 0.1 m^2.K/W

Variation on Floors 5 and 6 without the soil excavation and straw-soil refill.

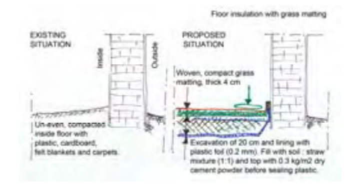
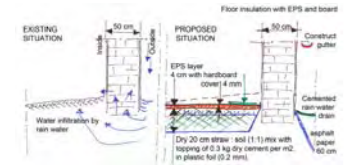
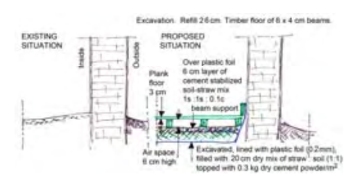
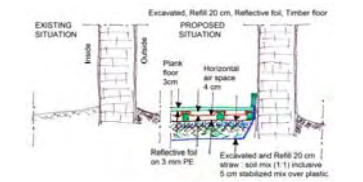
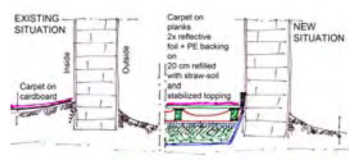
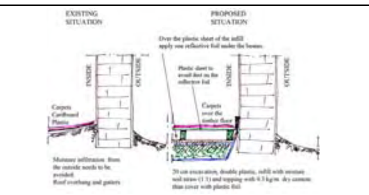
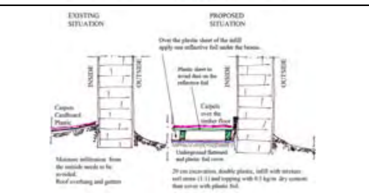
A plastic foil under the plank floor prevents dust falling on the reflective foil.

Floor #7: Levelling, plastic foil (0.2 mm), 1 x RFPE, plastic foil, timber floor. Thickness x R_M = R_C					New Value	Surface Unit of Estimation = **10 m^2**		
#	Description of the Existing Construction Layers	Thick Meter	R_M	R_C	Temp ºC	Material in PKR	Skilled Labour Cost	Non-skilled Labour
1	Soil transmission factor	-	-	0.00				
2	Carton sheets, flattened	0.005	5.00	0.025		remove		
3	Carpets, thin, existing	0.005	10.0	0.05		replace		
4	Inside transmission factor	-	-	0.17				
	Subtotal Existing Construction R_C			**0.245**				
#	Description of Each New Layer or New Activity to Install Insulation	Thick Meter	R_M	R_C	Temp ºC	Material in PKR	Skilled Labour Cost	Non-skilled Labour
-2	Remove carton layer	0.005	5.00	-0.025		*free*	-	-
10	Levelling existing soil floor	-	-	-		*free*	-	-
11	Plastic foil 0.2 mm	-	-	-		*50*	*10*	*10*
12	One reflective foil RFPE	0.003	22	0.066		*100*	*100*	*50*
13	Cavity horizon. RFPE-HRF	0.06	**Blue**	1.6		-	-	-
14	Plastic sheet under planks	0.002	-	-		*20*	*10*	-
15	Timber floor + beams	0.025	6	0.15		*600*	*200*	*100*
	Subtotal Newly Added Value R_C			**1.791**		*770*	*320*	*160*
	Total Existing and New R_C Values			**2.036**			***Total Cost 10 m^2***	***1250***
	Altitude Above Sea Level ___________m	Recommended R_C value		2.0--2.5 3.0--3.5 4.0--4.5	**ΔT**	Ratio = Total Cost / R_C Total		***614***

From the figures, the insulation value is lower than Floors 5 and 6, but the cost is much lower due to the omission of the excavation and straw-soil infill; thus the ratio improves. An extra plastic foil under the reflective foil is recommended to overlap joints. Floor 7 is therefore the most cost-efficient design compared with the Floors 5 and 6, and still provides excellent insulation.

COMPARISON TABLE OF EXAMPLE FLOORS #1 – #7

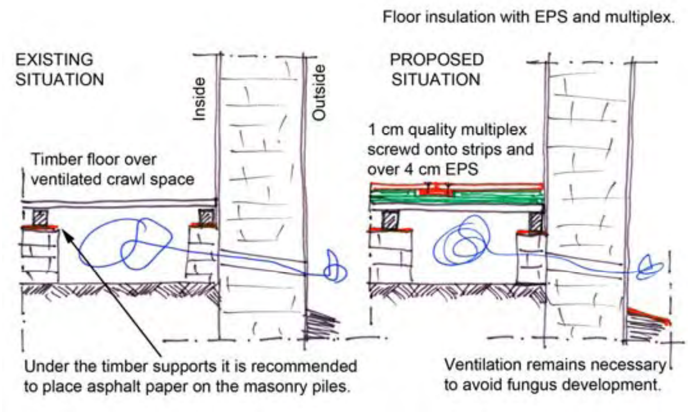
Floor designs with **additional insulation**.

#	Mini Picture of Construction Design	Description	Added R_C = m^2.K/W	Total Insulation Value	Total Cost of Added Insulation	Ratio = Total Cost / R_C Total
Floor # 1		Excavation (20 cm), plastic foil (0.2 mm), refill with straw clay-soil (20 cm), stabilized, straw-grass mat (4 cm), PE foam.	**0.69**	**0.93**	**970**	**1040**
Floor # 2		Excavation (20 cm), plastic foil (0.2 mm), refill with straw clay-soil (20 cm), stabilized, EPS (4 cm), hardboard.	**1.33**	**1.58**	**1420**	**901**
Floor # 3		Excavation (20 cm), plastic foil (0.2 mm), refill with straw clay-soil (20 cm), stabilized, timber floor.	**0.86**	**1.10**	**1570**	**1422**
Floor # 4		Excavation (20 cm), plastic foil (0.2 mm), refill with straw clay-soil (20 cm), stabilized, 1 x RFPE, timber floor.	**2.08**	**2.32**	**1940**	**836**
Floor # 5		Excavation (20 cm), plastic foil (0.2 mm), refill with straw clay-soil (20 cm), stabilized, 2 x RFPE, timber floor.	**2.04**	**2.29**	**1970**	**862**
Floor # 6		Excavation, plastic foil, refill with straw clay-soil (20 cm), stabilized, 1 x RFPE, plastic, timber floor.	**2.13**	**2.37**	**1800**	**759**
Floor # 7		Levelling, plastic foil (0.2 mm), 1 x RFPE, plastic foil, timber floor.	**1.79**	**2.04**	**1250**	**614**

While floor #3 is more expensive because of the added timber floor, each following floor designs has a more cost-efficiency ratio. Because the ground floor in a house needs only half the recommended minimum insulation of the walls and roofs, the last option #7 has a good thermal insulation for up to 4000 m altitude and has the advantage of a firm floor surface. Additional PE foam, mattresses and quilts will further improve the insulation and comfort level when sleeping on the floor.

Thermal Insulation Example Floor #8 Old and New Construction

Recommended Minimum <u>Average</u> R_C Value for Floors = 1/2 {0.5 + (altitude m/1000 m)} $m^2.K/W$



When people sleep on the floor, higher insulation values are recommended.

For each hour less than 5 hrs sun, the insulation value needs to be increased with R_C = 0.1 $m^2.K/W$.

This example is proposed for a clinic building where the patients sleep on elevated beds and the floor needs to be washable, making it more expensive.

Floor #8: Medium density EPS (4 cm) on existing elevated timber floor, multiplex (1 cm). Thickness x R_M = R_C					New Value	Surface Unit of Estimation = **10 m²**		
#	Description of the Existing Construction Layers	Thick Meter	R_M	R_C	Temp ºC	Material in PKR	Skilled Labour Cost	Non-skilled Labour
1	Soil transmission factor	-	-	x				
2	Crawl space, ventilated	1.0	-	0.10				
3	Plank floor	0.03	5.00	0.15				
4	Inside transmission factor	-	-	0.17				
	Subtotal Existing Construction R_C			**0.42**				
#	Description of Each New Layer or New Activity to Install Insulation	Thick Meter	R_M	R_C	Temp ºC	Material in PKR	Skilled Labour Cost	Non-skilled Labour
10	EPS 2 x 2 cm, overlap	0.04	25	1.0		*400*	*100*	*50*
11	Connecting strips, screws	-	-	-		*200*	*100*	*50*
12	Multiplex 1 cm, waterproof	0.01	5	0.05		*500*	*100*	*50*
13	Adjustment doors	-	-	-		*100*	*100*	*50*
	Subtotal Newly Added Value R_C			**1.05**		*1200*	*400*	*200*
	Total Existing and New R_C Values			**1.47**			***Total Cost 10 m²***	***1800***
	Altitude Above Sea Level ____________m	Recommended R_C value		2.0--2.5 3.0--3.5 4.0--4.5	**ΔT**	Ratio = Total Cost / R_C Total		***1224***

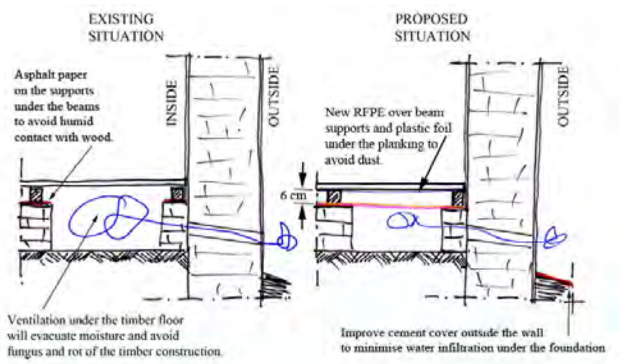
Because the area under the floor is ventilated, the temperature under the floor is also lower than when the same floor is built on the ground. The ventilation of the timber floor is required because of the moisture rising from the ground. This moisture will cause fungus and eventually rotting of the timbers when these are not durably protected or impregnated.

<u>Remarks</u>:

- Floor support beams need asphalt paper over supports.
- Multiplex connector strips need to be minimal 50 cm wide and double screw lines.
- Floor painting/varnish and plinth finishing not included.
- Outside rainwater drainage work not included.
- With raising the floor, the doors need to be adjusted.

Thermal Insulation Example Floor #9 Old and New Construction

Recommended Minimum <u>Average</u> R_C Value for Floors = 1/2 {0.5 + (altitude m/1000 m)} m^2.K/W



When people sleep on the floor, higher insulation values are recommended.

For each hour less than 5 hrs sun, the insulation value needs to be increased with R_C = 0.1 m^2.K/W.

This example is proposed for a school with tables or a clinic building where the patients sleep on elevated beds.

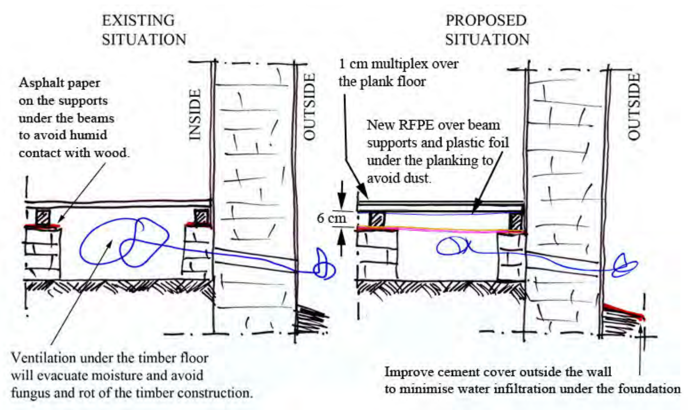
Floor #9: Remove plank floor and place 1 x RFPE over supports, plastic under planks. Thickness x R_M = R_C					New Value	Surface Unit of Estimation = **10 m^2**		
#	Description of the Existing Construction Layers	Thick Meter	R_M	R_C	Temp ºC	Material in PKR	Skilled Labour Cost	Non-skilled Labour
1	Soil transmission factor	-	-	x				
2	Open space under floor	1.0	-	0.10				
3	Plank floor	0.03	5.00	0.15		remove		
4	Inside transmission factor	-	-	0.17				
Subtotal Existing Construction R_C				**0.42**				
#	Description of Each New Layer or New Activity to Install Insulation	Thick Meter	R_M	R_C	Temp ºC	Material in PKR	Skilled Labour Cost	Non-skilled Labour
10	RFPE over posts	0.003	22	0.066		*600*	*100*	*50*
11	Replacement floor joists, Cavity horizon. GBM- HRF	0.06	**Blue**	2.0				
12	Plastic foil under planks	0.001	-	-		*100*	*50*	*50*
13	Plank floor replacement	-	x	x		*400*	*100*	*50*
Subtotal Newly Added Value R_C				**2.066**		*1100*	*250*	*150*
Total Existing and New R_C Values				**2.486**		***Total Cost 10 m^2***		***1500***
Altitude Above Sea Level ___________m		Recommended R_C value		2.0--2.5 3.0--3.5 4.0--4.5	**△T**	Ratio = Total Cost / R_C Total		***603***

In this design, the beams are protected from the damp area by the RFPE and humidity is stopped by the plastic foil under the plank.

It is important that the reflective foil under the floor remains intact and does not get damaged. Depending on the strength of the foil, wire supports may be necessary; increasing the cost and durability. The RFPE should not become dirty by dust falling through the planks. A thick quality (0.2 mm) plastic foil or a polypropylene tarpaulin stretched under the plank floor will protect the reflective foil from dust.

Thermal Insulation Example Floor #10 Old and New Construction

Recommended Minimum <u>Average</u> R_C Value for Floors = 1/2 {0.5 + (altitude m/1000 m)} m^2.K/W



When people sleep on the floor, higher insulation values are recommended.

For each hour less than 5 hrs sun, the insulation value needs to be increased with R_C = 0.1 m^2.K/W.

This example is proposed for a school with tables or a clinic building where the patients sleep on elevated beds.

Instead of plywood, another decorative floor or laminate can be used.

Floor #10: Remove plank floor, place 1 x RFPE over supports, plastic under planks, multiplex cover. Thickness x R_M = R_C					New Value	Surface Unit of Estimation = **10 m²**		
#	Description of the Existing Construction Layers	Thick Meter	R_M	R_C	Temp ºC	Material in PKR	Skilled Labour Cost	Non-skilled Labour
1	Soil transmission factor	-	-	x				
2	Open space under floor	1.0	-	0.10				
3	Plank floor	0.03	5.00	0.15		remove		
4	Inside transmission factor	-	-	0.17				
Subtotal Existing Construction R_C				**0.42**				
#	Description of Each New Layer or New Activity to Install Insulation	Thick Meter	R_M	R_C	Temp ºC	Material in PKR	Skilled Labour Cost	Non-skilled Labour
10	RFPE over posts	0.003	22	0.066		*600*	*100*	*50*
11	Replacement floor joists, Cavity horizon. GBM- HRF	0.06	**Blue**	2.0				
12	Plastic foil under planks	0.001	-	-		*100*	*50*	*50*
13	Plank floor replacement	-	x	x		*100*	*100*	*50*
14	Multiplex cover floor	0.01	5	0.05		*450*	*100*	*50*
Subtotal Newly Added Value R_C				**2.116**		*1250*	*350*	*200*
Total Existing and New R_C Values				**2.536**		***Total Cost 10 m²***		***1800***
Altitude Above Sea Level ___________m		Recommended R_C value		2.0--2.5 3.0--3.5 4.0--4.5	**ΔT**	Ratio = Total Cost / R_C Total		***710***

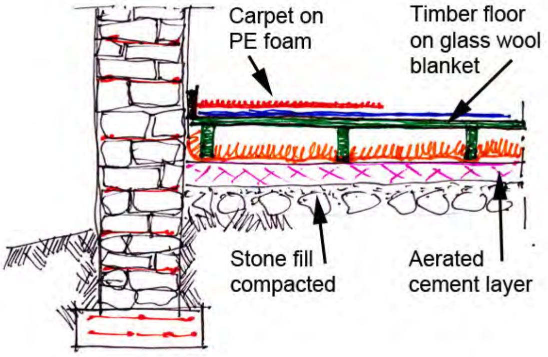
In this design, the beams are protected from the damp area by the RFPE and humidity is stopped by the plastic foil under the plank.

This design is more expensive because of the multiplex cover, but the original plank floor does not require much repairs. Because the overall cost goes up and the insulation value only raises a little, the cost/insulation value ratio also goes up.

The above cost estimate does not include painting, plinths or door correction.

Thermal Insulation Example Floor #11 Old and New Construction

Recommended Minimum <u>Average</u> R_C Value for Floors = 1/2 {0.5 + (altitude m/1000 m)} m^2.K/W



When people sleep on the floor, higher insulation values are recommended.

For each hour less than 5 hrs sun, the insulation value needs to be increased with R_C = 0.1 m^2.K/W.

Horizontal plank supports of the timber floor 8 cm.

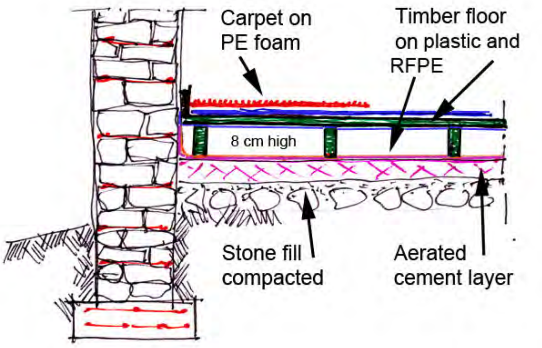
Floor #11: Excavation (20 cm), stone refill, aerated cement (10 cm), glass wool (4 cm), cavity, timber floor, PE foam (7 mm). Thickness x R_M = R_C					New Value	Surface Unit of Estimation = **10 m^2**		
#	Description of the Existing Construction Layers	Thick Meter	R_M	R_C	Temp ºC	Material in PKR	Skilled Labour Cost	Non-skilled Labour
1	Soil transmission factor	-	-	x				
2	Carton sheets, flattened	0.005	5.00	0.025		remove		
3	Carpets, thin, existing	0.005	10.0	0.05		replace		
4	Inside transmission factor	-	-	0.17				
Subtotal Existing Construction R_C				**0.245**				
#	Description of Each New Layer or New Activity to Install Insulation	Thick Meter	R_M	R_C	Temp ºC	Material in PKR	Skilled Labour Cost	Non-skilled Labour
-2	Carton sheets, flattened	0.005	5.00	-0.025		*free*	-	-
10	Excavation, refill gravel	0.20	-	-		*free*	-	-
11	Aerated cement fill	0.10	6.7	0.67		*1400*	*50*	*20*
12	Glass wool 4 cm	0.04	25	1.0		*600*	*100*	*50*
13	Cavity horizontal	0.04	**Black**	0.20		-	-	-
14	Timber floor	0.02	6.0	0.12		*300*	*200*	*100*
15	PE foam	0.007	22	0.154		*100*	*100*	*50*
Subtotal Newly Added Value R_C				**2.119**		*2400*	*450*	*220*
Total Existing and New R_C Values				**2.364**		***Total Cost 10 m^2***		***3070***
Altitude Above Sea Level ___________m		Recommended R_C value		2.0--2.5 3.0--3.5 4.0--4.5	△T	Ratio = Total Cost / R_C Total		***1299***

Comparing this construction design with floors 1-7, it is expensive. The aerated cement, however, gives a solid and durable underground. If many houses are realised with this technology at the same time, the cost may be less.

<u>Remarks</u>:
- Labour for excavation and assistance in mixing by house owner.
- The aerated cement also stops the humidity from the underground, but is expensive.
- Additional mattresses, quilts or pillows not included in calculation.

Thermal Insulation Example Floor #12   Old and New Construction

Recommended Minimum <u>Average</u> R_C Value for Floors = 1/2 {0.5 + (altitude m/1000 m)} m^2.K/W



When people sleep on the floor, higher insulation values are recommended.

For each hour less than 5 hrs sun, the insulation value needs to be increased with R_C = 0.1 m^2.K/W.

Horizontal plank supports of the timber floor 8 cm.

Floor #12: Excavation (20 cm), stone refill, aerated cement (10 cm), RFPE (3 mm), cavity, plastic, timber floor, PE foam (7 mm). Thickness x R_M = R_C					New Value	Surface Unit of Estimation = **10 m^2**		
#	Description of the Existing Construction Layers	Thick Meter	R_M	R_C	Temp °C	Material in PKR	Skilled Labour Cost	Non-skilled Labour
1	Soil transmission factor	-	-	x				
2	Carton sheets, flattened	0.005	5.00	0.025		remove		
3	Carpets, thin, existing	0.005	10.0	0.05		replace		
4	Inside transmission factor	-	-	0.17				
Subtotal Existing Construction R_C				**0.245**				
#	Description of Each New Layer or New Activity to Install Insulation	Thick Meter	R_M	R_C	Temp °C	Material in PKR	Skilled Labour Cost	Non-skilled Labour
-2	Carton sheets, flattened	0.005	5.00	-0.025		*free*	-	-
10	Excavation, refill gravel	0.20	-	-		*free*	-	-
11	Aerated cement fill	0.10	6.7	0.67		*1400*	*50*	*20*
12	1 x RFPE	0.003	22	0.066		*600*	*100*	*50*
13	Cavity horizont. GBM-HRF	0.08	**Blue**	2.0		-	-	-
14	Plastic dust proofing	0.002	-	-		*100*	*10*	-
15	Timber floor	0.02	6.0	0.12		*300*	*200*	*100*
16	PE foam	0.007	22	0.154		*100*	*100*	*50*
Subtotal Newly Added Value R_C				**2.985**		*2500*	*460*	*220*
Total Existing and New R_C Values				**3.23**		***Total Cost 10 m^2***		***3180***
Altitude Above Sea Level ____________m		Recommended R_C value		2.0--2.5 3.0--3.5 4.0--4.5	**ΔT**	Ratio = Total Cost / R_C Total		***985***

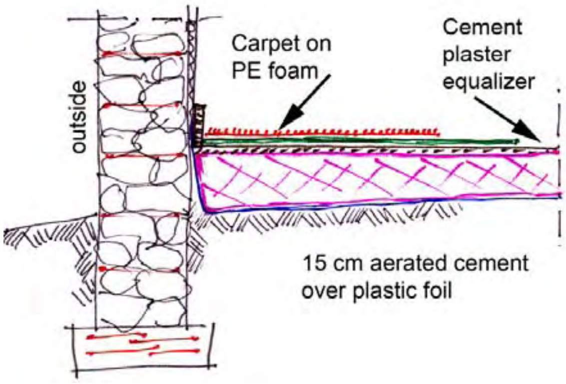
Comparing this construction design with floor #11, it is only slightly more expensive because of the additional plastic, but far more insulating. The result is that the ratio lowers considerable. The glass wool will prevent mice, but if it becomes moist, its insulating value will strongly reduce.

<u>Remarks</u>:

- Labour for excavation and assistance in mixing by house owner.
- The aerated cement also stops the humidity from the underground, but is expensive.

Thermal Insulation Example Floor #13 Old and New Construction

Recommended Minimum Average R_C Value for Floors = 1/2 {0.5 + (altitude m/1000 m)} m^2.K/W



When people sleep on the floor, higher insulation values are recommended.

For each hour less than 5 hrs sun, the insulation value needs to be increased with R_C = 0.1 m^2.K/W.

This floor design should also be compared with designs #1-7.

Floor #13: Excavation (20 cm), plastic foil (0.2 mm), refill with aerated cement (15 cm), cement plaster finish (3 cm), PE foam (7 mm). Thickness x R_M = R_C					New Value	Surface Unit of Estimation = **10 m^2**		
#	Description of the Existing Construction Layers	Thick Meter	R_M	R_C	Temp ºC	Material in PKR	Skilled Labour Cost	Non-skilled Labour
1	Soil transmission factor	-	-	x				
2	Carton sheets, flattened	0.005	5.00	0.025		remove		
3	Carpets, thin, existing	0.005	10.0	0.05		replace		
4	Inside transmission factor	-	-	0.17				
	Subtotal Existing Construction R_C			**0.245**				
#	Description of Each New Layer or New Activity to Install Insulation	Thick Meter	R_M	R_C	Temp ºC	Material in PKR	Skilled Labour Cost	Non-skilled Labour
-2	Carton sheets, flattened	0.005	5.00	-0.025		*free*	-	-
10	Excavation existing floor	0.20	-	-		*free*	-	-
11	Plastic foil 0.2 mm	-	-	-		*100*	*50*	*20*
12	Aerated cement fill (3 cm)	0.15	6.7	1.005		*2000*	*200*	*200*
13	Cement plaster topping	0.03	0.77	0.023		*200*	*100*	*50*
14	PE foam	0.007	22	0.154		*100*	*100*	*50*
	Subtotal Newly Added Value R_C			**1.157**		*2400*	*450*	*320*
	Total Existing and New R_C Values			**1.402**			***Total Cost 10 m^2***	***3170***
	Altitude Above Sea Level ___________m	Recommended R_C value		2.0--2.5 3.0--3.5 4.0--4.5	**△T**	Ratio = Total Cost / R_C Total		***2261***

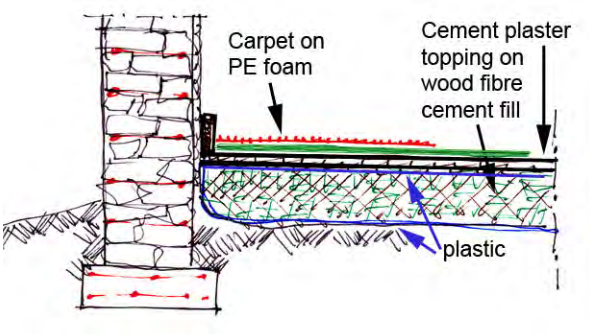
Comparing the ratio with other floors, this is not a very cost-efficient solution.

Remarks:

- Labour for excavation and assistance in mixing by house owner. Part of soil re-used.
- Plastic moisture barrier under the excavation is necessary to ensure a dry base.
- The 3 cm sand-cement-aluminium mixture expands to 15 cm on average. Values can vary.
- Additional mattresses, quilts or pillows not included in calculation.

Thermal Insulation Example Floor #14 Old and New Construction

Recommended Minimum <u>Average</u> R_C Value for Floors = 1/2 {0.5 + (altitude m/1000 m)} m^2.K/W



When people sleep on the floor higher, insulation values are recommended.

For each hour less than 5 hrs sun, the insulation value needs to be increased with R_C = 0.1 m^2.K/W.

This floor is almost similar to floors #1 and #2, but with a cemented (stronger) top surface. The surface can be made even stronger by putting a 5 mm metal bar reinforcement mesh in a 4 cm cement layer.

Floor #14: Excavation (20 cm), plastic foil (0.2 mm), refill with wood shavings cement (15 cm), plastic, cement plaster finish (3 cm), PE foam (7 mm). Thickness x R_M = R_C					New Value	Surface Unit of Estimation = **10 m^2**		
#	Description of the Existing Construction Layers	Thick Meter	R_M	R_C	Temp ºC	Material in PKR	Skilled Labour Cost	Non-skilled Labour
1	Soil transmission factor	-	-	0.00				
2	Carton sheets, flattened	0.005	5.00	0.025		remove		
3	Carpets, thin, existing	0.005	10.0	0.05		replace		
4	Inside transmission factor	-	-	0.17				
Subtotal Existing Construction R_C				**0.245**				
#	Description of Each New Layer or New Activity to Install Insulation	Thick Meter	R_M	R_C	Temp ºC	Material in PKR	Skilled Labour Cost	Non-skilled Labour
-2	Carton sheets, flattened	0.005	5.00	-0.025		*free*	-	-
10	Excavation existing floor	0.20	-	-		*free*	-	-
11	Plastic foil 0.2 mm	-	-	-		*100*	*50*	*20*
12	Wood shavings cement fill	0.15	5.5	0.825		*2500*	*200*	*200*
13	Plastic cover sheet	0.001	-	-		*50*	*20*	*10*
14	Cement plaster topping	0.03	0.77	0.023		*200*	*100*	*50*
15	PE foam	0.007	22	0.154		*100*	*100*	*50*
Subtotal Newly Added Value R_C				**0.977**		*2950*	*470*	*330*
Total Existing and New R_C Values				**1.222**		***Total Cost 10 m^2***		***3750***
Altitude Above Sea Level ___________m		Recommended R_C value		2.0--2.5 3.0--3.5 4.0--4.5	**ΔT**	Ratio = Total Cost / R_C Total		***3069***

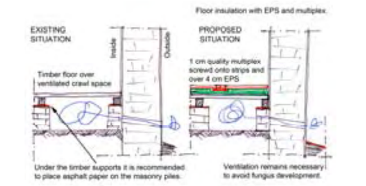
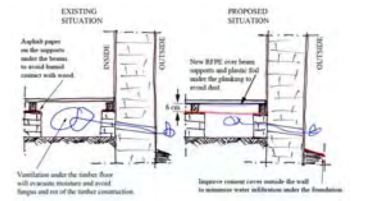
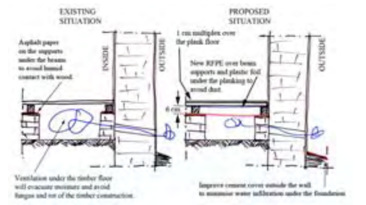
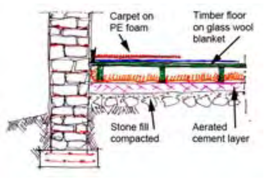
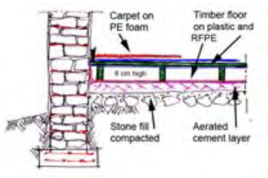
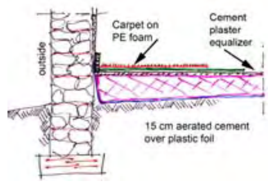
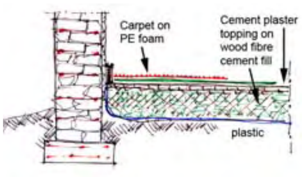
The advantage of a cement-bonded wood shavings under floor is that it is less vulnerable to insects. To avoid water infiltration from above, a plastic is needed under the cement floor. The same design can be made with a tiled floor, reducing the possible water infiltration (kitchen, shower, bathroom).

<u>Remarks</u>:

- Labour for excavation and assistance in mixing by house owner.
- Plastic moisture barrier under the excavation is necessary to ensure a dry base.
- The wood shavings cement, lightly compacted has a lower density than prefabricated panels.

COMPARISON TABLE OF EXAMPLE FLOORS #8 – #14

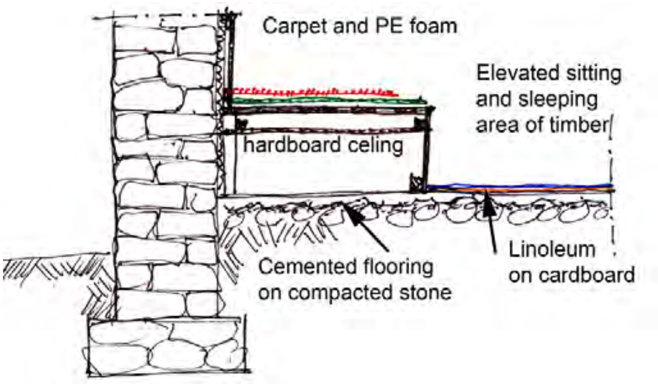
Floor designs with **additional insulation**.

#	Mini Picture of Construction Design	Description	Added R_C = $m^2.K/W$	Total Insulation Value	Total Cost of Added Insulation	Ratio = Total Cost / R_C Total
Floor # 8		Medium density EPS (4 cm) on existing elevated timber floor, multiplex (1 cm).	**1.05**	**1.47**	**1800**	**1224**
Floor # 9		Remove plank floor, place 1 x RFPE over supports, plastic under planks.	**2.07**	**2.49**	**1500**	**603**
Floor # 10		Remove plank floor, place 1 x RFPE over supports, plastic under planks, multiplex cover.	**2.12**	**2.54**	**1800**	**710**
Floor # 11		Excavation (20 cm), stone refill, aerated cement (10 cm), glass wool (4 cm), cavity, timber floor, PE foam (7 mm).	**2.12**	**2.36**	**3070**	**1299**
Floor # 12		Excavation (20 cm), stone refill, aerated cement (10 cm), 1 x RFPE (3 mm), cavity, plastic, timber floor, PE foam (7 mm).	**2.99**	**3.23**	**3180**	**985**
Floor # 13		Excavation (20 cm), plastic foil (0.2 mm), refill with aerated cement (15 cm), cement plaster finish (3 cm), PE foam (7 mm).	**1.16**	**1.40**	**3170**	**2261**
Floor # 14		Excavation (20 cm), plastic foil (0.2 mm), refill with wood shavings cement (15 cm), plastic, cement plaster finish (3 cm), PE foam (7 mm).	**0.98**	**1.22**	**3750**	**3069**

Floor #9 and variations on this design are the most cost-effective.

Thermal Insulation Example Floor #15 Old and New Construction

Recommended Minimum Average R_C Value for Floors = 1/2 {0.5 + (altitude m/1000 m)} m^2.K/W



When people sleep on the floor, higher insulation values are recommended.

For each hour less than 5 hrs sun, the insulation value needs to be increased with R_C = 0.1 m^2.K/W.

Elevated area for sitting and sleeping. The central floor in the room remains with a very low thermal insulation and large heat loss.

Floor #15: Stone cement plaster, elevated sitting, 2 x cavity, board, timber floor, PE foam (7 mm), carpet. Thickness x R_M = R_C					New Value	Surface Unit of Estimation = **10 m^2**		
#	Description of the Existing Construction Layers	Thick Meter	R_M	R_C	Temp ºC	Material in PKR	Skilled Labour Cost	Non-skilled Labour
1	Soil transmission factor	-	-	x				
2	Carton sheets, flattened	0.005	5.00	0.025		remove		
3	Carpets, thin, existing	0.005	10.0	0.05		replace		
4	Inside transmission factor	-	-	0.17				
Subtotal Existing Construction R_C				**0.245**				
#	Description of Each New Layer or New Activity to Install Insulation	Thick Meter	R_M	R_C	Temp ºC	Material in PKR	Skilled Labour Cost	Non-skilled Labour
-2	Carton sheets, flattened	0.005	5.00	-0.025		*free*	-	-
10	Timber construction	-	-	-		*1000*	*250*	*100*
11	Cavity horizon. GBM-GBM	0.35	**Black**	1.00		-	-	-
12	Hardboard ceiling	0.03	5	0.15		*200*	*100*	*50*
13	Cavity horizon. GBM-GBM	0.05	**Black**	0.30		-	-	-
14	Timber floor	0.02	6.0	0.12		*300*	*200*	*100*
15	PE foam	0.007	22	0.154		*100*	*100*	*50*
Subtotal Newly Added Value R_C				**1.699**		*1600*	*650*	*300*
Total Existing and New R_C Values				**1.944**		***Total Cost 10 m^2***		***2550***
Altitude Above Sea Level ___________m		Recommended R_C value		2.0--2.5 3.0--3.5 4.0--4.5	**ΔT**	Ratio = Total Cost / R_C Total		***1312***

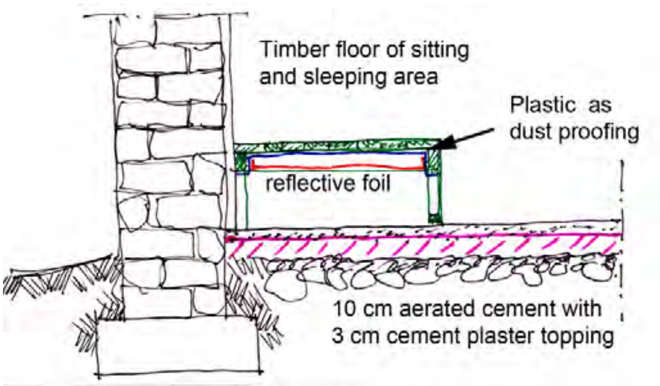
The advantage of this design is that the total surface area to be constructed is less than the total floor area of the room. Heat loss will continue from the central part of the floor.

Remarks:

- Space under sitting areas can be used as storage;
- Timber side panelling not included in the cost.

Thermal Insulation Example Floor #16 Old and New Construction

Recommended Minimum <u>Average</u> R_C Value for Floors = 1/2 {0.5 + (altitude m/1000 m)} m^2.K/W



When people sleep on the floor, higher insulation values are recommended.

For each hour less than 5 hrs sun, the insulation value needs to be increased with R_C = 0.1 m^2.K/W.

This design need to be compared with floors #12 and #15.

Floor #16: Stone with aerated cement (10 cm), cement plaster (3 cm), elevated sitting, 2 x cavity, RFPE, plastic, timber floor. Thickness x R_M = R_C					New Value	Surface Unit of Estimation = **10 m²**		
#	Description of the Existing Construction Layers	Thick Meter	R_M	R_C	Temp ºC	Material in PKR	Skilled Labour Cost	Non-skilled Labour
1	Soil transmission factor	-	-	x				
2	Carton sheets, flattened	0.005	5.00	0.025		remove		
3	Carpets, thin, existing	0.005	10.0	0.05		replace		
4	Inside transmission factor	-	-	0.17				
	Subtotal Existing Construction R_C			**0.245**				
#	Description of Each New Layer or New Activity to Install Insulation	Thick Meter	R_M	R_C	Temp ºC	Material in PKR	Skilled Labour Cost	Non-skilled Labour
-2	Carton sheets, flattened	0.005	5.00	-0.025		*free*	-	-
10	Aerated cement floor	0.10	6.7	0.67		*1400*	*200*	*100*
11	Cement plaster topping	0.03	0.77	0.023		*200*	*100*	*50*
12	Timber construction	-	-	-		*1000*	*250*	*100*
13	Cavity horiz. GBM-RFPE	0.35	Pink	1.50		-	-	-
14	Reflective foil PE backing	0.003	22	0.066		*200*	*100*	*50*
15	Cavity horiz. RFPE-GBM	0.05	Pink	1.10		-	-	-
16	Plastic dust proofing	-	-	-		*100*	*50*	*20*
17	Timber floor	0.02	6.0	0.12		*300*	*200*	*100*
	Subtotal Newly Added Value R_C			**3.454**		*3200*	*900*	*420*
	Total Existing and New R_C Values			**3.699**			***Total Cost 10 m²***	***4520***
	Altitude Above Sea Level __________m	Recommended R_C value		2.0--2.5 3.0--3.5 4.0--4.5	△T	Ratio = Total Cost / Rc Total		***1222***

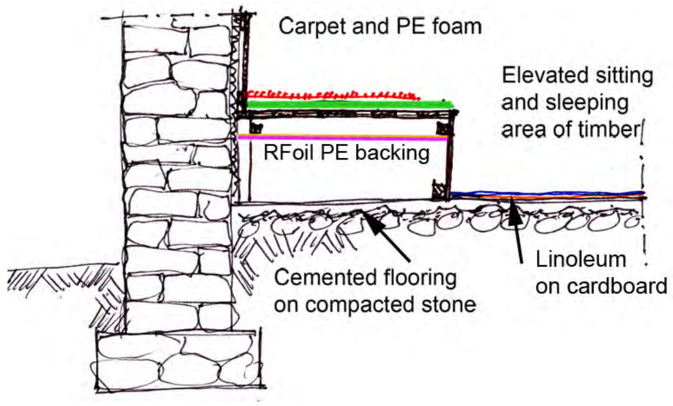
Placing the reflective foil with a cavity on both sides has an enormous impact on the thermal insulation quality. This makes the sitting area comfortable and cost-efficient. The cost of the aerated cement floor under the elevated sitting area is high, but when the house design changes and the elevated sitting area is removed, the whole floor has insulation.

<u>Remarks</u>:

- Avoid damage of RFPE when area is used for storage.

Thermal Insulation Example Floor #17 Old and New Construction

Recommended Minimum <u>Average</u> R_C Value for Floors = 1/2 {0.5 + (altitude m/1000 m)} m^2.K/W



When people sleep on the floor, higher insulation values are recommended.

For each hour less than 5 hrs sun, the insulation value needs to be increased with R_C = 0.1 m^2.K/W.

Elevated area for sitting and sleeping. The central floor in the room remains with a very low thermal insulation and large heat loss.

Floor #17: Stone cement plaster, elevated sitting, 2 x cavity, RFPE, timber floor, PE foam (7 mm), carpet. Thickness x R_M = R_C					New Value	Surface Unit of Estimation = **10 m²**		
#	Description of the Existing Construction Layers	Thick Meter	R_M	R_C	Temp ºC	Material in PKR	Skilled Labour Cost	Non-skilled Labour
1	Soil transmission factor	-	-	x				
2	Carton sheets, flattened	0.005	5.00	0.025		remove		
3	Carpets, thin, existing	0.005	10.0	0.05		replace		
4	Inside transmission factor	-	-	0.17				
	Subtotal Existing Construction R_C			**0.245**				
#	Description of Each New Layer or New Activity to Install Insulation	Thick Meter	R_M	R_C	Temp ºC	Material in PKR	Skilled Labour Cost	Non-skilled Labour
-2	Carton sheets, flattened	0.005	5.00	-0.025		*free*	-	-
10	Timber construction	-	-	-		*1000*	*250*	*100*
11	Cavity horiz. GBM-RFPE	0.35	**Pink**	1.50		-	-	-
12	RFPE foil	0.003	22	0.066		*600*	*100*	*50*
13	Cavity hor. HRF-GBM (½)	0.05	**Pink**	0.65		-	-	-
14	Timber floor	0.02	6.0	0.12		*300*	*200*	*100*
15	PE foam	0.007	22	0.154		*100*	*100*	*50*
	Subtotal Newly Added Value R_C			**2.465**		*2000*	*650*	*300*
	Total Existing and New R_C Values			**2.71**		***Total Cost 10 m²***		***2950***
Altitude Above Sea Level ___________m		Recommended R_C value		2.0--2.5 3.0--3.5 4.0--4.5	**ΔT**	Ratio = Total Cost / R_C Total		***1089***

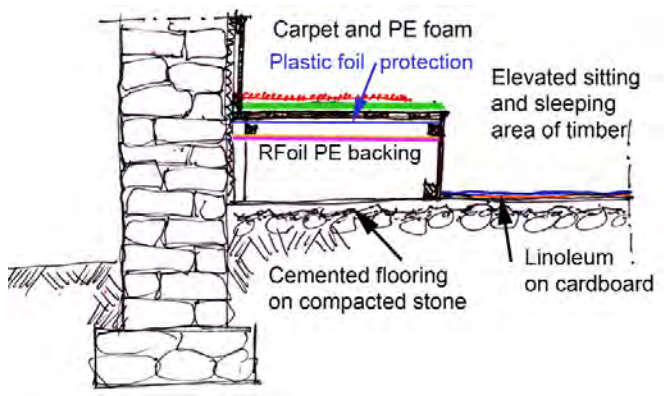
The advantage of this design is that the total surface area to be constructed is less than the total floor area of the room. Disadvantage is that heat loss from the central part of the floor will be high. The insulation value can be improved with a dust protection under the seating area, see floor #18.

<u>Remarks</u>:

- Space under sitting areas can be used as storage; damage to the foil needs to be avoided.
- Timber side panelling not included in the cost.

Thermal Insulation Example Floor #18 Old and New Construction

Recommended Minimum <u>Average</u> R_C Value for Floors = 1/2 {0.5 + (altitude m/1000 m)} m^2.K/W



When people sleep on the floor, higher insulation values are recommended.

For each hour less than 5 hrs sun, the insulation value needs to be increased with R_C = 0.1 m^2.K/W.

Elevated area for sitting and sleeping. The central floor in the room remains with a very low thermal insulation and large heat loss.

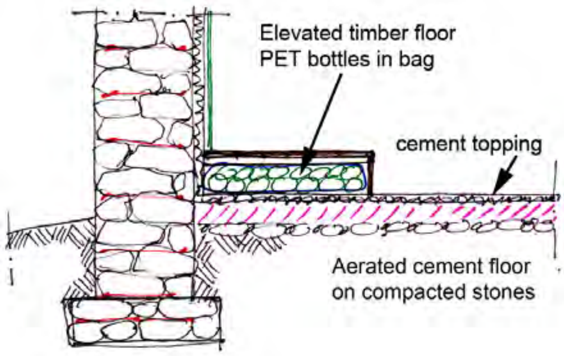
Floor #18: Stone cement plaster, elevated sitting, 2 x cavity, RFPE, plastic, timber floor, PE foam (7 mm). Thickness x R_M = R_C					New Value	Surface Unit of Estimation = **10 m^2**		
#	Description of the Existing Construction Layers	Thick Meter	R_M	R_C	Temp ºC	Material in PKR	Skilled Labour Cost	Non-skilled Labour
1	Soil transmission factor	-	-	x				
2	Carton sheets, flattened	0.005	5.00	0.025		remove		
3	Carpets, thin, existing	0.005	10.0	0.05		replace		
4	Inside transmission factor	-	-	0.17				
Subtotal Existing Construction R_C				**0.245**				
#	Description of Each New Layer or New Activity to Install Insulation	Thick Meter	R_M	R_C	Temp ºC	Material in PKR	Skilled Labour Cost	Non-skilled Labour
-2	Carton sheets, flattened	0.005	5.00	-0.025		*free*	-	-
10	Timber construction	-	-	-		*1000*	*250*	*100*
11	Cavity horiz. GBM-RFPE	0.35	**Pink**	1.50		-	-	-
12	RFPE foil	0.003	22	0.066		*600*	*100*	*50*
13	Cavity hor. HRF-GBM (½)	0.05	**Pink**	1.30		*100*	*50*	-
14	Plastic dust proofing	0.002	-	-				
15	Timber floor	0.02	6.0	0.12		*300*	*200*	*100*
16	PE foam	0.007	22	0.154		*100*	*100*	*50*
Subtotal Newly Added Value R_C				**3.115**		*2100*	*700*	*300*
Total Existing and New R_C Values				**3.36**		***Total Cost 10 m^2***		***3100***
Altitude Above Sea Level ___________m		Recommended R_C value		2.0--2.5 3.0--3.5 4.0--4.5	$\triangle$T	Ratio = Total Cost / R_C Total		***923***

The advantage of this design is that the total surface area to be constructed is less than the total floor area of the room. Disadvantage is that heat loss from the central part of the floor will be high.

<u>Remarks</u>:
- Space under sitting areas can be used as storage; damage to the foil needs to be avoided.
- Timber side panelling not included in the cost.

Thermal Insulation Example Floor #19 Old and New Construction

Recommended Minimum Average R_C Value for Floors = 1/2 {0.5 + (altitude m/1000 m)} m^2.K/W



When people sleep on the floor, higher insulation values are recommended.

For each hour less than 5 hrs sun, the insulation value needs to be increased with R_C = 0.1 m^2.K/W.

The re-utilization of empty PET bottles and packing these in plastic bags is highly effective for thermal insulation, but collection needs to be organized locally.

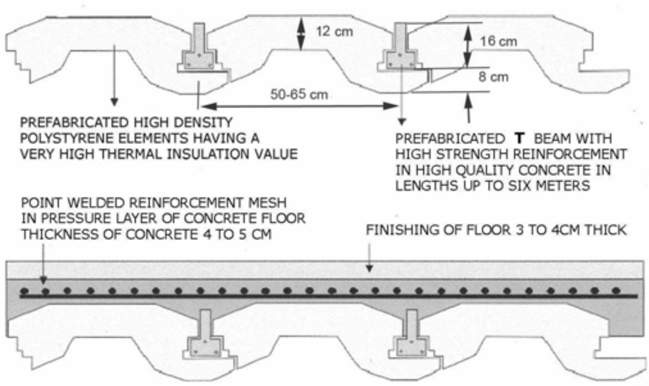
Floor #19: Stone with aerated cement (10 cm), cement plaster (3 cm), elevated sitting, PET bottles in plastic bags, timber floor. Thickness x R_M = R_C					New Value	Surface Unit of Estimation = **10 m^2**		
#	Description of the Existing Construction Layers	Thick Meter	R_M	R_C	Temp ºC	Material in PKR	Skilled Labour Cost	Non-skilled Labour
1	Soil transmission factor	-	-	x				
2	Carton sheets, flattened	0.005	5.00	0.025		remove		
3	Carpets, thin, existing	0.005	10.0	0.05		replace		
4	Inside transmission factor	-	-	0.17				
	Subtotal Existing Construction R_C			**0.245**				
#	Description of Each New Layer or New Activity to Install Insulation	Thick Meter	R_M	R_C	Temp ºC	Material in PKR	Skilled Labour Cost	Non-skilled Labour
-2	Carton sheets, flattened	0.005	5.00	-0.025		*free*	-	-
10	Aerated cement floor (2cm)	0.10	6.7	0.67		*1400*	*200*	*100*
11	Cement plaster topping	0.03	0.77	0.023		*200*	*100*	*50*
12	Timber construction	-	-	-		*1000*	*250*	*100*
13	PET bottles in bags	0.15	15	2.25		*300*	*100*	*50*
14	Timber floor	0.02	6.0	0.12		*300*	*200*	*100*
	Subtotal Newly Added Value R_C			**3.038**		*3200*	*850*	*400*
	Total Existing and New R_C Values			**3.283**			***Total Cost 10 m^2***	***4450***
	Altitude Above Sea Level ___________m	Recommended R_C value		2.0--2.5 3.0--3.5 4.0--4.5	ΔT	Ratio = Total Cost / R_C Total		***1355***

The advantage of a highly insulated sitting sleeping area is combined with a basic floor insulation.

Remarks:
- Labour for excavation and assistance in mixing by house owner.
- Central floor area has improved insulation value.
- PET bottles in bags is packed air and insulating; alternative to straw-lime in plastic bags.
- Area under elevated floor cannot be used for storage.

Thermal Insulation Example Floor #20 Old and New Construction

Recommended Minimum Average R_C Value for Floors = 1/2 {0.5 + (altitude m/1000 m)} m^2.K/W



When people sleep on the floor, higher insulation values are recommended.

For each hour less than 5 hrs sun, the insulation value needs to be increased with R_C = 0.1 m^2.K/W.

Typical prefabricated T beam floor with self-supporting formwork for casting reinforced concrete pressure layer.

Floor #20: EPS (12 cm), T beams, reinforced concrete (5 cm), floor finish (3 cm). Thickness x R_M = R_C					New Value	Surface Unit of Estimation = **10 m^2**		
#	Description of the Existing Construction Layers	Thick Meter	R_M	R_C	Temp ºC	Material in PKR	Skilled Labour Cost	Non-skilled Labour
1	Soil transmission factor	-	-	x				
2	Cavity floor (no vent)	0.50	**Black**	0.5				
3	Reinforced concrete floor	0.12	0.6	0.072		change		
4	Finishing of floor	0.03	0.7	0.021				
5	Inside transmission factor	-	-	0.17				
	Subtotal Existing Construction R_C			**0.763**				
#	Description of Each New Layer or New Activity to Install Insulation	Thick Meter	R_M	R_C	Temp ºC	Material in PKR	Skilled Labour Cost	Non-skilled Labour
-3	Reinforced concrete floor	0.12	0.6	-0.072		-	-	-
10	High tension T beams	0.16	0.6	-		*4000*	*300*	*200*
11	EPS supporting forms	0.12	25	3.00		*3000*	*300*	*100*
12	Reinforced concrete	0.05	0.6	0.03		*3000*	*400*	*200*
	Subtotal Newly Added Value R_C			**2.958**		*10000*	*1000*	*500*
	Total Existing and New R_C Values			**3.721**		***Total Cost 10 m^2***		***11500***
	Altitude Above Sea Level ____________m	Recommended R_C value		2.0--2.5 3.0--3.5 4.0--4.5	**△T**	Ratio = Total Cost / R_C Total		***3091***

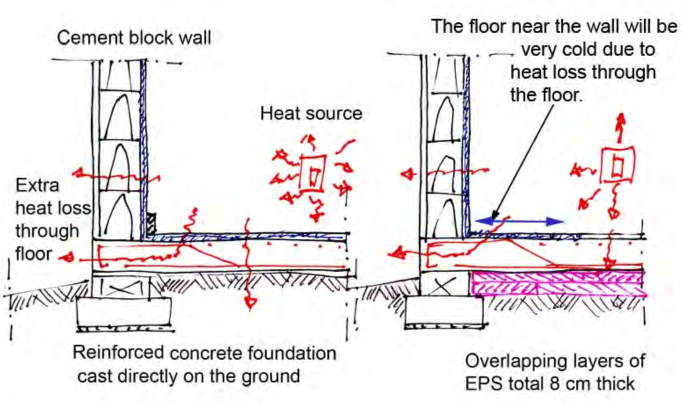
Reinforced concrete is an expensive building material and prefabricated concrete even more expensive. These materials are even more expensive in high altitude areas because of transport. For buildings in large towns, these constructions are sometimes possible.

Remarks:

- The reinforced concrete floor has a high heat storage capacity and will take a long time before it is warmed up. This means that the floor will have the daily average room temperature.
- Floor design possible with low temperature floor heating inside because heat will not go down.
- When the cavity under the floor is lightly ventilated, the cavity insulation will be half.

Thermal Insulation Example Floor #21 Old and New Construction

Recommended Minimum Average R_C Value for Floors = 1/2 {0.5 + (altitude m/1000 m)} m^2.K/W



When people sleep on the floor, higher insulation values are recommended.

For each hour less than 5 hrs sun, the insulation value needs to be increased with R_C = 0.1 m^2.K/W.

Typical reinforced concrete floor cast directly on the infill ground.

This design cannot be made after the concrete has been cast on the ground.

Floor #21: EPS (8 cm), reinforced concrete (12 cm), floor finish (3 cm). Thickness x R_M = R_C					New Value	Surface Unit of Estimation = **10 m^2**		
#	Description of the Existing Construction Layers	Thick Meter	R_M	R_C	Temp ºC	Material in PKR	Skilled Labour Cost	Non-skilled Labour
1	Soil transmission factor	-	-	x				
2	Reinforced concrete floor	0.12	0.6	0.072				
4	Finishing of floor	0.03	0.7	0.021				
5	Inside transmission factor	-	-	0.17				
Subtotal Existing Construction R_C				**0.263**				
#	Description of Each New Layer or New Activity to Install Insulation	Thick Meter	R_M	R_C	Temp ºC	Material in PKR	Skilled Labour Cost	Non-skilled Labour
10	EPS supporting sheets	0.08	25	2.00		*1000*	*100*	*50*
Subtotal Newly Added Value R_C				**2.00**		*1000*	*100*	*50*
Total Existing and New R_C Values				**2.263**		***Total Cost 10 m^2***		***1150***
Altitude Above Sea Level ___________m		Recommended R_C value		2.0--2.5 3.0--3.5 4.0--4.5	**△T**	Ratio = Total Cost / R_C Total		***508***

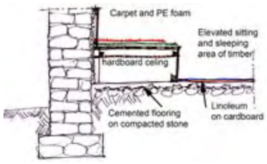
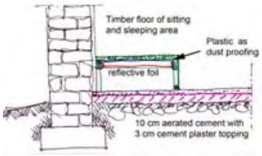
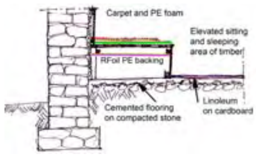
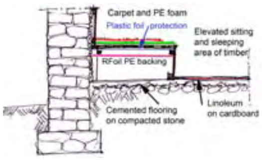
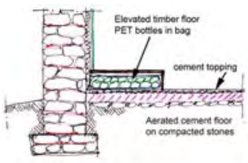
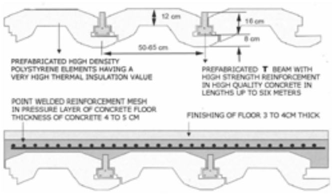
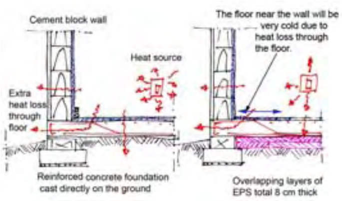
Reinforced concrete is an expensive building material and even more expensive in high altitude areas. For buildings in large towns, these constructions are frequently realized.

A thick layer of EPS under the concrete will substantially improve thermal insulation, but has to be realized before the floor is cast.

Remarks:
- The reinforced concrete floor has a high heat storage capacity and will take a long time before it is warmed up. This means that the floor will have the daily average room temperature.
- Heat loss through the sides should be avoided by insulating the sides and keeping the main floor separated from the outside wall.
- Floor design with insulated sides is possible with low temperature floor heating inside because heat will not go down.

COMPARISON TABLE OF EXAMPLE FLOORS #15 – #21

Floor designs with **additional insulation**.

#	Mini Picture of Construction Design	Description	Added Rc = m²K/W	Total Insulation Value	Total Cost of Added Insulation	Ratio = Total Cost / Rc Total
Floor # 15		Stone cement plaster, elevated sitting, 2 x cavity, board, timber floor, PE foam (7 mm), carpet.	**1.70**	**1.94**	**2550**	**1312**
Floor # 16		Stone with aerated cement (10 cm), cement plaster (3 cm), elevated sitting, 2 x cavity, RFPE, plastic, timber floor.	**3.45**	**3.70**	**4520**	**1222**
Floor # 17		Stone cement plaster, elevated sitting, 2 x cavity, RFPE, timber floor, PE foam (7 mm), carpet.	**2.47**	**2.71**	**2950**	**1089**
Floor # 18		Stone cement plaster, elevated sitting, 2 x cavity, RFPE, plastic, timber floor, PE foam (7 mm).	**3.12**	**3.36**	**3100**	**923**
Floor # 19		Stone with aerated cement 10 cm), cement plaster (3 cm), elevated sitting, PET bottles in plastic bags, timber floor.	**3.04**	**3.28**	**4450**	**1355**
Floor # 20		EPS (12 cm), reinforced concrete (5 cm), floor finish (3 cm).	**2.96**	**3.72**	**11500**	**3091**
Floor # 21		EPS (8 cm), reinforced concrete (12 cm), floor finish (3 cm).	**2.0**	**2.26**	**1150**	**508**

All of the above designs should be recalculated with the real or current construction costs, taking into consideration the contributions of the house owner. This way, realistic cost estimates can be made and the cost-efficiency factor better defined.

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