HUYS ADVIES

19 Examples of Wall Insulation

Technical Working Paper ~ Number 6

Thermal Insulation Values for Houses in High Mountain Areas 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:
Application of High Reflective Foil (HRF) on an office wall as a training exercise.
The insulation technique inside the wall remained visible through a viewing opening.
In addition, an explanatory text (poster) was affixed next to the viewing opening.

INTRODUCTION

This document provides examples of insulation methods for walls 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 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 outside; this can include a buffer room.

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

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.

EPS or Glass Wool
Glass wool can be substituted with Expanded Polystyrene (EPS), which is easier to work with and does not create skin or eye irritation when handling it. One problem of low quality glass wool is that it can absorb moisture and become less effective as a thermal insulator. EPS stays dry.

Moisture Barrier
For nearly all inside constructions, a full height moisture or humidity barrier on the warm side of the construction will be necessary; otherwise, condensation will occur inside the insulation material or on the inside of the wall. Both (recycled) plastic foils and reflective foils are moisture barriers.

Wall 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 walls 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.

[1] See: www.nienhuys.info

Use of Tables for Calculation of Cavities

Vertical air cavities have a good insulation value up to about 2 cm in width; wider cavities are influenced by the effect of air circulation or convection.

Although dry air is a very good thermal insulator, its insulating effect in narrow cavities is strongly reduced by the heat radiation from the warm side to the cold side.

The radiation can be stopped with the use of highly reflective metalized plastic foils and aluminium foils. The more reflective the foil is (with lesser emissivity = ε), the higher the insulation value.

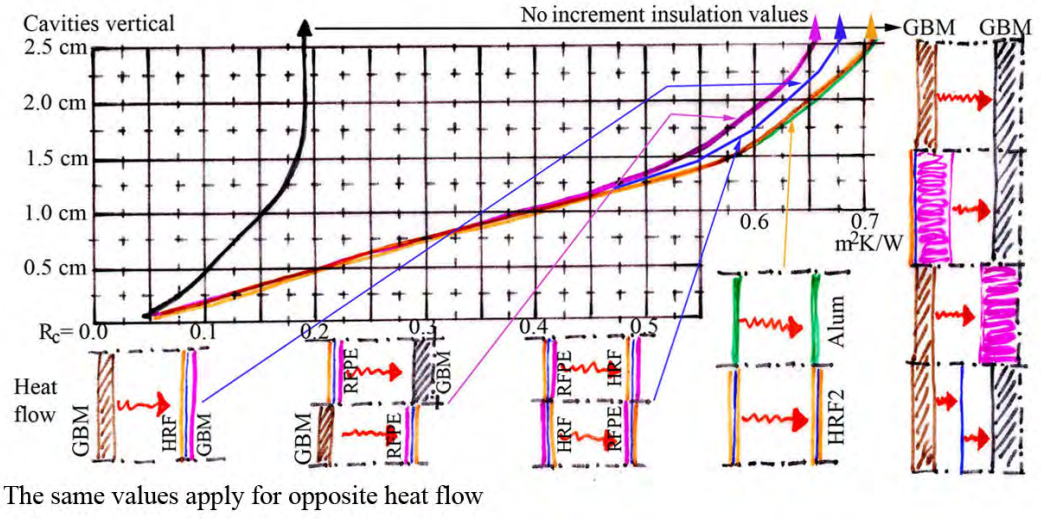
The table below shows that a vertical air cavity wider than 2 cm (¾") will be less effective than when the same space is filled with 2 cm wood shavings (R_C = 0.02 x 12 = 0.24 m^2.K/W) or 2 cm straw (R_C = 0.02 x 15 = 0.3 m^2.K/W); this is due to the increased air circulation for wider spaces. Air cavities wider than 2 cm therefore need to be filled with air-storing materials. The graph below also shows that increasing the air cavities more than 1.5 cm does not increase the insulation value for vertical cavities or horizontal heat flows.

GBM = General Building Materials (stone, straw, glass wool, timber, cement, plaster). ε = 0.9
HRF = Highly Reflective Foil (such as metalized polyester). ε = 0.04
HRF2 = Highly Reflective Foil with two sides metalized. ε = 0.04
RFPE = Reflective Foil with Polyethylene foam, or plasticized reflective foil. ε = 0.1
Alum = Aluminium (difference between shiny and non-shiny side is not important). ε = 0.04

Insulation values for vertical cavities, in both horizontal directions, such as with **walls**.

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	0.17	0.61	0.62	0.64
2.5	0.18	0.68	0.69	0.71
>3.0	0.19	0.68	0.69	0.71

INSULATION VALUES FOR CAVITIES AND REFLECTIVE FOILS

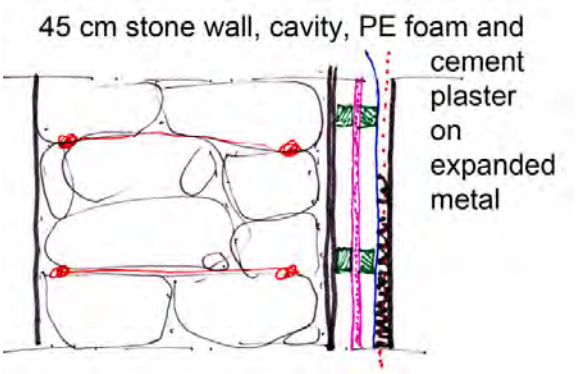


The same values apply for opposite heat flow

Unprotected aluminium foils can corrode over time due to moisture in the cavity or air. The reflectivity will then strongly reduce and accordingly the insulation value of the cavity. For those foils, a new line between the **Black** and **Pink** line is needed.

Thermal Insulation Example Wall #1 Old and New Construction

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



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

Wall insulation applied on the inside.

Cost calculation does not include stone masonry.

Wall #1: Stone wall (45 cm), cavity (1.5 cm), PE foam (7 mm), cavity (1.5 cm), plastic, cement plaster on expanded metal mesh. 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	Outside transmission factor	-	-	0.040				
2	Stone wall + plaster	0.45	0.83	0.374				
3	Inside transmission factor	-	-	0.130				
Subtotal Existing Construction R_C				**0.544**				
#	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
10	Cavity GBM, timber strips	>0.015	**Black**	0.17		*100*	*100*	*50*
11	Fixing materials 2 x	-	-	-		*50*	-	-
12	PE foam 7 mm	0.007	22	0.154		*400*	*50*	*20*
13	Cavity GBM, timber strips	>0.015	**Black**	0.17		*100*	*100*	*50*
14	Plastic foil 0.2 mm	0.0002	-	-		*100*	*20*	*10*
15	Expanded metal mesh	-	-	-		*300*	*50*	*20*
16	Cement plaster	0.04	0.77	0.030		*500*	*100*	*50*
Subtotal Newly Added Value R_C				**0.524**		*1550*	*420*	*200*
Total Existing and New R_C Values				**1.068**		***Total Cost 10 m^2***		***2170***
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		***2032***

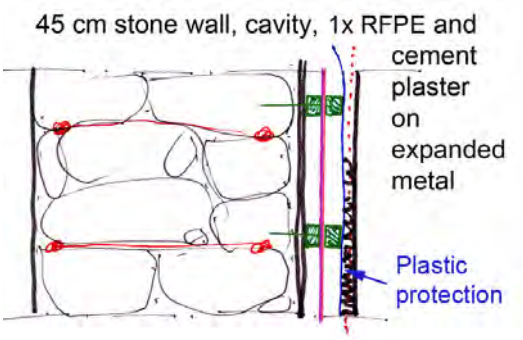
Existing stone wall is far below minimum recommended value for 1500 m altitude, R_C= 2.0 m^2.K/W. The double vertical cavity doubles the insulation value, but is still too low for 1500 m, according to recommendation.

Remarks:

- Making the PE foam thicker will increase the insulation value. It functions as a moisture barrier.
- Replacing the PE foam with EPS will increase the insulation value.
- The strips should be fitted with corrosion-free anchors into the stone wall
- The cemented wall plaster is durable, but expensive.
- The heat storage capacity of this wall is reasonable because of the heavy cement plaster.
- Bottom side of the wall can be reinforced with an extra layer of expanded metal and plaster.

Thermal Insulation Example Wall #2 Old and New Construction

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



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

Wall insulation applied on the inside.

Cost calculation does not include stone masonry.

Wall #2: Stone wall (45 cm), cavity (1.5 cm), 1 x RFPE, cavity (2 cm), plastic, cement plaster on expanded metal mesh. 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	Outside transmission factor	-	-	0.040				
2	Stone wall + plaster	0.45	0.83	0.374				
3	Inside transmission factor	-	-	0.130				
Subtotal Existing Construction R_C				**0.544**				
#	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
10	Cavity vertical, GBM-RFPE	>0.017	**Pink**	0.45		*600*	*100*	*50*
11	Fixing materials 2 x	-	-	-		*50*	-	-
12	Timber strips 1 x	0.02	-	-		*100*	*50*	*20*
13	1 x RFPE middle cavity	0.003	22	0.066		*600*	*100*	*50*
14	Cavity, RFPE-GBM, timber	>0.017	**Pink**	0.45		*100*	*100*	*50*
15	Plastic foil 0.2 mm	0.0002	-	-		*100*	*20*	*10*
16	Expanded metal mesh	-	-	-		*300*	*50*	*20*
17	Cement plaster	0.04	0.77	0.030		*500*	*100*	*50*
Subtotal Newly Added Value R_C				**0.996**		*2350*	*520*	*250*
Total Existing and New R_C Values				**1.54**		***Total Cost 10 m^2***		***3120***
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		***2026***

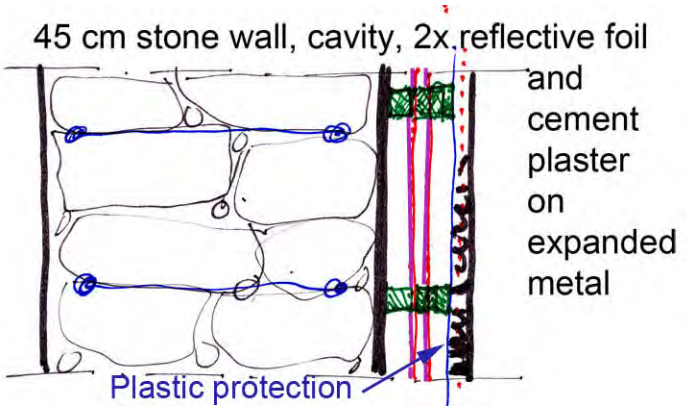
The double vertical cavity with RFPE triples the insulation value, but is still too low for 1500 m.

Remarks:

- The plastic foil behind the cement plaster is necessary to minimise falling mortar, to improve the curing of the cement plastered layer and to keep the distance to the reflective foil.
- The strips should be fitted with corrosion free anchors into the stone wall.
- The cemented wall plaster is durable, but expensive.
- The heat storage capacity of this wall is reasonable because of the heavy cement plaster.
- Bottom side of the wall can be reinforced with an extra layer of expanded metal and plaster.

Thermal Insulation Example Wall #3 Old and New Construction

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



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

Wall insulation applied on the inside.

Cost calculation does not include stone masonry.

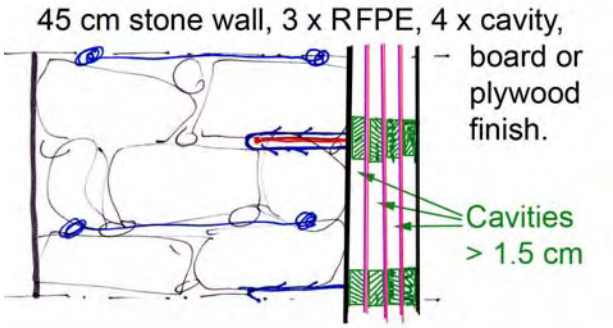
Wall #3: Stone wall (45 cm), cavity (1.5 cm), RFPE, cavity (1.5 cm), RFPE, cavity (2 cm), plastic, cement plaster on expanded metal mesh. Thickness x R_M = R_C					New Value	Surface Unit of Estimation = **10 m^2**		
#	Description of the Existing Construction Layers	Thick Meter	R_M	R_C	Temp °C	Material in PKR	Skilled Labour Cost	Non-skilled Labour
1	Outside transmission factor	-	-	0.040				
2	Stone wall + plaster	0.45	0.83	0.374				
3	Inside transmission factor	-	-	0.130				
	Subtotal Existing Construction R_C			**0.544**				
#	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
10	Timber strips 1 x	0.015	-	-		*100*	*50*	*20*
11	Fixing materials 2 x	-	-	-		*50*	-	-
12	Cavity vertical, GBM-RFPE	>0.017	**Pink**	0.45		-	-	-
13	1 x RFPE wall side	0.003	22	0.066		*600*	*100*	*50*
14	Cavity, RFPE-HRF, timber	>0.017	**Blue**	0.46		*100*	*100*	*50*
15	Timber strips 1 x	0.025	-	-		*100*	*50*	*20*
16	1 x RFPE plaster side	0.003	22	0.066		*600*	*100*	*50*
17	Cavity vertical, GBM-RFPE	>0.017	**Pink**	0.45		-	-	-
18	Plastic foil 0.2 mm	0.0002	-	-		*100*	*20*	*10*
19	Expanded metal mesh	-	-	-		*300*	*50*	*20*
20	Cement plaster	0.04	0.77	0.030		*500*	*100*	*50*
	Subtotal Newly Added Value R_C			**1.522**		*2450*	*570*	*270*
	Total Existing and New R_C Values			**2.066**		***Total Cost 10 m^2***		***3290***
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		***1592***

The insulation value is adequate for 1500 m altitude, according to recommendation.

The plastic foil behind the cement plaster is necessary to minimise falling mortar, to improve the curing of the cement plastered layer and to keep the distance to the reflective foil.

Thermal Insulation Example Wall #4 Old and New Construction

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



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

Wall insulation applied on the inside.

Cost calculation does not include stone masonry.

Wall #4: Stone wall (45 cm), 4 x >1.5 cm cavity, 3 x RFPE, hardboard. 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	Outside transmission factor	-	-	0.040				
2	Stone wall + plaster	0.45	0.83	0.374				
3	Inside transmission factor	-	-	0.130				
Subtotal Existing Construction R_C				**0.544**				
#	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
10	Timber strips 1 x	>0.017	-	-		*100*	*50*	*20*
11	Fixing materials 2 x	-	-	-		*50*	-	-
12	Cavity vertical, GBM-RFPE	>0.017	**Pink**	0.45		-	-	-
13	2 x RFPE	0.006	22	0.132		*1200*	*100*	*50*
14	2 x Cavity, RFPE-HRF	>0.017	**Blue**	0.92		*100*	*100*	*50*
15	Timber strips 1 x	0.025	-	-		*100*	*50*	*20*
16	1 x RFPE plaster side	0.003	22	0.066		*600*	*100*	*50*
17	Cavity vertical, GBM-RFPE	>0.017	**Pink**	0.45		-	-	-
18	Hardboard	0.004	6	0.024		*300*	*100*	*50*
Subtotal Newly Added Value R_C				**2.042**		*2450*	*500*	*240*
Total Existing and New R_C Values				**2.586**		***Total Cost 10 m^2***		***3190***
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		***1234***

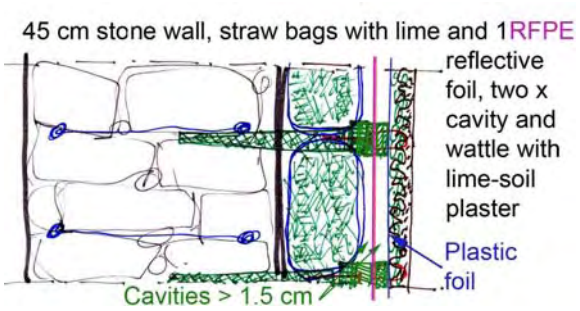
The insulation value is adequate for 2000 m altitude, according to recommendation.

Remarks:

- Lower construction cost with higher insulation value gives lower cost ratio.
- Painting of board is not included.
- More than three foils is not recommended. Other materials should be used.
- This wall has a very low heat storage capacity; therefore the room will warm up very fast.

Thermal Insulation Example Wall #5 Old and New Construction

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



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

Wall insulation applied on the inside.

Cost calculation does not include stone masonry.

Wall #5: Stone wall (45 cm), straw bags + lime (15 cm), cavity, RFPE, cavity, plastic, cavity, soil-lime plaster on wattle wall panels. 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	Outside transmission factor	-	-	0.040				
2	Stone wall + plaster	0.45	0.83	0.374				
3	Inside transmission factor	-	-	0.130				
	Subtotal Existing Construction R_C			**0.544**				
#	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
10	Long pegs inside the wall	-	-	-		*70*	*100*	*50*
11	Fixing materials 1 x	-	-	-		*40*	-	-
12	Bags straw-lime (village)	0.15	12.5	1.875		*200*	*100*	*50*
13	Cavity, GBM-RFPE	0.02	**Pink**	0.17		*50*	*100*	*50*
14	1 x RFPE, timber strips	0.003	22	0.066		*600*	*40*	*20*
15	Cavity, GBM-RFPE	0.02	**Pink**	0.17		*50*	*100*	*50*
16	Plastic foil protection	0.0002	-	-		*50*	*50*	*10*
17	Cavity, GBM-GBM	0.01	**Black**	0.1		-	-	-
18	Wattle wall panels (village)	-	-			*free*	*100*	*50*
19	Lime-cement plaster	0.08	1.25	0.1		*100*	*100*	*50*
	Subtotal Newly Added Value R_C			**2.481**		*1160*	*690*	*330*
	Total Existing and New R_C Values			**3.025**		***Total Cost 10 m^2***		***2180***
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		***721***

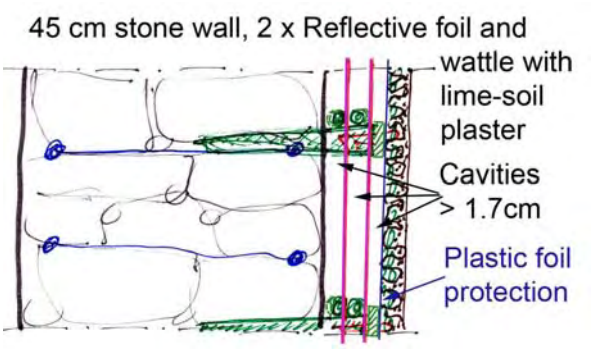
The insulation value is adequate for altitudes up to 2500 m, according to recommendation.

Remarks:

- Generally, when the villagers supply the straw and wattle, this can be a cost-efficient solution.
- The villagers must supply the wattle panels and straw during the summer.
- The lower part of the wall can be strengthened with a stronger cement plaster at table/chair level. Alternatively, plywood or timber panelling can be applied.
- The heat storage capacity of this wall is good because of the weight of the plaster.
- Soil-lime plaster gives a good internal climate of the room because it regulates humidity.

Thermal Insulation Example Wall #6 Old and New Construction

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



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

Wall insulation applied on the inside.

Cost calculation does not include stone masonry.

Wall #6: Stone wall (45 cm), 3 x 1.7 cm cavity, 2 x RFPE, plastic, cavity, soil-cement plaster on wattle wall panels. 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	Outside transmission factor	-	-	0.040				
2	Stone wall + plaster	0.45	0.83	0.374				
3	Inside transmission factor	-	-	0.130				
Subtotal Existing Construction R_C				**0.544**				
#	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
10	Pegs inside the wall	-	-	-		*70*	*100*	*50*
11	Fixing materials 1 x	-	-	-		*30*	-	-
12	RFPE Cavity, GBM-RFPE	>0.017	**Pink**	0.45		*650*	*50*	*20*
13	RFPE Cavity, HRF-RFPE	>0.017	**Blue**	0.46		*600*	*40*	*20*
14	Cavity, HRF-GBM	>0.03	**Pink**	0.45		*50*	*50*	*20*
15	Plastic foil protection	0.0002	-			*50*	*20*	*10*
16	Cavity, GBM-GBM	0.01	**Black**	0.1		-	-	-
17	Wattle wall panels (village)	-	-	-		*free*	*100*	*50*
18	Soil-cement plaster	0.08	1.25	0.1		*100*	*100*	*50*
Subtotal Newly Added Value R_C				**1.56**		*1550*	*460*	*220*
Total Existing and New R_C Values				**2.104**		***Total Cost 10 m^2***		***2230***
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		***1060***

Insulation value is adequate for altitudes up to 1600 m, according to recommendation.

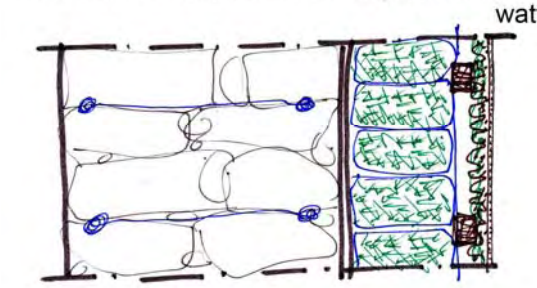
Remarks:

- The soil lime plaster will be partly pushed through the wattle panels and keep a cavity behind the plastered wall and the protective plastic.
- The villagers must supply the wattle panels and straw during the summer.
- Lower part of the wall can be strengthened against damage (chairs, tables or leaning against) with a stronger cement plaster or wood panelling.
- The heat storage capacity of this wall is good because of the heavy soil-lime wattle wall.

Thermal Insulation Example Wall #7 Old and New Construction

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

45 cm stone wall, with straw bags, plastic,timber frame, wattle panels soil-lime plaster



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

Wall insulation applied on the inside.

Cost calculation does not stone include masonry.

Wall #7: Stone wall (45 cm), straw bags + lime (25 cm), plastic, cavity, soil-lime plaster on wattle wall panels. 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	Outside transmission factor	-	-	0.040				
2	Stone wall + plaster	0.45	0.83	0.374				
3	Inside transmission factor	-	-	0.130				
Subtotal Existing Construction R_C				**0.544**				
#	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
10	Timber frame support	-	-	-		*400*	*200*	*100*
11	Fixing materials	-	-	-		*40*	-	-
12	Bags straw-lime (village)	0.25	12	3.0		*250*	*100*	*50*
13	Plastic foil	0.0002	-	-		*100*	*20*	*10*
14	Cavity, GBM-GBM	0.02	**Black**	0.17		-	-	-
15	Wattle wall panels (village)	-	-	-		*free*	*100*	*50*
16	Soil-lime plaster	0.08	1.25	0.1		*100*	*100*	*50*
Subtotal Newly Added Value R_C				**3.27**		*890*	*520*	*260*
Total Existing and New R_C Values				**3.814**		***Total Cost 10 m^2***		***1670***
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		***438***

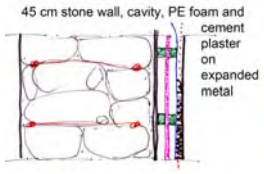
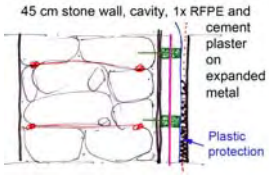
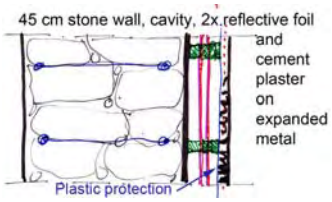
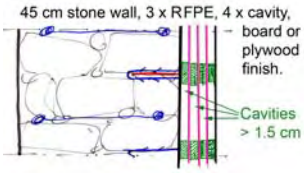
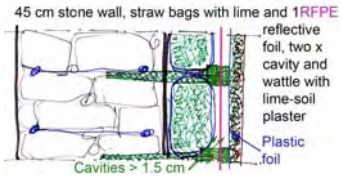
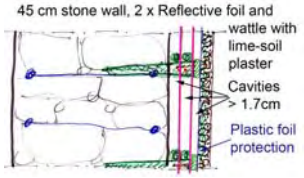
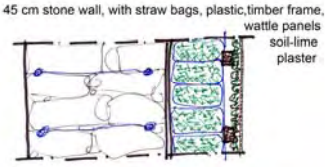
Insulation value is adequate for altitudes up to 3300 m, according to recommendation.

Remarks:

- With thick layers of straw, the straw can become compressed and the insulation value reduced.
- A freestanding timber support frame needs to be made to fix the inside wall.
- Because the straw will prick holes in the plastic bags, an additional plastic foil is needed to provide a good moisture barrier on the warm side.
- The villagers must supply the wattle panels and straw during the summer.
- The heat storage capacity of this wall is good because of the weight of the plaster.
- Soil-lime plaster gives a good internal climate of the room because it regulates humidity.
- The insulation value will be greatly improved with a reflective foil.

COMPARISON TABLE OF EXAMPLE WALLS #1 – #7

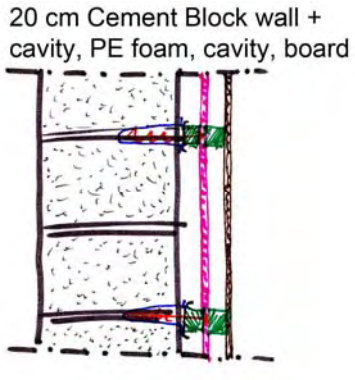
Stone Wall Designs with **additional insulation**.

#	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
Wall # 1		Stone wall (45 cm), cavity (1.5 cm), PE foam (7 mm), cavity (1.5 cm), plastic, cement plaster on expanded metal mesh.	**0.52**	**1.07**	**2170**	**2032**
Wall # 2		Stone wall (45 cm), cavity (1.5 cm), 1 x RFPE, cavity (2 cm), plastic, cement plaster on expanded metal mesh.	**1.00**	**1.54**	**3120**	**2026**
Wall # 3		Stone wall (45 cm), cavity (1.5 cm), RFPE, cavity (1.5 cm), RFPE, cavity (2 cm), plastic, cement plaster on expanded metal mesh.	**1.52**	**2.07**	**3290**	**1592**
Wall # 4		Stone wall (45 cm), 4 x >1.5 cm cavity, 3 x RFPE, hardboard.	**2.04**	**2.59**	**3190**	**1234**
Wall # 5		Stone wall (45 cm), straw bags + lime (15 cm), cavity, RFPE, cavity, plastic, cavity, soil-lime plaster on wattle wall panels.	**2.48**	**3.03**	**2180**	**721**
Wall # 6		Stone wall (45 cm), 3 x 1.7 cm cavity, 2 x RFPE, plastic, cavity, soil-cement plaster on wattle wall panels.	**1.56**	**2.10**	**2230**	**1060**
Walls # 7		Stone wall (45 cm), straw bags + lime (25 cm), plastic, cavity, soil-lime plaster on wattle wall panels.	**3.27**	**3.81**	**1670**	**438**

Insulation values can vary with different thickness of the straw or wood shavings in bags.
Supply of wattle wall panels requires timely ordering/manufacturing in large sizes.
For houses, the larger heat storage capacity created by the wattle and soil plaster or the cement plaster (more expensive) is recommended.

Thermal Insulation Example Wall #8 Old and New Construction

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



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

Wall insulation applied on the inside.

Cost calculation does not include masonry.

Wall #8: Cement block (20 cm), cavity (1.7 cm), PE foam (7 mm), cavity (1.7 cm), cement plaster on expanded metal mesh. 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	Outside transmission factor	-	-	0.04				
2	Solid cement block wall	0.20	1.5	0.30				
3	Inside transmission factor	-	-	0.13				
	Subtotal Existing Construction R_C			**0.47**				
#	Description of Each New Layer or New Activity to Install Insulation	Thick Meter	R_M	R_M	Temp °C	Material in PKR	Skilled Labour Cost	Non-skilled Labour
10	Cavity GBM, timber strips	>0.017	**Black**	0.17		*100*	*100*	*50*
11	Fixing material plug, screw	-	-	-		*200*	-	-
12	PE foam 7 mm	0.007	22	0.154		*400*	*50*	*20*
13	Cavity, GBM, timber strips	>0.017	**Black**	0.17		*100*	*100*	*50*
14	Board MDF or plywood	0.004	7	0.028		*300*	*100*	*50*
	Subtotal Newly Added Value R_C			**0.522**		*1100*	*350*	*170*
	Total Existing and New R_C Values			**0.992**		***Total Cost 10 m^2***		***1620***
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		***1633***

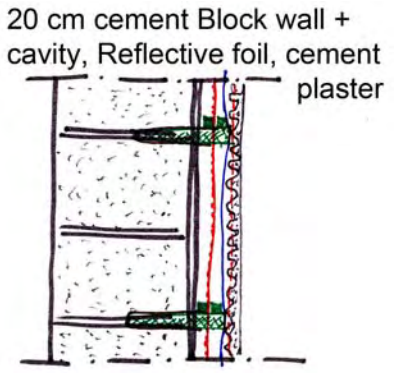
Insulation value is very inadequate for 1500 m altitude, according to recommendation.

Remarks:

- Wall insulation value is about the same as the cement block wall alone.
- Because the PE foam is not thick, nearly the same results would be obtained with a plastic foil.
- The inside board application is very fast, but the supports need to be placed according to the size of the finishing material.
- Good stapling or nailing tools will speed up application.
- Painting or other finishing costs are not included.

Thermal Insulation Example Wall #9 Old and New Construction

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



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

Wall insulation applied on the inside.

Cost calculation does not include masonry.

Wall #9: Cement block (20 cm), 2 x cavity, 1 x RFPE, plastic, cement plaster on wire mesh. 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	Outside transmission factor	-	-	0.040				
2	Cement block, plaster	0.21	1.5	0.315				
3	Inside transmission factor	-	-	0.130				
Subtotal Existing Construction R_C				**0.485**				
#	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
10	Pegs inside the wall	-	-	-		*50*	*100*	*50*
11	Fixing materials 1 x	-	-	-		*50*	-	-
12	Cavity, GBM-RFPE, strips	>0.017	**Pink**	0.45		*150*	*100*	*50*
13	1 x RFPE	0.003	22	0.066		*600*	*40*	*20*
14	Cavity, GBM-HRF, strips	>0.017	**Pink**	0.45		*150*	*100*	*50*
15	Plastic foil 0.2 mm	0.0002	-	-		*100*	*20*	*10*
16	Expanded metal mesh	-	-	-		*300*	*50*	*20*
17	Cement plaster	0.04	0.77	0.03		*500*	*100*	*50*
Subtotal Newly Added Value R_C				**0.996**		*1900*	*510*	*250*
Total Existing and New R_C Values				**1.481**		***Total Cost 10 m^2***		***2660***
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		***1796***

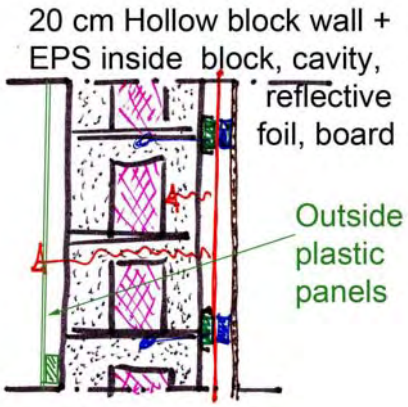
Insulation value is very inadequate for 1500 m altitude, according to recommendation.

Remarks:

- Wall pegs need to be well treated against moisture.
- The plastic foil on the inside is necessary to avoid cement falling inside the cavity.
- PE backed foils are easier to work with for free hanging solutions if flat, but more difficult if the sides of the roll are wider. In that case, the resulting waves need to be removed.
- The inside wall plaster creates a reasonable heat storage capacity for the room.
- The plastered wall can be tiled.

Thermal Insulation Example Wall #10 Old and New Construction

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



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

Wall insulation applied on the inside, panel on outside.

Cost calculation does not include masonry.

Because the hollow blocks have large thermal bridges, the effect of the EPS filling is limited.

Wall #10: Outside panel, cavity, hollow cement block (20 cm) with EPS core, 2 x cavity, 1 x RFPE, hardboard. 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	Outside transmission factor	-	-	0.040				
2	Cement block, hollow EPS	0.20	3	0.60				
3	Inside transmission factor	-	-	0.130				
	Subtotal Existing Construction R_C			**0.77**				
#	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
10	Fixing materials, anchors	-	-	-		*200*	-	-
11	Timber strips 2 and 3 cm	-	-	-		*300*	*100*	*50*
12	Plastic panels 3 mm	0.003	20	0.06		*1000*	*100*	*50*
13	Cavity, GBM-GBM outside, not ventilated	0.03	**Black**	0.17		-	-	-
14	Cavity inside, GBM-RFPE	>0.017	**Pink**	0.45				
15	RFPE	0.003	22	0.066		*600*	*100*	*50*
16	Cavity inside, GBM-RFPE	>0.017	**Pink**	0.45		-	-	-
17	Timber strips 2 cm	-	-	-		*200*	*100*	*50*
18	Board MDF or plywood	0.004	7	0.028		*300*	*100*	*50*
	Subtotal Newly Added Value R_C			**1.224**		*2600*	*500*	*250*
	Total Existing and New R_C Values			**1.994**		***Total Cost 10 m^2***		***3350***
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		***1680***

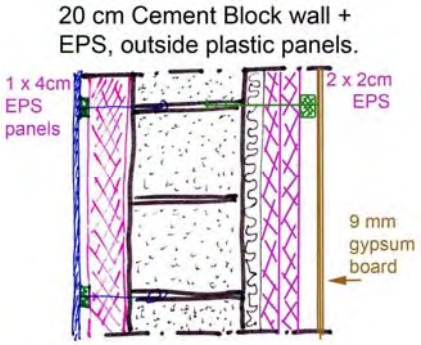
Insulation value is almost enough for 1500 m altitude, according recommendation.

Remarks:

- When the outside cavity is ventilated, that insulation value will be eliminated.
- The heat storage capacity of this wall is low because of the lightweight board.

Thermal Insulation Example Wall #11 Old and New Construction

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



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

Wall insulation applied on the inside and outside of the cement block wall.

Cost calculation does not include masonry.

Wall #11: Cement block (20 cm) + plaster, EPS (4 cm), cavity, gypsum board, EPS on outside (4 cm), cavity, plastic panel. 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	Outside transmission factor	-	-	0.040				
2	Solid cement block wall	0.20	1.5	0.30				
3	Sand lime plaster	0.02	1.1	0.022				
4	Inside transmission factor	-	-	0.130				
	Subtotal Existing Construction R_C			**0.492**				
#	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
10	Fixing materials, anchors	-	-	-		*100*	-	-
11	EPS panels outside	0.04	25	1.0		*300*	*100*	*50*
12	Timber strips 1" x ¾"	-	-	-		*300*	*100*	*50*
13	Cavity, GBM-GBM	0.02	**Black**	0.17		-	-	-
14	Plastic panel 5 mm	0.0005	10	0.005		*1600*	*200*	*100*
15	EPS inside (2 x 2 cm)	0.04	25	1.0		*300*	*100*	*50*
16	Cavity, GBM-GBM	0.02	**Black**	0.17		-	-	-
17	Gypsum carton board	0.009	6	0.054		*400*	*100*	*50*
	Subtotal Newly Added Value R_C			**2.399**		*3000*	*600*	*300*
	Total Existing and New R_C Values			**2.891**		***Total Cost 10 m^2***		***3900***
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		***1349***

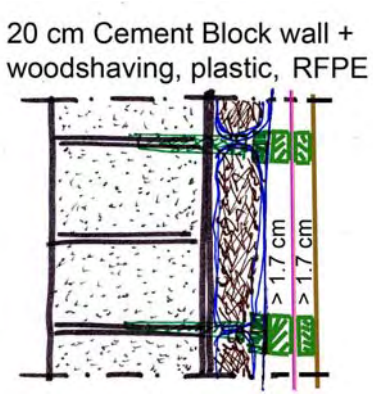
Insulation value is almost enough for 2400 m altitude, according recommendation.

Remarks:

- The thermal insulation on the outside is generally more costly because of the outside weather-resistant material needed. In some cases, outside panelling is needed for aesthetic reasons.
- The plastic panels can be fixed to galvanised wall anchors (3 mm wire) by winding the wire around the strip. For non-straight walls, a separate support frame is needed (extra cost).
- With a reflective foil, the inside insulation would increase considerably (+ R_C = 0.7 m^2.K/W).

Thermal Insulation Example Wall #12 Old and New Construction

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



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

Wall insulation applied on the inside.

Cost calculation does not include masonry.

Wall #12: Cement block (20 cm) + plaster, straw bags + lime (10 cm), plastic, 2 x cavity, 1 x RFPE, hardboard. 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	Outside transmission factor	-	-	0.040				
2	Cement block + plaster	0.21	1.5	0.315				
3	Inside transmission factor	-	-	0.130				
Subtotal Existing Construction R_C				**0.485**				
#	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
10	Pegs inside the wall	-	-	-		*70*	*100*	*50*
11	Fixing materials 1 x	-	-	-		*40*	-	-
12	Bags straw-lime (village)	0.10	12	1.20		*200*	*100*	*50*
13	Plastic foil 0.2 mm	0.0002	-	-		*100*	*20*	*10*
14	Cavity, GBM-RFPE, strips	>0.017	**Pink**	0.45		*100*	*50*	*10*
15	RFPE	0.003	22	0.066		*600*	*100*	*50*
16	Cavity, HRF-GBM strips	>0.017	**Pink**	0.45		*100*	*50*	*10*
17	Board MDF or plywood	0.004	7	0.028		*300*	*100*	*50*
Subtotal Newly Added Value R_C				**2.194**		*1510*	*520*	*230*
Total Existing and New R_C Values				**2.679**		***Total Cost 10 m^2***		***2260***
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		***844***

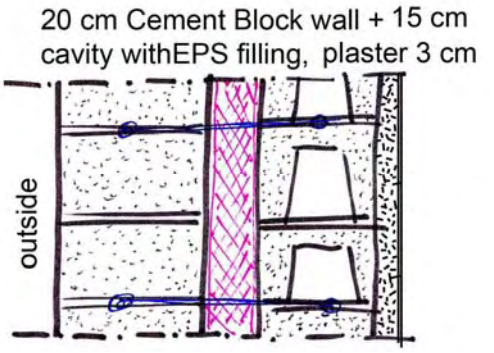
Insulation value is sufficient for altitudes up to 2100 m, according recommendation.

Remarks:

- Estimate assumes that the house owner supplies the straw to be put into the bags.
- The lime dust is to protect the straw from insects; the same applies for wood shavings.
- The insulation value of straw and wood shavings is about the same.
- The plastic foil is necessary to ensure that any gaps between the bags and frame are closed.
- The heat storage capacity of this wall is low.

Thermal Insulation Example Wall #13 Old and New Construction

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



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

Wall insulation applied on the inside of cement block cavity wall before the second wall is masoned.

Cost calculation does not include masonry.

Wall #13: Cement block (20 cm), cavity filled with EPS panels (6 cm), hollow cement block (15 cm), insulating plaster. 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	Outside transmission factor	-	-	0.04				
2	Solid cement block wall	0.20	1.5	0.30				
3	Cavity, not ventilated	0.06	**Black**	0.17				
4	Cement block, hollow	0.15	1.5	0.023				
5	Inside transmission factor	-	-	0.13				
Subtotal Existing Construction R_C				**0.663**				
#	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
-3	Remove cavity	0.06	**Black**	- 0.17		-	-	-
10	Fill cavity EPS panels	0.06	25	1.50		*600*	*100*	*50*
11	Insulating gypsum plaster	0.03	2.0	0.6		*300*	*100*	*50*
Subtotal Newly Added Value R_C				**1.93**		*900*	*200*	*100*
Total Existing and New R_C Values				**2.593**		***Total Cost 10 m^2***		***1200***
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		***463***

Insulation value is sufficient for altitudes up to almost 2100 m, according recommendation.

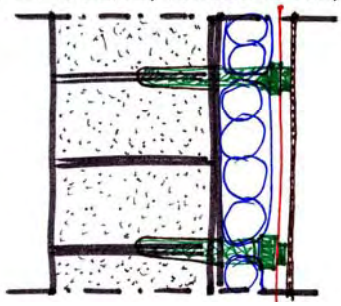
Remarks:

- Anchors between the two walls must be corrosion free, such as galvanised steel.
- The hollow cement block has about the same insulation value as the massive block because cement is more dense and less thick, while the air insulation in the hollow area does not add more than R_C = 0.2 m^2.K/W.
- The cavity wall without the EPS is far below the required minimum insulation value.
- If the cavity wall is ventilated, the insulation value is will be less.
- The heat storage capacity of this wall is very high because of the heavy inside wall. This stabilizes the inside temperature and is suitable for buildings needing to be warm all the time.
- Painting or other finishing costs are not included.

Thermal Insulation Example Wall #14 Old and New Construction

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

20 cm Cement block wall +
PET bottles, reflective foil, board



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

Wall insulation applied on the inside.

Cost calculation does not include masonry.

Wall #14: Cement block (20 cm), plastic bags with PET bottles (10 cm) 1 x RFPE, 2 x cavity, board or plywood. 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	Outside transmission factor	-	-	0.040				
2	Cement block + plaster	0.21	1.5	0.315				
3	Inside transmission factor	-	-	0.130				
Subtotal Existing Construction R_C				**0.485**				
#	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
10	Fixing materials, plugs	-	-	-		*100*	-	-
11	PET bottles in plastic bags	0.10	12	1.20		*400*	*100*	*50*
12	Cavity, GBM-RFPE	>0.017	**Pink**	0.45		-	-	-
13	1 x RFPE	0.003	22	0.066		*600*	*100*	*50*
14	Cavity, HRF-GBM	>0.017	**Pink**	0.45		-	-	-
15	Timber strips 2 cm x 3 cm	0.02	-	-		*200*	*100*	*50*
16	Board MDF or plywood	0.004	7	0.028		*300*	*100*	*50*
Subtotal Newly Added Value R_C				**2.194**		*1600*	*400*	*200*
Total Existing and New R_C Values				**2.679**		***Total Cost 10 m^2***		***2200***
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		***821***

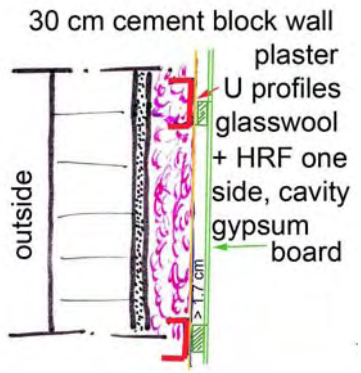
Insulation value is sufficient for altitudes up to almost 2200 m, according recommendation.

Remarks:

- Lightweight insulation option suitable for earthquake areas.
- The Cost/R_C is rather low, but this depends on the cost of the PET bottle bags. These need to be contracted in town because only a few bottles will be available at the village level.
- Collecting a large amount of bottles over time is advised for people who want this design.
- Making bags with a double layer of PET bottles will increase the insulation value. Bags must be packed tightly to avoid openings in between them.
- The heat storage capacity of this wall is low because of the low weight of the plywood and PET.

Thermal Insulation Example Wall #15 Old and New Construction

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



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

Wall insulation applied on the inside.

Cost calculation does not include masonry.

Wall #15: Block wall (30 cm), plaster, cavity, glass wool (10 cm) + HRF, cavity, gypsum board on sheet metal profiles. 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	Outside transmission factor	-	-	0.04				
2	Solid cement block	0.32	1.5	0.48				
3	Inside gypsum plaster	0.03	2.0	0.06				
4	Inside transmission factor	-	-	0.13				
	Subtotal Existing Construction R_C			**0.71**				
#	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
10	Profiles - metal pharing	-	-	-		*500*	*200*	*100*
11	Anchoring materials	-	-	-		*100*	*100*	*50*
12	Timber strips	0.02	-	-		*100*	*20*	*10*
13	Cavity, GBM-GBM	>0.017	**Black**	0.17		-	-	-
14	Glass wool blanket, loose with HRF one side	0.10	25	2.5		*1500*	*100*	*50*
15	Cavity, HRF-GBM	>0.017	**Pink**	0.45		-	-	-
16	Gypsum board	0.009	1.7	0.015		*300*	*100*	*50*
	Subtotal Newly Added Value R_C			**3.135**		*2500*	*520*	*260*
	Total Existing and New R_C Values			**3.845**		***Total Cost 10 m^2***		***3280***
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		***853***

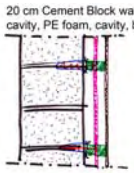
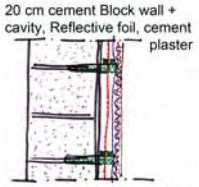
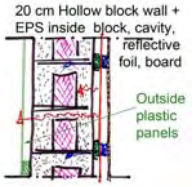
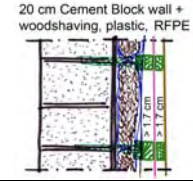
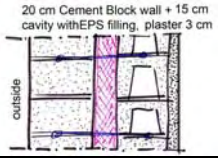
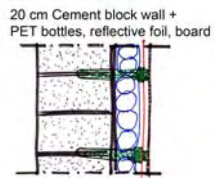
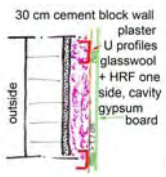
Insulation value is sufficient for altitudes up to 3300 m, according recommendation.

Remarks:

- The metal support frames are highly conductive. They should not have any contact with the cold wall and need to be additionally insulated from the wall by pieces of EPS.
- Timber strips cause heat leaks. The gypsum panels are screwed onto the timber strips; some discolouring on the paint can appear after some time because of temperature differences.
- Glass wool blankets need to be taped together to ensure moisture block. Low quality glass wool will have a lower insulation value and can absorb humidity. When humidity enters the glass wool, the thermal insulation value will strongly reduce.

COMPARISON TABLE OF EXAMPLE WALLS #8 – #15

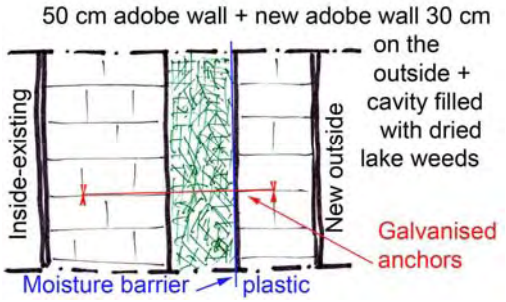
Cement Block Wall Designs with **additional insulation**.

#	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
Wall # 8		Cement block (20 cm), cavity (1.7 cm), PE foam (7 mm), cavity (1.7 cm), cement plaster on expanded metal mesh.	**0.52**	**0.99**	**1620**	**1633**
Wall # 9		Cement block (20 cm), 2 x cavity, 1 x RFPE, plastic, cement plaster on wire mesh.	**1.0**	**1.48**	**2660**	**1796**
Wall # 10		Outside panel, cavity, hollow cement block (20 cm) with EPS core, 2 x cavity, 1 x RFPE, hardboard.	**1.22**	**1.99**	**3350**	**1680**
Wall # 11		Cement block (20 cm) + plaster, EPS (4 cm), cavity, gypsum board, EPS on outside (4 cm), cavity, plastic panel.	**2.40**	**2.89**	**3900**	**1349**
Wall # 12		Cement block (20 cm) + plaster, straw bags + lime (10 cm), plastic, 2 x cavity, 1 x RFPE, hardboard.	**2.19**	**2.68**	**2260**	**844**
Wall # 13		Cement block (20 cm), cavity filled with EPS panels (6 cm), hollow cement block (15 cm), insulating plaster.	**1.93**	**2.59**	**1200**	**463**
Wall # 14		Cement block (20 cm), plastic bags with PET bottles (10 cm), 1 x RFPE, 2 x cavity, board or plywood.	**2.19**	**2.68**	**2200**	**821**
Wall # 15		Block wall (30 cm), plaster, cavity, glass wool (10 cm) + HRF, cavity, gypsum board on sheet metal profiles.	**3.14**	**3.85**	**3280**	**853**

Costs and C/R_C ratios will vary when free materials or labour is supplied or transport cost increased.

Thermal Insulation Example Wall #16 Old and New Construction

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



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

Wall insulation applied on the OUTSIDE.

Cost calculation does not include old wall.

Wall #16: Adobe wall (50 cm), anchors, dried weeds (15 cm), plastic, adobe wall (30 cm) added on the outside. 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	Outside transmission factor	-	-	0.04				
2	Solid adobe wall, existing	0.5	2.00	1.00				
3	Inside transmission factor	-	-	0.13				
Subtotal Existing Construction R_C				**1.17**				
#	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
10	Galvanised wire anchors	-	-	-		*100*	*50*	-
11	Dried lake weeds + lime	0.15	7.0	1.05		*300*	*100*	*50*
12	Moisture barrier plastic	0.0002	-	-		*100*	*50*	*10*
13	New outside adobe wall	0.30	2.00	0.60		*200*	*100*	*50*
14	Construction foundation	-	-	-		*free*	*200*	*100*
15	Extending roof	-	-	-		*500*	*200*	*100*
Subtotal Newly Added Value R_C				**1.65**		*1200*	*700*	*310*
Total Existing and New R_C Values				**2.82**		***Total Cost 10 m^2***		***2210***
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		***784***

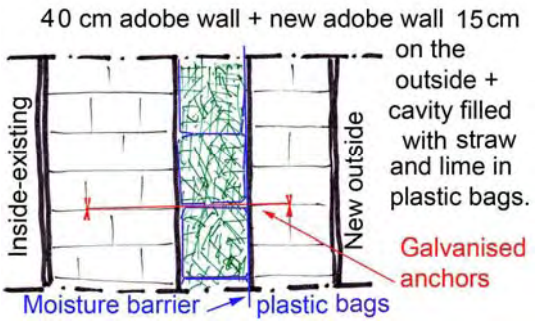
Insulation value is sufficient for altitudes up to 2300 m, according recommendation.

Remarks:

- The design assumes there is a large participation of the house owner in making the adobe blocks and collecting the dried lake weeds. Only the bags and transport costs are included.
- The two walls need to be linked together with 3 mm galvanised wire anchors (>2 /m^2). Making a hole in the existing adobe wall to place the anchors is necessary.
- The cost of the outside wall construction is increased by foundations and roof extensions.
- Heat storage value of the wall is very good, but not advised for buildings with low occupancy per day, such as schools, as it requires a lot of heating of the inside walls.
- Adobe internal walls create a comfortable indoor climate due to moisture regulation.
- Packing the dried weeds first into plastic bags with lime dust will make the work easier.
- Plastic moisture barrier will avoid internal condensation inside the insulation material.

Thermal Insulation Example Wall #17 Old and New Construction

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



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

Wall insulation applied on the OUTSIDE.

Cost calculation does not include old wall.

Wall #17: Adobe wall (40 cm), anchors, straw-lime in plastic bags (15 cm), adobe wall (15 cm) added on the outside. 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	Outside transmission factor	-	-	0.04				
2	Solid adobe wall, existing	0.4	2.00	0.80				
3	Inside transmission factor	-	-	0.13				
Subtotal Existing Construction R_C				**0.97**				
#	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
10	Galvanised wire anchors	3 mm	-	-		*150*	*50*	-
11	Straw + lime in bags	0.15	11	1.65		*350*	*100*	*50*
12	New outside adobe wall	0.15	2.00	0.30		*100*	*100*	*50*
13	Construction foundation	-	-	-		*free*	*200*	*100*
14	Extending roof	-	-	-		*400*	*200*	*100*
Subtotal Newly Added Value R_C				**1.95**		*1000*	*650*	*300*
Total Existing and New R_C Values				**2.92**		***Total Cost 10 m^2***		***1950***
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		***668***

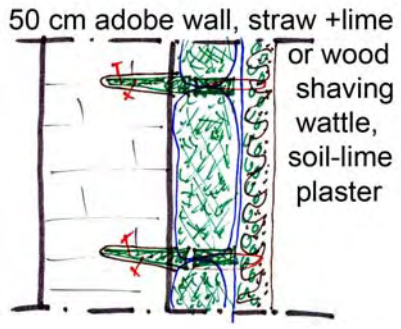
Insulation value is sufficient for altitudes up to 2400 m, according recommendation.

Remarks:

- The design assumes there is a large participation of the house owner in making the adobe blocks and collecting the dried lake weeds. Only the bags and transport costs are included.
- The two walls need to be linked together with 3 mm galvanised wire anchors (>2 /m^2). Making a hole in the existing adobe wall to place the anchors is necessary.
- The cost of the outside wall construction is increased by foundations and roof extensions.
- Heat storage value of the wall is very good, but not advised for buildings with low occupancy per day, such as schools, as it requires a lot of heating of the inside walls.
- Adobe internal walls create a comfortable indoor climate due to moisture regulation.
- Packing the dried straw first into plastic bags with lime dust will create at the same time the required moisture barrier. Straw should be slightly compacted to avoid settlement.

Thermal Insulation Example Wall #18 Old and New Construction

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



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

Wall insulation applied on the inside.

Cost calculation does not include masonry.

Wall #18: Adobe wall (50 cm), straw bags + lime (15 cm), plastic, cavity, wattle with soil-lime plaster. 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	Outside transmission factor	-	-	0.04				
2	Adobe block	0.50	2.0	1.00				
3	Inside transmission factor	-	-	0.13				
Subtotal Existing Construction R_C				**1.17**				
#	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
10	Pegs inside the wall	-	-	-		*200*	*150*	*50*
11	Fixing frame materials	-	-	-		*300*	*200*	*100*
12	Bags straw-lime (village)	0.15	12	1.8		*250*	*150*	*50*
13	Plastic foil 0.2 mm	-	-	-		*100*	*20*	*10*
14	Cavity, GMB-GBM	0.015	**Black**	0.16		-	-	-
15	Wattle wall panels (village)	-	-	-		*free*	*100*	*50*
16	Soil-lime plaster	0.08	1.25	0.1		*100*	*100*	*50*
Subtotal Newly Added Value R_C				**2.06**		*950*	*720*	*310*
Total Existing and New R_C Values				**3.23**		***Total Cost 10 m^2***		***1980***
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		***613***

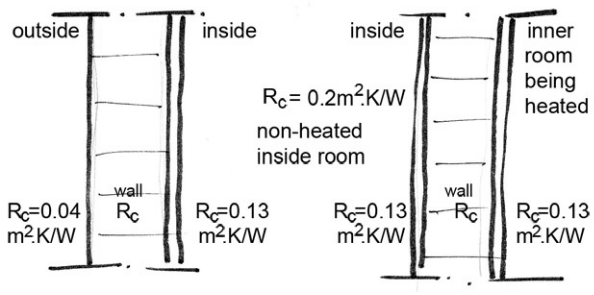
Insulation value is sufficient for altitudes up to 2700 m, according recommendation.

Remarks:

- Because the soil lime plaster is not pushed fully through the wattle panel, a cavity remains behind the plaster and the plastic moisture barrier.
- Wattle panels should be contracted well in time.
- Straw has about the same insulation value as wood shavings, also needing lime.
- The heat storage capacity of this wall is low.

Thermal Insulation Example Wall #19 Extra Room and Wall

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



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

Wall insulation applied on the inside.

Cost calculation does not include masonry.

Wall #19: Two 40 cm and 30 cm adobe walls with room in between. 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	Outside transmission factor	-	-	0.04				
2	Adobe block wall	0.40	2.0	0.80				
3	Soil lime/straw plaster	0.03	2.5	0.075				
4	Inside transmission factor	-	-	0.13				
Subtotal Existing Construction R_C				**1.045**				
#	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
10	Inside room	-	-	0.2		-	-	-
11	Inside transmission	-	-	0.13		-	-	-
12	Second adobe wall	0.30	2.0	0.6		*200*	*200*	*100*
13	2 x soil lime/straw plaster	0.06	2.5	0.15		*200*	*200*	*100*
14	Inside transmission	-	-	0.13		-	-	-
Subtotal Newly Added Value R_C				**1.21**		*400*	*400*	*200*
Total Existing and New R_C Values				**2.255**		***Total Cost 10 m^2***		***1000***
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		***443***

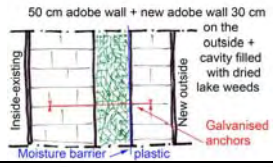
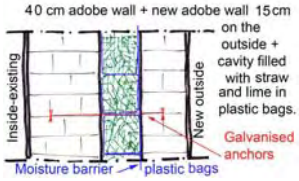
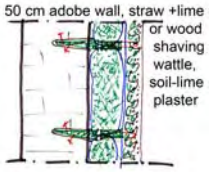
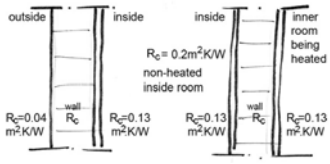
Insulation value is sufficient for altitudes up to 1700 m, according recommendation.

Remarks:

- The additional non-heated space between the heated room and the outside will increase the insulation value of the heated room.
- If the wall surface of the heated room is similar to the wall surface of the non-heated room and the outside, the temperature in the non-heated room will be: ½ ΔT between the heated room and the outside. If the outside wall surface of the in-between room is larger than that of the inside room, the temperature in the non-heated room will be on the lower side.
- If the outside wall has little thermal insulation, such as a timber vestibule or porch, the insulation value of the addition will also be less. A porch, however, avoids strong drafts when the door to the outside is opened.

COMPARISON TABLE OF EXAMPLE WALLS #16 – #19

Adobe Wall Designs with **additional insulation**.

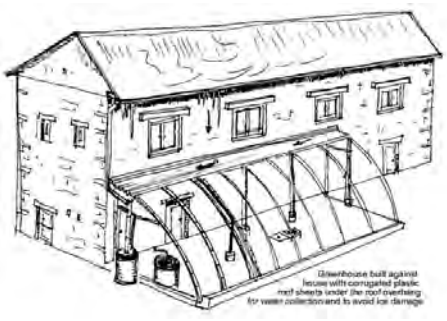
#	Mini Picture of Construction	Description	Added R_C = m^2.K/W	Total Insulation Value	Total Cost of Added Insulation	Ratio = Total Cost / Total R_C
Wall # 16		Adobe wall (50 cm), anchors, dried weeds (15 cm), plastic, adobe wall (30 cm) added on the outside.	**1.65**	**2.82**	**2210**	**784**
Wall # 17		Adobe wall (40 cm), anchors, straw-lime in plastic bags (15 cm), adobe wall (15 cm) added on the outside.	**1.95**	**2.92**	**1950**	**668**
Wall # 18		Adobe wall (50 cm), straw bags + lime (15 cm), plastic, cavity, wattle with soil-lime plaster.	**2.06**	**3.23**	**1980**	**613**
Wall # 19		Two 40 cm and 30 cm adobe walls with room in between.	**1.21**	**2.26**	**1000**	**443**

Adobe Wall Construction Designs

The insulation of adobe wall constructions is similar to the designs with the stone or cement block walls. Thick adobe block walls have a higher own insulation value than stone or cement block walls to start with. Some adobe wall insulation designs, along with the calculation tables, are mentioned in Technical Working Paper #2 ~ Calculations (February 2012).

Greenhouse

A greenhouse on the south side and built against the house has the same insulation effect as an additional room, but the insulation value of the glass is less than that of an additional wall. This means that during no sun hours, the greenhouse will cool off considerably if no double glass and insulating curtains have been installed.



On the other hand, during sun hours, the sunlight entering the greenhouse will be converted into heat when it touches a building material. This heating will be faster when the surface is dark. The walls and floor area inside the greenhouse will be heated up and will serve as a heat storage. The warmed-up walls and floor will later release the stored heat when the sun disappears.

Installing vents in the upper part of the greenhouse, which can easily be regulated, can optimise the heat gain into the house.

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