Urban Energy Technical Note

Building Materials

Building materials play a very important role in the adaptation of buildings to the local climate. The capacity to insulate, transmit and store heat, as well as the natural regulation of indoor temperature and humidity in buildings are all determined by the materials used.

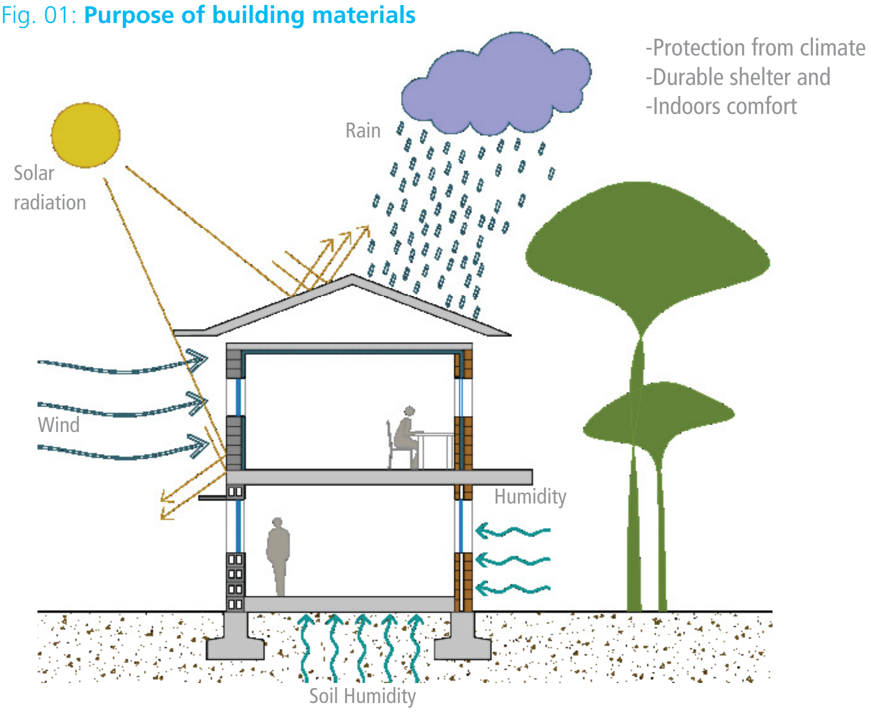
The choice of materials is also crucial in terms of the environmental impact, economic affordability and socio-cultural sustainability of the building. The use of appropriate building materials can reduce by 40% the environmental footprint of construction, it can provide more affordable shelter, create a healthier indoor environment, strengthen local culture by promoting traditional materials and promote the local economy through to the boost of local materials industry.

This document focuses on the use of appropriate materials to adapt buildings to the local climate and provide indoor comfort whilst promoting durable shelter and environmental sustainability.

Behaviour mitigating environmental conditions

The main building components foundations, structure, walls and roof, need different kinds of building materials in order to provide durable shelter, protection from climate and indoor comfort. These among other design characteristics, will be given by the building technology used and the ability of the chosen materials to mitigate environmental conditions including heat transmission, water, humidity, noise and pollution.

Fig. 01: **Purpose of building materials**



Thermal behaviour

The thermal properties of building materials will determine the building's thermal performance and its adaptation to the local climate. Good thermal performance can drastically reduce the energy consumed for cooling and heating whilst providing thermal comfort and a healthier indoor environment. The main thermal properties we should look at are listed below:

- Thermal conductivity: ability of the material to conduct heat
- U-value: ability of the component to gain-lose heat through conduction, convention and radiation. This depends mainly on the thermal conductivity and the thickness of each material. The U-value can be used to calculate the thermal transmittance of floors, walls, roofs and the thermal performance of the whole building
- Thermal mass: ability of the material to store heat

Thermal conductivity

Thermal conductivity measures how easily heat flows through a specific material. The lower the thermal conductivity the less the heat flow and the greater the insulation properties. Thermal conductivity depends on the density of the material and its specific heat capacity. The density of building material is normally related to the material's air content. This means that a porous stone like volcanic stone has lower thermal conductivity and thus better insulation properties than a dense stone like blue stone. In the same way the configuration and shape of building materials influence the insulation properties of the manufactured product, so cavity bricks insulate better from the exterior environment than solid bricks, since they contain layers of air. The same principle applies to other building materials: the higher the air content the lower the thermal conductivity and the better the insulation properties.

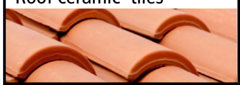
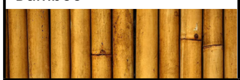
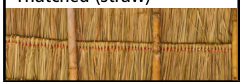
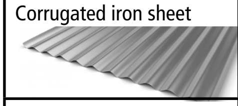
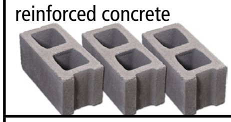
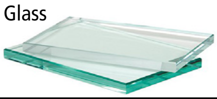
Thermal conductivity values below around 0.08 W/mK are considered insulation materials, whilst highly conductive materials like metals range from 15-20 W/mK up to more than 400 W/mK. The lower the conductivity values of insulation materials the worse the heat conductivity and the greater the resistance against heat gains. As shown in Figure 02 metals are the materials with the higher capacity to conduct heat, whilst wood, bamboo and straw have better insulation properties.

Thermal mass

Thermal mass determines how materials react to variations in temperature: how much heat is gained and for how long a certain volume of material is capable of storing it before releasing it into the environment. Materials with high thermal mass such as blue stone or rammed earth, have a large capacity for storing heat and greater resistance to temperature fluctuations during the day. They will protect the indoor environment from temperature changes in climates where the variation in temperatures during the day and night is broad, as in hot and arid or in highland climates.

Materials with high thermal mass are over 1600 kJ/m³K approximately, and include soil blocks, stone or some types of concrete. They perform well in highlands and hot and arid climates, where temperatures fluctuate considerably between day and night.

Fig. 02: **Thermal conductivity and thermal mass of common building materials**

Material	Main parts of building				Thermal conductivity (W/mK)	Thermal mass. Volumetric heat capacity (kJ/m³K)
	Foundation	Structure	Walls	Roof		
Stone 	X	X	X	X	0.55 (porous stone) - 2.50 (blue stone)	1600 - 2300
*Moulded earth (adobes) / *Compacted earth 		X	X	X	0.50 - 1.50 / 0.70 - 1.70	1300 - 1600 / 1700 - 1800
Stabilized soil blocks 		X	X	X	1.04	1850
Bricks, burnt 	X	X	X	X	0.35 (perforated) - 0.81 (not perforated)	630 (perforated) - 1600 (not perforated)
Roof ceramic tiles 				X	1.30	1900
Wood 	X	X	X	X	0.11 - 0.23	1000 - 1300
Bamboo 		X	X	X	0.12 - 0.38	1200 - 2500
Thatched (straw) 			X	X	0.07	340
Corrugated iron sheet 			X	X	61.00	3700
Concrete blocks / reinforced concrete 	X	X	X	X	0.19 (light) - 1.63 (heavy) / 1.40 - 1.80	600 (light) - 2300 (heavy) // 2000 - 2500
Glass 			X	X	1.10	2100
Steel 		X			47	3700
Insulation material 	X	X	X	X	0.03 - 0.08	65 - 450

*Note: thermal properties of earth construction technologies have wide variation depending on the building technology used, the natural additives (straw, etc) and the level of compactness of the technique.

Materials with low thermal mass (under 1300 kJ/m³K approximately), such as wood, do not have resistance to temperature changes and their capacity to store heat is minimal. Low thermal mass materials are adequate for climates with high temperatures throughout the day and night, like hot and humid areas, so the materials do not release extra heat inside the building during the night.

U-Value

The thermal performance of roof, walls and floor, however, will be determined by the U-Value , which measures the capacity of these components to loose and gain heat according to the materials and their thickness. It will help determine the response of the building to the local climate. The lower the U-value the better the insulation properties and the less the heat gains-losses.

Figure 03 shows possible building technologies and their U-values, which depend on the combination of different building materials and their thickness.

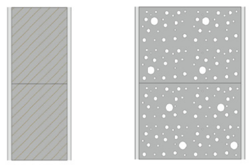
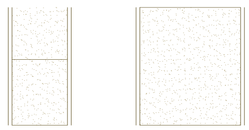
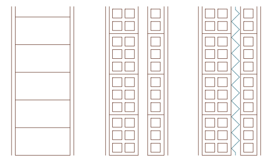
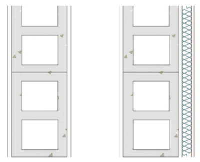
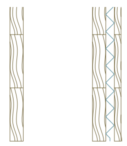
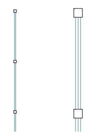
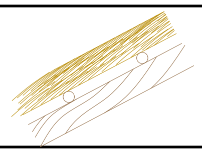
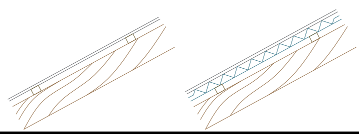
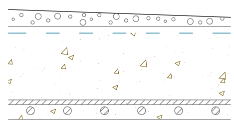
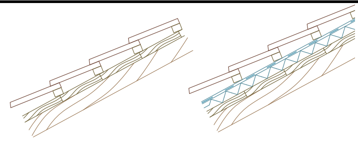
In tropical countries U-values should not exceed 1 W/m²K for walls, 0.85W/m²K for roofs and 5.00 W/m²K for windows. In hot and humid and hot and arid climates it is preferable to reduce these values by at least 20%, especially in buildings using air conditioning.

Humidity control and water resistance

An important characteristic of building materials especially in humid climates and climates with rainy seasons is resistance to water and humidity control. High levels of humidity indoors can cause poor air quality, discomfort, facilitate the growth of fungi and bacteria and damage buildings. This can be prevented by insulating the building from the sources of humidity:

- Roofs: water proof layer combined with other building materials like ceramic tiles, concrete slab, etc., or rigid water proof building materials like corrugated iron sheet with sealed rings.
- Walls: water resistant building

Fig. 03: **U-Value of building components with common building materials**

Component	Description	Materials	U-Value (W/m²K)
Walls		Blue Stone 220mm + plaster Porous stone 450mm + plaster	3.11 0.97
		Compressed Earth blocks 220 mm + plaster Rammed earth 450 mm +mud plaster	1.92 1.00
		Bricks single skin 220 mm + plaster Cavity bricks 220 mm + plaster Cavity bricks 220 mm+EPS 20 mm +plaster	2.07 1.43 0.79
		Cavity concrete blocks 220 mm + plaster Cavity concrete blocks 220 mm + EPS 20 mm + plaster	1.65 0.85
		Eucalyptus wood 50 mm Eucalyptus wood 50 mm+EPS 20 mm+wood 25 mm	1.99 0.67
		Glass 4 mm/10 mm Double glass 25 mm	5.76/ 5.58 2.45
Roof		Thatched 100 mm	0.66
		Corrugated iron sheet Corrugated iron sheet with 30 mm EPS insulation	7.14 0.84
		150 concrete slab, plastered, 75 screed + asphalt Same, but lightweight concrete	1.80 0.8 0.84
		Ceramic tiles+eucalyptus soft board Ceramic tiles+asphalt+25 mm EPS+eucalyptus soft board	2.21 0.85

materials and finishes (stone, brick, concrete, stabilized soil blocks, and/or rain resistant finishes like cement plaster, improved soil plaster, etc.). Overhangs to protect the walls from rain. For earth constructions in rainy weather it is highly recommended that at least 50 cm stone, burnt brick or concrete wall be used over the foundations in order to protect the bottom of the wall from erosion due to rain.

- Floors / foundations: vapour barrier located in between the source of humidity and the component to prevent humidity by capillarity.

Humidity indoors can be regulated with appropriate building materials. For instance, natural earth has the capacity to absorb and release humidity maintaining indoor humidity comfort.

Acoustic insulation

The acoustic performance of a room depends on the building materials, the design, the building technology and the quality of the finishes.

The acoustic properties of materials are normally related to the thermal insulation capacity, so those with good thermal insulation also have good acoustic insulation. These materials are characterised by the high content of air in their structure or configuration. However, some of them do not respond well against humidity, which is why they should be carefully chosen, especially in humid climates.

Acoustic insulation properties are mainly determined by the sound that the material is able to reflect and absorb. Like thermal insulation they improve as thickness is increased.

Pollution protection

Building materials are also able to protect the indoor environment from exterior pollution. Some, like earth construction, can even absorb pollutants from the indoor environment.

Building materials with low embodied energy (those with low energy consumption for extraction, transport, manufacturing and construction) are able to reduce the Green House Gas emissions of the construction process by 40%.

Climate oriented building materials and construction technologies in tropical climates

How to choose appropriate building materials according to climate

The selection of the type of building materials should depend not only on the characteristics of the local climate and the local availability of resources, but also on socio-cultural factors and the acceptability of the materials. In tropical highland climates like Nairobi and Kigali the use of high thermal mass materials such as stone or clay bricks for walls contributes to thermal comfort throughout the year. These materials, with high thermal mass, store heat during the day and release it indoors at night when temperatures fall. In hot and humid zones like Dar es Salaam and Mombasa, light materials such as light and thin stone, thin mud walls or wood are more appropriate as they do not store heat. Figures 06 to 10 show adequate building materials for each component in the different climatic zones in tropical climates.

Fig. 04: **Humidity control**

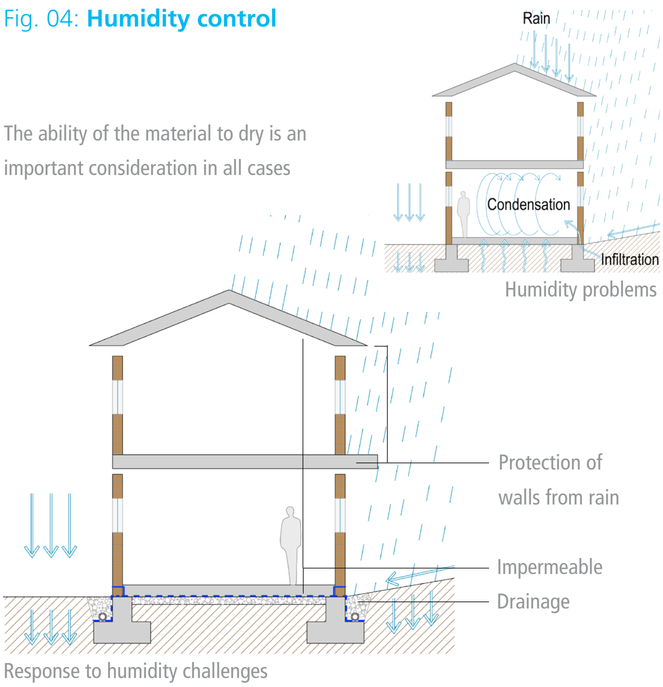


Fig. 05: **Thermal mass**

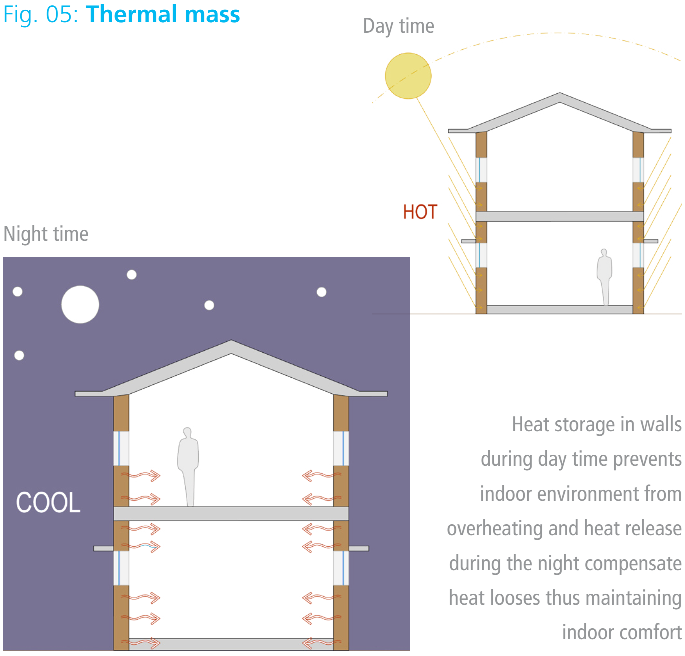
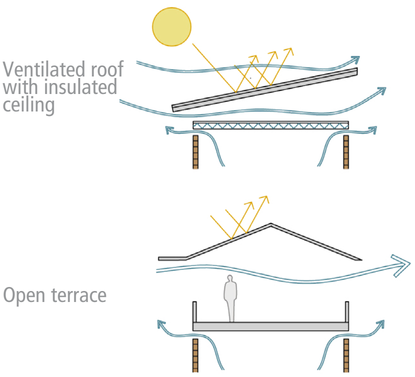
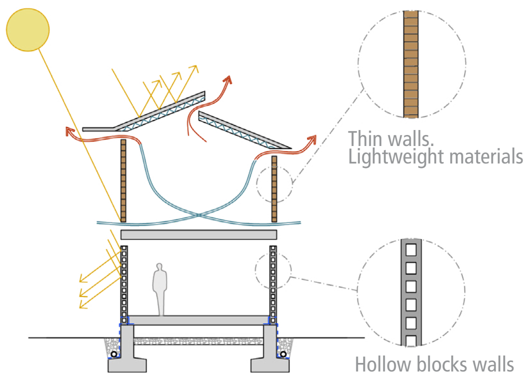


Fig. 06: **Building materials appropriate for hot and humid climates**

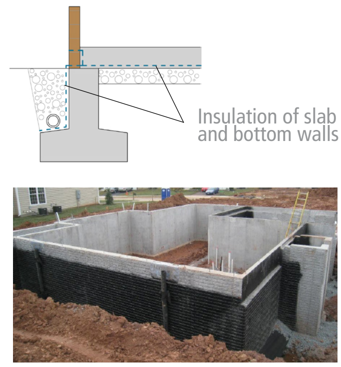
	Roof	Walls	Foundations	Finishes
HOT AND HUMID	Lightweight materials with low thermal capacity and high reflectivity. They must be ventilated or insulated to reduce heat gains	Low thermal mass walls to prevent heat storage	Good insulation from ground humidity: 1/ Insulation layer between the source of humidity and the bottom of the walls or slab; 2/ Air chamber between the soil and the ground floor; 3/ Elevated ground floor	Light external colours to reflect solar radiation and light internal colours to improve natural lighting
	Materials: very well insulated iron sheet; thatched roof; ventilated roof made of clay tiles or iron sheets with insulating ceiling (plywood, reeds with earth plaster, EPS panels, etc.); iron sheet roof covering and open terrace	**Materials:** porous stone, thin wooden reinforced rammed earth walls (over 50 cm high stone or concrete walls); wood; bamboo; cavity walls or hollow block walls (preferable for non-shaded elevations)	**Materials:** Stone; reinforced concrete; concrete blocks; burnt bricks; treated hard wood appropriate for foundations	**Materials:** none (light coloured raw material), light coloured paint; light coloured natural soil plasters; white cement; lime.



ROOF



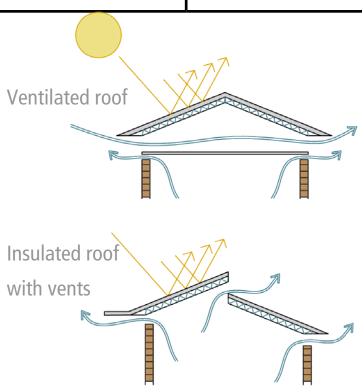
WALLS AND FINISHES



FOUNDATIONS

Fig. 07: **Building materials appropriate for hot- semi arid / savannah climate**

	Roof	Walls	Foundations	Finishes
HOT- SEMI ARID / SAVANNAH	Mid-weight building materials with high reflectivity finishes	Mid-weight building materials to smooth indoor temperature	Insulation from ground humidity as explained in hot and humid climate (point a and 2) is highly recommended	Light external /internal colours to reflect solar radiation and improve natural lighting
	Materials: well insulated iron sheet; thatched roof; ventilated roof made of clay tiles or iron sheets with insulating ceiling (plywood, reeds with earth plaster, EPS panels, etc.)	**Materials:** mid-weight stone; 20 cm rammed earth or stabilized soil blocks walls; mid-weight concrete blocks; 25 cm burnt brick.	**Materials:** stone; reinforced concrete; concrete blocks; burnt bricks	**Materials:** none (light coloured raw material), light coloured paint, light coloured natural soil plasters, white cement, lime.



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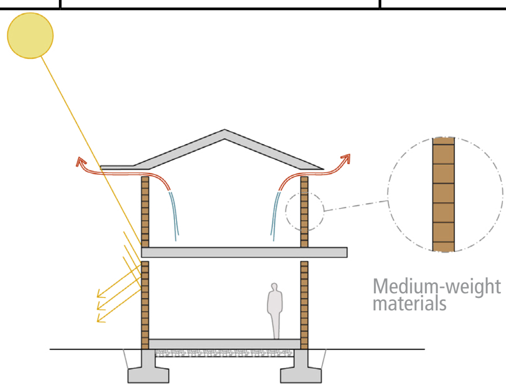
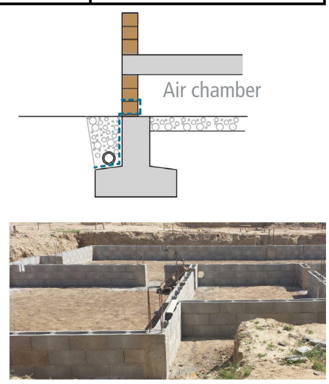


WALLS AND FINISHES



FOUNDATIONS

Fig. 08: **Building materials appropriate for highland climate**

	Roof	**Walls**	**Foundations**	**Finishes**
HIGHLANDS	Roofs can be light or heavy but they must have a good insulation value. Ventilation of roof may not be necessary if it is well insulated	Medium-weight walls are recommended for the best exploitation of solar passive gains. Walls of some insulating value are also recommended	Good insulation from ground humidity: 1/ Insulating layer between the source of humidity and the bottom of the walls ; 2/ Air chamber between the soil and the ground floor	Light or medium external colours to reflect solar radiation and light internal colours to improve natural lighting
	Materials: clay tiles with insulation layer; insulated iron sheets; ventilated roof made of iron sheet and ceiling	**Materials:** mid-weight stone; concrete blocks; 25 cm brick wall; 25 cm rammed earth or stabilized soil blocks walls	**Materials:** stone; reinforced concrete; concrete blocks; burnt bricks	**Materials:** none (raw material), light - medimum coloured paint, light - medium coloured natural soil plasters, white cement, lime.

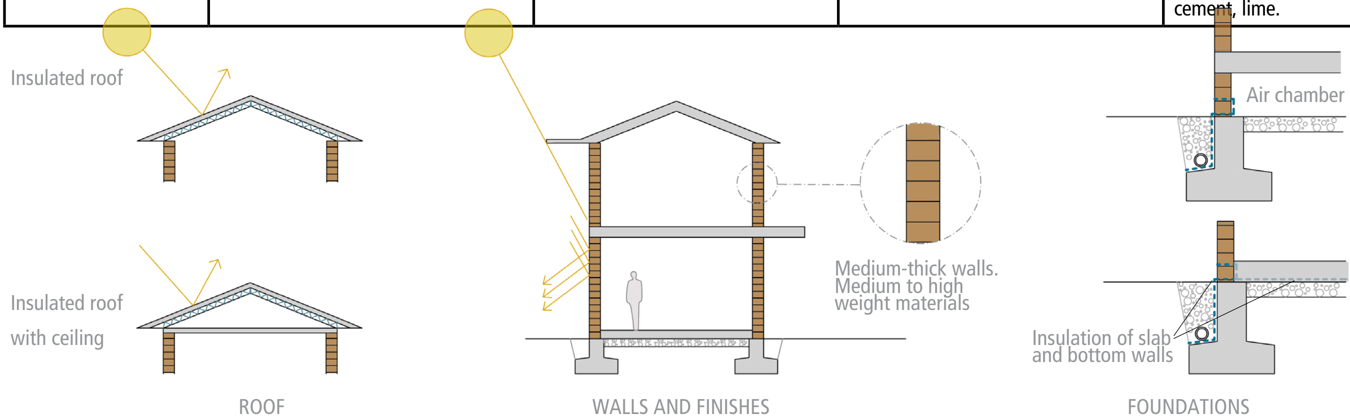


Fig. 09: **Building materials appropriate for great lakes climate**

	Walls	**Roof**	**Foundations**	**Finishes**
GREAT LAKES	Mid-weight walls are recommended to smooth indoor temperature: night temperature is often below the comfort range	Lightweight materials with low thermal capacity and high reflectivity. Ventilated or insulated roofs to reduce heat gains	Good insulation from ground humidity: 1/ Insulation layer between the source of humidity and the bottom of the walls; 2/ Air chamber between the soil and the ground floor; 3/ Elevated ground floor	Light external colours to reflect solar radiation and light internal colours to improve natural lighting
	Materials: mid-weight stone;	**Materials:** very well insulated iron	**Materials:** stone; reinforced	**Materials:** none