ENERGY CONSERVATION IN TRADITIONAL BUILDINGS IN THE MOUNTAINS

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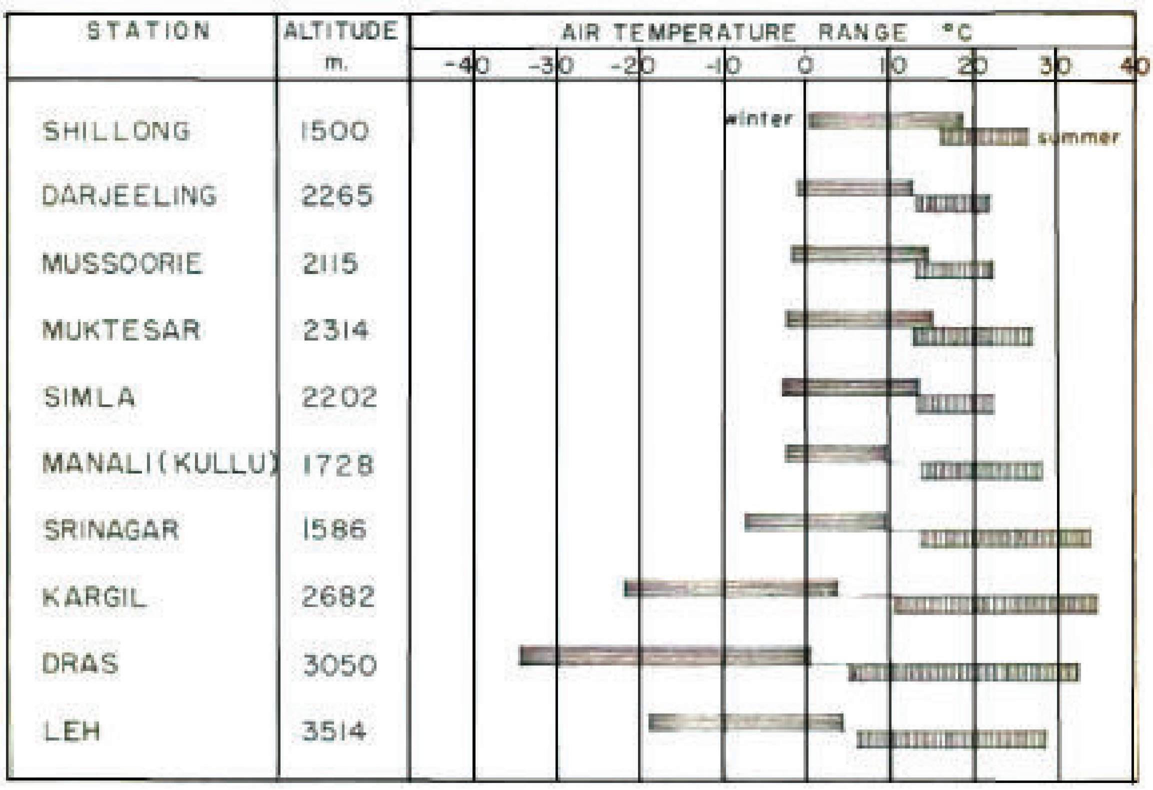
INTRODUCTION

The Himalaya region in India stretches from Kashmir and Ladakh in the west to Arunachal in the east. The climate varies respectively from very cold dry to humid temperate. As a response to climatic variation and local availability of building materials, many different types of dwellings are found in the mountains. This paper is a study of some of these building responses, suggesting possible improvements in traditional designs.

THE MOUNTAIN MICROCLIMATE

In the plains, climate is determined by temperatures, wind, relative humidity, solar radiation and precipitation. In the mountains, this is compounded by fog and snow, which together with clouds determine the amount of solar radiation available. In the plains, the microclimate effects cause only minor variations in the general climate, but in the hills, climate depends to a large extent upon local factors and can vary considerably within a few kilometers. Unfortunately, little published climatic data exists for the mountains, and climatic data is recorded regularly in only few places in the hills (Figure 1). Both the diurnal and the annual ranges increase from Shillong in the east to Dras in the west. There is also a general decrease in temperature as the altitude increases, but as can be seen, Darjeeling is much warmer with an altitude comparable to Kargil. One important microclimate feature of the hills is the wind, characterized by its velocity and direction. During the daytime as the ground warms up, wind blows up the slopes (adiabatic wind), and at night the direction is reversed (katabatic wind). Both these winds can reach high velocities, particularly along mountain passes, and they can cause considerable damage to buildings and people.

A second important factor is the direction of available solar radiation in mountain areas. Unlike the plains,



AIR TEMPERATURES FOR STATIONS IN THE INDIAN HIMALAYA FOR TYPICAL WINTER AND SUMMER DAYS (AFTER SESHADRI, 1969) where the winter sun is always from the sounth (in the northern hemisphere), on mountain slopes, solar radiation from certain directions get obscured by other mountains and, therefore, the direction of available sunlight may be east or west rather than south. Steep north slopes get no sunlight at all, while south slopes are ideal for solar radiation. Thus, solar radiation availability varies considerably over short distances, and within an area, the most favourable orientation also changes from point to point.

Because of the great variations in wind and sunlight, building design in the mountains is more site-specific than in the plains, and the builder has to take greater care to make use of favorable elements, while guarding against unfavorable ones. Snow and rain are also important climatic parameters, and a good understanding of local microclimate is needed for an optimum building design.

BUILDING IN THE MOUNTAINS

Transport of materials involves much greater labor in the mountain than in the plains, and because of this, traditional buildings in the mountains relied almost entirely on locally available materials. The building form is clearly dependent upon available materials also. Thus, one finds flat roofs in Ladakh, and sloping roofs in neighboring valleys. With the development of transport facilities in previously inaccessible mountain areas, many new materials have become available in recent years and, as a result, the traditional building form in undergoing a major change. Srinagar in Kashmir Valley is one such area where traditional buildings have almost completely disappeared.

Dwellings in the mountains have to provide protection from cold winter. Ideally, these buildings should be designed to utilize natural energies--solar radiation in particular--to provide a comfortably warm interior. This has been rarely possible and a heating system, however simple, has been needed in all cases. The main fuel used for heating is wood, which is becoming increasingly expensive as well as scarce. Thus, it is extremely important to conserve heat and thereby conserve fuel also. The one building that is absolutely essential for preventing heat loss through window opening (i.e. glass) has become available in the mountains only recently. This is the only material that lets sunlight into the building while keeping cold air out. Without glass, a building in a cold region can never be very satisfactory, but as the use of glass in many modern buildings has shown, it is also possible to build unsatisfactory buildings with glass.

Since the purpose of this paper is to look at methods of energy conservation, the discussion will be restricted to the Western Himalayas, as the climate of the Eastern Himalayas in only mildly cold and hardly any energy is consumed there for heating or cooling of buildings. Although there are many regional styles of building in the Western Himalayas also, this paper will deal with three areas: Kullu Valley, the Kashmir Valley and the Ladakh region. These three regions have distinct building methods and are reasonably representative of the entire Western Himalayas.

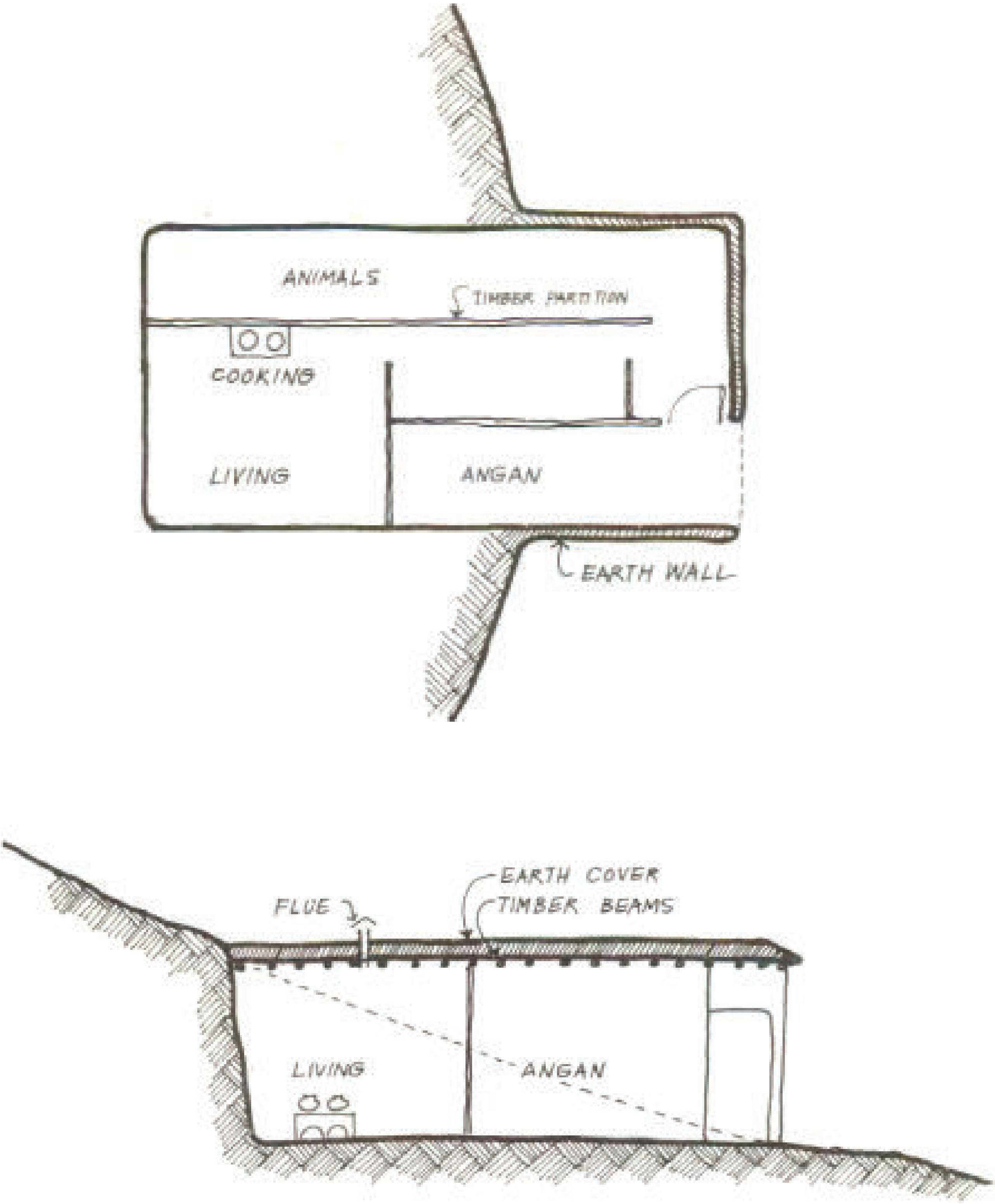
Kashmir Valley

The climate of Kashmir Valley is characterized by a cold humid winter and a slightly warm, humid summer. Rainfall is distributed throughout the year, and during winters there is snow as well. Little variation is found in the day and night temperatures, but the annual temperature range is broad, and the summer period becomes uncomfortably warm.

A wide variety of building materials are available here. These included earth, burnt brick, stone for masonry, timber of many varieties and thatch. In recent times, galvanized iron sheets, which are not produced locally, have become a commonly used roofing material. Based on the materials used for construction, three kinds of dwellings are commonly seen in Kashmir. The first of these are used by shepherds and are found along the Banihal pass and on mountain slopes. The second type of building is located in villages, while the third and the most complex type is Found in the towns.

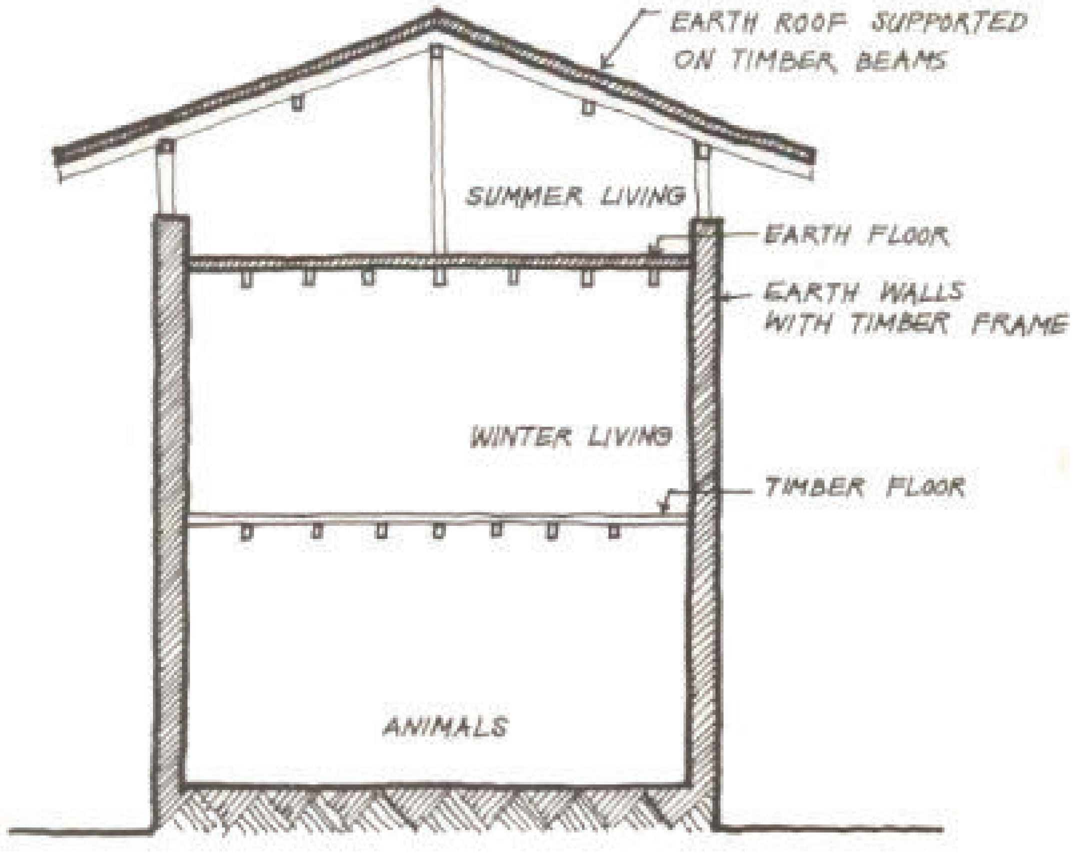
Gujjar (shepherd) house. This simple dwelling is an earth-sheltered structure built entirely from locally available building materials. The building is made by partially cutting into the mountain slope and raising earth walls to enclose a rectangular space. The flat roof is made of earth supported on timber beams. There are practically no openings for windows and only one door which lets in light and ventilation (Figure 2). Such buildings are well equipped to retain heat,, but are used mainly in summer. During winter most members of the Gujjar Family move to the plains with the cattle.

The house is divided into three parts: a front part where all daytime activities take place (the only part with natural light), one part for cattle, and an innermost part used by the family for cooking and sleeping. The front space acts as a buffer between the external environment and the protected internal space. The



PLAN AND SECTION -----
GUJJAR HOUSE of KASHMIR
Figure 2.

doors to the two inner rooms are arranged so there is no possibility for wind to enter. The heat from people, animals, and the cooking stove keeps the living room warm. Rut with this kind of house there are obvious hygienic problems, as cattle and humans are separated by a thin partition only and light and ventilation are inadequate.



RURAL HOUSE - KASHMIR

Rural house. Most rural houses are two or three floors high (Figure 3). The materials used For construction of walls and floors are earth and timber, and the main sloping roof over the house is covered with paddy thatch. Occasionally, the sloping roof is covered with earth also. While the two lower floors are fully enclosed with walls, the second floor is open under the gable. The ground floor of the house is invariably used for housing cattle and for storage of fodder, while the first floor is the main winter living room and kitchen. The well-ventilated space under the gable is used for storage of fuelwood.

During winter, the house is kept warm by heat from cattle,, which rises to the upper-level living room, as well as by heat from cooking. The massive earth walls insulate the interior space and cold air is kept out by minimizing ventilation. During summers, the household activities of cooking and sleeping shift to the second floor which is well lit and ventilated. This seasonal shift is necessary as the poorly ventilated first floor living rooms become quite uncomfortable in summer.

Urban house. The traditional urban house is usually two stories high, and is better constructed than the rural house. The walls either have a timber frame and earth infill, or random rubble masonry. Even burnt clay bricks are used. The floors are of timber beams and boarding, sometimes covered with earth. Two kinds of roofing materials are used: timber singles or timber boarding waterproofed with birch leaf and topped with a layer of earth on which irises can be grown in summer. The second type of roof was the more common one, but has been replaced by galvanized iron sheeting in recent years. Urban living requires the houses to be better lit than in the villages, and therefore the rooms have an adequate number of windows. Earlier, when glass was not available, the windows were fitted with timber shutters (sometimes lattice work), which was covered with translucent oil paper in winter.

The ground floor of the house has the hammam (heated living room) and the cooking and dining areas. The upper floors are used for sleeping and other household activities. The windows are placed in the south wall to let in the sun. The house was previously heated by the hammam under the floor heating system. This consumed a great deal of timber and, in the last few decades, has been replaced by the more efficient bukhari (a stove placed in the living room itself). Although an improvement over the ancient system, the current bukharis are still very inefficient when compared to, for instance, closed metal radiant woodstoves in the USA. Their efficiency can be greatly improved.

This type of building conserves energy by reducing air infiltration through windows, by good insulation in the thick earth roof and walls, and by accommodating daytime activities in the sunny part of the house. Because such a house could become quite uncomfortable in summer, the oil paper is taken off the windows to let in more air, and as in the case of rural houses, the family moves up to the better ventilated part of the house.

Artificial heating. With good building design, it is possible to reduce heat loss through the building envelope, but this does not always ensure comfortable conditions inside the house. However, in Kashmir the main emphasis is on keeping people warm and not on house heating. For this, the Kashmiris have developed a very warm baggy dress called pheran which covers the body from head to toe, and a portable personal heater called kangri. This remarkable heater is actually a small charcoal brazier, which is carried under the pheran. The heat from the kangri warms the air enclosed by the pheran, keeping the person warm even outdoors. This would be a very good low energy-consuming heating system, were it not for the many health and safety problems associated with it. The kangri is carried very close to the skin and people even sleep with a burning kangri between their legs. Despite good training, which Kashmiris receive at a young age, sometimes kangris do overturn, causing fires, but much worse is the occurrence of cancer of the thighs because of prolonged use of a kangri.

KuIlu Valley The climate of Kullu Valley is different from that of Kashmir, and temperature variation is greater. There is less moisture in the air, but more snow, and the valley is windier. The winds flow along the river Beas as well as up and down the slopes on either side of the valley (Figure 4). These winds can be very sharp. The occupational pattern in KuIlu is not entirely different from that of Kashmir.
In addition to agriculture, people practice horticulture. Since fuelwood is available in plenty, its collection does not involve as much time and effort as in Kashmir, and people have more time to spend on activities like weaving. Therefore, not only is shelter needed from cold and wind, but also the buildings must provide a warm and well-lit space for weaving.

The KuIlu Valley has a variety of natural building materials available. Stone for masonry and slate for roofing can be obtained easily from nearby areas. There is no dearth of good building timber also.

Building system and planning. Planning for protection from cold begins with the setting of the villages themselves. Basically, the location has to be such that water is easily available, there is plenty of sunshine, and there is some protection from the cold winds. In view of these requirements, no village is ever located on a north slope and in the Kullu Valley which runs north-south, and there are more villages on the eastern side than on the western side because the former gets more sun in the afternoon when the sky is clearer. The villages are located well out of reach of the river and the cold winds that flow along it, and are tucked away in flatter areas on the mountain slope (Figure 5). This location gives protection from the winds that blow during the daytime, but other means are needed to protect the houses from the descending winds at night.

The house. Because of snow and rain, the houses in Kullu Valley have pitched roofs (Figure 6). The main building is built of stone rubble masonry and floors of earth supported on timber beams. On the first and second floors, the stone structure is surrounded by a lightweight balcony of timber. Usually there is a high plinth and the slate roof projects beyond the balcony. As in Kashmir, the ground floor is used for housing the milk cattle and for storage of fodder. During the winter, the kitchen is located at the first floor level and the family spends most of its time around the smokeless cooking stove. The balcony at this level has various uses. On the sunny side of the house, the balcony is used for sitting and working in the well-lighted area, while on the north and the non-sunny side, the balcony becomes a store for wood and for fodder. On the shaded side, the balcony is also completely shuttered so that the main house is protected from the cold winds that come down the mountain slope. During the more active summer season, the kitchen moves up to the attic, where there is a smokeless cooking stove.

Thus the special design features of the house are:
- There is a healthy respect for sun; the houses are located so there is plenty of sunshine on the balcony and in the drying yard around the house.
- The main living area of the house is kept warm by the heat from the cooking stove and by the body heat of humans and cattle. The heat is retained by insulat-

ing the north side and the darker side (east or west) of the house.

• In the absence of glass for windows, it is difficult to use solar radiation for heating of the house, but the houses are oriented so sunlight is available to sit in and for drying activities in and around the house.

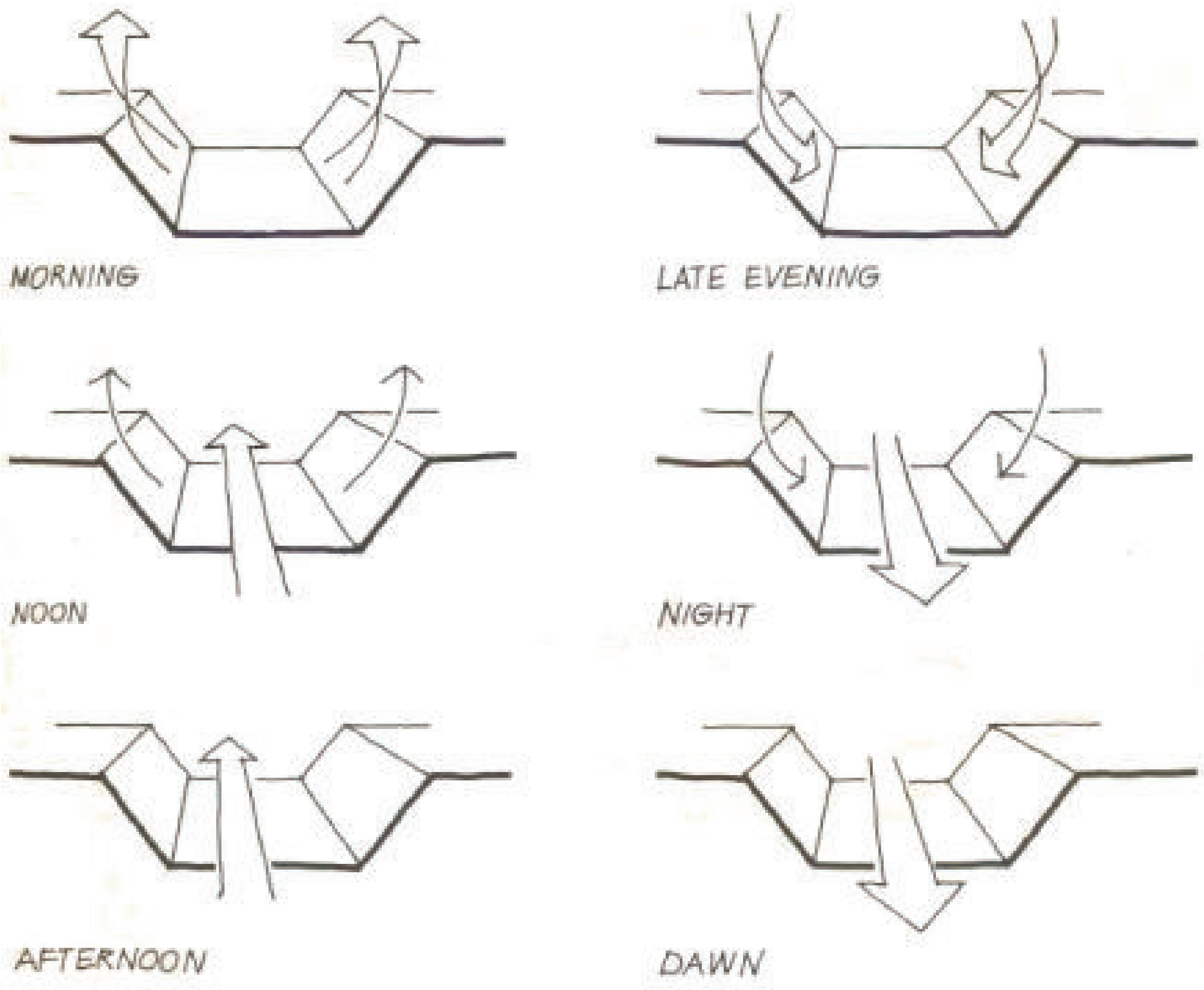
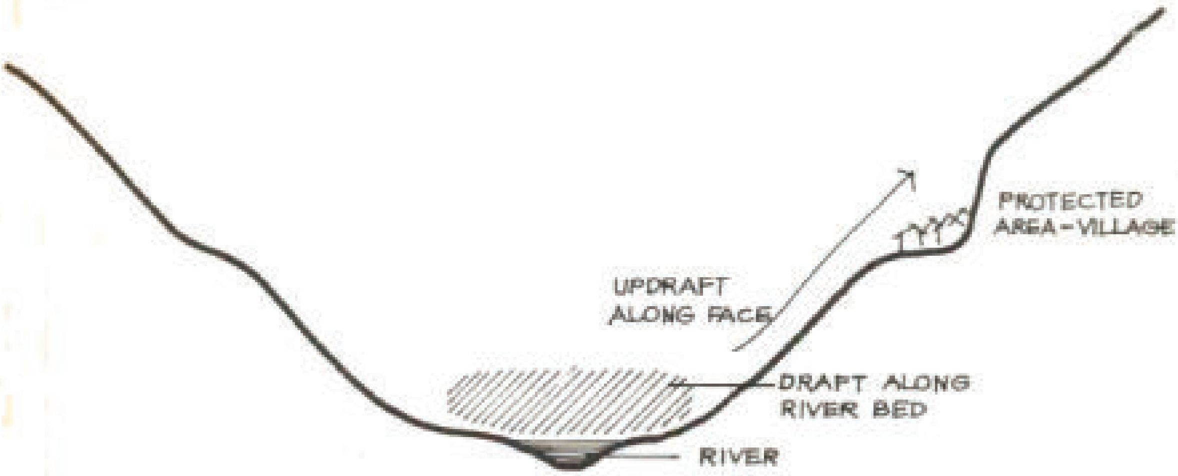


Fig.- 4
WIND FLOW DUE TO SLOPES (AFTER WATSON, 1983)

Figure 4.



VILLAGE LOCATION IN KULLU VALLEY

KULLU VALLEY HOUSES (ALLE-O)

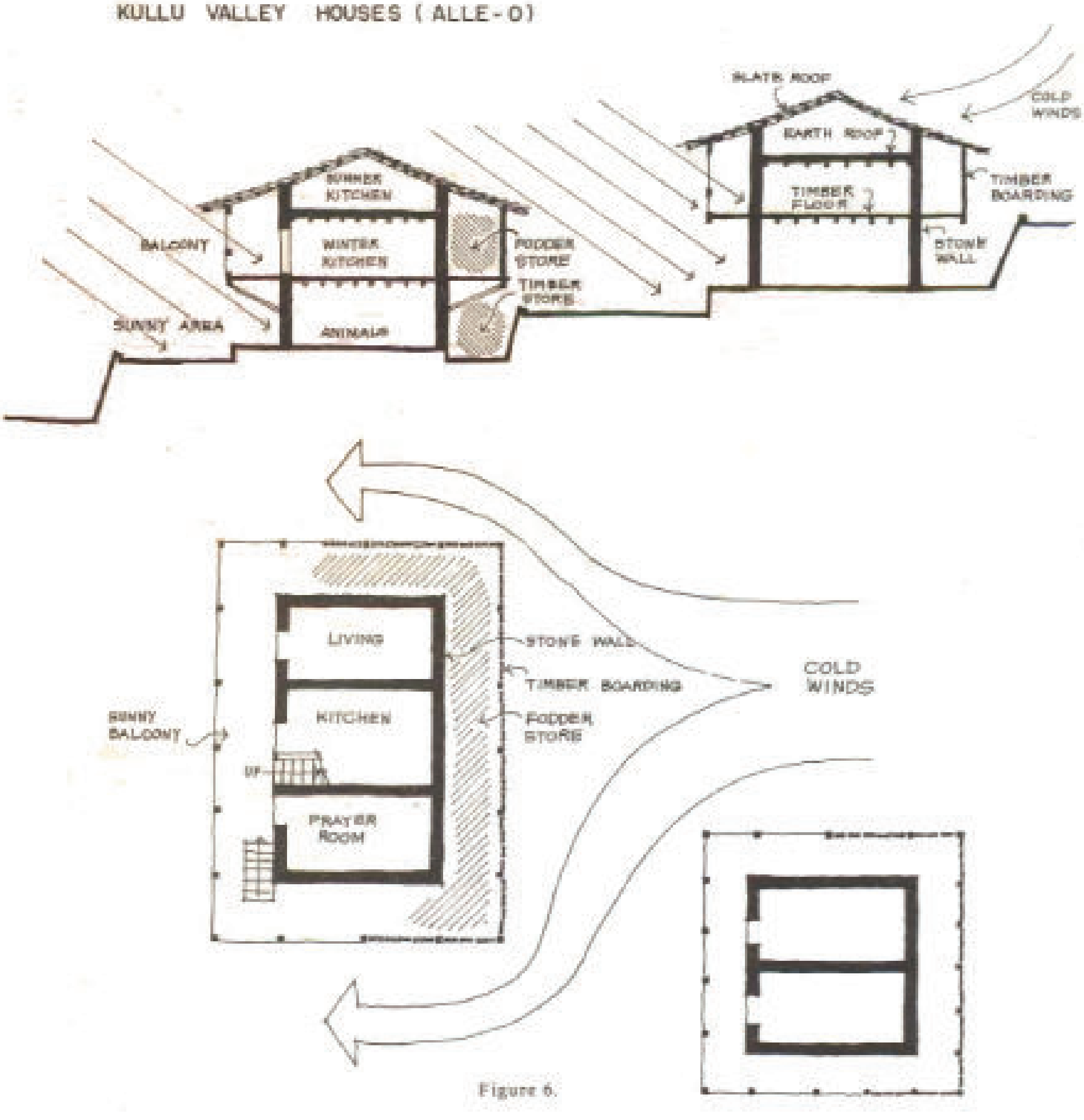
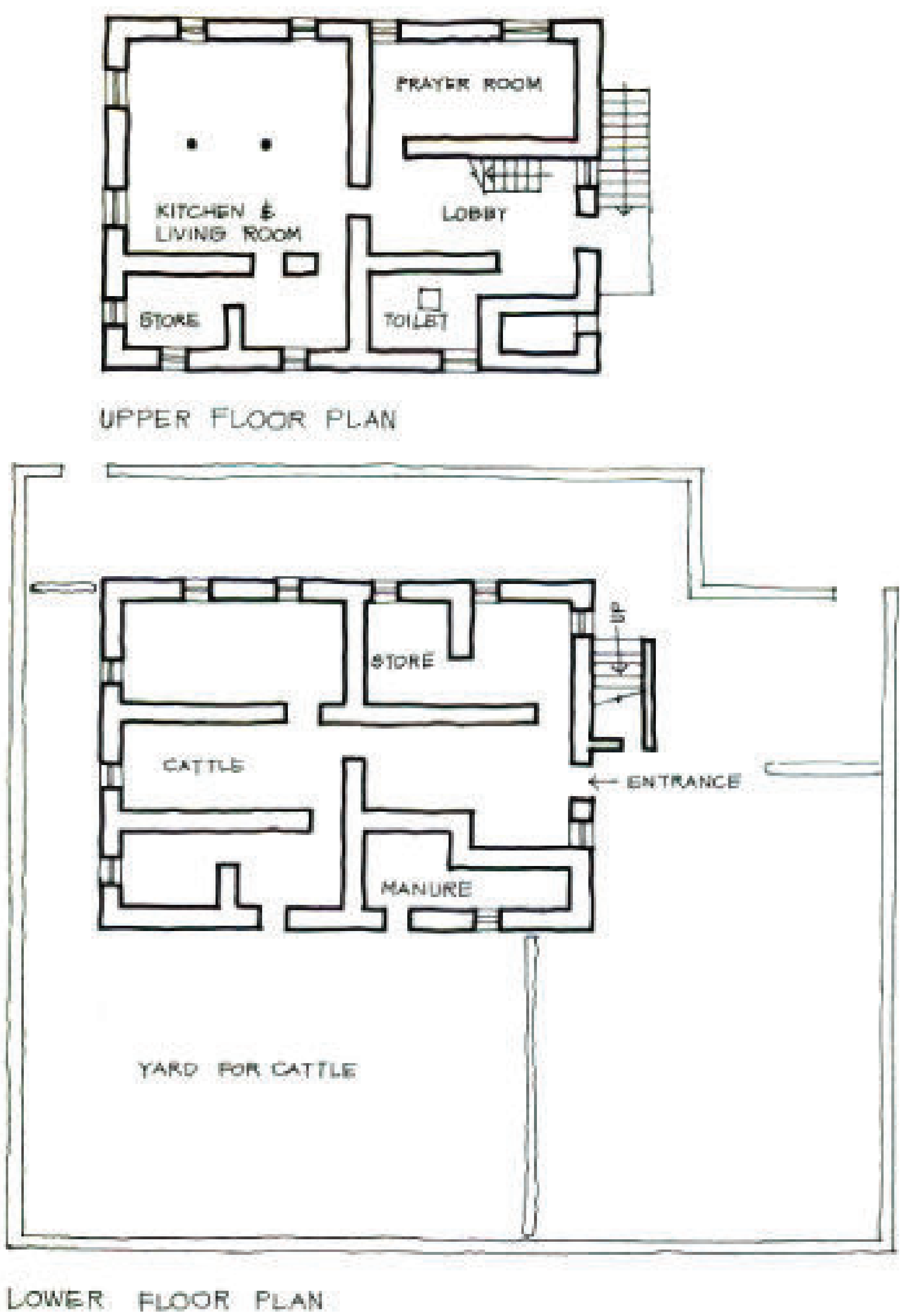


Figure 6.

Ladakh

The climate of Ladakh is very cold and dry with only about 238 mm annual precipitation. Even snowfall during the winter is meager. The area is almost completely devoid of vegetation and may be classified as a cold desert. Due to the absence of moisture, the sky is usually clear and solar radiation is intense. The nights are cold throughout the year, but summer days are usually warm. This type of climate demands that the buildings be able to even out the temperature differences between day and night.

Because Ladakh has remained isolated, it has been necessary for people to build houses using only locally available materials and skills. Timber is in short supply and even good building stone is not easily available. The one abundantly available material is earth, and this is the principal building material for walls, roofs, and floors. In the dry climate of Ladakh, compacted earth walls are durable, and the mud-plastered surface requires little maintenance as there is hardly any rainfall. In fact, mud walls are used not only for houses but also for more important buildings like monasteries. It is not unusual to see three or four storied mudwall structures in Ladakh, and some even higher. Roofs are generally flat and are constructed



LADAKH HOUSE (AFTER KHOSLA, 1984)

Figure 7.

with earth supported on a framework of timber beams. This is done simply in houses, but takes elaborate forms in the monasteries.

The house. The typical house of Ladakh is two stories high (Figure 7). In this extremely cold climate, even cattle may not venture out in winter, and they occupy the lower floor of the house. Sometimes there is an enclosed yard on the ground floor where cattle can sun themselves. During winter, the family lives on the first floor and the kitchen is the main living room of the house. This is also where the family sleeps.

Usually there is a smokeless stove in the kitchen so it is possible to stay in this room even when cooking is going on. The few existing windows are small. Since glass was not available in Ladakh until recently, windows are fitted with solid timber shutters which give one the choice of letting in light as well as cold air, or of keeping both out. The window openings are limited to the sunny sides of the building, and the sides exposed to cold winds have no openings at all.

Because of sub-zero temperatures in winter, the family stays inside most or the time. A large quantity of fuelwood is required for cooking and heating during winter, and this is normally gathered during the warmer summer months and stocked on the roof of the house. This layer of wood adds to the insulation value of the roof. During summer, the well-insulated and poorly ventilated house can become uncomfortably warm, and the typical Ladakhi family shifts its activities, including cooking and sleeping, to the roof. Sometimes cloth awnings are erected over the roof for shade from the fierce sun.

Thermal comfort. During January, the coldest month of the year, the indoor temperature of the unheated house falls below the freezing point, and even during the milder winter months the temperatures are far from comfortable (Figure 1). Thus, some space heating is definitely needed and this is usually done by the smokeless cookstove or bukhari. The typical Ladakhi family spends the whole summer gathering fuel wood for use in the stove during winter.

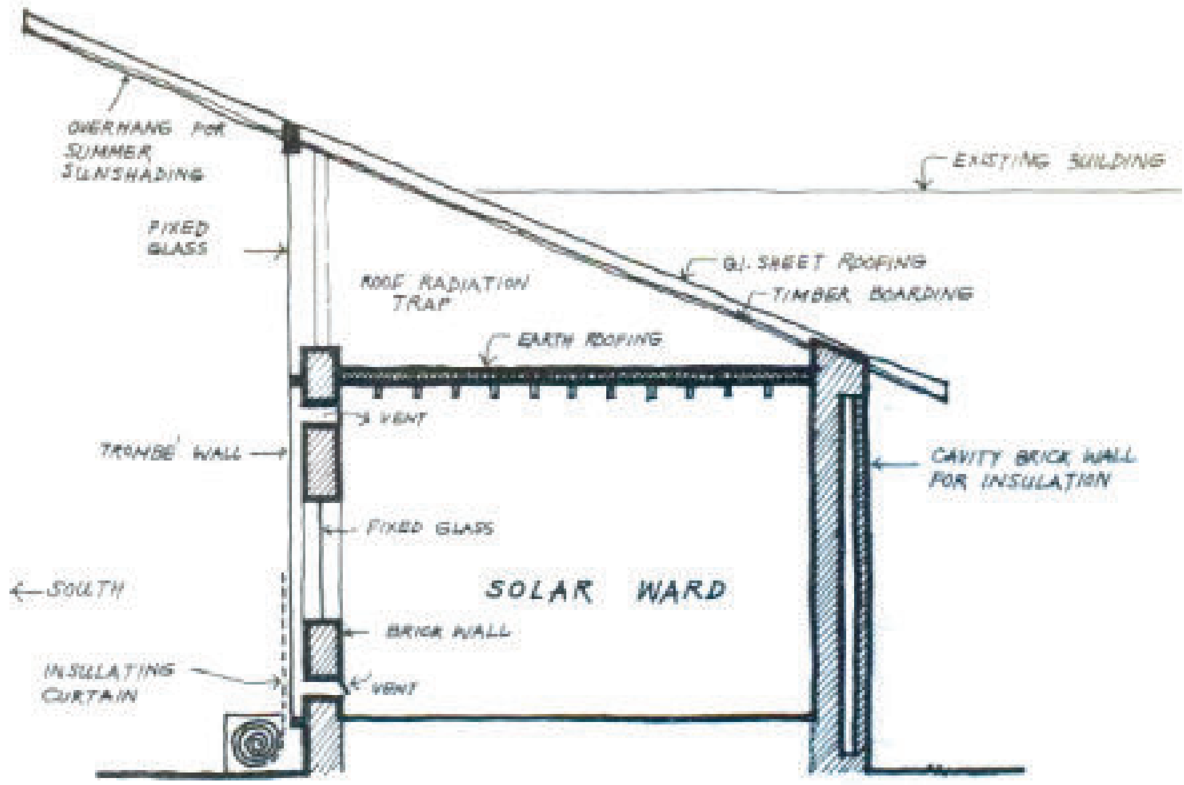
MODERN BUILDINGS

As mentioned earlier, glass is now available in the mountains along with several other new insulation materials. For the general population, however, these imported materials remain quite expensive and, with the exception of glass, their use has been limited to public buildings. It has been shown by experiments in Leh (Gupta 1981) that glass can be used effectively for solar passive heating of buildings, but more commonly it is seen that this new material is not used judiciously so the resulting buildings are thermally inferior to the unglazed ones, though they may be better lit.

While many traditional buildings are carefully designed with respect to solar orientation, buildings are usually constructed according to local custom based on religion. Thus, Muslim houses in the Kashmir Valley have openings toward the west (Mecca) even though they are not efficient thermally. These days, buildings are being constructed for educational facilities, hotels, factories, and other functions which did not exist earlier. These buildings are designed by architects and engineers who are rarely sensitive to and aware of the local practices. In any case, the rules for house planning cannot be applied to other types of buildings. Therefore, it is not uncommon to find buildings in the mountains that are similar to their counterparts in the plains and have almost nothing to do with an appropriate design for the mountains. Often technology and materials from the plains are used in the mountains, resulting in poorer buildings.

In the Kashmir Valley, the traditional roofing material was earth supported on timber beams, and usually a timber false ceiling was also provided in the house. Since galvanized iron sheets were introduced in Srinagar, earth roofs have been gradually replaced to the extent that they have all but disappeared. The galvanized iron sheeting did solve the problem of roof waterproofing. It also enabled sharper pitched roofs so that snow could slide off by itself, but this roofing material has little insulation value. Add to this indiscriminate use of glass in walls and we have a prescription for buildings that are hot in summer and cold in winter. Of course, galvanized iron roofs can be insulated with a variety of materials and the insulation value of glazed walls can be improved by use of double glazing, but these are rarely used in Kashmir. As a result, newer buildings require more heating than traditional buildings. Thus, one can say that people in urban areas are willing to sacrifice thermal comfort (and energy savings) for the sake of convenience. This is not necessarily so in the rural areas where life still moves at a slower pace and time is available for building maintenance.

From the point of view of development, it is necessary to find appropriate building methods that combine the benefits of old and new materials. In the case of roofing, for example, it is possible to use earth for its insulation value and galvanized iron sheets for



SOLAR HEATED ADDITION TO DISPENSARY AT SRINAGAR

Figure 8

waterproofing. Such a roof is being used for a solar-heated dispensary in Srinagar, where galvanized iron sheeting is the external sloping weatherproof covering and a flat earth roof is the insulating false ceiling (Figure 8). This is very similar to the roofing used in certain parts of Himachal Pradesh and not very different from the traditional roof of rural houses in Kashmir. Its performance can be further improved by placing insulation under the galvanized iron sheets and by glazing the south-facing attic wall to form a roof radiation trap (Givoni et al 1976).

Energy Conservation and Space Heating

Energy for heating of buildings can be conserved by;

- Retaining heat within the building
- Admitting building ambient heat into the building
- Using an efficient space-heating system

The first of these requires the building shell to be well insulated and all openings to be made airtight. The objective is to reduce conduction heat loss through the walls and the roof and to reduce infiltration heat loss which normally occurs through cracks around window and door shutters. Modern building materials like fiberglass or rockwool blankets, expanded polystyrene and polyurethane foam can be combined with any kind of wall or roof construction to improve the insulation value. These can be applied to existing buildings also. Reduction of infiltration heat loss is a little more difficult as it requires substantial improvement in the quality of construction of doors and windows. Inexpensive rubber gaskets can be used to ensure tighter seals but these arc not popular because they need to be replaced intermittently.

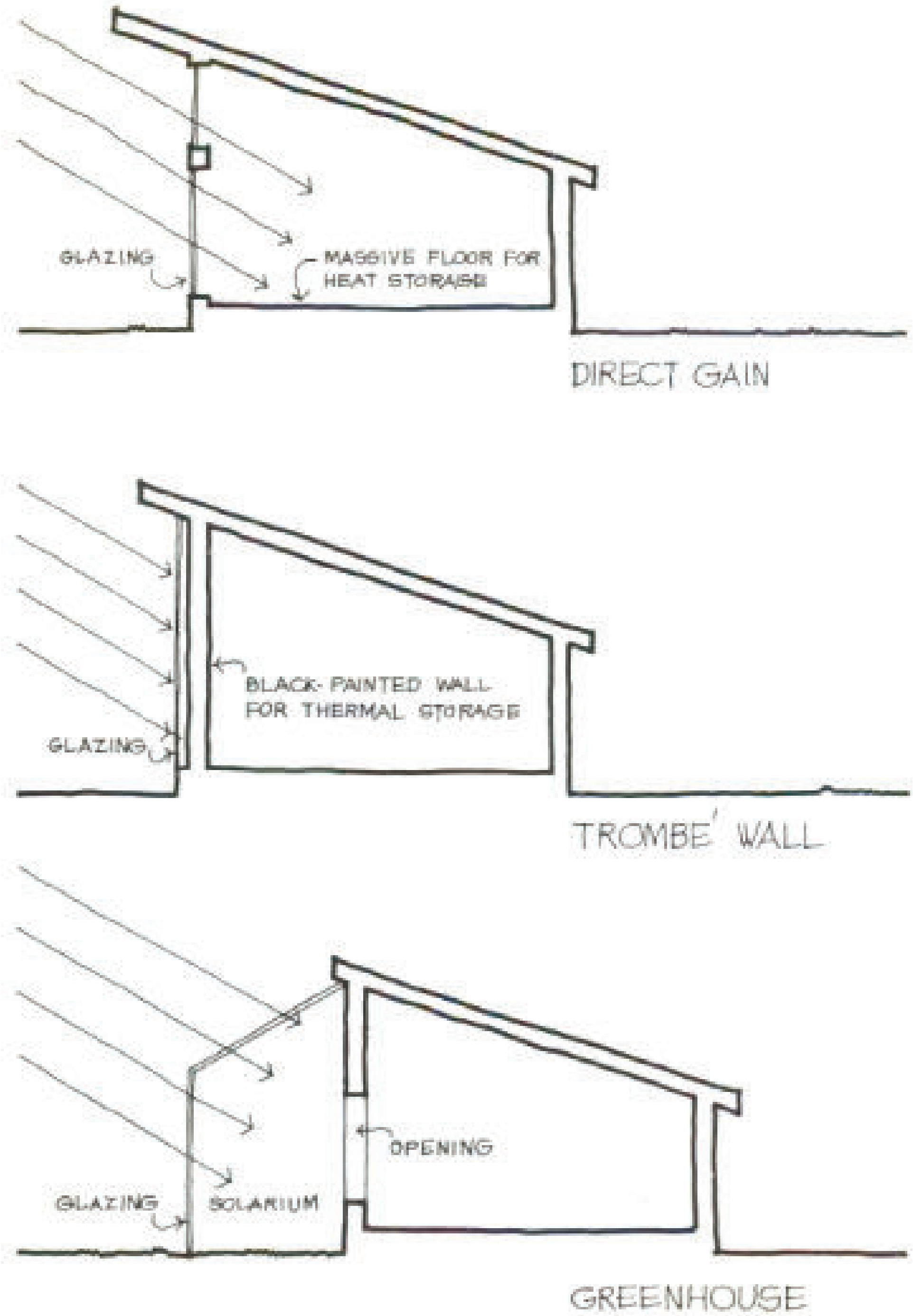
Building shape and orientation also determine heat lass. Compact buildings have less external surface area than extended building forms and since heat loss occurs only through external surfaces, the former lose less heat than the latter. Wind action results in increased heat loss through external surfaces and infiltration. The windier sides of the building should therefore be sheltered and without openings as far as possible. Earth embankments on the windier side can help streamline air-flow and thereby reduce heat loss through the walls. Not all parts of the building require equal heating. Bedrooms and Living areas have to be warmer than storerooms or passageways which can consequently be used as a buffer between the warm living areas and the cold outdoors.

In the cold climate of mountain areas, the only ambient source of heat is sunlight and the buildings must be built to admit as much sunlight as possible. Glazed openings allow sun to come into the building while keeping the warm air in. But ordinary single glass has poor insulation value so glazing has to be insulated with the help of curtains, blinds, or some other kind of shutters. The distance between buildings, the shape of buildings, and their orientation with respect to the sun has to be carefully regulated to ensure that one building does not shade the windows of another. The temperature can be controlled and maintained within the comfort limits by using one or more of the solar passive heating systems described below.

Despite good design, some heating is usually necessary. The ordinary fireplace is quite inefficient as a space heating device, as heat escapes through the chimney. Fully enclosed stoves with a considerable length of flue pipe within the heated space are more efficient and fuel conserving. Many new designs for such stoves are now available.

Solar Heating

Energy savings are possible by use of solar passive space heating. As distinct from active solar heating systems, passive systems use a minimum of mechanical equipment, with the building itself being designed



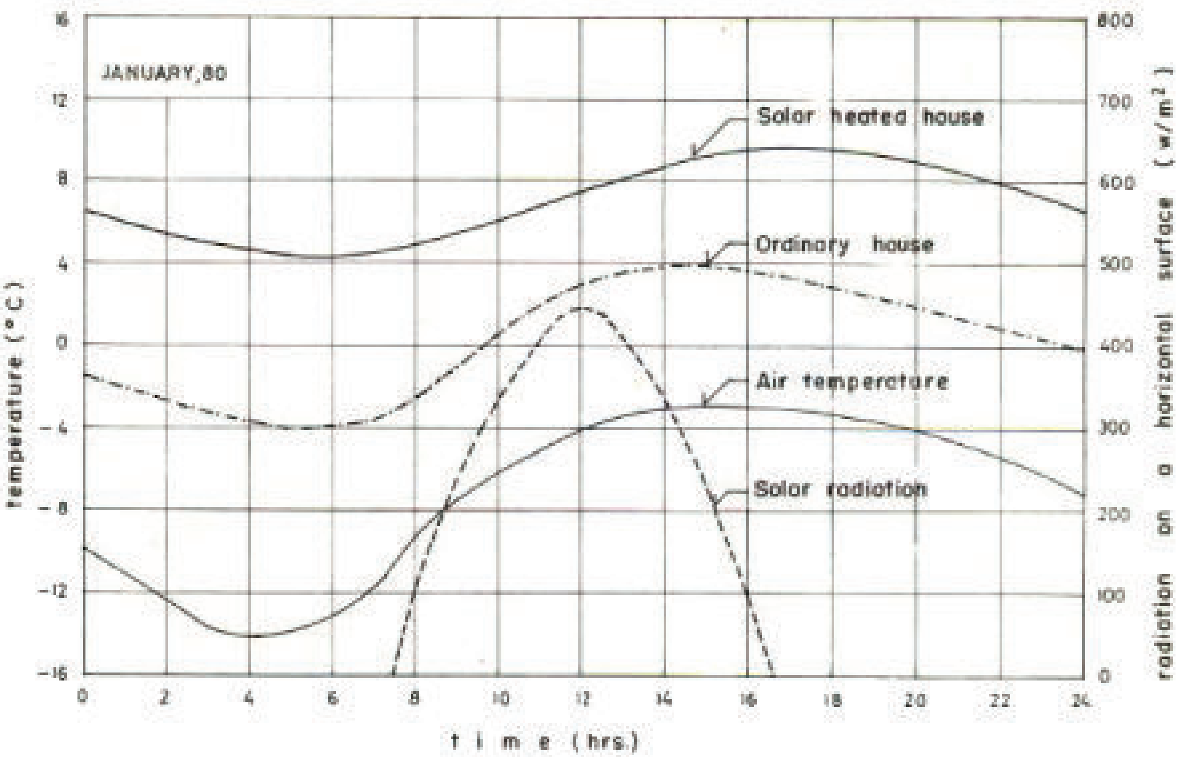
SOLAR PASSIVE HEATING SYSTEMS
Figure 9

and used as a large solar collector. Essentially, all solar heating systems require a south-facing surface that receives sun throughout the day, a way of trapping or collecting the solar energy, and a method of storing and distributing the heat.

The three potentially applicable systems are:
- Direct gain
- Greenhouse or solarium
- Trombe wall

The first is simply a large, south-facing window, possibly with an insulating shutter for use at night (Figure 9). This is the system most commonly used, but it usually results in temperatures too high during the daytime and too low at night. It is useful for buildings such as offices and factories that are used only during the day but of lesser use in houses. The greenhouse or solarium, as the name implies, is a glasshouse attached to the main building. While the sun shines, the greenhouse heats up and slowly warms the main building by convection. Once again, an insulating shutter over the glass is desirable for use at night. This system ensures somewhat better control of heating and less temperature fluctuation. Its major advantage is the addition of a pleasant and sometimes profitably useful space to the house.

The system that gives the best control over heating is the trombe wall. In its simplest form, this is a south-facing masonry wall painted black, to which a glass cover has been added. Solar heat is absorbed by the black surface and it gets into the building slowly through the masonry wall. In more complicated versions of this system, vents are placed in the masonry wall to allow circulation of air between the cavity and the room, thus bringing heat into the room early in the day. This system has been found useful in Ladakh, and since its introduction in 1979, many residents of Leh have added trombe walls to their houses. In the reported thermal performance study (Gupta 1981), two small single-storied buildings with trombe walls were compared to normal buildings and it was found that, during mid-winter, the temperature in the solar-heated buildings was higher by 8° to 12°C (Figure 10). This represents a great improvement in indoor environmental conditions in Ladakh. It was calculated that in case the buildings were to be heated to a constant temperature of 18°C, solar heating would provide one-third to three-fourths of the fuel needs. It was also calculated that for a 30 m2 house, 5.7 tons of fuelwood or 992 liters of kerosene would he saved every winter. Ladakhis usually heat their houses to less than 18°C and therefore the actual savings of fuel would be less, but then solar heating will provide for even more than two-thirds or the heating fuel,(Table 1)



COMPARISON OF DIURNAL TEMPERATURES IN SOLAR HEATED AND ORDINARY HOUSE IN LADAKH (AFTER GUPTA , 1981)

Figure 10

CONCLUSIONS

Much improvement is desirable in the planning, design, and construction of new buildings in the mountains in order to conserve fuel and to provide better thermal comfort. New materials, designs, and construction techniques can help in realizing this goal.

It is necessary to:
- Construct model buildings to demonstrate new techniques
- Undertake studies to evaluate the effectiveness of the new techniques
- Organize training programs for architects and engineers who build in the mountains to expose the architects to the useful aspects of traditional buildings, the use of new buildings materials, and the use of solar energy for heating

Even though traditional buildings are energy conserving, improvements are desirable in the indoor environment of these buildings. Specifically, the use of new material for insulation and glazing needs to be popularized, and fuel efficient stoves for cooking and space heating need to be made available to the people in the mountains.

Table 1: Estimated Solar Heat Effectiveness and Fuel Savings.

Month	Heating load MJ/Day Normal room	Heating load MJ/Day Solar room	Solar heating fraction	Fuel savings Wood kg/day	Fuel savings Kerosene liter/day
December	387	129	0.67	38.2	6.68
January	468	159	0.66	55.2	9.70
February	393	141	0.64	44.9	7.84
March	423	141	0.72	41.9	7.18
April	159	54	0.66	08.0	1.39

Area of House = 30 Sq. M.
Reference Temperature of Solar Heating Fraction = 18°C
Gross Heat Value of Fuelwood is 4710 kcal/kg and at 24% Efficiency
Gross Heat Value of Kerosene is 8964 kcal/liter and at 72% Efficiency

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