ABE 414 FARM STRUCTURES AND ENVIRONMENTAL CONTROL

TOPICS

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TEXTBOOKS

1. **Farm Structures by Yahaya Mijinyawa, Ibadan University Press, Second Edition.**
2. **The Design of Farm Structures by Yahaya Mijinyawa, Ibadan University Press, First Edition**
3. **Structures and Environment Handbook, Midwest Plan Service, Eleventh Edition**
4. **Farm Structures in Tropical Climates by Lennart P. and Bengtsson James H. Whitaker**
5. **Rural Structures in The Tropics : Design and Development. FAO Publication**

INTRODUCTION TO FARM STRUCTURES

A farm can be defined as a parcel of land which is developed by way of vegetation removal and land preparation for the purpose of producing crops and livestock. The production of such items may be either for family consumption, for sale to generate income or both. The buildings and adjacent grounds of such a farm are referred to as farm structures. The term ‘farm structures’ has a dual meaning either as a discipline or a facility.

As a facility, a farm structure refers to an item or building which is either originally designed or fabricated, previously existing for other uses or considered of no use, but which has been converted for use within and occasionally outside a farm. Although, structures and buildings are used interchangeably, they are not exactly the same. Buildings refers to shelters, which provide accommodation for human beings, livestock, farm produce and farm machinery whie structures include both buildings and non sheltered structures such as roads, bridges, fences, towers and agricultural dams which either allow access to the farm, provide security or are for multipurpose uses. The distinction between a structure and a building is therefore the presence or absence of a wall and roof which provides a shelter.

As a discipline, farm structures which can also be referred to as farm structures and environment or farm structures and conveniences, is the branch of agricultural engineering that deals with the provision and maintenance of built-up facilities within and occasionally outside the farm environment. A farm structures engineer is a specialist in the fields of agricultural and civil engineering whose interests, education, training and experience have developed the knowledge of scientific principles, construction materials, construction procedures and economics necessary to direct the design, construction, utilization and maintenance of farm houses, barns, sheds, silos and related structures. Farm structures are shelters for farm animals or crops. It could also be a shelter for processing or storing products of farm animals or crops, or for storing or repairing farm implements**.** A structure can be defined as an object whose purpose is to carry a set of loads or forces, from one place to another (Mijinyawa, 2009). The aim is usually to transmit the applied loading from somewhere in space to the ground without collapsing and without deforming excessively. By this broad definition, the list of structures would be inexhaustible ranging from a small kitchen stool to a ship on the high sea or aircraft in space. William and Todd (2000) outlined some common characteristics of structures as follows:

a) They are designed to carry load in space.

b) They are usually supported either on the ground or on another structure (though exceptions such as the aeroplanes are possible) with reaction forces generated at the support points.

c) The applied loads and reactions cause forces to be generated within the members of the structure.

d) The structural members must not collapse or (in most cases) deform excessively under these forces.

The two primary functions of farm structures are to provide a conducive environment for the humans, livestock and produce that may occupy such a structure and to support the loads due to such occupants. The objective of structural analysis is therefore to determine appropriate building components and sizes that will be adequate to withstand the expected loads.

Functions of Farm Structures

a)Regulation of Environmental Factors

Some important environmental factors are the temperature and relative humidity. The interaction between those factors gives rise to a number of other factors that affect the performance and comfort of human beings, livestock and the quality of crops especially while in storage. The ability to regulate these factors to such a level that is required for optimum human and livestock comfort, and the quality of crops especially while in storage. The ability to regulate these factors to such a level that is required for optimum human and livestock comfort and the quality of stored produce is a basic requirement of some farm structures. Examples are vapour barriers and insulation materials to regulate the temperature and relative humidity in an enclosure occupied by either human beings or livestock, or where harvested produce are stored.

b)Protection

Farm structures offer protection to human beings, livestock, cultivated crops and harvested produce, and machinery in a number of ways. They offer shelter against rain, sun and wind – the combined effect of which can greatly reduce the farmer's efficiency, productivity of livestock, quality of crops and cause wear and tear or rusting of machinery components. In some cases, farm buildings are needed to offer protection against the attack of enemies. Some farm structures provide security against pilferage especially of poultry products and stored produce. Vandalization and pilfering of machine parts are checked through keeping them in fenced yards with lockable gates.

c) Acccessibility

Farm structures such as roads, bridges and culverts provide access from farms to urban areas and vice versa. This is important for effective communication, conveyance of farm inputs which include labour, machinery, seeds/seedlings, agro-chemicals and fertilizers to the farms and the evacuation of harvested farm produce from farms to the urban areas..

CLASSIFICATION OF FARM STRUCTURES

There are two major ways of classifying it: these are the material of construction and the utilization of the structures.

Based on the material of construction, farm structures may be grouped into earth, wooden, concrete, plastic and steel structures. Under this classification, a structure is placed in a goup depending on the material which is predominantly used In its construction.

The utilization criterion groups farm structures into farm houses, building for crop production, buildings for processing agricultural produce, crop storage structures, bhildings for livestock and miscellaneous structures. Under this criterion, a structure is placed in a group based on its utilization.

Classification	Functions	Specific Examples
1.Farm houses	They are for human habitation providing accommodation for all persons that have to be accommodated on the farm. They provide facilities and conveniences suitable for a comfortable living such as sleeping, laundry, cooking and relaxation. They protect accommodated persons against inclement weather conditions such as rain, sunshine and cold, security especially at night against wild animals.	This include dwellings built to standard to accommodate employees, their nucleus and extended family members and visitors. Remodelled or improvised buildings can serve as well.
2. Buildings for Crop Production	They are used in situations where the ambient conditions require some modifications for crop production. They are now being used on farms for commercial purposes.	Greenhouses, screen houses, glasshouses and growth chambers.
3.Buildingsfor processing agricultural produce	This provide convenient environment in terms of space and health wise for processing activities to be carried out. They provide conducive environment for those who may be involved in the processing activities.	Oil palm processing centre, cassava processing centre, abattoir, fish smoking kilns and timber yards.
4. Crop Storage Structures	Provide conducive environment for the long term storage of agric. Produce. They are equally of adequate capacity to meet the required volume of storage and strong enough to resist the imposed loads.	Cribs, silos, warehouses, platforms, barns, cold rooms, underground pits, evaporative coolers.
5.Livestock Structures	Regulation of environmental conditions such as temp. and humidity to ensure increased yield and production of milk, meat and good quality eggs. It also reduces drudgery of animal husbandry in terms of ease of getting feed and water to them quickly.	Barns, sheds, pens, yards for goats, sheep, pigs and cattle. Battery cages, deep litter house for poultry. Fish ponds and tanks as well.
6.Miscellaneous structures	Its function depends on the type of structure.	Implement sheds, garages, farm workshops, fuel depots, water and wastewater ttreatment plants, dams, fences, roads, bridges and culverts.

Farm Stead Planning

Planning is an important activity which determines the success of any endeavor. It is often said that "without plans, purposes are frustrated".

Planning is the first and most important step in designing a farm stead. The cost of changing a plan on paper is very low when compared with an alteration to a completed building; also, an ill-conceived arrangement of buildings can diminish profits on a long term. At the planning stage, it beneficial to evaluate all necessary factors that must be considered and reasonable compromises made. For example, the distance between each building in a farm stead is important, convenience and efficiency might indicate very close proximity, while fire safety may dictate a minimum distance of 30m.

Offensive odours might inform distance of over 100m apart from dwellings. Careful planning with adequate information will help to attain desirable compromises.

1.1 Site Selection

A number of factors necessary for consideration for site selection for a farm stead are outlined below:

(A) **Drainage**: - Adequate surface and sub-surface drainage will ensure that foundations of structures are dry and will prevent local flooding. Well drained soil is necessary for the operation of Septic tank and for the removal of feed lot runoff and other wastes.

(B) **Waste Management**: - The ability to handle waste without problems is very important. This is

particularly so if the farmstead will house a major livestock enterprise. The site must conform to all state and local environmental regulations; the topography must be satisfactory for the required storage and drainage of manure and other effluents; prevailing wind direction is required to prevent pollution or dust from mills etc.

(C) **Water**: - Availability of good quality of water for the farm is very important, almost all activities on the farm require water and it must be available in adequate quantity.

(D) Utilities and Services: - These include telephone, electrical services, school bus, product delivery and pick up, access drives etc. The soil should be well drained and rich enough to provide landscaping gardens, play areas etc.

(E) **Orientation**: - Air drainage and maximum sunshine may require orientation on a gentle southerly slope. Prevailing winds must be considered and natural barriers used where possible.

(F) **Expansion**: - Adequate provision for future expansion must be provided for. Growth in this farm stead enterprises should be anticipated and the layout should facilitate expansion of buildings and services. It is pertinent to also provide for expansion of all facilities such as machineries, utilities etc. It is wise to look for twice as much area as that required initially, because of the impact of increasing production volume in future

1.2 Building Arrangement

The arrangement of facilities for maximum efficiency of operation should be a prime concern. Proper arrangement increases efficiency by reducing walking distance to a minimum and providing adequate drive ways and turn around. It is important to note that fire protection, safety and security and all influenced by the farmstead planning.

When a site has been selected, it is then needful to draw a map which will show major details. There should be contour lines, the direction of the north, direction of prevailing wind and general slopes, existing roads, natural wind barriers and water ways. The arrangement and rearrangement of buildings should then follow till a satisfactory layout is designed. An operation center should be located first, this will often be the farm house; the farm house should be sited such that it can be accessed from any direction in the farm stead, in general cases, it should be centrally located since the entire farm is administered from the farm house. The remaining buildings can then be arranged in relation to the operating center.

Building arrangement requires the consideration of some environmental factors such as slope, prevailing wind, sun etc. buildings should be located on relatively high ground with surface drainage directed away from foundations. Buildings should be arranged to take advantage of natural conditions; winds can blow in all direction but the prevailing direction is important, winds carry odours, dust, and noise, proper arrangement of buildings will use the wind to carry these away from the living center.

Livestock yards and buildings should be located down wind (wind ward) from farm home and from neighbours. Buildings lined up at right angles to the wind rather than parallel are less subject to the spread of fire. Also, open front buildings, stockyards and solar heated facilities should be arranged so that during cold season they receive the full benefit of sunlight. Tall buildings, such as tower Silos, should be located so they do not cast shadow on feed lots.

Labour efficiency is improved by reducing travel to a minimum; buildings which will require frequent movement of workers should be sited close. Arrange buildings in relation to drive and yard to allow easy manoeuvring of large vehicles and equipment

1.3 **Planning Of Farm Buildings**

Farm buildings represent a production or storage cost. Every enterprise requires a return on every investment made hence a return on feed and labour cost is expected. In view of this, a benefit from a building investment should also be anticipated. Some of the benefits derivable from a farm building include: -

- Provide facilities for efficient operations
- An environment providing conducive and sanitary conditions.
- Provide desirable condition suitable for production
- Provide comfortable surroundings for both livestock and workers.
- Provide safe conditions for both livestock and workers.

It should be noted that a number of design factors must be considered in planning a building to obtain the greatest number of benefits at a reasonable cost, some of these factors includes:

1. The functional requirement for the enterprise such as space, temperature, light, safety, sanitation, physical protection etc.
2. Efficiency of system, including centralized operation, bulk material handling etc.
3. Adequate structural design for the loads to which the building will be subjected to.
4. Suitability of materials with respect to characteristics like durability, cost, fire resistance, ease of cleaning etc.
5. Economy of construction, costs are reduced by choosing prefabricated assemblies, standard size materials and components etc.
6. Flexibility of design that will allow proposed enterprise to be altered or a new enterprise to be established with minimum expense and effort.

STRUCTURAL ANALYSIS AND BASIC MECHANICS

A structure is designed to perform a certain function. To perform this function satisfactorily it must have sufficient strength and rigidity. Economy, and an attractive appearance are also of importance in structural design.

Structures are subjected to a variety of loads either singly or in combination. These include the self-weight of the materials used for construction as well as the weight of products stored, animals housed or water dammed. The short-term loads due to wind and even earthquakes must also be included. The designer must have an understanding of the nature and significance of these forces and apply this knowledge to the design, materials and methods of construction if the structure is to safely survive all situations. Each of the various elements, such as ties, struts and beams, has a unique purpose in maintaining the integrity of the structure and must be designed to have sufficient strength to withstand the maximum stress to which it may be subjected.

The many building materials available differ greatly in their resistance to loading and in other characteristics that relate to their use in various building elements. They must be selected carefully to be suitable for the type or types of loading which are determined during the structural design procedure.

Structural design is the methodical investigation of the stability, strength and rigidity of structures. The basic objective in structural analysis and design is to produce a structure capable of resisting all applied loads without failure during its intended life. The primary purpose of a structure is to transmit or support loads. If the structure is improperly designed or fabricated, or if the actual applied loads exceed the design specifications, the device will probably fail to perform its intended function, with possible serious consequences. A well engineered structure greatly minimizes the possibility of costly failures. Structural design could either involve rigorous calculations or selection based on a code of practice. Design codes, codes of practice or standards are documents which provide information on the sizes of construction materials and methods of assembly that are adequate to resist various loads. They are developed from long term research or local practices which have proved safe over a long period of observation. Codes of practice take into account not only the properties of the materials and loading, but in addition the environment where it is used. Codes of practice are therefore country based and those suited to the place of work must be consulted.

Stages in Structural Design

The exercise of providing a farm structure or any engineering project can be divided into three stages. These are planning, design and construction.

Planning involves a consideration of the various requirements and factors which affect the general layout and dimensions of the structure and leads to the choice of one or perhaps several alternative types of structures which offer the best general solution. This primary consideration is the function of the structure whether it is to serve as an enclosure or to provide a support. Many secondary considerations which are also involved include aesthetic, sociological, legal, financial, economic, and environmental or resource-conservation factors. In addition, there are structural and constructional requirements and limitations which may also affect the structural type selected.

Design involves a detailed consideration of the alternative solutions evolved in the planning phase and leads to the most suitable proportions, dimensions and details of the structural elements and connections for constructing each alternative structural arrangement being considered. Usually before the final design stage is reached, the best solution has to be identified and final construction plans are prepared for this selection. Occasionally, the choice may also be dependent on economic and constructional features which should be duly considered.

The objective of structural design is to determine the proportions, and select materials and fastenings required for each component. The design procedure consists of the following three parts:

a)The consideration of external loads and conditions which involves the establishment of the loading and other design conditions that must be resisted by the structure and therefore must be considered in its design.

b) The consideration of internal loads and conditions which involves the analysis or computation of the internal gross forces (thrust, shears, bending moments and twisting moments), stress intensities, strains, deflections and reactions produced by the loads, temperature, shrinkage, creep and other design conditions.

c) The proportioning and selection of materials for the members and connections so as to resist adequately the effects produced by the design conditions.

Construction involves the procurement of materials, equipment and personnel, shop fabrication of the members and sub-assemblies, transportation to the site and actual field construction and erection. During this phase, some redesign may be required if unforeseen difficulties develop, or if specified materials cannot be found or for any number of other reasons.

Design Criteria

The ultimate goal of structural analysis is to ensure that a structure does not fail in service. This is achieved through the selection of appropriate dimensions that would be able to resist the imposed loads. Although there are a number of ways through which failure could occur, in most farm structures, the aim is usually to prevent excessive bending and shear stresses, sagging of beams, crushing and buckling of column components.

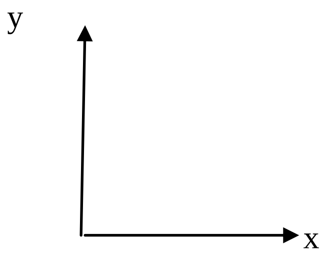
The traditional basis of design in agricultural structures is the elastic design method. Under this method, the allowable or permissible or actual stress intensities are chosen in accordance with the concept that the stress or strain corresponding to the yield point of the material should not be exceeded at the most highly stressed points of the structure. Usually in this method, the stresses produced in the structure by service loadings and other design conditions are compared with allowable stresses for the material involved. The selection of allowable stresses may also be modified by a consideration of the possibility of failure due to fatigue, buckling or brittle fracture or by consideration of the permissible deflections of the structure. The elastic design approach is applicable to all materials of construction and it is the one commonly used

Basic Principles of Statics

Statics is the branch of mechanics that deals with the equilibrium of stationary bodies under the action of forces. The other main branch – dynamics – deals with moving bodies, such as parts of machines.

Static equilibrium

A planar structural system is in a state of static equilibrium when the resultant of all forces and all moments is equal to zero, i.e



$\Sigma f_x = 0$ this means that the resultant of all horizontal external forces is zero

$\Sigma f_y = 0$ this means that the resultant of all vertical external forces is zero

$\Sigma M_a = 0$ this means that the sum of all moments about any point is zero.

where F refers to forces and M refers to moments of forces.

<u>Static determinacy</u>

In structural analysis, the assignment is usually to determine the magnitudes and directions of the forces that will act on a structure in service. This itself depends on the way and manner in which the structure is supported and the number of supports used. It may happen that the number of support reactions to be determined is not more than three in which case; they can be evaluated using the three equations of static equilibrium. If on the contrary, the need arises to determine more than three unknown reactions, then the three equations of static equilibrium will not be enough to determine the unknowns. While the former case is said to be statically determinate, the latter is not. A structure in which the reactions can be determined using only the three equations of static equilibrium is said to be statically determinate while if the three equations are inadequate to determine all the reactions, the structure is said to be statically indeterminate .The degree of indeterminacy is the difference between the number of reactions to be determined and the number of equations of static equilibrium. If a body is in equilibrium under the action of coplanar forces, the statics equations above must apply. In general, three independent unknowns can be determined from the three equations. Note that if applied and reaction forces are parallel (i.e. in one direction only), then only two separate equations can be obtained and thus only two unknowns can be determined. Such systems of forces are said to be statically determinate.

Degree of indeterminacy = Number of unknown reactions – Number of equation of static equilibrum

You may also use $M = 2J - 3$

Where M = No of members

J = Joints in the frames (Statically determinate if equal to each other)

<u>Stability</u>

Recall that for a body to be in a state of static equilibrium, there are three equations which are

$\sum fx = 0$,

$\sum fy = 0$

$\sum Mz = 0$.

To solve these equations, there has to be three unknown elements. If there are less than three unknown, the three simultaneous equations cannot be solved completely. The implication of this is that the structure does not have enough supports and is statically unstable. In general therefore, if there are fewer than three unknown independent reaction elements, there are not enough unknowns to satisfy the three equations of static equilibrium simultaneously.

Fewer than three unknown reactions are therefore insufficient to keep a planar structure in equilibrium when it is acted upon by a general system of loads. Under such a condition, a structure is said to be statically unstable. From the above, it would appear as if the presence of at least three reactions in a planar structure automatically makes the structure stable. This is not true as there is an exception. If there are three or more reactions but arranged in such a way that motion is still possible in any direction, then the structure is unstable due to the way the reactions are arranged. This is referred to as geometrical instability or geometrically unstable.

In general therefore, the stability of a structure is determined not only by the number of reaction elements but also by their arrangement. Usually unstable structures are also statically indeterminate.

Force

A force is defined as any cause that tends to alter the state of rest of a body or its state of uniform motion in a straight line. A force can be defined quantitatively as the product of the mass of the body that the force is acting on and the acceleration of the force.

$P = ma$

where

P = applied force, m = mass of the body (kg), a = acceleration caused by the force (m/s^2)

The *Système Internationale* (SI) units for force are therefore kg m/s2, which is designated a Newton (N).

The following multiples are often used:

1 kN = 1 000 N, 1 MN = 1 000 000 N

All objects on earth tend to accelerate toward the centre of the earth due to gravitational attraction; hence the force of gravitation acting on a body with the mass (m) is the product of the mass and the acceleration due to gravity (g), which has a magnitude of 9.81 m/s^2

$F = mg = v\text{rg}$

where:

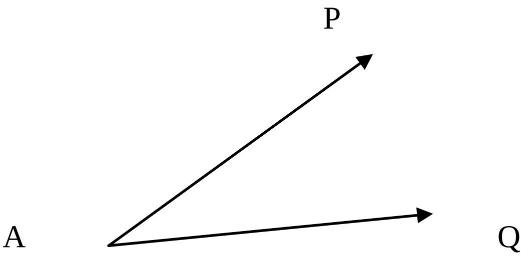
F = force (N), *m* = mass (kg), *g* = acceleration due to gravity ($9.81 m/s^2$), *v* = volume (m^3) and r = density (kg/m^3)

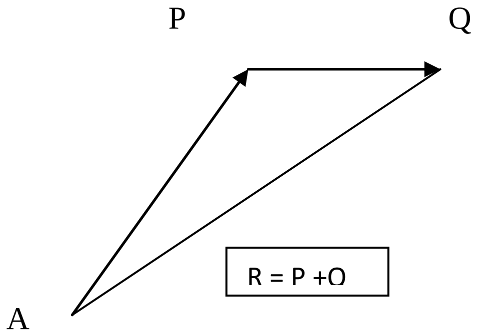
Vector

Most forces have magnitude and direction and can be shown as a vector. The point of application must also be specified. A vector is illustrated by a line, the length of which is proportional to the magnitude on a given scale, and an arrow that shows the direction of the force.

Vector addition

The sum of two or more vectors is called the resultant. The resultant of two concurrent vectors is obtained by constructing a vector diagram of the two vectors. The vectors to be added are arranged in tip-to-tail fashion. Where three or more vectors are to be added, they can be arranged in the same manner, and this is called a polygon. A line drawn to close the triangle or polygon (from start to finishing point) forms the resultant vector.





Moments of Forces

The effect of a force on a rigid body depends on its point of application as well as its magnitude and direction. It is common knowledge that a small force can have a large turning effect or leverage. In mechanics, the term moment is used instead of turning effect. The moment of force with a magnitude (F) about a turning point (O) is defined as: M = F x d, where d is the perpendicular distance from O to the line of action of force F. The distance d is often called lever arm. A moment has dimensions of force times length (Nm). The direction of a moment about a point or axis is defined by the direction of the rotation that the force tends to give to the body. A clockwise moment is usually considered as having a positive sign and an anti-clockwise moment a negative sign. The determination of the moment of a force in a coplanar system will be simplified if the force and its point of application are resolved into its horizontal and vertical components.

Concurrent coplanar forces

Forces whose lines of action meet at one point are said to be *concurrent. Coplanar* forces lie in the same plane, whereas *non-coplanar* forces have to be related to a three-dimensional space and require two items of directional data together with the magnitude. Two coplanar non-parallel forces will always be concurrent.

Equilibrium of a particle

When the resultant of all forces acting on a particle is zero, the particle is in *equilibrium*, i.e. it is not disturbed from its existing state of rest (or uniform movement). The closed triangle or polygon is a graphical expression of the equilibrium of a particle. The equilibrium of a particle to which a single force is applied may be maintained by the application of a second force that is equal in magnitude and direction, but opposite in sense, to the first force. This second force, which restores equilibrium, is called the *equilibrant*. When a particle is acted upon by two or more forces, the *equilibrant* has to be equal and opposite to the resultant of the system. Thus the *equilibrant* is the vector drawn closing the vector diagram and connecting the finishing point to the starting point.

Point of concurrency

Three coplanar forces that are in equilibrium must all pass through the same point. This does not necessarily apply for more than three forces. If two forces (which are not parallel) do not meet at their points of contact with a body, such as a structural member, their lines of action can be extended until they meet.

Collinear forces

Collinear forces are parallel and concurrent. The sum of the forces must be zero for the system to be in equilibrium.

Coplanar, non-concurrent, parallel forces

Three or more parallel forces are required. They will be in equilibrium if the sum of the forces equals zero and the sum of the moments around a point in the plane equals zero. Equilibrium is also indicated by two sums of moments equal to zero.

Reactions

Imagine that a crib has been fabricated and left on the ground. If wind were to blow past the structure and of adequate magnitude, the structure will continue to move. In order to prevent this, there must be a way of holding the structure in place such that when external forces act on it, it cannot move. This is provided by what are called supports. They may or may not be part of the structure but when they have to be used, they are secured onto the structure. When external forces act on the structure, these supports react against the tendency of the structure to move. Forces are therefore generated within the supports called the reactions. There are various types of supports depending on the structure and the type of loads it is subjected to. Some of such supports which are commonly encountered in farm structures are the roller, pin, built-in and fixed-end supports.

Structural components are usually held in equilibrium by being secured to rigid fixing points; these are often other parts of the same structure. The fixing points or supports will react against the tendency of the applied forces (loads) to cause the member to move. The forces generated in the supports are called reactions.

In general, a structural member has to be held or supported at a minimum of two points (an exception to this is the cantilever).

a) Roller support

In a roller support, the reaction is normal to the supporting surface only. In the Table 1 below, the roller supports are not capable of resisting movement in the horizontal direction. The supports themselves can move in the horizontal direction as in a sliding door. The reactive force of a roller support is directed through the centre of the pin. If the rollers are frictionless, they can transmit only a pressure which is normal to the surface on which they roll. Hence a roller support supplies a resultant reactive force which acts normal to the surface on which the rollers roll and is directed through the centre of the hinge pin. It is therefore evident that a roller support supplies a reactive force which is applied at a known point and acts in a known direction but the magnitude of which is unknown. Roller supports are usually detailed so that they can supply reaction acting either away from or towards the supporting surface.

b) Pin or Hinged Support

The hinged or pin support is fixed in position i.e its location is fixed. It can neither move vertically nor horizontally but it can rotate. It is capable of resisting movement in both the vertical and horizontal directions. An example of this is shown in Table 1 below.

In the hinge support, it is assumed that the pin of the hinge is frictionless in the pinhole, the contact pressures between the pin and its hole are normal to the circular contact surface and directed through the centre of the pin. The reaction R, that the support supplies to the structure completely counteracts the action of the force P (the external load) and therefore R and P are collinear and numerically equal but act in opposite directions. It is therefore evident that a hinge support supplies a reactive force the line of action of which is known to pass through the centre of the hinge pin but the magnitude and direction of which are unknown.

These two unknown elements of such a reaction could also be represented by the unknown magnitudes of its horizontal and vertical components, R respectively, both acting through the centre of the hinge pin.

c) Built-in Support

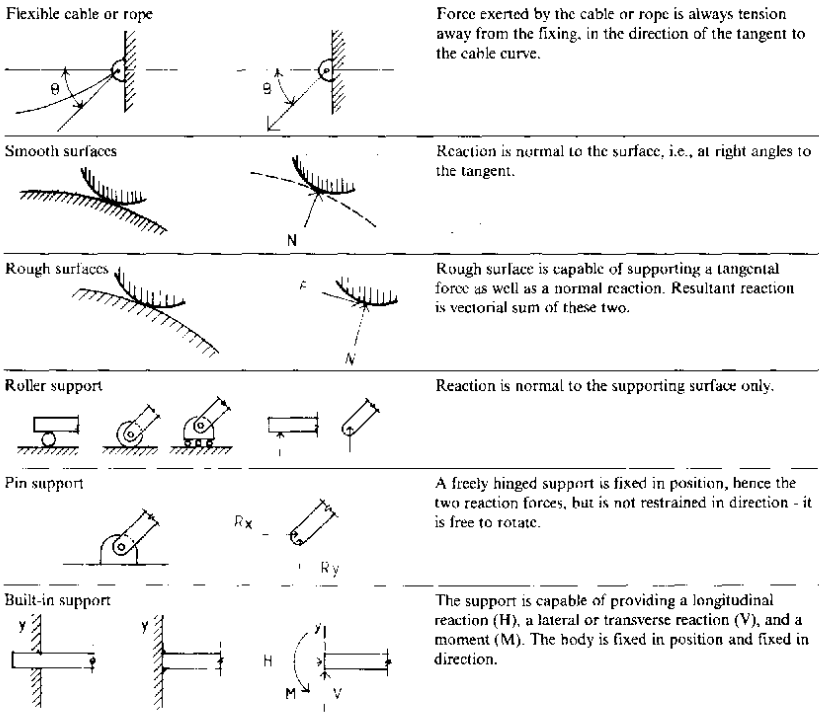
In a built-in support, the support is fixed in position in that its location is fixed and there is no freedom of rotation implying that the direction is also fixed. It provides three reactions which are a vertical and horizontal reactions and a bending moment. The degree of freedom is nil. The determination of the reactions developed by this support requires the knowledge of three parameters. These are the direction and magnitude of a force passing through any point chosen at will and the magnitude of the moment about the same point. An example of this is shown in Table 1 below.

d) Fixed Support

A fixed support encases the member so that both translation and rotation of the end of the member are prevented. A fixed support therefore supplies a reaction, the magnitude, the point of application and the direction of which are all unknown. These three unknown elements may also be considered to be a force which acts through a specific point but has an unknown magnitude and direction, and a couple of unknown magnitude.

For example, the three unknown elements could be selected as a couple, and a horizontal and a vertical force, the two later acting through the centre of gravity of the end cross-section. A fixed support is shown in Table 1 below.

Table 1: Actions and Reactions



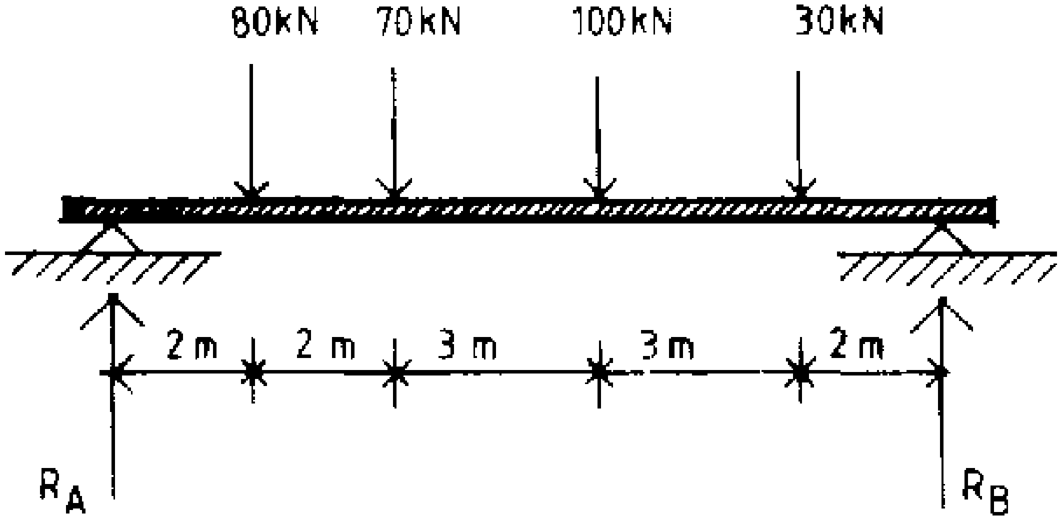
Flexible cable or rope	Force exerted by the cable or rope is always tension away from the fixing, in the direction of the tangent to the cable curve.
Smooth surfaces	Reaction is normal to the surface, i.e., at right angles to the tangent.
Rough surfaces	Rough surface is capable of supporting a tangental force as well as a normal reaction. Resultant reaction is vectorial sum of these two.
Roller support	Reaction is normal to the supporting surface only.
Pin support	A freely hinged support is fixed in position, hence the two reaction forces, but is not restrained in direction - it is free to rotate.
Built-in support	The support is capable of providing a longitudinal reaction (H), a lateral or transverse reaction (V), and a moment (M). The body is fixed in position and fixed in direction.

Resultant of Parallel Forces

If two or more parallel forces are applied to a horizontal beam, then theoretically the beam can be held in equilibrium by the application of a single force (reaction) which is equal and opposite to the resultant, R. The equilibrant of the downward forces must be equal and opposite to their resultant. This provides a method for calculating the resultant of a system of parallel forces. However, two reactions are required to ensure the necessary stability and a more likely arrangement will have two or more supports.

The reactions RA and RB must both be vertical, since there is no horizontal force component. Furthermore the sum of the reaction forces RA and RB must be equal to the sum of the downward acting forces.

Beam Reactions



The magnitude of the reactions may be found by the application of the third condition for equilibrium, i.e., the algebraic sum of the moments of the forces about any point must be zero.

Example 1: Take the moments around point A, then:

(80 x 2) + (70 x 4) + (100 x 7) + (30 x 10) - (R_B x 12) = 0;

R_B= 120kN

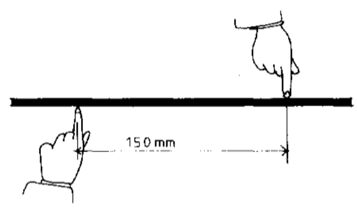
RA is now easily found with the application of the second condition for equilibrium.

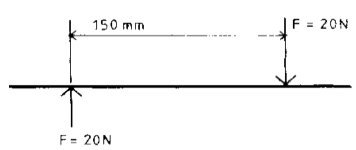
R_A = 75 - 70 - 100 -30+ R_B=0; RB= 120kN gives:

R_A=160kN.

Couples

Two equal, parallel and opposite but not colinear forces are said to be a couple. A couple acting on a body produces rotation. Note that the couple cannot be balanced by a single force. To produce equilibrium another couple of equal and opposite moment is required.





Loading Systems

Before any of the various load effects (tension, compression, bending etc.) can be considered, the applied loads must be rationalized into a number of ordered systems. Irregular loading is difficult to deal with exactly but even the most irregular loads may be reduced and approximated to a number of regular systems. These can then be dealt with in mathematical terms using the principle of superposition to estimate the overall combined effect.

Concentrated loads are those which can be assumed to act at a single point e.g., a weight hanging from a ceiling, or a man pushing against a box.

Concentrated loads are represented by a single arrow drawn in the direction and through the point of action of the force. The magnitude of the force is always indicated.

Uniformly distributed loads, written as u.d.l. are those which can be assumed to act uniformly over an area or along the length of a structural member, e.g., roof loads, wind loads, the effect of the weight of water on a horizontal surface, etc.

For the purpose of calculation, a u.d.l. is normally considered in a plane and is represented as shown.

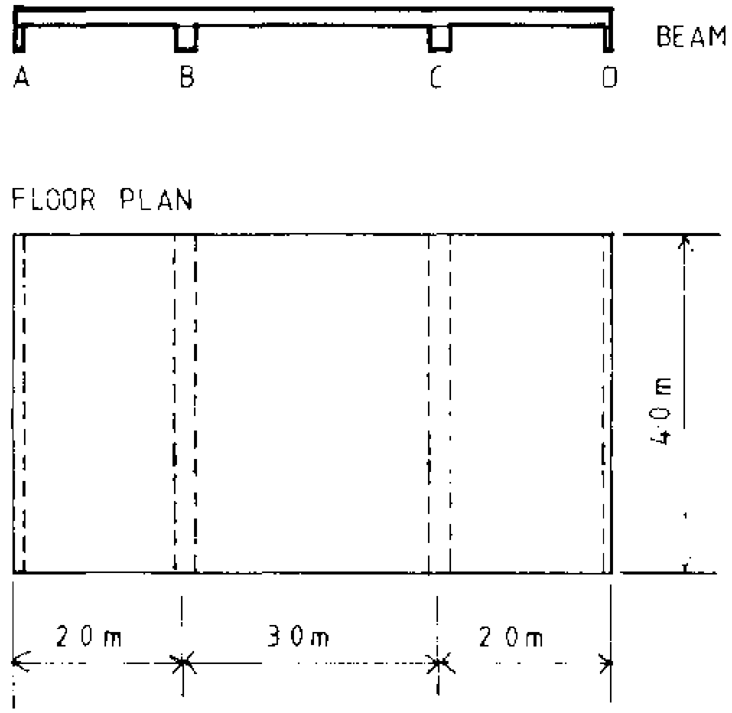
In calculating reactions, uniformly distributed loads can in most, but not all cases be represented by a concentrated load equal to the total distributed load and passing through the centre of gravity of the distributed load.

This technique must not be used for calculation of shear force, bending moment or deflection.

Example 2

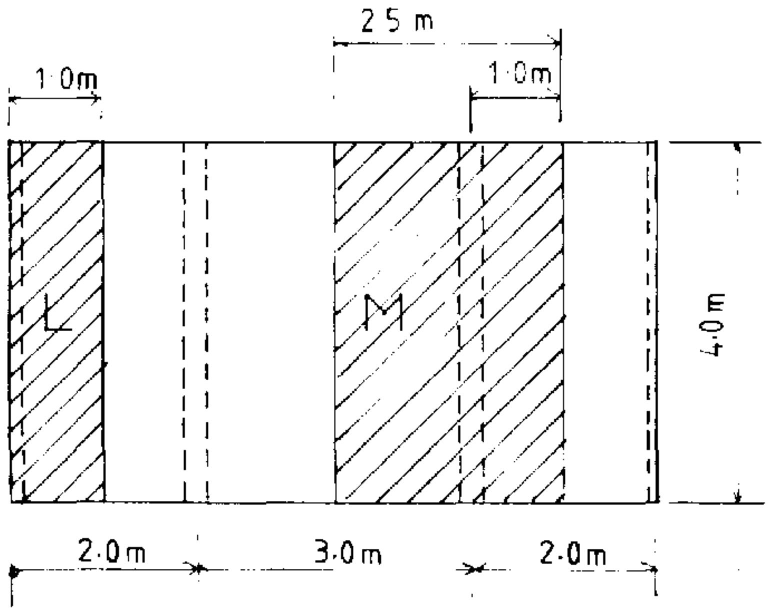
Consider a suspended floor where the loads are supported by a set of irregularly placed beams. Let the load arising from the weight of the floor itself and the weight of any material placed on top of it (e.g., stored grain) be $10kN/m^2$. Determine the u.d.l. acting on beam A and beam C.

FLOOR SECTION



It can be seen from the figure below that beam A carries the floor loads contributed by half the area between the beams A and B i.e., the shaded area L. Beam C carries the loads contributed by the shaded area M.

Floor section part 2



Therefore beam A carries a total load of:

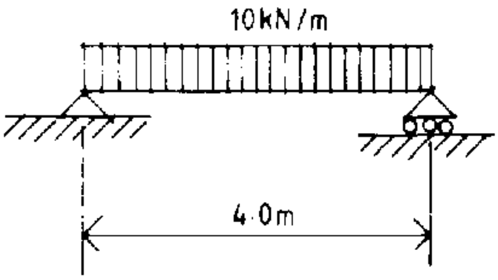
1 m x 4m x 10kN/ m² = 40kN, or 40kN / 4 = 10kN / m.

In the same way the loading of beam C can be calculated to 25kN / m. The loading per metre run can then be used to calculate the required size of the beams.

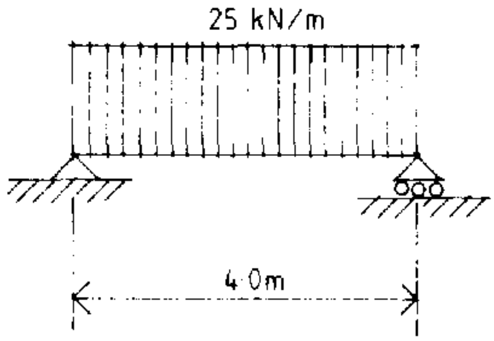
Distributed loads with linear variation is another common load situation.

The loading shape is triangular and is the result of such actions as the pressure of water on retaining walls and dams.

Loading of Beam C



Loading of Beam A



Shearing Force and Bending Moment

A beam is a structural member subject to lateral loading in which the developed resistance to deformation is of flexural character. The primary load effect that a beam is designed to resist is that of bending moments, but in addition, the effects of transverse or vertical shearing forces must be considered.

Consider the cantilever AB shown in (a). For equilibrium, the reaction force at A must be vertical and equal to the load W.

The cantilever must therefore transmit the effect of load W to the support at A by developing resistance (on vertical cross-section planes between the load and the support) to the load effect called shearing force. Failure to transmit the shearing force at any given section, e.g., section x-x, will cause the beam to fracture as in (b). The bending effect of the load will cause the beam to deform as in (c). To prevent rotation of the beam at the support A, there must be a reaction moment at A, shown as M_A, which is equal to the product of load W and the distance from W to point A.

The shearing force and the bending moment transmitted across the section x-x may be considered as the force and moment respectively that are necessary to maintain equilibrium if a cut is made severing the beam at x-x. The free-body diagrams of the two portions of the beam are shown in (d).

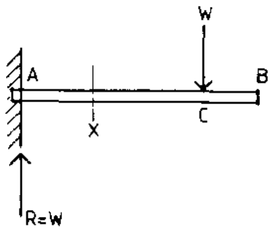
Then the shearing force between A and C = Q_x = W

and the bending moment between A and C = M_x = W_x

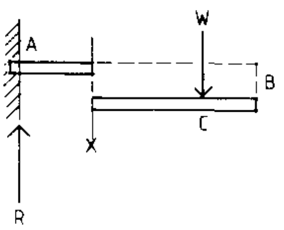
Note: Both the shearing force and the bending moment will be zero between C and B.

Shearing force part 1

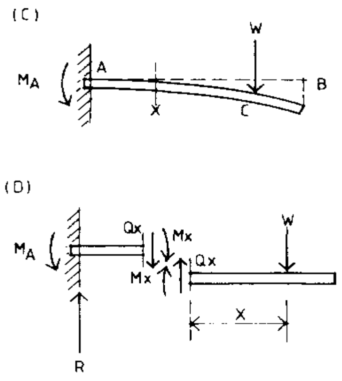
(A)



(B)



Shearing force part 2



Definitions

Shear force (Q) is the algebraic sum of all the transverse forces acting to the left or to the right of the chosen section.

Bending moment (M) at any transverse cross section of a straight beam is the algebraic sum of the moments, taken about an axis passing through the centroid of the cross section, of all the forces applied to the beam on either side of the chosen cross section.

Direct Stress

When a force is transmitted through a body, the body tends to change its shape. Although these deformations seldom can be seen by the naked eye, the many fibres or particles which make up the body, transmit the force throughout the length and section of the body, and the fibres doing this work are said to be in a state of stress. Thus, a stress may be described as a mobilized internal reaction which resists any tendency towards deformation. Since the effect of the force is distributed over the cross-section area of the body, stress is defined as force transmitted or resisted per unit area.

Thus Stress =Force/Area

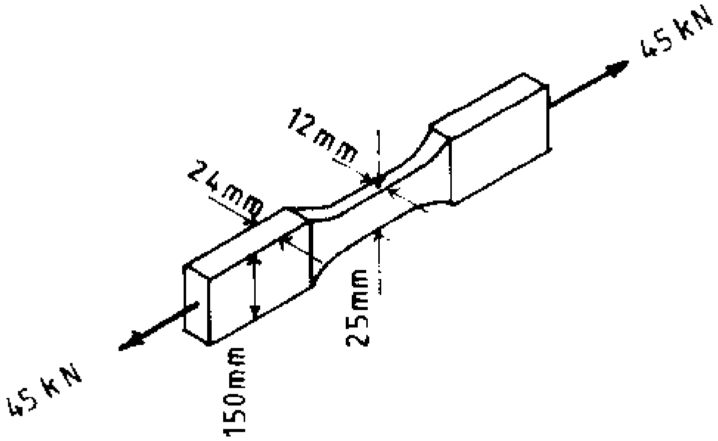
The unit for stress in S.l. is newtons per square metre (N/m²). This is also called a Pascal (Pa). However, it is often more convenient to uses the multiple N/mm².

Note that 1N /mm² = 1 MN 1 m² = 1 M Pa

Tensile and compressive stress, which result from forces acting perpendicular to the plane of cross section in question, are known as normal stress and are usually symbolized with (the Greek letter sigma), sometimes given a suffix t for tension (at) or a c for compression (c). Shear stress is produced by forces acting parallel or tangential to the plane of cross section and is symbolized with r (Greek letter tau).

Tensile Stress

Example 3

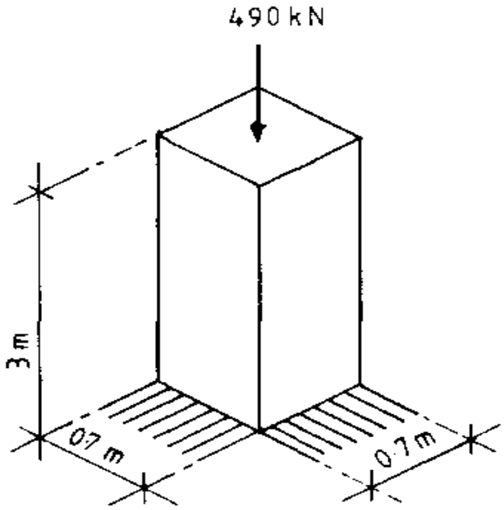


Consider a steel bar which is thinner at the middle of its length than elsewhere, and which is subject to an axial pull of 45kN.

If the bar were to fail in tension, it would be due to breaking where the amount of material is a minimum. The total force tending to cause the bar to fracture is 45kN at all cross sections, but whereas the effect of the force is distributed over a cross-sectional area of 1200mm² for part of the length of the bar, it is distributed over only 300mm² at the middle position. Thus, the tensile stress is greatest in the middle and is: at = 300 2 = 15ON/mm²

Compressive Stress

Example 4



A brick pier is 0.7m square and 3m high and weighs l9kN/ m^3. It is supporting an axial load from a column of 490kN. The load is spread uniformly over the top of the pier, so the arrow shown merely represents the resultant of the load. Calculate a) the stress in the brickwork immediately under the column, b) the stress at the bottom of the pier.

Solution a

Cross-section area = $0.49m^2$

Stress = σc = 490kN / $0.49m^2$ = l000kN/ m^2 or 1 N/mm^2

Solution b

Weight of pier: = 0.7m x 0.7m x 3.0m x 19kN/m^3 = 28kN

Total load = 490 + 28 = 518kN and

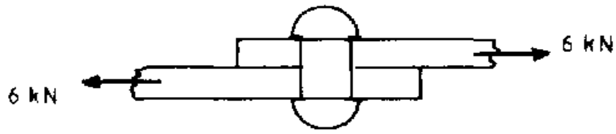
Stress = σ_c = 518kN / $0.49m^2$ = 1057kN/ m^2 or 1.06N/mm^2

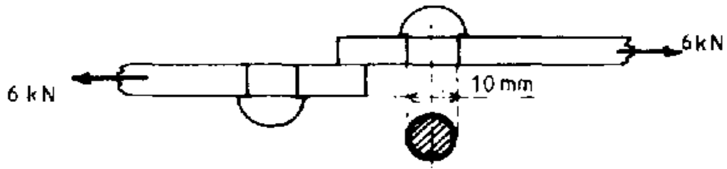
<u>Shear Stress</u>

Example 5

A rivet is connecting two pieces of flat steel. If the loads are large enough, the rivet could fail in shear, i.e., not breaking but sliding of its fibres. Calculate the shear stress of the rivet when the steel bars are subject to an axial pull of 6kN.

Diagrams





Note that the rivets do, in fact, strengthen the connection by pressing the two steel bars together, but this strength, due to friction, cannot be calculated easily and is therefore neglected, i.e., the rivet is assumed to give all strength to the connection.

Cross-section area of rivet = 1/4 x π x 10^2 = 78.5 mm²
Shear stress = r = 6kN / 78.5mm^2 = 76N/mm²

Strain

When loads of any types are applied to a body, the body will always undergo dimension changes, this is called deformation. Thus, tensile and compressive stresses cause changes in length; torsional-shearing stresses cause twisting, and bearing stresses cause indentation in the bearing surface.

In farm structures, where mainly a uniaxial state of stress is considered, the major deformation is in the axial direction. There are always small deformations present in the other two dimensions, but they are seldom of significance.

Direct Strain = Change in length / Original length = = $\varepsilon = \Delta L$

By definition strain is a ratio of change and thus it is a dimensionless quantity.

Elasticity

All solid materials will deform when they are stressed, and as the stress is increased, the deformation also increases. In many cases, when the load causing the deformation is removed, the material returns to its original size and shape and is said to be elastic. If the stress is steadily increased, a point is reached when, after the removal of the load, not all of the induced strain is recovered. This limiting value of stress is called the elastic limit. Within the elastic range, strain is proportional to the stress causing it. This is called the modulus of elasticity. The greatest stress for which strain is still proportional is called the limit of proportionality (Hooke's law).

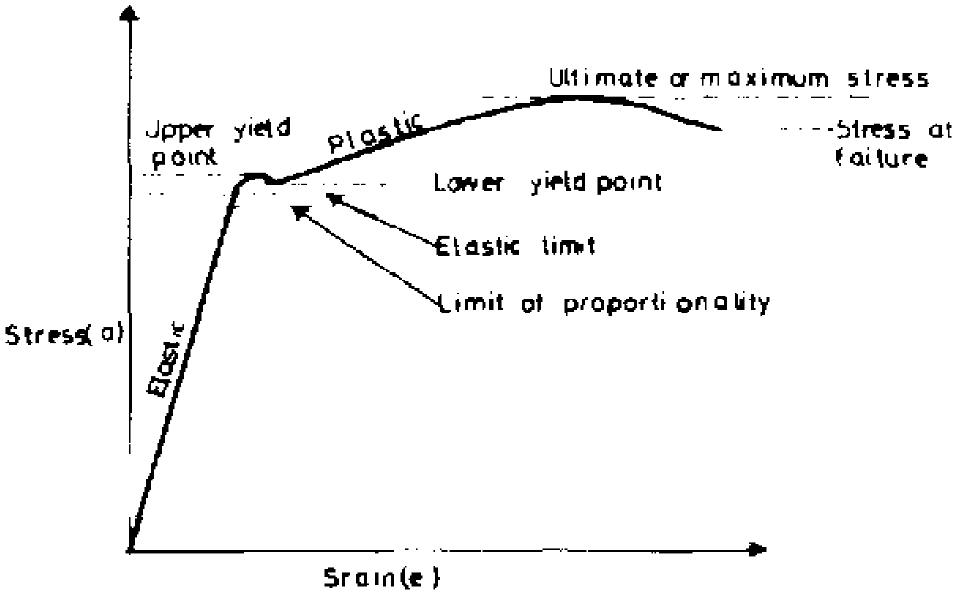
Thus, if a graph is produced of stress against strain as the load is gradually applied, the first portion of the graph will be a straight line. The slope of this straight line is the constant of proportionality, modulus of elasticity (E), or Young's modulus and should be thought of as a measure of the stiffness of a material.

Modulus of elasticity = E = Stress/Strain = $FL/A\Delta L$

The modulus of elasticity will have the same units as stress (N/mm^2). This is because strain has no units.

A convenient way of demonstrating elastic behaviour is to plot a graph of the results of a simple tensile test carried out on a thin mild-steel rod. The rod is hung vertically and a series of forces applied at the lower end. Two gauge points are marked on the rod and the distance between them measured after each force increment has been added. The test is continued until the rod breaks.

Behaviour of mild-steel rod under tension.



Example 6

Two timber posts, 150mm square and 4m high, are subject to an axial load of 108 kN each. One post is made of pine timber (E = 7800N/mm²) and the other is Australian blackwood (E = 15300N/mm²). How much will they shorten due to the load?

Cross-section area A = 22500mm²; length L = 4000mm

Pine: ΔL = FL / AE= (108000 x 4000) / (22500 x 15300) = 1.3m

Australian blackwood: ΔL = (108000 x 4000) / (22500 x 15300) = 1.3mm

Factor of Safety

The permissible stresses must, of course, be less than the stresses which would cause failure of the members of the structure; in other words there must be an ample safety margin. (In 2000 B.C. a building code declared the life of the builder be forfeited should the house collapse and kill the owner).

Also deformations must be limited since excessive deflection may give rise to troubles such as cracking of ceilings, partitions and finishes, as well as adversely affecting the functional needs.

Structural design is not an exact science, and calculated values of reactions, stresses etc., whilst they may be mathematically correct for the theoretical structure (i.e., the model), may be only approximate as far as the actual behaviour of the structure is concerned.

For these and other reasons it is necessary to make the design stress, working stress, allowable stress and permissible stress less than the ultimate stress or the yield stress. This margin is celled factor of safety.

Design stress = [Ultimate (or yield) stress]/Factor of safety

In the case of a material such as concrete, which does not have a well-defined yield point, or brittle materials which behave in a linear manner up to failure, the factor of safety is related to the ultimate stress (maximum stress before breakage). Other materials, such as steel, have a yield point where a sudden increase in strain occurs, and at which point the stress is lower than the ultimate stress. In this case, the factor of safety is related to the yield stress in order to avoid unacceptable deformations.

The value of the factor of safety has to be chosen with a variety of conditions in mind, such as:

- the accuracy in the loading assumptions
- the permanency of the loads
- the probability for casualties or big economic losses in case of failure
- the purpose of the building
- the uniformity of the building material
- the workmanship expected from the builder
- the strength properties of the materials
- the level of quality control ensuring that the materials are in accordance with their specifications
- the type of stresses developed
- the building material cost

However, values of 3 to 5 are normally chosen when the factor of safety is related to ultimate stress and values of 1.4 to 2.4 when related to yield-point stress.

In the case of building materials such as steel and timber, different factors of safety are sometimes considered for common loading systems and for exceptional loading systems in order to save materials. Common loadings are those which occur frequently, whereas a smaller safety margin may be considered for exceptional loadings, which occur less frequently and seldom with full intensity, e.g., wind pressure, earthquakes.

1. WOOD

Wood is a hard and fibrous substance which forms a major part of the trunk and branches of a tree. It can also be defined as a natural polymeric material which practically does not age. Wood as a building material falls in two major classes—natural and man-made. With the advances in science and technology, wood in its natural form as timber, lumber, etc. is being rapidly replaced by composite wood materials in which natural wood is just a basic ingredient of a matrix or a laminate. The latter are found to be more useful and adaptable as they may be treated chemically, thermally or otherwise as per requirements. Some examples are plywood, fibreboards, chipboards, compressed wood, impregnated wood, etc. Wood has many advantages due to which it is preferred over many other building materials. It is easily available (this won't be true after some years) and easy to transport and handle, has more thermal insulation, sound absorption and electrical resistance as compared to steel and concrete. It is the ideal material to be used in sea water. Wood is a good absorber of shocks and so is suitable for construction work in hilly areas which are more prone to earthquakes.
Finally, since wood can be easily worked, repairs and alterations to wood work can also be done easily. Owing to the above mentioned advantages, wood is very widely used in buildings as doors, windows, frames, temporary partition walls, etc. and in roof trusses and ceilings apart from formwork.

Characteristics of Timber

The principal characteristics of timber of concern are strength, durability and finished appearance.

1. Narrow annual rings, closer the rings greater is the strength.
2. Compact medullary rays.
3. Dark colour.
4. Uniform texture.
5. Sweet smell and a shining fresh cut surface.

6. When struck sonorous sound is produced.
7. Free from the defects in timber.
8. Heavy weight.
9. No woolliness at fresh cut surface.

Seasoning of Timber

Timber cut from freshly felled trees is too wet for normal use and is dimensionally unsuitable. Seasoning is the process of reducing the moisture content (drying) of timber in order to prevent the timber from possible fermentation and making it suitable for use. It can also be defined as the process of drying the wood to a moisture content approximately equal to the average humidity of the surroundings, where it is to be permanently fixed. Very rapid seasoning after removal of bark should be avoided since it causes case hardening and thus increases resistance to penetration of preservatives. Some of the objects of seasoning wood are as follows:

1. Reduce the shrinkage and warping after placement in structure.
2. Increase strength, durability and workability.
3. Reduce its tendency to split and decay.
4. Make it suitable for painting.
5. Reduce its weight.

METHODS OF SEASONING

Timber can be seasoned naturally or artificially.

Natural or air seasoning: The log of wood is sawn into planks of convenient sizes and stacked under a covered shed in cross-wise direction in alternate layers so as to permit free circulation of air. The duration for drying depends upon the type of wood and the size of planks. The rate of drying is however very slow. Air seasoning reduces the moisture content of the wood to 12–15 per cent. It is used very extensively in drying ties and the large size structural timbers.

Artificial seasoning: The prevalent methods of artificial seasoning are as follows:

Water Seasoning: The logs of wood are kept completely immersed in running stream of water, with their larger ends pointing upstream. Consequently the sap, sugar, and gum are leached out and are replaced by water. The logs are then kept out in air to dry. It is a quick process but the elastic properties and strength of the wood are reduced.

Boiling in water or exposing the wood to the action of steam spray is a very quick but expensive process of seasoning.

Kiln Seasoning: is adopted for rapid seasoning of timber on large scale to any moisture content. The scantlings are arranged for free circulation of heated air with some moisture or superheated steam. The circulating air takes up moisture required from wood and seasons it. Two types of kilns, the progressive and the compartment are in use.

DEFECTS IN WOOD

Defects can occur in timber at various stages, principally during the growing period and during the conversion and seasoning process. The defects in the wood are due to irregularities in the character of grains. Defects affect the quality, reduce the quantity of useful wood, reduce the strength, spoil the appearance and favour its decay.

Defects due to abnormal growth

Following are some of the important defects commonly found in wood due to abnormal growth or rupture of tissues due to natural forces.

Checks: is a longitudinal crack which is usually normal to the annual rings. These adversely affect the durability of timber because they readily admit moisture and air.

Shakes: are longitudinal separations in the wood between the annual rings. These lengthwise separations reduce the allowable shear strength without much effect on compressive and tensile values. The separations make the wood undesirable when appearance is important.

Boths the shakes and checks if present near the neutral plane of a beam they may materially weaken its resistance to horisontal shear.

Heart Shakes: occurs due to shrinkage of heart wood, when tree is overmatured. Cracks start from pith and run towards sap wood. These are wider at centre and diminish outwards.

Cup Shakes: appears as curved split which partly or wholly separates annual rings from one another. It is caused due to excessive frost action on the sap present in the tree, especially when the tree is young.

Star Shakes: are radial splits or cracks wide at circumference and diminishing towards the centre of the tree. This defect may arise from severe frost and fierce heat of sun. Star shakes appear as the wood dries below the fibre saturation point. It is a senous fault leading to separated log when sawn.

Knots:are bases of twigs or branches buried by cambial activity of the mother branch. The root of the branch is embedded in the stem, with the formation of annual rings at right angles to those of the stem. The knots interrupt the basic grain direction of the wood, resulting in a reduction of its strength. In addition these affect the appearance of the wood. A *dead knot* can be separated from the body of the wood, whereas *live knot* cannot be. Knots reduce the strength of the timber and affect workability and cleavability as fibres get curved. Knots are classified on the basis of size, form, quality and occurrence.

End Splits: are caused by greater evaporation of sap at the end grains of log and can be reduced by painting the exposed end grains with a water proof paint or capping the exposed end with hoop iron bandage.

Twisted Fibers: are caused by wind constantly turning the trunk of young tree in one direction.

Upsets: are caused by the crushing of fibres running transversely during the growth of the tree due to strong winds and unskilled felling consequently resulting in discontinuity of fibres.

Foxiness: is a sign of decay appearing in the form of yellow or red tinge or discolouration of overmatured trees.

Rupture: is caused due to injury or impact.

Defects due to conversion: Conversion is the term used to describe the process whereby the felled tree is converted into marketable sizes of timber. Conversion defects are basically due to unsound practice in milling or attempts to economise during conversion of timber. A *wane* occurs in timber which contains, on one or more faces, part of the bark or the rounded periphery of the trunk. This reduces the cross sectional area, with consequent reduction in strength in the parts affected. Excessive slope of grains may also be classed as a conversion defect when conversion has not been done parallel to the axis of the trunk.

Defects due to Seasoning: These defects are directly caused by the movement which occurs in timber due to changes in moisture content. Excessive or uneven drying, exposure to wind and rain, and poor stacking during seasoning can all produce distortions in timber. These defects result in loosening of fixings or disruption of decoration, or both. The common types of seasoning defects are: checks—longitudinal separation of fibres not extending throughout the cross-section of wood; splitting—separation of fibres extending through a piece of timber from one face to another; warpage—consists of cupping, twisting and bowing.

DISEASES OF TIMBER

Dry Rot

It is decomposition of felled timber caused by the action of various fungi. The fungus reduces fibres to fine powder and the timber looses its strength. This disease is highly infectious and causes tremendous destruction. It occurs when the timber is imperfectly seasoned and placed in a moist, warm and confined atmosphere having no free access of air. Fungus rapidly dies when exposed to air or sunlight. The best remedy is to cut away the affected part and paint the remaining part.

Wet Rot

When timber is subjected to alternate wet and dry conditions, decomposition of tissues takes place. This is not caused by fungal attack. In a living tree, it is set up by the access of water through wounds in the bark and causes the decomposition of sap and fibres of the tree. This may also occur when timber is seasoned by exposing it to moisture. To avoid wet rot, well seasoned timber is used with preservatives and paints.

PRESERVATION OF TIMBER

The durability of wood is decidedly variable property. If well-seasoned and kept in a dry place, if immersed in water, or if buried in ground, wood often lasts for centuries. When, however, unprotected wood can easily decay by swelling (when it gets wet), fungi, insects, fire, etc. The rapidly with which it decays depends on external conditions, the species of the wood, its preliminary conditioning, and its structure. One of the basic approaches to protect it is to create conditions unfavourable to fungi. Low humidity, heat and water insulation, etc. help to maintain the timber dry and thus make it insusceptible to damage by fungi. Water absorption, decay and other undesirable effects can be minimized by coating the surface of wood with polymer films or drying oils, oil base paints, varnishes and synthetic enamels. Preservative treatment of timber is not supposed to improve its basic properties like mechanical, electrical, or chemical properties. Some of the methods used to poison the food supply to fungus are as below.

Oil type preservatives (type 1): applied over outside of exposed timber, give unpleasant smell and are not suitable when timber is to be painted. The types in use are creosote, carbolinium, solignum etc. with or without admixture with petroleum or suitable oils having a high boiling range.

Organic solvent preservatives (type 2): *(Preservatives Insoluble in Water)* consists of toxic chemical compounds, e.g. pentachlorophenol, benzene-hexa-chloride, dichlorodiphenyl trichloro-ethane (D.D.T) and copper naphthenate. These are dissolved in suitable organic solvents like naphtha, or in petroleum products such as kerosene, spirit, etc. The treated timber can be painted, waxed or polished.

Acetic Anhydride treatment- is used for protection of veneers, plywood and light lumbers against decay by acetylation. They are treated with acetic anhydride vapour, which minimises swelling and improves resistance to decay and attack by insects.

Water Soluble Preservatives (type 3): are odourless organic or inorganic salts and are adopted for inside locations only. If applied over outside surfaces, the salts can be leached by rainwater. Examples of leachable (3A-water soluble) type of preservatives are zinc chloride, boric acid (borax), etc. Zinc chloride, sodium fluoride and sodium-penta-chloro-phenate are toxic to fungi. These are expensive and odourless (except for sodium-penta-chloro-phenate). Benzenehexa-chloride is used as spray against borers. Boric acid is used against Lyctus borers and to protect plywood in tea chests.

Various Treatment Processes

Surface Application: is done either by spraying, dipping or by brushing the preservative for a short period on thoroughly debarked timber. For the oil type preservatives, the moisture content in timber should not be more than 14 per cent. With water soluble preservatives, a moisture content of 20 to 30 per cent is permissible. At least two coats should be applied. The second and subsequent coats should not be applied until the first one has dried or soaked into the wood. Where possible, the treatment is done hot. Surface treatment is used mostly for treating timber at site and for retreatment of cut surfaces.

Soaking Treatment:□consists in submerging debarked timber in the preservative solution for a sufficiently long period until the required absorption of the preservative is obtained. For dry vineers 15–30 minutes of soaking are enough.

Hot and cold process ensures sterilisation against fungi and insects. The timber is submerged in the preservative solution. Which is then heated to about 90° to 95°C and maintained at this temperature for a suitable period depending on the charge. It is then allowed to cool until the required absorption is obtained. During the heating period, the air in the timber expands and is partially expelled. While cooling, the residual air in the timber contracts and creates a partial vacuum which causes the preservative to be sucked into the timber. Generally two baths are used, the first containing water where the hot treatment is given and the second the cold bath containing the preservatives into which the timber is transferred immediately after heating. This overcomes the danger of precipitation of chemicals at high temperatures. This arrangement also helps to make the process continuous in case the quantity of timber is large.

Boucherie Process: Sapwood of almost all green timbers with the bark on and of bamboos in green condition, soon after felling, can be treated using any of the inorganic water soluble preservatives by this process. The log of wood attached to the hose pipe and connected to the reservoir containing preservative at an air pressure of 0.1–0.2 N/mm2 on its surface. Due to hydrostatic pressure, the preservative displaces the sap in the wood. The treatment is stopped when the concentration of preservative at the lower end of the log is the same as that in the reservoir.

2. MATERIALS FOR MAKING CONCRETE

Cements in a general sense are adhesive and cohesive materials which are capable of bonding together particles of solid matter into a compact durable mass. For civil engineering works, they are restricted to calcareous cements containing compounds of lime as their chief constituent, its primary function being to bind the fine (sand) and coarse (grits) aggregate particles together. Cements used in construction industry may be classified as hydraulic and non hydraulic. The latter does not set and harden in water such as non-hydraulic lime or which are unstable in water, e g. Plaster of Paris. The hydraulic cement set and harden in water and give a product which is stable. Portland cement is one such. Cement can be manufactured either from natural cement stones or artificially by using calcareous and argillaceous materials. The examples of natural cements are Roman cement, Puzzolana cement and Medina cement and those of artificial cement are Portland cement and special cements.

2.1 Portland Cement

It is a cementing material resembling a natural stone quarried from Portland in U.K. Portland cement may be defined as a product obtained by finely pulverizing clinker produced by calcining to incipient fusion, an intimate and properly proportioned mixture of argillaceous and calcareous materials. Care must be exercised in proportioning the raw materials so that the clinker of proper constitution may be obtained after burning. The three constituents of hydraulic cements are lime, silica and alumina. In addition, most cements contain small proportions of iron oxide, magnesia, sulphur trioxide and alkalis. There has been a change in the composition of Portland cement over the years, mainly reflected in the increase in lime content and in a slight decrease in silica content. An increase in lime content beyond a certain value makes it difficult to combine completely with other compounds. Consequently, free lime will exist in the clinker and will result in an unsound cement. An increase in silica content at the expense of alumina and ferric oxide makes the cement difficult to fuse and form clinker. Portland cement comes in five basic types and a number of specialty varieties to fulfill different physical and chemical requirements. The most frequently used cements are

Type I — Normal or general purpose

Type II — Moderate sulfate resistant

Type III — High early strength

Type IV — Low heat of hydration

Type V — Sulfate resistant

Types I, II, and III with an A after the number signifies that the cement contains an air-entraining agent. There also is a white portland cement for special purposes in Types I and III. This does not exhaust the list of hydraulic cements that are available but it will suffice for the purpose here.

2.2 AGGREGATES

Aggregates are the inert particles that are bound together by the cementing agent (such as Portland cement) to form a mortar or a concrete. Mortar is a mixture of fine aggregate, a cementing material, and water. A mixture of only cement and water is referred to as “neat cement.” Concrete is composed of the ingredients of mortar plus coarse aggregates. The boundary size definition of fine aggregates is one that passes a 5 mm (#4) sieve. Coarse aggregate particle sizes are those that are retained on a 5 mm (#4) sieve opening. There is no real maximum size aggregate, but in most concretes for pavements and structures the upper limit is usually 5 cm (2 in.), but may be larger. Coarse aggregates are obtained from gravel or crushed stone, blast furnace slag, or recycled concrete. Trap rocks, granite, limestones, and sandstones are satisfactory for crushed stone. Fine aggregates are derived from the same sources except that in the place of gravel, naturally occurring sand is used. All aggregates should be composed of hard particles and free of injurious amounts of clay, loam, and vegetable matter. The principal characteristics of aggregates that affect the strength, durability, and workability of a concrete are cleanness, grading, hardness, and shape. Usually the aggregates are stronger than the concrete from which they are made. A coating of dirt or dust on the aggregate will reduce the strength of concrete because it prevents the particles from properly bonding to the mortar. A well-graded aggregate mix is essential to obtaining an economical concrete of good quality. If poorly graded, even clean, sound aggregates will require excessive water for workability, resulting in lower strength, or the mix will require an excessive amount of cement to develop a given strength.

The ASTM specification for the grading and quality of aggregates for normal weight concrete is defined by ASTM Designation: C 33. There are seven standard sieve openings for fine aggregate and up to 13 sieve sizes for coarse aggregates.

2.3 WATER

The water used for concrete should be clean and free from dirt or organic matter. Water containing even small quantities of acid can have a serious deleterious effect upon concrete. The presence of oil will result in slowing the set and reducing the strength. Generally speaking, if water is potable, it is satisfactory for the production of a good concrete.

3. NATURAL FIBRES

Natural fibres have been used for building since ancient times. Fibrous materials can be used by themselves as roofing material or for walls and mats. Natural fibres can also be combined with hydraulic-setting binders to make various types of roofing board, wall board, block and shingle. Animal hair is often used for reinforcing plaster.

Thatch

Thatch, whether made of grass, reeds, palm or banana leaves, is susceptible to decay caused by fungi and insects, and to destruction by fire. Preservative treatment is desirable but expensive. A treatment combining copper sulphate, sodium chromate and acetic acid reduces attack by rot and may considerably increase the life span of a thatched roof .

Grass

The use of thatched roofs is common in many countries, and suitable grass can be found almost everywhere. When well laid and maintained, it can last for 10–20 years or longer. A good-quality thatching grass must be fibrous and tough, with a minimum length of 1 metre. It should also have thin stems without hollows, a low content of easily digestible nutrients and the ability to withstand repeated wetting without decaying. An annual treatment with a mixture of the following chemicals will improve the fire-resistance of a thatched roof, and also give some protection against decay: 14 kg ammonium sulphate, 7 kg ammonium carbonate, 3.5 kg borax, 3.5 kg boric acid, 7 kg alum and 200 kg water.

Reeds

Reeds must be dry before use as a building material, and can be impregnated or sprayed with copper-chrome preservatives to prevent rotting. Ammonium phosphate and ammonium sulphate are used to protect the reeds against fire. Reeds can be woven into mats for use as wall or ceiling panels, shade roofs, etc. The mats can be plastered easily. In tropical areas, thatch from untreated reeds may last only 1 year but, if well laid, treated and maintained, it can last 5–10 years.

Sisal stems

Before dying, at 7–12 years of age, the sisal plant forms a pole shoot to carry the flowers. The pole may reach a height of 6 metres or more and has a fibrous circumference, which makes it tough, but the inner parts are quite soft. Sisal poles have limited structural strength and durability, but are sometimes used for wall cladding in semi-open structures, such as maize cribs. The poles can be split and are joined in the same way as bamboo.

Sisal fibre

Sisal fibre is one of the strongest natural fibres. It has traditionally been used as reinforcement in gypsum plaster sheets. Sisal fibres have the ability to withstand degradation from bacteriological attack better than other organic fibres, but are attacked by the alkalinity of cement. However, research has been carried out to make sisal fibre, like other natural fibre composites, into a reliable cement reinforcement for long-term use in exposed situations.

Coir waste

Coir is a by-product of coconuts. The husk is used for making coir mats, cushions and as fuel. It can be mixed with cement, glue or resins, either to produce low-density boards with good insulating and sound absorption properties, or to be compressed to make building boards. It is also used as reinforcement in cement for making roofing sheets.

Elephant grass

Elephant grass is a tall plant similar to bamboo, but with the difference that the stem is not hollow. The fibres of the grass can be used to partly or wholly replace the asbestos in net and corrugated roofing sheets. However, the sheets are more brittle and have a slightly lower strength than asbestos-cement sheets.

Straw

Baled straw, if supported by a framework of wooden poles, can be used to construct temporary walls. Straw has also been used as raw material for manufactured building boards. Straw and split bamboo can be cement plastered to permanent structures, such as vaults and domes, at low cost.

4. NATURAL STONE PRODUCTS

Natural stones are strong in compression and are generally extremely durable, although deterioration may result from the action of soluble salts, wetting and drying, or thermal movement. According to the manner of their geological formation, all stones used in building fall into one of three classes: *igneous, sedimentary* or *metamorphic.*

Igneous rocks are mostly very hard and difficult to cut to size and shape. However, they are very durable. *Sedimentary rocks*, such as sandstone and limestone, are used extensively for building. They are not difficult to work, yet are quite durable. Coral stone is found in coastal areas, where chips or small stones are used in mud walls. Coral stone is also cut into blocks and, although not very strong, can be used in foundations and walls in multi storey houses.

Metamorphic stones consist of older stones that have been subjected to intense heat and pressure, causing structural change. Thus clay becomes slate, limestone becomes marble and sandstone becomes quartzite. Slate develops cleavage planes during formation. Roofing slates are split along these planes. They make very durable roof surfaces, but require strong frames because of their weight.

5. EARTH AS A BUILDING MATERIAL

Earth is one of the oldest materials used for building construction in rural areas. The advantages of earth as a building material are:

1. It is resistant to fire.
2. It is cheaper than most alternative wall materials,

and is readily available at most building sites.

3. It has a very high thermal capacity, which enables it to keep the inside of a building cool when it is hot outside and *vice versa*.
4. It absorbs noise well.
5. It is easy to work using simple tools and skills.

These qualities encourage and facilitate self-help and community participation in house building. Despite its good qualities, earth has the following drawbacks as a building material:

1. It has low resistance to water penetration, resulting in crumbling and structural failure.
2. It has a very high shrinkage/swelling ratio, resulting in major structural cracks when exposed to changing weather conditions.
3. It has low resistance to abrasion, and requires frequent repairs and maintenance when used in building construction. However, there are several ways to overcome most of these weaknesses that make earth a suitable building material for many purposes.

5.1 Soil classification

Soil and earth are synonymous when used in relation to building construction. The term 'soil' refers to subsoil, and should not be confused with the geological or agricultural definition of soil, which includes the weathered organic material in topsoil. Topsoil is generally removed before any engineering works are carried out, or before soil is excavated for use as a building material. Mud is the mixture of one or more types of soil with water. There are several ways in which soil may be classified: by geological origin, by mineral content (chemical composition), by particle size or by consistency (mainly related to its moisture content).

5.2 Particle size

Soils are grouped and named according to their particle size, as shown in the table below.

5.3 Grading

The soil materials in table below seldom occur separately, and this necessitates a further classification according to the percentage of each contained in the soil. This is shown in the soil classification triangle, which shows, for example, that a sandy clay loam is defined as soil that contains 50–80 percent sand, 0–30 percent silt and 20–30 percent clay. Only a few mixes can be used successfully for building construction in the state in which they are found. However, many mixes can be improved to make good building material by correcting the mix and/or adding stabilizers. The clay fraction is of major importance in earth construction because it binds the larger particles together. However, soils with more than 30 percent clay tend to have very high shrinkage/swelling ratios which, together with their tendency to absorb moisture, may result in major cracks in the end product. High-clay soils require very high proportions of stabilizer or a combination of stabilizers. Some soils produce unpredictable results, caused by undesirable chemical reactions with the stabilizer. Black cotton soil, a very dark coloured clay, is an example of such a soil. Generally speaking, soils that are good for building construction purposes are characterized by good grading, i.e. they contain a mix of different-sized particles similar to the ratios in Table 5.6, where all voids between larger particles are filled by smaller ones. Depending on use, the maximum size of coarse particles should be 4–20 mm. Laterite soils, which are widely distributed throughout the tropical and subtropical regions, generally give very good results, especially if stabilized with cement or lime. Laterite soils are best described as highly weathered tropical soils containing varying proportions of iron and aluminium oxides, which are present in the form of clay minerals, usually together with large amounts of quartz. Their colours range from ochre, through red, brown and violet to black. The darker the soil, the harder, heavier and more resistant it is to moisture. Some laterites harden on exposure to air.

Classification of soil particles

Material	Size of particles	Means of field identification
Gravel	60–2 mm	Coarse pieces of rock, which are round, flat or angular.
Sand	2–0.06 mm	Sand breaks down completely when dry; the particles are visible to the naked eye and gritty to the touch.
Silt	0.06–0.002 mm	Particles are not visible to the naked eye, but slightly gritty to the touch. Moist lumps can be moulded but not rolled into threads. Dry lumps are fairly easy to powder.
Clay	Smaller than 0.002 mm	Smooth and greasy to the touch. Holds together when dry and is sticky when moist.
Organic	Up to several centimetres	Spongy or stringy appearance. The organic matter is fibrous, rotten or partially rotten, several centimetres deep, with an odour of wet, decaying wood.