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GLOSSARY

Aftershocks

Violent main shocks of earthquakes are followed by shocks of decreasing intensity which occur at increasing intervals. These aftershocks may last for months and keep the threatened population in a state of anxiety which generally leads to evacuation.

Disaster management

The efficient use of resources to co-ordinate the processes of relief, recovery and reconstruction.

Earthquake: see Appendix A.

Epicentre

The point on the Earth's surface directly above the focus of an earthquake

Fault

A fracture or zone of fractures along which there has been displacement of the sides relative to one another, parallel to the fracture

Hazard mapping

The process of establishing geographically where certain phenomena are likely to pose a threat to human settlements

Intensity

A subjective measure of the force of an earthquake at a particular place as determined by its effects on persons, structures, and earth materials. Intensity is a measure of effect, in contrast with magnitude, which is a measure of energy.

Isoseismals

Map contours drawn to define limits of estimated intensity of shaking for a given earthquake

Landslide

Mass movement or sliding of hillsides caused by a variety of factors such as heavy rains, earthquake, ground shaking or geological forces. The term is also used to denote almost all varieties of slope movement, such as rock-falls, topples, slips or debris flow.

Liquefaction

The transformation of a granular soil to a liquefied state usually caused by strong earthquake shaking.

Magnitude

A measure of earthquake size that describes the amount of energy released.

Mercalli scale

A rating scale for classifying the degree of ground shaking at a specific location.

Natural hazard

The probability of occurrence, within a specific period of time in a given area, of a potentially damaging natural phenomenon.

Return period

The time period (in years) in which there is a good statistical probability that an earthquake of a certain magnitude will recur.

Richter magnitude scale

A measure of earthquake size that describes the amount of energy released. The measure is determined by taking the common logarithm (base 10) of the largest ground motion observed during the arrival of a P-wave or seismic surface wave and applying a standard correction for distance to the epicentre.

Risk

The expected number of lives lost, persons injured, property damaged and economic activity disrupted due to a particular natural phenomenon. Risk is therefore the product of specific risk and elements at risk.

Risk assessment

The quantification of risk by means of hazard mapping and vulnerability analysis. Risk assessment can be made on the basis of both empirical and theoretical data.

Risk mapping

The process of identifying high risk areas by correlating a hazard to the terrain and to the probability of occurrence. The results of these analyses are usually presented in the form of risk maps which show the type and degree of hazard represented by a natural phenomenon at a given geographic location.

Seismicity

The distribution of earthquakes in space and time. A general term for the number of earthquakes in a unit of time, or for relative earthquake activity.

Specific risk

The expected degree of loss due to a particular natural phenomenon as a function of both natural hazard and vulnerability.

Strain (elastic)

The geometrical deformation, or change in shape, of a body. The change in an angle, length, area, or volume divided by the original value.

Stress (elastic)

A measure of forces acting on a body in units of force per unit area.

Tectonics

The study of the Earth's broad structural features

Vulnerability

The degree of loss to a given element at risk, or a set of such elements, resulting from the occurrence of a natural phenomenon of a given magnitude and expressed on a scale from 0 (no damage) to 1 (total loss). It is the degree to which an individual, family, community or region is at risk from suffering a sudden and serious misfortune following an extreme natural event.

Vulnerability analysis

The process used to identify vulnerable conditions that will result in a disaster when they meet a natural phenomenon. The analysis must first study societies at risk by exploring such issues as social density, incomes, gender, home-ownership patterns and occupations. Secondly it must examine the physical factors of property at risk, buildings, crops, infrastructure, economic assets etc

Zoning

The division of land surface into areas and the ranking of these areas according to degree of actual or potential hazard

APPENDIX - A

WHAT IS AN EARTHQUAKE ?

An earthquake is a sudden motion or trembling of the ground produced by abrupt displacement of rock masses, usually within the upper 15 to 50 km of the Earth's crust. Most earthquakes result from the movement of one rock mass past another in response to tectonic forces.

Rock is elastic and can, up to a point, accumulate strain. When the stress exceeds the strength of the rock, the rock fails along a pre-existing or new fracture plane called a fault. This rupture extends outward along the fault plane from its point of origin, or focus. The epicentre of an earthquake is the point on the Earth's surface that is directly above the focus.

The rupture usually does not proceed uniformly its progress is typically irregular During the rupture, the sides of the fault rub against one another so that considerable energy is expended by frictional forces and in the crushing of rock.

Earthquake waves are generated at the same time by the rebounding of the adjacent sides of the fault at the rupture surfaces, as well as by rubbing and crushing. The seismic energy is emitted from the rupture as seismic waves.

The fastest are the primary (or P) waves, also called compressional waves, which are compression-dilation waves and travel in average crustal rocks at about 5 km per second. The secondary (or S) waves, which are slower, are shear waves with a speed in the crust of about 3 km per second. The slowest waves are surface waves, called Rayleigh and Love waves, which travel near the surface of the Earth with a speed of less than 3 km per second.

The body (P and S) and surface (Rayleigh and Love) seismic waves propagate outward in all directions from the focus when a fault rupture causes the ground to vibrate at frequencies ranging from about 0 1 to 30 Hertz (cycles per second)

As a generalization, the severity of ground shaking increases as magnitude increases and decreases as distance from the epicentre increases Buildings vibrate as a consequence of the ground shaking: damage takes place if the building cannot withstand these vibrations.

Compressional waves (P waves) and shear waves (S waves) mainly cause high-frequency vibrations (greater than 1 Hertz), cause low buildings to vibrate. The fast-moving P waves are the first waves to cause vibration of building S waves arrive next and cause a structure to vibrate from side to side They are the most damaging waves because buildings are more susceptible to horizontal motion than from vertical motion. Rayleigh and Love waves, which arrive last, mainly cause low-frequency vibrations, which are more likely to cause tall buildings to vibrate

Seismic shaking contributes to losses not only directly through vibratory damage to man-made structures but also indirectly through triggering of secondary effects such as landslides or other forms of ground failure. Thus, an important element in seismic zoning on a regional basis is the geographical assessment of potential ground shaking

EARTHQUAKE SCALES: MAGNITUDE AND INTENSITY

Earthquake are described in terms of their magnitude (M) and intensity (I). These are two distinct scales which should not be confused. Earthquake magnitude is a measure of strength of an earthquake, i.e. the strain energy released at its source. Earthquake intensity is a measure of the observed effects of the earthquake on man, buildings and the earth's surface at a particular place.

Magnitude

Earthquake magnitude is a measure of the strength of an earthquake, or the strain energy released by it, as calculated from the instrumental record made by the event on a calibrated seismograph. In 1935, seismologist Charles F. Richter first defined local magnitude or Richter magnitude, as the logarithm, to the base 10, of the amplitude in micrometers of the maximum amplitude of seismic waves that would be observed on a standard torsion seismograph at a distance of about 100 km from the epicentre. The seismic waves used for local magnitude have periods ranging approximately from 0.1 to 2 seconds, equivalent to a wavelength of 300 metres to 6 km.

Although the magnitude scale is logarithmic, the energy associated with an increase of one degree of magnitude is not ten-fold, but about thirty-fold. For example, approximately 900 times more energy is released in a magnitude 7 earthquake than in a magnitude 5 earthquake.

It must be understood that earthquake magnitude is not, strictly-speaking, an adequate planning or mitigation tool, unless a magnitude/intensity relationship can be established for a particular area or region. The intensity scale is the most commonly used for building and planning

Intensity

Earthquake intensity is a measure of the effects of an earthquake at a particular place. Intensity is determined from observations of an earthquake's effect on people, structures, and the Earth's surface. This first intensity scale to gain wide use was developed in Europe in 1883 by DeRossi and Forel. The Rossi-Forel scale grouped earthquake effects into 10 steps of intensity beginning with 1 for the least noticeable In 1902, Giuseppe Mercalli, introduced an improved scale which also had 10 grades of intensity (later increased to 12)

Two intensity scales are used today the Modified Mercalli scale (short version of 1931) symbolized as MM, and the Medvedev-Sponheuer-Karnikscale of 1964, known as the MSK scale. The MM scale is used in the USA and certain western countries of Europe. The MSK scale is used predominantly in Eastern Europe. The MSK scale is a much more elaborate and explicit scale than the MM scale, but both are useful The damage assessment in this report is based on the MSK scale, however historical records of the GSI in the Garhwal region report intensity on the MM scale

Source Adapted from UNDRO, Mitigating Natural Disasters, 1991, Geneva

APPENDIX - A

THE MEDVEDEV-SPONHEUER-KARNIK SCALE (MSK) OF 1964

CLASSIFICATION OF THE SCALE

1. Types of structures (buildings)

(a) Buildings in field-stone, rural structures, adobe houses.

(b) Ordinary brick buildings. buildings of the large block and prefabricated type. half timbered structures. buildings in natural hewn stone.

(c) Reinforced buildings, well-built wooden structures.

2. Definition of quantity

Single, few: about 5 per cent
Many. about 50 per cent
Most: about 75 per cent

3. Classification of damage to buildings

Grade 1:	Slight damage:	Fine cracks in plaster; falls of small pieces of plaster.
Grade 2:	Moderate damage:	Small cracks in walls: falls of fairly large pieces of plaster. pantiles slip off: cracks in chimneys: parts of chimneys fall down
Grade 3	Heavy damage:	Large cracks in walls, falls of chimneys.
Grade 4:	Destruction:	Gaps in walls. parts of buildings may collapse, separate parts of buildings lose their cohesion. inner walls collapse.
Grade 5.	Total damage:	Total collapse of buildings

4. Arrangement of the scale

(a) Persons and surroundings.
(b) Structures of all kinds.
(c) Nature.

THE MEDVEDEV-SPONHEUER-KARNIK SCALE (MSK) OF 1964

INTENSITY SCALES

Intensity

I Not noticeable.

The intensity of the vibrations is below the limit of sensibility; the tremor is detected and recorded by seismographs only.

II Scarcely noticeable (very slight).

Vibration is felt only by individual people at rest in houses, especially on upper floors of buildings.

III Weak, partially observed only.

The earthquake is felt indoors by a few people, outdoors only in favorable circumstances. The vibration is like that due to the passing of a light truck. Attentive observers notice a slight swinging of hanging objects.

IV Largely observed

The earthquake is felt indoors by a few people, outdoors by few. Here and there people awake but no one is frightened. The vibration is like that due to the passing of a heavily loaded truck. Windows, doors, and dishes rattle. Floors and walls creak. Furniture begins to shake. Hanging objects swing slightly. Liquids in open vessels are slightly disturbed. In standing motor cars the shock is noticeable.

V Awakening.

a. The earthquake is felt indoors by all, outdoors by many. Many sleeping people awake. A few run outdoors. Animals become uneasy. Buildings tremble throughout. Hanging objects swing. Pictures knock against walls or swing out of place. Occasionally pendulum clocks stop. Unstable objects may be overturned or shifted. Doors and windows are thrust open and slam back again. Liquids spill in small amounts from well-filled open containers. The sensation of vibration is like that due to a heavy object falling inside the building.

b. Slight waves on standing water; sometimes change in flow of springs.

VI Frightening.

a. Felt by most indoors and outdoors. Many people in buildings are frightened and run outdoors. A few persons lose their balance. Domestic animals run out of their stalls. In many instances dishes and glassware may break, books fall down, pictures move, and unstable objects overturn. Heavy furniture may possibly move and small steeple bells may ring.

b. Damage of grade 1 is sustained in single buildings of type B and in many of type A. Damage in some buildings of type A is of grade 2.

c. Cracks of widths up to 1 cm possible in wet ground; in mountains occasional landslips; change in flow of springs and in level of well-water.

THE MEDVEDEV-SPONHEUER-KARNIK SCALE (MSK) OF 1964

Intensity

VII **Damage to buildings.**

a. Most people are frightened and run outdoors. Many find it difficult to stand. The vibration is noticed by persons driving motor cars. Large bells ring.

b. In many buildings of type C, damage of grade 1 is caused; in buildings of type B, damage is of grade 2. Most buildings of type A suffer damage of grade 3, some of grade 4. In single instances landslips of roadway on steep slopes; cracks in roads; seams of pipelines damaged, cracks in stone walls.

c. Waves are formed on water, and water is made turbid by mud stirred up. Water levels in wells change, and the flow of springs changes. Sometimes dry springs have their flow restored and existing springs stop flowing. In isolated instances parts of sandy or gravelly bank slip off

VIII Destruction of buildings.

a. Fright and panic; also persons driving motor cars are disturbed Here and there branches of trees break off Even heavy furniture moves and partly overturns Hangingh lamps are in part damaged.

b. Most buildings of type C suffer damage of grade 2. Most buildings of type B suffer damage of grade 3, and most buildings of type A suffer damage of grade 4. Many buildings of type A suffer damage of grade 4, here and there of grade 5 Occasional breakage of pipe seams. Memorials and monuments move and twist Tombstones overturn Stone walls collapse

c Small landslips in hollows and on banked roads on steep slopes, cracks in ground up to widths of several centimetres. Water in lakes becomes turbid. New reservoirs come into existence Dry wells refill and existing wells become dry In many cases change in flow and level of water.

IX General damage to buildings

a. General panic; considerable damage to furniture. Animals run to and fro in confusion.

b. Many buildings of type C suffer damage of grade 3, some of grade 4. Many buildings of type B show damage of grade 4, a few of grade 5. Monuments and columns fall. Considerable damage to reservoirs; underground pipes partly broken. In individual cases railway lines are bent and roadways damaged.

c. On flat land overflow of water, sand, and mud in often observed. Ground cracks to widths of up to 10 cm, on slopes and river banks more than 10 cm, falls of rock, many landslides and earth flows, large waves on water. Dry wells renew their flow and existing wells dry up.

X General destruction of buildings

a Many buildings of type C suffer damage of grade 4, some of grade 5. Many buildings of type B show damage of grade 5; most of type A have destruction category 5; critical damage to dams and dikes and severe damage to bridges. Railway lines are bent slightly. Underground pipes are broken or bent. Road paving and asphalt show waves.

XI Destruction.

a. Severe damage even to well-built buildings, bridges, water dams, and railway lines; highways become useless; underground pipes destroyed.

APPENDIX -B

EARTHQUAKE HAZARD ASSESSMENT AND MAPPING

Hazard micro-zoning consists of recording in detail all seismological, geological and hydrogeological parameters that may be needed in planning and implementing a given project area at an appropriate scale for physical planners, engineers and architects, or any other qualified user.

Seismic micro-zoning consists in mapping in detail all possible earthquake and earthquake-induced hazards. These maps should contain information that is limited to the user's requirements, and presented in a form comprehensible to them. Invariably, the users' maps will be different to those prepared by or for the specialists. The main aim of seismic micro-zoning is the definition of seismic hazards which may affect the areas in question and to present data in summary form so that it may be useful to governmental agencies, urban planners and householders.

The result will be used to facilitate either the planning or the repair and strengthening of buildings destroyed or damaged by previous earthquakes. This in turn will limit the potentially destructive effects of future earthquakes.

The framework for a micro-zoning study must include the following tasks.

A geological survey of the sites concerned in order to identify those which are potentially dangerous, such as those which follow active faults or which are susceptible to landslides, and to delimit spatially different surface deposits.

A compilation and analysis of existing geotechnical data and tests to characterize the geotechnical properties of the lithological units identified on photogeological maps.

Determination of maximum ground acceleration for return periods of 50, 200 and 500 years and the development of typical response spectra for the bedrock and for the different general categories of subsurface conditions which take into account the sites under study.

An evaluation of flood potential due to landslips caused by an earthquake which could block river flow.

The preparation of summary maps of seismic hazards. These maps should contain potential seismic hazards and divide each district into zones of comparable risk due to the combined effects of these hazards.

Source: Adapted from UNDRO, Mitigating Natural Disasters, 1991, Geneva

APPENDIX-C

WHAT IS A LANDSLIDE ?

The general term landslides covers a wide variety of land forms and processes involving the downslope transport of soil and rock under the influence of gravity. Different types of landslides move down-slope at a wide range of speeds. The more rapidly moving landslides may pose a greater hazard to life because they can destroy dwellings or damage roads quickly and with little warning. Slower moving landslides will gradually cause increasing amounts of damage, but the expected movements can be anticipated.

Much of the damage (and often the loss of life) during earthquake is due to landslides For example, in the May 1970 earthquake in Peru, which took about 70,000 lives, about 20,000 people perished in the avalanche of debris from the north peak of Nevado Huascaran.

Types of landslides

Landslides can be classified according to two criteria: types of movement and types of material. Thus classifications are important to planners in the hazard reduction process

Falls are masses of rock and/or other material that move down slope primarily by falling or bouncing through the air They are most common along steep roads, along steep scarps formed either by landsliding or stream erosion. Large individual boulders or blocks of rock can cause considerable damage to houses or roads located at the base of the slope.

Slides result from shear failure along one or several surfaces The slide materials can be broken up and deformed or remain fairly cohesive and intact. A cohesive landslide is called a slump. Movement in both slides and slumps is controlled primarily by pre-existing structural features such as faults, joints and bedding.

Lateral spread (earth spread) is a lateral movement of a fractured mass Horizontal movement are commonly as much as 10 to 15 feet. but, when slopes have the adequate angle, lateral movement may be as much as 100 to 150 feet.

The movement of flows resembles that of a viscous fluid, and slip surfaces are almost non-existent Flow can take place as one or more lobes that move at different rates depending upon the viscosity of the material and the local slope angle. Water is not necessary for flows to take place, but most flows occur during or after periods of heavy rainfall, when the cohesiveness of soil and the bonding of soil by clay minerals breaks down, permitting downslope flow even on fairly gentle slopes These landslides can move very rapidly and cover distances of several miles along available drainage paths

Causes of landslides

The elements that affect slope stability are numerous and varied, and they interact in complex ways.

All slides involve the failure of earth materials under shear stress. The initiation, or "triggering", of the process can, therefore, be thought of in terms of the factors which contribute to increased shear stress. The basic conditions that affect stability are: geomorphology, hydrology and climatology, and vegetation.

An important geomorphological characteristic to be considered is the presence or absence of former landslides, for such evidence of past instability is frequently the best guide of the future behaviour in the locality. Steepness of slope in relation to the strength of slope-forming materials is very important.

APPENDIX-D

LANDSLIDE HAZARD ASSESSMENT AND MAPPING

Although the distribution of places susceptible to slope failure may not be delineated with the same precision as areas subject to high water, they can be located more exactly than those subject to other hazards. The causes inherent in the terrain are relatively well understood. Hence it is feasible to base area zoning on the lithological qualities of the terrain with reasonable certainty that hazard spots can be identified.

Landslide hazard zoning has been pursued actively for only about 20 years and is still in an experimental stage

The simplest type of map consists of a general purpose geological map, showing conventional geological formations, with remarks in the map explanation or accompanying tabular text about the relative stability of the geological units.

In general, a geomorphological map, based on historical events can be used together with overlays with information on lithology, hydrology and vegetation This set of maps may serve as a basis for hazard mitigation programmes.

It may be helpful to devise and apply a numerical rating system for certain contributing factors. For example: clay factor, water factor, slope angle, slope complexity and land use.

The total score for each site could give an indication of the relative landslide hazard

Source: Adapted from UNDRO, Mitigating Natural Disasters, 1991, Geneva

APPENDIX-E : NUMERICAL EXAMPLE OF INTERNAL TEMPERATURE IN EMERGENCY SHELTER

The following sections considers the translation of thermal principles into numerical terms by studying the effects of varying various parameters on a 3.5 m x 3.5 m module, 2.2 m high with only two faces exposed.

Conductivity of materials (W/m.°C)

Mud	0.50
Dry timber	0.14
Wet timber	0.20
Quilt	0.10 (conservative , could be lower)
Thin films infinite	(ignored in calculation)

Surface resistances (m^2.°C/W)

(Taken for normal exposure: wind speeds 2 - 3 m/s)

External roof	0.044
Ceiling	0.105
External wall	0.053
Internal wall	0.123
Floor	0.149
Tight cavity	0.180
Large unsealed air gap	0.110

Heat generated by various elements (W)

People sleeping	72
Undernourished people sleeping	60
Cattle	1000
Typical kitchen fire	500

U-values of elements (W/m^2.°C)

(Taken for normal exposure: wind speeds 2 - 3 m/s)

Ground floors:

Suspended timber	1.0
Solid	0.9
Insulated	0.7

Water is a main factor in slope instability. Identification of the source, movement, amount of water, and water pressure is as important as the identification of the different soil and rock layers.

The effect of vegetation of slope stability appears to be complex in that a vegetative cover in some ways definitely promotes stability and in other ways it may not. This depends on local conditions of soil depth, slope, and type of vegetation. A forest protects the surface from weathering actions of sunshine, rain and winds and retains considerable amounts of water by wetting the large vegetative surface. Vegetation cuts down on water runoff and erosion while the root system may increase the shear resistance of the mass and may increase soil cohesion by the creation of negative pore pressure. On the other hand, trees may exert deleterious effects by their load and the load of retained water on soils of steep slopes, by the mechanical action of wind forces transmitted to the soil by trees, felling of trees and propagation of failures under strong seismic motion, and the wedging action of tree roots which widens fractures and promotes infiltration.

Triggering factors

Landslides will occur after sudden or gradual changes in the shear stress and strength condition. The most important factors are the water content of the geologic mass and vibrations by earthquakes.

Factors that alter shear stress and thereby trigger landslides are,

Vibrations from earthquakes, blasting machinery, traffic and even thunder In seismically active parts of the world, some of the most disastrous of all historic landslides have been triggered by seismic shock.

Removal of lateral support by such means as erosion by streams and rivers ; previous slope failure and results from construction, especially where cuts, quarries, pits, are established or lakes and reservoirs are created and their levels altered.

Loading by such natural or human means as weight of rain hail snow; accumulation of loose rock fragments . stockpiles of ore of rock; waste piles: and weight of buildings and other structures.

Changes in direct water content and pore pressure and in structure Thus relative stability of a slope in either soil or rock may change radically with changes in *ground water level*. If the soil or rock contains narrow but open fractures minor increase in total water content through precipitation may produce a large rise of the water level in the fractures and markedly decrease the internal stress and shearing resistance. Thus, heavy rainfall often has a triggering effect on landslides.

Source: Adapted from UNDRO, Mitigating Natural Disasters, 1991. Geneva

U-VALUES OF VARIOUS BUILDING ELEMENTS	
ROOFS	W/m² °C
RCC roof 15 cm thick with 15 cm thick mud, bhusa and 5 cm thick brick tile work	1.62
Corrugated steel sheets, single or multiple in contact, with no air gaps, or fabrics, all termed "thin films" over any light-weight framework which could be ignored for thermal resistance	6 71
Thin film and frame with sealed 10 cm thick quilt of pine/straw/hay in contact on top	0.97
Two thin films and frames with well sealed air gap of 25 to 50 mm	3.04
Thin film and frame with 10 cm thick quilt in contact below	0.87
Thin film and frame with a not well sealed air gap below with 10 cm thick quilt at bottom	0.79
Thin film and frame with 10 cm thick mud stacked above	2 87
Thin film and frame with 10 cm thick mud stacked above and 10 cm quilt in contact below	0.74
Thin film and frame with 2 cm thick wet timber slats below	4.02
Thin film and frame with 2 cm thick dry timber slats below	3.40
Thin film and frame with 2 cm thick wet timber slats below but 50% gaps between slats	5 36
Thin film and frame with 10 cm thick mud below stacked on 2 cm thick wet timber slats	2 23
WALLS	
45 cm thick random rubble wall	2.00
Thin film and frame	5.68
Thin film and frame with 10 cm thick quilt outside	0.85
Two thin film and frames with well sealed air gap of 25 to 50 mm	2.81
Thin film and frame with 10 cm thick quilt in contact inside	0 85
Thin film and frame with a not well sealed air gap inside with 10 cm thick quite innermost	0.78
Thin film and frame with 2 cm thick dry timber slats inside	3.12
Thin film and frame with 2 cm thick wet timber slats inside but 50% gaps between the slats	4.65

COMPUTATION

Steady state calculations are made for the following conditions :

Outside temperature = - 5°C
Inside temperature = t

U-value of wall	=	Uw
U-value of roof	=	Ur
U-value of flood	=	Us
Area of walls	=	Aw
Area of roof	=	Ar As
Area of floor	=	V
Volume of room	=	
No. of air changes per house	=	n

Net heat loss (w) or inner generated heat for steady state = H

$$= Uw\ Aw\ (t - [-5]) + Ur\ Ar\ (t - [-5]) + \frac{Uf\ Af\ (t - [-5])}{3}$$

$$= (Uw\ Aw + Ur\ Ar + Uf\ Af + Vn/3)(t + 5)$$

Inside temperature, t

$$= \frac{H}{(Uw\ Aw + Ur\ Ar + \frac{Vn}{3} + Uf\ Af} - 5$$

WORKED EXAMPLE

50% slatted wet timber for walls and roof, with solid floor, 6 people + fire, Ventilation = 1 air charge per hour, normal exposure

$$= \frac{H}{Uw\,Aw + Ur\,Ar + Uf\,Af + \frac{Vn}{3}} - 5$$

$$= \frac{(6 \times 60 + 500)}{(4.65 \times 15.4 + 5\ 36 \times 12.25 + 0\ 9 \times 12.25 + 26\ 95 \times 1/3}$$

= 0 5°C

If it sheltered from the wind and floor also insulated then temperature inside can rise to 1 2°C. Both cases show poor thermal performance

WORKED EXAMPLE 2

QuiLt inside, GI/alkathene all over, insulated floor, 6 people, no fire, no buffalo, vent = 1 air change per hour, normal

$$= \frac{(6 \times 60)}{(0.85 \times 15\ 4 + 0.87 \times 12.25 + 0.7 \times 12.25 + 26\ 95 \times 1/3)}$$

= 3.7°C

If ventilation is reduced to 0.5, air changes per hour, t = 4.8°C. If fire is also lit, the temperature will reach 18.4°C. In such cases, air changes would be allowed to be more again and floor need not be insulated.

Since it is not possible to ensure that the fire will remain lit at 4:30 am, a buffalo might be thermally subject to distribution of heat. The insulated cabin is sensitive to internal heat. It is about four times more effective than the first case.

CONDENSATION

A vapour barrier is desirable on the inside face to prevent condensation. Putting quilt only on the outside will create condensation on the metal walls inside.

Indirect gain

Glazed walls
Trombe walls
Making thermal mass appropriately located/sized

Isolated gain

Greenhouse
Sunspaces and solaria

Ground coupling

Earth berms
Surface treatment

Retaining the heat
Insulation: capacitance
Insulation and cavities: resistance

PASSIVE SOLAR HEATING

In comparison with the hot regions, it is easier to create comfort conditions in colder climates as long as there is some sunshine. The main source utilised for this is radiant solar heat.

Even in low temperatures, the radiation of the sun or warm walls is particularly warming on the human skin. It is a property of our skin that it is more responsive to radiant warmth than to convection currents on the skin. So we feel comfortable in the bright sun even in sub-zero temperatures. It is best to try to get the sun to directly shine on the people, at least in day-use rooms. For the night, it is best to have a radiant source (hot wall, fire, radiator) rather than try to heat the air of the room and circulate it which would be very wasteful of energy.

Even in open areas outside the building, streets, meeting places, terraces, care should be taken to try and shield from the breeze while allowing the sun to directly fall on people.

Some general physical processes must be understood before getting into the details.

The Greenhouse Effect

Solar radiation passes through glass into a space where it is absorbed by the objects in the space. As the space heats up, it re-radiates the energy to the outside again. But the wavelength of the re-radiated heat is longer than the solar radiation. Glass has the property that it is 'more transparent' to solar radiation and comparatively opaque to radiant heat. Thus the space is heated up, with glass acting as a non return valve for energy coming in. This process is called the greenhouse effect.

The effect is reduced with most plastics, but even then can be made use of at least for animal and plant (non-human) buildings.

Orientation

Of course, the solar radiation must fall on the glass in the first place. For this it will not do to have a window on the north faces in our Himalayan Latitudes. Orientation of the building at the design stage is very important. If the building is already built, the remodelling will have to be done keeping orientation in mind to whatever extent possible. Normally, if there are no obstructions, the best face above 25°. N latitude is the south face. The sun is low in the sky in the winter and shines all day on this face. For areas where overheating during summer is a problem, a small chujja (horizontal overhang) can be provided to shield the higher summer sun without loss in the winter radiation quantities.

Orientation of $\pm$20 deg of due south is acceptable as the best face of a building, especially if the face is to be provided with large windows. The next set of faces where some windows may be provided if necessary are the west and the east, though, in extremely cold areas even windows on these faces are net loser of therefore there windows heat over the day and should be given for lighting or essential ventilation only. The worst vertical face of the building for providing windows is the north.

The horizontal roof surface is as good as the south for provision of glass. However, providing horizontal roof openings creates other practical problems of hail and snow, and roof openings lose more heat in the night and so must be provided with some form of cover or at least an internal closing arrangement.

The best surface for heat collection is actually an inclined surface facing south and inclined about 25° to 65° depending upon latitude and time of year for which best performance is required. But like the roof, they are difficult to provide for other considerations.

In any case horizontal or inclined surfaces are not such a great advantage so as to necessarily be required. Vertical south glazing in a liberal quantity would be quite suitable for almost all cold areas in our country.

Opaque walls

For opaque walls also, the comments on the window orientations are applicable. However, the effect of opaque walls in heating the rooms is less than glass and is slower to carry through. But the implication is that barring south walls, all other wall surfaces should be as well insulated as affordable.

Systems of Heat Gain

For indoor spaces, there are three basic interconnected components of any heating system: the source of heat, the space itself, and the thermal storage. In a bukhari, the source (bukhari, coal/wood/ kerosene) is inside the space, and thermal storage is automatically provided by the objects of the room and the enclosing walls. In formal terms, there are three types of passive heating systems:

Direct Gain Systems: When the source (sun) directly enters the space (room) and the storage is minimal or incidental (objects and walls).

Indirect Gain Systems: Where the source (sun) heats the storage (typically an external wall, a roof), which over a longer period of time heats the space.

Isolated Gain Systems: Where the source (sun) heats a space with storage (typically an attached sun room), and the heated space in turn heats the main space over a much longer period of time.

Prevention of infiltration involves:

weather-stripping window joints (with hay, cowdung, rubber, thick cloth, newspaper, softwood, cork), providing air locks at entrances to buildings (the air locks need not be very heavy or expensive structures: an added-on shed is quite effective for controlling cold draught),

A thumb rule for testing the weather tightness of a building is that no part should make any rattling, creaking or whistling sounds in a storm or strong wind. But take care that some minimum ventilation is desirable for basic human health and survival, and also that rooms with fireplaces cannot be too well sealed to prevent carbon monoxide build up. The quantities of ventilation required to meet these criteria, however, are small.

Paradoxically, the behaviour of heat, and its property of flowing from a hotter to a colder body, implies that the better heated a building becomes, the more heat it loses. Therefore the meticulous provision of insulation and weather-stripping does not matter in designs which have few passive features. But the better the design of the heat gain systems of a passive house, the better must be the quality and quantity of insulation and weather-stripping.

It is interesting to note that Sweden, despite its extreme cold conditions, has achieved one of the lowest fuel consumption rates for domestic heating in Europe and the U.S.A. Their major thrust has not been so much on the trapping of solar heat but on insulating and weather-stripping their buildings.

It is unfortunate that richer families in cold climates, especially, in India, spend more money by (wastefully) burning more fuel for longer periods in more rooms. If they would only invest in correct glazing, insulation, and weather-stripping their houses, the wealth would be wisely used, both from a personal and a national viewpoint.

PRACTICAL OPTIONS

1. Weather-stripping

The most important component of a house in a cold climate. These should be placed within window beading, rebates, and other joints. Rubber or PVC are good, but for very cold climates, where they may crack, cork can be tried out. Though the quantity required for a house is small and therefore weatherstripping is inexpensive, if even greater cost savings were desired then paper and cloth can be nailed on rebates. All timber work in doors and windows should have rebated joints which do not allow a straight passage of a gust of wind.

2. Trombe walls

Primary type of Indirect Gain System. Consists of outer layers of glass (1 or 2 layers) gap (not more than 15 cm) darkened mass wall (33 cm stone, etc.), and optional vents at the top and bottom. The wall receives and stores daytime heat. By opening the vents in the day, this heat is used in the room. However, the wall still retains enough heat and by the night-time, starts radiating this heat to the room from its inner face. At this time the vents could be closed. It is possible and simpler to modify the above described classical pattern of design of a Trombe wall by not having the vents, therefore using the heat only in the night. For daytime heat, additional windows for direct gain may be provided.

3. Overheating & Smoking

Do not make all glazing of any room completely fixed. In passive houses, overheating or choking/stagnation may occur occasionally. It is obviously extremely wasteful to invest in and run fans in most cold regions. It is also dangerous to not provide any ventilation or openable glazing in a room.

4. Compact overall shape

Buildings should have smallest exposed surfaces generally for all faces except the south. This means that rectangular buildings with no unnecessary niches are better than buildings with large numbers of staggers or niches. Lack of niches and staggers in the south walls are also recommended since staggers and niches cause mutual shading of south glazed areas and walls, reducing the effective gain. But in itself, the area of the south face should be made as large as possible.

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TARU is a group of professionals and development workers with experience in public, non-governmental, co-operative and corporate institutions. We address issues of local concern that demand expedient action and areas which require long-term transformation. We design and implement programmes that enable economic, social and gender equity and conservation of natural and human resources. The group provides services in the following areas:

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Information Systems & Communication

Database development and information dissemination; geographic information systems and resource mapping, ecological and economic systems modelling and software development; financial planning and management services for development agencies; multi-media communication: film, video, still, audio-visual database and syndicated services

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