

Chapter 5

Related technical issues

5.1 Construction

Using concrete in freezing temperatures

In cold regions, concrete structures (slabs, walls) can suffer from a lack of strength caused by small cracks in the material. These cracks form while the concrete is curing, due to ice expansion within the concrete material. Seasonal variations in temperature may result in further weakening of such structures. It is worth bearing in mind that local construction contractors and builders should be competent at making concrete of reasonable quality in the prevailing conditions, and their skills are worth using.

Methods of improving the quality of concrete, by altering the curing process, are suggested here.

Heat addition

If the concrete is kept warm, it reaches a 'critical hardness' before its temperature falls below freezing. The concrete can then be allowed to cool without any significant loss of strength resulting from the expansion of contained water turning into ice. There are several ways to keep concrete warm:⁴⁸

- Construct components (e.g. latrine slabs) indoors or, for in situ concrete, construct a shelter so that the whole area can be heated to above 0°C.
- Mix in situ concrete using warm water, then cover formwork with insulation to retain heat (known as 'thermos curing').
- Heat formwork by means of electrical wires. Alternatively heat the concrete itself by burying in the mixture resistance wire, which can be warmed electrically.

These methods are expensive since they require additional resources, materials and facilities, and use a lot of energy.

⁴⁸ Krylov (1998)

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Antifreeze admixtures

Antifreeze chemicals can be added to the concrete while mixing the dry ingredients. These chemicals prevent the water in the mix from becoming solid ice and expanding in the spaces between aggregate particles before the critical hardness is reached. With their addition the concrete can cure properly.

There are many chemical compounds that lower the freezing point of water, but most will upset the chemical processes taking place inside concrete as it cures. Sodium nitrate (NaNO_3), potassium carbonate (K_2CO_3), potassium chloride (KCl) and sodium chloride (NaCl) are all possible antifreeze admixtures.

Antifreeze admixtures force the water within the concrete to remain at least partially liquid until the temperature falls below the 'eutectic point', the temperature at which no matter how much antifreeze is added, the solution will completely freeze. The temperature of the eutectic point varies depending on which compound is used. Because some ice crystals form at temperatures above the eutectic point, the operating range for each mix is usually limited to temperatures a few degrees higher than the eutectic point.⁴⁹

Unreinforced concrete (for dome-shaped latrine slabs)

One of the cheapest and most common antifreeze admixes is sodium chloride (table salt). Its eutectic point is at -21°C , so it should be safe to use where the minimum daily temperature does not fall below -15°C . However, chlorides are highly corrosive to steel reinforcing bars, so while acceptable for unreinforced concrete, they cannot be used in reinforced concrete.

Concrete made with an admixture of sodium chloride is suitable for making unreinforced latrine slabs in subzero temperatures down to -15°C . In colder regions calcium chloride, which has a eutectic point of -55°C , could be used. Chlorides should be added at between 5 per cent and 10 per cent of the dry mixture by weight. While curing, latrine slabs should be covered with a tarpaulin to prevent the wind-chill effect from lowering the concrete temperature even more.

Reinforced concrete

Sodium nitrate and potassium carbonate (Potash) are non-corrosive to steel reinforcing bars. Recommended amounts to add depend on the ambient temperature, and are shown in Table 5.1 as a percentage of the weight of the dry concrete mixture.

As with unreinforced concrete, structures should be covered with tarpaulins while curing, so that wind-chill cannot cool them to below the ambient temperature.

Insulating concrete

Insulating concrete is used in Alaska as insulation for buried pipes that may be prone to stress, for example under a road. It can also be used as a base for water tanks to prevent loss of heat, or to maintain the structural integrity of frozen ground.

⁴⁹ Krylov (1998)

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Table 5.1. Amount of antifreeze admix added to concrete, by percentage of dry weight⁵⁰		
<i>Admixture</i>	<i>Minimum daily temperature (°C)</i>	<i>Admix added (% weight of dry mix)</i>
Sodium nitrate (NaNO ₃)	0 to -5	4 to 6
	-6 to -10	6 to 8
	-11 to -15	8 to 10
Potassium carbonate (K ₂ CO ₃)	0 to -5	5 to 6
	-6 to -10	6 to 8
	-11 to -15	8 to 10
	-16 to -20	10 to 12
	-21 to -25	12 to 15

Insulating concrete can be made using polystyrene beads, pumice or expanded shale as the aggregate, instead of gravel. This produces a lightweight mix with high strength and thermal resistance⁵¹. The density and thermal properties of insulating concrete are shown in Appendix B.

Building on frozen ground

Properties of soil can differ greatly during different seasons. Frozen ground is fairly stable structurally, but it may become very weak and unstable when it thaws in spring or summer. Ground instability can cause the walls and floors of buildings to crack or subside.

In winter, construction on top of soil banks, which are liable to subside or collapse in the spring, should be avoided. Ground which is frozen in the winter but could become marshland when winter ends should also be avoided. Consultation with local people should establish this fact; plants growing in the area could also indicate of seasonal marshland.

Water tanks are especially likely to face problems of structural damage. First because they are very heavy, and secondly they need to be located on high ground. Building water tanks on a bank of earth may appear to be a good idea in winter but it could lead to disaster in the spring. Thirdly, the relatively high temperature of stored water can melt frozen ground in contact with the tank, causing collapse. The design of water storage tanks is discussed in detail in section 3.3.

⁵⁰ Figures from Krylov (1998)

⁵¹ Smith (ed., 1996)

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In general there are three factors affecting construction on hard, frozen ground which is not necessarily frozen in the summer:

1. Mechanical digging equipment may be necessary. SIDA (Swedish International Development Agency) has, in the past, used mechanical digging equipment mounted on snow vehicles.
2. Ground may become unstable in the spring/summer. Particular care is necessary when constructing at the top of slopes or on ground that could be marshy in the summertime. Use local knowledge to determine where it is safe to build.
3. Construction work is best done in the summer although, obviously, this will not always be possible. Unfrozen ground is much easier to work, and it can easily be established whether the ground is strong enough to support structures. In addition, construction materials may be more easily available at warmer times of the year due to better logistical links.

Frost jacking

After several years the action of repeated freezing and thawing of the ground can force piles and telegraph poles to start rising out of the ground. One method of avoiding this is to wrap piles in several layers of plastic sheeting to allow the soil to move independently of the piles. Borehole casings are also liable to frost jacking, the effects of which can be alleviated by using bentonite as annular grouting instead of concrete. Bentonite grout, not concrete, should be used in the annular space around borehole casings. Concrete forms strong bonds with casing steel, and frost jacking of the concrete can then pull sections of casing apart, damaging the structure of wells and boreholes.

Calculating snow loads

Roof structures must be able to support the weight of snow that settles on them. The following equation can be used to calculate the load:⁵²

$$L = F \times H \times D \times A$$

where L = total load exerted on the roof (kg)

F = footprint (plan area) of the roof (m²)

H = maximum expected depth of snow on the ground (m). Use the 30 or 50-year expected maximum depth of snow if designing a structure for long-term use.

⁵² Figures and theory from Boyd (et al., 1981)

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- D = density of snow (kg/m^3). Old snow with a density between 200 and $400\text{kg}/\text{m}^3$ weighs more than new snow with a density of as little as $100\text{kg}/\text{m}^3$. Canadian design criteria use $D = 240\text{kg}/\text{m}^3$ but an attempt should be made to determine a local value if possible.
- A = conversion factor taking into account that roofs are generally more exposed than the ground, hence higher wind speeds over them cause less snow to settle. In Canada $A = 80\%$ (0.8) is used for general calculations of flat or sloping roofs or $A = 60\%$ (0.6) is used for roofs in very exposed areas.

5.2 Logistics

The effects of cold climates on aid provision are accentuated in winter, one of the main reasons being the effect of the weather on logistics. In some areas road and rail links are liable to closure due to snow blockage, and air support may be hampered by foul weather. In other areas frozen lakes may provide landing sites for aircraft, and roads that are poor in the summer may be better to drive on when frozen.

This section deals with the implications of winter logistics with respect to water supply options and other issues. Some recommendations for vehicle maintenance are given in section 5.3.

Water haulage

Hauling water by truck is not possible if roads are blocked with snow, or if ice makes the trip too dangerous for the driver. The effect that this will have on water supply will be that the emphasis must be on using very local sources of water, despite the fact that the quality of these sources may be less than ideal. Therefore, in some cold regions the option of expensive treatment of poor quality water is preferable to hauling in water by truck, which may be simply impossible.

Stockpiling for winter

Problems of bringing diesel fuel into an area by road will affect the ability of agencies to run their vehicles and pumps; similarly fuel for heating and cooking purposes could be more scarce in winter due to transport difficulties. Therefore it is worth considering, carefully, whether it is feasible to stockpile quantities of fuel before winter arrives, tackling the problems of storage, security, and distribution.

Materials worth stockpiling include fuel, medical supplies, building materials, water treatment chemicals, bags to contain wastes, and other hardware that may be needed to implement repairs to water supply or sanitation systems.

Use of vehicles for personal transport

Obviously, vehicles for the transport of personnel or materials need to fulfil requirements necessary for summer and winter driving. Four-wheel drive vehicles offer distinct advantages in mountainous areas in winter, and in other areas where the quality of roads is poor.

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In terms of safety, personnel should not set out in winter without:

- snow chains and shovels, in case the vehicle becomes stuck;
- food, water and four-season sleeping bags, in case the driver and passengers have to stay out all night or longer; and
- leaving information with colleagues about travel plans.

The value of keeping warm should not be underestimated. Besides being more comfortable, personnel will also work more efficiently. Cab heating and tea-making facilities are important and should not be considered luxuries.

Chemical control of snow and ice on roads

The purpose of applying chemicals and abrasive materials to road surfaces is to increase the friction between the wheels of vehicles and the road surface, reducing the possibility of skidding. Vehicle journeys are made safer, and the stopping distances that vehicles require are reduced.

Abrasives and/or chemicals should only be applied to a relatively thin covering of ice or snow, such as that created after a snowplough has initially cleared the road of snow, or to an icy surface created when ambient temperatures fall below 0°C after rain. If applied to thicker layers of snow and ice, the abrasives and/or chemicals are likely to become dispersed and less concentrated, reducing their effectiveness.

The quantities of chemicals recommended for ice control and snow removal are shown in Table 5.3. These quantities are designed to produce a 30 per cent melt within 30 minutes of the beginning of snow accumulation.

Side effects of using chemicals to treat roads

It should be noted that the use of chemicals has some adverse side effects, particularly on the environment, so they should be used sparingly and only when necessary. These include:

- damage to certain species of plants;
- potential pollution of shallow wells, ponds or streams that are used as water sources;
- reduction in soil fertility in the surrounding area;
- corrosion of concrete reinforcement, if the concrete is permeable; and
- corrosion of vehicles, if damaged surface coatings expose raw metal.

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Table 5.2. Advantages and disadvantages of chemicals and abrasives⁵³		
Material applied	Main advantages	Main disadvantages
Sodium chloride (rock salt) NaCl	Effective between 0°C and -9.5°C Immediate traction Salt particles quickly bore through the ice layer Low cost	Ineffective below -12.3°C Low rate of solution
Calcium chloride, CaCl ₂	Effective down to -29.1°C High rate of solution Liberates heat on dissolving	High cost Pavement remains wet afterwards
Mixtures of NaCl and CaCl ₂	Effective down to -17.9°C Faster than either chemical applied alone	High cost Pavement stays wet longer than with CaCl ₂
Mixtures of abrasives and chemicals	Effective In very cold weather Immediate improvement in skid resistance if clean ploughing is impossible Free flowing material No freezing of stockpiles Abrasive anchored to the road	Clean-up problems in the springtime May not remove all ice and snow, depending on amount of chemical added Damage to vehicles at high speed from abrasive particles
Abrasives	Immediate improvement to skid resistance	As with abrasive and chemical mixtures (above) Easily brushed off road by tyres

⁵³ From Keyser (1981)

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Table 5.3. Recommended applications of chemicals to paved roads with an average daily traffic of 500 vehicles or more⁵⁴				
Air Temperature (°C) and road conditions	Application — – before snowfall or freezing rain	– to melt loose snow (per cm depth)	– to clean up thin crusts after ploughing	– to clean up thick crust of hard snow or ice
a) -4 or higher, in shade b) -7 to -4, in sun	55 to 115kg of NaCl or mixture (if NaCl is removed by wind or traffic)	100kg of NaCl	85kg of NaCl	170kg of NaCl or 85 kg of mixture
c) -4 or higher, temperature is falling d) -7 to -4, in shade e) -12 to -7 in sun	55 to 115kg of NaCl or mixture (if NaCl is removed by wind or traffic)	170 to 225kg of NaCl or 135kg of mixture	130kg of NaCl	170 to 280kg of NaCl or 170kg of mixture
f) -7 to -4, temperature is falling g) -12 to -7, in shade h) -18 to -12, in sun	70 to 140kg of NaCl or mixture	165kg of mixture	170kg of mixture	280kg of mixture
-18 to -12, in sun	No chemical application	No chemical application	210kg of mixture	340kg of mixture or 1700kg of treated abrasive (abrasive mixed with salt)
Below -18	No chemical application	No chemical application	Abrasive mixed with salt	340kg of mixture or 1700kg of treated abrasive (abrasive mixed with salt)

Note 1: All mixtures in the above table are NaCl and CaCl₂ in a 3:1 ratio

Note 2: All quantities (above) are given in kg per km of two-lane road

⁵⁴ From Keyser (1981)

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Logistics in mountainous regions

In mountain areas poor accessibility can severely affect the feasibility of hauling water for use in refugee camps. Possible haulage methods include use of water trucks or tanks pulled by tractors, although difficulties can be expected with water spilling out of tanks on steep gradients. Winter weather could make access problems worse. Transport of water tanks, full of potable water, by means of helicopters was used in the mountains of Northern Iraq in 1991, although the operation was extremely expensive.

The logistics for supplying shelters, blankets, other materials and food are also, obviously, potentially very difficult. One possibility that has proved necessary in the past (e.g. to supply the Kurdish people in Northern Iraq) has been for civilian NGOs to work with the military, co-ordinating air drops and other supply routes. Although many NGOs are reluctant to work with the military, on the grounds that working with the military may compromise the neutral status of NGOs, in some circumstances military logistical expertise should not be ignored, even if only to seek logistical advice. The military have experience of using both air-drops and pack animals to transport water and materials into otherwise inaccessible areas.

Supply by air

Transporting equipment for water supply or sanitation facilities by helicopter is the only quick way to reach some mountainous areas, assuming there are no roads to the area. Helicopters have been used successfully (if expensively) to bring water, in tanks, to refugee supply points in the mountains.

In 1991, in Northern Iraq, air drops of potable water, in plastic bottles strapped to pallets, were made using C90 Hercules aircraft. Approximately 95 per cent of all bottles broke upon impact with the ground.⁵⁵ Air drops of food or materials, including those used in water and sanitation construction, may be more feasible, but airdrops are so expensive that other methods of transport should be used whenever possible. Airdrops are the option of last resort.

Use of pack animals

Use of pack animals is a common transport solution in many mountainous countries, for example in Nepal. The British army sometimes uses pack animals, instead of helicopters, to transport materials, for example when the helicopters are needed elsewhere or are too expensive to use for transporting non-essential materials.

Mules, donkeys and horses are all suitable for use in mountainous regions. They can reach areas which are inaccessible to road transport and could be used to transport materials for water supply or sanitation systems, as well as tents, blankets, food and other equipment. The approximate requirements and capabilities of different animals are shown in Table 5.4 .

⁵⁵ Cuny (1994)

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Food (per animal per day)	10lbs (4.5kg) of hay and 10lbs (4.5kg) oats/grain
Drinking water (per animal per day)	8 to 10 gallons (40 to 50 litres)
Maximum carrying load	Pack pony or horse: 70 to 75kg Donkey: 45kg
Average speed	3 to 4mph (4 to 6km/h)
Distance covered in one day	20 to 30km

Note 1: The above figures are approximate. They will vary depending on the size of the animals and the type of terrain to be covered.

Note 2: The above figures are for guidance only. Local advice should also be sought.

5.3 Mechanics

Vehicles, pumps and generators

Diesel and other engines are almost certain to experience running problems due to the cold, especially if it is not possible to keep vehicles indoors when not in use, or if mechanical water pumps or generators have to be left outside temporarily. Petrol engines are less prone to fuel problems and would be the only choice for extremely cold areas. A good guide is to observe whether local vehicles are run on petrol or diesel.

Many starting problems can be avoided by keeping mechanical plant indoors, especially at night, or by starting the engine periodically (for example running a vehicle engine for 10 minutes every hour or two). Use the skills of *local* mechanics who will already be adept at keeping engines running in the cold.

Problems that are likely to affect the engines of vehicles and pumps are listed, with solutions, in Table 5.5.

Diesel fuel

Diesel fuel, whether local or imported, must be suitable for use in cold weather. Additives are available in some countries that, if necessary, can be put into warm-weather diesel to prevent it from gelling. In the UK this fraction is known as the ‘middle distillate flow improver’; in Iran there is an additive called ‘Nesto’.⁵⁷ Note that these additives must be put into the fuel in advance, and will not remedy the problem after the fuel has gelled.

⁵⁶ Kohler (1999)

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Table 5.5. Mechanical problems with engines	
Engine problem	Solution
<p>Diesel gels Diesel partially solidifies when left for periods of time, undisturbed, in freezing temperatures.</p> <p>Engine will turn over but not fire and inspection of fuel tank reveals gelled diesel.</p>	<p>Prevention Use diesel designed for use in the cold or put additives into standard diesel.</p> <p>Light a fire under the fuel tank at night. <i>Warning: diesel is not likely to catch fire, but do not try this with petrol which is highly flammable!</i></p> <p>Repair Change fuel filters (which are probably clogged); fill filter casing with warm diesel and heat diesel in the tank by building a fire underneath it.</p>
<p>Water freezing in cooling system Check in radiator if in doubt.</p>	<p>Prevention Use more antifreeze in the cooling system.</p> <p>Repair Warm things up slowly, do not start the engine otherwise the water pump could break. Only when everything is unfrozen start the engine and look for leaks. It may be necessary to replace pipes and gaskets and/or get the radiator repaired.</p>
<p>Oil too viscous Engine has difficulty turning over.</p> <p>Only happens in extremely cold conditions or when oil is unsuitable for use in the cold.</p>	<p>Prevention Use correct grade of oil.</p> <p>Light fire under the engine at night (diesel vehicles only – petrol is explosive!)</p> <p>Repair Change the engine oil for a more suitable grade.</p> <p>Light fire underneath the engine sump.</p>
<p>Engine will start but runs badly Engine too cold or icing in carburettor (petrol engines only).</p>	<p>Prevention Increase the engine idling speed, wrap multiple layers of tin foil (insulation) around various water pipes, or hang sacking over the radiator grill (reducing its efficiency to dissipate heat).</p>

In some countries drivers mix a small quantity of petrol (gasoline) or kerosene in with the diesel fuel. Each 10 per cent by volume of added diluent will lower the ‘cloud point’, the temperature at which the fuel begins to gel, by about 2°C. An absolute maximum of 50 per cent of petrol must not be exceeded, since the risks of fire and explosion increase as more petrol is used. This method is only suitable for occasional use because regular use leads to reduced power output and wear of fuel injection equipment.⁵⁸

⁵⁷ Goulding (1998)

⁵⁸ Owen (ed., 1989)

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Diesel fuel is very likely to gel after driving from a warm area into the mountains, where the ambient temperatures are much lower, especially at night. Diesel gelling on the first night in the field will delay activities planned for the next day.

If diesel-powered pumps are left outside, the pumping cavity should be drained at night to prevent cracking from ice formation inside.

5.4 Shelter

In emergencies the functions of shelter are to protect people from the elements, to help people to feel more secure, and to provide privacy and space for personal or group needs. Transitional settlement options must also contribute to local and regional political, social, environmental and economic security, and options should be considered part of a strategy agreed between the affected population, national and local governments, host populations and the aid sectors. Water supply and sanitation decisions are dependent on first establishing the best shelter option, in cold regions as in the tropics.

Equipment which is provided to improve personal comfort may not necessarily be used for their intended purposes, so attention should be given to the choice of equipment. Certain items may be sold by the intended beneficiaries, and other items (such as doors and door frames) may be used as fuel, instead of being used for their intended purposes.

Rehabilitation of urban shelter

In the urban case, local housing is the obvious place for refugees to live, if there is any housing to spare. Community centres, schools, churches, mosques, or sports halls may also be used, as collective centres, although in this case consideration should be given to the activities displaced by using these buildings in a different way than usual.

The role of aid agencies in providing shelter for urban disasters becomes that of fixing and repairing (floors, windows, roofs, etc.). In order to improve the weather proofing and thermal retention properties of the buildings. It may be possible to employ and co-ordinate local craftsmen to do much of this work.

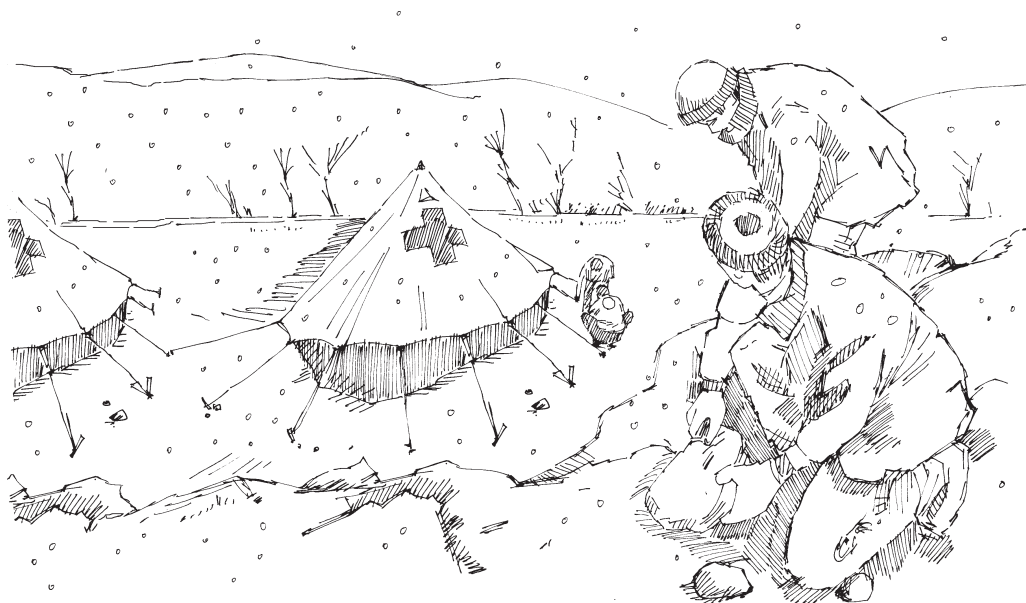
When people move back into previously vacated housing, there are likely to be problems of broken or frozen water supply or sewer service pipes for the houses. Advice on defrosting metal and plastic pipes in which water has frozen solid is contained in section 3.5.

Tents

Tents, huts and other shelters may be used in rural locations where there is a scarcity of proper construction materials due to strained logistics. Temporary shelter may also be necessary while reconstruction of permanent housing takes place. The proper location of tented camps is a crucial factor in cold regions: for example, poorly drained areas should be avoided. In hilly areas a temperature inversion (when cold air sinks to the valley floor) may mean that a camp located on the lower slopes of a mountain or hill is actually in a warmer location than a camp on the valley floor itself. Several factors are relevant to the use of tents in cold regions:

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- Heavy duty, waterproof, tent material is preferable to provide protection against the cold. If the material is not sufficiently waterproof then people will tend to throw plastic sheeting over the top. This can cause the tent material to rot because the plastic restricts ventilation and prevents condensation on the inside of the tent from escaping.
- Wooden, raised floors in tents help to keep the occupants warm by avoiding the need to walk, sit or sleep on the cold ground. Giving people some form of bed also significantly increases their comfort, for the same reason.
- The heat-retaining properties of tents without an in-built ground sheet can reportedly be improved by excavating the floor down by half a metre or so. This may simply cut out draughts at floor level, increasing the comfort of people sleeping on or close to the floor. Building low mud walls inside the tent has the same effect.
- Thermal tent liners, for standard UNHCR and other tents, which greatly improve their heat retention properties, are currently being developed by Shelterproject.org.⁵⁹



⁵⁹ Battilana and Corselhis (2002)